Surface Water-Sediment Feasibility Study Report for the McCormick and Baxter Superfund Site, Stockton, California

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EXECUTIVE SUMMARY

This Feasibility Study (FS) evaluates the remedial alternatives for the Surface Water-Sediment Operable Unit (OU) of the McCormick & Baxter (M&B) Superfund site in Stockton, California. A separate FS report was prepared for the Soil-Groundwater OU (ICF 1998). Past operations at the site had resulted in the release of wood-preserving chemicals to soils, groundwater, and surface water. Surface water bodies adjacent to and/or potentially affected by the M&B site are Old Mormon Slough, New Mormon Slough, and the Stockton Deepwater Channel (SDC). New Mormon Slough and SDC do not appear to be adversely affected by contamination from the M&B site. However, sediments in Old Mormon Slough were contaminated by chemical spills, stormwater runoff, and, at the oily waste ponds (OWP) area, by subsurface migration of non-aqueous phase liquids (NAPLs) from upland contamination sources.

Nature and Extent of Contamination

The following Contaminants of Concern (COCs) have been identified:

- Low-molecular-weight polycyclic aromatic hydrocarbons (LPAHs)
- High-molecular-weight PAHs (HPAHs)
- Dioxin (2,3,7,8-tetrachlorodibenzo-p-dioxin/2,3,7,8-tetrachlorodibenzo-p-furan)
- Pentachlorophenol (PCP)
- Metals (chromium, arsenic, zinc, copper).

Total PAH concentrations decrease with increasing depth in the western half of Old Mormon Slough, and increase with increasing depth in the eastern half. The depth of contamination in Old Mormon Slough generally ranged from 0 to 2.4 m (0 to 8 ft) below mudline; however, PAH contamination was found deeper than 5.5 m (18 ft) at two sampling locations next to the central processing area. PCP is not widely distributed and was detected in only six samples from the eastern half of Old Mormon Slough. Dioxin contamination is found at lower concentrations relative to the reference concentrations, and affects a smaller volume of sediment, than PAHs. Dioxin contamination was highest in shallower (upper 1.2 m [4 ft]) sediment in the vicinity of former discharge pipes.

Arsenic, copper , zinc, and chromium concentrations in Old Mormon Slough were not attributable to past M&B discharges.

Human Health Risks

The M&B site and neighboring lands are zoned for heavy industrial uses. The nearest residences are located approximately 150 m (500 ft) to the southwest and west. Recreational and subsistence fishing is known to occur in all of the main surface water bodies surrounding the M&B site, including Old Mormon Slough. The baseline Human Health Risk Assessment (HHRA) found that potential risks to humans related to the Surface Water-Sediment OU are primarily through the ingestion of dioxin-contaminated fish. The average concentration of dioxin in fish tissue collected from Old Mormon Slough relates to an additional cancer risk of 8E-4 (assuming a consumption rate of 150 g/day, 350 days/year, for 30 years). The maximum concentration relates to a worst case risk of 1E-3 (assuming a consumption rate of 200 g/day for the same duration).

A second potential pathway to humans is the migration of contamination from sediments in Old Mormon Slough to groundwater beneath the site. However, any potential contribution from these deep sediments is expected to be very low and would be captured by the network of groundwater extraction wells being designed for the major groundwater plume emanating from upland sources.

Ecological Risks

The primary ecological risks posed to receptor species (e.g., catfish, aquatic avifauna) are from the occurrence of PAHs, dioxins, and, to a lesser extent, PCP. The current levels of dioxins in the surface sediments adjacent to the central processing area are 30 to 50 times higher than the site-specific maximum sediment concentrations (MSC) predicted to cause no adverse effects to aquatic biota (Thom et. al. 1997). The concentrations of PAHs near the OWPs were nearly 80 times higher than the site-specific MSCs. Metals were not found to be a risk factor to any of the assessment endpoints.

Remedial Action Objectives (RAOs)

The overall goal of the remedial action at the M&B site is to protect human health and the environment from the risks presented by contaminated soil, groundwater, and sediment. The focus of this feasibility study is directed at potential response actions for Old Mormon Slough, where surface water/sediment contamination and risks are the greatest and directly attributable to the M&B site. If sediment contamination in Old Mormon Slough is not addressed, it will continue to present a risk to ecological receptors, and to human receptors who consume significant quantities of certain fish species.

The primary goals for remediation of sediment contamination related to the M&B site are to accomplish the following:

- Reduce potential risks to human health from the consumption of fish contaminated with site-related chemicals.
- Prevent humans and aquatic organisms from direct contact with sediment having contaminants in excess of risk-based concentrations or that have been shown to be toxic to aquatic organisms.
- Prevent or minimize the migration of contaminants from Old Mormon Slough sediments into the surface-water column.
- Prevent or minimize the migration of contaminants from Old Mormon Slough sediments to groundwater.
- Allow full attainment of the beneficial uses of surface waters in the vicinity of the site. These beneficial uses include fish and shellfish harvesting and the protection of aquatic life and wildlife.

The preliminary cleanup levels for sediment contamination associated with the M&B site are summarized in **Table ES.1**. These preliminary cleanup levels are based on an anticipated future occupational use of the site consistent with current industrial zoning.

Remedial Alternatives

Potential remedial response actions, remedial technologies, and process options were screened to identify the most reasonable actions. The technologies and process options that were retained from the initial screening have been assembled into five remedial action alternatives:

- SD-1 - No-Action
- SD-2 - In Situ Capping
- SD-3 - Dredging and Confined Disposal (combined with limited in situ capping)
- SD-4 - Dredging and Offsite Disposal (combined with limited in situ capping)
- SD-5 - Dredging and Onsite Treatment, Solvent Extraction and Solidified/Stabilized (S/S) (combined with limited in situ capping).

Each of these alternatives is briefly described in the following paragraphs. Although the use of institutional controls was also considered, it was not developed as a stand-alone alternative for sediment because it would not meet the RAOs for protection of the environment.

SD-1 - No-Action

Under this alternative, the site would be abandoned as is without any additional access controls or remedial actions. Over time, some natural attenuation would gradually occur through deposition of new uncontaminated sediments and biological degradation of the organic contaminants. This alternative would not meet the RAOs, but is retained for comparison with the other alternatives. The only cost associated with this alternative would be for sediment and biota monitoring.

SD-2 - In Situ Capping

This alternative would meet the RAOs by placing a cap over approximately three-fourths of the slough to isolate the contaminated sediments. The cap materials would consist of a minimum of 60 cm (2 ft) of clean fine sand armored with rip-rap where needed to prevent erosion. Institutional controls would be implemented to prevent disruption of these cap materials and the two residual hotspots located in the mouth of the slough. Additional controls would restrict public access and fishing. Short-term and long-term monitoring would be performed to assess the integrity and maintenance needs of the sediment cap.

SD-3 - Dredging and Confined Disposal

This alternative meets the RAOs by removing and isolating a preponderance of the contamination in a confined disposal facility (CDF). Mechanical dredging would remove contaminated sediment from principal threat areas in the central and western portion of the slough. A CDF would be constructed using sheet piling to contain the dredged materials in the east end of the slough. After a period of consolidation, the dredged material would be capped with a permeable geotextile fabric and an estimated 0.6 m (2 ft) of clean fill. Following the completion of dredging activities and confirmatory sampling, a 150-m to 390-m (480-ft to 1280-ft) long stretch of Old Mormon Slough would be capped with fine sand to isolate residual contamination left behind by dredging activities.

As with Alternatives SD-2, SD-4, and SD-5, institutional controls and environmental monitoring would be used to protect the integrity of the cap materials, the two residual hotspots in the mouth of the slough, and would restrict public access and fishing.

SD-4 - Dredging and Offsite Disposal

This alternative also meets the RAOs by removing a preponderance of the contamination from the slough, but would transport it offsite for treatment and/or disposal. Mechanical dredging would remove contaminated sediment from all of the principal threat areas of the slough. The dredged material would be dewatered and transported offsite to a treatment, storage, and disposal facility (TSDF) for treatment and/or disposal. A 420 m to 664 m (1380 ft to 2180 ft) section of the slough would then be capped with fine sand to isolate residual contamination left behind by dredging activities. Institutional controls and environmental monitoring would be conducted to protect the integrity of the cap materials and the two residual hotspots in the mouth of the slough, and to restrict public access and fishing.

SD-5 - Dredging and Onsite Treatment

The Dredging and Onsite Treatment Alternative also meets the RAOs by removing a preponderance of the contaminated sediment, but would treat and dispose of it onsite. Dredging would be conducted throughout the slough except near its mouth. The dredged materials would be dewatered and treated onsite using solvent extraction to remove PAHs and dioxin from the sediment. The concentrated organic contaminants from the solvent extraction process would be shipped offsite for incineration/disposal. The sediment residuals would be solidified/stabilized to address inorganic contamination as necessary, and then disposed onsite, assuming sufficient upland capacity is available. Following the completion of dredging activities and confirmatory sampling, a 420 m to 664 m (1380 ft to 2180 ft) long stretch of Old Mormon Slough would be capped with fine sand to isolate any residual contamination left behind by dredging activities. Institutional controls and environmental monitoring would be conducted to protect the integrity of the cap materials and the two residual hotspots in the mouth of the slough, and to restrict public access and fishing.

Analysis of Alternatives

Each of these remedial alternatives was evaluated independently against the two threshold and five balancing criteria listed in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). A comparative analysis of the alternatives was also conducted and is summarized in **Table ES.2**. The two “modifying” criteria will be evaluated in the record of decision (ROD).

Protection of Human Health and the Environment

Alternatives SD-4 and SD-5 provide the greatest level of protection to human health and the environment. The In Situ Capping alternative (SD-2) relies on physically isolating the contamination in place under a sand cap. However, long-term monitoring, maintenance, and institutional controls are required to ensure the integrity of the cap. The alternatives involving dredging (i.e., SD-3, SD-4 and SD-5), all provide additional protection by reducing the mass of contamination present in the slough. Alternatives SD-4 and SD-5 provide even greater protection by completely removing nearly all of the dioxin contamination and the accessible PAH contamination from the slough. However, all alternatives leave some deeper PAH contamination behind, and must still rely to some degree on in situ capping and long-term management.

Compliance with Applicable or Relevant and Appropriate Requirements (ARARs)

All of the alternatives would comply with applicable or relevant and appropriate requirements (ARARs), including the action-specific ARARs triggered by the dredging and construction activities proposed for Old Mormon Slough. Dredging and Onsite Treatment (SD-5) may require treatment within the same area of contamination or designation of a RCRA Corrective Action Management Unit (CAMU) in order to comply with land disposal restriction ARARs.

Long-Term Effectiveness and Permanence

Alternatives SD-4 and SD-5 provide the greatest long-term effectiveness and permanence relative to human health (i.e., removal of nearly all dioxin). However, all of the alternatives (except No-Action) ultimately rely on capping and long-term management to some degree to provide long-term effectiveness and permanence relative to protection of the environment (i.e, reduce exposure to PAHs). The No-Action alternative would not be effective in reducing current or future risks. Natural attenuation processes are expected to take hundreds or thousands of years. In situ capping of contaminated sediment (SD-2) is a proven and accepted technology, and is expected to be very effective in isolating these contaminants. However, long-term monitoring, maintenance, and institutional controls are required to ensure the integrity of the cap. Alternatives SD-3, SD-4, and SD-5 all provide additional permanence and long-term effectiveness by reducing the mass of contamination present in Old Mormon Slough. Alternatives SD-4 and SD-5 provide even greater permanence by removing nearly all of the dioxin contamination and the accessible PAH contamination from the slough. The dredged sediment would be disposed (and treated) offsite or treated onsite. This would provide an added measure of effectiveness and permanence for the protection of human health and the environment.

Reduction in Toxicity, Mobility, or Volume Through Treatment

Only one of the alternatives, SD-5, is designed to treat the contaminated sediment to reduce its toxicity, mobility, or volume. This treatment train is estimated to remove and destroy more than 85% to 94% of the dioxin contamination and more than 60% to 98% of the PAH contamination. However, land disposal restrictions (LDRs) may necessitate treatment of dredged materials prior to offsite disposal (Alternative SD-4). Offsite incineration of the contaminated sediment prior to disposal would reduce the organic contamination by an estimated

90-99%. The other alternatives (SD-2 and SD-3) do not involve treatment and would not reduce the toxicity or volume of the slough sediments. However, they would reduce the mobility of the contamination through containment.

Short-Term Effectiveness

All of the alternatives, except No-Action, present some risk to workers, primarily from operation of heavy equipment and the hazards of working over water. All of the alternatives would also cause severe short-term impacts to the benthic community in the slough. The In Situ Capping alternative (SD-2) presents the least risk to workers and the fewest impacts to the slough ecosystem. All dredging alternatives would present increased industrial risk to the workers and even more detrimental ecological effects to the slough. The Dredging and Onsite Treatment alternative (SD-5) presents the greatest risk to workers, not only from the operation of heavy equipment associated with dredging and the industrial treatment processes, but also due to the potential for direct exposure and inhalation of contamination while handling and treating the dredged material. The Dredging and Confined Disposal alternative (SD-3) would cause the greatest environmental damage by permanently filling approximately 30% of the slough and its aquatic habitat.

Implementability

All of the alternatives are technically feasible, and all necessary equipment, materials, and expertise for dredging and the installation of sediment caps is readily available in the Stockton area. However, the presence of large debris or steep bottom slopes can complicate dredging and capping activities. Dewatering of the fine-grained sediments sufficiently for offsite transport can be difficult. The Dredging and Onsite Treatment alternative (SD-5) is the most technically complex alternative with the greatest implementation concerns. Onsite disposal of the large volumes of solid residuals from the solvent extraction/solidification treatment train would be difficult due to limited capacity in the upland OU. The availability and accessibility of an offsite TSDF permitted to receive the contaminated sediment (SD-4) could cause significant scheduling delays and increased costs. The acceptability of any of these alternatives to neighboring land owners, the community, and regulatory agencies is uncertain. In situ capping would raise the bottom of the slough and would restrict future activities in the slough (e.g., dredging, barge traffic) that might disrupt the cap and release the buried contamination. The Dredging and Confined Disposal alternative (SD-3) would fill approximately 30% of the slough and would eliminate the waterfront access of the property owner on the northern shore of Old Mormon Slough. However, the CDF alternative (along with the other dredging alternatives) would deepen the remainder of the slough. The CDF, depending on its design, could serve as a new wharf for future waterfront access, should future conditions in the slough allow resumption of normal slough uses. The Dredging and Offsite Disposal alternative (SD-4) could raise public concerns regarding the transportation and offsite treatment/disposal of hazardous waste from the site.

Cost

Costs for the No-Action alternative are the lowest since it only involves monitoring sediment and biota for a 30-year period. The In Situ Capping and Dredging and Confined Disposal alternatives (SD-2 and SD-3) have the lowest capital and overall costs among the active remediation alternatives. The Dredging and Offsite Disposal (SD-4) alternative would likely be the most expensive of all the alternatives, due to transportation and pre-disposal treatment requirements.

Table ES.1. Preliminary Cleanup Levels for Surface-Water Sediment OU

Medium	Contaminant of Concern	Exposure Route	Receptor	Cleanup Level
Fish Tissue	Dioxin	Food Chain	Human	4.3E-6 μ/kg(a)
Sediment	Dioxin	Food Chain	Receptor Species	21 μ/kg(b)
Sediment (By sub-area of Old Mormon Slough)	PAH	Food Chain	Receptor Species	12,000 μ/kg(b) for east end; 5,000 μ/kg(b) for central processing area; 5,334 μ/kg(b) for OWP area; 3,667 μ/kg(b) for mouth of slough.

(a) The cleanup level for fish tissue concentration was developed based on a back calculation for the fish tissue concentration that would produce a total excess cancer risk of less than 10^{-6} assuming a consumption rate of 150 g/day, 350 days/year for 30 years (ICF, personal communication).

(b) The cleanup levels for dioxin and PAH in sediment are based on the risk-based MSC developed in the Ecological Risk Assessment (Thom et al. 1997).

Table ES.2. Comparison of Remedial Alternatives for Sediments in Old Mormon Slough

Alternative	Overall Protection of Human Health and the Environment	Compliance with ARARS	Long-Term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume Through Treatment	Short-Term Effectiveness	Implementability	Cost ($ Million)
SD -1: No-Action	Not protective.	Does not comply with ARARs.	Does not reduce long-term risks for hundreds to thousands of years.	Does not provide treatment.	Does not create any short-term risks	Not administratively feasible; would conflict with other environmental and public health objectives	Capital: $0 30 Year O&M: $0 Total Present Worth Cost: $0.33 (Monitoring only)
SD-2: In Situ Capping	Reduces risk to the aquatic ecosystem and to humans. Contaminated sediments continue to be a potential, though minor, threat to groundwater.	Expected to comply with ARARs.	Contaminated sediment remains in place; isolated by a sand cap. Long-term effectiveness depends on continued inspection and maintenance.	Does not provide treatment, but would reduce the mobility of contaminated sediment.	Some risks to workers installing the cap. Severe short-term impacts on the benthic community. Completion time for cap is estimated at 1 to 2 months.	Easiest to implement, but a long-term inspection and maintenance program is necessary.	Capital: $1.21-2.37 30 Year O&M: $0.09-0.15 Total Present Worth Cost: $1.85-2.94
SD-3: Dredging and Confined Disposal	Risk reduction is slightly greater than SD-2. Potential threats to groundwater would be reduced.	Expected to comply with ARARs.	Completely removes contaminated sediment from 1/4 of the slough. Deeper contamination may remain inplace in another areas but isolated by a sand cap. Requires long-term inspection and maintenance program.	Does not provide treatment, but reduces the volume and mobility of contaminated sediment available for uptake by aquatic organisms.	Risks to workers are greater than for SD-2. Would have significant short-term impacts on the aquatic ecosystem. Habitat would be permanently lost by construction of the confined disposal facility. Time to complete SD-3 is estimated at 4 to 10 months.	SD-3 is more difficult to implement than SD-2. A long-term inspection and maintenance program is necessary. Filling a portion of Old Mormon Slough may not be acceptable to the community, adjacent landowners and regulatory agencies.	Capital: $2.01-2.46 30 Year O&M: $0.04-0.07 Total Present Worth Cost: $2.43-2.94
SD-4: Dredging and Offsite Disposal	Provides a greater degree of protectiveness than SD-2 or SD-3 because all accessible sediment contamination would be removed and disposed off-site. Potential threats to groundwater would be reduced.	Expected to comply with ARARs.	Completely removes all accessible sediment contamination. Some deeper contamination may remain but isolated by a sand cap, requiring a long-term inspection and maintenance program.	Would not provide treatment unless required by land band restrictions prior to disposal. However, the majority of contaminated sediment would be removed from the site.	Risks to workers are approximately the same as for SD-3. There would be potential risks to the public from the transportation of hazardous material to the off-site treatment, storage and disposal facility. Time to complete is estimated at 4 months up to 10 months.	Implementation is similar to that for SD-3. However, excavated sediments would be transported from the site for off-site disposal and/or treatment. Depending on their waste classification and LDRs, there may be a limited number of facilities able to accept the sediment. A long-term inspection and maintenance program is necessary.	Capital: $39.1-350.5 30 Year O&M: $0.05-0.10 Total Present Worth Cost: $39.6-351.0

Table ES.2. (contd)

Alternative	Overall Protection of Human Health and the Environment	Compliance with ARARS	Long-Term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume Through Treatment	Short-Term Effectiveness	Implementability	Cost ($ Million)
SD-5: Dredging and Onsite Treatment	SD-5 provides approximately the same degree of protectiveness as SD-4.	Expected to comply with ARARs. May require treatment within the same area of contamination or designation of a CAMU.	As with SD-4, completely removes all accessible sediment contamination from Old Mormon Slough. Some deeper contamination may remain inplace requiring a sand cap and long-term inspection and maintenance program.	Provides treatment of the contaminated sediment, to reduce toxicity, mobility, and volume of organic contaminants; and to immobilize other hazardous constituents into a solid matrix. Some secondary wastes would be generated that would also require treatment and disposal. Use of stabilizing reagents increases the volume of treated soil.	Short-term risks to workers are higher than for SD-4 due to on-site treatment operations and increased handling of contaminated sediment. Potential for dust generation during treatment operations. Time to complete is estimated at 4 to 10 months.	Most technically complex alternative with the greatest implementation concerns. Availability of solvent extraction vendors may be limited. Extensive testing may be necessary to evaluate treatment efficiency. Treatment residuals would also need to be treated and disposed of. Treatment greatly increases sediment handling over the other alternatives. Volume would be increased during the S/S process, and upland disposal of the large volume of treated sediment may be a problem.	Capital: $66.7-67.1 30 Year O&M: $0.05-0.10 Total Present Worth Cost: $67.1-67.7

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ACRONYMS

ACE	Army Corps of Engineers
AOC	area of contamination
ARAR	applicable or relevant and appropriate requirements
AWQC	ambient water quality criteria
BACT	Best Available Control Technology
BAP	benzo(a)pyrene
BCD	base catalyzed decomposition
BCF	bioaccumulation factor
bgs	below ground surface
CAA	Clean Air Act
CAMU	corrective action management unit
CDF	confined disposal facility
CDFG	California Department of Fish and Game
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CO_2	carbon dioxide
COC	Contaminants of Concern
CPA	central processing area
CPAH	carcinogenic polynuclear aromatic hydrocarbons
CWA	Clean Water Act
DHS	California Department of Health Services
DNAPL	dense non-aqueous phase liquid
DOT	U.S. Department of Transportation
DTSC	Department of Toxic Substances Control
END	east end
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
ESA	Endangered Species Act
FDA	Food and Drug Administration
FS	Feasibility Study
GAC	granular activated carbon
GRA	general response actions
H_2O	water
HCl	hydrogen chloride
HHRA	Human Health Risk Assessment
HI	hazard index
HPAH	high-molecular-weight polycyclic aromatic hydrocarbons
HWCA	Hazardous Waste Control Act
KPEG	potassium polyethylene glycol
LDR	land disposal restrictions

LNAPL	light non-aqueous phase liquid
LPAH	low-molecular-weight polycyclic aromatic hydrocarbons
LTR	liquid tank reactor
M&B	McCormick & Baxter
MCL	Maximum Contaminant Levels
MLLW	mean lower low water
MSC	maximum sediment concentrations
MSL	mean sea level
MTH	mouth of the slough
MTRL	maximum tissue residue levels
MTTD	medium temperature thermal desorption
NAAQS	National Ambient Air Quality Standards
NAPL	non-aqueous phase liquids
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRMRL	National Risk Management Research Laboratory
O&M	operating and monitoring
OU	Operable Units
OWP	oily waste ponds
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCP	pentachlorophenol
ppb	parts per billion
ppt	parts per thousand
RAO	Remedial Action Objectives
RCRA	Resource Conservation and Recovery Act
RHA	Rivers and Harbors Act
RI/FS	remedial investigation and feasibility study
ROD	Record of Decision
RWQCB	Regional Water Quality Control Board
S/S	solidified/stabilized
SARA	Superfund Amendments and Reauthorization Act of 1986
SDC	Stockton Deepwater Channel
SDCR	Stockton Deepwater Channel Reference
SIP	State Implementation Plan
SJVUAPCD	San Joaquin Valley Unified Air Pollution Control District
So_x	sulfur oxides
SPLP	Synthetic Precipitation Leaching Procedure
SVOC	semi-volatile organic compounds
T/M/V	toxicity, mobility, or volume

TBC	to be considered
TEQ	toxicity equivalent concentrations
TH	total hydrocarbon
TI	technical impracticability
TOC	total organic content
TSDF	treatment, storage, and disposal facility
U.S. ACE	U.S. Army Corps of Engineers
UV	ultra-violet
VDE	visible dust emission
VOC	volatile organic compounds
VRS	vapor recovery system
WDR	waste discharge requirements

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1.0 INTRODUCTION

1.1 PURPOSE AND ORGANIZATION OF REPORT

The purpose of this Feasibility Study (FS) is to evaluate the remedial alternatives for the Surface-Water Sediment Operable Unit (OU) at the McCormick & Baxter Superfund Site (M&B), a former woodtreating facility located in Stockton, California. Past activities at the site resulted in the release of hazardous substances to soils, groundwater, surface water, and sediment.

The site has been divided into two OUs: 1) upland soil and groundwater, and 2) surface water and sediment in the adjacent Old Mormon Slough. Remedial investigation and feasibility study (RI/FS) activities for both OUs are being conducted concurrently. This FS report addresses the Surface-Water Sediment OU. A separate FS report was prepared for the Soil-Groundwater OU (ICF 1998). The following is a list of other major reports prepared for EPA as part of the M&B RI/FS:

- M&B Soil and Groundwater Remedial Investigation Report (ICF 1998)
- M&B Surface Water and Sediment Remedial Investigation Report (White et al. 1996)
- Human Health Risk Assessment for the M&B Superfund Site (ICF 1997)
- Ecological Risk Assessment of the Surface Water Operable Unit, M&B Superfund Site, Stockton, California (Thom et al. 1997).

The RI and FS for the M&B site have been carried out in accordance with the requirements of the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA). Specific guidance used in the preparation of this report is the *Guidance for Conducting Remedial Investigations and Feasibility Studies under CERCLA* (EPA 1988a).

This FS report is organized into six chapters. Chapter 1.0 provides background information about the M&B site, including a site description and history, a summary of previous investigations, contaminants of concern (COC), discussions of the nature and extent of contamination and contaminant fate and transport, and summaries of the human health and ecological risk assessments. (A more detailed site description and history can be found in the Soil-Groundwater OU RI report).

Chapter 2.0 presents the remedial action objectives for Old Mormon Slough sediments, the development of cleanup levels based on applicable or relevant and appropriate requirements (ARARs) and risk assessment findings, general response actions (GRAs), and the areas and volumes of sediment to which removal, containment, or treatment may be applied.

Chapter 3.0 presents the remedial technology types and process options potentially applicable to each GRA. These technologies are screened based on their effectiveness, implementability, and cost. This section also summarizes the results of treatability studies conducted for the M&B site.

Chapter 4.0 presents the development and screening of remedial alternatives based on combinations of the technology options retained from the screening process in Chapter 3.0. The rationale for development of the remedial alternatives, as well as a discussion and evaluation of each alternative, are included.

Chapter 5.0 presents individual and comparative analyses of the final alternatives. This analysis is conducted using seven of the nine evaluation criteria specified in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP). The final two criteria, state and community acceptance, will be evaluated after comments are received on the proposed remedy.

References are provided in Chapter 6.0. Assumptions and calculations used in the detailed development and evaluation of alternatives (Chapter 5.0) are presented in Appendixes A and B. Detailed cost estimates for these remedial alternatives are presented in Appendix C.

1.2 BACKGROUND INFORMATION

This section presents background information describing the site, its characteristics and operational history, the nature and distribution of contaminants, potential fate and transport pathways, and findings of the Human Health and Ecological Risk Assessments.

1.2.1 Site Description

M&B is a defunct wood-preserving company that operated between 1942 and 1990 on a 29-acre site in an industrial area of Stockton, California (**Figure 1.1**). Site activities resulted in the release of wood-preserving chemicals to soils, groundwater, surface water, and sediment. Sediments in Old Mormon Slough have become contaminated as a result of chemical spills, stormwater runoff, direct discharge of stormwater through outfalls, non-point source stormwater runoff, and/or subsurface migration of non-aqueous phase liquids (NAPLs) from upland contamination sources (i.e., seepages from the former OWP area).

The M&B site is bordered by Old Mormon Slough to the north, Washington Street to the south, the Continental Grain property to the west, and the Interstate 5 (I-5) interchange to the east. The site is fenced and 24-hour security is maintained. Zoned areas within 600 feet of the site include heavy industrial, light manufacturing, general business, commercial manufacturing, and single-family residential districts. The nearest residential area is located approximately 150 m (500 ft) to the southwest. Additional residences are located across the I-5 freeway, approximately 750 feet southeast of the M&B site.

1.2.2 Summary of Site Physical Characteristics

This section summarizes the physical characteristics of the upland area and potentially important surface-water bodies.

1.2.2.1 Upland Area (Soil-Groundwater OU)

Topography across the site is generally level, with elevations ranging from 3 m (10 ft) above mean sea level (msl) in the east and central areas to 4 m (13 ft) in the north. The main wood-treatment area was located in the central and northwest portion of the site (**Figure 1.2**). The southern and eastern areas were used primarily for storage of treated and untreated wood. A berm, approximately 1 m (3 ft) higher than the upland area, borders the south bank of Old Mormon Slough and prevents surface runoff into the slough. Stormwater is collected and stored in two ponds in the southwest corner of the site. Stormwater from the ponds is discharged under permit to the Stockton Regional Wastewater Control Facility.

Regional and local geology, hydrogeology, and groundwater quality are discussed in detail in the RI report for the Soil-Groundwater OU. The following is a list of the conclusions of that report that are relevant to this FS:

- Five interconnected water-bearing zones (A through E) have been defined beneath the site.

- No continuous confining layers have been identified between the zones.

- A downward vertical gradient exists between the five zones; however, localized deviations from this general trend are noted.

- Groundwater-flow direction in all zones ranges from east-southeast to southeast.

- Groundwater recharge is from nearby surface-water sources located to the northwest (Port of Stockton Turning Basin and Old Mormon Slough).

- Onsite infiltration is not considered to be a major contributor to groundwater recharge.

- Shallow groundwater is brackish and non-potable; however, salinity decreases with depth.

- Naturally occurring arsenic is found in all zones; the concentration increases with depth.

The A-Zone extends from the surface to approximately 60 ft below ground surface (bgs). The B- through D-Zones have been divided into the following depth intervals: B-Zone, 60 ft to 100 ft bgs; C-Zone, 100 ft to 150 ft bgs; and D-Zone, 150 ft to 200 ft bgs. The underlying E-Zone is the uppermost regime of a deep aquifer system extending to at least 1000 ft bgs. For the purposes of the FS, the E-Zone is defined as the interval between 200 and 250 ft bgs.

1.2.2.2 Surface Water and Sediment OU

The surface-water bodies adjacent to and/or potentially affected by the M&B site are Old Mormon Slough, New Mormon Slough, and the Stockton Deepwater Channel (SDC) (see Figure 1.1). Before 1970, Mormon Slough was a single channel into the SDC, near the Port of Stockton Turning Basin. When Interstate-5 was constructed, part of Mormon Slough was filled, and the portion of the slough adjacent to the M&B site was designated "Old Mormon Slough" (**Figure 1.3**). The remaining section of the slough, now on the eastern side of Interstate-5, was connected by a new channel to the SDC and named "New Mormon Slough." The SDC discharges to the San Joaquin River approximately 2 km (1.2 mi) downstream (west) of the Turning Basin, and terminates approximately 2 km (1.2 mi) upstream of the basin. The San Joaquin River joins the Sacramento River and discharges into San Francisco Bay approximately 150 km (93 mi) west of Stockton.

Both Old and New Mormon Sloughs are tidally influenced, with a maximum tidal range of approximately 1 m (3 ft). Salinities are generally 3 parts per thousand (ppt), but may fluctuate throughout the year from rainfall, saltwater intrusion, and agricultural runoff (NOAA 1993). Circulation in the SDC and Old Mormon Slough is driven by weak tidal currents, with a maximum current of about 1 knot. The SDC, the Turning Basin, and the mouth of Old Mormon Slough are areas of net sediment deposition, and are periodically dredged to maintain depths appropriate for ship traffic.

Old Mormon Slough. Old Mormon Slough is approximately 760 m (2500 ft) long and 55 m (180 ft) wide. The majority of the slough is approximately 3 m (10 ft) deep; the mouth of the slough was dredged in 1987 to a depth of approximately -5 m (-16 ft) mean lower low water (MLLW) (White and Kohn 1996). Dredge spoils were sampled and placed behind a sheetpile wall constructed on the northern shore of the slough. The bathymetry of the slough and part of SDC in late 1994 are shown in **Figure 1.4**. Old Mormon Slough enters SDC at the east end (END) of the Turning Basin. The Turning Basin is maintained by the Port of Stockton at a depth of -11 m (-35 ft) MLLW. Upstream of the Turning Basin, the SDC depth is approximately -7 m

(-22 ft) MLLW. The shorelines of Old Mormon Slough and the SDC are composed primarily of rip-rap, piers, pilings, and sheetpile walls. Old Mormon Slough is also fringed with shrubby vegetation and some larger trees.

New Mormon Slough. New Mormon Slough consists of a steep-sided, concrete-and-rubble-lined channel. The slough is shallow (less than 1 m [3 ft]), and its silty and fine sand sediments are exposed at low tide. A discharge pipe from the City of Stockton storm drain system is located approximately 1 km upstream of the mouth of New Mormon Slough (see Figure 1.3). This discharge pipe carries runoff from the city storm drain system, which from approximately 1970 to 1978 included runoff from the M&B site. Wetland vegetation occurs approximately 1.6 km (1 mi) upstream from the mouth of New Mormon Slough, and continues upstream for approximately 100 m (328 ft). At this point, the New Mormon Slough enters an underground conduit that is connected to the Stockton Diverting Canal, east of Highway 99.

1.2.3 Site History

The main processing operations at M&B were located in the north-central area of the site, with the remainder of the site used primarily for storage of treated and untreated wood (see Figure 1.2). The central processing area (CPA) included the retorts, track pit, pole-washing area, and various storage tanks. Most treatment processes at the M&B site consisted of pressure impregnation of preservative solutions in retorts (large pressure cylinders) with various preservation solutions, including creosote, pentachlorophenol (PCP), and various compounds containing arsenic, chromium, copper, and zinc. Pressure-treated wood was removed from the retorts and allowed to dry in storage areas throughout the site. The Cellon process was used during a period of the site's operation to pressure treat wood with PCP in a solution of butane and ether solvent. For a brief period of time, pole ends were also dipped in an oil-PCP mixture at the butt tank area, located south of the main processing area.

Waste oils and drippage generated from the wood treatment process were stored in three unlined ponds (now referred to as the "oily waste ponds"[OWP]) located in the northwest corner of the site next to Old Mormon Slough. M&B operation's reports indicate that the ponds were periodically emptied and the contents disposed of offsite. A small pond was reportedly used from 1942 until 1965, and larger ponds from 1965 until 1985, when they were closed. When in operation, the ponds reportedly contained three layers of liquids: a floating oil layer, a layer of wastewater, and a more dense layer of heavy oil (CH2M Hill 1991). These ponds covered an area of 1700 m^2 (18000 ft^2) and were less than 12 m (40 ft) from Old Mormon Slough.

Stormwater from the M&B site was discharged into Old Mormon Slough from the early 1940s, when the plant was first constructed, until approximately 1978. M&B had a National Pollutant Discharge Elimination System (NPDES) permit issued in 1974 for the discharge of cooling water, boiler blowdown water, and stormwater from the site into Old Mormon Slough. At least two discharge points drained portions of the eastern and north central plant site used for storage of treated and untreated wood (Figure 1.2). Two other discharge points drained the south central and southwest plant areas. After 1970, storm drainage from the south central and southwest plant area was apparently rerouted to New Mormon Slough in conjunction with the construction of Interstate 5. Storm drainage from the east and north central plant site remained connected to Old Mormon Slough until late 1976 when M&B reported them closed. Self-monitoring reports by M&B indicated violations of storm drain discharge requirements. Between October 31, 1974, and November 11, 1976, for example, PCP concentrations ranged from 0.40 to 13.4 mg/L, exceeding the permitted limit of 0.01 mg/L.

In late 1977, the California Department of Fish and Game (CDFG) investigated a fish kill involving both New Mormon Slough and the Port of Stockton following a major storm event. The CDFG study established that PCP-contaminated stormwater runoff from the M&B site, discharged to New Mormon Slough via the City of Stockton storm drain system, was responsible. In response to a Regional Water Quality Control Board (RWQCB) Cleanup and Abatement Order against M&B, the company installed a stormwater collection system and constructed a perimeter dike around most of the site. M&B also sealed all storm drains known to carry stormwater from the site to the City of Stockton system. From mid-1978 through the present, the only discharge of stormwater from the plant site has been through the permitted stormwater control system. M&B continued to have an NPDES permit for cooling water and boiler blowdown water until operations ceased in 1991. Stormwater is currently collected and piped to two stormwater collection ponds in the southwestern corner of the site. After sampling, it is discharged under permit to the local wastewater control facility.

Several spills of small amounts of site-related chemicals into Old Mormon Slough have been documented. In June 1986, approximately 20 gal of 30% creosote and 70% heavy fuel oil were released from an effluent discharge pipe in the central processing area. In 1987, M&B reported a small oil/PCP pipe leak and spill (0.5% to 15% PCP) into the slough from the Cellon oil wash system through another discharge point in the CPA.

The OWP were closed in 1981, when approximately 635,000 kg (144 tons) of contaminated soil was removed from the ponds, and the area was covered with clean fill. However, later subsurface soil sampling conducted by U.S. Environmental Protection Agency (EPA) revealed that contaminated soils and oily waste remained in the area of the former OWP. In addition, oily seeps into Old Mormon Slough were observed along this section of the shoreline during sediment sampling conducted by EPA in 1995.

In 1984, M&B entered into an agreement with the California Department of Health Services (DHS), now the Department of Toxic Substances Control (DTSC), and the RWQCB to investigate and clean up contamination at the site. M&B conducted soil and groundwater sampling, and submitted site investigation reports, a Baseline Public Health Assessment, an

FS report, and a Remedial Action Plan to the state agencies. None of these documents was approved. M&B declared bankruptcy in 1988 and ceased operations in 1990.

The M&B site was added to the EPA National Priorities List (NPL) in October 1992, at which time EPA became the lead agency for the site. EPA conducted several phases of soil, groundwater, NAPL, and sediment sampling between 1993 and 1996, as reported in the two RI reports. EPA also carried out several phases of removal actions to dispose of chemicals and sludges remaining at the site, to demolish above-ground tanks and buildings, and to improve site security. In 1996, EPA installed a sheetpiling wall along the shoreline of Old Mormon Slough to control seeps from the old OWP into the slough. In July 1997, approximately 12,000 cy of contaminated soil were excavated from behind the sheetpiling wall. The soil was moved to existing concrete sumps and to a newly constructed lined repository in the central portion of the site. The OWP area was backfilled with clean imported fill. The central area of the site was covered over with clean imported fill and an asphalt cap.

As of today, all wood treatment process units and tanks associated with historical operations at the M&B site have been emptied of chemicals, cleaned, and removed from the site. In addition, all above-ground structures at the site, with the exception of the office, two storage sheds, and the stormwater collection system pumping station, have been demolished.

1.2.4 Nature and Extent of Upland Contamination (Soil-Groundwater OU)

This section presents the current conceptual understanding of the nature and distribution of contaminants in the upland soils and groundwater.

1.2.4.1 Soil Contamination

Five wood treatment-derived chemical contaminants, identified in the RI and risk assessment process as COCs, were used as indicator chemicals to define the nature and extent of soil and groundwater contamination: PCP; 2,3,7,8-tetrachlorodibenzo-*p*-dioxin/ 2,3,7,8-tetrachlorodibenzo-*p*-furan (2,3,7,8-TCDD/TCDF)[1]; carcinogenic polynuclear aromatic hydrocarbons (CPAHs) from creosote; arsenic (primarily as a soil COC); and naphthalene. The 2,3,7,8-TCDD/TCDF (hereafter identified as “dioxin” or “TCDD TEQ”) originated as a contaminant (approximately 0.1 percent) in the technical-grade PCP used at the site. Naphthalene has been included as a COC because, even though it is relatively non-toxic, it is widely distributed at relatively high concentrations in soil and groundwater. It also serves as a good indicator for

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[1] The International Toxicity Equivalency Factors (I-TEFs) methodology as developed by EPA was applied to the various subclasses of dioxin/furan congeners. Each non-2,3,7,8-TCDD congener is expressed in terms of an equivalent amount of 2,3,7,8-TCDD. Expressing the equivalent toxicity of all congeners in terms of 2,3,7,8-TCDD results in a sum total amount of 2,3,7,8-TCDD that can be considered equivalent (in terms of potency) to a unit amount of any dioxin and furan mixture. From this, a scaling factor (the TEQ) can be identified that, when multiplied by the concentration of the mix, represents the toxicity equivalent concentration of 2,3,7,8-TCDD (TCDD TEQ).

non-carcinogenic PAHs. The nature and extent of soil contamination are described in detail in the RI report for the Soils-Groundwater OU. In summary, general findings regarding the extent of soil contamination are the following:

- Only shallow soils are contaminated in the eastern portion of the site, with the exception of a few small, isolated areas of deeper contamination.
- Deeper soil contamination is found in the western portion of the site.
- Arsenic and dioxin are found primarily in shallow soils.
- Benzo(a)pyrene (BAP) has the greatest vertical extent of the COCs (excluding naphthalene).

Arsenic is prevalent in very shallow soils throughout the site, but concentrations rapidly decrease with depth except at locations in the main processing area and the former OWP. In surface soils (0 to 1 ft bgs), arsenic was found above the preliminary soil cleanup level of 24 mg/kg at most sampled locations across the site. Below this depth, arsenic was found only at isolated locations in the eastern portion of the site; however, in the western portion of the site it was found to 13 ft bgs beneath the main processing area and at one location in the OWP area.

Dioxin is present at levels above the preliminary soil cleanup level of 1 ppb in very shallow soils throughout the site, but concentrations are higher in the western portion of the site. In the western end, concentrations of dioxin rapidly decrease with increasing depth, except for locations of high dioxin concentrations in the CPA and the OWP area.

Unlike dioxin and arsenic, PCP is not widely distributed across the site. Except for one sampling station in the eastern portion of the site, PCP above the preliminary soil cleanup level of 79 mg/kg is restricted to the western portion of the site, again primarily in the CPA and OWP area. Outside of these two areas, concentrations of PCP decrease rapidly with depth.

CPAHs are generally found in deeper samples than arsenic, dioxin, and PCP. CPAHs are found in surface soils throughout the western site from the OWP area to the CPA. The lateral extent of CPAHs diminishes with depth, but remains centered below the OWP area and CPA to 30 ft bgs or more.

1.2.4.2 Groundwater Contamination

PCP and dioxin at levels above their respective Maximum Contaminant Levels (MCLs) are currently limited to the central portion of the site and is only present in the A-Zone. Concentrations of PCP in wells at this location were above the MCL of 1 mg/L, ranging from 26 mg/L to 36,000 mg/L. Dioxin contamination extends from the A-Zone to the C-Zone, primarily in the central and southeastern areas of the site. Concentrations range from the 2,3,7,8-TCDD MCL of 30 pg/L to 27,038 pg/L.

There is limited CPAH groundwater data because of analytical interferences due to high concentrations of naphthalene in many samples that raised the detection limits for the CPAHs. CPAHs (as BAP equivalents) have been detected above the BAP MCL (0.2 mg/L) in groundwater samples from only three wells, again in the central and southeastern areas. Maximum concentrations in these wells were 10 mg/L, 240 mg/L, and 2300 mg/L, respectively.

Naphthalene is widely distributed in groundwater beneath the site, and has been detected in two D-Zone and one E-Zone wells. Arsenic is a naturally occurring regional groundwater constituent and, with the exception of one well immediately downgradient from the retort area, it is not found at concentrations elevated above background levels in groundwater beneath the site.

1.2.4.3 Non-Aqueous Phase Liquids (NAPLs)

NAPLs have been detected in soils and groundwater (as well as in Old Mormon Slough sediments, as described in Section 1.2.5) at the M&B site. Both dense NAPLs (DNAPLs) and light NAPLS (LNAPLs) have been detected. NAPLs are free-phase materials thought to be derived from the creosote and PCP wood-treatment solutions. The chemical components of LNAPL and DNAPL are similar, though proportions vary. PCP and at least some creosote were dissolved in petroleum carriers such as fuel oil, diesel fuel, or kerosene. Creosote is denser than water, while petroleum in less dense. However, waste solutions may have been allowed to mix before they were released.

The presence of NAPL in the upland portion of the M&B site was evaluated directly by measurement or visual inspection in groundwater monitoring wells, by the visual inspection of soil borings, and indirectly by interpretation of measured groundwater concentrations to determine if concentrations exceeded the effective solubilities of NAPL component mixtures. Chemical and physical analyses were performed on NAPL samples collected from monitoring wells. The presence of NAPL in Old Mormon Slough sediments was evaluated by visual observations of sediment cores collected for the RI. The following general conclusions were made in the Soil-Groundwater FS report regarding the nature and extent of NAPL in the upland portion of the M&B site:

- NAPL is considered to be the principal present-day source of contamination in the upland portion of the M&B site.

- LNAPL and DNAPL samples from M&B have densities very close to water.

- LNAPL appears to be restricted to one A-Zone well; however, its extent has not been fully delineated.

- DNAPL has been measured in the A- and B-Zones, is suspected in the C- and D-Zones through observations and indirect methods, and may be in the E-Zone. The widespread occurrence of DNAPL presents a significant problem for source removal as a response action at the M&B site.

- The lateral and vertical extent of DNAPL is not fully delineated in the upland portion of the site. Because DNAPL migration pathways are intricate, particularly in complex hydrogeologic environments such as the M&B site, the resulting contaminant distribution is highly uniform and complex, and thus it typically is not possible to fully characterize the extent of DNAPL at a site.

1.2.5 Nature and Extent of Contamination in Surface-Water Sediment OU

The first phase of sediment sampling at and in the vicinity of the M&B site was conducted by EPA in the Surface-Water Sediment OU. The Phase I RI sediment sampling was part of a study conducted jointly by several state agencies (Petreas and Hayward 1994). The Phase II RI sampling for the Surface-Water Sediment OU was conducted in 1995 to 1996 (White and Kohn 1996). The objectives of the RI were to define the horizontal and vertical extent of sediment contamination, estimate contaminated sediment volumes, describe the subsurface geology of Old Mormon Slough, and evaluate contaminant fate and transport for the site.

Old Mormon Slough was divided into four subareas for purposes of the RI sampling: OMS-END (closed eastern end); OMS-CPA (portion adjacent to the upland central processing area); OMS-OWP (portion adjacent to the upland OWP); and OMS-MTH (mouth of the slough). The divisions were based on previous sediment data and the locations of known contaminant sources (e.g., discharge pipes). This usage is continued in this report for the discussion of Old Mormon Slough remediation areas.

Contaminant levels in New Mormon Slough were expected to be higher in the vicinity of the City of Stockton stormwater discharge pipe, and lower in the newer channelized section downstream of the discharge. Because of this, New Mormon Slough was divided into two sections, with five sampling stations in each: NMS-UPS (upstream portion of the slough, near the stormwater discharge pipe) and NMS-DNS (downstream channelized portion of the slough).

Sediment core samples were collected at 24 stations in Old Mormon Slough (six stations in each of the four sub-areas), three stations in SDC, and four stations in New Mormon Slough. Cores were collected to the maximum depth of penetration, which varied from about 1 m (3 ft) in New Mormon Slough to 3 m (11 ft) in SDC and up to 9 m (29 ft) in Old Mormon Slough. Samples were combined in a cost-effective, two-way (vertical and horizontal) compositing scheme designed to yield contaminant distribution data from analysis of fewer samples. All New Mormon Slough and SDC vertical composites and all Old Mormon Slough horizontal composites were analyzed for grain size, total organic carbon, PAHs, chlorinated phenols, metals, and dioxin. Vertical composites from Old Mormon Slough were also analyzed for dioxin.

Contaminant concentrations in the composites were compared with those in two reference sediment samples, one from the eastern end of SDC and one from the San Joaquin River upstream of the confluence with SDC.

The following COCs were identified in the RI report for the Surface-Water Sediment OU:

- LPAHs
- HPAHs
- Dioxin
- PCP
- Metals (chromium, arsenic, zinc, copper).

Based on the findings of the RI sampling, PAH contamination associated with the M&B site appears to be confined to Old Mormon Slough. PAH concentrations in Old Mormon Slough were elevated above those found in the Stockton Deepwater Channel Reference (SDCR). Total PAH concentrations decreased with increasing depth in the western half of Old Mormon Slough, and increased with increasing depth in the eastern half. The origin of PAHs in deeper sediments (>6 ft below mudline) appears to be from old discharges or spills. The full vertical extent of PAH contamination was not determined for part of Old Mormon Slough: PAH contamination extends deeper than 8.9 m and 5.5 m (29.2 ft and 18 ft) below mudline at two stations north of the former central processing area of the M&B site. The origin of PAHs at such depths at these two locations is not clear. At the western end of the slough, seepage from the upland area at the former OWP probably contributed PAHs to this portion of the slough until the seeps were controlled in 1996.

PCP was not widely distributed; it was detected in six samples, all from the eastern half of Old Mormon Slough. Chlorinated phenols were not detected in samples from New Mormon Slough, the SDC, or the reference locations.

Dioxin concentrations in Old Mormon Slough and in the New Mormon Slough background sample were elevated above the SDCR. Dioxin contamination in Old Mormon Slough occurred at lower concentrations relative to reference than did PAHs, and affected a smaller volume of sediment. Dioxin contamination in Old Mormon Slough was highest in shallower (upper 1.2 m [4 ft]) sediment in the vicinity of former discharge pipes. Dioxin was an impurity in PCP formulations and in sediment. There is a probability that this derived from spills or the direct discharge of stormwater into the slough. Higher dioxin concentrations in shallow sediments relative to deeper sediments in the western end of the slough may reflect the resuspension, transport, and deposition of contaminated surface sediments from the END of the slough. In addition, the higher concentrations are probably also related to ongoing seepage from the OWP into this portion of the site. Dioxin in New Mormon Slough was highest in the background (furthest upstream) sample and had different congener ratios, which suggests additional sources other than the past (1970-1978) M&B site stormwater discharge.

Coplanar PCB concentrations in sediment were measured as part of the ecological assessment sampling. Concentrations in the SDCR sample were higher than those in all but eight samples from the study area. Based on their distribution, they do not appear to be associated with activities at the M&B site.

Arsenic, copper, and zinc were highest in the New Mormon Slough background sample, not in Old Mormon Slough. These metals are more likely derived from runoff from adjacent roadways or industrial sources along the upgradient section of New Mormon Slough than from the past, short-term M&B site discharge. Chromium was slightly elevated (a maximum of 1.4 times reference) in six samples from the END of Old Mormon Slough, the background sample from New Mormon Slough, and two samples from the SDC. These concentrations may represent natural variations and also do not appear to be directly attributable to the M&B site.

New Mormon Slough and the SDC are waterways in highly developed areas that receive input from industry, shipping, runoff from streets and highways, and stormwater discharges. New Mormon Slough received stormwater discharge from the M&B site for only about eight years; it was combined with discharges from other sources in the area before entering New Mormon Slough, and no runoff from the M&B site has entered New Mormon Slough since 1978. As far as the movement of contamination out of Old Mormon Slough into the SDC, White and Kohn (1996) describe the rate of sediment transport out of Old Mormon Slough as very low, with a net sedimentation rate estimated at 3.6 cm/yr (1.4 in/yr). This rate would tend to bury and stabilize the contamination in place, rather than transport it outside of Old Mormon Slough.

During an October 1994 site visit, an oily sheen was observed on the water and banks of Old Mormon Slough (White and Kohn 1996). The sheen extended from the slough's END to three-quarters of the way to the mouth, and covered approximately 30% of the water's surface area at some locations. Active degassing was indicated by bubbles bursting at the water surface. The degassing area covered approximately 50% of the eastern end of the slough. During a low tide in June 1995, oily seeps were observed on the exposed bank of Old Mormon Slough near the former OWP (see Figure 1.2). As noted earlier, the source of these seeps was addressed by removal actions in 1996 to 1997.

Soil cores from the top five to ten feet of sediments underlying Old Mormon Slough were logged as being oily (White and Kohn 1996). Because the oil was encountered below the water surface, it is believed to be a DNAPL. The relatively thin occurrence of the Old Mormon Slough DNAPL may be an indication that the oils are at residual saturation and therefore probably not mobile.

Two isolated borings in the slough (OMS-45 and OMS-48) had oily soils to deeper depths (29.2 ft below mudline and 18 ft below mudline, respectively). The presence of DNAPL at these depths is believed to be due to past direct releases from the upland process areas, and not due to migration from upland DNAPL sources. Evidence supporting the hypothesis of direct release to the slough as the source of DNAPLs in sediment includes 1) an oily sheen was observed in both borings throughout their entire lengths, 2) the DNAPL was often associated with wood fibers (which may be from the site wood-treatment process and deposited at the same time as the oil), and 3) DNAPL has not been detected in borings or wells between the upland site DNAPL locations and the deep slough borings.

1.2.5.1 Nature and Extent of PAH Contamination

PAH contamination of sediments near the site is primarily confined to Old Mormon Slough. The maximum total PAH concentration measured in a sample from New Mormon Slough was 14.2 mg/kg, which is slightly higher than the SDCR concentration of 10.4 mg/kg. The difference in composition of the PAH mixtures suggests that the sources of PAHs at the reference sites and in New Mormon Slough are different than the sources in Old Mormon Slough. PAHs at the reference sites and in New Mormon Slough were predominately composed of HPAH compounds (87% to 100% of total PAHs). HPAHs are primarily the products of incomplete combustion, and were likely transported to the reference sites and New Mormon Slough in runoff from adjacent roadways. In Old Mormon Slough, PAHs were predominately composed of LPAH compounds, representing a range of 51% to 96% and an average of 74% of the total PAHs. The preponderance of LPAHs relative to HPAHs is typical of creosote or possibly the carrier oil for creosote or PCP.

Lateral Extent in Old Mormon Slough. PAH contamination in Old Mormon Slough was greatest adjacent to the CPA (OMS-CPA), where total PAH concentrations ranged from below detection to 1811 mg/kg in horizontally composited samples (**Figure 1.5**). PAH-contaminated sediments were also found adjacent to the OWP (OMS-OWP) where concentrations ranged from 15.5 to 1195 mg/kg. Concentrations of up to 123 mg/kg were found in the closed eastern end of the slough (OMS-END); contamination in this area was detected in sediments below 6 m (20 ft). Sediments at the mouth of the slough (OMS-MTH) were relatively free of PAH contamination, with the exception of two apparent “hot spots” in surface sediments (OMS-58 and OMS-61). This area was reported to have been dredged in 1987 to a maximum depth of -5 m (-16 ft) MLLW.

The most highly contaminated sediments were found at stations OMS-48, OMS-50, and OMS-45, which were located on the southern side or in the center of Old Mormon Slough directly north of the CPA (see Figure 1.5). The sediments from Station OMS-53 on the south side of Old Mormon Slough at the eastern end of the OMS-OWP subarea were the most contaminated in the sub-area.

Vertical Extent in Old Mormon Slough. PAH contamination increased with depth from mudline to -2.4 m (-8 ft) in OMS-END and OMS-CPA, and decreased with depth in OMS-OWP (Figure 1.5). The highest total PAH concentration of 1811 mg/kg was measured in the 1.8 to 2.4 m (6 to 8 ft) composite from OMS-CPA. Total PAH concentrations exceeded the SDCR in all but three samples from OMS-CPA and OMS-END: OMS-41E (2.4 to 3.0 m [8 to 10 ft]), and OMS-47D (1.8 to 2.4 m [6 to 8 ft]), and OMS-50F (3.0 to 3.6 m [10 to 11.7 ft]). Elevated PAH concentrations were measured in samples from the bottoms of two cores: OMS-45 (87 mg/kg total PAH from 8.2 to 8.9 m [27 to 29.2 ft] below the mudline) and OMS-48 (1573 mg/kg 4.9 to 5.5 m [16 to 18 ft] below mudline). PAH contamination may extend even deeper at those two stations. In OMS-OWP, total PAH concentrations decreased from 1195 mg/kg in the 0 to 0.6 m (0 to 2 ft) interval to 15.5 mg/kg in the 1.8 to 2.4 m (6 to 8 ft) interval. None of the samples from OMS-OWP had total PAH concentrations below the SDCR, although no samples from greater than 2.4 m (8 ft) below mudline were analyzed. The 1.8 to 2.4 m (6 to 8 ft) composite was 1.5 times reference.

Sources of PAH Contamination in Old Mormon Slough. Two different sources of contamination probably caused PAH contamination of shallow (0 to 1.8 m [0 to 6 ft]) and deep (>1.8 m [>6 ft]) sediments in Old Mormon Slough. The black, oily clayey silts generally found between 0.6 m (2 ft) and 1.8 m (6 ft) below the mudline probably originated from spills and stormwater discharges into Old Mormon Slough. The most highly contaminated sediments are found at sampling stations adjacent to the discharge pipes (OMS-53, OMS-50) and directly north of the CPA (OMS-48). An additional and ongoing source of contamination to shallow sediments was the observed oily seepage from the banks of Old Mormon Slough near the OWP. The shallow (<0.6 m [<2 ft]) sediments are less contaminated than buried sediments in OMS-END and OMS-CPA, possibly because direct discharges to the slough decreased over time, and then ceased when the site became inactive. The shallow (0 to 0.6 m [0 to 2 ft]) sediments in OMS-OWP may be more highly contaminated than the buried sediments, because this area was still receiving contamination from oily seeps along the bank of the slough until recently.

In deeper sediments (generally >1.8 m [>6 ft] below mudline) oil droplets and sheen were observed in the pore spaces of alluvial sediments, particularly in sandier layers. The source of this deep contamination is unknown. While some locations (OMS-46 and OMS-47) had deep PAH contamination, adjacent cores (OMS-46 and OMS-47) did not. In addition, there is no evidence of a migration pathway (i.e., continuous permeable layers, residue in soil borings, high concentrations in monitoring wells between the known upland source areas and the slough) from the upland soils to Old Mormon Slough sediment.

1.2.5.2 Nature and Extent of Dioxin Contamination

Dioxin was present in samples from Old and New Mormon Sloughs at international toxicity equivalent concentrations (TEQs) exceeding reference. The TEQs in SDC samples were below reference. The highest TEQ in New Mormon Slough was 579 pg/g (7 times reference) at NMS-67, which is the background sample for New Mormon Slough. This indicates other sources of dioxin to New Mormon Slough in addition to the 1970 to 1978 stormwater discharges from the M&B site.

Lateral Extent in Old Mormon Slough. In Old Mormon Slough, TEQS decreased from east to west; from OMS-END (concentrations ranging from 1.03 to 1347 pg/g) to OMS-MTH (concentrations ranging from 58.3 to 0.0016 pg/g) (**Figure 1.6**). TEQS were above the SDCR concentration in some samples from OMS-END, OMS-CPA, and OMS-OWP.

Vertical Extent in Old Mormon Slough. In Old Mormon Slough, TEQ concentrations decreased with increasing depth from mudline to 2.4 m (8 ft), from 1347 to 1.03 pg/g in OMS-END, 1064 to 76.8 pg/g in OMS-CPA, 366 to 0.043 pg/g in OMS-OWP, and 39.9 to 0.0016 pg/g in OMS-MTH (Figure 1.6). TEQS were above reference in the 0 to 0.6 m (0 to 2 ft) composites from OMS-END, OMS-CPA, and OMS-OWP, and in the 0.6 to 1.2 m (2 to 4 ft) composites from OMS-END and OMS-CPA. The results of the two-way compositing scheme indicate that the most dioxin-contaminated sediments (>10 times SDCR in both horizontal and vertical composites) are in the upper 60 cm (2 ft) of sediment at stations OMS-40 and OMS-41, and in the upper 120 cm (4 ft) at OMS-48V and OMS-50V.

Sources of Dioxin Contamination in Old Mormon Slough. The source of dioxin to Old Mormon Slough sediments is most likely the PCP used at the M&B site. Dioxins are impurities in PCP formulations, where they are primarily composed of hepta- and octa-chlorinated congeners (Eisler 1989). Dioxins were most likely discharged to Old Mormon Slough via PCP spills and in PCP-contaminated stormwater from the M&B site. The two-way compositing scheme showed that shallow sediments at stations OMS-40, OMS-41, OMS-48, and OMS-50 contained the highest levels of dioxins. Stations OMS-40 and OMS-41 are adjacent to two stormwater discharge pipes at the END of the slough and OMS-50 is adjacent to a discharge pipe north of the CPA.

1.2.5.3 Nature and Extent of PCP Contamination

Chlorinated phenols were not detected in most of the sediment samples collected from the study area and reference locations. Although detection limits were raised in many samples because of analytical interferences, the maximum detection limit for all analytes was 550 µg/kg (2,4,5-trichlorophenol), and was 63 µg/kg for PCP. These detection limits are lower than those achieved in previous studies. Chlorinated phenols were not detected in samples from New Mormon Slough, the SDC, or the reference locations. Analytical interferences in the samples from New Mormon Slough and the SDCR prevented the positive identification and quantification of some compounds; they might have been present at or below the reported detection limits. In particular, samples collected from New Mormon Slough downstream of the discharge pipe that formerly carried runoff from the M&B site were expected to contain traces of PCP or its degradation products because of the documented PCP discharge that occurred in this area in 1977.

Lateral Extent in Old Mormon Slough. PCP was detected in samples from OMS-END at a maximum concentration of 120 µg/kg, and in samples from OMS-CPA at a maximum concentration of 5600 µg/kg. Several other chlorinated phenols were detected in samples from OMS-CPA. Chlorinated phenols were not detected in samples from OMS-OWP and OMS-MTH.

Vertical Extent in Old Mormon Slough. PCP was detected at concentrations of 40 and 120 µg/kg in the 0 to 0.6 m (0 to 2 ft) and 0.6 to 1.2 m (2 to 4 ft) composites, respectively, in OMS-END. It was not detected in deeper composites. PCP was detected in all composites from OMS-CPA, increasing by two orders of magnitude from the 1.2 to 1.8 m (4 to 6 ft) interval (47 µg/kg) to the 1.8 to 2.4 m (6 to 8 ft) interval (5600 µg/kg). The vertical extent of PCP contamination in OMS-CPA was not fully defined at two sampling locations.

Sources of PCP Contamination in Old Mormon Slough. The PCP from 0 to 1.2 m (0 to 4 ft) in OMS-END and 0 to 1.8 m (0 to 6 ft) in OMS CPA was most likely spilled or contained in stormwater discharged directly into Old Mormon Slough from discharge pipes, in addition to the observed seeps from the OWP area. PCP was the major contaminant present in stormwater runoff collected from the onsite stormwater collection ponds (CH2M Hill 1991) and in stormwater discharged directly into the slough prior to the construction of the ponds. In addition, NPDES permit violations for PCP in process wastewater were documented. These sediments also contained elevated levels of dioxin, which was present as an impurity in the PCP.

1.2.6 Contaminant Fate and Transport

The M&B site has been inactive for seven years, and contaminant levels in surface sediments are expected to decrease with time (White and Kohn 1996). In the absence of mixing and an ongoing source of contamination, contaminant levels in the surface sediments would gradually decrease as the previously contaminated sediment is buried by naturally occurring uncontaminated deposits. However, solid-phase contaminants may be mixed into the surface sediments by bioturbation and mechanical processes (i.e., boat traffic). Contaminants may also move vertically in the sediment by desorption, transport in porewaters, and subsequent adsorption (porewater diffusion). Bubbles formed as organic matter decays are also a means of vertical transport of contaminants from the sediment through the water column.

The origin, transport, and fate of anthropogenic organic contaminants in sediments from Old Mormon Slough are discussed in the following sections taken from the Surface-Water Sediment RI Report. As previously discussed, New Mormon Slough and the SDC do not appear to be adversely affected by contamination from the M&B site. One metal, chromium, occurs in some samples from Old Mormon Slough at concentrations exceeding the SDCR sample; however, the maximum concentration is only 1.4 times the reference.

1.2.6.1 Fate and Transport of PAHs

PAHs in Old Mormon Slough sediment are composed primarily of the LPAHs naphthalene, acenaphthene, fluorene, phenanthrene, and anthracene. Fluoranthene and pyrene are the dominant HPAHs. Potential sources of PAHs are spills of site-related chemicals directly into the slough, discharge of stormwater through outfalls, and the past migration of NAPLs from subsurface soils in the OWP area. Most of the sources of contamination to the slough ceased to exist when the site became inactive, with the exception of the OWP area seeps. These seeps were first observed during sampling in 1995, although it is not known when they first began. As noted earlier, they have been addressed and no longer represent a continuing source to the slough.

The physical and chemical properties of PAHs vary with molecular weight (**Table 1.1**). With increasing molecular weight, aqueous solubility decreases, and logs Kow (octanol-water partitioning coefficient) and Koc (organic carbon partitioning coefficient) increase. Therefore, HPAHs are less mobile and more persistent in aquatic environments and they tend to bioaccumulate in aquatic organisms more readily than LPAHs. PAHs that are dissolved in the water column will rapidly degrade by photo-oxidation (EPA 1980a); they can also evaporate or volatilize, disperse in the water column, undergo chemical oxidation, or biodegrade (Suess 1976). PAHs that are incorporated into the bottom sediments may biodegrade, although degradation rates are slow in the absence of radiation and oxygen (Suess 1976). PAHs may persist for long periods of time in anoxic sediments (Neff 1979). Low dissolved oxygen levels due to organic loading in Old Mormon Slough has been reported (NOAA 1993) and evidence of decomposing organic matter in the slough sediments was observed in October 1994 (White and Kohn 1996). Therefore, the PAHs present in the sediments from Old Mormon Slough are expected to persist for a long period of time under the current site conditions.

1.2.6.2 Fate and Transport of Dioxin

Dioxins and furans are hydrophobic, lipophilic, and extremely stable under most environmental conditions (Table 1.1). They persist in the environment long after PCP residues degrade (Petreas and Hayward 1994). They resist degradation by oxidation, hydrolysis, or biological activity (Stehl 1973; Miller and Zepp 1987; Arthur and Frea 1989). Photodegradation is the only significant path of destruction in natural environments (Koester and Hites 1992). In most aquatic environments, dioxins and furans are strongly sorbed to particulate and organic matter and are relatively immobile. Thus, their transport in the aquatic environment will occur primarily by the resuspension and migration of contaminated sediment.

1.2.6.3 Fate and Transport of PCP

PCP readily degrades in aquatic environments. It breaks down by chemical processes such as oxidation and dechlorination, and reductive dehalogenation (Williams 1982; Kaufman 1978). It also readily photodegrades (EPA 1980b). In estuarine sediments, aerobic, and anaerobic microbial degradation was found to be the major PCP breakdown process; tidal transport and photodegradation were minor (DeLaune et al. 1983). In the absence of a continuing source, PCP does not persist for long periods of time in aquatic environments.

1.2.6.4 Sediment Transport Mechanisms

The dominant transport mechanism for contaminants that are strongly bound to sediment particles (dioxins and HPAHs) is the migration of fine-grained sediment. For transport to occur, the contaminated sediments must be resuspended and carried away by tidal currents. The current speeds in sloughs are slow and are probably incapable of eroding the sediments in the absence of other disturbances. Resuspension may be caused by boat wakes and propeller wash, dredging or construction activities, and biological activity (bioturbation, bioaccumulation, and degassing). Wind and wave action is probably insignificant because the slough is protected. Boat traffic is rare in the eastern (stagnant) end of the slough, but barges occasionally use the dredged western portion, which contains the least-contaminated sediment. Consequently, the rate of sediment transport out of Old Mormon Slough appears to be very low. This conclusion is supported by the absence of site-related contamination measured in samples collected near the mouth of Old Mormon Slough and in the SDC nearest the site.

The need for maintenance dredging in the Port of Stockton indicates that it is an area of net sediment deposition. The sedimentation rate depends upon the sediment load of the waters flowing in and out of the slough, the volume of water exchanged during each tidal cycle, and the settling velocity of the suspended sediment (Downing et al. 1987). White and Kohn (1996) estimated an average sedimentation rate of 3.6 cm/yr (1.4 in./yr) in Old Mormon Slough by dividing the average thickness of sediment overlying a marker bed, assumed to be associated with construction of Interstate 5, by the 25 years since its construction.

1.2.7 Potential Routes of Exposure

The primary source of risk from the Surface-Water Sediment OU is from contaminated sediments in Old Mormon Slough (White and Kohn 1996; Thom et al. 1997). Contamination in the water column is assumed to be a direct result of these contaminants partitioning into the surface water and as such surface water has not been evaluated separately.

Baseline human health and ecological risk assessments have been conducted to evaluate the threat posed by contamination at the M&B site (ICF 1996; Thom et al. 1997). The results of these studies as they relate to the Surface-Water Sediment OU are summarized in the following subsections.

1.2.7.1 Findings of the Human Health Risk Assessment

The baseline Human Health Risk Assessment (HHRA) (ICF 1997) primarily addressed the potential human health risks posed by hazardous substances in surface soils and groundwater at the M&B site. Human health risks associated with the Surface-Water Sediment OU that were evaluated in the HHRA focused on the consumption of locally caught fish.

The M&B site and neighboring lands are zoned for heavy industrial uses. The nearest residences are located approximately 150 m (500 ft) to the southwest and west. Additional residences are located approximately 230 m (750 ft) to the southeast and are separated from the site by Interstate 5 and Highway 4. Recreational and subsistence fishing is known to occur in Old Mormon Slough, New Mormon Slough, and in the SDC. In conducting the HHRA, the future land use of the M&B site was assumed to remain industrial. Four potential exposure pathways were evaluated:

- incidental ingestion and dermal adsorption of COCs in surface soils by onsite workers
- inhalation of fugitive dust from onsite surface soils by onsite workers and nearby offsite residents
- incidental ingestion and dermal adsorption of COCs in groundwater
- ingestion of fish by recreational and subsistence fishermen.

Potential receptors addressed in the HHRA were onsite industrial workers, offsite residents, and local fishermen and their families.

Potential Risks from Soil and Groundwater Contamination. The greatest excess carcinogenic risk from the M&B site is through exposure of onsite workers to soil contamination via incidental ingestion and dermal adsorption. The HHRA estimated a potential cumulative average and reasonable maximum exposure of 7E-4 and 3E-3, respectively, with TCDD TEQ contributing the vast majority to the carcinogenic risks. PAHs, PCP, metals, and TCDD TEQ have also been detected in groundwater beneath the site in excess of their corresponding MCL. A complete discussion of the human health risks associated with the Soils-Groundwater OU can be found in the HHRA.

Potential Risks from the Consumption of Fish. The impact on individuals eating contaminated fish from Old Mormon Slough and the SDC was evaluated using data on chemical concentrations in fish tissue taken from the 1994 Cal/DHS study (Petreas and Hayward 1994). The only site-related contaminants analyzed in local fish tissue from this study were dioxins and furans. The concentrations of TCDD TEQ in both fish fillets and whole body is shown in **Table 1.2**, compared to the CWA-derived fish tissue criterion of 7E-8 mg/kg. Table 1.2 also compares fish tissue concentrations with the Food and Drug Administration (FDA) standards (FDA 1981, 1983). Concentrations of TCDD TEQ in whole body fish samples collected from Old Mormon Slough (in the immediate vicinity of the M&B site) and the END of the SDC exceeded both the FDA Standard of 0.025 µg/kg (2.5E-5 mg/kg) and the CWA-derived fish tissue criterion (ICF 1997), while the concentrations of TCDD TEQ in fish fillets does not exceed the FDA standard. The mean TCDD TEQ concentrations in whole body fish collected during the Ecological Risk Assessment is presented in **Table 1.3** (Thom et al. 1997). These whole body fish concentrations appear to average about one order of magnitude lower than those from the Cal/DHS 1994 study.

Table 1.4 presents the potential risks associated with the average and maximum TCDD TEQ concentrations observed in fish fillet from the 1994 Cal/DHS study as calculated in the HHRA. The consumption scenarios evaluated in this table assume a residential adult receptor and various consumption rates ranging from 6.5 g/day to a worst-case consumption rate of 200 g/day of fish fillet. Potential risks for subsistence fishing and worst-case scenarios exceed the carcinogenic risk range (1E-4 to 1E-6) considered acceptable by EPA. The average concentration of dioxin in fish tissue collected from Old Mormon Slough (Petreas and Hayward 1994) relates to an additional cancer risk to humans of 8E-4 (assuming a consumption rate of 150 g/day, 350 days/year, for 30 years). The maximum concentration relates to a worst-case risk of 1E-3 (assuming a consumption rate of 200 g/day for the same duration) (ICF 1997). In general, the potential risks associated with consumption of dioxin-contaminated fish are higher for Old Mormon Slough than for the SDC. However, these data alone are insufficient to determine if locally caught and consumed fish pose an unacceptable risk to local fishermen and their families. As noted earlier, fish samples collected for the ERA had TCDD TEQ concentrations one order of magnitude lower than those used for the HHRA. Thus, there is some uncertainty regarding the representativeness of the fish data used in the HHRA. These uncertainties include the degree of fish mobility, the method of collection, the distribution of fish sizes, ages, and species evaluated relative to the sizes, ages, and species caught and consumed by local fishermen, and the link between contaminant concentrations in fish and the concentrations of contaminants observed in Old Mormon Slough sediments (ICF 1997).

1.2.7.2 Findings of the ERA

Because there are no known threatened or endangered terrestrial species and no sensitive terrestrial habitats at or in the vicinity of the M&B site, a screening level ecological assessment only was conducted for the upland portion of the site. No terrestrial impacts were identified related to the M&B site.

A full-scale ERA was performed for the aquatic ecosystem to determine whether contamination from the M&B site was affecting food web integrity and productivity (Thom et al. 1997). The exposure, effects, and risk from the COCs to the aquatic ecosystem were investigated. The receptor species of interest consisted of two resident fish, bluegill and white catfish, and two fish-eating birds, great blue heron and double-crested cormorant. Exposure was measured through analysis of COCs in surface sediments and tissues of fish, crayfish, and oligochaete worms. Effects were established through sediment toxicity tests with benthic invertebrates (an amphipod and larval insect), prediction of sediment toxicity based on COC concentrations in sediments, and prediction of toxicity to fish and birds based on measured or estimated COC body burdens. The presence of risk was assessed by comparing exposure and effects data for Old and New Mormon Sloughs with similar data for reference sites in the SDC and the San Joaquin River, and with published benchmark risk values. The relative degree of risk was assessed by a “weight of evidence” approach for each endpoint in which the level of exceedance of reference and benchmark values, data quality, and level of uncertainty were considered.

Table 1.5 presents a summary of the ecological risk posed by each class of COC relative to the threshold for each assessment endpoint (Thom et al. 1997), while **Table 1.6** summarizes the relative ecological risks for each of the surface-water bodies and reference areas. The results from this study support the conclusion that ecological risk is greatest from contamination in Old Mormon Slough. In general, sediment contamination was greatest in the END, CPA, and the OWP areas of Old Mormon Slough. Contaminant concentrations were much lower near the mouth of the slough. PAHs were found to pose the greatest risk to all assessment endpoints, and threshold limits for PAHs were exceeded principally for fish and benthic fauna. Dioxins were estimated to be a potential low risk to birds and fish. Metals were not found to be a risk factor to any of the assessment endpoints. While some risk to receptor species was attributed to the presence of PAHs and dioxins, and possibly PCP, in surface sediments, there is no evidence of widespread impact to the aquatic ecosystem. However, Old Mormon Slough is a dead end slough that is not well flushed by river or tidal action, and thus, contamination in Old Mormon Slough sediment is likely to persist for a long time.

New Mormon Slough and the SDCR were less contaminated and posed less risk; however, both were contaminated relative to the San Joaquin River reference. Although ecological risk to aquatic communities from contamination in Old Mormon Slough is attributable to the

M&B site, it is much more difficult to attribute contamination (and risk) in New Mormon Slough and the SDC to the M&B site, for reasons discussed in Subsection 1.2.5.

Several approaches were used in the ERA to estimate maximum sediment concentrations (MSCs) of COCs that were predicted to cause no adverse effect to receptor species. The use of equilibrium partitioning models that predict toxicity to aquatic biota was found to be the most useful approach. **Tables 1.7 through 1.10** provide estimates for (dry weight normalized) MSC of COCs that are predicted to be protective of aquatic biota based on literature values and toxicity tests reported in the HHRA. **Table 1.11** provides a comparison between the MSC and the measured concentrations of COCs in Old Mormon Slough. In the END and off the CPA of Old Mormon Slough, TCDD TEQ concentrations were approximately 30 to 50 times higher than the site-specific MSCs. In the vicinity of the OWP, sediment LPAHs were nearly 80 times higher than the estimated site-specific MSC. Whether a sub-area-specific MSC or a conservative MSC for the entire cleanup area is used, the COC with the highest magnification above the MSC could thus become the driver for setting cleanup criteria that are protective of the aquatic biota in the surface-water OU.

1.2.7.3 Conclusions

Since Old Mormon Slough is not used for recreational purposes, potential risks to humans related to the Surface-Water Sediment OU are primarily through the ingestion of dioxin-contaminated fish taken from Old Mormon Slough and nearby waters. Fish accumulate contamination in their tissues through contact with the sediment and water, gill uptake from the water column, and ingestion of water and contaminated prey. Potential risks for subsistence fishing and worst-case scenarios exceeded the 1E-4 to 1E-6 acceptable risk range (ICF 1997).

A second potential pathway to humans related to the Surface-Water Sediment OU is the migration of contaminated sediments in Old Mormon Slough to groundwater beneath the site. Recharge of the A-Zone aquifer is believed to occur along the length of the slough, thereby providing a driving force for contaminant movement. However, concentrations and total mass of COCs in deep sediments are extremely low relative to the major source areas identified at the OWP area and the CPA in the upland portion of the site. In any event, because Old Mormon Slough is located upgradient from the main groundwater contamination plume, any contribution of contaminants from the deep sediment is expected to be captured by the network of groundwater extraction wells that will be designed to address the major groundwater plume emanating from upland sources.

The primary ecological risks posed to receptor species (e.g., catfish, aquatic avifauna) are from the occurrence of PAHs and dioxins, and to a lesser extent, PCP, in the sediments of Old Mormon Slough. The current levels of dioxins in the surface sediments adjacent to the CPA are 30 to 50 times higher than the site-specific MSC predicted to cause no adverse effects to aquatic biota (Thom et al. 1997). The concentrations of PAHs near the OWP were nearly 80 times higher than the site-specific MSCs. Metals were not found to be a risk factor to any of the assessment endpoints.

Although site-related COCs (and their associated human health and ecological risks) have been detected in both Old and New Mormon Sloughs and along the south edge of SDC, only those contaminants found in Old Mormon Slough are directly attributable to the M&B site. The majority of contamination found in New Mormon Slough appears to be from sources other than the M&B site because concentrations are generally highest at the background location (upstream from the M&B outfall) (White and Kohn 1996). Both New Mormon Slough and the SDC receive input of chemical contaminants from industry, shipping, runoff from streets and highways, and stormwater discharges. The ratios of specific contaminants/congeners found in these surface waters are not consistent with those found in areas known to have been impacted by the M&B site (White and Kohn 1996).

These other sources of contamination to New Mormon Slough and the SDC are likely to have overwhelmed the COC contributions from M&B (Thom et al. 1997). In addition, New Mormon Slough received stormwater discharge from the M&B site for a period of only eight years; it was combined with discharges from other sources in the area before entering New Mormon Slough, and no runoff from the M&B site has entered New Mormon Slough since 1978.

In regard to the movement of contamination out of Old Mormon Slough into the SDC, White and Kohn (1996) describe the rate of sediment transport out of Old Mormon Slough as very low, with a net sedimentation rate estimated at 3.6 cm/yr (1.4 in./yr). This rate would bury and stabilize the contamination in place, rather than transport it outside of Old Mormon Slough. Sediments along the southern edge of SDC near the mouths of Old and New Mormon Sloughs does not appear to be affected by contaminants from the M&B site. Thus, the focus of this feasibility study is directed at potential response actions for remediation of Old Mormon Slough, where contaminant concentrations and risks are the greatest, and directly attributable to the M&B site.

If sediment contamination in Old Mormon Slough is not addressed, it will continue to present a risk to ecological receptors, and to human receptors who consume significant quantities of certain fish species. Although no direct ecological risks have been identified for the upland (Soil-Groundwater OU) portion of the M&B site, potential human health risks have been identified related to soil and groundwater contamination in that OU. If not addressed, contaminated soil and groundwater will continue to represent potential risks to site workers and nearby residents. Remedial actions to address the potential exposure pathways related to soil and groundwater are evaluated in the FS report for the Soil-Groundwater OU and are not discussed in this report, except where areas of overlap are noted.

Figure 1.1. Location of McCormick & Baxter Superfund Site, Stockton, Californa

Figure 1.2. Old Mormon Slough and the McCormick & Baxter Site

Figure 1.3. New Morman Slough

Figure 1.4. Bathymetry of Old Mormon Slough and Stockton Deepwater Channel

Figure 1.5. PAHs in Sediment Samples from Old Mormon Slough (after White and Kohn 1996)

Figure 1.6. PCDD/PCDF I-TEQs in Sediment Samples from Old Morman Slough (after White and Kohn 1996)

Table 1.1. Physical and Chemical Properties of Organic Contaminants (after White and Kohn 1996)

Compound	Molecular Weight[a] (g/mole)	Water Solubility[b] (mg/L)	Log K_{oc}[c]	Log K_{ow}[c]
Naphthalene	128	30.0	2.97	3.23
2-Methylnaphthalene	142	24.6	3.65	3.86
Acenaphthylene	152	3.93	3.40	3.70
Acenaphthene	154	3.88	3.66	4.00
Fluorene	166	1.90	3.86	4.20
Anthracene	178	0.075	4.15	4.45
Phenanthrene	178	1.65	4.15	4.46
Fluoranthene	202	0.240	4.58	4.90
Pyrene	202	0.165	4.58	5.32
Benzo(a)anthracene	228	0.011	6.14	5.60
Chrysene	228	0.0015	5.30	5.61
Benzo(a)pyrene	252	0.004	6.74	6.06
Benzo(b)fluoranthene	252	0.0015	5.74	6.06
Benzo(k)fluoranthene	252	0.0008	5.74	6.06
Indeno(1,2,3-cd)pyrene	276	NA	6.20	6.50
Benzo(g,h,i)perylene	276	0.00026	6.20	7.10
Dibenz(a,h)anthracene	278	0.0005	6.52	5.61
Pentachlorophenol	266	14	4.72	5.00
PCDD/PCDFs	306 to 460	7.4E-08 to 4.19E-04	5.68 to 5.97	6.10 to 7.92

(a) Molecular weight for PAHs and PCP except benzo(g,h,i)perylene: Strenge and Peterson (1989). Molecular weight for benzo(g,h,i)perylene and tetra- through octa-PCDD/PCDF congener: Mackay et al. (1992).

(b) Water solubility data for PAHs at 25°C: Mackay et al. (1992). Water solubility value for PCP at 20°C: Eisler (1989). Water solubility data for tetra- through octa-PCDD/PCDF congeners (decreases with increasing degree of chlorination): Friesen et al. (1985); Shiu et al. (1988); Friesen et al. (1990).

(c) Log K_{oc} and Log K_{ow} data for PAHs and PCP except benzo(g,h,i)perylene: Strenge and Peterson (1989). Log K_{oc} and Log K_{ow} data for benzo(g,h,i,)perylene: Mackay et al. (1992). Log K_{oc} range for tetra-through hexa-PCDD/PCDF congeners (Webster et al. 1986). Log K_{ow} range for 73 PCDD/ PCDF congeners: Sijm et al. (1989).

Table 1.2. Concentrations of TCDD/TEQ Observed in Tissues of Locally Caught Fish Near the M&B Site During the Cal/DHS (1994) Study (after ICF 1997)

Fish Tissue Sample		Old Mormon Slough Dioxins (TCDD/TEQ) (mg/kg)	END of SDC Dioxins (TCDD/TEQ) (mg/kg)	CWA Derived Fish Tissue Criterion (mg/kg)(1)	FDA Level (mg/kg)(2)
Carp #1	(fillet)	3.1E-7	2.5E-7	7.0E-8	2.5E-5
	(whole body)	1.5E-6	1.7E-6		
Carp #2	(fillet)	7.9E-7	NA		
	(whole body)	1.6E-6	NA		
Bass(a) #1	(fillet)	6.1E-7	2.0E-7		
	(whole body)	6.8E-6	2.2E-6		
Bass(a) #2	(fillet)	7.2E-7	2.6E-7		
	(whole body)	5.5E-6	3.6E-6		
Bass(b) #1	(fillet)	NA	1.5E-6		
	(whole body)	NA	6.5E-6		
Bass(b) #2	(fillet)	NA	4.4E-7		
	(whole body)	NA	2.8E-6		
Bluegill:	(fillet)	4.9E-7	2.8E-7		
	(whole body)	4.7E-6	3.3E-6		
Average of fillets		5.8E-7	4.9E-7	7.0E-8	2.5E-5
Average of whole bodies		4.0E-6	3.4E-6		

NA = Not applicable.
(a) Large mouth bass.
(b) Striped bass.
(1) EPA Region VIII. 1993. Memorandum (dated July 14): Updated Version of the Region's CWA 304(a) Criteria Chart.
(2) FDA, 1981 and 1983.
Sources: Cal/DHS. 1994. California Department of Health Services, Hazardous Materials Laboratory. April.
ICF Technology, Inc. (ICF). 1996. Draft-Final Human Health Risk Assessment for the McCormick & Baxter Superfund Site, Stockton, California. ICF Technology, Inc., Oakland, California.

Table 1.3. Mean TCDD/TCDF TEQ Concentrations in Whole Body Fish Tissue Collected Near the M&B Site (after Thom et al. 1997)

		(Mean TCDD/TCDF TEQ)[a] (mg/kg wet weight)					
Fish Tissue Samples		Old Mormon Slough	New Mormon Slough	Stockton Channel Reference	San Joaquin River Reference	CWA Derived Fish Tissue Criterion (mg/kg)(1)	FDA Level (mg/kg)(2)
Catfish	(whole body)	9.0E-6	8.0E-6	7.4E-6	1.7E-6	7.0E-8	2.5E-5
Bluegill	(whole body)	4.1E-6	1.7E-6	1.7E-6	1.3E-6		
Forage Fish	(whole body)	6.6E-6	2.9E-6	2.4E-6	2.3E-6		
Average of whole bodies		6.6E-6	4.2E-6	3.8E-6	1.8E-6	7.0E-8	2.5E-5

(a) PCDD/PCDF TEQs calculated using the mean PCDD/PCDF and congener concentrations and toxic equivalent factors from Zabel et al. (1995) for rainbow trout egg exposure end point.

(1) EPA Region VIII. 1993. Memorandum (dated July 14): Updated Version of the Region's CWA 304(a) Criteria Chart.

(2) FDA, 1981 and 1983.

Sources: Thom et al. 1997. Ecological Risk Assessment of the Surface Water Operable Unit, McCormick & Baxter Superfund Site, Stockton, California.
ICF Technology, Inc. (ICF). 1997. Human Health Risk Assessment for the McCormick & Baxter Superfund Site, Stockton, California. ICF Technology, Inc., Oakland, California.

Table 1.4. Potential Risks Associated with Dioxins in Fish from Old Morman Slough Based on Various Exposure Scenarios (after ICF 1997)

				Potential Human Health Risk			
Fish Type	Sample Date	Dioxin(a) Concentration (mg/kg)	Consumption Rate (g/day)	6 Children Years *	30 Adult Years	Age Weighted 30 Years **	Lifetime
Carp - Fillet	1992	5.5E-7	6.5	3.0E-6	3.0E-6	5.0E-6	7.0E-6
			64	3.0E-5	3.0E-5	5.0E-5	7.0E-5
			132	6.0E-5	6.0E-5	1.0E-4	1.0E-4
			150	7.0E-5	7.0E-5	1.0E-4	2.0E-4
Carp - Whole Body	1992	1.5E-6	6.5	8.0E-6	9.0E-6	1.0E-5	2.0E-5
			64	8.0E-5	8.0E-5	1.0E-4	2.0E-4
			132	2.0E-4	2.0E-4	3.0E-4	4.0E-4
			150	2.0E-4	2.0E-4	3.0E-4	5.0E-4
Large Mouth Bass - Fillet	1992	6.7E-7	6.5	4.0E-6	4.0E-6	7.0E-6	9.0E-6
			64	4.0E-5	4.0E-5	7.0E-5	9.0E-5
			132	7.0E-5	8.0E-5	1.0E-4	2.0E-4
			150	8.0E-5	9.0E-5	2.0E-4	2.0E-4
Large Mouth Bass - Whole Body	1992	6.2E-6	6.5	3.0E-5	4.0E-5	6.0E-5	8.0E-5
			64	3.0E-4	4.0E-4	6.0E-4	8.0E-4
			132	7.0E-4	7.0E-4	1.0E-3	2.0E-3
			150	8.0E-4	8.0E-4	1.0E-3	2.0E-3
Bluegill - Fillet	1992	4.9E-7	6.5	3.0E-6	3.0E-6	5.0E-6	7.0E-6
			64	3.0E-5	3.0E-5	5.0E-5	6.0E-5
			132	5.0E-5	6.0E-5	1.0E-4	1.0E-4
			150	6.0E-5	6.0E-5	1.0E-4	2.0E-4
Bluegill - Whole Body	1992	4.7E-6	6.5	3.0E-5	3.0E-5	5.0E-5	6.0E-5
			64	2.0E-4	3.0E-4	5.0E-4	6.0E-4
			132	5.0E-4	5.0E-4	9.0E-4	1.0E-3
			150	6.0E-4	6.0E-4	1.0E-3	1.0E-3
Bluegill - Fish Tissue	June, 1995	4.5E-6	6.5	2.0E-5	3.0E-5	4.0E-5	6.0E-5
			64	2.0E-4	3.0E-4	4.0E-4	6.0E-4
			132	5.0E-4	5.0E-4	9.0E-4	1.0E-3
			150	6.0E-4	6.0E-4	1.0E-3	1.0E-3
Catfish - Fish Tissue	June, 1995	1.0E-5	6.5	5.0E-5	6.0E-5	1.0E-4	1.0E-4
			64	5.0E-4	6.0E-4	1.0E-3	1.0E-3
			132	1.0E-3	1.0E-3	2.0E-3	3.0E-3
			150	1.0E-3	1.0E-3	2.0E-3	3.0E-3

(a) Dioxin (TCDD/TCDF) TEQs calculated using the mean TCDD/TCDF congener concentrations and toxic equivalent factors from Zabel et. al. (1995) for rainbow trout egg exposure end point.

* Based on a 6 year duration for children

** Based on an age-weighted exposure duration, 6 years as a child and 24 years as an adult

A consumption rate of 6.5 g/day is based on the state objectives.

A consumption rate of 132 g/day is based on an assumed rate for subsistence fishermen.

Shaded values exceed an acceptable target risk of 1E-4.

Sources: Thom, et. al, 1997. Ecological Risk Assessment of the Surface Water Operable Unit, McCormick & Baxter Superfund Site, Stockton, California. PNL-11466. Pacific Northwest National Laboratory, Richland, Washington.
ICF Technology, Inc. (ICF). 1997. Human Health Risk Assessment For the McCormick and Baxter Superfund Site Stockton, California. ICF Technology, Inc., Oakland, California.

Table 1.5. Summary of Ecological Risk Posed by COCs Relative to Assessment Endpoints (after Thom et al. 1997)

Table 1.6. Summary of Ecological Risk Posed Within Each Study Area Relative to Assessment Endpoints (after Thom et al. 1997)

Table 1.7. Maximum Concentrations of Metals in Sediment Predicted to Cause No Adverse Effect (after Thom et al. 1997)

Metals (µg/g dry weight)	AET	ER-L	EqP-M (AVS = 3.6 µmole/g)[(a)]	EqP-M (AVS = 58.3 µmole/g)[(b)]	Toxicity Test NOEC[(c)]
Arsenic	130	8.2	NA[(d)]	NA	35.6
Chromium	96	81	NA	NA	118
Copper	390	34	***226***[(e)]	***3702***	147
Zinc	460	150	***233***	***3813***	1250

(a) Lowest AVS concentration measured in OMS-END.
(b) Highest AVS concentration measured in OMS-MTH.
(c) NOEC No-observable-effects concentrations of metals are those measured in NMS-UPS sediments, which exhibited the highest non-significant percentage mortality.
(d) NA - AVS normalization not applicable for this metal
(e) Sediment concentrations bolded and italicized are our recommendations for cleanup levels.

Table 1.8. Maximum Concentrations of Pentachlorophenol (PCP) in Sediment Predicted to Cause No Adverse Effect (after Thom et al. 1997)

Table 1.9. Maximum Concentrations of TCDD-TEQs in Sediment that Would Pose Low Risk to Aquatic Life (after Thom et al. 1997)

Table 1.10. Maximum Concentrations of PAHs in Sediment Predicted to Cause No Adverse Effect (after Thom et al. 1997)

Table 1.11. Comparisons with and Ratios of Measured and Maximum Sediment Concentrations of COCs in Old Mormon Slough, New Mormon Slough, Stockton Channel Reference, and San Joaquin Reference (after Thom et al. 1997)

2.0 REMEDIAL ACTION OBJECTIVES AND GENERAL RESPONSE ACTIONS

In this section, RAOs and GRAs are developed to address contaminants in sediment at the M&B site. This section also provides a summary of areas and volumes of sediment to which the GRAs are expected to be applied. Based on the developed RAOs and GRAs, potential remediation technologies will be identified, evaluated, and screened in Section 3.0.

2.1 REMEDIAL ACTION OBJECTIVES FOR SEDIMENT

RAOs are used to establish site-specific cleanup levels that address the current or potential exposure pathways that were identified in the HHRA and the ERA conducted for the M&B site. RAOs are developed for each COC in each medium at the site.

The overall goal of the remedial action at the M&B site is to protect human health and the environment from the risks presented by contaminated soil, groundwater, and sediment. Based on the current zoning designation of the M&B property and nearby land for industrial use, EPA has determined that cleanup levels that are protective for continued industrial use of the site are appropriate. This report presents the RAOs and preliminary cleanup levels for sediment contamination related to the M&B site; those addressing soil and groundwater contamination are presented in a separate FS report (ICF 1997).

General goal statements for sediment are presented first, followed by preliminary numerical standards that the treatment and removal response actions will be required to meet.

2.1.1 General Remedial Goals for Sediment

As summarized in Section 1.0 (and described in detail in the RI report), past woodtreating operations at the M&B site have resulted in contaminated surface soils across most of the site as well as deep soil contamination in some areas that represents an ongoing source to groundwater contamination. Surface waters and sediments near the M&B site were in turn contaminated by process spills, direct discharges of stormwater, non-point source stormwater runoff, and subsurface migration of contaminants from upland soils (i.e., via seeps from the former OWP area). If not addressed, the contaminated sediments in Old Mormon Slough will continue to be a potential source of contamination to the aquatic ecosystem, to fish that are consumed by humans, and, to a lesser extent, to groundwater underlying the site.

The following is a list of primary goals for remediation of sediment contamination related to the M&B site:

- Reduce potential risks to human health from the consumption of fish contaminated with site-related chemicals.
- Prevent humans and aquatic organisms from direct contact with sediment having contaminants in excess of risk-based concentrations or that have been shown to be toxic to aquatic organisms.
- Prevent or minimize the migration of contaminants from Old Mormon Slough sediments into the surface-water column.
- Prevent or minimize the migration of contaminants from Old Mormon Slough sediments to groundwater.
- Allow full attainment of the beneficial uses of surface waters in the vicinity of the site. These beneficial uses include fish and shellfish harvesting and the protection of aquatic life and wildlife.

2.1.2 Numerical Cleanup Levels for Sediment

The NCP (40 CFR 300.430[e][2][I]) requires that the development of cleanup standards consider ARARs and establish acceptable exposure levels that are protective of human health and the environment.

ARARs, used to establish cleanup standards, are chemical-specific federal or more stringent state promulgated criteria. In the absence of ARARs, non-promulgated advisories or guidance, referred to as “to-be-considered” (TBC) criteria, may be used in the development of cleanup standards. Other sources used to develop numerical cleanup standards for sediment are 1) reference concentrations measured in those areas that are believed to be unaffected by the M&B site, and 2) site-specific, risk-based estimates of sediment concentrations that are predicted to be protective of human health and aquatic biota.

For human receptors, the NCP states that for carcinogenic contaminants “acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of 10^{-4} to 10^{-6}.” For non-carcinogens, a hazard index (HI) of one or less is considered an acceptable exposure level. This section presents the numerical standards for sediment that represent protective levels of the COCs found at the M&B site. Treatment and removal response actions would be required to meet these levels.

2.1.2.1 Chemical-Specific ARARs and TBCs

There are three categories of ARARs: chemical-specific, location-specific, and action-specific. Chemical-specific ARARs are health- or risk-based concentration limits for specific hazardous substances in various environmental media. Location- and action-specific ARARs are considered during the development of alternatives. Location- and action-specific ARARs relate to site-specific and technology-specific characteristics that could limit the application of certain remedies at a site. They are discussed in detail in Section 5.0.

Remedial actions must attain ARARs, which are promulgated under federal environmental or more stringent state environmental or facility siting laws, unless a statutory ARAR waiver is granted. As previously noted, TBCs may also be incorporated into the evaluation of potential remedies. Superfund remedies are not required to meet TBCs, but TBCs may be used in the absence of applicable or sufficiently protective ARARs. Once adopted in the Record of Decision (ROD), TBCs become enforceable standards.

The following chemical-specific ARARs and TBCs were considered in the development of numerical cleanup standards for the M&B site.

<u>Surface-Water ARARs and TBCs</u>

EPA ambient water quality criteria (AWQC) (40 CFR 131.36) for PCP, arsenic, chromium (VI), copper, and zinc are presented in **Table 2.1**. Other COCs found at the M&B site do not yet have defined AWQC. Human health (10^{-6} cancer risk) values are also shown in this table.

The AWQCs were developed under Section 304 of the Federal Clean Water Act. This Act required EPA to publish criteria for water quality that accurately reflect the latest knowledge on the effects of contaminants in surface water on health and welfare of humans and aquatic life based on the substance's whole-water concentration.

The saltwater AWQCs were used for the M&B site because both Old and New Mormon Sloughs have brackish water (i.e., they have salinities on the order of 3 ppt, or 3000 g/m^3, which according to Tchobanoglous and Schroeder (1987) exceeds the approximate upper limit of 1500 g/m^3 for freshwater). In addition, the saltwater criteria are more conservative.

Section 121(d)(2)(A)(ii) of CERCLA requires that remedial actions meet federal water quality criteria established under Section 304 or 303 of the CWA where such water quality criteria are determined by EPA to be relevant and appropriate to remedial actions at an NPL site. In evaluating whether specific water quality criteria are relevant and appropriate, 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.

The California Porter-Cologne Water Quality Act contains provisions that control release of hazardous substances to surface waters. However, no state chemical-specific values for the COC at the M&B site have been defined.

TBC criteria consist of marine water quality objectives developed by the California State Water Resources Control Board (SWRCB 1990, 1991) and by the San Francisco Bay Regional Water Quality Control Board (SFBRWQCB 1992). These criteria are also shown in Table 2.1.

Sediment ARARs and TBCs

There are no Federal or state ARARs for sediment. TBC criteria for sediment consist of the EPA Sediment Quality Criteria (EPA 1993a, b, c), the results of the Ecological Risk Assessment (Thom et al. 1997), and National Oceanic and Atmospheric Administration (NOAA) Effects Ranges (Long et al. 1995). EPA Sediment Quality Criteria are only available for the PAHs acenaphthene, phenanthrene, and fluoranthene; these are shown in **Table 2.2**.

Groundwater ARARs and TBCs

Groundwater ARARs and TBCs may be an issue for sediment remediation, since sediment contamination in Old Mormon Slough represents a potential source to groundwater contamination beneath the site. No direct evidence has been found that slough sediments are contributing to groundwater contamination at the M&B site. In addition, the slough sediments represent a minor potential source area in relation to the major sources at the site (i.e., the deep soils and NAPLs contamination found in the upland OU). If contaminated sediments were left in place and/or capped rather than removed, they would continue to serve as a potential source to groundwater contamination (although the effect would be somewhat reduced because of the overlying cap). However, because Old Mormon Slough is located upgradient from the main groundwater contamination plume, any contribution of contaminants from the sediment is expected to be captured by the network of groundwater extraction wells that will be designed to address the major groundwater plume emanating from the upland sources. For this reason, ARARs and TBCs for groundwater are discussed in the Soils-Groundwater OU FS report and are not repeated here. The evaluation of alternatives for the remediation of groundwater at the M&B site is found in the Soils-Groundwater OU FS report (ICF 1998).

Fish and Shellfish TBCs

There are no chemical-specific fish or shellfish ARARs for the COCs found at the M&B site. The FDA (41 CFR 321) established that fish with a 2-, 3-, 7- , and 8-TCDD content averaging <0.025 ug/kg pose no serious health concerns (EPA 1995; ICF 1997). FDA values are generally used as guidance to remove contaminated fish and shellfish from the marketplace.

Maximum tissue residue levels (MTRLs) are defined for the California Mussel Watch Program (SWRCB 1994) for total PAHs at 0.93 ug/kg (enclosed bays and estuaries) and 0.08 ug/kg (inland surface waters), and for PCP at 90.0 ug/kg (enclosed bays and estuaries) and 3.1 ug/kg (inland surface waters). These values are based on EPA AWQC (40 CFR 131.36) multiplied by a bioaccumulation factor (BCF).

2.1.2.2 Reference Concentrations

As part of sediment sampling conducted for the RI and ERA, samples were collected at locations (upstream SDC and the San Joaquin River) that are believed to be out of the area of influence of the M&B site. The SDC was considered representative of sediment conditions in an industrial area such as the Port of Stockton. The San Joaquin River sample location was considered to be away from industrial sources and, therefore, more representative of true background conditions. The reference concentrations are included in Table 2.2.

2.1.2.3 Risk-Based Cleanup Levels

Risk-based sediment cleanup levels were derived based on both human health (consumption of fish) and environmental risk. A preliminary cleanup level based on human consumption of locally caught fish was developed for TCDD TEQ only, because it is the risk driver for this pathway. It used a back calculation for the fish tissue concentration that would produce a total excess cancer risk of 10^{-6} or less. The calculation assumed an extremely conservative consumption rate of 150 g/day, 350 days/year for 30 years, which represents the potential consumption of locally caught fish from Old Mormon Slough by subsistence fishermen under a worst-case scenario. This value is shown in **Table 2.3**.

The ERA defined values for MSC cleanup levels for the COCs at the M&B site. The MSCs are dry weight concentrations that are predicted to be protective of aquatic biota based on literature values and toxicity tests conducted for the M&B ERA. For most of the COCs, several approaches were used to calculate these maximum concentrations, including sediment quality guidelines, equilibrium partitioning models, contaminant mixtures models, correlations with sediment toxicity, and sediment quality criteria. Not all approaches could be applied to each COC. The development of MSCs for the M&B site is summarized in Appendix C. The MSCs are shown in Table 2.2.

The risk-based preliminary cleanup level for total PAHs varies for each sub-area of Old Mormon Slough based on the total organic content (TOC) of the sediment (see Table 2.3). The greater the organic content, the fewer PAHs that are available for biological uptake. The preliminary cleanup levels range from 3.6 mg/kg at the mouth of the slough to 12 mg/kg at the END of the slough. The reference location in the SDC has a background total PAH concentration of 10.4 mg/kg.

2.1.2.4 Preliminary Sediment Cleanup Levels

The reference concentrations in sediment for each contaminant, the TBCs, and risk-based levels are summarized in Table 2.2. Maximum and minimum concentrations that were measured in the four sub-areas of Old Mormon Slough are listed for comparison.

The preliminary cleanup levels for sediment contamination associated with the M&B site are presented in Table 2.3. As discussed earlier, this table also includes an extremely conservative preliminary cleanup level for fish tissue (TCDD TEQ only) that was back calculated for the fish tissue concentration that would produce a total excess cancer risk of less than 10^{-6}. This addresses the exposure pathway related to human consumption of locally caught fish, while the other preliminary cleanup numbers in the table are for sediment and address the ecological risk pathways.

The preliminary cleanup levels in Table 2.3 are based on an anticipated future occupational use of the site consistent with current industrial zoning. The preliminary sediment cleanup levels are based on PAHs and dioxin. These constituents were identified as the primary risk drivers in sediment; metals were not found to be a risk factor to any of the ecological endpoints (Thom et al. 1997). The MSC is the more conservative number and so it was selected.

2.2 GENERAL RESPONSE ACTIONS

This section summarizes the GRAs for sediment that would satisfy the RAOs for the M&B site presented in the previous section. As indicated in the previous discussion, both fish and sediment near the M&B site have been found to be contaminated with site-related COCs. It is assumed, however, that if the source of contamination in the sediment is removed the exposure of fish to these contaminants will decrease as the contaminated sediments are naturally buried and degraded. Eventually, levels of contamination in the fish will return to safe levels. By reducing the highest concentrations and mass of PAHs and dioxin in sediment that is available for transport into the surface water system for uptake by the water column organisms, fish population will eventually achieve acceptable tissue concentrations (i.e., fish that may be consumed by humans, concentrations of dioxin as well as the other COCs). Therefore, sediment is the primary target for remediation in this FS.

2.2.1 Principal and Low-Level Threats

GRAs are broad classes of responses or remedies intended primarily to allow categorization of technologies for screening purposes. GRAs fall into the categories of institutional controls, containment technologies, removal, treatment (in situ or ex situ) technologies, and disposal. To identify those GRAs that are appropriate at a site, contaminated media are discussed in terms of principal and low-level threats.

Principal and low-level threat wastes are identified in accordance with the NCP (40 CFR Section 300.430(a)(1)(iii)) and EPA guidance. Principal threat wastes are those source materials considered to be highly toxic or highly mobile that generally cannot be reliably contained or that would present a significant risk to human health or the environment, should exposure occur. There is no fixed threshold level of toxicity/risk that is used to define principal threats.

Low-level threat wastes are those source materials that generally can be reliably contained and that would present a low risk in the event of a release. They include source materials that exhibit low toxicity, low mobility in the environment, or are near health-based levels.

For the purposes of this FS, the potential areas of principal threat are considered to be those portions of Old Mormon Slough that contain a preponderance of the contamination (by mass) and/or the highest levels of contamination that are most likely biologically available or pose a significant potential threat to groundwater. To define these areas the results of the two-way composite sediment sampling, conducted by White and Kohn (1996), were compared to the preliminary sediment cleanup levels in Table 2.3 and the SDCR concentrations shown in Table 2.2. In this evaluation, each sub-area of the slough (i.e., mouth of he slough [MTH], OWP, CPA, and END) was represented by a series of cells two feet thick and centrally located around each sampling point (**Figure 2.1**).

As shown in **Figures 2.2 and 2.3**, the distribution of PAHs and TCDD TEQ that exceed the preliminary sediment cleanup levels are confined primarily to the OWP, CPA, and END sub-areas of the slough. Contamination is not widespread in the MTH sub-area; only three “hot spots,” which represent only a fraction of the contamination, were identified. One of these “hot spots” is located at OMS-58, immediately adjacent to the OWP sub-area, and can easily be remediated in conjunction with it. The principal threat area for the MTH sub-area is defined as the area south and east of a midline between OMS-58 and OMS-59 (**Figure 2.4**).

The area of low-level threat is defined as that area surrounding the two “hot spots” in the MTH sub-area of Old Mormon Slough and the deeper sediment contamination that is not biologically available and that is not believed to represent a significant source to groundwater contamination. Of the two “hot spots,” the one at OMS-61 (see Figure 2.2) exceeded the MSC for PAHs and the other at OMS-60 (see Figure 2.3) exceeded the MSC for TCDD TEQ. The two isolated high values are located in the uppermost sediments and are not considered to pose a threat to groundwater. There is no obvious spatial continuity between these high values and the surrounding values; thus, these values are unlikely to represent an area of contamination that could be located again. They are extremely difficult to define for implementation of any active remedial action such as capping or dredging. Applying containment or other active remedial technology to the entire MTH sub-area is not warranted based on the degree of risk reduction expected in relation to its anticipated additional cost. In addition, they are both located in the portion of the slough that historically has been used for barge traffic. The most feasible general response action for this low-level threat area would be the use of institutional controls to control access to and limit the types of activities conducted in this area of Old Mormon Slough, and long-term monitoring.

The highest percentage of contamination is located in subsurface sediments that are expected to remain buried and out of contact with aquatic organisms, and will not effectively partition into the surface water. As noted in Section 1.0, Old Mormon Slough and the Port of Stockton Turning Basin are thought to recharge the groundwater system beneath the M&B site. Although the deeper slough sediments are a potential threat to groundwater contamination, and thus a potential principal threat, they are not considered a significant source to groundwater contamination in relation to the extensive deep soil and NAPL contamination in the upland portion of the site. In addition, any contribution of COCs from slough sediment to groundwater is expected to be captured by the proposed groundwater extraction system that was evaluated for the Soil-Groundwater OU.

2.2.2 Sediment Volume Calculations

Preliminary volumes of contaminated sediment relative to the SDCR concentrations were calculated for the M&B site (White and Kohn 1996). The volume of sediment at 0 to 2.4 m (0 to 8 ft) below the mudline in Old Mormon Slough that exceeded the SDCR value for total PAH was 54,000 m^3 (70,590 cy). Approximately 20,800 m^3 (27,140 cy) of the sediment exceeds total PAH concentrations greater than 100 times the SCR. White and Kohn (1996) also estimated the volume of sediment exceeding the SCR TCDD TEQ concentrations as 22,800 m^3 (29,800 cy), with approximately 14,700 m^3 (19,230 cy) exceeding 10 times the SCR.

To better define potential volume and contaminant mass estimates for GRAs, a volume and average contaminant concentration was estimated for each 2-ft-thick cell surrounding each sampling location. These estimates are presented in Appendix B. The following sections describe the sediment volumes and contaminant mass that were estimated to exceed the preliminary sediment cleanup levels.

For comparison purposes, volumes are calculated in relation to both the risk-based cleanup numbers (MSCs) and the SCR reference value.

Volume Calculations for PAHs. The depth of contamination of PAHs varies in each designated sub-area of Old Mormon Slough. The majority of contamination appears to be located in the top 2.4 m (8 ft) of the slough sediments; however, PAH contamination has been detected to a depth greater than 6 m (20 ft) in boreholes OMS-48 and -45 in the central and END of the slough. For these volume calculations a maximum depth of 2.4 m (8 ft) was used because analytical data was not available below that depth for the entire length of Old Mormon Slough. Therefore, the total volume could be higher.

The preliminary sediment cleanup level for total PAH varies based on the TOC of the sediment because the higher the organic content, the less PAH that is available for biological uptake. The sub-area cleanup levels range from 3.6 mg/kg at the mouth of the slough to

12 mg/kg at the END of the slough. The reference location in the SDC has a background total PAH concentration of 10.4 mg/kg. The volume of sediment that exceeds these levels in each subarea is shown in **Table 2.4**. Sediment exceeds the cleanup level for total PAH to a depth of 0.6 m (2 ft) at the mouth of the slough, and to a depth of at least 2.4 m (8 ft) in the OWP sub-area, central processing sub-area, and the eastern end of the slough. The total volume of PAH contaminated sediment within the top 2.4 m (8 ft) below the mud line is estimated to range from 93386 m^3 (122,149 cy) to 84831 m^3 (110,959 cy).

Volume Calculations for Dioxin. The depth of dioxin contamination also varies in each Old Mormon Slough sub-area. Using the MSC for TCDD TEQ of 21 pg/g, sediment exceeds the preliminary sediment cleanup level to a depth of 1.2 m (4 ft) in the OWP sub-area of the slough, to a 2.4 m (8 ft) depth in the central processing sub-area, and to a 1.8 m (6 ft) depth in the eastern end of the slough. The total volume of contaminated sediment is calculated to be 63,030 m^3 (82,443 cy) (**Table 2.5**). Compared to the SCR concentration of 87.7 pg/g, the total volume of contaminated sediment is calculated to be 42,693 m^3 (55,842 cy).

2.3 GENERAL RESPONSE ACTIONS FOR SEDIMENT

Areas of principal threats are generally considered for treatment while other contaminated media that pose low-level threats are expected to be managed through the use of engineering controls (such as containment) and institutional controls (such as proprietary and/or governmental restrictions). The NCP states that EPA expects to “use treatment to address the principal threats posed by a site, wherever practicable” and “engineering controls, such as containment, for waste that poses a relatively low long-term threat or where treatment is impracticable” (40 CFR Section 300.430[a][1][iii]).

Generally, no single technology can be used to clean up an entire woodtreater site because of the number and type of contaminants typically present. A sequence of cleanup technologies in a “treatment train” may be needed to address all of the contaminants at different areas of the site. Some contamination may remain in place after remediation and institutional or engineering controls must be used to prevent exposure to the remaining contamination.
EPA expects remedial actions to use a combination of methods, as appropriate, to achieve protection.

In addition to treatment, the range of alternatives to be considered for remediation of NPL sites is required by the NCP to include one or more that involve containment of waste with little or no treatment, but that protect human health and the environment by preventing potential exposure and/or reducing the mobility of contaminants. In addition, the NCP requires the development of a No-Action alternative as a basis for comparison of alternatives. Under the No-Action alternative, no remedial measures would be performed.

As stated in the preamble to the NCP (55 FR at 8703, March 8, 1990), there may be situations where wastes identified as constituting a principal threat may be contained rather than treated due to difficulties in treating the wastes. Specific situations that may limit the use of treatment include the following:

- Treatment technologies are not technically feasible or are not available within a reasonable time frame.

- The extraordinary volume of materials or complexity of the site make implementation of treatment technologies impracticable.

- Implementation of a treatment-based remedy would result in greater overall risk to human health and the environment due to risks posed to workers or the surrounding community during implementation.

- Severe effects across environmental media resulting from implementation would occur.

Conversely, there may be situations where treatment will be selected for both principal threat wastes and low-level threat wastes.

As discussed earlier, if the Old Mormon Slough sediments were a major source of groundwater contamination at the site they would be considered a principal threat. If, however, the surface sediment is not a significant source of groundwater contamination relative to the upland sources, it may be more effectively handled as a low-level threat. Because the highest percentage of contamination is located in subsurface sediments that are expected to remain buried (if undisturbed) and out of contact with aquatic organisms, and will not effectively partition into the surface water, the sediment-to-surface-water and sediment-to-fish pathways may be effectively blocked by containment and/or institutional controls. While institutional controls do not actively address the contaminated sediments they can reduce the possibility of human and environmental exposure to the contaminated sediment in Old Mormon Slough.

Sediment RAOs for the M&B site may be met in several ways. As noted earlier, the NCP specifies a preference for the use of treatment technologies for principal threat wastes in order to reduce risks by destroying contaminants. Some treatment methods do not completely destroy contaminants, but convert them to a less toxic form (e.g., biotreatment degrades PAHs to less toxic organic compounds).

Some contaminants, such as metals, cannot be destroyed. In the absence of treatment, risk may be reduced by containing (e.g., capping) or immobilizing (e.g., stabilization) the contaminants, which contributes to achieving RAOs by reducing contaminant mobility.

Another method of achieving soil RAOs is to remove the contaminated material to a secure disposal location located onsite or an offsite commercial landfill (e.g., a RCRA landfill). This method contains but does not destroy the contaminants, but does remove the risk to human health and the environment from the site.

Generally, technologies are designed to remediate a wide range of contaminants within a particular class of compounds such as metals, volatile organic compounds (VOCs), or semi-volatile organic compounds (SVOCs). Both organics and inorganics are present at the M&B site. Thus, some treatment options are effective for some of the contaminants at the M&B site, but not others. Some technologies are appropriate for metals and others for organics; few technologies address both organics and inorganics with the same process.

The range of GRAs and possible remedial technologies most applicable to aquatic sediments at the M&B site includes those that eliminate the need for long-term management through treatment and/or disposal, those that focus on containment, and those that rely on institutional controls. The GRAs potentially applicable for meeting the RAOs for Old Mormon Slough include the following:

- No-Action
- Institutional Controls
- Containment/Isolation
- In situ treatment
- Removal
- Ex situ treatment
- Disposal.

Figure 2.1. Location of Composite Core Samples and Discretionary Grid Blocks

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Figure 2.2. Location of Grid Blocks with Elevated Total PAH Concentrations Using the Two-Way Compositing Strategy (after White and Kohn 1996)

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Figure 2.3. Location of Grid Blocks with Elevated TCDD/TCDF Concentrations Using the Two-Way Compositing Strategy (after White and Kohn 1996)

Figure 2.4. Areas of Principal Threat and Lesser Threat

Table 2.1. Surface Water Chemical-Specific ARARs/TBCs

	ARARs (40 CRF 131.26)				To Be Considered
Contaminant	Federal AWQC Saltwater Acute (µg/L)	Federal AWQC Saltwater Chronic (µg/L)	Human Health Water + Organism Consumption (µg/L)	Human Health Organism Consumption Only (µg/L)	SFB-RWQCB Marine Water Quality Objective (µg/L)
Total PAHs					0.031[(a)] 0.0028[(b,c)]
TCDD/TCDFs					14,000[(b)]
PCP	13	7.9	0.28	8.2	8.2[(b,d)] 0.28[(b,c)]
Metals					
- Arsenic	69	36	0.018	0.14	36[(a)] 5[(b,c)]
- Chromium (Cr 6)	1,100	50			50[(a)]
- Copper	2.9	2.9			2.9[(a)]
- Zinc	95	86			86[(a)]

(a) San Francisco Bay Regional Water Quality Control Board (SFBRWQCB). 1992. Water Quality Control Plan, San Francisco Bay Basin, Oakland, California.

(b) From the Draft November 26, 1990, Functional Equivalent Document - Development of Water Quality Plans For: Inland Surface Waters of California and Enclosed Bays and Estuaries of California (SWRCB 1990); the Draft April 9, 1991, Supplement to the Functional Equivalent Document (SWRCB 1991).

(c) Value for Inland Surface Waters.

(d) Value for Enclosed Bay and Estuary.

Table 2.2. Measured and Reference Sediment Contamination Concentrations, To Be Considered Criteria, and Risk-Based Levels

		Measured Concentration		Reference		To Be Considered			
Location	Contaminant	Maximum(a)	Minimum(a)	Stockton Channel(a)	San Joaquin River(a)	SQC mg/kg-OC (salt-water)	SQCk mg/g-OC (fresh water)	Ecological Risk MSC Value(b)	NOAA Effects Range ER-L/ER-M(d)
OMS-END	Total PAHs (mg/kg dry wt.)	122.6	ND(c)	10.4	0.0601			12	4.02/44.8
	acenaphthene (mg/kg)					230	130		0.16/0.50
	phenanthrene (mg/kg)					240	180		0.24/1.50
	fluoranthene (mg/kg)					300	620		0.60/5.10
	TCDD/TCDF I-TEQs (ng/kg dry wt.)	1,347	1.03	87.7	0.29			21	
	PCP (μg/kg dry wt.)	120 J	8.7 U	62 YU	9.1 U			10,506	
	Arsenic (mg/kg dry wt.)	31.1	11.3	25.9	7.1			--	8.20/70.0
	Chromium (mg/kg dry wt.)	177	135	128	84.3			--	81.0/370.
	Copper (mg/kg dry wt.)	141	56.5	153	31.9			3,702	34.0/270.
	Zinc (mg/kg dry wt.)	378	158	767	82.2			3,813	150./410.
OMS-CPA	Total PAHs (mg/kg dry wt.)	1,811	ND	10.4	0.0601			5	4.02/44.8
	acenaphthene (mg/kg)					230	130		0.16/0.50
	phenanthrene (mg/kg)					240	180		0.24/1.50
	fluoranthene (mg/kg)					300	620		0.60/5.10
	TCDD/TCDF I-TEQs (ng/kg dry wt.)	1,137	76.8	87.7	0.29			21	
	PCP (μg/kg dry wt.)	5,600	47	62 YU	9.1 U			4,378	
	Arsenic (mg/kg dry wt.)	41.6	6.1	25.9	7.1			--	8.20/70.0
	Chromium (mg/kg dry wt.)	153	107	128	84.3			--	81.0/370.
	Copper (mg/kg dry wt.)	79.8	42.2	153	31.9			1,772	34.0/270.

Table 2.2. (contd)

		Measured Concentration		Reference		To Be Considered			
Location	Contaminant	Maximum[a]	Minimum[a]	Stockton Channel[a]	San Joaquin River[a]	SQC mg/kg-OC (salt-water)	SQCk mg/g-OC (fresh water)	Ecological Risk MSC Value[b]	NOAA Effects Range ER-L/ER-M[d]
	Zinc (mg/kg dry wt.)	203	114	767	82.2			1,825	150./410.
OMS-OWP	Total PAHs (mg/kg dry wt.)	1,195.8	15.53	10.4	0.0601			5	4.02/44.8
	acenaphthene (mg/kg)					230	130		0.16/0.50
	phenanthrene (mg/kg)					240	180		0.24/1.50
	fluoranthene (mg/kg)					300	620		0.60/5.10
	TCDD/TCDF I-TEQs (ng/kg dry wt.)	366	0.043	87.7	0.29			21	
	PCP (μg/kg dry wt.)	14 U	8.0 U	62 YU	9.1 U			4,669	
	Arsenic (mg/kg dry wt.)	17.6	6.6	25.9	7.1			--	8.20/70.0
	Chromium (mg/kg dry wt.)	128	104	128	84.3			--	81.0/370.
	Copper (mg/kg dry wt.)	84	32	153	31.9			1,492	34.0/270.
	Zinc (mg/kg dry wt.)	171	67.2	767	82.2			1,537	150./410.
OMS-MTH	Total PAHs (mg/kg dry wt.)	15.7[b]	0.439	10.4	0.0601			3.667	4.02/44.8
	acenaphthene (mg/kg)					230	130		
	phenanthrene (mg/kg)					240	180		
	fluoranthene (mg/kg)					300	620		
	TCDD/TCDF I-TEQs (ng/kg dry wt.)	58.3	0	87.7	0.29			21	
	PCP (μg/kg dry wt.)	8.6 U	8.2 U	62 YU	9.1 U			3,210	
	Arsenic (mg/kg dry wt.)	7.5	4.03	25.9	7.1			--	8.20/70.0
	Chromium (mg/kg dry wt.)	117	83.2	128	84.3			--	81.0/370.

Table 2.2. (contd)

		Measured Concentration		Reference		To Be Considered			
Location	Contaminant	Maximum[(a)]	Minimum[(a)]	Stockton Channel[(a)]	San Joaquin River[(a)]	SQC mg/kg-OC (salt-water)	SQCk mg/g-OC (fresh water)	Ecological Risk MSC Value[(b)]	NOAA Effects Range ER-L/ER-M[(d)]
	Copper (mg/kg dry wt.)	41.3	28	153	31.9			226	34.0/270.
	Zinc (mg/kg dry wt.)	95.2	57	767	82.2			233	150./410.

(a) White and Kohn (1996).
(b) Thom et al. (1997).
(c) ND = None Detected.
(d) Long et al. (1995).
Y = Raised Detection Limit Due to Interference.
U = Not Detected at or Above the Given Concentration.
J = The associated value is an estimated quantity.

Table 2.3. Preliminary Cleanup Levels for Surface-Water Sediment OU

Medium	Contaminant of Concern	Exposure Route	Receptor	Cleanup Level
Fish Tissue	Dioxin	Food Chain	Human	4.3E-6 µg/kg[(a)]
Sediment	Dioxin	Food Chain	Human	--
Sediment	Dioxin	Groundwater	Human	--
Sediment	PAHs	Groundwater	Human	--
Sediment	PCP	Groundwater	Human	--
Sediment	Dioxin	Food Chain	Receptor Species	21 µg/kg[(b)]
Sediment	PCP	Food Chain through water column	Receptor Species	--
Sediment (By subarea of Old Mormon Slough)	PAH	Food Chain	Receptor Species	12,000 µg/kg[(b)] for END; 5,000 µg/kg[(b)] for central processing area; 5,334 µg/kg[(b)] for OWP area; 3,667 µg/kg[(b)] for mouth of slough.

(a) The cleanup level for fish tissue concentration was developed based on a back calculation for the fish tissue concentration that would produce a total excess cancer risk of less than 10^{-6} assuming a consumption rate of 150 g/day, 350 days/year for 30 years (ICF, personal communication).
(b) The cleanup levels for dioxin and PAH in sediment are based on the risk-based MSC developed in the Ecological Risk Assessment (Thom et al. 1997).

Table 2.4. Sediment Volumes Exceeding the MSC Level (PRGs) and the Stockton Deepwater Channel Reference Concentration for Total PAH

	Exceeding the MSC Concentration			Exceeding the SCR Concentration		
Slough Section	Area (m^2)	Average Depth (m)	Volume (m^3)	Area (m^2)	Average Depth (m)	Volume (m^3)
MTH	19745 (1834 ft^2)	0.6 (2 ft)	12038 (15745 cy)	5713 (1834 ft^2)	0.6 (2 ft)	3483 (4555 cy)
OWP	11191 (1040 ft^2)	2.4 (8 ft)	27293 (35699 cy)	11191 (1040 ft^2)	2.4 (8 ft)	27293 (35699 cy)
CPA	12120 (1126 ft^2)	2.4 (8 ft)	29559 (38663 cy)	12120 (1126 ft^2)	2.4 (8 ft)	29559 (38663 cy)
END	10044 (933 ft^2)	2.4 (8 ft)	24496 (32040 cy)	10044 (933 ft^2)	2.4 (8 ft)	24496 (32040 cy)
Total	53101 (4933 ft^2)	NA	93386 (122149 cy)	39069 (3630 ft^2)	NA	84831 (110959 cy)

Table 2.5. Sediment Volumes Based on the MSC of 21 pg/g and SCR Concentration of 87.7 µg/kg for PCDD/PCDF I-TEQ

	Exceeding the MSC Concentration			Exceeding the SCR Concentration		
Slough Section	Area (m^2)	Average Depth (m)	Volume (m^3)	Area (m^2)	Average Depth (m)	Volume (m^3)
MTH	4496 (418 ft^2)	0.6 (2 ft)	2741 (3585 cy)	4496 (418 ft^2)	0.6 (2 ft)	2741 (3585 cy)
OWP	11191 (1040 ft^2)	1.2 (4 ft)	12358 (16164 cy)	9078 (418 ft^2)	0.6 (2 ft)	5535 (7240 cy)
CPA	12120 (1126 ft^2)	2.4 (8 ft)	29559 (38663 cy)	12120 (418 ft^2)	1.8 (6 ft)	22169 (28997 cy)
END	10044 (933 ft^2)	1.8 (6 ft)	18372 (24030 cy)	10044 (418 ft^2)	1.2 (4 ft)	12248 (16020 cy)
Total	37852 (3516 ft^2)	NA	63030 (82443 cy)	35739 (418 ft^2)	NA	42693 (55842 cy)

3.0 IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES AND PROCESS OPTIONS

The purpose of this section is to identify and evaluate a range of potentially applicable remedial technologies and process options for sediments in Old Mormon Slough that will achieve the RAOs identified in the previous section. “Technology” refers to general categories of technologies, such as chemical treatment or capping. The term “process option” refers to specific processes within each technology family, such as solvent extraction or use of a sand cap.

The potential technologies and process options identified in this section are those that are most appropriate for remediation of aquatic (brackish) sediments contaminated with dioxin, PAHs, PCP, and metals, taking into consideration the location of the M&B site in an active industrial area. The physical characteristics of the site, as well as ongoing activities in the area, influence the effectiveness and implementability of potential response actions and remedial technologies. Site-specific factors considered in the screening steps are listed as follows:

- Old Mormon Slough is currently rarely subject to barge traffic, but such traffic could cause resuspension of sediment.

- Old Mormon Slough is thought to recharge the groundwater system throughout the year over much of the slough’s length.

- The strong sorption characteristics of dioxin and PAHs onto the fine-grained sediment of Old Mormon Slough, and the submerged nature of these contaminated sediments under 2.4 m to 4.3 m (8 to 14 ft) of standing water, limits the application of most in situ treatment technologies.

- Some institutional controls (e.g., signs, educational outreach programs) are already in place to limit public consumption of fish.

- The primary medium of concern for this OU is the sediment. Potential risks to humans through consumption of fish and to the environment can be mitigated through the remediation of sediment. Potential risks to groundwater will be addressed by remedial actions for the Soils-Groundwater OU.

- Old Mormon Slough sediments contain relatively high concentrations of dioxin.

- Sediment contamination is widespread in Old Mormon Slough.

- If similar ex situ treatment and/or disposal technologies are selected for both sediment and upland soil, they may be carried out in combination. However, they have been evaluated separately and remediation costs have been estimated separately.

Sediments of Old Mormon Slough are very fine grained, which can be detrimental to many remedial technologies. The sediments are described as stratified clay, silt, and sand (White and Kohn 1996). The uppermost sediments range from very soft, dark gray to black clayey silt to a sticky, very soft dark gray clay. The TOC content of these sediments ranges from about 2.5% to 0.7%. Deeper sediments are described as soft to firm, very dark gray or dark olive gray silt, sand, and clay. These sediments are predominantly silt at the eastern end of the slough and sand at the western end, and contain some plant remains (roots and twigs). A sharp contact separates these soft to firm alluvial sediments from an underlying hard, dry, dark gray to olive brown silt or silty clay.

3.1 IDENTIFICATION AND TECHNICAL SCREENING OF REMEDIAL TECHNOLOGIES FOR SEDIMENT

In this subsection, technologies and process options that are considered technically feasible for sediments at woodtreater sites are assembled for the remediation of M&B sediments. Among the information sources used in assembling these technologies and evaluating their application at the M&B site are EPA and other agency wood treater publications, presumptive remedy guidance documents, information on innovative technologies, and site-specific treatability testing.

3.1.1 Presumptive Remedies

A variety of technologies and process options is available for each of the GPAs identified for the M&B site. Potential remedial technologies considered for Old Mormon Slough sediments have been adapted from the universe of technologies presented in *Presumptive Remedies for Soils, Sediments, and Sludges at Woodtreater Sites* (EPA 1995) and *Contaminants and Remedial Options at Wood Preserving Sites* (EPA 1992). They represent technologies that have been consistently considered for the remediation of soils and sediments at sites similar to M&B and that were evaluated in selecting the wood treater presumptive remedies.

Since the enactment of CERCLA, EPA has acquired considerable experience in the evaluation and remediation of certain categories of sites that have similar characteristics, such as the types of contaminants present, disposal practices performed, or environmental media affected. For these groups of sites, including woodtreaters, the Superfund program has developed a “presumptive remedy” approach that uses the program’s past experience to streamline site investigations and the selection of cleanup actions. The presumptive remedy approach is consistent with all of the requirements of the NCP; this approach has been incorporated into the FS process at the M&B site to the extent possible.

Presumptive Remedies for Soils, Sediments, and Sludges at Woodtreater Sites identifies bioremediation, thermal desorption, and incineration as the preferred technologies (presumptive remedies) for treating areas of principal threat consisting of organic contamination in soils, sediments, and sludges. The presumptive remedy for inorganic contamination is identified as immobilization. The applicability of these presumptive remedies is dependent on specific site characteristics; for example, if dioxin is present at high levels. While the presumptive technologies were not directly applicable to the M&B site, the presumptive remedy approach was employed in the M&B FS to limit the number of technologies to be evaluated and to streamline the analysis of alternatives. Thus, additional technologies were also considered for the M&B site, primarily to address dioxin contamination.

3.1.2 Innovative Technologies for Sediment

Section 300.430(a)(1)(iii)(E) of the NCP states that "EPA expects to consider using innovative technology when such technology offers the potential for comparable or superior treatment performance and implementability, fewer or lesser adverse impacts than other available approaches, or lower costs for similar levels of performance than demonstrated technologies."

The base catalyzed decomposition (BCD) dechlorination process was evaluated as an innovative technology for remediation of dioxin-contaminated soils, and potentially for dioxin-contaminated sediment. A pilot-scale medium temperature thermal desorption/base catalyzed decomposition (MTTD/BCD) treatability test was carried out at the site. The results of this test are summarized in Subsection 3.1.3.5.

Two other innovative technologies were identified as potential remedial technologies that might achieve the RAOs for Old Mormon Slough sediments. A brief description of each is presented below.

3.1.2.1 In Situ Activated Sludge Bioremediation

An innovative approach to treating the sediment in Old Mormon Slough would be to operate an in situ activated sludge system to bioremediate the PAHs and PCP. The approach would segregate a section of the slough by installing barriers (e.g., silt curtains or sheetpilings) across the width of the slough. That section could then be operated as an aerobic treatment system. Such a system would require two key components: 1) the sediment would have to be well mixed and 2) the water would have to be aerated. PAHs and PCP have a low solubility and mixing the sediment would facilitate desorption of contaminants into the aqueous phase where they could be biodegraded. Mixing also greatly increases the availability of oxygen to the deeper sediments. If the system were merely oxygenated without disturbing the sediments, the oxygen diffusion rate would be much too slow to stimulate bioremediation of even three feet of sediment in a practical time.

Mixing could be accomplished in several ways. A “rake” could be periodically dragged across the bottom of the slough to essentially till and mix the sediment. This has disadvantages, in that 1) the mixed depth will be limited if short tines are used and 2) if large objects are present (i.e., tree trunks, large boulders) the rake will be unable to mix through the objects. Another approach would be to use high pressure air/water injection through a slotted pipe that either laid on the bottom of the slough or was installed as a horizontal well. In the former case, it could be expected that the slotted pipe would dig itself down into the sediment as material was moved by the injected fluid. For horizontal wells, the pressure would have to be high enough to fluidize the overburden sediment. A third mixing method would be to use a hydraulic dredge, but redeposit the dredged material into the bioremediation system.

Other considerations for implementing this system include nutrient amendments, microbial culture, encapsulated microbes, use of surfactants, and byproducts of biodegradation. Nutrient amendment (nitrogen, phosphorous, etc.) may be appropriate to stimulate microbial growth and get higher degradation rates. The choice of microbial culture (indigenous, exogenous, bacterial, fungal, etc.) will have an effect on which compounds are biodegraded and at what rate. Growing an enrichment of microbes in an ex situ reactor may provide an inoculum with high numbers of organisms, but there could be concerns about effects on the native microbial population. Encapsulated bacteria have been shown to have improved degradation capability and may be desirable. However, it may not be appropriate to introduce the encapsulating material (polyurethane, vermiculite, agarose, etc.) into an environmental setting where they would not be easily recoverable. Surfactants can be important to use for dissolving the contaminants off of the sediment and into the aqueous phase, thus improving the contaminant bioavailability.

This technology is similar to an aerobic activated sludge basin at a wastewater treatment plant. However, this technology is not known to have been applied for in situ environmental remediation. Treatability testing would be required to determine effectiveness and design information. Because of poor results from bioremediation treatability studies conducted on site soils (see Subsection 3.1.3.3) and implementation concerns in the slough, this technology was not evaluated further.

3.1.2.2 Ex Situ Vitrification (TerraVit™)

Terra-Vit™ is a melter/vitrification technology for ex situ treatment of low-level or non-radioactive waste. It can process 25 to 400 tons of contaminated soil, sludge, and combustible waste per day. It is a low-cost method of reducing waste volume, destroying organics, and immobilizing heavy metals and low-level radioactive materials for a wide range of nonhazardous and chemical, radioactive, and mixed hazardous wastes. The end product is a stable, chemically durable glass that will remain intact indefinitely. Vitrified non-radioactive waste is salable and recyclable. Terra-Vit can process different waste streams without requiring equipment changeover. It also can operate onsite, reducing costs associated with waste transportation and storage. However, its effectiveness has not been demonstrated for woodtreater wastes.

3.1.3 Treatability Testing

Site-specific treatability tests were conducted on the upland soils for several of the treatment technologies under consideration. The upland soils contain the same general contaminants as the slough sediments and, therefore, the test results are potentially applicable to the Surface-Water Sediment OU. However, the physical natures of the soils and sediments are likely to be significantly different. The sediments have a higher moisture content and a finer grain size; therefore, additional sediment-specific treatability studies would be needed for promising treatment technologies.

Bench-scale tests for the M&B site were conducted by the EPA National Risk Management Research Laboratory (NRMRL) in Cincinnati, Ohio. Soil treatability tests were conducted for solvent extraction, biotreatment (land farming, biotreatment with Fenton's reagent, and inoculated biotreatment), solidification/stabilization (S/S), and soil wet sieving/screening. Results from treatability studies (S/S and soil washing) that were conducted by NRMRL for similar EPA wood treater sites were also considered potentially applicable to the M&B site. In addition to the soil studies, NRMRL also conducted water treatment tests that may be relevant for management of treatment residuals. Bench-scale groundwater treatability tests were conducted for carbon adsorption and ultra-violet (UV) oxidation, and a pilot-scale test was conducted at the site for UV oxidation. Results of the treatability tests will be included with results from other NPL wood treater sites in a NRMRL report scheduled for release in Fall 1997. In addition, as mentioned in the discussion of innovative technologies, a pilot-scale MTTD/BCD treatability test was conducted at the site in June 1995 to evaluate a potential technology for dioxin-contaminated soils.

The results of the M&B treatability tests and their potential applicability to sediments are discussed below. (The tests are described in more detail in the Soils-Groundwater FS report.) The results of these treatability tests formed part of the decision to retain or reject these technologies for further evaluation. Conclusions regarding the tests are included in **Table 3.1**.

In general, the soil treatability test results indicated that S/S and solvent extraction might be useful for the sediments, while soils washing was not likely to be effective. The specific tests conducted on M&B soils also indicated that biodegradation was not an effective treatment. The results of the groundwater treatability tests generally indicated that carbon adsorption and H_2O_2/UV treatment might be effective treatments.

3.1.3.1 Soil Washing Techniques

Physical Separation (Wet Screening Analysis). If a certain size fraction (usually the fine fraction) contains the majority of the contamination, physical soil washing techniques can be used to reduce waste volumes. Initial indications can be obtained from a wet screening analysis. Wet screening done on M&B END soils indicated that there was a 3 to 4 times higher contaminant concentration in the finer (-50+100 mesh) soils. However, the lower concentrations in the coarse fraction of the soil are still well above the required treatment levels so physical soil washing alone is probably not useful for soil treatment. The finer grain size of the sediments relative to the soils would make soil washing less effective.

Soil Washing (Wet Screening Analysis). The wet screening treatability study of M&B soils also showed that little of the contamination was with the water fraction, indicating that aqueous soil washing would require amendments if it were to be successful. Soil washing treatability studies from other sites indicated that water was not an effective washing agent. Amendments (3% Makon 12 and 3% Igepal CA-720) were shown to increase the concentration of contamination in the water but not by amounts large enough to indicate that soil washing would be a feasible option for these types of contaminants.

3.1.3.2 Solvent Extraction

The CF System Dimethyl Ether Extraction Process uses pressurized dimethyl ether to extract contaminants from soils. This material is a gas at ambient pressure and temperatures but liquefies when pressurized. The liquid dimethyl ether is contacted with the contaminated soil in an extraction vessel and then transferred to a separation vessel. The pressure in the separation vessel is reduced to ambient and the solvent vaporizes leaving the removed contaminants and a portion of the soil moisture in the separation vessel. The concentrated contaminant/water mixture are collected for subsequent treatment/disposal.

The treatability studies conducted on M&B soils indicate that this may be an effective technology for removing dioxins, furans, and SVOCs. The technology will not remove metals. Two extractions were generally able to remove greater than 95% of the organic contamination present in the soils. This technology may be an effective treatment for sediment; however, the high moisture content of the sediments may be an issue.

3.1.3.3 Bioremediation

Bioremediation (land farming) studies were conducted with M&B soils using the Utah Water Resource Laboratory Biotic Process to assess if a strong oxidizing agent such as manganese enhances biodegradation of PCP and PAHs in soil. One sample had 1000 mg/kg of MnO added to the sediment. Although significant contaminant concentration reductions using biodegradation processes have been shown at other wood treater sites (EPA 1992), both of these tests showed minimal overall biodegradation after 91 days on M&B site soils. Contaminant concentrations in samples without manganese were no lower than pretreatment levels. For samples treated with manganese, BAP was decreased by 9%, BAP equivalence values by 16.2%, and PCP by 31%.

3.1.3.4 Solidification/Stabilization

S/S treatability studies, two for M&B site soils, were conducted for NRMRL by three separate vendors. In one study, two M&B soil samples were tested with mixes containing activated carbon (5% and 7.5%, respectively), cement, and water. After 29 days, sampling by Synthetic Precipitation Leaching Procedure (SPLP) indicated that PCP was reduced by 99.4% and 99.8%, respectively, and arsenic was reduced by more than 89%. BAP was not detected in untreated soil; however, reductions of other PAH compounds were reduced by 79% to 98%. In each case, equivalent or better results were obtained with the mix containing more carbon.

In the other S/S study, M&B soils were treated with formulations containing a proprietary mixture of reagents and water, with and without cement. PCP was reduced by 98.7% for the formulation without cement, and by greater than 99.9% for formulations with cement. Zinc levels were reduced by 56% without cement and 89% or better with cement. BAP was not found in the untreated soils extract.

3.1.3.5 Pilot-Scale BCD Test

Pilot-scale testing of an ETG Environmental, Inc. MTTD/BCD treatment system was performed at the M&B site in June 1995. The purpose of the test was to evaluate the effectiveness of the process as a potential treatment technology for organic COCs, particularly dioxin. MTTD/BCD is a physical and chemical process that thermally desorbs and decomposes chlorinate organic compounds from soil or sludge. The vapors emitted from the MTTD are collected by a vapor recovery system (VRS) that collects and condenses the desorbed organic compounds and water, followed by two-stage (a direct contact oil scrubber and a water scrubber) vapor scrubbing. Granular activated carbon (GAC) and polymer adsorber are used to polish the vapors prior to atmospheric discharge.

The organic contaminants recovered from the VRS are sent to a liquid tank reactor (LTR). Dechlorination of contaminants is effected in the LTR by heating from 610°F to 650°F in the presence of an added base (i.e., sodium bicarbonate), a catalyst, and a hydrocarbon source (specially formulated oil) that serves as the reaction medium and the hydrogen donor.

While the test plan called for six separate MTTD runs on soils from two different locations at the site (with and without the addition of sodium bicarbonate), followed by three BCD LTR runs, problems were encountered with the total hydrocarbon (TH) emissions from the stack and with the soil feed rate during the first run. Modifications were made to the scrubber system to reduce the TH emissions before a second run was attempted. During the second run, the soil feed rate (<25 lb/h) was again below the specified feed rate and TH emissions were again above acceptable levels; as a result, the second run was stopped.

The results from the first two test runs showed that TCDD TEQs were reduced from 272 mg/kg to 16.5 mg/kg (93.9% reduction) and to 2.5 mg/kg (99.1% reduction) for Run #1 and Run #2, respectively. Although the destruction rates were high, they did not achieve the preliminary soil cleanup level for dioxin. For this reason and because of the implementation problems with the MTTD/BCD unit, no further test runs of the process were performed for the M&B site and the technology was not carried forward in the FS as a potential technology.

3.1.3.6 Water Treatment Systems

The following technologies would be applicable if dredged sediments were dewatered and the liquids required further treatment:

Calgon Carbon Accelerated Tests. This test evaluated the effectiveness of carbon adsorption for removing organic contaminants from water samples. The carbon was effective (concentrations were reduced to less than 10 µg/liter) for all of the COCs tested except PCP.

Cav-Ox System. This system destroys contaminants in aqueous streams through the addition of H_2O_2 and the use of UV light. Several tests were conducted with different H_2O_2 addition rates and different UV powers. The technology generally was not effective for PAHs.

Vulcan Peroxidation Water Treatment. This system destroys contaminants in aqueous streams through pH adjustments, the addition of H_2O_2 and the use of UV light. The main finding in this treatability study was that this technology was not very effective for treating water with suspended sediments. The technology was effective for destroying SVOCs, if the particles were removed with a 5-micron filter.

3.1.4 Summary of Sediment Remedial Technologies

Table 3.1 lists and describes the potential remedial technologies and process options for meeting sediment RAOs at the M&B site. Process options that were eliminated based on technical infeasibility are indicated on the table and are not carried forward for the initial screening.

3.2 INITIAL SCREENING OF REMEDIAL TECHNOLOGY PROCESS OPTIONS

This evaluation considers those technologies that have been shown to be technically implementable for wood treater sites. It focuses on the process options screening according to the criteria of implementability, effectiveness, and cost. For screening purposes, these criteria are defined as follows (EPA 1988a):

- Implementability has two primary components:
    - Technical implementability - assessing whether the technology can effectively manage the wastes, specifically considering factors such as the chemical and physical nature of the waste and site-specific features (such as contamination at great depth) that could limit the application of the technology
    - Administrative feasibility - assessing whether legal or other requirements can be met or obstacles can be overcome, such as the ability to obtain permits for offsite actions, the availability of treatment services and/or disposal services (including disposal capacity), and the availability of the technology (including equipment and skilled workers).
- Effectiveness has three primary components:
    - Potential effectiveness of the process option in handling the estimated area or volume of affected media and meeting the RAOs

  - Potential impacts to human health and the environment during the construction and implementation phase

  - Reliability of the process with respect to the contaminants and conditions at the site.

- Relative costs are screened according to two primary cost components:

  - Relative capital cost
  - Relative operation and maintenance cost.

At this screening level evaluation, costs are given only limited weight in comparison to effectiveness and implementability. Relative costs are considered as “high,” “medium,” or “low” within a remedial technology group and are developed from readily available sources including EPA presumptive remedy guidance and engineering judgement and experience.

Results of this screening for M&B slough sediments are summarized in **Table 3.2**. Process options that were eliminated based on this screening are indicated on the table and are not carried forward for the detailed analysis in Section 4.0.

3.2.1 No-Action

The No-Action response does not include any remedial technologies or process options to actively remediate the site. This response action will not meet the RAOs, but is retained for comparison purposes as required by the NCP.

3.2.2 Institutional Controls

Institutional controls do not actively address the contamination, but do reduce the possibility of human and environmental exposure. Potential institutional controls consist of land use, access restrictions, and site monitoring. Access and use restrictions reduce the likelihood of exposure to contaminants arising from trespassing, future development, or excavation at the site. Proprietary and/or governmental restrictions and notifications can be used to ensure that the land use of the property is restricted; for example, to ensure maintenance and integrity of containment systems such as a cap. While these controls are unlikely to meet the RAOs by themselves, many of them are retained for use in combination with other general response actions.

3.2.2.1 Land Use and Access Restrictions

Land use and access restrictions include the use of proprietary and/or governmental restrictions such as: deed restrictions, physical site access restrictions, and/or fishing advisories or restrictions.

Deed and Land Use Restrictions. These institutional controls would include proprietary and/or governmental (including enforcement) restrictions such as: limiting future land uses to appropriate industrial uses (and prohibiting other uses); restricting access to and use of upper aquifer groundwater to prevent exposure to contaminated groundwater; prohibiting activities that would disturb the integrity of the remedy, including appropriate prohibitions on activities that would disturb a cap placed over contaminated slough sediments; requiring appropriate handling of dredged materials (e.g., silt curtains would be required and dredge material would have to be properly treated and/or disposed); providing for appropriate notice (in land records and otherwise) that hazardous wastes remain on site; and prohibiting other activities that could cause a potential threat to human health or the environment.

Site Access Controls. The M&B site is currently completely fenced, posted with warning signs, and security service is maintained 24 hours. Old Mormon Slough is posted with signs stating that swimming and fishing are not recommended due to the presence of contaminated sediment. Additional physical site access restrictions for Old Mormon Slough would consist of strategically placed security fencing and warning signs along the slough. In addition, log booms would be placed to limit water traffic (boats and barges) into all or portions of the slough. These supplemental access restrictions could reduce direct human exposure to contaminated sediments in Old Mormon Slough and indirect exposure via consumption of fish caught in the slough; however, these restrictions would not be effective with respect to ecological receptors. Warning signs aimed at reducing boat/barge traffic and protective booms would also be effective in reducing the potential for resuspension of contaminated sediment.

Fishing Advisories/Restrictions. Promulgation of fishing advisories, restrictions and/or limitations (e.g., “Catch and Release”) for Old Mormon Slough and other nearby water bodies would only be effective in reducing recreational fishing. These actions are unlikely to have much effect on subsistence fishing, because subsistence fishermen generally do not have valid fishing licenses and may not comply with current fishing regulations. This process option was not retained because it is unlikely to be effective.

3.2.2.2 Monitoring

Periodic sampling and analysis would be conducted to monitor contaminant levels in resident fish populations and other representative biota and sediment. The physical system would also be monitored for changes in sedimentation/erosion rate, bottom stability, and sediment transport. Monitoring is not retained as a stand-alone option. However, it will be a component of the remedial alternatives to determine whether remedial action objectives are achieved and/or the effectiveness of containment structures or other remedial actions are confirmed.

3.2.3 Containment/Isolation Technologies

Containment and isolation technologies physically control or stabilize the contamination in place, thereby retarding and/or eliminating the migration and exposure pathways. Potential engineering controls for containment and isolation of the contaminated sediments include in situ capping, backfilling of the slough, vertical hydraulic barriers, and/or sedimentation controls.

3.2.3.1 In Situ Capping

In situ capping would bury and stabilize the contaminated sediments in place, thereby isolating them from the ecosystem and human exposure. Two types of caps were examined; a single layer (sand) cap and a multilayer (armored) cap. Both types of cap would be effective in reducing the bioavailability of contaminated sediments. However, the installation of a submarine cap can be difficult, especially over soft unstable sediment. Thus, the cap design would have to consider the engineering properties of the bottom sediments to avoid mixing of cap materials with the contaminated sediment and to avoid slumping and/or other failure of the cap. The integrity of the cap could also be destroyed by future activities in the slough (e.g., prop wash from barges, future dredging). Capping would temporarily destroy the local benthic community; however, recolonization by a more diverse community is expected within 1 or 2 growing seasons. Regular monitoring and maintenance would be required to maintain the integrity of the cap.

Sand Cap. The single layer sand cap is expected to be less expensive and more easily installed and maintained than the armored cap. It is also expected to be thinner than an armored cap (thus not impacting the depth of the slough as much) and would better facilitate recolonization and regeneration of the benthic community. However, sand caps can be susceptible to erosion in a high-energy environment. Since Old Mormon Slough is a dead end slough with a low-energy water action, and a net deposition of sediment, the sand cap process option was retained for consideration as the primary capping technology.

Armored Cap. The cost of a high energy armored cap has been estimated at 3.5 times that of a low-energy sand cap (PTI 1995). The necessarily thicker cap would dramatically raise the bottom of the slough, thereby decreasing future uses of Old Mormon Slough. The coarser (rip-rap) surface material is also expected to retard re-establishment of benthic community. Thus, this process option was not retained for consideration as a principal component of potential remedial alternatives. However, localized armoring of the sand cap is considered where erosion protection may be an important consideration.

3.2.3.2 Channel Filling

Another containment/isolation technology considered for Old Mormon Slough was to completely backfill portions of the slough with dredged and/or upland materials and top with clean soil. This would reduce the size of the slough and effectively isolate the contaminated sediment from the ecosystem and human exposure. This would also eliminate the hydraulic driving force for potential migration of aqueous phase contaminants from the slough into the groundwater system. Implementation would be relatively straightforward; however, it would permanently destroy portions of the existing aquatic habitat. This process option is retained for consideration in conjunction with construction of a CDF.

3.2.3.3 Vertical Walls

Vertical barriers were considered to address the potential pathway of contaminated slough sediments as a source to groundwater contamination by preventing the horizontal movement of contaminants. Several types of vertical barriers were considered, including soil-bentonite slurry walls, cement-bentonite slurry walls, synthetic material sheet walls, and steel sheetpiling. All of these technology options can be effective in reducing potential threats to groundwater; however, their added benefit to the already low permeability Old Mormon Slough sediments and highly sorbing COCs is uncertain. Implementation and the practical depth limit of the slurry wall and synthetic sheet wall options are not considered as favorable in this environment as that of sheetpiling (which has already been implemented at the site). In addition, the impermeability of cement-bentonite mixtures can be adversely affected by organic contaminants and/or soluble salts, requiring detailed treatability testing. Sheetpiling, on the other hand, is effective and relatively straightforward to implement. In addition to preventing the horizontal migration of contaminants, it can be designed to provide structural support in the form of a retaining wall. Thus, only sheetpiling has been retained for further consideration as a component of the slough remedial alternatives. (The use of vertical walls at the M&B site was evaluated in more detail in the FS for the Soil-Groundwater OU for potential applications for groundwater remediation.)

3.2.3.4 Sedimentation Controls (Silt Curtains)

Silt curtains consist of permeable, fine-mesh geotextile fabric that is suspended from a metal framework and stretched across the slough to trap and contain potentially contaminated sediment that is resuspended. It can also be used for the same purpose during dredging or other disruptive remedial actions. This is a proven means of controlling the downstream movement of fine-grained sediment. It is not retained as a stand-alone option, but is retained for further evaluation in the development of the slough remedial alternatives.

3.2.4 In Situ Treatment Technologies

As described in Table 3.1, in situ treatment technologies for Old Mormon Slough include biological, chemical, and physical processes that reduce the toxicity, mobility, and/or volume (T/M/V) of contaminated sediment while left in place. However, the strong sorption characteristics of dioxin and PAHs onto the fine-grained sediment of Old Mormon Slough, and the submerged nature of these contaminated sediments under 2.4 to 4.3 m (8 to 14 ft) of standing water, limits the applicability of in situ treatment technologies. For these reasons, no in situ treatment technologies were retained for further analysis and are not evaluated according to the three screening criteria.

3.2.5 Sediment Removal Technologies

All ex situ treatment or disposal response actions require the removal of contaminated sediment from Old Mormon Slough. The most applicable sediment removal technology is dredging. Dredging is typically performed from a barge, by lowering removal equipment into the water and extracting the sediment. Dredged sediments are then typically loaded on a companion vessel or pumped by pipeline to shore. Dredged sediments are then transported to the treatment and/or disposal areas by pipeline, barge, railroad, or truck.

Dredging is a proven and an effective method for sediment removal. However, dredging does result in short-term impacts from resuspension of contaminated sediment and the loss of existing benthic communities.

There are a variety of specific dredging processes to remove contaminated sediment; however, the two most common types of dredging are mechanical and hydraulic dredging. The selection of the appropriate dredging technique is dependent on the needs of the specific applications, operating conditions, sediment types and depth, and the need to minimize sediment disturbance and resuspension. Some processes are also more effective at recovering concentrated sediment, and reducing the need for additional dewatering.

3.2.5.1 Mechanical Dredging

Mechanical dredging uses a clamshell bucket or other similar mechanism to extract the contaminated sediment. Substantial amounts of sediment can be resuspended during the dredging process from insertion and removal of the bucket, leakage from the bucket, and washing of the bucket as it passes through the water column. Closed clamshell buckets can reduce some of this resuspension. Silt curtains can also be used to reduce suspended sediment concentrations outside of the dredge area. Mechanical dredging is typically less efficient and less accurate than hydraulic dredging, but has a high solids content (similar to that of the in situ sediment). Mechanical dredging is retained because it is a proven, high-solids method for removing the contaminated sediment.

3.2.5.2 Hydraulic Vacuum Dredging

Hydraulic vacuum dredging uses centrifugal pumps or similar mechanism to hydraulically vacuum the sediments up from the bottom in a liquid slurry. A mechanical cutting head is usually attached to the end of the vacuum line to break up the sediment and establish the slurry form. Less sediment is resuspended during hydraulic dredging. Hydraulic dredging is typically faster, more efficient, and easier to control than mechanical dredging. However, the slurry is typically 80% water. Depending on the preferred treatment/disposal technology, the slurry would require much more dewatering than mechanically dredged sediment and would produce large volumes of waste water that would require treatment. Hydraulic vacuum dredging is also retained for further evaluation because of its efficiency and ease of control.

3.2.5.3 Temporary Dam, Dewatering, and Excavation

An alternative to dredging is the temporary damming and dewatering of Old Mormon Slough to excavate the slough sediments. Approximately 31 million gallons of water would have to be pumped from the slough once a temporary (sheetpile) dam was constructed. An additional 840,000 gal/day of water would have to be pumped to keep the sediments dry (assuming an infiltration rate of approximately 2 gpd/ft^2, which is a reasonable hydraulic conductivity for silt). Assuming a four-month operational period, this option would require the treatment (filtering) of approximately 260 million gallons of water. In addition, the cost of installing and removing a temporary dam, dewatering the sediment, and excavating the sediment was estimated at approximately $539,000 more than dredging alone. If treatment of the water from the dewatering process was necessary before discharging back into the slough, the cost would be even higher. Based on implementability and cost, this alternative is not retained for further analysis.

3.2.6 Ex Situ Treatment Technologies

The screening of ex situ treatment technologies for sediment is similar to that conducted for upland soils (ICF 1997). It is envisioned that the treatment of sediment would be conducted in conjunction with that of the upland soils if similar technologies were selected for both OUs. There may be some differences in the effectiveness and implementation of these technologies for sediment compared with soils due to the potential differences in organic content and water content. However, the characteristics of the sediment and soils, such as particle size and the types of contaminants, are similar enough that the screening of remediation technologies for soils is considered applicable to sediments.

The following four categories of ex situ treatment technologies are associated with this general response action: biological, thermal, chemical, and physical treatment processes. Sediment characteristics that can influence the effectiveness of these treatment options are the type of contaminant present, clay content, particle size, and water content.

3.2.6.1 Ex Situ Biological Treatment

Biological destruction technologies use either aerobic or anaerobic methods that rely on microorganisms to chemically degrade organic contaminants. Two ex situ bioremediation processes are potentially applicable to remediation of Old Mormon Slough sediments: solid-phase bioremediation and slurry-phase bioremediation.

Solid-Phase Bioremediation. Solid-phase bioremediation (land farming) places the contaminated sediment in a lined bed to which nutrients (i.e., nitrogen and phosphorous) are added. Aeration and moisture content are also controlled to facilitate the development of the microorganisms. Composting is a variant of the solid-phase bioremediation process that mixes the contaminated sediment with straw, bark, manure, or wood chips to improve the texture, workability, and aeration of the waste materials.

Solid-phase bioremediation is one of the EPA presumptive remedies for treating organic contaminated soils and sediment at wood treater sites (EPA 1995), and can be very effective.

EPA (1992) reported removal efficiencies on the order or 87% for PAHs and 74% for halogenated phenols and cresol; the effects on dioxin are uncertain. However, land farming treatability studies on M&B site soils showed minimal overall biodegradation after 91 days.

This process requires a relatively large land area and could interfere with other remediation at the M&B site. Degradation rates can be on the order of months; however, continued operator attendance is not required. Costs for landf arming are relatively low, generally in the range of \$38-\$60/m^3 (\$50-\$80/cy), while composting is on the order of \$76/m^3 (\$100/cy) (EPA 1992). However, because of the poor results of the site-specific treatability studies, this process is not retained for further evaluation.

Slurry-Phase Bioremediation. This process option is also an EPA wood treater site presumptive remedy for organics. Slurry-phase bioremediation mixes dredged sediment or slurry with water in a tank or lagoon, which is then mechanically agitated. Nutrients, oxygen, etc., are added in a controlled process. While degradation rates are typically much faster than the solid-phase (land farming) treatment, it is generally conducted in much smaller batches. This process has higher capital and operating costs than solid phase (\$60-\$115/m^3 [\$80-\$150/cy]) (EPA 1992). This option is not retained for further consideration.

3.2.6.2 Ex Situ Thermal Treatment

Thermal treatment technologies can be used to extract (thermal desorption) and/or destroy (incineration and pyrolysis) organic contaminants in the soil, and to physically solidify/ stabilize inorganic contamination (ex situ vitrification). The expected effectiveness of each process option on Old Mormon Slough sediments is discussed below, with the exception of ex situ vitrification, which was discussed in Subsection 3.1.2.2 as a potential innovative technology.

Thermal Desorption. Thermal desorption physically separates volatiles and some semi-volatile contaminants from excavated soils and sediment. It uses ambient air, heat, and/or mechanical agitation to volatilize the contaminants into a gas stream for further treatment. Typically, the contaminated sediments are heated in a low-temperature furnace. The organics are then collected from the off-gas (e.g., on activated carbon) for disposal or further treatment.

This is a proven technology and is an EPA presumptive remedy for treating organic contaminants (except dioxin) at wood treater sites (EPA 1995). It can be very effective; however, the high moisture content of sediments can increase operating costs. It also requires treatment/disposal of the off-gas, condensate, and solid residuals from the process. This process option was not retained due to its high cost (\$90-\$500/m^3) (\$250-\$650/cy) (EPA 1995), potential emissions concerns, and because it would not be effective for dioxin in the sediments.

Incineration. Incineration destroys organic compounds by subjecting them to temperatures typically greater than 537°C (1000°F) in the presence of oxygen. Volatilization and combustion of the organic contaminants occurs converting them to carbon dioxide (CO_2), water (H_20), hydrogen chloride (HCl), and sulfur oxides (So_x) (EPA 1992).

Incineration is one of the EPA presumptive remedies for treatment of soils and sediments at wood treater sites. It is very effective for all organics, including dioxin. Residual solids would require further treatment for metals contamination. The high moisture content of dredged sediment can reduce the incinerator's capacity and thus increase the costs. The incinerator may also require a high degree of off-gas treatment to meet clean air standards (ARARs). Because of potential emission concerns, particularly due to the presence of dioxin in site soils, state agency and community acceptance is considered unlikely. The costs of setting up, permitting, and operating an onsite incinerator are very high. Estimated costs for incineration are on the order of \$370-\$1200/m^3 (\$480-\$1600/cy) (EPA 1992). Onsite incineration has not been retained for further analysis because of its high cost and implementation concerns.

Pyrolysis. Pyrolysis differs from incineration in that it uses high temperature in the absence of oxygen. It transforms long-chain organic compounds into gaseous components (CO, H_2, and methane) and a solid residue (coke) containing fixed carbon and ash. As with incineration, residual solids would require further treatment to address metals. Pyrolysis produces fewer emissions, allows more control, permits higher throughput, and operates at lower temperatures than incineration (EPA 1992). However, the process produces residuals that require further treatment. This technology has not been proven for wood treater wastes. Implementation and cost considerations are expected to be similar to those for incineration. Pyrolysis has not been retained for further analysis.

3.2.6.3 Ex Situ Chemical Treatment

Potentially applicable chemical treatment technologies consist of those processes used to remove the contaminants from the sediment (conventional solvent extraction and supercritical fluid extraction) and those that will chemically destroy the contaminant (dehalogenation and chemical oxidation). The expected effectiveness of these process options on Old Mormon Slough sediment is discussed below.

Conventional Solvent Extraction. Conventional solvent extraction uses organic solvents to selectively extract the COCs, primarily organics (EPA 1992). The process may require several passes to reduce contamination to the desired levels. The extracted solvent can be stripped of the contaminant, condensed, recycled, and reused. Treatability studies on M&B site soils indicate that this technology can be >95% effective in reducing dioxin concentrations and 67% to 98.8% effective in reducing PAH concentrations. However, the high water content of Old Mormon Slough sediment can reduce the effectiveness of solvent extraction and increase its costs. The sediment would require additional treatment to address the inorganic contaminants. Sufficient capacity may not be available in the upland portion of the site to dispose of the treated material. Solvent extraction generates concentrated contaminants and separated solvent that must be further treated and/or disposed. Estimated costs range from \$120-\$850/m^3 (\$160-\$1120/cy) (EPA 1992). Because of its demonstrated effectiveness for the organic COCs this process has been retained for further evaluation in conjunction with the potential treatment technologies identified for the upland soils.

Dehalogenation. Dehalogenation uses a chemical reaction to remove chlorine atoms from chlorinated molecules making them less toxic. Contaminated soil is placed in a reactor with reagents (i.e., potassium polyethylene glycol [KPEG]), mixed, and heated. This reaction replaces chlorine atoms with an ether or hydroxyl group. Soil and reagents are separated and the soil neutralized. There is a possibility that a more toxic end product could be formed, in which case further treatment would be necessary. The technology is applicable to chlorinated organics (e.g., PCP, dioxin); its effectiveness for PAHs is uncertain. The process generates reagent waste, other liquid wastes, and potentially contaminated residuals that require further treatment. The cost of dehalogenation is high. For these reasons it is not retained for further evaluation.

3.2.6.4 Physical Treatment Technologies

Potential physical treatment options that were considered for Old Mormon Slough sediments were S/S, soil washing and solids classification, and dewatering. The expected effectiveness of each process option for the slough sediments are discussed below.

Solidification/Stabilization. S/S is a well-established technology for soils containing metals, and is the EPA wood treater site presumptive remedy for inorganic contaminants. However, ex situ S/S treatability studies on M&B site soils indicate that S/S is also effective in reducing the leachability of organics, including dioxin. Solidification processes reduce the mobility of contaminants by physically restricting their contact with a mobile phase (e.g., water) (EPA 1992). Solidification also refers to the use of binders for waste bulking to facilitate handling of liquid wastes. Stabilization chemically alters and/or binds the contaminants with cementatious and other proprietary materials to reduce their mobility (EPA 1992).

Volume would increase during the S/S process and sufficient capacity may not be available in the upland portion of the site to dispose of the solidified material. The effectiveness of these processes can be adversely affected by complex organic mixtures and/or soluble salts, thus additional sediment-specific treatability studies would be necessary. Ex situ S/S is fairly easy to implement and vendors are readily available. The relative cost is medium. Ex situ S/S is retained as a process option for metals contamination in sediments and/or treatment residuals.

Soil Washing/Solids Classification. Soil washing is a water-based process for mechanically scrubbing excavated soils/sediment to remove contaminants by either dissolving or suspending them in a wash solution, or by concentrating them into a smaller volume via particle size separation techniques (solids classification). Solids classification generally uses screens and/or cyclone separators to segregate fine-grained contaminated sediments from coarser, cleaner sediments. This is often used to prepare a uniform composite for further treatment or disposal. The coarser fractions (sand and gravel) are often washed with a detergent (or solvent) to aid the removal of contaminants.

This process option can be effective in reducing the volume of contaminated sediments; however, the fine-grained clayey nature of Old Mormon Slough sediments makes the effectiveness of these processes somewhat questionable. Contaminant extraction processes (e.g., solvent extraction) are generally more favorable, as demonstrated by the treatability studies conducted for the M&B site. Soil washing also generates liquid wastes and potentially contaminated residuals, which would require further treatment.

This option has not been retained as a stand-alone technology or as a primary component of any general response action. However, some solids classification may be used to remove large debris prior to other ex situ treatment processes.

Dewatering. Dewatering is a physical unit operation that reduces the water/moisture content of slurries or sludges to facilitate handling and to prepare the materials for treatment and/or disposal. Typical dewatering methods include drying beds, centrifugation, and filtration. Actual selection of the dewatering methodology depends on the volume to be treated, the solids content, availability of land area, and the degree of dewatering required. Dewatering is not retained as a stand-alone technology, but will be included in the development of alternatives as a pretreatment technology prior to further treatment or disposal.

3.2.7 Disposal Technologies

Disposal technologies for sediment and/or treatment residuals include near-shore disposal (in a CDF), onsite upland disposal (engineered landfill or used as fill if not hazardous), and offsite disposal in a commercial facility.

3.2.7.1 Nearshore Confined Disposal

Nearshore confined disposal technology is commonly used for sediment disposal. CDFs are used to contain approximately 30% of the dredge material produced by the U.S. Army Corps of Engineers (U.S. ACE) Navigation Program (Lincoff et al. 1994). Implementation of this technology would consolidate dredged contaminated sediment from Old Mormon Slough behind a dammed or diked structure (e.g., behind sheetpiling) located within or alongside the slough for disposal beneath an isolation cap. The CDF would be designed to permanently contain the dredged material.

CDFs are effective for isolation of contaminated sediment; however, they can severely impact and/or destroy portions of the aquatic habitat. Their construction could also have temporary effects on water quality. This process would also require long-term monitoring and maintenance to ensure its continued integrity in containing the waste materials. The relative cost for a CDF is low to medium. This technology has been retained for further evaluation in combination with partial backfilling of the slough, as discussed in Section 3.2.2.2.

3.2.7.2 Onsite (Upland) Disposal

Dredged sediments from Old Mormon Slough and/or solid treatment residuals could be disposed in the upland portion of the site. Hazardous wastes would be disposed in a specially designed and constructed onsite landfill that would contain liners or leachate collection, as appropriate. Although contaminants are not destroyed (i.e., toxicity is not decreased) and their volume is not reduced, this process option prevents the migration of contaminants by isolating the waste within an impervious landfill. Other non-hazardous treatment residuals (such as the clean coarse fractions from the soil washing/classification process or other clean solid treatment residuals) could be used as fill or for other construction materials in the upland portion of the site. To the extent that dredged hazardous media is involved, this action would not be subject to the RCRA LDRs if 1) the hazardous media were returned to the "area of contamination" (AOC) from which they came, or 2) if not considered the same AOC, a corrective action management unit (CAMU) was designated.

Development and operation of an engineered landfill would require long-term monitoring and maintenance. The cost of onsite landfilling for the expected volume of dredged sediment is low to medium for construction and long-term maintenance. Although onsite upland disposal may be appropriate on a limited basis for disposal of sediment solid treatment residuals, because capacity problems in the upland portion of the site upland disposal has not been retained for further evaluation as a stand-alone remedy for sediment dredged from Old Mormon Slough.

3.2.7.3 Offsite Disposal

Offsite disposal options for contaminated sediment (and possibly treatment residuals) would be dependent on the eventual waste designation of that material. Offsite disposal to a permitted hazardous waste landfill is appropriate for hazardous materials that are not subject to LDRs. LDRs for F032-, F034-, and F035-classified sediments[1] require offsite treatment prior to disposal at an appropriate treatment, storage, and disposal facility (TSDF). Because of this costs can be very high. Offsite transportation and treatment/disposal costs range from \$89 to \$1,096/m^3 (\$116 to \$1,433/cy), depending on the waste designation and the location of suitable disposal facilities. There would be some significant short-term impacts from the excavation, handling, and transportation of the soil. Applicable laws and regulations relating to the transportation and disposal of hazardous material would have to be met. Offsite disposal removes contaminated material from the site but transfers it to another location where it would be managed. However, because this represents an effective and relatively easy-to-implement option for dredged sediment, offsite disposal is retained for further evaluation.

3.3 SUMMARY OF REMEDIAL PROCESS OPTIONS FOR SEDIMENT

Based on the EPA presumptive remedy guidance for wood treater site sediments and the site-specific screening summarized in Table 3.2, the following technologies and process options are retained for sediment remediation:

- Institutional controls
- Capping
- Dredging

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[1] Sediments at the M&B site are contaminated with a variety of chemicals used in the wood treatment process, including the F032, F034, and F035 wastes listed pursuant to 40 CFR Part 261 of the RCRA regulations.

- Ex situ solvent extraction (treatment for organics)
- Ex situ solidification/stabilization (treatment for inorganics)
- Confined disposal facility
- Offsite disposal.

Table 3.1. General Response Actions and Technologies/Process Options for Sediment Remediation

General Response Actions	Remedial Technologies	Process Options	Description
No Action	None	Not applicable	No active remediation of the site. Includes monitoring.
Institutional Controls	Land Use and Access Restrictions	Proprietary or governmental controls on land use and notice requirements	These would restrict future land use to appropriate (i.e., industrial) uses. Would prevent future disturbance (i.e., by dredging) of Old Mormon Slough sediments. Not a stand-alone remedy, but retained for evaluation as part of the other remedies.
		Site access controls (warning signs, security fencing, log booms in Old Mormon Slough)	Additional warning signs, fencing, and/or security booms would be strategically placed to restrict pedestrian and boat access to Old Mormon Slough. Not a stand-alone remedy, but retained for evaluation as part of the other remedies.
		Fishing advisories or restrictions	Promulgation of fishing advisories, restrictions, and/or limitations (e.g., "catch and release") might be effective in reducing recreational fishing, but are unlikely to reduce subsistence fishing in the area. Because of this, it is not retained as a permanent remedy.
	Monitoring	Sediment and fish monitoring	Sediment and fish would be sampled periodically to monitor contaminant levels. The physical system could also be monitored for changes in sedimentation/erosion rate, bottom stability of the slough, and sediment transport. Not a stand-alone remedy, but it is retained as component of other remedies.
Containment/ Isolation	Capping	Single layer (sand) cap	Contaminated sediments would be covered with 1 to 2 feet of clean sand and silt. Sand caps are effective in low-energy aquatic environments such as Old Mormon Slough.
		Multi-layered (armored) cap	Contaminated sediment would be capped with multiple layers of sand, gravel, and rip-rap. Because an armored cap is generally only required in high-energy aquatic environments it is not retained as a stand-alone remedy. However, localized armoring may be effective for some portions of Old Mormon Slough that are more susceptible to erosion.

Table 3.1. (contd)

General Response Actions	Remedial Technologies	Process Options	Description
	Channel Filling	Backfill part of Old Mormon Slough	Contaminated sediments would be buried by backfilling portions of the slough with dredged and/or clean materials. Retained for further evaluation in conjunction with consolidation of dredge materials into a CDF.
	Vertical Barriers	Soil-bentonite or cement-bentonite slurry wall; synthetic sheet wall	Wall would confine deep sediment contamination that could potentially move into groundwater beneath the site. Not retained for further evaluation due to practical depth limits and difficulty of installation. Groundwater contamination will be addressed in the FS for the Soils-Groundwater OU.
		Sheetpiling	Sheetpiling would confine deep sediment contamination that could potentially move into groundwater beneath the site and/or could be used to confine dredged material in a confined disposal facility. Retained for further evaluation in conjunction with the construction of a confined disposal facility in the slough.
	Sedimentation controls	Silt curtains	Curtains would trap and contain resuspended sediment. Not an effective stand-alone remedy, but retained as a component of alternatives involving dredging or other disturbance of Old Mormon Slough sediments.
In Situ Treatment	Chemical Treatment	Soil flushing	Contaminants are flushed (extracted) from sediment via a solution injected into the sediment. Technology not expected to be effective using water alone because of low solubility of COCs; thus, amendments would have to be added to enhance process. Extracted fluids must be collected for ex situ treatment. Process would be difficult to implement because of the clayey sediment in Old Mormon Slough. Not retained for further evaluation.

Table 3.1. (contd)

General Response Actions	Remedial Technologies	Process Options	Description
	Physical Treatment	Solidification/Stabilization (S/S)	Solidifying agents (e.g., cement, clay, synthetics, etc.) are mixed with (or injected into) the sediment in place in order to reduce the mobility of the contaminants. Effectiveness of solidification agents can be adversely affected by complex organic mixtures, fine-grained sediments, and saline waters. Not considered effective under the conditions found in Old Mormon Slough. Also would be difficult to implement to address the full depth of sediment contamination. Not retained for further evaluation.
	Biological Treatment	In situ aerobic bioremediation	The addition of oxygen and other nutrients enhances microbiological degradation and detoxification of organic contaminants in sediment. Effectiveness on clayey sediments in Old Mormon Slough is uncertain. Not retained for further evaluation.
		Activated sludge bioremediation	This process option was evaluated as an innovative technology (see Section 3.1.2.1). The slough would be divided into sections, aeration and mixing equipment would be installed to operate the sections as individual aerobic treatment lagoons. Not expected to address all of the organic COCs found in Old Mormon Slough sediment. Not retained for further evaluation.
Removal	Dredging	Mechanical dredging	Contaminated sediments are mechanically removed from the slough via clam shell, backhoe, or other mechanism. Retained because it is a proven high solids removal technology.
		Hydraulic vacuum dredging	Contaminated sediments are hydraulically vacuumed from the slough bottom. Retained because of its efficiency and ease/accuracy of control.
		Temporary dam, dewatering, and excavation	Old Mormon Slough would be temporarily dammed in order to dewater it for access to excavate the sediments. Although extracted water may require treatment prior to discharging it back into the slough, the process is retained for further evaluation.

Table 3.1. (contd)

General Response Actions	Remedial Technologies	Process Options	Description
Ex Situ Treatment	Biological Treatment	**Solid-phase bioremediation (Composting, landfarming)**	Microbiological degradation of dredged sediment is conducted in lined beds, piles, and cells. EPA Wood Treater Presumptive Remedy for organic contaminants (except dioxin). Retained for further evaluation.
		Slurry-phase bioremediation (Bio- reactor)	Excavated sediments, in the form of a slurry, are microbially degraded in a treatment tank or lagoon that is mechanically agitated. EPA Wood Treater Presumptive Remedy for organic contaminants (except dioxin). Retained for further evaluation.
	Thermal Treatment	**Thermal Desorption**	Soil is heated to volatilize water and organic contaminants into a gas stream for subsequent treatment of the concentrated contaminants. The process can be low temperature (200°-600°F) or high temperature (600°-1000°F). Thermal desorption has not been proven effective for dioxin-contaminated soil or sediment. EPA Wood Treater Presumptive Remedy for organic contaminants. Retained for further evaluation.
		Incineration	Process volatilizes and combusts organic contaminants in soil or sludge by heating to greater than 1000°F in the presence of oxygen. Has been demonstrated to be effective for dioxin-contaminated soil and sediment. EPA Wood Treater Presumptive Remedy for organic contaminants. Retained for further evaluation.
		Pyrolysis	Organic contaminants are exposed to high temperature in the absence of sufficient oxygen for complete combustion. Organic materials are transformed into gaseous components and a solid residue (coke) containing fixed carbon and ash. The technology is not proven at wood treater sites and it produces residuals requiring further treatment. Does not affect metals. For these reasons it is not retained for further evaluation.

Table 3.1. (contd)

General Response Actions	Remedial Technologies	Process Options	Description
		Ex Situ Vitrification	Contaminated sediments are converted into glass-like material. Organic contaminants are destroyed and metal contaminants are stabilized in low-leachability solid. Although this is not a proven technology for site COCs, it was evaluated as an innovative technology to address both organic and inorganic contaminants (see Section 3.1.2.2). Not retained for further evaluation.
	Chemical Treatment	Conventional Solvent Extraction	Uses an organic solvent to extract organic contaminants from the sediments and concentrate them in a stream for subsequent treatment and disposal. Site-specific soil treatability studies have shown the process effective for organic COCs, including dioxin. Not applicable to metals contamination. Retained for further evaluation in conjunction with similar treatment for upland soils.
		Supercritical Fluid Extraction	Process uses highly compressed gases (e.g., CO_2) raised above their critical temperatures to extract contaminants that generally resist extraction by conventional solvent extraction. Extracted contaminants require further treatment. The high water content of the sediments is likely to reduce the effectiveness of the process. Not retained for further evaluation.
		Dehalogenation	Dehalogenation uses a chemical reaction to remove chlorine atoms from chlorinated molecules, making them less toxic. Dewatered sediment is placed in a reactor with reagents, mixed, and heated. Sediment and reagents are separated and the soil neutralized. The technology is applicable to chlorinated organics (e.g., PCP, dioxin); its effectiveness for PAHs is uncertain. Process generates reagent waste, other liquid wastes, and potentially contaminated residuals. Although this is not a proven technology for wood treater wastes it is retained for further evaluation.

Table 3.1. (contd)

General Response Actions	Remedial Technologies	Process Options	Description
		Chemical Oxidation	**Process adds chemical compounds (e.g., hydrogen peroxide, ozone) to soil in a reactor to oxidize organic contaminants and liberate free oxygen. It can be enhanced by heat, a catalyst (e.g., metals such as iron, aluminum and copper), ultraviolet radiation, or photosensitive material. Process produces residuals that may require further treatment. While this is a well-established technology for liquids, it has not been proven for wood treater site soils or sediment. Studies indicate this technology is not effective for sorbed contaminants. For these reasons, this process is not retained for further evaluation.**
	Physical Treatment	**Ex Situ S/S**	Process physically binds or encloses contaminants in excavated soil within a stabilized mass (solidification) or induces chemical reactions between a stabilizing agent and the contaminants to reduce their mobility (stabilization). S/S is the Wood Treater Presumptive Remedy for inorganic contaminants. Site-specific soil treatability studies indicate S/S is an effective method for treating site COCs, including organics. Retained for further evaluation.
		Soil Washing/Solids Classification	Process uses screens and cyclone separators to segregate contaminated soils from cleaner soils by size, thus reducing the volume and preparing a uniform composite for treatment or disposal. Soil may be washed with a detergent or solvent to remove contaminants from the coarser (i.e., less contaminated) fraction. It generates liquid wastes and contaminated residuals that require further treatment. Not retained as a stand-alone technology; however, some solids classification may be used to remove large debris prior to other ex situ treatment processes.

Table 3.1. (contd)

General Response Actions	Remedial Technologies	Process Options	Description
		Dewatering	Removes residual water from saturated sediments. Not retained as a stand-alone technology, however, it may be used as a pretreatment technology prior to other treatment processes or disposal.
Disposal	Near Shore Disposal	Confined Disposal Facility	Dredged material would be placed in a dammed or diked structure within or alongside the slough. Retained for further evaluation.
	Onsite (Upland) Landfill	Engineered Landfill	Sediment (and possibly solid treatment residuals) would be buried in a specially-designed and constructed onsite landfill which would contain liners or a leachate collection system, as appropriate. Retained for further evaluation.
		Used as fill or road construction material	Sediments are re-used for fill materials, etc. This is only suitable for non-hazardous wastes such as the clean coarse fractions from the soil washing/classification process or other clean solid treatment residuals. Not retained because this is expected to only apply to a very small amount of material.
	Offsite Disposal and/or Treatment	RCRA permitted commercial facility	Excavated soils (and possibly treatment residuals) would be sent offsite for disposal and/or treatment (if necessary to meet land disposal restrictions [LDRs]) at a permitted hazardous waste landfill or treatment storage and disposal facility (TSDF). Retained for further evaluation.

Technologies that are not retained for further evaluation are indicated with shading. EPA Wood Treater Site Presumptive Remedies are indicated in boldface.
References: White and Bryant (1993); EPA (1992, 1995); PTI Env. Service (1995); Lincoff et al. (1994).

Table 3.2. Screening of Technologies and Process Options for Sediment Remediation

General Response Actions	Remedial Technologies	Process Options	Effectiveness	Implementability	Relative Cost
No Action	None	Not applicable	Not applicable.	Not applicable.	Not applicable
Institutional Controls	Land Use and Access Restrictions	Proprietary and governmental controls on land use and notice requirements	Effectiveness depends on continued future implementation. Does not reduce sediment contamination. Not effective as a stand-alone remedy, but retained for possible implementation in conjunction with other remedies.	Relatively easy to implement, however, some legal requirements and authority issues must be overcome.	Low
		Site access controls (fencing, warning signs, log booms in Old Mormon Slough)	Does not reduce contamination but can reduce direct human exposure potential via contact with contaminated sediment and consumption of contaminated fish. Effective as part of overall site remediation, but not as a stand-alone remedy. Not effective as a stand-alone remedy, but retained for possible implementation in conjunction with other remedies.	Controls must be maintained (some are already in place). May be difficult to enforce.	Low
	Monitoring	Sediment and fish monitoring	Does not reduce contamination or exposure. As a stand-alone technology, it is used to assess the migration of contaminants in the absence of remediation. Effective as part of overall site remediation, but not as a stand-alone remedy. Not effective as a stand-alone remedy, but retained for possible implementation in conjunction with other remedies.	Easily implemented.	Low
Containment/ Isolation	Capping	Single layer (sand) cap	Does not treat contaminated sediments, but is effective in isolating them and reducing their bioavailability. Prevents direct human exposure via contact with contaminated sediment if it is properly maintained and protected from erosion, slumping, and bioturbation. Also somewhat effective in reducing potential migration of contaminants via infiltration to groundwater. (Localized armored cap may be used for portions of Old Mormon Slough.)	Fairly straightforward to implement. Cap design must consider engineering properties of sediments to avoid mixing of cap materials into the contaminated sediment and to avoid slumping and/or other potential failures of the cap. Requires monitoring and maintenance. Would have temporary local impacts on ecosystem and minor effects on the depth of the slough.	Medium

Table 3.2. (contd)

General Response Actions	Remedial Technologies	Process Options	Effectiveness	Implementability	Relative Cost
	Channel Filling	Backfill Old Mormon Slough	Would be effective in isolating the contamination from the ecosystem. Also would eliminate the hydraulic driving force potentially driving aqueous phase contaminants into the groundwater system. Partial backfilling of Old Mormon Slough is an element of the confined disposal facility.	Implementation should be relatively straightforward; however, state and federal agency acceptance is uncertain. Will destroy (reduce the size) existing aquatic habitat in Old Mormon Slough. Requires some monitoring and maintenance.	Medium
	Vertical Barriers	Sheet piling	As a stand-alone technology, sheetpiling may be effective in reducing threats to groundwater by confining deep sediment contamination, if necessary depths could be reached. However, the added benefits of reducing migration over the low permeability of the natural geologic formation materials is uncertain. Sheetpiling does not address surface sediment contamination. It would be effective in retaining dredge and/or backfill material in combination with filling of the slough or a CDF.	Could be difficult to implement because the practical depth limitations for containment to prevent contaminant migration to groundwater is uncertain.	Medium
	Sedimentation Controls	Silt curtains	Not a stand-alone remedy, but effective in controlling migration of fine-grained sediment during dredging or other disturbances of Old Mormon Slough sediments. Retained as a component of other alternatives.	Implementation is fairly straightforward. Proper design for site-specific conditions and proper installation is necessary.	Medium
Removal	Dredging	Mechanical Dredging	Can effectively remove contaminated sediment. Could cause substantial resuspension of sediment that would need to be controlled with silt curtains or other methods.	Fairly easy to implement. Uses standard dredging equipment. Can be difficult to control the accuracy of the excavation. Could cause adverse release of contamination to the water column (short-term). Would have a substantial short-term impact on the ecosystem by removing benthic organisms. However, recolonization by a more diverse community would be expected.	Medium

Table 3.2. (contd)

General Response Actions	Remedial Technologies	Process Options	Effectiveness	Implementability	Relative Cost
		Hydraulic Vacuum Dredging	Can effectively remove contaminated sediment. Could cause resuspension of sediment and release of contamination to the water column, but significantly less than with mechanical dredging.	Fairly easy to implement. Faster and easier to control than mechanical dredging. However, the process produces large volumes of waste water (the resulting slurry is typically 80% water), dewatering and effluent treatment may be necessary. Can leave the coarser sediments behind. Would have substantial short-term impacts on the ecosystem by removing benthic organisms. However, re-colonization by a more diverse community would be expected.	Medium
		Temporary dam, dewatering, and excavation	Provides an optional method to dredging for removal of contaminated sediment from Old Mormon Slough.	Approximately 31 million gallons of water would have to be pumped initially from the slough once the dam was in place, followed by additional dewatering to keep the remaining sediment dry. A total of 260 million gallons of water would have to be filtered or treated before discharged back into the slough. Like dredging, this option would also have substantial short-term impacts on the environment.	Medium to High
Ex Situ Treatment	Biological Treatment	**Solid-phase bioremediation (Composting, landfarming)**	EPA Wood Treater Presumptive Remedy for organics, except dioxin. Proven technology for lower molecular weight organic contaminants (i.e., PAHs with four rings or less, PCP, PCBs). However, the bioremediation treatability studies for the M&B site found no significant degradation after 91 days. Not effective for inorganics.	There is adequate land available onsite and it should be relatively easy to implement. Requires very little operator attention, only occasional tilling and/or nutrient/water addition. It may lead to a concentration of metals at the base of the treatment bed. Residuals may require treatment (subject to LDRs).	Low
		Slurry-phase bioremediation (Bio-reactor)	EPA Wood Treater Presumptive Remedy for organics (except dioxin). Proven technology for lower molecular weight organic contaminants (i.e., PAHs with four rings or less, PCP, PCBs). However, the limited bioremediation treatability studies for the M&B site found no significant degradation after 91 days. Not effective for inorganics.	Should be relatively straightforward to implement. Generally much faster than land farming, but also handles smaller volumes. Residuals (solids and effluent) may require treatment (subject to LDRs).	Medium

Table 3.2. (contd)

General Response Actions	Remedial Technologies	Process Options	Effectiveness	Implementability	Relative Cost
	Thermal Treatment	**Thermal Desorption**	EPA Wood Treater Presumptive Remedy for organics. Has not been demonstrated to be effective for dioxin. Not effective for inorganic contaminants. Thermal desorption was evaluated for dioxin-contaminated soil as the first stage of a pilot-scale medium temperature thermal desorption/base catalyzed thermal desorption (MTTD/BCD) treatability test. Dioxin cleanup levels were not attained for site soils.	Implementability is medium to high in difficulty. The technology has not been proven on dioxin-contaminated soils or sediment. There are potential emissions concerns for this process because of the presence of dioxin. There were implementation problems identified for the thermal desorption process during a pilot-scale treatability test on site soils. High moisture content of sediments can increase operating costs. Sediment would require additional treatment to address inorganics.	High
		Incineration	EPA Wood Treater Presumptive Remedy for organics. Incineration is the only proven technology for dioxin. Not effective for inorganic contaminants.	Implementability is medium to high in difficulty. Incineration technology is well established. However, because of potential emission concerns due to the presence of dioxin in the sediment, state agency and community acceptance is unlikely. High moisture content of sediments can increase operating costs. Sediment would require additional treatment to address inorganics.	High
	Chemical Treatment	Conventional Solvent Extraction	Site-specific treatability studies indicate this can be an effective process for removing organics, including dioxins, from soils. However, the high moisture content of the sediments could reduce the effectiveness. Process is retained for further evaluation because it represents the only demonstrated effective treatment option for sediment organic contaminants.	Implementation may be difficult. A large volume of treatment residuals must be further treated. Process will be retained because it represents the only viable treatment option for soil and sediment at the site. Sediment would require additional treatment to address inorganics.	High
		Dehalogenation	Dehalogenation is not a proven technology for wood treater wastes. It uses a chemical reaction to remove chlorine atoms from chlorinated molecules (e.g., PCP and dioxin), making them less toxic. Its effectiveness for PAHs is uncertain.	Dehalogenation is difficult to implement. It generates reagent waste, other liquid wastes, and potentially contaminated solid residuals. There are also potential air emission concerns for this process.	High

Table 3.2. (contd)

General Response Actions	Remedial Technologies	Process Options	Effectiveness	Implementability	Relative Cost
	Physical Treatment	**Solidification/ Stabilization (S/S)**	EPA Wood Treater Presumptive Remedy for inorganics. May also be effective for some organics. Treatability studies on site soils indicate that S/S is effective in significantly reducing the leachability of organics, including dioxin, as well as inorganics.	Ex situ S/S treatment process should be relatively easy to implement, and vendors are widely available. Volume is increased due to addition of solidifying agents. Retained as a process option for metals contamination in sediment and/or treatment residuals.	Medium
		Dewatering	Effective for removing residual water from sediment prior to treatment or disposal. This is retained as a pretreatment technology for the development of other alternatives.	Fairly straightforward to implement, but may require some initial trial runs. Residuals may require treatment.	Low to Medium
Disposal	Near Shore Disposal	Confined Disposal Facility	Confined disposal facilities are commonly used for sediment disposal. Can effectively isolate organic and inorganic contaminants from the ecosystem. Can also prevent migration of contaminants to groundwater.	Fairly easy to implement, but depends on the design. May be used in combination with sheetpiling and/or capping technology. May reduce aquatic habitat area and could have temporary effects on water quality. Requires monitoring and maintenance.	Low to Medium
	Onsite (Upland) Landfill	Engineered landfill	Effective in isolating excavated organic and inorganic sediments and/or treatment residuals. Although toxicity and volume are not reduced, this process option eliminates the migration of contaminants by isolating the waste within the impervious landfill.	Implementability at the M&B site may be difficult. Sufficient landfill capacity may not be available in the upland portion of the site. Would require long-term maintenance. Not retained as a stand-alone remedy for all dredged sediment, but may be appropriate on a limited basis for disposal of solid treatment residuals.	Low to Medium

Table 3.2. (contd)

General Response Actions	Remedial Technologies	Process Options	Effectiveness	Implementability	Relative Cost
	Offsite Disposal and/or Treatment	RCRA permitted commercial landfill	Allows removal of both organic- and inorganic-contaminated material from the site. Offsite disposal removes contaminated material from the site, but transfers it to another location.	This would be medium in relative implementation difficulty. Sediment would require dewatering before transport. There could be some short-term impacts from the loading and transportation of the contaminated sediment. Requirements for transportation of hazardous wastes and land disposal restrictions (LDRs) would have to be met. This is potentially a very high cost option because of the large volume of contaminated sediment involved and the waste classification for disposal.	High

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Technologies that are not retained for further evaluation are indicated with shading. EPA Wood Treater Site Presumptive Remedies are indicated in boldface.
References: White and Bryant (1993); EPA (1992, 1995); PTI Env. Service (1995); Lincoff et al. (1994); WMI (1996).

4.0 DEVELOPMENT OF REMEDIAL ALTERNATIVES

The purpose of this section is to assemble, based on the screening of technologies and process options conducted in Section 3.0, a set of remedial action alternatives applicable to Old Mormon Slough sediments. The NCP (Section 300.430[e][1]) states that the lead agency shall include an alternative screening step (using the criteria of effectiveness, implementability, and cost) when needed to select a reasonable number of alternatives for detailed analysis. Because a reasonable number of sediment alternatives (i.e., five, including No-Action) were developed, this FS report proceeds directly from a description of the sediment alternatives in this section to their detailed analysis in Section 5.0 without a preliminary screening step.

Preliminary design assumptions were developed for each alternative, such as the extent and volume of contaminated material, the size of major technologies/process options, the time frames involved, and an estimated order-of-magnitude (+50% to -30%) cost. The design assumptions used here are not necessarily the same as the design basis that would be used for the final, detailed remedial design. In most cases, additional investigations or studies (e.g., treatability tests) would be necessary to allow final design.

It should be noted that there are some areas of overlap between the potential remedial actions for Old Mormon Slough sediments and for upland soils. Similar ex situ treatment and/or disposal technologies have been evaluated for both media. For cost-effectiveness during site remediation, implementation of similar treatment technologies, if selected for soil and sediment, would likely be carried out concurrently. However, remedial costs have been estimated separately for sediment and soil; soil remediation costs are not included in this FS report.

As noted earlier in this report, sediment contamination in Old Mormon Slough may represent a source to groundwater contamination beneath the site, although to a much lesser degree than the deep upland source areas. No direct evidence has been found that slough sediments are contributing to groundwater contamination at the M&B site; however, the sediments are considered a potential source to groundwater. If contaminated sediments are left in place and capped rather than removed, they could continue to serve as a source to groundwater, although the effect would be somewhat reduced because of the overlying cap. However, concentrations and total mass of COCs in deep slough sediments are low in relation to the significant upland sources that have been identified at the OWP and CPAs, which represent the primary sources to groundwater contamination. In any event, because Old Mormon Slough is located upgradient from the main groundwater contamination plume, any contribution of contaminants from the sediment is expected to be captured by the network of groundwater extraction wells that will be designed to address the major groundwater plume emanating from the upland sources. For this reason, groundwater remediation is not included in the scope of this FS report. The evaluation of alternatives for the remediation of groundwater at the M&B site is found in the Soils-Groundwater OU FS report (ICF 1998).

4.1 DEVELOPMENT OF REMEDIAL ACTION ALTERNATIVES

Remedial alternatives, with the exception of No-Action, are developed to be protective of human health and the environment and to achieve RAOs to the extent practicable. The NCP requires that a range of alternatives be developed for source control actions such as those being considered for Old Mormon Slough sediments. The assembled alternatives represent different levels of control and risk reduction and are required to include

- a No-Action alternative, representing a baseline case, that does not include any action towards achieving site RAOs

- one or more alternatives that involve little or no treatment, but protect human health and the environment through the use of institutional controls and/or engineering controls

- one or more alternatives that use treatment to reduce the toxicity, mobility, or volume of contaminants. If appropriate, the range of alternatives should include an alternative that removes or destroys contaminants to the maximum extent feasible in order to eliminate or minimize the need for long-term site management. Other appropriate alternatives should treat the principal threats posed by a site, but vary in the degree of treatment employed and the quantities and characteristics of the treatment residuals and untreated waste that must be managed.

As identified in Section 3.0, the RAOs for the M&B site can be achieved by a number of GRAs including: isolating the contamination, treating it in place, removing and treating the contaminated sediment ex situ, or removing and disposing of the contaminated sediments. The technologies and process options that were retained from the initial screening conducted in Section 3.0 have been assembled into five remedial action alternatives:

- SD-1 - No-Action

- SD-2 - In Situ Capping

- SD-3 - Dredging and Confined Disposal (combined with limited in situ capping)

- SD-4 - Dredging and Offsite Disposal (combined with limited in situ capping)

- SD-5 - Dredging and Onsite Treatment (Solvent Extraction and S/S) (combined with limited in situ capping).

Although the use of institutional controls was considered, it was not developed as a stand-alone alternative for sediment because it would not meet the RAOs for protection of the environment. In addition, unlike the upland portion of the site, implementation of institutional controls is difficult for an aquatic environment. However, implementation of institutional controls was retained as a component of the other alternatives that involve containment or treatment.

4.2 COMMON ELEMENTS

Many of the components of individual alternatives are common to other alternatives, such as the use of institutional controls, monitoring, capping, dredging, silt curtains, and dewatering. These common elements are discussed in the following subsection to eliminate repetition in the discussion of individual alternatives.

4.2.1 Institutional Controls

Institutional controls would be used to restrict access to Old Mormon Slough, thereby reducing human exposure to contaminated fish and sediment. However, institutional controls would not meet the RAOs for protection of the environment, and so are not considered as a stand-alone alternative. At present, fencing and warning signs are already in place along the M&B shoreline of Old Mormon Slough. Under the No-Action alternative, these existing controls would remain but would not be maintained. Under all the other alternatives, the existing fencing and warning signs would be maintained and improved if necessary. In addition, other institutional controls, including proprietary and governmental controls, notification requirements, and physical controls would be included to some extent as a component of each remedy.

The use of additional institutional controls is dependent on the specific alternative, but could include all or portions of the following activities as a means for controlling exposure from the low-level threat area near the mouth of Old Mormon Slough that will not be addressed by capping or removal under any of the alternatives. These controls are directed primarily at reducing the potential for resuspension and transport of contaminated sediment found in localized “hot spots,” as discussed in Subsection 2.2.1, while sediment accumulation and other natural attenuation processes reduce the exposure to and/or the contaminant concentrations of these hot spots (see Appendix A).

The two apparent “hot spots” near the mouth of the slough, one exceeding the MSC for PAHs at OMS-61 (see Figure 2.2) and the other exceeding the MSC for dioxin at OMS-60 (see Figure 2.3), are located in the uppermost sediments and so are not considered to pose a threat to groundwater. These “hot spots” represent less than 0.3% of the total PAH and only 2% of the dioxin mass in the slough sediments. There is no obvious spatial continuity between these high values and the surrounding values; thus, these values are unlikely to represent an area of contamination that could be located again. Such “hot spots” are extremely difficult to define in an aquatic environment for implementation of any active remedial action such as capping or dredging. Applying containment or dredging to the entire MTH portion of the slough for the sole purpose of remediating these two localized, low-level threat areas is not warranted based on the degree of risk reduction expected versus the anticipated remedial cost. Therefore, the only feasible GRA for the mouth area of the slough is to use institutional controls to control access to and limit the types of activities conducted in this area of Old Mormon Slough.

Specific institutional controls for the mouth area of Old Mormon Slough include the installation of a log boom and warning signs across the mouth of the slough to limit or restrict navigational access to the slough. This would prevent inadvertent erosion (via boat prop wash) and resuspension of the surface sediment (and “hot spots”). Deed notices would be promulgated to keep the site zoned for appropriate industrial and/or commercial uses only and to prohibit dredging in the slough without further study, use of proper controls (e.g., silt curtains, proper disposal and/or treatment of dredged material), or remediation. Environmental monitoring would be conducted to assess the progress of natural attenuation processes.

Under all of the sediment alternatives, except No-Action, similar institutional controls might be implemented for the other portions of Old Mormon Slough to prevent inadvertent erosion or other disruption of in situ sediment cap materials that would cause exposure of more highly contaminated older sediment. In addition, access controls (i.e., log booms, additional fencing, and warning signs to fully encompass the areas of principal and low-level threats) might be added under the other alternatives to reduce human exposure to contaminated sediment and fish by restricting access to the slough.

4.2.2 Monitoring

Monitoring is included as a component of all remedial action alternatives, including the No-Action alternative. Monitoring is generally conducted for both short-term (during remediation) and long-term (post-remediation) purposes. Short-term monitoring is conducted to 1) detect any negative impacts of the remedial actions, thereby allowing prompt mitigation; 2) evaluate the performance of the remedial action for comparison to design expectations; and 3) identify operation and maintenance concerns that need to be addressed to optimize remedial performance. Long-term monitoring is conducted primarily to allow timely maintenance of containment measures and to ensure that remedial actions are effective in achieving RAOs over the long term.

A general description of appropriate monitoring activities is presented here and a conceptual monitoring program is presented in **Table 4.1**. However, specific details of a monitoring program are dependent on the selected remedial action(s). Detailed monitoring plans will be developed for the selected remedial actions during the remedial design phase. In general, monitoring would begin with intensive efforts to establish the environmental baseline and to monitor active remedial measures. Following the construction and active remediation activities, the level of monitoring would be reduced to support long-term performance assessment of the remediation. Both physical and chemical monitoring would be performed to assess site conditions and monitor the fate and effects of residual contamination.

Short-term monitoring would include sediment, water, and biota sampling and analyses. Sediment sampling would be conducted to more precisely define heavily contaminated areas for dredging (if applicable) and/or capping. Monitoring would also be performed during dredging and/or cap placement to evaluate the short-term effects on water quality and adjacent sediment quality and to ensure that the dredging and/or capping meet specifications for location, depth or thickness, material design, final bottom topography, etc. Biological monitoring would be performed to assess the short-term biological effects of dredging and/or capping, to assess the re-establishment of a healthy benthic community and ensure that biological activity will not damage the cap integrity.

Long-term monitoring would include sediment, water and biological sampling, and chemical analyses to monitor the long-term stability and natural degradation of residual contamination. This would include sediment core sampling and chemical analyses. Capped surfaces would be monitored for maintenance requirements to identify areas of scouring or suspension and redeposition, thereby identifying areas requiring additional cap materials or armoring. The cap surface would be sampled and analyzed to determine if adjacent uncapped areas are contaminating the cap. Sampling and analysis of water samples from Old Mormon Slough would determine compliance with EPA AWQC and other ARARs. Periodic biological monitoring would be conducted for comparison with the California State Mussel Watch program standards. Uncapped areas would be sampled and analyzed (both sediment and biota) to monitor the progress of natural attenuation.

4.2.3 Sediment Capping

Sediment capping is used to physically cover and isolate contaminated sediment. All of the sediment remedial alternatives (except No-Action) employ sediment capping to varying degrees to isolate PAH and dioxin-contaminated sediment from the ecosystem. A general discussion of design assumptions is presented here. Details for each alternative are provided in later subsections.

Capping would be performed using locally quarried clean fine sand as the cap material. An armored multilayer cap was also considered during the screening process in Section 3.0. However, the capital cost to install an armored cap was estimated to be two to three times that of the natural cap (EPA 1992), and conditions in Old Mormon Slough do not warrant an armored cap for the entire slough area. The quiescent nature of the slough, with limited erosion and net deposition of sediment, as well as the lack of navigational traffic, suggests that an armored multilayer cap is unnecessary. Localized armoring of the cap (with rip-rap and an underlying gravel filter layer) would be installed in areas found to be susceptible to erosion, based on data (such as nearshore wave action, bottom velocities, and barge/boat traffic patterns and frequencies) acquired during remedial design. For these reasons, a sand cap was selected as the representative in situ capping technology for the development of alternatives.

Installation of the cap would be conducted when the tides are lowest and are incoming to ensure containment of any disturbed sediment and to prevent the release of contamination outside of the slough. Minimal preparation of the slough bed (removal of rubble, pilings, etc.) would be performed prior to installation of the cap. Thickness of the cap would be a minimum of 0.6 m (2 ft), which conservatively accounts for chemical, biological, and operational (i.e., placement accuracy and thickness irregularity) characteristics (**Table 4.2**). The cap would cover the entire targeted portion of the slough bottom. The use of a permeable sand cap would promote the re-establishment of a benthic community, yet bioturbation is estimated to be limited to the upper 2 cm of the cap material and thus would not affect the integrity of the cap. The permeable sand cap would also permit any gases formed during decomposition of organic mater to escape. A 10% safety factor is used in estimating the volume of material required.

4.2.4 Sediment Dredging

Three alternatives employ the use of selective dredging to remove the most heavily contaminated sediment from the slough and to reduce the mass of contamination available for bioaccumulation in the aquatic organisms. The areas identified for contaminant removal (dredging) vary, ranging from the portion of the slough just north of the OWP area to the END of the slough. Both mechanical and hydraulic vacuum dredging passed the technology screening process. However, mechanical dredging was selected as the representative process option because hydraulically dredged material would have a very high water to solids ratio (~5:1), which would make sediment handling, treatment, and/or disposal more difficult and costly.

The sediment to be dredged from Old Mormon Slough has been described as stratified clay, silt, and sand (White and Kohn 1996). The uppermost material in the OWP, CPA, and END sections of the slough consists of very soft, very dark gray to black homogeneous clayey silt ranging in thickness from 0.4 to 1.2 m (1.4 to 3.8 ft). Gas holes were commonly observed in core samples. Gravel fill was found at or near two of the sampling stations. Throughout the CPA and END sections this clayey silt is underlain by sticky, very soft dark gray clay, ranging in thickness from 0.3 to 0.7 m (0.9 to 2.2 ft). The TOC content of these upper sediments ranges from about 2.5 to 0.7%. The clayey silt and sticky gray clay units are underlain by soft to firm, very dark gray or dark olive gray silt, sand, and clay. These sediments are predominantly silt at the eastern end of the slough and sand at the western end. They contain some plant remains (roots and twigs). Buried trees that had apparently fallen into the slough were encountered at two sampling locations. A sharp contact separates these soft to firm alluvial sediments from an underlying hard, dry, dark gray to olive brown silt or silty clay at 3.0 to 6.4 m (9.7 to 20.9 ft) below mudline in the CPA and END portions of the slough, respectively.

Dredging would be conducted using a derrick barge and cable arm clamshell bucket to provide a level cut and to minimize turbidity (Chemical Waste Management, Inc. 1996). Sediments removed by the bucket would be placed into the barge or a scow. When the scow was loaded it would be moved to the designated offload point(s) (i.e., the CDF or the dewatering cells) and the dredge materials mechanically removed, either by positive displacement pump or clamshell. Any debris encountered during dredging would be placed in a holding area of the site for salvage or disposal. Free liquids in the scow would be pumped to a series of holding/settling basins where they would be treated and managed. Dredging would be conducted during incoming tides and on the upstream side of a silt curtain to contain any suspended sediment. Dredging would progress on a grid-by-grid pattern starting at the western end of the slough (in the MTH section) and working back and forth toward the END of the slough. This would keep undredged portions of the slough in front of the dredge crew and would minimize the spread of contamination to clean areas.

The estimated depth of dredging ranges from 0.6 to 2.4 m (2 to 8 ft), although contaminated sediment has been found at depths greater than 6 m (20 ft) at two locations in the CPA and END portions of the slough (**Table 4.3**). Thus, the maximum depth of contamination has not been defined for these locations. In any event, dredging to depths greater than 2.4 m (8 ft) in the slough is generally not considered practicable due to the instability of the sediments and high associated costs. Actual dredging depths will be adjusted during remedial design and field implementation. A 10% over dig factor is assumed to ensure complete removal of the target contamination. A bulking factor of 20% has also been assumed to account for expansion during the removal and handling process.

4.2.5 Silt Curtains

All three dredging alternatives employ the use of a silt curtain to prevent transport of sediment disturbed by dredging activities. The silt curtain would be erected across the mouth of Old Mormon Slough prior to dredging. This curtain would remain in place until removal of contaminated sediments is completed and the water turbidity has subsided to an acceptable level. However, there may be a need to move the silt curtain, once dredging has been completed in the lower (western) portion of the slough, to allow barge traffic into this area.

The curtain would be designed and placed to capture sediments generated during dredging activities, yet not be affected by tidal surges, wind waves, or wakes. A conceptual design for this curtain was taken from Chemical Waste Management, Inc. (1996). The curtain would extend from the water line down to the bottom of the slough and would be held in place by ropes to the shorelines, chains and anchors to the bottom, and a floating boom on the top. The estimated dimensions of the curtain are 73 by 10 m (240 x 34 ft). The detailed design would be developed during remedial design. A second curtain may be used to filter water escaping from the CDF under that alternative.

The curtain(s) would be monitored periodically (~3 times per day) to ensure that no tears or breaches have developed. Any tears or holes discovered in the silt curtain will be immediately repaired.

4.2.6 Sediment Dewatering

Dewatering is a physical treatment technology used to reduce the moisture content of dredged sediment. The reduction in moisture content is necessary to enable handling and transport of the dredged material and to increase the efficiency of the treatment processes (particularly incineration). Both the offsite disposal and onsite treatment alternatives require some level of dewatering.

Four main process options are generally available to dewater solid waste streams: centrifugation, drying beds (gravity drainage), drying lagoons (percolation basins), and filtration (Delta Research Corporation 1996). Filter presses generally produce the driest filter cake, but are labor-intensive, generally operate in batches, and require regular maintenance (PNNL 1995). Vacuum filtration is effective at removing liquids in a continuous process. However, it is limited by the pressure drop induced across the filter and operating expenses are high. Centrifugation can also be performed in a continuous operation, but operating costs are high. Gravity drainage is the simplest dewatering technology process and has the lowest capital, operation, and maintenance costs. However, it generally produces the wettest filter cake, has the largest space requirements with the lowest throughput capacity. A chemical conditioner is often added to assist coagulation of the very fine sediment particles to improve yield and clarify the supernatant.

Recent experience at the United Heckathorn Superfund site indicates that gravity drainage of silty/clay materials can be an extremely slow process and can hold up large volume dredging operations. To increase the throughput at this site dewatering was supplemented with solidification technology (addition of sodium silicate and Portland cement). This simply ties up the moisture content in water of hydration making the sediment fairly dry and easier to handle and transport. However, this water of hydration can adversely affect the efficiency of thermal treatment processes. Thus, for this FS a combination of gravity drainage and filter pressing (i.e., belt filter press, recessed plate, and/or diaphragm plate filters) has been chosen as the representative dewatering technology process option. Recessed plate or diaphragm plate filters generally achieve the maximum solids content of mechanical dewatering processes (EPA 1994). The belt filter press was selected as the representative filter press option because more design and cost information is available.

Dredged sediment to be dewatered would be transferred from the scows using a clamshell bucket or positive displacement pump, mixed with a chemical conditioner (e.g., lime) to assist coagulation, and placed into a series of unlined holding/dewatering cells. Here, gravity drainage, percolation, and evaporation would partially dewater the sediment. The holding/dewatering cells would be designed such that a maximum amount of water will drain from the sediments as soon as possible. Once the sediments have been drained of free liquid they would be screened to remove oversize material and debris to produce a uniform feed material and conveyed to the filter press for further dewatering. The extent of dewatering that is necessary is dependent on the choice of treatment/disposal options. The dewatered sediment would then be transferred to an onsite holding area for further treatment (e.g., solvent extraction) or placed directly into shipping containers for offsite disposal.

The recovered drainage water would be channeled to a collection cell where the water would be processed through a series of cascading settling tanks. The drainage would then proceed to hydrocyclone where it would remove suspended solids prior to draining back into the slough, upstream of the silt curtain. The strong sorption capacity and low water solubility of the primary COCs (PAHs and dioxin) suggests that most of the contamination would be associated with fine sediment particles and thus would be removed by filtering. The filtered water would be discharged back into the slough behind the silt curtain. A treatability test would be performed to ensure that the filtered water would meet acceptable criteria (e.g., AWQC) before discharge into the slough. If it does not, then carbon adsorption could be added to the treatment train to further treat the water. The cost for this added treatment is expected to be minor relative to the overall cost of the offsite disposal or onsite treatment alternatives, so it has not been calculated. Recovered solids would be transferred back to the holding/dewatering cells.

Assuming a dredging rate of 1530 m^3/day (2000 cy/day) over an 8 h shift (Section 3.4), the dewatering system should be sized to handle this same volume over a 24 hr shift. Approximately five holding/dewatering cells would be constructed to hold 1530 m^3 (2000 cy) each, allowing 5 to 7 days for gravity drainage (**Table 4.4**). The filter press system would be designed to handle 77 m^3/hr (100 cy/hr), with operations around the clock (24 hrs/day), and allowing for 20% maintenance/downtime.

4.3 DESCRIPTION OF SEDIMENT REMEDIAL ACTION ALTERNATIVES

This section provides a description of each alternative developed for detailed analysis. The alternative descriptions identify the technologies, describe the representative process options, and present the design assumptions necessary to complete the detailed analysis. Information on the assumptions and calculations used in the estimation of sediment volumes for each alternative is provided in Appendix B. A detailed cost estimate for each alternative is provided in Appendix C.

4.3.1 SD-1 - No-Action

Under this alternative, the site would be abandoned as is, without any additional access controls or remedial actions to reduce the exposure to and/or toxicity of the COCs. A No-Action alternative would be taken to address the sediment contamination or the affected environmental receptors. This alternative does not actively reduce risks to human health and the environment related to contaminated sediment and aquatic organisms. However, over time some natural attenuation would gradually occur through deposition of new uncontaminated sediments and biological degradation of the organic contaminants. This alternative would not meet the RAOs, but is retained for comparison with the other alternatives. The only cost associated with this alternative would be for sediment and biota monitoring.

4.3.2 SD-2 - In Situ Capping

The In Situ Capping alternative seeks to meet the RAOs by isolating contaminated sediments in the principal threat areas by blanketing them with a minimum of 60 cm (2 ft) of clean sand. Approximately three-fourths of the slough would be capped with clean, fine sand to isolate a preponderance of the PAH- and dioxin-contaminated sediment from the ecosystem. As discussed in Section 4.2.3, the sediment cap would consist of a minimum of 60 cm (2 ft) of clean, fine sand. These cap materials would be armored with rip-rap and gravel filter layer where needed to prevent erosion. The portion of the slough to be capped would run from just north of the OWP area, between sampling stations OMS-58 and OMS-59 to the END of the slough (**Figure 4.1**). The dimensions of the cap, based on rough drawings from White and Kohn (1996), are estimated at approximately 710 m (2330 ft) long by approximately 51 m (167 ft) wide. This cap would cover an estimated 3.6 hectares (8.8 acres) (**Table 4.5**). This portion of the slough contains nearly all of the PAH and dioxin concentrations exceeding the preliminary sediment cleanup levels and accounts for an estimated 99.5% of the mass of accessible (œ2.4 m [œ8 ft] deep) PAH contamination and 98% of the mass of dioxin contamination. The estimated volume of clean, fine sand needed for cap material (including a 10% safety factor) is estimated at 23,900 m^3 (31,200 yd^3).

A sand cap was selected as the representative in situ capping technology for Old Mormon Slough (see Subsection 4.2.3). However, localized armored capping may be necessary in areas of the slough susceptible to erosion. Two scenarios were used to estimate Alternative SD-3 costs. The expected cap is assumed to be a 90% sand/10% armored cap combination; for comparison purposes a cost estimate for a full armored cap was also prepared (see Appendix C).

As noted earlier, two apparent “hot spots,” one of PAH contamination and one of dioxin contamination, are located in the mouth of the slough outside of the proposed capped area. As with all of the other alternatives, remediation of these two hot spots would be limited to the use of institutional controls to limit navigational access to the slough, provide more fencing and warning signs to fully encompass the area(s) of principal and low-level threats, limit the future use of Old Mormon Slough and the upland portion of the site to appropriate uses, and control future dredging of the slough to prevent disturbance of residual sediment contamination in the mouth of the slough. Environmental monitoring would be conducted to assess the progress of natural attenuation processes for these two “hot spots.”

Under Alternative SD-2, similar institutional controls would be implemented for the capped portion of Old Mormon Slough (OWP, CPA, and MTH) to prevent inadvertent erosion or other disruption of in situ sediment cap materials that would cause exposure of more highly contaminated sediment under the cap. Short-term and long-term monitoring would be performed to assess the integrity and maintenance needs of the confined disposal facility and sediment cap.

Isolating the sediment COCs through capping would eliminate exposure to water column organisms and, over time, reduce concentrations in the fish population, including those species consumed by humans. The use of institutional controls as part of the overall slough remediation (see Subsection 4.2.1) would provide additional protectiveness. Access restrictions at Old Mormon Slough would reduce human exposure to contaminated fish and sediment until concentrations have been reduced to safe levels. Although capping would adversely affect existing benthic organisms, recolonization is expected to occur. This alternative does not directly address the potential migration of contamination from slough sediments into groundwater beneath the site, although the cap would be somewhat effective in reducing the migration via infiltration.

4.3.3 SD-3 - Dredging and Confined Disposal Alternative

This alternative was developed to meet RAOs by removing and consolidating a preponderance of the PAH and dioxin contamination and isolating it in a confined disposal facility. Alternative SD-3 consists of the following combination of technologies/process options:

- selective removal of heavily contaminated sediment via mechanical dredging
- use of a silt curtain to contain disturbed sediment within Old Mormon Slough

- disposal of dredged materials into a CDF behind sheet piling, located at the END of the slough

- capping of residual contamination after dredging (either OWP/CPA cap or CPA cap only)

- institutional controls (e.g., access controls, deed restrictions) and monitoring.

A discussion of those components that are common to more than one alternative (i.e., institutional controls, capping, dredging, silt curtain, and monitoring) was provided in Section 4.2.

A silt curtain would be erected across the mouth of Old Mormon Slough and contaminated sediments from designated principal threat areas would be removed via dredging and transferred to a CDF constructed in the END of the slough. Mechanical dredging would be conducted to remove contaminated sediment from the principal threat areas of the slough, starting at a small portion of the eastern MTH subarea to the END of the CPA portion, where the CDF would begin (**Figure 4.2**). This portion of the slough contains nearly all of the PAH and dioxin concentrations that exceed the preliminary sediment cleanup levels, except those located in the confined disposal area and the two hot spots located in the mouth of the slough.

The dimensions of the dredge area, based on rough drawings in White and Kohn (1996), is estimated to be a 406 m (1340 ft) long by 55 m (180 ft) wide (Figure 4.2, Table 4.7). Dredging would extend to a depth of 0.7 m (2.2 ft) in the principal threat area of the MTH and to 2.7 m (8.8 ft) (the maximum practical depth) from all but the eastern-most 69 m (225 ft) of the CPA. This incorporates a 10% overdig to ensure complete removal of the target contamination. The resulting volume of dredged sediment is estimated to account for 70% of the mass of the accessible (top 2.4 m [8 ft]) total PAH contamination and 47% of the dioxin contamination (see Appendix B). The rest of the END of the slough (containing another approximately 35% of the PAH and 51% dioxin contamination) would be used for a CDF and thus would not be dredged. Dredging would remove an estimated 55,400 m^3 (72,500 yd^3) of contaminated sediment. Expansion during removal and handling (using a bulking factor of 20%) would produce an estimated 66,500 m^3 (87,000 yd^3).

A CDF in the slough is preferable to an upland disposal facility because sufficient capacity is not available upland and because disposal of sediments there could interfere with the expected soil and groundwater remediation. CDFs are commonly used for dredged material (Lincoff et al. 1994). In this disposal option a CDF would be constructed in the eastern-most 293 m (960 ft) of the slough occupying all of the END and the eastern-most 69 m (225 ft) of the CPA portions. This would result in an estimated disposal capacity of 74,300 m^3 (97,200 yd^3). This CDF would be constructed by installing sheetpiling across the slough and lining the inside of the sheet wall with high-density polyethylene or similar material. This structural wall would require an adequate foundation (deep installation, estimated at twice its height), tie backs, support pilings, anchor pilings, etc.

Contaminated sediment located within the CDF would remain in place (not dredged). Surface water retained in the CDF would be allowed to escape back into the slough through a silt curtain and overflow weir, as the remaining storage capacity of the CDF was filled with contaminated sediment from dredging operations. Dredged material would be filled to within approximately 0.6 m (2 ft) of the upland ground surface. After a period of consolidation the dredged material would be capped with a permeable geotextile fabric and an estimated 0.6 m (2 ft) of clean fill. Wick drains could be installed to reduce consolidation time (EPA 1994).

Following the completion of dredging activities and confirmatory sampling, a 150-m to 390-m (480-ft to 1280-ft)-long stretch of Old Mormon Slough would be capped with natural materials (fine sand) to isolate residual contamination left behind by dredging activities. The portion of the slough to be capped would be dependent on confirmatory sampling. If sampling confirms that total PAH concentrations in the OWP and western end of the CPA are at or below the preliminary sedliment cleanup levels, then no cap will be installed there. However, the high concentrations of total PAH at depth in the eastern portion of the CPA indicates that this portion of the slough would require a cap after dredging. Thus, this alternative assumes that a CPA cap will be required, while an OWP area cap might be required if dredging alone does not meet the RAOs.

The CPA cap would run from just west of the CDF to the end of the CPA area (see Figure 4.2). The cap would cover an estimated 6,300 m^2 (67,800 ft^2), 0.6 ha (1.6 ac) of the slough. The OWP area cap (if required) would run from the CPA cap to the west end of the OWP area. This cap would cover an estimated 13,800 m^2 (149,000 ft^2), 1.4 ha (3.4 ac). General information regarding the design and installation of the sediment caps is provided in Subsection 4.2.3. Detailed design assumptions are provided in **Table 4.6**. Costs were estimated for both Alternative SD-3 capping scenarios (CPA/OWP Cap and CPA Cap Only) in Appendix C.

As with Alternatives SD-2, SD-4, and SD-5, Alternative SD-3 would address the two “hot spots” located in the mouth of the slough, outside of the proposed dredge and cap areas, by the use of institutional controls rather than active remediation (see Subsection 4.2.1). Remediation would be limited to the use of institutional controls to limit navigational access to the slough, provide more fencing and warning signs to fully encompass the area(s) of principal and low-level threats, limit the future use of Old Mormon Slough and the upland portion of the site to appropriate uses, and control future dredging of the slough to prevent disturbance of residual sediment contamination in the mouth of the slough. Environmental monitoring would be conducted to assess the progress of natural attenuation processes for the “hot spots.”

Under Alternative SD-3, institutional controls would also be implemented for the capped portion of Old Mormon Slough and the CDF to prevent inadvertent erosion or other disturbance of in situ sediment cap materials and the CDF that would expose residual sediment contamination. Monitoring would be performed to assess the integrity and maintenance needs of the sediment cap and CDF.

Removal of the most heavily contaminated sediment from principal threat areas of the slough and isolation in a CDF would reduce the mass of contamination available for exposure to and bioaccumulation in the aquatic organisms, including those species consumed by humans.

Over time, this would lead to a reduction in the PAH and dioxin concentrations in the fish population. Implementation of institutional controls would restrict access to Old Mormon Slough, thereby reducing human exposure to contaminated fish and sediment until concentrations in fish and sediment have been reduced to safe levels. Alternative SD-3 reduces the threat to groundwater from sediment in the OWP and CPA portions of the slough. The CDF would contain dewatered sediment above the water table and would be covered to prevent infiltration, thus reducing the threat to groundwater from the END portion of the site.

4.3.4 SD-4 - Dredging and Offsite Disposal Alternative

This alternative was developed to meet the RAOs by removing a preponderence of the PAH and dioxin contamination from the slough and transporting it for offsite disposal and/or treatment. Alternative SD-4 consists of the following technologies/process options:

- selective removal of heavily contaminated sediment via mechanical dredging
- use of a silt curtain to contain disturbed sediment within Old Mormon Slough
- dewatering of dredged sediment
- transportation and offsite disposal at a permitted TSD facility
- capping of residual contamination after dredging (CPA/END Cap only or Full Cap)
- institutional controls (e.g., access controls, deed restrictions) and monitoring.

A discussion of those components common to more than one alternative (i.e., institutional controls, capping, dredging, dewatering, silt curtain, and monitoring) was provided in Section 4.2.

A silt curtain would be erected across the mouth of Old Mormon Slough to prevent transport of sediment disturbed by dredging activities out of the slough. Mechanical dredging would be conducted to remove contaminated sediment from the principal threat areas of the slough, including a portion of the MTH sub-area and all of the OWP, CPA, and END sub-areas. Dredging would be conducted to a depth of 0.7 m (2.2 ft) in the principal threat area of the MTH and to 2.7 m (8.8 ft) (the maximum practical depth for dredging operations) throughout the rest of the slough. This depth incorporates a 10% overdig to ensure complete removal of the target contamination. The resulting volume of dredged sediment is estimated to account for 99.5% of the mass of the accessible (top 2.4 m [8 ft]) total PAH contamination and nearly 100% of the dioxin contamination (see Appendix B).

Dredging will remove an estimated 91,000 m^3 (119,000 yd^3) of contaminated sediment. With expansion during removal and handling (using a bulking factor of 20%) this would produce an estimated 109,000 m^3 (143,000 yd^3). The contaminated dredge material removed from the slough would be dewatered, reducing the volume by 20%, producing an estimated 91,000 m^3 (119,000 yd^3) of solids, and an estimated 21,800,000 L (5,760,000 gal) of wastewater. As described in Subsection 4.2.6, the recovered water would be processed through a series of cascading settling tanks and hydrocyclones to remove suspended solids prior to draining back into the slough, upstream of the silt curtain. For cost estimating purposes, it is assumed that most of the contamination would be associated with fine sediment particles and thus would be removed by filtering without additional treatment.

The dewatered sediment would be transported offsite to a TSDF for treatment, if necessary to comply with RCRA LDRs, and/or disposal. RCRA LDRs for listed wood preserving wastes F032, F034, and F035, which are the expected waste classifications for the Old Mormon Slough sediments, became effective in August 1997. Thus, selection of the actual disposal facility is dependent on the final waste designation(s) for these dewatered sediments and their applicable LDRs. Transportation would be either by truck or rail depending on the selection of the TSDF.

To estimate a range of costs for this alternative, two different offsite disposal options were examined, which depend on the TSDF selected and the area of the slough requiring capping after dredging. The lower cost option assumes that the waste would not be subject to LDRs requiring treatment prior to disposal. In this case it is assumed that the waste would be shipped via truck to a TSDF for direct disposal, and that only the CPA and END areas of the slough would require capping. For the higher cost option it is assumed that the waste would have to be incinerated prior to disposal in order to comply with LDRs and that the entire slough (CPA/END Cap plus OWP Cap) would need to be capped. In this case, it was assumed the sediment would be shipped to the TSDF for treatment and disposal (see Appendix C). Note that there currently is a variance from the treatment requirement for F032, F034, and F035 listed wastes, but not for D037 (PCP) characteristic waste. Until May 1999, dredged sediment classified as F032, F034, or F035 waste could be disposed offsite without treatment; after this time, the sediment would have to be treated first (by incineration for F032 and F034, and by stabilization for F035). However, even before May 1999, dredged sediment that exceeds the toxic characteristic leach procedure criterion for PCP (100 mg/L) would have to be incinerated before offsite disposal.

Following the completion of dredging activities and confirmatory sampling, a 420 m to 664 m (1380 ft to 2180 ft) section of Old Mormon Slough would be capped with natural materials (fine sand) to isolate residual contamination left behind by dredging activities. The portion of the slough to be capped would be dependent on confirmatory sampling in the OWP area and western end of the CPA area. If sampling confirms that total PAH concentrations in that portion of the slough are at or below the preliminary sediment cleanup levels no cap would be installed there. However, the relatively high concentrations of total PAH at depth in the eastern part of the CPA area and the END area indicate that these sections of the slough would require a cap after dredging. Thus, a CPA/END cap would be required while an additional OWP area cap may be required if dredging alone does not meet the RAOs.

The CPA/END cap (**Figure 4.3**) would cover an estimated 9,500 m^2 (102,000 ft^2), 2.3 acres of the slough. The OWP cap (if required) would cover an estimated 13,800 m^2

($149{,}000\ ft^2$), 3.4 acres. General information regarding the design and installation of the sediment caps is provided in Section 4.2.3. Detailed design assumptions for Alternative SD-4 are provided in **Table 4.7**.

As with Alternatives SD-2, SD-3, and SD-5, Alternative SD-4 would address the two “hot spots” located in the mouth of the slough, outside of the proposed dredge and cap areas, by the use of institutional controls rather than active remediation (see Subsection 4.2.1). Remediation would be limited to the use of institutional controls to limit navigational access to the slough, provide more fencing and warning signs to fully encompass the area(s) of principal and low-level threats, limit the future use of Old Mormon Slough and the upland portion of the site to appropriate uses, and control future dredging of the slough to prevent disturbance of residual sediment contamination in the mouth of the slough. Environmental monitoring would be conducted to assess the progress of natural attenuation processes for the hot spots.

Under Alternative SD-4, institutional controls would also be implemented for the capped portion of Old Mormon Slough to prevent inadvertent erosion or other disturbance of in situ sediment cap materials that would expose residual sediment contamination. Monitoring would be performed to assess the integrity and maintenance needs of the sediment cap.

Removal of the most heavily contaminated sediment from principal threat areas of the slough would reduce the mass of contamination available for exposure to and bioaccumulation in the aquatic organisms, including those species consumed by humans. Over time, this would lead to a reduction in the PAH and dioxin concentrations in the fish population. Implementation of institutional controls would restrict access to Old Mormon Slough, thereby reducing human exposure to contaminated fish and sediment until concentrations in fish have been reduced to safe levels. Alternative SD-4 reduces the threat to groundwater from sediment in the END, CPA, and OWP portions of the slough.

4.3.5 SD-5 - Dredging and Onsite Treatment

This alternative was developed to meet the RAOs by removing a preponderence of the PAH- and dioxin-contaminated sediment from the slough and treating it onsite. Alternative SD-5 consists of the following technologies/process options:

- selective removal of heavily contaminated sediment via mechanical dredging
- use of silt curtain to contain disturbed sediment within Old Mormon Slough
- dewatering of dredged sediment
- onsite ex situ treatment of dewatered sediment by solvent extraction
- onsite ex situ S/S of treated sediment as necessary prior to upland disposal
- capping of residual contamination after dredging (CPA/END Cap only or Full Cap)
- institutional controls (e.g., access controls, deed restrictions) and monitoring.

Elements of this alternative common to the other sediment alternatives (i.e., institutional controls, capping, dredging, dewatering, silt curtain, and monitoring) were described in Section 4.2.

Dredging would be conducted from just north of the OWP area to the END of the slough (**Figure 4.4**). This portion of the slough contains nearly all of the PAH and dioxin concentrations exceeding the preliminary sediment cleanup levels. A silt curtain would be erected across the mouth of the slough prior to dredging to contain any resuspended sediment. Mechanical dredging would be conducted along a 710 m (2330 ft) long portion of the slough. This would include the top 0.7 m (2.2 ft) from the OWP area and the top 2.7 m (8.8 ft) (maximum practical depth plus 10% overdig) from the OWP, CPA, and END of the slough. This volume of sediment would account for an estimated 99.5% of the accessible (<=2.4 m [<=8 ft]) mass of total PAH contamination and approximately 100% of the mass of PCDD/PCDF contamination. Dredging would produce an estimated 109,000 m^3 (143,000 yd^3) of contaminated sediment (assuming a 20% bulking factor). This material would be dewatered, producing an estimated 91,000 m^3 (119,000 yd^3) of solids and 21,800 L (5,760,000 gal) of waste water. As described in Subsection 4.2.6, the recovered waste water will be processed through a series of cascading settling tanks and hydrocyclones to remove suspended solids prior to draining back into the slough, upstream of the silt curtain. For cost estimating purposes, it was assumed that most of the contamination would be associated with fine sediment particles and thus would be removed by filtering without additional treatment.

The dewatered dredge materials would be treated onsite by ex situ solvent extraction to address PAHs and dioxin, followed by S/S to address inorganic contamination as necessary. Offsite incineration/disposal of the concentrated organic contaminants from the solvent extraction process has also been factored into the cost estimates for this alternative (see Appendix C). Solidified residuals from this treatment train are expected be disposed onsite, assuming sufficient upland capacity is available. The actual throughput and residual volumes generated will be determined in pilot-scale testing during the remedial design phase.

The selection of the final onsite treatment technology/process option for the dewatered sediments would likely be the same as that for the treatment of contaminated soils. Treatability tests conducted on site soils indicate that solvent extraction can be greater than 95% effective in reducing the concentration of dioxin, and greater than 67 to 98.9% effective in reducing PAH concentrations (see Subsections 3.1.3.2 and 3.2.6.3).

Following the completion of dredging activities and confirmatory sampling, a 420 m to 664 m (1380 ft to 2180 ft)-long stretch of Old Mormon Slough would be capped with natural materials (fine sand) to isolate any residual contamination that may be left behind by dredging activities. The portion of the slough to be capped would be dependent on confirmatory sampling in the OWP and western end of the CPA. If sampling confirms that total PAH concentrations in this portion of the slough are at or below the preliminary sediment cleanup levels, no cap will be installed there. However, the relatively high concentrations of total PAH at depth in the eastern portion of the CPA and END indicates that these portions of the slough would require a cap after dredging. Thus, a CPA/END cap would be required while an OWP area cap may be required if dredging alone does not meet the RAOs.

The CPA/END cap would run from the END to the western end of the CPA area (see Figure 4.4). The cap would cover an estimated 9500 m^2 (102,000 ft^2), or 2.3 acres of the slough.

The OWP area cap, if required, would run from the CPA/END cap to the west end of the OWP area. This cap would cover an estimated 13,800 m^2 (149,000 ft^2), or 3.4 acres. General information regarding the design and installation of the sediment caps was provided in Subsection 4.2.3. Detailed design assumptions for this alternative are provided in **Table 4.8**. Costs were estimated for both Alternative SD-5 capping scenarios (CPA/END Cap only or Full Cap).

As with Alternatives SD-2, SD-3, and SD-4, Alternative SD-5 would address the two “hot spots” located in the mouth of the slough, outside of the proposed dredge and cap areas, by the use of institutional controls rather than active remediation (see Subsection 4.2.1). Remediation would be limited to the use of institutional controls to limit navigational access to the slough, provide more fencing and warning signs to fully encompass the area(s) of principal and low-level threats, limit future use of Old Mormon Slough and the upland portion of the site to appropriate uses, and control future dredging of the slough to prevent disturbance of residual sediment contamination in the mouth of the slough. Environmental monitoring would be conducted to assess the progress of natural attenuation processes for the hot spots.

Under Alternative SD-5, institutional controls would also be implemented for the capped portion of Old Mormon Slough to prevent inadvertent erosion or other disturbance of in situ sediment cap materials that would expose residual sediment contamination. Monitoring would be performed to assess the integrity and maintenance needs of the sediment cap.

Removal of the most heavily contaminated sediment from principal threat areas of the slough would reduce the mass of contamination available for exposure to and bioaccumulation in aquatic organisms, including those species consumed by humans. Over time, this would lead to a reduction in the PAH and dioxin concentrations in the fish population. Implementation of institutional controls would restrict access to Old Mormon Slough, thereby reducing human exposure to contaminated fish and sediment until concentrations in fish and sediment have been reduced to safe levels. Alternative SD-5 reduces the threat to groundwater from sediment in the END, CPA, and OWP portions of the slough.

Figure 4.1. Alternative SD-2, In Situ Capping

Figure 4.2. Alternative SD-3, Dredging and Confined Disposal

Figure 4.3. Alternative SD-4, Dredge and Offsite Disposal

Figure 4.4. Alternative SD-5, Dredging and Onsite Treatment

Table 4.1. Conceptual Monitoring Program

Medium/Monitoring Activity	Parameters	Analytical Methods	Estimated Frequency
Short-Term Monitoring (During Construction/Active Remediation)			
Sediment Grab Sampling	PAHs, dioxin	Field Screening and Confirmatory Laboratory Analyses	Daily/Periodically During Remediation
Depth Soundings	Depth/Surface Topography	Bathymetry	Periodically During Remediation
Water Quality	DO, BOD, COD, turbidity, TDS, PAHs, PCP, indicator metals	Laboratory Analyses	Periodically During Remediation
Long-Term Monitoring (30-year post-remediation period)			
Sediment Core Sampling	PAHs, dioxin, PCP, metals	Field Screening and Confirmatory Laboratory Analyses	Annually
Depth Soundings	Depth/Surface Topography	Bathymetry	Annually
Water Quality	DO, BOD, COD, turbidity, TDS, PAHs, PCP, indicator metals	Laboratory Analyses	Annually
Bioassays and Bioaccumulation Studies	PAHs, dioxin	Laboratory Analyses, State Mussel Watch Program Procedures	Annually to Every 5 Years

Table 4.2. Sediment Cap Design Assumptions

Cap Placement Method	Barge-mounted conveyor and downpipe
Cap Materials	Locally quarried clean, fine sand; armored with a gravel filter bed and rip-rap where necessary
Cap Thickness	0.6 m (2 ft) minimum
Material Volume Safety Factor	10%

Table 4.3. Design Assumptions for Sediment Dredging

Dredging Area	
Dredging method	Mechanical: Derrick barge with cable arm clamshell (or similar) bucket
Dredging rate (per 8 hr shift)	1530 m^3 (2000 cy)
Dredging depth (assuming 10% overdig)	0.7 to 2.7 m (2.2 to 8.8 ft)
Bulking/expansion factor for dredged volumes	20%

Table 4.4. Design Assumptions for Sediment Dewatering

<u>Holding/Dewatering Cells</u>	
Number/Capacity	5 @ 1530 m^3 (2000 cy)
Dimensions	40 m x 40 m (135 x 135 ft)
Initial Solids/Liquid Ratio of Sediment	50:50 by weight
Holding Time	5 to 7 days
Intermediate Solids/Liquid Ratio	60:40
<u>Belt Filter Press</u>	
Typical Capacity (2 m belt)*	18 to 23 m^3/h (24 to 30 cy/h)
Required Capacity	77 m^3/h (100 cy/h)
Required Number of Units	4
Operation	24 h/day
Maintenance/Downtime	20%
Final Solids/Liquid Ratio (by weight)	70:30 by weight
Estimated Water Removed	200 L/m^3 (40 gal/cy); 2260 L/min (67 gpm)

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*After EPA (1994).

Table 4.5. Design Assumptions for the In Situ Capping Alternative

Cap Placement	3/4 of the slough; OWP, CPA, END sections
Length	710 m (2330 ft)
Width	37 to 55 m (120 to 180 ft)
Cap Area	3.6 ha (8.8 ac); 35,600 m^2 (383,000 ft^2)
Cap Material	Locally quarried clean fine sand; armored with rip-rap and gravel filter layer (where necessary)
Cap Thickness	0.6 m (2 ft) minimum
Volume of Cap Materials*	23,900 m^3 (32,200 yd^3)

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*Assumes a 10% Safety Factor.

Table 4.6. Design Assumptions for Selective Dredging and Confined Disposal Alternative

<u>Dredging Area</u>	
Length	406 m (1340 ft)
Width	46 to 61 m (150 to 200 ft)
Area	2.2 ha (5.5 ac); 22,300 m^2 (240,000 ft^2)
Dredging Depth (includes 10% overdig)	0.7 to 2.7 m (2.2 to 8.8 ft)
Volume Removed	55,400 m^3 (72,500 yd^3)
Volume Produced (includes 20% bulking/safety factor)	66,500 m^3 (87,000 yd^3)
<u>Confined Disposal Facility</u>	
Length	293 m (960 ft)
Width	37 to 67 m (120 to 220 ft)
Area	1.4 ha (3.4 ac); 13,600 m^2 (146,000 ft^2)
Available Capacity	74,300 m^3 (97,200 yd^3)
<u>Confined Disposal Cap</u>	
Cap Material	Locally quarried native materials (sand, silt, and clay); geotextile fabric
Thickness	0.6 m (2 ft)
Volume of Cap Materials (assuming 3:1 side slopes)	12,500 m^3 (16,400 yd^3)
<u>In Situ Cap</u>	
Length	CPA: 150 m (480 ft) OWP: 390 m (1280 ft)
Width	CPA: 46 to 55 m (150 to 180 ft) OWP: 49 to 61 m (160 to 200 ft)
Area	CPA: 0.6 ha (1.6 ac) OWP: 1.4 ha (3.4 ac)
Cap Material	Locally quarried fine sand; rock armoring where needed
Thickness	0.6 m (2 ft)
Volume of Cap Materials (assuming 3:1 side slopes)	12,500 m^3 (16,400 yd^3)

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*After EPA (1994).

Table 4.7. Design Assumptions for Selective Dredging and Offsite Disposal Alternative

Dredging Area	
Length	710 m (2330 ft)
Width	37 to 55 m (120 to 180 ft)
Area	3.6 ha (8.8 ac); 35,600 m^2 (383,000 ft^2)
Dredging Depth (includes 10% overdig)	0.7 to 2.7 m (2.2 to 8.8 ft)
Volume Removed	91,000 m^3 (119,000 yd^3)
Volume Produced (includes 20% bulking/safety factor)	109,000 m^3 (143,000 yd^3)
Sediment Dewatering	
Volume of Wastewater Generated	21,800,000 L (5,760,000 gal)
Volume of "Dry" Dredge Material	91,000 m^3 (119,000 yd^3)
Final Moisture Content	30% by weight
Transportation and Disposal	
Shipping Distance	257 to 2250 km (160 to 1400 miles)
Disposal/Incineration Costs	\$78 to 6590/m^3 (\$60 to 5000/yd^3)
In Situ Cap	
Length	CPA/END: 420 m (1380 ft) OWP: 244 m (800 ft)
Width	CPA/END: 37 to 55 m (120 to 180 ft) OWP: 49 to 61 m (160 to 200 ft)
Area	CPA/END: 1 ha (2.3 ac) OWP: 1.4 ha (3.4 ac)
Cap Material	Locally quarried fine sand; rock armoring where needed
Thickness	0.6 m (2 ft)
Volume of Cap Materials (includes a 10% safety factor)	CPA/END: 6370 m^3 (8340 yd^3) OWP: 9300 m^3 (12,100 yd^3)

Table 4.8. Design Assumptions for Selective Dredging and Onsite Treatment Alternative

Dredging Area	
Length	710 m (2330 ft)
Width	37 to 55 m (120 to 180 ft)
Area	3.6 ha (8.8 ac); 35,600 m^2 (383,000 ft^2)
Dredging Depth (includes 10% overdig)	0.7 to 2.7 m (2.2 to 8.8 ft)
Volume Removed	91,000 m^3 (119,000 yd^3)
Volume Produced (includes 20% bulking/safety factor)	109,000 m^3 (143,000 yd^3)
Sediment Dewatering	
Volume of Wastewater Generated	21,800,000 L (5,760,000 gal)
Volume of "Dry" Dredge Material	91,000 m^3 (119,000 yd^3)
Final Moisture Content	30% by weight
Solvent Extraction	
Residuals/Assumed Treatment (volumes to be determined):	
- Solid Residues - Concentrated Contaminants	Solidification/Stabilization Incineration
In Situ Cap	
Length	CPA/END: 420 m (1380 ft) OWP: 244 m (800 ft)
Width	CPA/END: 37 to 55 m (120 to 180 ft) OWP: 49 to 61 m (160 to 200 ft)
Area	CPA/END: 1 ha (2.3 ac) OWP: 1.4 ha (3.4 ac)
Cap Material	Locally quarried fine sand; rock armoring where needed
Thickness	0.6 m (2 ft)
Volume of Cap Materials (includes a 10% safety factor)	CPA/END: 6370 m^3 (8340 yd^3) OWP: 9300 m^3 (12,100 yd^3)

5.0 DETAILED ANALYSIS OF ALTERNATIVES

In this section, the sediment remedial alternatives from Section 4.0 are evaluated in detail against the nine NCP criteria consistent with RI/FS guidance (EPA 1988a). The detailed evaluation is performed in two stages. In the first stage, the remedial alternatives are evaluated against the NCP criteria individually. The second stage is the comparative analysis in which the alternatives are evaluated relative to each other using the same criteria.

The following subsections present a description of the nine NCP criteria followed by the individual and comparative analysis of the sediment remedial alternatives.

5.1 EVALUATION CRITERIA

The NCP, 40 CFR Section 300.430(e)(9)(iii) sets forth nine criteria to be used for a detailed, comparative analysis of the alternatives retained after the initial screening portion of the FS. These criteria are further described in the EPA FS guidance.

The first two criteria are categorized as “threshold” criteria in that each alternative must meet them or, in the case of ARARs, any ARARs not met must be waived. The subsequent five criteria are “primary balancing” factors. The last two criteria address “modifying” considerations. The following nine subsections describe each of the nine criteria.

5.1.1 Overall Protection of Human Health and the Environment

Each alternative must be assessed to determine whether it can adequately protect human health and the environment, in both the short and the long term, from hazardous substances, pollutants, or contaminants present at the site by eliminating, reducing, or controlling exposures to levels established during the development of remediation goals. The evaluation of the overall protection of human health and the environment for each alternative draws upon the factors assessed under other evaluation criteria. The criteria specifically considered are long-term effectiveness and permanence, short-term effectiveness, and compliance with ARARs.

5.1.2 Compliance with ARARs

Each alternative must be evaluated to determine whether it complies with all ARARs. ARARs are those cleanup standards, standards of control, or other substantive environmental protection requirements promulgated under federal environmental or more stringent state or state subdivision environmental or facility siting laws that have been identified by the state in a timely manner. Because California may give enforcement authority for delegated federal programs to local agencies that develop implementing regulations, some apparently local regulations can also be ARARs. Pursuant to CERCLA §121 and the NCP, only substantive, not administrative, requirements are ARARs and permits are not required for those portions of a CERCLA cleanup that are conducted entirely onsite, as long as those actions are selected and carried out in compliance with CERCLA §121.

“Applicable” requirements are those substantive environmental requirements that specifically address a hazardous substance, pollutant, contaminant, remedial action, or other circumstance found at a CERCLA site. “Relevant and appropriate” requirements are such standards that, while not applicable, address problems or situations sufficiently similar to those encountered at the site that their use is well suited.

ARARs are generally categorized as follows: 1) chemical-specific requirements, 2) action-specific requirements, and 3) location-specific requirements.

Chemical-specific ARARs are risk-based cleanup standards or methodologies that, when applied to site-specific conditions, result in the development of numerical cleanup standards for COCs. These standards must be achieved at the completion of the remedial action. Since no numerically set standards exist for sediments under federal or state law, risk-based cleanup standards for sediments have been developed for the M&B site. These were discussed in detail in Section 2.0.

Location-specific ARARs are restrictions placed on the concentration of hazardous substances or the conduct of activities at a site due to its special location, such as an area with important geographical, biological, or cultural features. Examples of special locations include wetlands, flood plains, sensitive ecosystems, and seismically active areas. Location-specific ARARs are summarized in **Table 5.1** and described below. Both location-specific and action-specific ARARs must be complied with during the design and implementation of the remedy as well as at the completion of the remedy.

Action-specific ARARs are technology-based or activity-based requirements or limitations on actions taken to handle hazardous substances. They are triggered by the particular remedial activities selected to accomplish a remedy. Consideration of a sediment capping, dredging, filling or onsite treatment, and/or disposal remedy trigger a number of action-specific ARARs that govern design, construction, and operation and maintenance of the remedy. These ARARs are summarized in Table 5.1 and described below.

When no ARAR exists for a given chemical, action, or location, EPA may consider non-promulgated federal or state advisories and guidance as TBC criteria. Although consideration of a TBC is not required, if standards are selected based on TBCs, those standards are legally enforceable as if the TBC were an ARAR. The preliminary sediment cleanup standards are based on a TBC, which in turn was developed using risk-based considerations.

ARARs compliance is one of the nine CERCLA evaluation criteria that are considered “threshold criteria” (i.e., they must be met unless they are waived). CERCLA Section 121(d)(4) allows for limited ARARs waivers where an ARAR cannot be met. A waiver is available where it is determined that it is “technically impracticable from an engineering perspective” to attain required cleanup standards. Where such a determination has been made, EPA must establish alternative, protective remedial strategies.

None of the alternatives being considered in this FS report would ensure compliance with the preliminary chemical-specific ARARs applicable to the groundwater underlying the site, including the groundwater beneath Old Mormon Slough. These ARARs were identified in the FS report prepared for the Soils-Groundwater OU (ICF 1997). The Evaluation of Technical Impracticability (TI Evaluation), included as part of the FS report, concludes that it would be technically impracticable to remediate M&B site groundwater impacted by DNAPLs to these ARARs.

5.1.3 Long-Term Effectiveness and Permanence

The evaluation of a remedial alternative relative to its long-term effectiveness and permanence is made considering the risks remaining at the site after the response objectives have been met and the degree of certainty that the alternative will prove successful. The assessment of long-term effectiveness is made considering the following three major factors:

- the magnitude of the residual risk to human and environmental receptors remaining from untreated waste or treatment residuals remaining at the completion of remedial activities

- an assessment of the type, degree, and adequacy of long-term management (including engineering controls, institutional controls, monitoring, and operation and maintenance) required for untreated waste or treatment residues remaining at the site

- the potential need for replacement of the remedy and the continuing need for repairs to maintain the performance of the remedy.

5.1.4 Reduction of Toxicity, Mobility, or Volume (T/M/V) Through Treatment

This evaluation criterion addresses the degree to which remedial actions employ treatment technologies that permanently and significantly reduce the T/M/V of hazardous substances at the site. The evaluation considers the following specific factors:

- the treatment processes

- the amount of hazardous substances, pollutants, or contaminants that will be destroyed, treated, or recycled

- the degree of expected reduction in T/M/V due to treatment, including the degree to which treatment reduces the inherent hazards posed by the principal threats at the site

- the degree to which the treatment will be irreversible

- the type and quantity of treatment residuals that will remain following treatment.

5.1.5 Short-Term Effectiveness

The short-term effectiveness of a remedial alternative is evaluated relative to its effect on human health and the environment during implementation of the remedial action. The short-term effectiveness assessment is based on four key factors

- short-term risks that might be posed to the community during implementation of an alternative
- potential impacts on workers during remedial action and the effectiveness and reliability of protective measures
- potential environmental impacts of the remedial action and the effectiveness and reliability of mitigative measures during implementation
- time until protection is achieved.

5.1.6 Implementability

Remedial alternatives must be evaluated to estimate the degree to which each can satisfy implementability criteria. Implementability refers to the ease or difficulty of implementing an alternative considering the following factors, as appropriate:

- technical feasibility, including technical difficulties and unknowns associated with the construction and operation of a technology, the reliability of the technology, the ease of undertaking additional remedial actions, and the ability to monitor the effectiveness of the remedy
- administrative feasibility, including activities needed to coordinate with other offices and agencies and the ability and time required to obtain any necessary approvals and permits from other agencies (for offsite actions)
- availability of services and materials, including the availability of adequate offsite TSD capacity and services; the availability of necessary equipment and specialists and provisions to ensure any necessary additional resources; the availability of services and materials; and availability of prospective technologies.

5.1.7 Cost

For each remedial alternative, a detailed cost estimate is developed. Cost estimates for each alternative are based on conceptual engineering data, unit costs available from EPA guidance documents when available, costs developed based on treatability tests, other literature available, vendor quotes, and PNNL experience. The detailed cost estimates are presented in Appendix C. The cost estimate for a remedial alternative consists of three principal elements

- Capital Costs: Capital costs consist of direct (construction) and indirect (non-construction and overhead) costs. Direct costs include the cost for equipment, labor, and materials incurred to develop, construct, and implement a remedial action. Indirect costs are expenditures for engineering, financial, and other services that are not actually a part of construction but are required to implement a remedial alternative.

- Annual Operating and Monitoring (O&M) Costs: O&M costs refer to post-construction cost items necessary to ensure the continued effectiveness of a remedial action. This typically consists of long-term power and material costs (primarily applicable to the operational costs of a water treatment facility), equipment replacement costs, and long-term O&M costs.

- Present Worth Analysis: This analysis is used to evaluate the capital and O&M costs of a remedial alternative on a present worth basis. Present worth analysis is a method of comparing expenditures for various alternatives that occur over different time periods. By discounting all costs to a common base year, the costs for different remedial action alternatives can be compared on the basis of a single cost figure for each alternative. The total present worth for a given alternative is equal to the full amount of all capital and initial costs plus the series of expenditures in following years reduced by the appropriate future value/present worth discount factor. This analysis allows the comparison of remedial alternatives on the basis of a single cost representing an amount that, if invested in the base year and disbursed as needed, would be sufficient to cover all costs associated with the remedial action over its planned life.

As specified in the FS guidance, a 30-year performance period is assumed for all alternatives. For the sediment alternatives, the remedial alternatives would be implemented in a shorter time period, but cost estimates for institutional controls and maintenance activities will continue for 30 years. For cost comparison purposes, the cost of the institutional controls, including long-term monitoring, is calculated for a performance period of 30 years.

A discount rate of 5% is assumed for base calculations consistent with the RI/FS guidance. The discount rate represents the anticipated difference between the rate of inflation and investment return. The alternatives have been developed conceptually in this FS and the cost estimates are intended to reflect the actual cost of the remedial alternative to within -30 to +50 percent.

5.1.8 State Acceptance

This criterion evaluates the state’s position and key concerns related to the alternatives and state comments on ARARs as the proposed use of waivers. The assessment of state concerns may not be completed until comments on the RI/FS are received.

5.1.9 Community Acceptance

This criterion evaluates the issues/concerns raised by the public regarding each of the alternatives being considered. This assessment will not be completed until comments on the proposed plans are received. Comments may be submitted during the public comment period.

5.2 COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

This section identifies potential ARARs for the sediment alternatives. Because a remedy for the M&B site has not yet been selected, all ARARs identified in this FS report are preliminary. Final determinations of the ARARs will be included as appropriate in the ROD.

5.2.1 Action-Specific Applicable or Relevant and Appropriate Requirements

Action-specific ARARs are primarily concerned with those activities that can have a detrimental effect on navigable water ways and/or wetlands, such as dredging, filling, installation of pilings construction of dams and piers, and/or point source discharges.

5.2.1.1 Rivers and Harbors Act (33 USC, §403, Section 10)

The Rivers and Harbors Act (RHA) prohibits the unauthorized obstruction or alteration of any navigable water of the United States. Section 10 of the RHA regulates structures or work in, above, or under navigable waters. Navigable waters of the United States are defined as waters that are subject to the ebb and flow of the tide shoreward to the mean high water mark and/or are presently used, or have been used in the past or may be susceptible to use, to transport interstate or foreign commerce; Old Mormon Slough falls within the definition of a navigable water. Examples of regulated activities would include dredging, filling, installation of pilings, and construction of dams and piers. At non-CERCLA sites, the U.S. ACE is responsible for reviewing and approving applications for permits to conduct such activities. The standard of review for such applications generally may be described as an inquiry into whether the proposed action provides a benefit to the public. The procedures set forth in 33 CFR Parts 320 and 322 require an examination into the impact on the public interest.

Remedial alternative activities under consideration for the M&B site, that may be considered dredge and fill activities under Section 10 of the RHA, include capping (Alternative SD-2, SD-3, SD-4, and SD-5), backfilling (Alternative SD-3), installation of vertical barriers (Alternative SD-3), installation of silt curtains (Alternatives SD-3, SD-4, and SD-5), dredging (Alternatives SD-3, SD-4, and SD-5), dewatering (Alternatives SD-3, SD-4, and SD-5), and construction of a nearshore CDF in OMS (Alternative SD-3). The in situ capping alternative (SD-2) assumes that a permanent sand cap will be placed over most of the bottom area of Old Mormon Slough, with the exception of the mouth of the slough. In addition, the dredging alternatives (SD-3, SD-4, and SD-5) consider limited capping as a component of the alternative to address residual deep sediment contamination that is not technically feasible to remove from the slough, thus, the RHA would also apply to this limited capping (if a temporary dam was constructed to dewater Old Mormon Slough and excavate sediment as an alternative to mechanical dredging in the slough, the RHA would apply to that option also).

The RHA is also a location-specific ARAR.

5.2.1.2 Clean Water Act (33 USC §1344, Section 404)

Section 404 of the CWA regulates the discharge of dredged or fill material to all waters of the United States, including wetlands. While Section 404 would not regulate proposed dredging activities in Old Mormon Slough, Section 404(b)(1) and the regulations promulgated thereunder, 40 CFR 230.10, would regulate the placement of dredged or fill materials in Old Mormon Slough. At non-CERCLA sites, U.S. ACE is responsible for reviewing and approving applications for permits to conduct such activities; EPA also reviews Section 404 permits. The substantive requirements of Section 404 regulations are potential action-specific ARARs.

Proposed sediment remedial alternative activities that would constitute discharge for the purposes of the Section 404 regulations include capping (Alternatives SD-2, SD-3, SD-4, and SD-5, since they all involve sediment capping to some degree), backfilling (Alternative SD-3), installation of vertical barriers (Alternative SD-3), installation of silt curtains (Alternatives SD-3, SD-4, and SD-5), dredging (Alternatives SD-3, SD-4, and SD-5), dewatering (Alternatives SD-3, SD-4, and SD-5), and construction of a nearshore confined disposal facility in OMS (Alternative SD-3).

The guiding principle of Section 404 regulations is that degradation or destruction of wetlands and other special aquatic sites should be avoided to the extent possible. EPA has developed the following guidelines for CERCLA response actions involving wetlands that have already been severely degraded by virtue of prior discharges of waste (EPA 1988b):

> While part of the CERCLA remedy may be to fill in the wetland, the remedy would contemplate that the fill will serve an environmental benefit. Where the functioning of the wetland has already been significantly and irreparably degraded, mitigation would be oriented towards minimizing further adverse environmental impacts, rather than attempting to recreate the wetland's original value onsite or offsite.

Thus, the EPA guidance specifies that the remedial action plan may include filling of a wetland. That regulation provides that no discharge of dredged or fill material shall be permitted if there is a practicable alternative to the proposed discharge that would have less adverse impact on the aquatic ecosystem, so long as the alternative does not have other significant adverse environmental consequences. EPA believes that this rationale as applied to wetlands in many instances would also apply to other navigable waters, such as Old Mormon Slough. Therefore, Section 404 would be relevant and appropriate to proposed remedies involving discharge of dredged or filled material.

5.2.1.3 National Pollutant Discharge Elimination System Regulating Discharge of Pollutants to Surface Water

The substantive requirements of an NPDES permit are applicable to point source discharges such as those from a treatment system with an outfall to surface waters. The RWQCB issues WDRs where discharged waste could affect the quality of waters of the State. The WDRs typically include effluent discharge limitations and monitoring requirements based on Water Quality Standards set forth in the RWQCB's Basin Plan.

5.2.1.4 Resource Conservation and Recovery Act (as amended, 42 USC §6921 et seq.)

Action-specific ARARs relating to the TSD of hazardous wastes are applicable to dredged sediments containing hazardous wastes. All dredging of hazardous media undertaken in connection with the sediment remedy must comply with all applicable or relevant and appropriate RCRA requirements for the management of hazardous wastes. Sediments associated with the M&B site, in addition to containing characteristic hazardous wastes, contain wood treater listed wastes F032, F034, and/or F035. The RCRA LDRs for these listed wastes became effective on August 11, 1997, and would apply as of its effective date to the "placement" of these listed hazardous wastes on land (62 Fed. Reg. 25998; May 12, 1997).

Ex situ treatment activities that would trigger the RCRA requirements listed in Table 5.1 are solvent extraction (Alternative SD-5) and treatment of contaminated water from dewatering (Alternatives SD-3, SD-4, and SD-5). Where the treatment or handling of sediments is similar to that for the upland soils remediation, the potential action-specific ARARs identified in the Soil-Groundwater FS report would govern such activities. RCRA requirements may also be triggered by onsite or offsite land disposal of treated sediment or treatment residuals (Alternatives SD-4 and SD-5).

In addition, contaminated sediment shipped offsite must meet all applicable RCRA and U.S. Department of Transportation (DOT) requirements for offsite shipment, treatment, and disposal.

5.2.1.5 SJVUAPCD Requirements for Potential Air Emissions from Sediment Alternatives

Air emissions from any onsite treatment system, excavation and/or transport of sediment, and/or construction activities may trigger the air emissions ARARs set forth in Table 5.1.

The Clean Air Act (CAA) regulates air emissions by controlling stationary and mobile sources through combined federal, state and local programs. Pursuant to the CAA, EPA promulgated National Ambient Air Quality Standards (NAAQS) and New Source Performance Standards, each of which may apply to a source depending on the pollutant involved. NAAQSs are implemented through State Implementation Plans (SIPs). Upon EPA approval, the SIP requirements become federal ARARs.

EPA has promulgated primary and secondary standards in the NAAQS, 40 CFR Part 50, for six criteria pollutants, including particulate matter equal to or less than 10 microns in particle size (PM10), and ozone that results from the photo-chemical oxidation of VOCs.

In general, only "major sources," considering all sources of emissions at the site, are subject to NAAQS requirements. Stockton has been designated as a non-attainment area for PM10 and ozone NAAQS. In attainment areas, activities at a site will only be considered a major source if all of the activities are expected to emit 250 tons or more per year of regulated pollutant. If applicable, the source must use Best Available Control Technology (BACT).

As EPA has approved the State of California's SIP, the San Joaquin Valley Unified Air Pollution Control District requirements set forth in Table 5.1 are federal ARARs for remediation activities at the site.

5.2.2 Location-Specific Applicable or Relevant and Appropriate Requirements

Location-specific ARARs are restrictions that are considered solely because of specific setting characteristics. Potential location-specific ARARs, such as requirements found in 40 CFR 264.18 (a) and (b) regarding siting of hazardous waste facilities, the ESA, the Executive Order on Protection of Wetlands, and the Archeological and Historic Preservation Act were considered.

Both the upland and Old Mormon Slough areas of the M&B site were evaluated for unique site features, including requirements regarding floodplains, active earthquake fault zones, wetlands, endangered species habitat, and historically or culturally significant properties. While the slough portion of the site would be affected by actions related to capping, dredging and the CDF, the upland portion of the site would also be affected by construction and operation of dewatering and/or solvent extraction treatment units, by S/S activities, by activities related to the offsite transport of sediment, and/or by onsite land disposal. Unique characteristics of Old Mormon Slough and other surface water bodies in the area include wetlands habitat and endangered species.

Designed to conserve species of fish, wildlife, and plants designated as threatened, the ESA of 1973, 16 USC §§1531, et seq., is a potential location-specific ARAR at the M&B site. The ESA provides for the designation of critical habitats that are "specific areas within the geographical area occupied by the endangered or threatened species on which are found those physical or biological features essential to the conservation of the species..."

Substantive compliance with the ESA means that the lead agency must identify whether a threatened or endangered species, or its critical habitat, will be affected by a proposed response action. If so, the lead agency must avoid the action or take appropriate mitigation measures so that the action does not affect the species or its critical habitat. If the lead agency determines that endangered species are not present or will not be affected, no further action is required. Based on the findings of the ERA conducted for the M&B site, no threatened or endangered terrestrial species and no sensitive terrestrial habitats have been identified in Old Mormon Slough or in the vicinity of the M&B site. No federal endangered or threatened species have been found to utilize aquatic habitats at the site; however, delta smelt, a state threatened species, may be found in waters near the site.

The Archeological and Historic Preservation Act provides for the preservation of historical and archeological data that might otherwise be lost as a result of dam construction or alterations of the terrain. If any federal project might cause loss to significant scientific, prehistorical, or archeological data the act requires the lead agency to preserve the data or request the Department of Interior to do so. Old Mormon Slough and the SDC are man-made channels that were constructed within this century by dredging. No prehistoric or archeological artifacts are expected in any of these deposits and none were noted in any of the sampling that was conducted for the RI.

The only characteristic that would trigger location-specific ARARs related to the upland portion of the site is that it is located in a 100 year floodplain.

5.3 INDIVIDUAL ANALYSIS OF ALTERNATIVES

This section presents an individual analysis of the five remedial alternatives for Old Mormon Slough sediments that were developed in Section 4.0. The alternatives are evaluated in detail against the two threshold and five primary criteria. An evaluation relative to the two modifying criteria will be presented in the ROD following receipt and review of public and state agency comments on the FS report and proposed plan. A brief description of the alternative and key points of the individual analysis are discussed below.

5.3.1 SD-1 - No-Action Alternative

The No-Action alternative provides a baseline for comparison with other alternatives. No active remedial measures would be implemented and, thus, no reduction in human health and environmental risk would occur.

Operations at the M&B site ended approximately eight years ago. The primary sediment COCs (PAHs and dioxin) are high molecular weight organic compounds with low solubility and high sorption partitioning coefficients and, thus, are generally not very mobile except through resuspension of sediments. Old Mormon Slough is an area of net sediment deposition where natural resuspension of sediment due to large tidal currents is not a major concern (assuming no disturbance and resuspension due to boat prop wash). This natural deposition of uncontaminated sediment can, over time, isolate contaminated sediment from the water column, reducing the bioavailability of the contaminants. This isolation can also reduce the natural biodegradation of these compounds by limiting the exchange of oxygen and other critical nutrients.

Natural attenuation of PAHs is evaluated in Appendix A. The appendix provides calculations estimating the potential for using natural attenuation as a stand-alone remedy. Results indicate that the time to degrade total PAHs (from an initial concentration of 1000 mg/kg to a cleanup level of 10 mg/kg) to a depth of 3 feet in the sediment would be 3,350 years. Using an initial total PAH concentration of 50 mg/kg, the cleanup time is reduced to 135 years. Consequently, it appears that, without outside assistance, oxygen limitations are too great for natural attenuation to treat the Old Mormon Slough sediment in a reasonable period of time. In addition, no calculations were attempted for dioxin, which is more persistent in the environment than the PAHs. Thus, the COCs are expected to persist for an indefinite period, and would continue to threaten fish and benthic fauna (particularly from PAH contamination) as well as human health through the ingestion of contaminated fish. Thus, the risks to human health and the environment are assumed to remain essentially the same as those identified in the baseline human health risk assessment (ICF 1996) and ecological risk assessment (Thom et al. 1997). Natural attenuation (No-Action) is inappropriate as a stand-alone alternative for the majority of Old Mormon Slough contamination. However, as previously discussed, natural attenuation (i.e., the use of institutional controls alone) for those portions of the slough that contain only a few isolated areas of contamination or areas of low concentrations of COCs may provide sufficient protection of human health and the environment.

An assessment of this alternative against the evaluation criteria follows.

Overall Protection of Human Health and the Environment

The No-Action Alternative provides no reduction in human and/or ecological exposure to, or toxicity of, the contaminated sediment and fish in the area. It also could potentially allow migration of the contaminants from sediment to groundwater through recharge, which could contribute to the degradation of the groundwater in addition to that from upland soils. However, as noted earlier, the sediments in Old Mormon Slough are not considered a significant source to groundwater contamination. Thus, this alternative is not protective of human health and the environment.

Compliance with Applicable or Relevant and Appropriate Requirements

Because No-Action is being taken, this alternative would not reduce the sediment contaminant concentrations to levels considered protective of human health and the environment and would not meet ARARs.

Long-Term Effectiveness and Permanence

This alternative would not remove contamination sources and so would not provide any source controls or exposure controls. All current and future risks would remain essentially unchanged for hundreds or thousands of years.

Reduction of T/M/V Through Treatment

This alternative does not involve any treatment and so there would be no reduction in T/M/V of the contaminated sediment.

Short-Term Effectiveness

This alternative would have no short-term impacts because no activity would be implemented. There would be no additional risks to the community, workers, or the environment as a result of this alternative.

Implementability

There are no implementability concerns associated with this alternative.

Cost

The cost for 30 years of sediment and biota monitoring (sampling, analysis, and reporting) is estimated at $325,745.

5.3.2 SD-2 - In Situ Capping

As defined in Section 4.3.2, the in situ capping alternative relies on the use of a 0.6 m (2 ft) thick sand cap to contain contaminated sediment in the principal threat areas of the slough and institutional controls (access restrictions, deed notices, etc.) to restrict public access and future activities in the slough. The sand cap would blanket an area estimated at 8.8 acres and would cover nearly all of the known PAH and dioxin concentrations exceeding the preliminary sediment cleanup levels. Two hot spots of limited extent, one of PAH contamination and the other of dioxin contamination, located outside of the area of principal threat would not be capped, but would be addressed through the use of institutional controls.

An assessment of this alternative against the evaluation criteria follows.

Overall Protection of Human Health and the Environment

This alternative would be protective of human health and the environment by controlling human exposure to contaminated fish and isolating a preponderance of the contamination from the water column. It would have a limited effect on the potential migration of contamination from Old Mormon Slough into groundwater beneath the site. However, this is considered a minimal potential migration pathway in relation to the extensive deep soil and NAPL contamination in the upland portion of the site. In any event, any contribution of COCs from slough sediment to groundwater is expected to be captured by the proposed groundwater extraction system that was evaluated separately for the Soil-Groundwater OU FS report.

Compliance with Applicable or Relevant and Appropriate Requirements

This alternative would comply with ARARs. More particularly, the construction activities associated with this alternative would comply with the substantive requirements of the RHA because the activity would provide a benefit to the public by protecting human health and the environment. Construction would also comply with the substantive requirements of Section 404 of the CWA.

Long-Term Effectiveness and Permanence

All contamination would remain in place, but nearly all of it (except the two "hot spots") would be isolated from benthic and water column organisms via the sand cap. Remedial action objectives for protection of the aquatic environment would be achieved following the completion of the sediment cap, which is estimated to take a few (perhaps 4 to 8) weeks. Capping of contaminated sediment is a common and proven technology. Since the slough is an area of net sediment deposition, natural erosion from tidal action and other causes is not expected to be of concern. However, if areas of potential erosion (either natural or man-made, e.g., from boat prop wash) are identified during the remedial design stage, a rip-rap and gravel filter armoring will be placed over those areas of the cap. The expected continuation of natural sediment deposition in the slough (estimated by White and Kohn [1996] to be at a rate of 3.6 cm [1.4 in.] per year) is expected to further bury the contamination and protect the integrity of the cap. Periodic monitoring and maintenance (if needed) of the cap will ensure the long-term effectiveness and permanence of the remedial action.

Although existing warning signs and fencing have not completely prevented public access and fishing in the slough, additional physical and administrative controls (e.g., log booms, improved fencing, additional warning signs, and increased security) could be more effective. Additional institutional controls such as proprietary and governmental controls, including deed restrictions, would prohibit dredging or other uses of the slough that would be detrimental to the cap and could lead to re-surfacing and/or resuspension of the contaminated sediment.

Capping would have only a limited effect on preventing the potential migration of contaminants from slough sediment into the groundwater system. However, the low solubility and high sorption coefficients for the COCs suggests that such migration, if any, would be extremely slow.

Reduction of T/M/V Through Treatment

There is no treatment involved in this alternative, thus, there would be no reduction in toxicity or volume of the contaminated sediment. However, capping of the contaminated sediment would significantly reduce the potential for resuspension and transport of contaminated sediment and secondarily would somewhat reduce the potential for migration of contaminants from sediment into groundwater via recharge.

Short-Term Effectiveness

There would be some risk to workers installing the sediment cap. These short-term risks would be primarily from the hazards associated with operation of heavy equipment and work over water. Direct worker exposure to contamination would be minimal, limited to contaminated debris removed prior to installation of the cap materials.

Some short-term adverse effects on the aquatic ecosystem are expected from the placement of sand. Installation of the sediment cap is estimated to take 1 to 2 months and is expected to have severe short-term impacts on the benthic community in the slough. Burial of the existing slough bottom under 0.6 m (2 ft) of sand will essentially destroy the existing benthic community. However, the new sand bottom is expected to provide a good substrate for the development of a new healthy and diverse benthic community. Thus, over the longer term, installation of the sand cap is thought to provide beneficial effects to aquatic organisms.

Isolating contaminated sediment would eliminate exposure to water column organisms and, over time, reduce concentrations in those species consumed by humans. The implementation of access controls should somewhat reduce human health risks in the short term by limiting catching and consumption of potentially contaminated fish until safe concentrations in fish are achieved. The implementation of stronger access controls would almost immediately reduce the risk to the community by limiting the catching and consumption of potentially contaminated fish.

Implementability

The installation of a sand cap in this type of environment is a fairly common and proven method of containing contaminated sediment. The necessary equipment, materials, and expertise is readily available in the area. However, the presence of large debris, steep slopes, and/or large areas of potential erosion (primarily through prop wash) could complicate installation of the cap and lead to increased implementation time and/or cost increases.

Installation of the sand cap will raise the bottom of the slough a minimum of 0.6 m (2 ft), which may reduce the future useability of the slough and thus may impact neighboring land owners who may wish to use the slough.

Cost

The 30 year present worth cost of this alternative, assuming 5% inflation, is estimated to be on the order of $1,848,597, with a capital cost of $1,207,025, and an annual O&M cost of $41,735. The capital cost is primarily for installation of the cap. The annual O&M costs are primarily for monitoring and maintenance of the cap. Cost estimates for the capping alternative have assumed the use of a 90% sand cap/10% armored cap combination. The total cost of an armored cap for the entire slough was estimated at $2.9 million.

5.3.3 SD-3 - Dredging and Confined Disposal Facility

The Dredging and Confined Disposal Facility alternative uses mechanical dredging to remove contaminated sediment from principal threat subareas of the slough and consolidate it with existing contamination in the END of the slough in an engineered CDF (refer to Section 4.3.3 for a detailed description). The CDF would be constructed by installing a sheetpiling wall across the slough approximately 244 m (800 ft) from its END, producing a volume sufficient to contain the dredged material (estimated 55,400 m^3 [72,500 yd^3]) and a 0.6 m (2 ft) cap of clean local backfill materials. Water initially present in the CDF would be allowed to drain back into the slough during backfilling after passing through a silt curtain or other passive filtering system. This water would be discharged into the area still being dredged behind the main silt curtain.

Dredging would be performed to a depth of 0.7 to 2.7 m (2.2 to 8.8 ft) leaving deeper contamination in place, which would be capped with 0.6 m (2 ft) of sand to isolate it from water column organisms. The size of this cap is estimated to range from 1.6 to 4.0 acres, depending on the results of confirmatory sampling conducted at the completion of dredging activities.

A silt curtain would be used during these remedial activities to prevent the uncontrolled release of resuspended sediment. Institutional controls would be implemented to prevent access and fishing in the slough to ensure the integrity of the sand cap and to isolate low-level threat areas from the public.

An assessment of this alternative against the evaluation criteria follows.

Overall Protection of Human Health and the Environment

This alternative would be protective of human health and the environment by removing and/or isolating a preponderance of the contaminated sediment from the slough. Remedial action objectives for protection of the aquatic environment would be achieved in most of the slough following completion of the remedial actions, which are estimated to take several months (perhaps on the order of 4 to 10). Natural attenuation and degradation processes may take hundreds to thousands of years to decrease the two “hot spots” and residual contaminant concentrations to acceptable levels. This alternative would also provide a reduction in the potential for migration of contamination into the groundwater by reducing the mass of contamination directly influenced by the hydraulic driving force of the slough. Contamination removed from the slough would be contained in an unsaturated condition above the water table. In addition, the cap over the confined disposal unit would further reduce infiltration.

Compliance with ARARs

This alternative would comply with ARARs. More particularly, the construction activities associated with this alternative would comply with the substantive requirements of the RHA because the activity would provide a benefit to the public by protecting human health and the environment. Construction would also comply with the substantive requirements of Section 404 of the CWA. The consolidation of contaminated sediments from principal threat subareas into the contaminated area in the eastern end of the slough would occur within the same area of contamination and therefore would not constitute placement for purposes of triggering LDRs.

Long-Term Effectiveness and Permanence

Approximately 30% of the accessible (top 2.4 [8 ft]) PAH contamination and 53% of the dioxin contamination would remain in place. However, nearly all of it (except the two “hot spots” in the mouth of the slough) would be contained inside the CDF and isolated from the slough. Deep residual PAH contamination not removed during dredging would be capped with 0.6 m (2 ft) of sand. Dredging and confined disposal of sediment, as well as capping are common and proven technologies. Since the slough is an area of net sediment deposition, natural erosion of cap materials due to tidal action or other means is not expected to be of concern. However, if areas of potential erosion (either natural or man-made, e.g., from boat prop wash) are identified during the remedial design stage, a rip-rap and gravel filter armoring will be placed over those areas of the cap. The expected continuation of natural sediment deposition in the slough (estimated by White and Kohn [1996] to be at a rate of 3.6 cm [1.4 in.] per year) is expected to further bury the deep residual contamination and protect the integrity of the cap. Periodic monitoring and maintenance (if needed) of the cap and CDF will ensure the long-term effectiveness and permanence of the remedial action.

Although existing warning signs and fencing have not completely prevented public access and fishing in the slough, additional physical and administrative controls (e.g., log booms, improved fencing, additional signs, and increased security) could provide additional safeguards as a component of this alternative. Institutional controls such as proprietary and governmental controls, including deed restrictions, would prohibit dredging or other uses of the slough and adjacent lands that would be detrimental to the cap and/or CDF and may lead to re-surfacing and/or resuspension of the contaminated materials.

Reduction of T/M/V Through Treatment

There is no treatment under this alternative, thus, there would be no reduction in toxicity or volume of the contaminated sediment. However, removal, confined disposal, and/or capping of nearly all of the contaminated sediment (except the two “hot spots”) would significantly reduce the mobility of the contamination by isolating it in the CDF.

Short-Term Effectiveness

There would be some risk to the workers during the 4- to 10-month-long remedial operations, while constructing the CDF, performing dredge and fill activities, and installing the sediment cap. These risks would primarily result from the hazards associated with the operation of heavy equipment and working over water. Increased worker exposure to contamination would be expected through direct contact with contaminated debris and sediment during the dredge and fill operations. This could be mitigated by the use of proper protective clothing.

Removing and isolating contaminated sediment would eliminate exposure to water column organisms and over time would reduce concentrations in those species consumed by humans. The implementation of access controls should somewhat reduce human health risks in the short term by limiting catching and consumption of potentially contaminated fish until safe concentrations in fish are achieved. The implementation of stronger access controls would almost immediately reduce the risk to the community by limiting the catching and consumption of potentially contaminated fish.

Although remedial actions would be conducted during incoming tides and behind silt curtains to contain potentially resuspended sediment, this alternative is expected to have severe short-term and long-term (permanent) impacts on the aquatic ecosystem. Creation of the CDF will eliminate approximately 3.4 acres of aquatic habitat, about 30% of the slough. Dredging and installation of the sand cap is expected to have severe short-term impacts on the benthic community over another 5.5 acres, approximately one-half of the slough. However, the sand cap materials are expected to provide a good substrate for the development of a new healthy and diverse benthic community. Thus, over the longer term, installation of the sand cap is thought to provide beneficial effects.

The removal, consolidation and confined disposal of nearly all of the accessible (top 2.4 m [8 ft]) will reduce the contaminant mass directly influenced by the hydraulic driving force of the slough. Thus, the potential migration of contaminants out of the slough sediment and into the groundwater system will be reduced. However, the low solubility and high sorption of the COCs, as well as the already highly degraded nature of the groundwater due to the major upland source areas, suggests this reduction will likely have little effect.

Implementability

Implementation of this alternative is technically feasible. Dredging, confined disposal, and capping are all fairly common practices and are proven methods for control of contaminated sediment. The necessary equipment, materials, and expertise is available in the local area. However, the presence of large amounts of debris, large areas of potential erosion (primarily through prop wash), and/or difficulties in consolidating the dredge material, could complicate these remedial actions and lead to increased implementation time and/or cost increases.

The acceptability of filling in a portion of the slough to the community, adjacent landowners, and regulatory agencies is unknown at this time. Creation of the CDF would destroy approximately 30% of the slough and its aquatic habitat. In addition, the adjacent land owner would lose its existing waterfront access. Dredging of the slough would deepen the channel making it more accessible to future water traffic, should monitoring indicate that this traffic would have no adverse impacts on the residual contamination. The CDF, if properly designed and constructed, could serve as a new wharf.

Cost

The 30 year present worth cost of this alternative, assuming 5% inflation, is estimated to be on the order of $2.4 million, with a capital cost of $2.0 million, and an annual O&M cost of $27,442. The capital cost is primarily for construction of the CDF, dredging and filling operations, and installation of the sand cap. The annual O&M costs are primarily for monitoring and maintenance of the cap and CDF. This cost estimate assumes that only the CPA area of the slough would be capped. If necessary to cap both the OWP and CPA areas of the slough, the 30 year present worth cost was estimated at $2.9 million.

5.3.4 SD-4 - Dredging and Offsite Disposal

This alternative would remove contaminated sediment from principal threat portions of the slough by mechanical dredging. An estimated 91,000 m^3 (119,000 yd^3) would be removed accounting for an estimated 99.5% of the accessible (top 2.4 m [8 ft]) PAH contamination and nearly 100% of the dioxin contamination. This dredged material would be transferred to an upland dewatering facility constructed near the southeastern end of the slough. A combination of gravity drainage and filter press (or similar) technology would be used to dewater the sediment at a rate estimated at 77 m^3/h (100 yd^3/h). The recovered water (estimated at 2300 liters per minute [70 gpm]) would be filtered prior to draining back into the area of the slough being dredged above the silt curtain, unless treatment was required.

Once the dredged material was sufficiently dewatered and/or stabilized (if needed) it would be transported offsite for treatment (if necessary) and/or disposal. The choice of an offsite disposal facility, and the need for treatment prior to disposal, is dependent on the eventual waste designation of the dewatered dredge material, as discussed in Subsection 4.3.4.

Deep residual contamination (i.e., the areas of contaminated sediment not removed during dredging, principally areas below 8 ft below the mudline) would be capped with a 0.6 m-(2 ft)-thick sand cap. The size of this cap, estimated to be on the order of 2.3 to 5.7 acres, is dependent on the results of confirmation sampling.

A silt curtain would be used during dredging activities to prevent the uncontrolled release of resuspended sediment. Institutional controls would be implemented to prevent access to and fishing in the slough, to ensure the integrity of the sand cap, and to isolate low-level threat areas.

An assessment of this alternative against the evaluation criteria follows.

Overall Protection of Human Health and the Environment

Remedial action objectives for sediment and the protection of the aquatic environment should be achieved in most areas of the slough following the completion of dredging and capping activities. This alternative would be protective of human health and the environment by removing or capping nearly all of the contamination. Removing contaminated sediment from the slough would eliminate exposure to water column organisms and over time reduce concentrations in those species consumed by humans. The implementation of stronger access controls could almost immediately reduce the risk to the community by preventing the catching and consumption of potentially contaminated fish until safe levels in fish are achieved. It would also provide a reduction in the potential for migration of contamination into the groundwater by reducing the mass of contamination directly influenced by the hydraulic driving forces from the slough. Two “hot spots” believed to be of limited extent, one of PAH contamination and one of dioxin contamination, would not be actively addressed, but would allow to be naturally buried by natural sedimentation processes or naturally degraded. Natural attenuation and degradation processes may take hundreds or thousands of years to decrease the “hot spot” and residual contaminant concentrations to acceptable levels. Short-term adverse effects are expected on the aquatic ecosystem from dredging and capping operations.

Compliance with ARARs

This alternative would comply with ARARs. More particularly, the construction activities associated with this alternative would comply with the substantive requirements of the RHA because the activity would provide a benefit to the public by protecting human health and the environment. Construction would also comply with the substantive requirements of Section 404 of the CWA. If water recovered from the dewatering facility requires treatment, the dewatering facility and the treatment facility would comply with the RCRA requirements set forth in Table 5.1.

Long-Term Effectiveness and Permanence

Virtually none of the accessible (top 2.4 [8 ft]) contamination would remain in place except the two “hot spots” in the mouth of the slough. Deep residual PAH contamination not removed during dredging would be capped with 0.6 m (2 ft) of sand. Dredging and capping are common and proven technologies. Since the slough is an area of net sediment deposition, further burial of the deep residual contamination and protection of the integrity of the cap are expected. Should the remedial design phase identify areas of potential erosion of the cap, those areas will be armored with rip-rap and gravel filter. Periodic monitoring and maintenance (if needed) of the cap will ensure the long-term effectiveness and permanence of the remedial action. Although existing warning signs and fencing have not completely prevented public access and fishing in the slough, additional physical and administrative controls (e.g., log booms, improved fencing, additional warning signs, and increased security) should be more effective. Additional institutional controls such as proprietary and governmental controls, including deed restrictions, would prohibit dredging or other uses of the slough that would be detrimental to the cap. Natural attenuation and degradation processes are not expected to reduce residual contaminant concentrations to acceptable levels for hundreds or thousands of years (Appendix A).

Reduction of T/M/V Through Treatment

Dredged material from the principal threat areas, estimated 91,000 m^3 (119,000 yd^3), would be dewatered using gravity drainage and filter press technology (or similar) to make it acceptable for offsite shipping. This represents nearly 100% of the accessible (top 2.4 m [8 ft]) contamination in the slough. The need for offsite treatment prior to disposal is dependent on the eventual waste designation of the material; this could range from no treatment required to incineration.

While some degradation is likely to occur during dewatering through photodegradation, biodegradation, and volatilization, it is considered insignificant over the anticipated implementation period. Dewatering would produce a residual water stream which would be filtered, or treated if necessary, prior to release back into the slough.

Short-Term Effectiveness

There would be some risk to workers over a 4- to 10-month period during dredging, dewatering, and capping activities. These risks would be primarily from the hazards associated with operation of heavy equipment and working over water. Increased worker exposure to contamination would be expected through direct contact with contaminated debris and sediment during the dredge and dewatering operations. This could be mitigated by the use of proper protective clothing.

Although remedial actions would be conducted during incoming tides and behind silt curtains to contain potentially resuspended sediment, this alternative is expected to have severe short-term impacts on the aquatic ecosystem from dredging and capping activities. Dredging will remove and essentially destroy the existing benthic community over three-quarters of Old Mormon Slough. However, the new sand cap materials are expected to provide a good substrate for the development of a healthy and diverse benthic community. Re-establishment of a vigorous benthic community is expected to take only a few growing seasons (perhaps 1 to 3 years). Over the long-term, dredging and installation of the sand cap is thought to provide beneficial environmental effects.

The removal of nearly all accessible (top 2.4 m [8 ft]) contamination from the slough will greatly reduce the contaminant mass directly influenced by hydraulic driving forces in the slough. Thus, the potential migration of contaminants out of the slough sediment and into the groundwater system will be reduced. However, the low solubility and high sorption of the COC, and the already highly degraded nature of the groundwater due to the major upland source areas suggests that this reduction will likely have little obvious effect.

Implementability

Implementation of this alternative is technically feasible. Dredging and capping are fairly common practices and proven methods for controlling contaminated sediment. The necessary equipment, materials, and expertise for these activities is available in the local area. However, dewatering of the fine-grained (clay silt) sediment and the availability or accessibility of a commercial disposal facility may pose some difficulties. Based on recent experience at the United Heckathorn Superfund site, dewatering was found to be an extremely slow process that eventually had to be supplemented by solidification technology. Suitable dewatering technology may not be readily available, and could be quite costly. Dredging activities would likely be conducted at the same rate as the dewatering operations to limit the need for large-scale holding areas.

Completion of this alternative is expected to take between 4 and 10 months. Commercial TSDFs are available that are licensed to take the dredged material. However, the availability and accessibility of TSDFs for certain listed waste types could cause severe schedule and/or cost constraints. The presence of large amounts of debris, large areas of potential cap erosion (primarily through prop wash), and/or difficulties in arranging offsite transportation (particularly by rail) could also complicate these remedial actions and lead to increased implementation time and cost increases.

The acceptability of this alternative to neighboring land owners, the community, and regulatory agencies is unknown at this time. Dredging of the slough will deepen the channel, making it more accessible to future water traffic (should monitoring indicate that this traffic would have no adverse impacts on the residual contamination). There are potential risks to the public from the shipment of hazardous wastes from the site over long distances.

Cost

The cost for Alternative SD-4 depends on the location of the TSDF and the pre-disposal treatment requirements (see Subsection 4.3.4). Because of the uncertainties involved with this alternative, low-end and high-end costs were estimated. The low-end cost assumed that the waste could be shipped to a facility in California, and, based on its waste classification, it could be landfilled without treatment. However, LDRs for the expected waste classification of sediment from the M&B site (i.e., listed wood preserving wastes F032, F034, and F035) became effective in August 1997, and a treatment variance for these wastes expires in May 1999. In addition, if the dredged sediment exceeded the TCLP criterion for PCP, it would be characterized as D037 waste and would be subject to treatment (incineration) before disposal. Thus, a high-end cost estimate is also included to comply with LDRs for offsite disposal. This limits the number of facilities that can accept the sediments, which greatly increases transportation costs and adds the high cost of incineration for this large volume of sediment to the total cost. Thus, the present worth value for offsite disposal could range from $39.6 million to as high as $351 million (see Appendix C). The low-end 30-year present worth cost of this alternative (assuming 5% inflation) is estimated to be on the order of $39.6 million with a capital cost of $39.1 million, and an annual O&M cost of $28,735. The high-end 30-year present worth cost of this alternative (assuming 5% inflation) is estimated to be on the order of $351 million, with a capital cost of $350.5 million, and an annual O&M cost of $28,735. However, as noted, the low-end value is no longer considered a realistic figure for offsite disposal since the LDRs recently became effective.

5.3.5 SD-5 - Dredging and Onsite Treatment

This alternative (described in detail in Section 4.3.5) would remove contaminated sediment from the principal threat area of the slough by mechanical dredging. As with the offsite disposal alternative, an estimated 91,000 m^3 (119,000 yd^3) would be removed, which accounts for an estimated 99.5% of the accessible (top 2.4 m [8 ft]) PAH contamination and nearly 100% of the dioxin contamination. This dredged material would be transferred to a dewatering facility where a combination of gravity drainage, percolation, and evaporation would partially dewater the sediment. The recovered water would be filtered prior to draining back into the area of the slough being dredged (above the silt curtain), unless additional treatment was necessary. Once the dredge material was suitably dewatered it would be treated using solvent extraction to remove the organic (PAH and dioxin) contamination. Solid residuals from this process would be solidified to address the remaining metals contamination and disposed onsite in the upland area of the site.

Deep residual contamination (not removed during dredging) would be capped with a 0.6-m- (2-ft)-thick sand cap. The size of this cap, estimated to be on the order of 1 to 2.4 ha (2.3 to 5.7 ac) is dependent on the results of confirmation sampling. A silt curtain would be used during dredging activities to prevent the uncontrolled release of resuspended sediment. Institutional controls would be implemented to prevent access to and fishing in the slough, to ensure the integrity of the sand cap, and to isolate lesser threat areas from the public.

An assessment of this alternative against the evaluation criteria follows.

Overall Protection of Human Health and the Environment

This alternative would be protective of human health and the environment by removing or capping nearly all of the contamination. Remedial action objectives for sediment and protection of the aquatic environment for most of the slough would be achieved following the completion of dredging and capping activities. The two “hot spots” at the mouth of the slough would not be actively remediated, but would be addressed by the use of institutional controls. Natural attenuation and degradation processes may take hundreds or thousands of years to decrease the “hot spots” and residual contaminant concentrations to acceptable levels. This alternative would provide a reduction in the potential for migration of contaminants from sediment into the groundwater by reducing the mass of contamination directly influenced by the hydraulic driving forces from the slough. Short-term adverse effects to the aquatic ecosystem are expected from dredging and capping operations.

Compliance with ARARs

This alternative would comply with ARARs. More particularly, the construction activities associated with this alternative would comply with the substantive requirements of the RHA because the activity would provide a benefit to the public by protecting human health and the environment. Construction would also comply with the substantive requirements of Section 404 of the CWA. The onsite dredging treatment facility would comply with the RCRA requirements set forth in Table 5.1. If water recovered from the dewatering facility requires treatment, the dewatering facility and the water treatment facility would comply with the RCRA requirements set forth in Table 5.1.

Long-Term Effectiveness and Permanence

Virtually none of the accessible (top 2.4 [8 ft]) contamination would remain in place, except the two "hot spots" at the mouth of the slough. Deep PAH contamination (greater than 2.7 m [8.8 ft]) would not be removed during dredging, but instead would be capped with 0.6 m (2 ft) of sand. Dredging and capping are common and proven technologies. Since the slough is an area of net sediment deposition, further burial of the deep residual contamination and protection of the integrity of the cap are expected. Should activities during the remedial design phase identify areas of the cap susceptible to erosion (most likely from barge traffic), those areas will be armored with rip-rap and a gravel filter layer. Periodic monitoring and maintenance (if needed) of the cap will ensure the long-term effectiveness and permanence of the remedial action.

Although existing warning signs and fencing have not completely prevented public access and fishing in the slough, additional physical and administrative controls (e.g., log booms, improved fencing, additional warning signs, and increased security) should provide more safeguards. Additional institutional controls such as proprietary and governmental controls, including deed restrictions, would prohibit dredging or other uses of the slough that would be detrimental to the cap. Natural attenuation and degradation processes are not expected to reduce residual contaminant concentrations to acceptable levels for hundreds or thousands of years (Appendix A).

Reduction of T/M/V Through Treatment

This alternative would provide reduction of T/M/V for organic COCs (through solvent extraction) and reduction of mobility for inorganic COCs (through S/S). Dredged material from the principal threat areas, estimated at 91,000 m^3 (119,000 yd^3), would be dewatered using gravity drainage and treated using solvent extraction. This represents nearly 100% of the accessible (top 2.4 m [8 ft]) contamination in the slough.

Dewatering would produce a residual water stream that would require filtration and monitoring prior to release back into the slough. Solvent extraction is a separation technology that physically removes organic contamination from the sediments. Site-specific soil treatability tests (Section 3.3) have indicated that solvent extraction can be greater than 95% efficient in reducing the concentration of dioxin, and greater than 67% to 98.8% effective in reducing PAH concentrations. Solvent extraction can generate four primary residual streams; spent solvent, a recovered organic phase, a recovered aqueous phase, and solid residuals. The spent solvent and recovered organic would be destroyed via offsite incineration. The recovered aqueous waste stream would be filtered and treated using catalytic oxidation or similar technology (if needed), and the solid residuals would be treated using solidification technology and then disposed onsite in the upland area of the site. Treatability tests indicate that solidification of the solid residuals can reduce the mobility of residual organic and metal contamination by 73% to 98% (Section 3.3).

The removal of nearly all accessible (top 2.4 m [8 ft]) contamination from the slough will greatly reduce the contaminant mass directly influenced by hydraulic driving forces in the slough. Thus, the potential migration of contaminants out of the slough sediment and into the groundwater system will be reduced. However, the low solubility and high sorption of the COC, and the already highly degraded nature of the groundwater suggests this reduction will likely have little obvious effect.

Short-Term Effectiveness

There would be some risk to workers performing dredging, dewatering, treatment, disposal, and capping activities. These risks would be primarily from the hazards associated with operation of heavy equipment, industrial process equipment, and working over water. Increased worker exposure to contamination would be expected through direct contact with contaminated debris and sediment during the dredging, dewatering, and treatment operations. This could be mitigated with the use of proper protective clothing. Air emissions from the solvent extraction system and from the handling of the dewatered sediment could also cause short-term impacts at the site if not properly addressed.

Dredging activities would likely be conducted in conjunction with the dewatering and treatment operations to limit the need for large-scale holding areas. Completion of this alternative is expected to take the same amount of time as alternatives SD-3 and SD-4, approximately 4 to 10 months.

Although remedial actions would be conducted during incoming tides and behind silt curtains to contain potentially resuspended sediment, this alternative is expected to have severe short-term impacts on the aquatic ecosystem from dredging and capping activities. Dredging would remove and essentially destroy the existing benthic community over three-quarters of the slough. However, the new sand cap materials are expected to provide a good substrate for the development of a healthy and diverse benthic community. Re-establishment of a vigorous benthic community is expected to take only a few growing seasons (perhaps 1 to 3 years). Thus, over the long-term, dredging and installation of the sand cap may have a beneficial effect.

Implementability

Implementation of this alternative is technically feasible, although it is the most complex alternative with the greatest implementation concerns. Dredging and capping are fairly common practices and proven methods for controlling contaminated sediment. The necessary equipment, materials, and expertise for these activities should be available in the local area. However, dewatering of the fine-grained (clay silt) sediment and the availability or accessibility of suitably sized solvent extraction systems may pose some difficulties. The implementation of the solvent extraction process is more difficult, and the availability of solvent extraction vendors may be limited. Onsite disposal of the solidified solid residuals from the solvent extraction process (91,000 m^3 [119,000 yd^3] plus a 20% bulking factor) may be somewhat difficult to implement. The disposal of this volume of material would require a disposal pit estimated at 91 m (300 ft) wide by 366 m (1200 ft) long and 2.7 m (9 ft) deep. This is expected to exceed available storage capacity in the upland portion of the site, and would also have an impact on implementation of the soil and groundwater remedies. The presence of large amounts of debris and/or large areas of potential cap erosion (primarily through prop wash) could complicate the implementation of this alternative, resulting in time and/or cost increases.

Residuals generated during solvent extraction would need to be treated and/or disposed of. The ex situ S/S process on solids from the solvent extraction process greatly increases soils-handling and technology requirements over the other alternatives.

The acceptability of this alternative to neighboring land owners, the community, and regulatory agencies is unknown at this time. Dredging of the slough will deepen the channel, making it more accessible to future water traffic (should monitoring indicate that this traffic would have no adverse impacts on the residual contamination).

Cost

The 30-year present worth cost of this alternative (assuming 5% inflation) is estimated to be on the order of $66.6 million, with a capital cost of $66.7 million, and an annual O&M cost of $28,735. The capital cost is primarily for treatment and includes dredging, dewatering, and installation of the sand cap. The annual O&M costs are primarily for monitoring and maintenance of the cap. This cost estimate assumes only the CPA and END areas of the slough would be capped. If the entire slough was capped, the 30-year present worth cost for this alternative would increase to $67.7 million (see Appendix C).

5.4 COMPARATIVE ANALYSIS OF SEDIMENT ALTERNATIVES

In the following analysis, the alternatives are evaluated in relation to one another using the same evaluation criteria. **Table 5.2** summarizes the key points from this analysis.

5.4.1 Overall Protection of Human Health and the Environment

All of the alternatives (except No-Action) rely on access controls to some extent to reduce human exposure to contaminated sediment and fish in the area. To reduce the risk to the environment, the In Situ Capping Alternative (SD-2) relies on physically isolating the contamination in place under a sand cap. This essentially buries the contamination to prevent direct contact to benthic organisms and resuspension of the sediment, thereby decreasing the bioavailability of the contamination to water column organisms. Given their low solubility and high sorption properties, these contaminants are expected to have low mobility in the aqueous phase, and thus can be adequately contained with a permeable cap. With the isolation afforded by a cap, the concentration of contamination in resident fish is expected to decrease over time, thus reducing the risk to humans. However, long-term monitoring, maintenance, and institutional controls are required to ensure the integrity of the cap. Less monitoring and maintenance would be necessary for an armored cap.

The alternative involving dredging, CDF (SD-3), Offsite Disposal (SD-4), and Onsite Treatment (SD-5), all provide additional protection by reducing the mass of contamination present in the slough. This would reduce the mass of contamination directly influenced by the hydraulic driving force of the slough and so provide a reduction in the potential for migration of contaminants into groundwater beneath the site. Alternatives SD-4 and SD-5 provide even greater protection by completely removing nearly all of the dioxin contamination and the accessible PAH contamination from the slough, and either disposing of it offsite or destroying it. However, both of these alternatives leave some deeper PAH contamination behind, and still must rely to some degree on in situ capping and long-term management. Thus, Alternatives SD-3, SD-4, and SD-5 provide a somewhat greater level of protection. However, as noted in earlier sections, migration of contamination from Old Mormon Slough sediments to groundwater is considered a minimal potential migration pathway in relation to the extensive deep soil and NAPL contamination in the upland portion of the site. In addition, any contribution of COCs from slough sediment to groundwater is expected to be captured by the proposed groundwater extraction system, which was evaluated separately for the Soil-Groundwater OU FS report.

5.4.2 Compliance with Applicable or Relevant and Appropriate Requirements

All of the alternatives would comply with ARARs, including the action-specific ARARs triggered by the dredging and construction activities proposed for the slough. Onsite treatment (SD-5) potentially may require treatment within the same area of contamination or designation of a RCRA CAMU in order to comply with LDR ARARs.

5.4.3 Long-Term Effectiveness and Permanence

The No-Action alternative would not be effective in reducing current or future risks. Natural attenuation processes are expected to take hundreds or thousands of years to reduce contaminant concentrations in sediment to acceptable levels.

Institutional controls, to be implemented as part of all but the No-Action alternative, do not provide long-term effectiveness and permanence alone. Stronger, enforceable, and effective controls could limit human exposure to potentially contaminated fish until sediment remediation efforts are complete, and natural metabolic and other processes reduce contaminant concentrations in the resident fish population. Institutional controls, however, would not reduce risk to ecological receptors.

To reduce risk to the environment and to protect human health over the long term, all of the alternatives (except No-Action) either isolate or remove a preponderance of the accessible contamination from Old Mormon Slough. Alternative SD-2 buries the contamination in place beneath a sand cap. This prevents resuspension of the sediment and reduces the bioavailability of the contamination to water column organisms. In situ capping of contaminated sediment is a proven and accepted technology. Given the low solubility and high sorption properties of the COCs, capping is expected to be effective in isolating these contaminants. However, long-term monitoring, maintenance, and institutional controls are required to ensure the integrity of the cap.

The CDF (SD-3), Offsite Disposal (SD-4), and Onsite Treatment (SD-5) alternatives all provide additional permanence and long-term effectiveness by reducing the mass of contamination present in Old Mormon Slough. Alternatives SD-4 and SD-5 provide even greater permanence by removing nearly all of the dioxin contamination and the accessible PAH contamination from the slough. The dredged sediment would be disposed of (and treated) offsite or treated onsite. This would provide an added measure of effectiveness and permanence for the protection of human health and the environment. However, all of these alternatives leave some deeper PAH contamination in the slough that is technically infeasible to dredge. Once exposed by dredging activities, this residual contamination must be capped to prevent its bioavailability to water column organisms and to benthic organisms that may re-establish in Old Mormon Slough over time. This further requires long-term management to maintain the integrity of the cap. In addition, this residual contamination may still represent a small potential source to groundwater contamination. Thus, while Alternatives SD-4 and SD-5 may provide greater long-term effectiveness and permanence relative to human health (i.e., removal of nearly all dioxin), all of the alternatives (except No-Action) ultimately rely on capping and long-term management to some degree to provide long-term effectiveness and permanence relative to protection of the environment (i.e, reduce exposure to PAHs).

5.4.4 Reduction in Toxicity, Mobility, or Volume Through Treatment

Only one of the alternatives, SD-5, is designed to treat the contaminated sediment to reduce its T/M/V. The Onsite Treatment Alternative would use solvent extraction to remove the organic contaminants from the sediment. The recovered organics are expected to then be destroyed by offsite incineration. This treatment train is estimated to remove and destroy more than 85% to 94% of the dioxin contamination and more than 60% to 98% of the PAH contamination. Solidification of the solid residuals (i.e., the scavenged sediment) is estimated to reduce the mobility of the residual organic and inorganic (metal) contamination by 73% to 98%.

Because LDRs for the expected waste classification of the dredged M&B sediment will be in place when the remedial action occurs, the Offsite Disposal Alternative (SD-4) would also involve treatment. Offsite incineration of the contaminated sediment prior to disposal would reduce the organic contamination by an estimated 90% to 99%.

The other alternatives (SD-2 and SD-3) do not involve treatment and would not reduce the toxicity or volume of the slough sediments. However, they would reduce the mobility of the contamination through containment. Migration of contaminants to groundwater would still be a potential pathway. Of these two alternatives, SD-3 provides the greater reduction in mobility by removing nearly all of the accessible contamination from the slough and isolating it away from the biological and hydraulic influences of the slough.

5.4.5 Short-Term Effectiveness

All of the alternatives, except No-Action, present some risk to workers, primarily from operation of heavy equipment and the hazards of working over water. All of the alternatives also would cause severe short-term impacts to the benthic community in the slough. The In Situ Capping Alternative (SD-2) presents the least risk to workers and the fewest impacts to the slough ecosystem. All dredging alternatives would present increased industrial risk to the workers and even more detrimental ecological effects to the slough. The Onsite Treatment Alternative (SD-5) presents the greatest risk to workers, not only from the operation of heavy equipment associated with dredging and the industrial treatment processes, but also due to the potential for direct exposure and inhalation of contamination while handling and treating the dredged material. The CDF alternative (SD-3) would cause the greatest environmental damage by permanently filling approximately 30% of the slough and destroying its aquatic habitat.

5.4.6 Implementability

All of the alternatives are technically feasible, and all necessary equipment, materials, and expertise for dredging and the installation of sediment caps is readily available in the Stockton area. However, the presence of large debris or steep bottom slopes can complicate dredging and capping activities. Dewatering of the fine-grained sediments sufficiently for offsite transport can be difficult. The Onsite Treatment Alternative (SD-5) is the most technically complex alternative with the greatest implementation concerns. It could be difficult to locate suitably sized solvent extraction systems necessary to meet effluent control standards. The ex situ S/S process on solids from the solvent extraction process greatly increases soils-handling and technology requirements over the other alternatives.

Onsite disposal of the large volumes of solid residuals from the solvent extraction/solidification treatment train would be difficult due to limited capacity in the upland OU. The availability and accessibility of an offsite TSDF permitted to receive the contaminated sediment, which is dependent on the waste designation and LDRs, could cause significant scheduling delays and increased costs.

The acceptability of any of these alternatives to neighboring land owners, the community, and regulatory agencies is uncertain. However, it is anticipated that all of the alternatives could be of some concern. In situ capping would raise the bottom of the slough by a minimum of 0.6 m (2 ft); this would restrict future activities in the slough (e.g., dredging, barge traffic) that might disrupt the cap and release the buried contamination. The CDF alternative (SD-3) would fill approximately 30% of the slough and would eliminate the waterfront access of the property owner on the northern shore of Old Mormon Slough. However, the CDF alternative (along with the other dredging alternatives) would deepen the remainder of the slough. The CDF, depending on its design, could serve as a new wharf for future waterfront access, should future conditions in the slough allow resumption of normal slough uses. The Offsite Disposal alternative (SD-4) could raise public concerns regarding the transportation and offsite treatment/disposal of hazardous waste from the site.

5.4.7 Cost

Costs for the No-Action alternative are the lowest ($325,745), since it only involves monitoring sediment and biota for a 30-year period. The In Situ Capping alternative (SD-2) has the lowest capital and overall costs among the active remediation alternatives, with an estimated 30-year present worth value on the order of $1.8 million (assuming 5% inflation). Cost estimates for the capping alternative have assumed the use of a 90% sand cap/10% armored cap combination. The total cost of an armored cap for the entire slough was estimated at $2.9 million. The CDF alternative (SD-3) has higher capital costs but lower annual costs, with a present worth value estimated to be on the order of $2.4 million. The Onsite Treatment alternative (SD-5) is estimated at a present worth value on the order of $67.2 million. The Offsite Disposal (SD-5) alternative could be the most expensive of all the alternatives, depending on the location of the TSDF and the pre-disposal treatment requirements. Because of the uncertainties involved with this alternative, low-end and high-end costs were estimated. The low-end cost assumed that the waste could be shipped to a facility in California, and that based on its waste classification, it could be landfilled without treatment. Thus, the present worth value for offsite disposal could range from $39.6 million to as high as $351 million (see Appendix C). However, as noted, the low-end value is no longer considered a realistic figure for offsite disposal since the LDRs recently became effective.

5.4.8 State Acceptance

This section will be completed after state agency reviews of the M&B FS report and Proposed Plan have been completed.

5.4.9 Community Acceptance

This section will be completed after receipt of public comments on the M&B Proposed Plan.

Table 5.1. Potential Location- and Action-Specific Applicable or Relevant and Appropriate Requirements for Alternatives Retained for Detailed Analysis McCormick & Baxter Sediment Remedial Action

Source	Standard, Requirement, Criteria, or Limitation	Applicable or Relevant and Appropriate	Description of Standard, Requirement, Criteria, or Limitation	Manner in Which ARAR Applies to Alternative (Location- or Action-Specific ARAR)
Rivers and Harbors Act (RHA), 33 USC §403, Section 10	33 CFR Part 32	Applicable	Prohibits the unauthorized obstruction or alteration of any navigable water of the U.S. At non-CERCLA sites a permit from the U.S. Army Corps of Engineers is required to conduct dredging, filling, installation of pilings and construction of piers and dams. Requires that the activity benefit the public interest.	As Old Mormon Slough is a navigable water of the U.S., this would be an action-specific ARAR for proposed activities such as in situ capping; construction of berms and levees; channel filling; construction of vertical barriers such as silt curtains; dredging; and temporary damming and dewatering of the slough must comply with the substantive requirements.
Clean Water Act (CWA), 33 USC §1344, Section 404(b)	40 CFR 230.10	Applicable	At non-CERCLA sites requires permit from the U.S. Army Corps of Engineers and regulates discharge and placement of dredge or fill material to all U.S. waters.	This would be action-specific ARAR. Substantive requirements for activities that place dredge or fill material in Old Mormon Slough such as the in situ capping and CDF alternatives.
Federal Resource Conservation & Recovery Act (RCRA), Subtitle C, 42 USC §6921 et seq., Hazardous Waste Control Act, Calif. Health & Safety Code §25100 et seq., (HWCA)	40 CFR Part 261, as implemented through 22 CCR, Div. 4.5, Chap. 12 et seq. (Title 22)	Applicable	Establishes criteria for identifying hazardous waste subject to Subtitle C TSD requirements.	Action-specific ARAR. Requires determination as to whether dredged sediment or treatment residuals are RCRA waste. Applies to the following onsite treatment methods that generate wastes: wastewater from sediment dewatering; ex situ solvent extraction; and ex situ S/S process.
RCRA, Subtitle C; HWCA	40 CFR, Part 264, Subpart F (Releases from Solid Waste Management Units)	Applicable or relevant and appropriate, depending on the unit	Establishes groundwater monitoring and response actions for facilities that treat, store or dispose of hazardous waste, such as surface impoundments, land treatment units, landfills, incinerators, containment systems, tanks and piping systems, and containers.	The proposed treatment systems (ex situ solvent extraction, ex situ S/S, and treatment of liquid wastes from dewatering) would be subject to this action-specific ARAR.

Table 5.1. (contd)

Source	Standard, Requirement, Criteria, or Limitation	Applicable or Relevant and Appropriate	Description of Standard, Requirement, Criteria, or Limitation	Manner in Which ARAR Applies to Alternative (Location- or Action-Specific ARAR)
RCRA, Subtitle C; HWCA	40 CFR, Part 264, Subpart G (Closure and Post-Closure), as implemented through 22 CCR, Div. 4.5	Applicable or relevant and appropriate, depending upon the unit	Establishes closure and post-closure requirements for facilities that treat, store or dispose of hazardous waste, such as surface impoundments, land treatment units, landfills, incinerators, containment systems, tanks and piping systems, and containers.	The proposed treatment systems (ex situ solvent extraction, ex situ S/S, and treatment of liquid wastes from dewatering) would be subject to this action-specific ARAR.
RCRA, Subtitle C; HWCA	40 CFR, Part 264, Subpart X, as implemented through 22 CCR, Div. 4.5	Relevant and appropriate	Establishes criteria for regulating miscellaneous treatment units.	The proposed treatment systems (ex situ solvent extraction, ex situ S/S, and treatment of liquid wastes from dewatering) would be subject to this action-specific ARAR.
RCRA, Subtitle C; HWCA	40 CFR, Part 264, Subparts I and J as implemented by 22 CCR, Div. 4.5, Chap. 14, Articles 9 and 10 (Tanks and Containers)	Applicable	Establishes requirements for tanks and container systems used to hold RCRA hazardous wastes for TSD.	These are action-specific requirements that would be applicable to the extent that the sediment treatment alternatives use tanks or containers to treat or store hazardous waste.
RCRA, Subtitle C; HWCA	40 CFR, Part 264, Subparts K, L and M as implemented through 22 CCR, Div. 4.5, Chapter 14, Article 11 (Surface Impoundments, Waste Piles and Land Treatment)	Applicable or relevant and appropriate	Establishes requirements for surface impoundments, waste piles used to treat wastes, and areas in which hazardous waste is place on soils for treatment or immobilization.	These are action-specific requirements for sediment dewatering and ex situ treatment.

Table 5.1. (contd)

Source	Standard, Requirement, Criteria, or Limitation	Applicable or Relevant and Appropriate	Description of Standard, Requirement, Criteria, or Limitation	Manner in Which ARAR Applies to Alternative (Location- or Action-Specific ARAR)
RCRA, Subtitle C; HWCA	40 CFR, Part 264, Subpart N as implemented through 22 CCR, Div. 4.5, Chapter 14, Article 11 (Landfills)	Applicable or relevant and appropriate	Establishes requirements for landfill disposal units	These are action-specific ARARs for onsite disposal activities.
RCRA, Subtitle C; HWCA	40 CFR, Part 268 as implemented through 22 CCR §66268 (Land Disposal Restrictions)	Applicable	LDRs apply to the placement of hazardous waste in a land-based RCRA unit. Sets maximum contaminant concentration limits or specifies treatment technology to be used prior to land disposal of specified hazardous wastes.	LDRs for wood treater listed wastes F032, F034, and F035 became effective in August 1997. Action-specific ARAR; however, LDRs do not apply to site activities involving land-based treatment within an area of containment (AOC) or a Corrective Action Management Unit (CAMU). Potentially applies to surface impoundments and onsite landfilling. (Offsite shipment of hazardous waste would also need to comply with LDRs.)
RCRA, Subtitle C; HWCA	40 CFR Part 268 (§268.50) as implemented by 22 CCR §66268.50	Applicable	Regulates storage of land-banned wastes. Storage of more than one year requires demonstration that such storage is solely for the purpose of accumulation to allow for proper recovery, treatment, and disposal.	This is an action-specific ARAR that would potentially apply to storage of treatment residuals.
RCRA, Subtitle C; HWCA	40 CFR, Part 262 as implemented through 22 CCR, Div. 4.5, Chapter 12 §66262 et seq., (RCRA Standards Applicable to Generators of Hazardous Waste)	Applicable	Standards for generators of hazardous waste when the remedial action constititutes TSD of hazardous waste.	This is an action-specific ARAR. Standards apply to alternatives involving generation of hazardous wastes such as dredged sediment and treatment residuals.

Table 5.1. (contd)

Source	Standard, Requirement, Criteria, or Limitation	Applicable or Relevant and Appropriate	Description of Standard, Requirement, Criteria, or Limitation	Manner in Which ARAR Applies to Alternative (Location- or Action-Specific ARAR)
RCRA, Subtitle C; HWCA	40 CFR, Part 264, Subparts AA and BB, as implemented through 22 CCR, §66264	Applicable	Regulates air emissions from process vents.	This is an action-specific ARAR that applies to treatment units such as for solvent extraction.
RCRA, Subtitle C; HWCA	40 CFR, Part 264, Subpart S (Corrective Action Management Unit), as implemented through 22 CCR, §66264.552	Applicable	Allows designation of a Corrective Action Management Unit (CAMU) for placement of hazardous waste without violating LDRs.	Action-specific ARAR. CAMU designation would be made in connection with soil alternative options and is discussed in more detail in the Soils and Groundwater FS report.
Federal Clean Air Act, 42 USC §7401 et seq. (CAA)	San Joaquin Valley Unified Air Pollution Control District (SJVUAPCD), Rule 202, Section 301	Applicable	Requires the installation of Best Available Control Technology (BACT) to a new emissions unit or modification of an existing emissions unit that will result in emissions of Rog, Nox, Sox, PM10, or CO.	Action specific ARAR that would apply to any sediment treatment unit.
CAA	SJVUAPCD Rule 202, Section 302	Applicable	Requires offset for any stationary source with the potential to emit any pollutant in excess of specific levels for Rog, Nox, Sox, PM10, or CO.	Action-specific ARAR that would apply to any sediment treatment unit.
CAA	SJVUAPCD Rule 403	Applicable	Requires reasonable precautions to prevent fugitive dust emissions from being airborne beyond the property line from the point of origin.	Action-specific ARAR applicable to remedial activities that may cause the release of fugitive dust, including dredging, dewatering, excavation, and construction.
CAA	SJVUAPCD Rule 4201	Applicable	Prohibits the release or discharge from any single source operation of dust, fumes or total suspended particulate emission in excess of 0.1 grain per standard cubic foot.	Action-specific ARAR. Applicable to any remedial activities that may cause the release of fugitive dust, including dredging, excavation and construction.

Table 5.1. (contd)

Source	Standard, Requirement, Criteria, or Limitation	Applicable or Relevant and Appropriate	Description of Standard, Requirement, Criteria, or Limitation	Manner in Which ARAR Applies to Alternative (Location- or Action-Specific ARAR)
CAA	SJVUAPCD Rule 4202	Applicable	Establishes emission rates to control the discharge of dust and condensed fumes.	Action-specific ARAR applicable to any remedial activity that may cause the release of dust or condensed fumes, including dredging, excavation, and construction.
CAA	SJVUAPCD Rule 401	Applicable	Prohibits the discharge of air contaminants that obscure visibility by more than 20% for a period of more than three minutes in any one hour.	Action-specific ARAR that would apply to construction activities.
CAA	SJVUAPCD Rule 4102 (Nuisance)	Applicable	Prohibits the discharge of air contaminants in quantities that cause injury, detriment, nuisance or annoyance to any considerable number of persons or that endangers the comfort, response, health or safety, or that tends to cause injury or damage to business or property.	Action-specific ARAR that applies to any remedial activity that constitutes a source that emits air contaminants or other materials such as an onsite treatment unit.
CAA	SJVUAPCD Rule 8020	Applicable or Relevant and Appropriate	Requires (i) appropriate dust control measures, (ii) stabilization of disturbed area during the activity to effectively limit visible dust emissions or VDE (defined as view opacity greater than 40% for three minutes in any one hour), and (iii) effective limitation of VDE on unpaved onsite and offsite access roads.	Action-specific ARAR. Applies to any construction, demolition, excavation, extraction and water mining related disturbances of soil, including land clearing, ground excavation, land leveling, grading, cut and fill operations, travel on and to the site via access roads, demolition and the initial construction of landfills. Relevant and appropriate to capping.
CAA	SJVUAPCD Rule 8030 (Control of PM10 from Handling and Storage of Bulk Materials)	Applicable	Requires appropriate control measures for transporting bulk materials in open vehicles, trailers, rail cars, or containers and stabilization of stored bulk materials to effectively limit VDE.	Action-specific ARAR. Does not apply to earth movers used to add or remove bulk material from storage piles when conducting onsite operations.

Table 5.1. (contd)

Source	Standard, Requirement, Criteria, or Limitation	Applicable or Relevant and Appropriate	Description of Standard, Requirement, Criteria, or Limitation	Manner in Which ARAR Applies to Alternative (Location- or Action-Specific ARAR)
Endangered Species Act of 1973, 16 USC §1531 <u>et seq</u>.		Applicable	Requires identification of threatened or endangered species within the geographical area	Location-specific ARAR. EPA must identify whether a threatened or endangered species or its critical habitat will be affected by a proposed response action. If so, EPA must take mitigation measures in order to proceed.
	Exec. Order 11988, Floodplain Management	Applicable	Requires federal agencies to evaluate the potential effects of actions they may take in a floodplain to avoid adverse impacts associated with direct and indirect development of a floodplain.	Location-specific ARAR as the M&B site is located in a 100-year floodplain.

Table 5.2. Comparative Analysis Summary for Sediment Remedial Alternatives

Alternative	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume Through Treatment	Short-Term Effectiveness	Implementability	Cost ($ Million)
SD -1: No Action	Does not provide protection for human health or the environment. No remedial action is taken to address sediment contamination.	Does not comply with ARARs.	Does not reduce long-term risks to acceptable levels. Current risks would remain unchanged for hundreds to thousands of years.	Does not provide treatment.	Does not create short-term risks because no remedial action is performed.	Not administratively feasible because no action would conflict with objectives of other environmental and public health agencies.	Capital: $0 30 Year O&M: $0.33 (Monitoring) Total Present Worth Cost: $0.33
SD-2: In-Situ Capping	Reduces risk to the aquatic ecosystem by isolating contaminated sediments from benthic and water column organisms. By reducing contaminant uptake by water column organisms, levels of contaminants in fish that may be consumed by humans are expected to be reduced to safe levels. Contaminated sediments continue to be a potential, although relatively minor, threat to groundwater. (However, any migration of contaminants from sediment to groundwater would be captured by the onsite groundwater extraction system for the Soils-Groundwater OU.) Institutional controls would prevent exposure to isolated areas of contamination in the MTH portion of the slough.	Expected to comply with ARARs.	Although contaminated sediment remains in place, it is isolated by a sand cap (and an armored cap where necessary). However, capping is not a permanent remedy without an appropriate long-term inspection and maintenance program. Because Old Mormon Slough represents a low-energy system, natural deposition of clean sediment is expected to occur over time.	Does not provide treatment. However, capping would reduce the potential for resuspension and transport of contaminated sediment (i.e., mobility).	There would be some risks to workers installing the cap. Capping would have severe short-term impacts on the benthic community in Old Mormon Slough. Completion time for the cap is estimated at 1 to 2 months.	Capping is technically the easiest alternative to implement. Capping will raise the bottom of the slough a minimum of 0.6 m (2 ft). A long-term inspection and maintenance program is necessary to ensure cap integrity. Institutional controls would need to be implemented as part of the remedy.	Capital: $1.21-2.37 30 Year O&M: $0.57-0.64 Total Present Worth Cost: $1.85-2.94
SD-3: Dredging and Confined Disposal	Risk reduction is slightly greater than SD-2. Contaminated sediment would be removed from the OWP and CPA portions of the slough; however, it would be contained in a confined disposal facility in the END portion of the slough. Some deeper contamination may remain in the CPA section, requiring a sand cap after dredging. Potential threats to groundwater would be reduced in the OWP and CPA portions. The confined disposal facility would contain dewatered sediment above the water table and would be covered with a cap to prevent infiltration. Institutional controls would prevent exposure to isolated areas of contamination in the MTH section of the slough.	Expected to comply with ARARs.	Completely removes contaminated sediment from the OWP portion of the slough. Deeper contamination may remain in the CPA portion below depths that are considered technically feasible to dredge; this would be isolated by a CPA sand cap. The cap and confined disposal facility are not permanent remedies without an appropriate long-term inspection and maintenance program. Because Old Mormon Slough represents a low-energy system, natural deposition of clean sediment is expected to occur over time.	Does not provide treatment, but reduces the volume of contaminated sediment available for uptake by aquatic organisms by removal, isolation in a confined disposal facility, and capping.	Risks to workers are greater than for SD-2 because of the potential for direct contact with sediments during dredge and fill operations. Would have significant short-term impacts on the aquatic ecosystem. Habitat would be permanently lost by construction of the confined disposal facility. Time to complete SD-3 is estimated at 4 to 10 months.	SD-3 is more difficult to implement than SD-2 because it requires dredging, dewatering and construction of a confined disposal facility in the END portion of the slough. However, the capping area is smaller under this alternative. A long-term inspection and maintenance program is necessary to ensure integrity of the cap and confined disposal facility. Installation of silt curtains would be necessary during dredge and fill operations. Filling a portion of Old Mormon Slough may not be acceptable to the community, adjacent landowners and regulatory agencies. Institutional controls would need to be implemented as part of the remedy.	Capital: $2.01-2.46 30 Year O&M: $0.42-0.48 Total Present Worth Cost: $2.43-2.94

Table 5.2. (contd)

Alternative	Overall Protection of Human Health and the Environment	Compliance with ARARs	Long-term Effectiveness and Permanence	Reduction in Toxicity, Mobility, and Volume Through Treatment	Short-Term Effectiveness	Implementability	Cost ($ Million)
SD-4: Dredging and Offsite Disposal	SD-4 provides a greater degree of protectiveness than SD-2 or SD-3 because all accessible sediment contamination would be removed from Old Mormon Slough and disposed off-site. Some deeper contamination may remain in the CPA and END portion, requiring a sand cap after dredging. Potential threats to groundwater would be reduced in the OWP portion. Institutional controls would prevent exposure to isolated areas of contamination in the MTH portion of the slough.	Expected to comply with ARARs.	Completely removes all accessible sediment contamination from Old Mormon Slough. Some deeper contamination may remain in the CPA and END sections, requiring a sand cap after dredging. Institutional controls would prevent exposure to isolated areas of contamination in the MTH portion of the slough. The cap is not a permanent remedy without an appropriate long-term inspection and maintenance program. Because Old Mormon Slough represents a low-energy system, natural deposition of clean sediment is expected to occur over time.	Does not provide treatment, but the majority of contaminated sediment would be removed from the site.	Risks to workers are approximately the same as for SD-3 because of the potential for direct contact with sediments. Dredging would have significant short-term impacts on the aquatic ecosystem. There would be potential risks to the public from the transportation of hazardous material to the offsite treatment, storage, and disposal facility. Time to complete SD-4 is estimated at 4 months up to 10 months due to potential transportation coordination delays.	Implementation of dredging, dewatering and capping for SD-4 is similar to that for SD-3. However, excavated soils would be transported from the site for offsite disposal and/or treatment. Depending on their waste classification, there may be a limited number of facilities able to accept the sediment. Waste is expected to require treatment prior to disposal in order to meet land disposal requirements. A long-term inspection and maintenance program is necessary to ensure cap integrity. Installation of silt curtains would be necessary during dredge and fill operations. Institutional controls would need to be implemented as part of the remedy.	Capital: $39.1-350.5 30 Year O&M: $0.44-0.55 Total Present Worth Cost: $39.6-351.0
SD-5: Dredging and Onsite Treatment	SD-5 provides approximately the same degree of protectiveness as SD-4. All accessible sediment contamination would be removed from Old Mormon Slough. Sediment would be treated and disposed in the upland area of the site. As with SD-4, some deeper contamination may remain in the CPA and END sections, requiring a sand cap after dredging. Potential threats to groundwater would be reduced in the OWP portion. Institutional controls would prevent exposure to isolated areas of contamination in the MTH portion of the slough.	Expected to comply with ARARs. May require treatment within the same area of contamination or designation of a CAMU.	As with SD-4, completely removes all accessible sediment contamination from Old Mormon Slough. Some deeper contamination may remain in the CPA and END portions, requiring a sand cap after dredging. Institutional controls would prevent exposure to isolated areas of contamination in the MTH portion of the slough. The cap is not a permanent remedy without an appropriate long-term inspection and maintenance program. Because Old Mormon Slough represents a low-energy system, natural deposition of clean sediment is expected to occur over time.	Provides treatment of the contaminated sediment, using solvent extraction to address the organic contaminants followed by solidification/stabilization (S/S) to address the metals contamination. Solvent extraction reduces toxicity, mobility and volume of organic contaminants; S/S does not reduce volume or toxicity, but immobilizes hazardous constituents into a solid matrix, thereby limiting the potential for contaminant release. Secondary wastes would be generated from the solvent extraction process that would need to be treated and disposed of. Use of stabilizing reagents increases the volume of treated soil.	Short-term risks to workers are higher than for SD-4 due to onsite treatment operations and increased handling of contaminated sediment. There is a potential for dust generation during treatment operations, which would require controls and mitigation measures to reduce impacts to site workers and nearby residents. Time to complete SD-5 is estimated at 4 to 10 months.	Most technically complex alternative with the greatest implementation concerns. Availability of solvent extraction vendors may be limited. Extensive testing may be necessary to evaluate treatment efficiency of the technology. Residuals generated during the solvent extraction process would need to be treated and disposed of. Treatment greatly increases handling of contaminated sediments over the other alternatives. Volume would be increased during the S/S process, and upland disposal of the large volume of treated sediment may be a problem.	Capital: $66.7-67.1 30 Year O&M: $0.44-0.55 Total Present Worth Cost: $67.2-67.7

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APPENDIX A

NATURAL ATTENUATION OF PAHS

APPENDIX A: NATURAL ATTENUATION OF PAHs

Natural attenuation is defined as the degradation of contaminants by natural processes without assistance from humankind. This process, also called intrinsic remediation, can be mediated through geochemical reactions or microbial activity. However, since the PAHs at the McCormick and Baxter Superfund Site are organic chemicals, intrinsic microbial activity might be expected to remediate the contamination over time. Calculations based on a recent paper (Huesemann and Truex 1997) estimated the potential for using natural attenuation as a remedial alternative (i.e., the No-Action alternative).

The microbial degradation of PAHs is an aerobic process; the bacteria require oxygen to grow and metabolize the contamination. In this study, the media of concern, with respect to PAH contamination, is the sediment in Old Mormon Slough. Since the sediment is under water, transport of oxygen to the bacteria in the sediment is likely to be a limiting factor. The paper by Huesemann and Truex describes a method for calculating oxygen diffusion distances and total cleanup times for moist, but not saturated, soils. This analysis can be applied with slight modifications to Old Mormon Slough if the diffusion coefficient of oxygen in the sediment pore water is substituted for the diffusion coefficient of oxygen in unsaturated soil. Also, the sediment properties must be used instead of the unsaturated soil properties. In this approach, the thickness of a layer of sediment that will be treated in a fixed time span is calculated, incorporating both the diffusion of oxygen and the consumption of oxygen (due to microbial activity). Once a layer has been “treated” the oxygen can diffuse deeper and stimulate bacteria in the next layer.

For the natural attenuation calculations, the following assumptions are used to represent a “best case” scenario:

a) Oxygen concentration in the water above the sediment (C_{oxygen}) is a constant 8 mg/L.

b) The PAHs are the sole carbon source for the microbes. This is an optimistic assumption because sediment organic matter is likely to be present in the sediment.

c) The depth of contamination is assumed to be 0.91 meters (from the sediment surface to 3 feet below the sediment surface).

d) The PAH contamination is assumed to be uniformly distributed at a concentration of 1000 mg/kg (White and Kohn 1996). All of this contamination is assumed to be biodegradable.

e) The sediment is assumed to have a bulk density (p_{bulk}) of 1.5 g/cm^3.

f) The diffusivity of oxygen through water ($D_{oxygen,water}$) is $2.5 \cdot 10^{-5}$ cm^2/s (Perry and Green 1984).

g) The diffusion of oxygen through the sediment (D_s) is assumed to be unaffected by the tortuosity of the pores in the sediment. Thus, D_s = tortuosity · $D_{oxygen,water}$, where tortuosity = 1. D_s is also assumed to be constant throughout the depth of interest.

h) The degradation rate of PAHs (r_{PAH}) is arbitrarily assumed to be 1 mg/(kg·day). It is assumed that oxygen is the only limiting nutrient. As shown below, the choice of PAH biodegradation rates has little impact on the total cleanup times.

i) Once the microbes have mineralized the PAHs in a “layer” of sediment, the residual (non-biodegradable) PAHs do not affect oxygen diffusion to deeper layers of sediment.

j) The oxygen concentration in a “treated” layer is equal to the concentration in the water above the sediment.

k) The primary microbial reaction is the mineralization of the PAHs. Minimal biomass formation is assumed.

l) The rate of oxygen consumption (r_{oxygen}) is assumed to be constant when the oxygen concentration is greater than zero.

The reaction for the complete mineralization of a low molecular weight PAH ($C_{12}H_{10}$ is assumed here) is shown in Equation 1. The ratio of mass of oxygen consumed per mass of PAH degraded is derived from the stoichiometry of this reaction and is equal to 3.0 g O_2/g PAH. If a high molecular PAH (e.g., $C_{18}H_{12}$) is completely mineralized, the ratio is 2.94 g O_2/g PAH, which is of similar magnitude.

$$C_{12}H_{10} + 14.5\ O_2 \rightarrow 12\ CO_2 + 5\ H_2O \qquad \text{(Equation 1)}$$

The rate of oxygen consumption can now be calculated from the mass ratio and the rate of PAH biodegradation (Equation 2). The sediment bulk density is needed for the proper unit conversion.

$$r_{oxygen} = (3.0) \quad (\rho_{bulk}) \quad (r_{PAH})$$

$$\left[\frac{mg\ O_2}{L \cdot day}\right] = \left[\frac{mg\ O_2}{mg\ PAH}\right]\left[\frac{kg\ soil}{L\ soil}\right]\left[\frac{mg\ PAH}{kg\ soil \cdot day}\right] \qquad \text{(Equation 2)}$$

The distance that oxygen will penetrate after the nth layer is cleaned, L_n, is calculated using Equation 3 (Huesemann and Truex 1997). L_0 is equal to zero for our case because the contamination starts at the surface of the sediment. There is a factor of 86,400 in Equation 3 to convert from seconds to days. The factor of 2 (and the equation itself) is a result of the integration of the oxygen concentration equation and application of boundary conditions.

$$L_n = \sqrt{\frac{(2)(D_s)(C_{oxygen})(86400)}{r_{oxygen}} + (L_{n-1})^2} \qquad \text{(Equation 3)}$$

We know the thickness of the contamination (i.e., L_n). What we need to determine is the number of layers (n). Equation 3 can be solved iteratively for the value of n. Figure A.1 gives a conceptual view of the contaminated sediment showing consecutive layers. There could be many layers depending on the oxygen consumption and diffusion rates.

The time it takes to degrade the PAHs in a single layer (Δt_{layer}) is a function of the initial PAH concentration (C_{PAH}) and the rate of PAH degradation (r_{PAH}) as shown in Equation 4. The period of time required for natural microbial activity to degrade the PAHs for the whole thickness of contaminated sediment is determined by the number of layers (n) times the clean-up time per layer.

$$\Delta t_{layer} = \frac{C_{PAH}}{r_{PAH}} \qquad \text{(Equation 4)}$$

Using the above assumptions and equations, the time required to degrade the PAHs to a depth of 3 feet in the sediment would be 2,978 years. An increase in the PAH degradation rate does not significantly alter the remediation time because the degradation rate has a minor contribution to these calculations. Increasing the rate to 100 mg/(kg·day) results in a total clean-up time of 2,976 years. Consequently, it appears that without outside assistance oxygen limitations are too great for natural attenuation to treat the Old Mormon Slough sediment in a practical time.

It should be kept in mind that the above calculations were done with assumptions aimed at a best case scenario. The Old Mormon Slough is unlikely to be saturated with oxygen (8 mg/L) because of other organisms in the water that are likely to consume oxygen. Thus, the amount of oxygen available to diffuse into the sediment would be less. The diffusion will be hampered by the fact that the sediment is a porous medium and has an associated tortuosity. The diffusion of oxygen through the pore water will be retarded because of dead-end pores and contorted paths that must be followed. The bacteria in the sediment may preferentially metabolize the non-PAH carbon because it may be easier to biodegrade than PAHs. However, the non-PAH organic carbon that is present in the sediment was ignored in the above calculations.

The depth of the contamination was estimated at 3 feet, but it is known that there is contamination down to 18 feet below the mudline in at least some areas (White and Kohn 1996). While the deeper contamination may be determined to not be a risk, any increase in the depth that must be treated would increase the time required for natural attenuation.

If the assumption about the biodegradable PAH concentration were modified, the time for remediation of the sediment would not be as long. The above calculations were repeated with the same parameter values, except that an initial biodegradable PAH concentration of 50 mg/kg was used. Under these conditions, the resulting time required for natural attenuation to clean the sediment would be 149 years. Note that all of these calculations apply to biodegradable PAHs. Non-biodegradable PAHs will persist in the environment (or degrade at a much slower rate).

The natural attenuation (No-Action) remediation alternative appears to be an inappropriate stand-alone solution to the PAHs in the sediment of the Old Mormon Slough at the McCormick and Baxter Superfund Site. Further site characterization and risk assessment could be used to determine if certain portions of the Slough contain low concentrations of PAHs or they are inaccessible to an extent that intrinsic processes may be enough to protect human health and the environment.

References

Huesemann, M. H., and M. J. Truex. 1997. “The Role of Oxygen Diffusion in Passive Bioremediation of Petroleum Contaminated Soils.” Accepted for publication in *J. Hazardous Materials*.

Perry, R. H., and D. W. Green, eds. 1984. *Perry's Chemical Engineering Handbook*, McGraw-Hill, New York, pg. 3-259.

White, P. J., and N. P. Kohn. 1996. *Remedial Investigation of the Surface Water Operable Unit, McCormick and Baxter Superfund Site, Stockton, California*. PNNL-11418, Pacific Northwest National Laboratory, Richland, Washington.

Figure A.1. Conceptual Section of the Contaminated Thickness of Sediment. An example oxygen concentration profile is shown for the point where the PAHs in first layer have been biodegraded.

APPENDIX B

SEDIMENT VOLUME AND CONTAMINANT MASS ESTIMATES

APPENDIX C

REMEDIAL ACTION ALTERNATIVE COST ESTIMATES

APPENDIX C: REMEDIAL ACTION ALTERNATIVE COST ESTIMATES

This appendix presents an order-of-magnitude construction cost estimate for each of the five alternatives described in Sections 4.0 and 5.0. Cost is one of the seven criteria to evaluate the alternatives. A summary of the capital costs, annual operation and maintenance (O&M) costs, and the present worth costs is provided in Table C.1.

Table C.1. Summary of Estimated Remedial Alternative Costs

Alternative		Capital Cost	Annual O&M Cost	Annual Monitoring Cost	Present Worth of Annual Operations and Maintenance Cost(a)	Present Worth of Annual Monitoring Cost(a)	Total Present Worth Cost(a)
SD-1	No Action	$000	$000	$21,000	$0	$326,000	$326,000
SD-2a	In Situ Capping	$1,207,000	$10,000	$32,000	$153,000	$489,000	$1,849,000
SD-2b		$2,368,000	$6,000	$32,000	$85,000	$489,000	$2,941,000
SD-3a	Confined Disposal	$2,010,000	$3,000	$25,000	$44,000	$378,000	$2,432,000
SD-3b		$2,464,000	$5,000	$26,000	$72,000	$406,000	$2,941,000
SD-4a	Offsite Disposal	$39,110,000	$3,000	$25,000	$53,000	$389,000	$39,551,000
SD-4b		$350,459,000	$7,000	$29,000	$105,000	$441,000	$351,005,000
SD-4c		$350,193,000	$3,000	$25,000	$53,000	$389,000	$350,634,000
SD-5a	Onsite Treatment	$66,728,000	$3,000	$25,000	$53,000	$389,000	$67,170,000
SD-5b		$67,179,000	$7,000	$29,000	$105,000	$441,000	$67,726,000

(a) Present worth of capital and operations and maintenance cost, assuming 30 years at 5 percent.

C.1 OVERVIEW OF FEASIBILITY COST ESTIMATES

Cost estimates are rounded up to the nearest $1,000.00. These estimates were prepared using current pricing data, when available, to aid in the evaluation of alternatives. Final project costs will depend on actual labor and material costs, actual site conditions at the time of remediation, productivity, competitive market conditions, final project scope, final project schedule, the firm selected to perform the engineering, and many other variables. As a result, the final project cost will differ from the estimates presented here. Because of the inherent variability, financial needs and resources must be carefully reviewed before decisions are made or final remedial action budgets are estimated.

The cost estimates are order-of-magnitude cost estimates with an intended accuracy of +50 percent and -30 percent. This range applies only to the alternatives as described in Section 4.0 and 5.0 and does not account for major changes in the scope of any alternative. The specific technologies for each alternative were not selected with the intent of limiting flexibility in the remedial approach, but rather to provide a basis for cost estimating. The actual remedial actions and their associated costs will be determined when EPA selects the approach for the final design.

Cost estimates include total capital cost, annual O&M costs, and total present worth costs for each alternative. Both capital and unit price costs are based on information solicited from local contractors and from engineering judgement.

C.1.1 Capital Costs

Capital costs are the direct and indirect costs required to initiate and install the components of a remedial action. They include only those expenditures needed to design, construct, and install a remedial action. They exclude the costs needed to maintain a remedial action throughout its design life.

Installation costs include items such as costs for construction, site development, and buildings and services. Construction costs include costs needed to prepare for, or implement the actions, such as the costs for materials, labor, and equipment. These costs have been adjusted for the Stockton, California area wherever possible. Decontamination facilities, health and safety equipment, and costs associated with confirmatory sampling have also been included where possible.

Indirect costs consist of engineering, supervision during construction, licenses and permits, and other services necessary to carry out a remedial action. They are not incurred as part of the remedial action but are ancillary to installation and construction costs. Indirect capital costs include bid and scope contingencies that reduce the likelihood of a cost overrun. Bid contingencies cover unknowns associated with the construction of the project, such as material or labor shortages. Scope contingencies include provisions for changes that normally occur as part of the final design and implementation. EPA and the State of California administration are also indirect costs, but they have not been included in the cost estimate.

C.1.2. Annual Operating Costs

Annual operating costs for a remedial action include the costs incurred each year following construction or installation of a project. For the purposes of the economic evaluation, they are assumed to be paid at the end of the year in which they occur.

C.1.3 Present Worth Costs

Annual O&M costs occur over different periods of time for different alternatives. Present worth analyses provide a method for comparing costs that occur over different periods of time by discounting future costs to the present year. Present worth calculations were based on a maximum 30-year period. O&M costs that are incurred beyond the 30-year period become insignificant in the present worth analysis. The present worth analyses were calculated assuming 3, 5, and 10 percent interest rates in order to provide a range of values. Future costs are not escalated for inflation.

C.2 PRESENTATION OF ALTERNATIVE COSTS

The estimated costs calculated for each alternative are presented in the following attachments:

Alternative SD-1	No Action
Alternative SD-2	In Situ Capping
	a. Sand Cap with 10% Armoring
	b. Armored Cap
Alternative SD-3	Confined Disposal
	a. CPA Cap Only
	b. CPA & OWP Cap
Alternative SD-4	Offsite Disposal
	a. CPA & END Cap Only
	b. Full Cap
	c. CPA/END Cap plus temporary dam
Alternative SD-5	Onsite Treatment
	a. CPA & END Cap Only
	b. Full Cap

ALTERNATIVE SD-1
- NO ACTION -
Order-of-Magnitude Cost Estimate

Description:

Requires no action, except monitoring. Physical and contaminant monitoring would be performed to confirm that net sedimentation rates are keeping contaminated sediment buried and relatively isolated from the ecosystem and to assess the rate and effectiveness of natural attenuation processes. Sediment, water, and biota sampling and analyses would be performed initially to establish a baseline and then to monitor the long-term stability and natural degradation of residual contamination.

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
CAPITAL COSTS						
No Action Required	0				0	$0
CONSTRUCTION COST SUBTOTAL						$0
Mobilization and & Gen'l Reqm'ts @ 15%						$0
CONSTRUCTION COST SUBTOTAL						$0
Contingencies						
Bid Contingency @ 10%			10%			$0
Scope Contingency @ 20%			20%			$0
Other Costs						
Administrative @ 5%			5%			$0
Services During Construction @ 10%			10%			$0
Legal @ 5%			5%			$0
IMPLEMENTATION COST TOTAL						$0
Engineering/Design @ 15% ($1,500 min.)			15%			$0
CAPITAL COST TOTAL						**$0**
ANNUAL O&M COST						
No Action Required	0				0	$0
ANNUAL O&M COST TOTAL						**$0**

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
ANNUAL MONITORING COSTS						
Annual Monitoring (Years 1-30)						$21,190
Sediment & Biota Sampling and Analysis	8	EA	1,620	RACER	$12,960	
Contractor Overhead Adjustment			22%	RACER	$2,851	
Data Management & Reporting (Yearly)	75	HR	59	RACER	$4,409	
Contractor Overhead Adjustment			22%	RACER	$970	
ANNUAL MONITORING COSTS TOTAL						**$21,190**
PRESENT WORTH COSTS						
PRESENT WORTH OF O&M COSTS						
Present Worth of O&M Costs for Years 1-30						
Assuming annual cost for 1-30 years @			3%			($0)
Assuming annual cost for 1-30 years @			5%			($0)
Assuming annual cost for 1-30 years @			10%			($0)
Present Worth of Monitoring Costs for Years 1-30						
Assuming annual cost for 1-30 years @			3%			$415,337
Assuming annual cost for 1-30 years @			5%			$325,745
Assuming annual cost for 1-30 years @			10%			$199,758
ESTIMATED CAPITAL COST (from previous page)						$0
TOTAL PRESENT WORTH (CAPITAL + O&M + MONITORING COSTS)						
Assuming 30 years @			3%			$415,337
Assuming 30 years @			5%			$325,745
Assuming 30 years @			10%			$199,758

The cost estimates shown have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. Final project costs will depend on actual labor and material costs, actual site conditions at the time of remediation, productivity, competitive market conditions, final project scope, final project schedule, the firm selected to perform the engineering, and many other variables. As a result, the final project costs will differ from the estimates presented here. Because of these inherent variabilities, project feasibility and funding needs must be carefully reviewed before making specific financial decisions to help ensure proper project evaluation and adequate funding.

ALTERNATIVE SD-2a
- IN SITU CAPPING WITH 10% ARMORING -
Order-of-Magnitude Cost Estimate

Description:

This alternative will cap the principal threat areas of Old Mormon Slough and will implement institutional controls for low-level threat areas. A 710-m- (2,330-ft)-long stretch of the slough will be capped with fine sand to isolate a preponderance of the dioxin and PAH contamination. Two hot spots, one of PAH contamination and one of dioxin contamination located in the mouth of the slough, will be isolated via the use of institutional controls.

The cap would be installed after minimal preparation of the slough bed (removal of rubble, pilings, etc.), and would consist of a 60-cm- (2-ft)-thick layer of clean fine sand spread across the bottom of the slough. An estimated 10% of the surface area of the cap would be armored with rip-rap and an underlying gravel filler layer to protect areas most susceptible to erosion (e.g., near shore, or barge/boat traffic areas).

Assumptions:

These costs assume there is a local source (within 50 miles) of suitable cap materials. An estimated 23,900 m^3 (31,200 yd^3) of clean sand would be required for the cap (assuming a 10% safety factor). It is also assumed there is very little debris that would require removal before cap placement, and that this debris is small, and would be consolidated with upland soil debris for disposal.

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
CAPITAL COSTS						
Physical Access Controls						$13,456
Log Boom	180	LF	50		$9,000	
Haz. Waste Signs (& No Trespass): (1/100 ft)	60	EA	61	RACER	$3,653	
Contractor Overhead Adjustment			22%	RACER	$804	
In Situ Capping						$595,000
Debris Removal and Bed Preparation	1	EA	10,000		$10,000	
Sand Cap (2 ft thick), Installed	31200	CY	15	Kohn 1996*	$468,000	
Armored Cap (10%) of Cap Area	3120	CY	38		$117,000	
CONSTRUCTION COST SUBTOTAL						$608,456
Mobilization and & Gen’l Reqm’ts @ 15%						$91,268
CONSTRUCTION COST SUBTOTAL						$699,725

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
Contingencies						
Bid Contingency @ 10%			10%			$69,972
Scope Contingency @ 20%			20%			$139,945
Other Costs						
Administrative @ 5%			5%			$34,986
Services During Construction @ 10%			10%			$69,972
Legal @ 5%			5%			$34,986
IMPLEMENTATION COST TOTAL						$1,049,587
Engineering/Design @ 15%			15%			$157,438
CAPITAL COST TOTAL						$1,207,025
ANNUAL O&M COST						
Fence and Log Boom Maintenance (Years 1-30)						$1,152
Annual Maintenance (8 hrs/month)	96	HR	12		$1,152	
Cap Maintenance						$8,800
Annual Maintenance	8.8	AC	1,000	PTI 1995	$8,800	
ANNUAL O&M COST TOTAL						$9,952
ANNUAL MONITORING COST						
Annual Monitoring (Years 1-30)						$31,783
Cap Monitoring (includes Bathymetry)	8.8	AC	1,000		$8,800	
Sediment & Biota Sampling and Analysis	8	EA	1,620	RACER	$12,960	
Contractor Overhead Adjustment			22%	RACER	$2,851	
Data Management & Reporting (Yearly)	100	HR	59	RACER	$5,879	
Contractor Overhead Adjustment			22%	RACER	$1,293	
ANNUAL MONITORING COST TOTAL						$31,783
PRESENT WORTH COSTS						
PRESENT WORTH OF O&M COSTS						
Present Worth of O&M Costs for Years 1-30						
Assuming annual cost for	30	YR	3%			$195,064
Assuming annual cost for	30	YR	5%			**$152,987**

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
Assuming annual cost for	30	YR	10%			$93,817
PRESENT WORTH OF MONITORING COSTS						
Present Worth Monitoring Costs for Years 1-30						
Assuming annual cost for	30	YR	3%			$622,964
Assuming annual cost for	30	YR	5%			**$488,585**
Assuming annual cost for	30	YR	10%			$299,617
ESTIMATED CAPITAL COST (from above)						**$1,207,025**
TOTAL PRESENT WORTH OF CAPITAL COST & O&M COST						
Assuming 30 years @			3%			$2,025,053
Assuming 30 years @			5%			**$1,848,597**
Assuming 30 years @			10%			$1,600,459

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*Kohn, N. P. 1996. Personal Communication (10/24/96), Re: Remedial Costs at the United Heckathorn Site, Richmond, California.

The cost estimates shown have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. Final project costs will depend on actual labor and material costs, actual site conditions at the time of remediation, productivity, competitive market conditions, final project scope, final project schedule, the firm selected to perform the engineering, and many other variables. As a result, the final project costs will differ from the estimates presented here. Because of these inherent variabilities, project feasibility and funding needs must be carefully reviewed before making specific financial decisions to help ensure proper project evaluation and adequate funding.

References:

Delta Research Corporation. 1996. Remedial Action Cost Engineering and Requirements System (RACER). Version 3.2. Delta Research Corporation, Niceville, Florida.

PTI Environmental Services (PTI). 1995. McCormick & Baxter Creosoting Company, Revised Feasibility Study. Prepared for Oregon Department of Environmental Quality, Portland, Oregon.

ALTERNATIVE SD-2b
- IN SITU CAPPING WITH 100% ARMORING -
Order-of-Magnitude Cost Estimate

Description:

This alternative will cap the principal threat areas of Old Mormon Slough and will implement institutional controls for low-level threat areas. A 710-m- (2,330-ft)-long stretch of the slough will be capped with fine sand to isolate a preponderance of the dioxin and PAH contamination. Two hot spots, one of PAH contamination and one of dioxin contamination located in the mouth of the slough, will be isolated via the use of institutional controls.

The cap would be installed after minimal preparation of the slough bed (removal of rubble, pilings, etc.), and would consist of a 60-cm- (2-ft)-thick layer of clean fine sand spread across the bottom of the slough armored with rip-rap and an underlying gravel filter layer.

Assumptions:

These costs assume there is a local source (within 50 miles) of suitable cap materials. An estimated 23,900 m^3 (31,200 yd^3) of clean sand would be required for the cap (assuming a 10% safety factor). It is also assumed there is very little debris that would require removal prior to cap placement, and that this debris is small, and would be consolidated with upland soil debris for disposal.

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
CAPITAL COSTS						
Physical Access Controls						$13,456
Log Boom	180	LF	50		$9,000	
Haz. Waste Signs (& No Trespass): (1/100 ft)	60	EA	61	RACER	$3,653	
Contractor Overhead Adjustment			22%	RACER	$804	
In Situ Capping						$1,180,000
Debris Removal and Bed Preparation	1	EA	10,000		$10,000	
Armored Multilayer Cap (2 ft thick), Installed	31,200	CY	38		$1,170,000	
CONSTRUCTION COST SUBTOTAL						$1,193,456
Mobilization and & Gen'l Reqm'ts @ 15%						$179,018
CONSTRUCTION COST SUBTOTAL						$1,372,475
Contingencies						
Bid Contingency @ 10%			10%			$137,247
Scope Contingency @ 20%			20%			$274,495

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
Other Costs						
Administrative @ 5%			5%			$68,624
Services During Construction @ 10%			10%			$137,247
Legal @ 5%			5%			$68,624
IMPLEMENTATION COST TOTAL						$2,058,712
Engineering/Design @ 15%			15%			$308,807
CAPITAL COST TOTAL						$2,367,519
ANNUAL O&M COST						
Fence and Log Boom Maintenance (Years 1-30)						$1,152
Annual Maintenance (8 hrs/month)	96	HR	12		$1,152	
Cap Maintenance						$4,400
Annual Maintenance	8.8	AC	500		$4,400	
ANNUAL O&M COST TOTAL						$5,552
ANNUAL MONITORING COST						
Annual Monitoring (Years 1-30)						$31,783
Cap Monitoring (includes Bathymetry)	8.8	AC	1,000		$8,800	
Sediment & Biota Sampling and Analysis	8	EA	1,620	RACER	$12,960	
Contractor Overhead Adjustment			22%	RACER	$2,851	
Data Management & Reporting (Yearly)	100	HR	59	RACER	$5,879	
Contractor Overhead Adjustment			22%	RACER	$1,293	
ANNUAL MONITORING COST TOTAL						$31,783
PRESENT WORTH COSTS						
PRESENT WORTH OF O&M COSTS						
Present Worth of O&M Costs for Years 1-30						
Assuming annual cost for	30	YR	3%			$108,822
Assuming annual cost for	30	YR	5%			**$85,348**
Assuming annual cost for	30	YR	10%			$52,338

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
PRESENT WORTH OF MONITORING COSTS						
Present Worth Monitoring Costs for Years 1-30						
Assuming annual cost for	30	YR	3%			$622,964
Assuming annual cost for	30	YR	5%			**$488,585**
Assuming annual cost for	30	YR	10%			$299,617
ESTIMATED CAPITAL COST (from above)						**$2,367,519**
TOTAL PRESENT WORTH OF CAPITAL COST & O&M COST						
Assuming 30 years @			3%			$3,099,305
Assuming 30 years @			5%			**$2,941,452**
Assuming 30 years @			10%			$2,719,475

The cost estimates shown have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. Final project costs will depend on actual labor and material costs, actual site conditions at the time of remediation, productivity, competitive market conditions, final project scope, final project schedule, the firm selected to perform the engineering, and many other variables. As a result, the final project costs will differ from the estimates presented here. Because of these inherent variabilities, project feasibility and funding needs must be carefully reviewed before making specific financial decisions to help ensure proper project evaluation and adequate funding.

Reference:

Delta Research Corporation. 1996. Remedial Action Cost Engineering and Requirements System (RACER). Version 3.2. Delta Research Corporation, Niceville, France.

ALTERNATIVE SD-3a

- DREDGING AND CONFINED DISPOSAL WITH CAPPING OF THE CPA AREA -

Order-of-Magnitude Cost Estimate

Description:

This alternative would selectively remove heavily contaminated sediment with a mechanical dredge. A silt curtain would be used to contain any sediment resuspended by dredging activities. The contaminated sediments removed from the slough would be disposed in a confined disposal facility (CDF) located behind sheetpiling in the eastern end of the slough. Residual contamination in the east end of the central processing are (CPA) and outside of the CDF would then be capped with sand. Institutional controls would be implemented to ensure the integrity of the cap and isolate low-level threat areas from the public.

Assumptions:

Total material to be dredged is assumed to be 55,400 m^3 (72,500 yd^3) removed primarily from the Oily Waste Ponds (OWP) area. An expansion factor of 20% was assumed, resulting in a disposal volume of 66,500 m^3 (87,000 yd^3) to be placed in the CDF behind sheetpiling and covered with 0.6 m (2 ft) of clean fill. This assumes that dewatering will not be required prior to disposal. The cap area would consist of 0.6 ha (1.6 ac) of the CPA. This assumes that dredging of the OWP area to a depth of 2.4 m (8 ft) will remove contamination to acceptable levels (i.e., meet the Remedial Action Objectives (RAOs). The cap would be composed of 0.6 m (2 ft) of clean sand.

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
CAPITAL COSTS						
Physical Access Controls						$13,456
Log Boom (180 ft)	180	LF	50		$9,000	
Haz. Waste Signs (& No Trespass): (1/100 ft)	60	EA	61	RACER	$3,653	
Contractor Overhead Adjustment			22%	RACER	$804	
Silt Curtain						$100,000
Installation and Maintenance	1	EA	100,000	Kohn 1996[(a)]	$100,000	
Confined Disposal						$483,187
Sheetpile Wall (60 ft deep x 230 long), Installed[(b)]	13,800	SF	20	Kohn 1996[(a)]	$276,000	
HDPE Liner (installed behind Sheetpiling)	13,800	SF	3	RACER	$34,500	
CDF Cap (Installed)						
Geotextile	16,456	SY	1	RACER	$20,879	
Soil Cover (18” thick)	12,500	CY	7	RACER	$81,250	
Top Soil (6”)	4,178	CY	7	RACER	$29,246	

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
Revegetation	3.4	AC	1,162	RACER	$3,951	
Contractor Overhead Adjustment			22%	RACER	$37,362	
Dredge and Place Material in CDF						$295,910
Mobilize Barge and Mounted Dredge	1	EA	40,000	PTI 1995	$40,000	
Dredge Highly Contaminated Area	72,500	CY	4	Kohn 1996[(a)]	$253,750	
Bulk Material Sampling (Screening - 2/day)	36	EA	60		$2,160	
In Situ Capping						$105,000
Sand Cap, Installed	5,600	CY	15	Kohn 1996[(a)]	$84,000	
Armored Cap, Installed	560	CY	38		$21,000	
Verification Sampling						$15,811
Sediment Sampling and Analysis	8	EA	1620	RACER	$12,960	
Contractor Overhead Adjustment			22%	RACER	$2,851	
CONSTRUCTION COST SUBTOTAL						$1,013,365
Mobilization and & Gen'l Reqm'ts @ 15%						$152,005
CONSTRUCTION COST SUBTOTAL						$1,165,369
Contingencies						
Bid Contingency @ 10%			10%			$116,537
Scope Contingency @ 20%			20%			$233,074
Other Costs						
Administrative @ 5%			5%			$58,268
Services During Construction @ 10%			10%			$116,537
Legal @ 5% (includes permits)			5%			$58,268
IMPLEMENTATION COST TOTAL						$1,748,054
Engineering/Design @ 15%			15%			$262,208
CAPITAL COST TOTAL						$2,010,262
ANNUAL O&M COST						
Fence and Log Boom Maintenance (Years 1-30)						$1,152
Annual Maintenance (8 hrs/month)	96	HR	12		$1,152	
Cap Maintenance						$1,707
Annual CDF Cap Maint. (Incl. Contr. Overhead)	3.4	AC	32	RACER	$107	
Annual Sand Cap Maintenance	1.6	AC	1,000	PTI 1995	$1,600	

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
ANNUAL O&M COST TOTAL						$2,859
ANNUAL MONITORING COST						
Annual Monitoring (Years 1-30)						$24,583
Sand Cap Monitoring (includes Bathymetry)	1.6	AC	1,000		$1,600	
Sediment & Biota Sampling and Analysis	8	EA	1,620	RACER	$12,960	
Contractor Overhead Adjustment			22%	RACER	$2,851	
Data Management & Reporting (Yearly)	100	HR	59	RACER	$5,879	
Contractor Overhead Adjustment			22%	RACER	$1,293	
ANNUAL MONITORING COST TOTAL						$24,583
PRESENT WORTH COSTS						
PRESENT WORTH OF O&M COSTS						
Present Worth of O&M Costs for Years 1-30						
Assuming annual cost for	30	YR	3%			$56,044
Assuming annual cost for	30	YR	5%			**$43,955**
Assuming annual cost for	30	YR	10%			$26,955
PRESENT WORTH OF MONITORING COSTS						
Present Worth of Monitoring Costs for Years 1-30						
Assuming annual cost for	30	YR	3%			$481,841
Assuming annual cost for	30	YR	5%			**$377,904**
Assuming annual cost for	30	YR	10%			$231,743
ESTIMATED CAPITAL COST (from above)						**$2,010,262**
TOTAL PRESENT WORTH OF CAPITAL COST & O&M COST						
Assuming 30 years @			3%			$2,548,148
Assuming 30 years @			5%			**$2,432,121**
Assuming 30 years @			10%			$2,268,961

(a) Kohn, N. P. 1996. Personal Communication (10/24/96), Re: Remedial Costs at the United Heckathorn Site, Richmond, California.

(b) Stinson (1992) reports unit costs of 16 to 28 sq/ft.

The cost estimates shown have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. Final project costs will depend on actual labor and material costs, actual site conditions at the time of remediation, productivity, competitive market conditions, final project scope, final project schedule, the firm selected to perform the engineering, and many other variables. As a result, the final project costs will differ from the estimates presented here. Because of these inherent variabilities, project feasibility and funding needs must be carefully reviewed before making specific financial decisions to help ensure proper project evaluation and adequate funding.

References:

Delta Research Corporation. 1996. Remedial Action Cost Engineering and Requirements System (RACER). Version 3.2. Delta Research Corporation, Niceville, Florida.

PTI Environmental Services (PTI). 1995. McCormick & Baxter Creosoting Company, Revised Feasibility Study. Prepared for Oregon Department of Environmental Quality, Portland, Oregon.

Stinson, M. K. 1992. Contaminants and Remedial Options at Wood Preserving Sites. EPA/600/R-92/182. U.S. Environmental Protection Agency, Cincinnati, Ohio.

ALTERNATIVE SD-3b
- DREDGING AND CONFINED DISPOSAL WITH CAPPING OF THE CPA & OWP AREAS -
Order-of-Magnitude Cost Estimate

Description:

This alternative would selectively remove heavily contaminated sediment with a mechanical dredge. A silt curtain would be used to contain any sediment resuspended by dredging activities. The contaminated sediments removed from the slough would be disposed in a CDF located behind sheetpiling in the eastern end of the slough. Residual contamination in the OWP and CPA and outside of the CDF would then be capped with sand. Institutional controls would be implemented to ensure the integrity of the cap and isolate low-level threat areas from the public.

Assumptions:

Total material to be dredged is assumed to be 55,400 m^3 (72,500 yd^3) removed primarily from the OWP area. An expansion factor of 20% was assumed, resulting in a disposal volume of 66,500 m^3 (87,000 yd^3) to be placed in the CDF behind sheetpiling and covered with 0.6 m (2 ft) of clean fill. This assumes that dewatering will not be required prior to disposal. The cap area would consist of 1.4 ha (0.6 ac) of the CPA. The cap would be composed of 0.6 m (2 ft) of clean sand.

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
CAPITAL COSTS						
Physical Access Controls						$13,456
Log Boom (180 ft)	180	LF	50		$9,000	
Haz. Waste Signs (& No Trespass): (1/100 ft)	60	EA	61	RACER	$3,653	
Contractor Overhead Adjustment			22%	RACER	$804	
Silt Curtain						$100,000
Installation and Maintenance	1	EA	100,000	Kohn 1996[a]	$100,000	
Confined Disposal						$483,187
Sheetpile Wall (60 ft deep x 230 long), Installed[b]	13,800	SF	20	Kohn 1996[a]	$276,000	
HDPE Liner (installed behind Sheetpiling)	13,800	SF	3	RACER	$34,500	
CDF Cap (Installed)						
Geotextile	16,456	SY	1	RACER	$20,879	
Soil Cover (18” thick)	12,500	CY	7	RACER	$81,250	
Top Soil (6”)	4,178	CY	7	RACER	$29,246	
Revegetation	3.4	AC	1,162	RACER	$3,951	
Contractor Overhead Adjustment			22%	RACER	$37,362	

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
Dredge and Place Material in CDF						$295,910
Mobilize Barge and Mounted Dredge	1	EA	40,000	PTI 1995	$40,000	
Dredge Highly Contaminated Area	72,500	CY	4	Kohn 1996[(a)]	$253,750	
Bulk Material Sampling (Screening - 2/day)	36	EA	60		$2,160	
In Situ Capping						$333,750
Sand Cap, Installed	17,800	CY	15	Kohn 1996[(a)]	$267,000	
Armored Cap, Installed	1,780	CY	38		$66,750	
Verification Sampling						$15,811
Sediment Sampling and Analysis	8	EA	1,620	RACER	$12,960	
Contractor Overhead Adjustment			22%	RACER	$2,851	
CONSTRUCTION COST SUBTOTAL						$1,242,115
Mobilization and & Gen'l Reqm'ts @ 15%						$186,317
CONSTRUCTION COST SUBTOTAL						$1,428,432
Contingencies						
Bid Contingency @ 10%			10%			$142,843
Scope Contingency @ 20%			20%			$285,686
Other Costs						
Administrative @ 5%			5%			$71,422
Services During Construction @ 10%			10%			$142,843
Legal @ 5% (includes permits)			5%			$71,422
IMPLEMENTATION COST TOTAL						$2,142,648
Engineering/Design @ 15%			15%			$321,397
CAPITAL COST TOTAL						$2,464,045
ANNUAL O&M COST						
Fence and Log Boom Maintenance (Years 1-30)						$1,152
Annual Maintenance (8 hrs/month)	96	HR	12		$1,152	
Cap Maintenance						$3,507
Annual CDF Cap Maint. (Incl. Contr. Overhead)	3.4	AC	32	RACER	$107	
Annual Sand Cap Maintenance	3.4	AC	1,000	PTI 1995	$3,400	
ANNUAL O&M COST TOTAL						$4,659

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
ANNUAL MONITORING COST						
Annual Monitoring (Years 1-30)						$26,383
Sand Cap Monitoring (includes Bathymetry)	3.4	AC	1,000		$3,400	
Sediment & Biota Sampling and Analysis	8	EA	1,620	RACER	$12,960	
Contractor Overhead Adjustment			22%	RACER	$2,851	
Data Management & Reporting (Yearly)	100	HR	59	RACER	$5,879	
Contractor Overhead Adjustment			22%	RACER	$1,293	
ANNUAL MONITORING COST TOTAL						$26,383
PRESENT WORTH COSTS						
PRESENT WORTH OF O&M COSTS						
Present Worth of O&M Costs for Years 1-30						
Assuming annual cost for	30	YR	3%			$91,325
Assuming annual cost for	30	YR	5%			**$71,626**
Assuming annual cost for	30	YR	10%			$43,923
PRESENT WORTH OF MONITORING COSTS						
Present Worth of Monitoring Costs for Years 1-30						
Assuming annual cost for	30	YR	3%			$517,122
Assuming annual cost for	30	YR	5%			**$405,574**
Assuming annual cost for	30	YR	10%			$248,712
ESTIMATED CAPITAL COST (from above)						**$2,464,045**
TOTAL PRESENT WORTH OF CAPITAL COST & O&M COST						
Assuming 30 years @			3%			$3,072,492
Assuming 30 years @			5%			**$2,941,245**
Assuming 30 years @			10%			$2,756,680

(a) Kohn, N. P. 1996. Personal Communication (10/24/96), Re: Remedial Costs at the United Heckathorn Site, Richmond, California.
(b) Stinson (1992) reports unit costs of 16 to 28/sq ft.

The cost estimates shown have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. Final project costs will depend on actual labor and material costs, actual site conditions at the time of remediation, productivity, competitive market conditions, final project scope, final project schedule, the firm selected to perform the engineering, and many other variables. As a result, the final project costs will differ from the estimates presented here. Because of these inherent variabilities, project feasibility and funding needs must be carefully reviewed before making specific financial decisions to help ensure proper project evaluation and adequate funding.

References:

Delta Research Corporation. 1996. Remedial Action Cost Engineering and Requirements System (RACER). Version 3.2. Delta Research Corporation, Niceville, Florida.

PTI Environmental Services (PTI). 1995. McCormick & Baxter Creosoting Company, Revised Feasibility Study. Prepared for Oregon Department of Environmental Quality, Portland, Oregon.

Stinson, M. K. 1992. Contaminants and Remedial Options at Wood Preserving Sites. EPA/600/R-92/182. U.S. Environmental Protection Agency, Cincinnati, Ohio.

ALTERNATIVE SD-4a

- DREDGING AND OFFSITE DISPOSAL WITH CAPPING OF THE CPA AND END AREAS -

Order-of-Magnitude Cost Estimate

Description:

This alternative would remove a preponderance of the contamination via mechanical dredging. Dredge material would be pretreated via dewatering/solidification, and transported to a facility in California for disposal (without treatment). Extracted water would be treated via filtration and returned to the slough. Deep residual contamination left behind in the CPA/END portions of the slough would be capped with clean sand to isolate the contamination from water column organisms. Institutional controls would be maintained over low-level threat areas.

Assumptions:

Total material to be dredged is assumed to be 91,000 m^3 (119,000 yd^3). The saturated dredged sediment is assumed to contain 50% moisture by weight, and will increase in volume by 20% during handling, resulting in a total volume of 109,000 m^3 (143,000 yd^3) that would require dewatering to field capacity. It is assumed that this dewatering would produce an estimated 21,800,000 L (5,760,000 gal) of water that would require filtration before discharge to the slough. Capping of residual contamination in the CPA and END portions of the slough would consist of 0.6 m (2 ft) of clean sand.

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
CAPITAL COSTS						
Physical Access Controls						$13,456
Log Boom (180 ft)	180	LF	50		$9,000	
Haz. Waste Signs (& No Trespass): (1/100 ft)	60	EA	61	RACER	$3,653	
Contractor Overhead Adjustment			22%	RACER	$804	
Silt Curtain						$100,000
Installation and Maintenance	1	EA	100,000	Kohn 1996*	$100,000	
Dredge and Place Material in Treatment Area						$460,100
Mobilize Barge and Mounted Dredge	1	EA	40,000	PTI 1995	$40,000	
Dredge Highly Contaminated Area	119,000	CY	4	Kohn 1996*	$416,500	
Bulk Material Sampling (Screening - 2/day)	60	EA	60		$3,600	
Dewatering & Water Treatment						$5,165,280
Gravity and/or Belt Filter Press Dewatering	143,000	CY	36	EPA 1994	$5,148,000	
Water Treatment	5,760	1,000 GAL	3	Stinson 1992	$17,280	

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
Offsite Transportation and Disposal						$13,804,000
Transportation/Incineration/Disposal Charge	119,000	TN	116	ICF 1997	13,804,000	
In Situ Capping						$156,375
Sand Cap, Installed	8,340	CY	15	Kohn 1996*	$125,100	
Armored Cap, Installed	834	CY	38		$31,275	
Verification Sampling						$15,811
Sediment Sampling and Analysis	8	EA	1,620	RACER	$12,960	
Contractor Overhead Adjustment			22%	RACER	$2,851	
CONSTRUCTION COST SUBTOTAL						$19,715,023
Mobilization and & Gen'l Reqm'ts @ 15%						$2,957,253
CONSTRUCTION COST SUBTOTAL						$22,672,276
Contingencies						
Bid Contingency @ 10%			10%			$2,267,228
Scope Contingency @ 20%			20%			$4,534,455
Other Costs						
Administrative @ 5%			5%			$1,133,614
Services During Construction @ 10%			10%			$2,267,228
Legal @ 5% (includes dredging and effluent discharge permits)			5%			$1,133,614
IMPLEMENTATION COST TOTAL						$34,008,414
Engineering/Design @ 15%			15%			$5,101,262
CAPITAL COST TOTAL						$39,109,676
ANNUAL O&M COST						
Fence and Log Boom Maintenance (Years 1-30)						$1,152
Annual Maintenance (8 hrs/month)	96	HR	12		$1,152	
Cap Maintenance						$2,300
Annual Sand Cap Maintenance	2.3	AC	1,000	PTI 1995	$2,300	
ANNUAL O&M COST TOTAL						$3,452

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
ANNUAL MONITORING COSTS						
Annual Monitoring (Years 1-30)						$25,283
Sand Cap Monitoring (includes Bathymetry)	2.3	AC	1,000		$2,300	
Sediment & Biota Sampling and Analysis	8	EA	1,620	RACER	$12,960	
Contractor Overhead Adjustment			22%	RACER	$2,851	
Data Management & Reporting (Yearly)	100	HR	59	RACER	$5,879	
Contractor Overhead Adjustment			22%	RACER	$1,293	
ANNUAL MONITORING COSTS TOTAL						$25,283
PRESENT WORTH COSTS						
PRESENT WORTH OF O&M COSTS						
Present Worth of Fish Remediation O&M Costs for Years 1-30						
Assuming annual cost for	30	YR	3%			$67,661
Assuming annual cost for	30	YR	5%			**$53,066**
Assuming annual cost for	30	YR	10%			$32,542
PRESENT WORTH OF MONITORING COSTS						
Present Worth of Fish Monitoring Costs for Years 1-30						
Assuming annual cost for 1-8 years @	30	YR	3%			$495,561
Assuming annual cost for 1-8 years @	30	YR	5%			**$388,664**
Assuming annual cost for 1-8 years @	30	YR	10%			$238,342
ESTIMATED CAPITAL COST (from above)						**$39,109,676**
TOTAL PRESENT WORTH OF CAPITAL COST & O&M COST						
Assuming 30 years @			3%			$39,672,898
Assuming 30 years @			5%			**$39,551,406**
Assuming 30 years @			10%			$39,380,560

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*Kohn, N. P (PNNL). 1996. Personal Communication (10/24/96), Re: Remedial Costs at the United Heckathorn Site, Richmond, California.

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ICF (ICF Technology, Inc.). 1997. Soil and Groundwater Feasibility Study Report, McCormick & Baxter Superfund Site. Prepared for U.S. Environmental Protection Agency.

PTI Environmental Services (PTI). 1995. McCormick & Baxter Creosoting Company, Revised Feasibility Study. Prepared for Oregon Department of Environmental Quality, Portland, Oregon.

Stinson, M. K. 1992. Contaminants and Remedial Options At Wood Preserving Sites. EPA/600/R-92/182. U.S. Environmental Protection Agency, Cincinnati, Ohio.

U.S. Environmental Protection Agency. 1994. ARCS Remediation Guidance Document. EPA 905-B94-003. Chicago, Ill.: Great Lakes National Program Office.

ALTERNATIVE SD-4b
- DREDGING AND OFFSITE INCINERATION/DISPOSAL WITH A FULL CAP -
Order-of-Magnitude Cost Estimate

Description:

This alternative would remove a preponderance of the contamination via mechanical dredging. Dredge material would be pretreated via dewatering/solidification, and transported to a facility in Port Arthur, Texas for incineration and disposal. Extracted water would be treated via filtration and returned to the slough. Deep residual contamination left behind in the OWP, CPA, and END portions of the slough would be capped with clean sand to isolate the contamination from water column organisms. Institutional controls would be maintained over low-level threat areas.

Assumptions:

Total material to be dredged is assumed to be 91,000 m^3 (119,000 yd^3). The saturated dredged sediment is assumed to contain 50% moisture by weight, and will increase in volume by 20% during handling, resulting in a total volume of 109,000 m^3 (143,000 yd^3) that would require dewatering. It is assumed that this dewatering would produce an estimated 21,800,000 L (5,760,000 gal) of water that would require filtration before discharge to the slough. Capping of residual contamination would consist of 0.6 m (2 ft) of clean sand.

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
CAPITAL COSTS						
Physical Access Controls						$13,456
Log Boom (180 ft)	180	LF	50		$9,000	
Haz. Waste Signs (& No Trespass): (1/100 ft)	60	EA	61	RACER	$3,653	
Contractor Overhead Adjustment			22%	RACER	$804	
Silt Curtain						$100,000
Installation and Maintenance	1	EA	100,000	Kohn 1996*	$100,000	
Dredge and Place Material in Treatment Area						$460,100
Mobilize Barge and Mounted Dredge	1	EA	40000	PTI 1995	$40,000	
Dredge Highly Contaminated Area	119,000	CY	4	Kohn 1996*	$416,500	
Bulk Material Sampling (Screening - 2/day)	60	EA	60		$3,600	
Dewatering & Water Treatment						$5,165,280
Gravity and/or Belt Filter Press Dewatering	143,000	CY	36	EPA 1994	$5,148,000	
Water Treatment	5,760	1,000 GAL	3	Stinson 1992	$17,280	
Offsite Transportation and Disposal						$170,527,000
Transportation/Incineration/Disposal Charge	119,000	TN	1433	ICF 1997	$170,527,000	

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
Sand Cap, Installed	20,440	CY	15	Kohn 1996*	$306,600	
Armored Cap, Installed	2,044	CY	38		$76,650	
Verification Sampling						$15,811
Sediment Sampling and Analysis	8	EA	1,620	RACER	$12,960	
Contractor Overhead Adjustment			22%	RACER	$2,851	
CONSTRUCTION COST SUBTOTAL						$176,664,898
Mobilization and & Gen'l Reqm'ts @ 15%						$26,499,735
CONSTRUCTION COST SUBTOTAL						$203,164,632
Contingencies						
Bid Contingency @ 10%			10%			$20,316,463
Scope Contingency @ 20%			20%			$40,632,926
Other Costs						
Administrative @ 5%			5%			$10,158,232
Services During Construction @ 10%			10%			$20,316,463
Legal @ 5% (includes dredging and effluent discharge permits)			5%			$10,158,232
IMPLEMENTATION COST TOTAL						$304,746,948
Engineering/Design @ 15%			15%			$45,712,042
CAPITAL COST TOTAL						$350,458,991
ANNUAL O&M COST						
Fence and Log Boom Maintenance (Years 1-30)						$1,152
Annual Maintenance (8 hrs/month)	96	HR	12		$1,152	
Cap Maintenance						$5,700
Annual Sand Cap Maintenance	5.7	AC	1,000	PTI 1995	$5,700	
ANNUAL O&M COST TOTAL						$6,852
ANNUAL MONITORING COSTS						
Annual Monitoring (Years 1-30)						$28,683
Sand Cap Monitoring (includes Bathymetry)	5.7	AC	1,000		$5,700	
Sediment & Biota Sampling and Analysis	8	EA	1,620	RACER	$12,960	
Contractor Overhead Adjustment			22%	RACER	$2,851	
Data Management & Reporting (Yearly)	100	HR	59	RACER	$5,879	
Contractor Overhead Adjustment			22%	RACER	$1,293	
ANNUAL MONITORING COSTS TOTAL						$28,683

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
PRESENT WORTH COSTS						
PRESENT WORTH OF O&M COSTS						
Present Worth of Fish Remediation O&M Costs for Years 1-30						
Assuming annual cost for	30	YR	3%			$134,302
Assuming annual cost for	30	YR	5%			**$105,332**
Assuming annual cost for	30	YR	10%			$64,593
PRESENT WORTH OF MONITORING COSTS						
Present Worth of Fish Monitoring Costs for Years 1-30						
Assuming annual cost for 1-8 years @	30	YR	3%			$562,203
Assuming annual cost for 1-8 years @	30	YR	5%			**$440,931**
Assuming annual cost for 1-8 years @	30	YR	10%			$270,394
ESTIMATED CAPITAL COST (from above)						**$350,458,991**
TOTAL PRESENT WORTH OF CAPITAL COST & O&M COST						
Assuming 30 years @			3%			$351,155,496
Assuming 30 years @			5%			**$351,005,253**
Assuming 30 years @			10%			$350,793,978

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* Kohn, N. P (PNNL). 1996. Personal Communication (10/24/96), Re: Remedial Costs at the United Heckathorn Site, Richmond, California.

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ICF (ICF Technology, Inc.). 1997. Soil and Groundwater Feasibility Study Report, McCormick & Baxter Superfund Site. Prepared for U.S. Environmental Protection Agency.

PTI Environmental Services (PTI). 1995. McCormick & Baxter Creosoting Company, Revised Feasibility Study. Prepared for Oregon Department of Environmental Quality, Portland, Oregon.

Stinson, M. K. 1992. Contaminants and Remedial Options At Wood Preserving Sites. EPA/600/R-92/182. U.S. Environmental Protection Agency, Cincinnati, Ohio.

U.S. Environmental Protection Agency. 1994. ARCS Remediation Guidance Document. EPA 905-B94-003. Chicago, Ill.: Great Lakes National Program Office.

ALTERNATIVE SD-4c
- DREDGING AND OFFSITE INCINERATION/DISPOSAL USING A TEMPORARY DAM - TO DEWATER SEDIMENTS, INCLUDES CAPPING OF THE CPA AND END AREAS

Order-of-Magnitude Cost Estimate

Description:

This alternative would remove a preponderance of the contamination via construction of a temporary dam, dewatering, and excavation. Excavated material would be pretreated via dewatering/solidification, and transported to a facility near Port Arthur, Texas for incineration and disposal. Extracted water would be treated via filtration and returned to the slough. Deep residual contamination left behind in the CPA/END portions of the slough would be capped with clean sand to isolate the contamination from water column organisms. Institutional controls would be maintained over low-level threat areas.

Assumptions:

An estimated 31 million gallons of water would be pumped from behind a temporary sheetpile dam. Dewatering of the sediments behind the dam to a depth of 9 ft below the mud line will require a pumping rate of 840,000 gallons per day (assuming a hydraulic conductivity of 2 gpd/ft^2 and an infiltration area of approximately 420,000 ft^2).

Total material to be excavated is assumed to be 91,000 m^3 (119,000 yd^3). The saturated dredged sediment is assumed to contain 25% moisture by weight, and will increase in volume by 10% during handling, resulting in a total volume of 100,100 m^3 (130,900 yd^3) that would require dewatering to field capacity. It is assumed that this dewatering would produce an estimated 10,900,000 L (2,880,000 gal) of water that would require filtration prior to discharge to the slough. Capping of residual contamination in the CPA and END portions of the slough would consist of 0.6 m (2 ft) of clean sand.

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
CAPITAL COSTS						
Physical Access Controls						$13,456
Log Boom (180 ft)	180	LF	50		$9,000	
Haz. Waste Signs (& No Trespass): (1/100 ft)	60	EA	61	RACER	$3,653	
Contractor Overhead Adjustment			22%	RACER	$804	
Silt Curtain						$100,000
Installation and Maintenance	1	EA	100,000	Kohn 1996[(a)]	$100,000	
Temporary Dam						$533,591
Sheetpile Wall (60 ft deep x 230 long), Installed[(b)]	13,800	SF	20	Kohn 1996[(a)]	$276,000	
HDPE Liner (installed behind Sheetpiling)	13,800	SF	3	RACER	$34,500	

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
Pull and Salvage Sheetpile	13,800	SF	13	RACER	$176,640	
Contractor Overhead Adjustment			22%	RACER	$46,451	
In Situ Dewatering of Sediments						$211,302
30 hp (750 gpm) centrifugal pumps	2	EA	3,520	RACER	$7,040	
6” Class 200 PVC Piping	3,000	FT	9	RACER	$27,000	
Pump Repair	2	EA	411	RACER	$821	
Electrical Power Consumption (30 hp for 4 months)	64,800	KW	0.05	RACER	$3,337	
Water Treatment (Filtration)	260,000,000	GAL	0.00	RACER	$135,000	
Contractor Overhead Adjustment			22%	RACER	$38,104	
Excavate and Place Material in Treatment Area						$252,112
Excavate Highly Contaminated Area	119,000	CY	2	RACER	$178,500	
Load and Haul	130,900	CY	0.18	RACER	$24,070	
Heavy Equipment Decon.	2	EA	240	RACER	$480	
Bulk Material Sampling (Screening - 2/day)	60	EA	60		$3,600	
Contractor Overhead Adjustment			22%	RACER	$45,463	
Dewatering & Water Treatment						$4,721,040
Gravity and/or Belt Filter Press Dewatering	130,900	CY	36	EPA 1994	$4,712,400	
Water Treatment	2,880	1,000 GAL	3	Stinson 1992	$8,640	
Offsite Transportation and Disposal						$170,527,000
Transportation/Incineration/Disposal Charge	119,000	TN	1,433	ICF 1997	$170,527,000	
In Situ Capping						$156,375
Sand Cap, Installed	8,340	CY	15	Kohn 1996(a)	$125,100	
Armored Cap, Installed	834	CY	38		$31,275	
Verification Sampling						$15,811
Sediment Sampling and Analysis	8	EA	1,620	RACER	$12,960	
Contractor Overhead Adjustment			22%	RACER	$2,851	
CONSTRUCTION COST SUBTOTAL						$176,530,688
Mobilization and & Gen’l Reqm’ts @ 15%						$26,479,603
CONSTRUCTION COST SUBTOTAL						$203,010,291
Contingencies						
Bid Contingency @ 10%			10%			$20,301,029
Scope Contingency @ 20%			20%			$40,602,058

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
Other Costs						
Administrative @ 5%			5%			$10,150,515
Services During Construction @ 10%			10%			$20,301,029
Legal @ 5% (includes dredging and effluent discharge permits)			5%			$10,150,515
IMPLEMENTATION COST TOTAL						$304,515,437
Engineering/Design @ 15%			15%			$45,677,316
CAPITAL COST TOTAL						$350,192,753
ANNUAL O&M COST						
Fence and Log Boom Maintenance (Years 1-30)						$1,152
Annual Maintenance (8 hrs/month)	96	HR	12		$1,152	
Cap Maintenance						$2,300
Annual Sand Cap Maintenance	2.3	AC	1,000	PTI 1995	$2,300	
ANNUAL O&M COST TOTAL						$3,452
ANNUAL MONITORING COSTS						
Annual Monitoring (Years 1-30)						$25,283
Sand Cap Monitoring (includes Bathymetry)	2.3	AC	1,000		$2,300	
Sediment & Biota Sampling and Analysis	8	EA	1,620	RACER	$12,960	
Contractor Overhead Adjustment			22%	RACER	$2,851	
Data Management & Reporting (Yearly)	100	HR	59	RACER	$5,879	
Contractor Overhead Adjustment			22%	RACER	$1,293	
ANNUAL MONITORING COSTS TOTAL						$25,283
PRESENT WORTH COSTS						
PRESENT WORTH OF O&M COSTS						
Present Worth of Fish Remediation O&M Costs for Years 1-30						
Assuming annual cost for	30	YR	3%			$67,661
Assuming annual cost for	30	YR	5%			**$53,066**
Assuming annual cost for	30	YR	10%			$32,542

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
PRESENT WORTH OF MONITORING COSTS						
Present Worth of Fish Monitoring Costs for Years 1-30						
Assuming annual cost for 1-8 years @	30	YR	3%			$495,561
Assuming annual cost for 1-8 years @	30	YR	5%			**$388,664**
Assuming annual cost for 1-8 years @	30	YR	10%			$238,342
ESTIMATED CAPITAL COST (from above)						**$350,192,753**
TOTAL PRESENT WORTH OF CAPITAL COST & O&M COST						
Assuming 30 years @			3%			$350,755,975
Assuming 30 years @			5%			**$350,634,483**
Assuming 30 years @			10%			$350,463,637

(a) Kohn, N. P (PNNL). 1996. Personal Communication (10/24/96), Re: Remedial Costs at the United Heckathorn Site, Richmond, California.

(b) Stinson (1992) reports unit costs of 16 to 28/sq ft.

The cost estimates shown have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. Final project costs will depend on actual labor and material costs, actual site conditions at the time of remediation, productivity, competitive market conditions, final project scope, final project schedule, the firm selected to perform the engineering, and many other variables. As a result, the final project costs will differ from the estimates presented here. Because of these inherent variabilities, project feasibility and funding needs must be carefully reviewed before making specific financial decisions to help ensure proper project evaluation and adequate funding.

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ALTERNATIVE SD-5a

- DREDGING AND ONSITE TREATMENT WITH CAPPING OF THE CPA & END AREAS -

Order-of-Magnitude Cost Estimate

Description:

This alternative would remove a preponderance of the contamination via mechanical dredging. Dredge material would be treated via dewatering and solvent extraction, followed by solidification/ stabilization of solid residuals and incineration of concentrated organic contaminants. Extracted water would be treated via filtration and returned to the slough. Deep residual contamination left behind in the CPA and END portions of the slough would be capped with clean sand to isolate the contamination from water column organisms. Institutional controls would be maintained over low-level threat areas.

Assumptions:

Total material to be dredged is assumed to be 91,000 m^3 (119,000 yd^3). The saturated dredged sediment is assumed to contain 50% moisture by weight, and will increase in volume by 20% during handling, resulting in a total volume of 109,000 m^3 (143,000 yd^3) that would require dewatering to field capacity. It is assumed that this dewatering would produce an estimated 21,800,000 L (5,760,000 gal) of water that would require filtration prior to discharge to the slough. Dewatered materials are assumed to be treated in conjunction with upland soil and ground water operable unit (OU) wastes. A single cost is used for the solvent extraction/solidification/incineration treatment train. Capping of residual contamination would consist of 0.6 m (2 ft) of clean sand.

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
CAPITAL COSTS						
Physical Access Controls						$13,456
Log Boom (180 ft)	180	LF	50		$9,000	
Haz. Waste Signs (& No Trespass): (1/100 ft)	60	EA	61	RACER	$3,653	
Contractor Overhead Adjustment			22%	RACER	$804	
Silt Curtain						$100,000
Installation and Maintenance	1	EA	100,000	Kohn 1996(a)	$100,000	
Dredge and Place Material in Treatment Area						$460,100
Mobilize Barge and Mounted Dredge	1	EA	40,000	PTI 1995	$40,000	
Dredge Highly Contaminated Area	119,000	CY	4	Kohn 1996(a)	$416,500	
Bulk Material Sampling (Screening -2/day)	60	EA	60		$3,600	
Dewatering & Water Treatment						$5,165,280
Gravity and/or Belt Filter Press Dewatering	143,000	CY	36	EPA 1994	$5,148,000	
Water Treatment	5,760	1,000 GAL	3	Stinson 1992	$17,280	

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
Solvent Extraction/Solidification/Incineration						$27,727,000
Onsite solvent extraction, etc.[(b)]	119,000	CY	233	Campbell 1996	$27,727,000	
In Situ Capping						$155,625
Sand Cap, Installed	8,300	CY	15	Kohn 1996[(a)]	$124,500	
Armored Cap, Installed	830	CY	38		$31,125	
Verification Sampling						$15,811
Sediment Sampling and Analysis	8	EA	1620	RACER	$12,960	
Contractor Overhead Adjustment			22%	RACER	$2,851	
CONSTRUCTION COST SUBTOTAL						$33,637,273
Mobilization and & Gen'l Reqm'ts @ 15%						$5,045,591
CONSTRUCTION COST SUBTOTAL						$38,682,864
Contingencies						
Bid Contingency @ 10%			10%			$3,868,286
Scope Contingency @ 20%			20%			$7,736,573
Other Costs						
Administrative @ 5%			5%			$1,934,143
Services During Construction @ 10%			10%			$3,868,286
Legal @ 5% (includes dredging and effluent discharge permits)			5%			$1,934,143
IMPLEMENTATION COST TOTAL						$58,024,295
Engineering/Design @ 15%			15%			$8,703,644
CAPITAL COST TOTAL						$66,727,940
ANNUAL O&M COST						
Fence and Log Boom Maintenance (Years 1-30)						$1,152
Annual Maintenance (8 hrs/month)	96	HR	12		$1,152	
Cap Maintenance						$2,300
Annual Sand Cap Maintenance	2.3	AC	1,000	PTI 1995	$2,300	
ANNUAL O&M COST TOTAL						$3,452
ANNUAL MONITORING COSTS						
Annual Monitoring (Years 1-30)						$25,283
Sand Cap Monitoring (includes Bathymetry)	2.3	AC	1,000		$2,300	

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
Sediment & Biota Sampling and Analysis	8	EA	1,620	RACER	$12,960	
Contractor Overhead Adjustment			22%	RACER	$2,851	
Data Management & Reporting (Yearly)	100	HR	59	RACER	$5,879	
Contractor Overhead Adjustment			22%	RACER	$1,293	
ANNUAL MONITORING COSTS TOTAL						$25,283
PRESENT WORTH COSTS						
PRESENT WORTH OF O&M COSTS						
Present Worth of Fish Remediation O&M Costs for Years 1-30						
Assuming annual cost for	30	YR	3%			$67,661
Assuming annual cost for	30	YR	5%			**$53,066**
Assuming annual cost for	30	YR	10%			$32,542
PRESENT WORTH OF MONITORING COSTS						
Present Worth of Fish Monitoring Costs for Years 1-30						
Assuming annual cost for 1-8 years @	30	YR	3%			$495,561
Assuming annual cost for 1-8 years @	30	YR	5%			**$388,664**
Assuming annual cost for 1-8 years @	30	YR	10%			$238,342
ESTIMATED CAPITAL COST (from above)						**$66,727,940**
TOTAL PRESENT WORTH OF CAPITAL COST & O&M COST						
Assuming 30 years @			3%			$67,291,162
Assuming 30 years @			5%			**$67,169,670**
Assuming 30 years @			10%			$66,998,824

(a) Kohn, N. P (PNNL). 1996. Personal Communication (10/24/96), Re: Remedial Costs at the United Heckathorn Site, Richmond, California.

(b) Dewater costs subtracted out of unit cost.

The cost estimates shown have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. Final project costs will depend on actual labor and material costs, actual site conditions at the time of remediation, productivity, competitive market conditions, final project scope, final project schedule, the firm selected to perform the engineering, and many other variables. As a result, the final project costs will differ from the estimates presented here. Because of these inherent variabilities, project feasibility and funding needs must be carefully reviewed before making specific financial decisions to help ensure proper project evaluation and adequate funding.

References:

Campbell. C. (ICF Kaiser). 1996. Personal Communication (10/15/96), Re: Treatment Costs for Upland Soil and Groundwater OU, McCormick and Baxter Site, Stockton, California.

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PTI Environmental Services (PTI). 1995. McCormick & Baxter Creosoting Company, Revised Feasibility Study. Prepared for Oregon Department of Environmental Quality, Portland, Oregon.

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U.S. Environmental Protection Agency. 1994. ARCS Remediation Guidance Document. EPA 905-B94-003. Chicago, Ill.: Great Lakes National Program Office.

ALTERNATIVE SD-5b
- DREDGING AND ONSITE TREATMENT WITH A FULL CAP -
Order-of-Magnitude Cost Estimate

Description:

This alternative would remove a preponderance of the contamination via mechanical dredging. Dredge material would be treated via dewatering and solvent extraction, followed by solidification/stabilization of solid residuals and incineration of concentrated organic contaminants. Extracted water would be treated via filtration and returned to the slough. Deep residual contamination left behind in the OWP, CPA and END portions of the slough would be capped with clean sand to isolate the contamination from water column organisms. Institutional controls would be maintained over low-level threat areas.

Assumptions:

Total material to be dredged is assumed to be 91,000 m^3 (119,000 yd^3). The saturated dredged sediment is assumed to contain 50% moisture by weight, and will increase in volume by 20% during handling, resulting in a total volume of 109,000 m^3 (143,000 yd^3) that would require dewatering to field capacity. It is assumed that this dewatering would produce an estimated 21,800,000 L (5,760,000 gal) of water that would require filtration before discharge to the slough. Dewatered materials are assumed to be treated in conjunction with upland soil and ground water OU wastes. A single cost is used for the solvent extraction/solidification/incineration treatment train. Capping of residual contamination would consist of 0.6 m (2 ft) of clean sand.

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
CAPITAL COSTS						
Physical Access Controls						$13,456
Log Boom (180 ft)	180	LF	50		$9,000	
Haz. Waste Signs (& No Trespass): (1/100 ft)	60	EA	61	RACER	$3,653	
Contractor Overhead Adjustment			22%	RACER	$804	
Silt Curtain						$100,000
Installation and Maintenance	1	EA	100,000	Kohn 1996[(a)]	$100,000	
Dredge and Place Material in Treatment Area						$460,100
Mobilize Barge and Mounted Dredge	1	EA	40,000	PTI 1995	$40,000	
Dredge Highly Contaminated Area	119,000	CY	4	Kohn 1996[(a)]	$416,500	
Bulk Material Sampling (Screening - 2/day)	60	EA	60		$3,600	
Dewatering & Water Treatment						$5,165,280
Gravity and/or Belt Filter Press Dewatering	143,000	CY	36	EPA 1994	$5,148,000	

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
Water Treatment	5,760	1,000 GAL	3	Stinson 1992	$17,280	
Solvent Extraction/Solidification/ Incineration						$27,727,000
Onsite solvent extraction, etc.[(b)]	119,000	CY	233	Campbell 1996	$27,727,000	
In Situ Capping						$383,250
Sand Cap, Installed	20,440	CY	15	Kohn 1996[(a)]	$306,600	
Armored Cap, Installed	2,044	CY	38		$76,650	
Verification Sampling						$15,811
Sediment Sampling and Analysis	8	EA	1,620	RACER	$12,960	
Contractor Overhead Adjustment			22%	RACER	$2,851	
CONSTRUCTION COST SUBTOTAL						$33,864,898
Mobilization and & Gen'l Reqm'ts @ 15%						$5,079,735
CONSTRUCTION COST SUBTOTAL						$38,944,632
Contingencies						
Bid Contingency @ 10%			10%			$3,894,463
Scope Contingency @ 20%			20%			$7,788,926
Other Costs						
Administrative @ 5%			5%			$1,947,232
Services During Construction @ 10%			10%			$3,894,463
Legal @ 5% (includes dredging and effluent discharge permits)			5%			$1,947,232
IMPLEMENTATION COST TOTAL						$58,416,948
Engineering/Design @ 15%			15%			$8,762,542
CAPITAL COST TOTAL						$67,179,491
ANNUAL O&M COST						
Fence and Log Boom Maintenance (Years 1-30)						$1,152
Annual Maintenance (8 hrs/month)	96	HR	12		$1,152	
Cap Maintenance						$5,700
Annual Sand Cap Maintenance	5.7	AC	1,000	PTI 1995	$5,700	
ANNUAL O&M COST TOTAL						$6,852

Cost Component Description	Quantity	Unit	Unit Price	Cost Basis	Component Cost	Category Subtotal
ANNUAL MONITORING COSTS						
Annual Monitoring (Years 1-30)						$28,683
Sand Cap Monitoring (includes Bathymetry)	5.7	AC	1,000		$5,700	
Sediment & Biota Sampling and Analysis	8	EA	1,620	RACER	$12,960	
Contractor Overhead Adjustment			22%	RACER	$2,851	
Data Management & Reporting (Yearly)	100	HR	59	RACER	$5,879	
Contractor Overhead Adjustment			22%	RACER	$1,293	
ANNUAL MONITORING COSTS TOTAL						$28,683
PRESENT WORTH COSTS						
PRESENT WORTH OF O&M COSTS						
Present Worth of Fish Remediation O&M Costs for Years 1-30						
Assuming annual cost for	30	YR	3%			$134,302
Assuming annual cost for	30	YR	5%			**$105,332**
Assuming annual cost for	30	YR	10%			$64,593
PRESENT WORTH OF MONITORING COSTS						
Present Worth of Fish Monitoring Costs for Years 1-30						
Assuming annual cost for 1-8 years @	30	YR	3%			$562,203
Assuming annual cost for 1-8 years @	30	YR	5%			**$440,931**
Assuming annual cost for 1-8 years @	30	YR	10%			$270,394
ESTIMATED CAPITAL COST (from above)						**$67,179,491**
TOTAL PRESENT WORTH OF CAPITAL COST & O&M COST						
Assuming 30 years @			3%			$67,875,996
Assuming 30 years @			5%			**$67,725,753**
Assuming 30 years @			10%			$67,514,478

(a) Kohn, N. P (PNNL). 1996. Personal Communication (10/24/96), Re: Remedial Costs at the United Heckathorn Site, Richmond, California.

(b) Dewater costs subtracted out of unit cost.

The cost estimates shown have been prepared for guidance in project evaluation and implementation from the information available at the time of the estimate. Final project costs will depend on actual labor and material costs, actual site conditions at the time of remediation, productivity, competitive market conditions, final project scope, final project schedule, the firm selected to perform the engineering, and many other variables. As a result, the final project costs will differ from the estimates presented here. Because of these inherent variabilities, project feasibility and funding needs must be carefully reviewed before making specific financial decisions to help ensure proper project evaluation and adequate funding.

References:

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APPENDIX D

DEVELOPMENT OF PRELIMINARY SEDIMENT CLEANUP LEVELS

APPENDIX D: DEVELOPMENT OF PRELIMINARY SEDIMENT CLEANUP LEVELS

The following summary is taken from the *Ecological Risk Assessment of the Surface Water Operable Unit, McCormick & Baxter Superfund Site, Stockton, California,* December 1996:

Tables D.1 through D.4 (attached) of the Ecological Risk Assessment (ERA) provide estimates for maximum sediment concentrations (MSCs) (dry weight) of contaminants of concern (COC) that are predicted to be protective of aquatic biota based on literature values and toxicity tests conducted for the ERA. For most of the COCs, several approaches were used to calculate these maximum concentrations, including sediment quality guidelines, equilibrium partitioning models, contaminant mixtures models, correlations with sediment toxicity, and sediment quality criteria. Not all approaches could be applied to each COC, and each approach has a unique set of assumptions and uncertainties. Most of the proposed cleanup levels are environmentally conservative values based on modeled predictions of COC bioavailability and effects reported in scientific literature. In all cases, safety factors were not built into the estimates.

Metals: Table D.1 provides estimates of MSCs for arsenic, chromium, copper and zinc, based on Apparent Effects Threshold (AET) (WDOE 1995), Effects Range-Low (ER-L) (Long et al. 1995), the equilibrium partitioning for metals (EqP-M) approach (EPA 1994a), and correlations with sediment toxicity (PNNL 1997). AETs and ER-Ls were calculated as the dry weight sediment concentration above which adverse biological effects are correlated to occur, but do not account for metal bioavailability in the calculations. Furthermore, these two guidelines were derived for marine and estuarine biota, and their applicability to freshwater and oligohaline ecosystems is untested. The EqP-M was calculated as the molar concentration of the metal (in Simultaneously Extracted Metals [SEM] phase) that would equal the molar concentration of Acid Volatile Sulfides (AVS), so that the resulting SEM/AVS molar ratio equaled one. For example, the EqP-M concentration of zinc in sediment with an AVS of 3.56 umole/g would be 3.56 * 65.39 (the molecular wt. of Zn) = 233 umole/g. (Note that the AVE value of 3.6 umole/g reported in Table D.1 was a rounded value of the measured AVS for OMS-END). MSCs calculated by the EqP-M approach are the metal concentrations that are equimolar to the AVS concentrations measured in OMS-END and OMS-MTH, which had the highest and lowest AVS concentrations, respectively. It was not possible to estimate the bioavailability of arsenic or chromium using the EqP-M approach, because appropriate equilibrium partitioning models do not yet exist for these metals. MSCs calculated by the toxicity test approach are the dry weight sediment concentrations measured in the M&B composite that had the highest nonsignificant percentage mortality (compared to references), NMS-UPS. For cleanup levels, the MSCs derived from the EqP-M approach were used, because these values attempt to account for the bioavailability of the metals. Cleanup levels could differ between upstream and downstream ends of Old Mormon Slough and New Mormon Slough because of differences in AVS concentrations.

Chlorinated Phenols: Table D.2 provides estimates of MSCs for PCP based on AET and the equilibrium partitioning approach for organics (EqP-O) (DiToro et al. 1991). PCP was the only chlorinated phenol that was detected or measured, and it was detected only in OMS-CPA. This prevented the use of the toxicity test approach for calculating an MSC. However, significant mortality was measured in this sediment by both toxicity test species. The EqP-O approach applied to PCP used the organic carbon-based equilibrium partitioning equation to predict the sediment dry weight PCP concentration that corresponded to sediment porewater concentrations equal to either EPA freshwater chronic water quality criteria (13 mg/L PCP) or Eisler's (1989) proposed chronic criteria to protect freshwater biota (3.2 mg/L PCP).

It is not certain how accurately the EqP-O approach predicts the bioavailability of PCP, because this compound is somewhat polar and its toxicity varies with pH, which is not accounted for in the model used here (Eisler 1989). However, the EqP-O approach was used rather than the AET approach for setting a cleanup level because the AET approach did not account for PCP bioavailability and was derived for marine and estuarine life. Furthermore, the inability to correlate chlorinated phenol concentrations with sediment toxicity creates further uncertainty regarding the range of actual COC concentrations that may have caused effects at the site. For these reasons, the MSCs derived using the EqP-O approach and Eisler's (1989) proposed water quality criteria were used, although there is a high level of uncertainty. As with metals, the dry weight MSC will vary between sediments with low and high TOC contents.

Dioxin: Table D.3 provides estimates for MSCs for TCDD TEQs based on the guidelines suggested by Cook et al. (1993) and based on correlations between TEQs and sediment toxicity. Cook et al. (1993) estimated sediment concentrations for TCDD that through trophic transfer were predicted to result in tissue concentrations of fish or piscivorous birds that were correlated with larval mortality or reproductive impairment, respectively. The MSC estimated by the toxicity test approach was the TCDD TEQ for NMS-UPS, which caused the highest nonsignificant mortality to *C. tentans*. Because dioxins are believed to be nontoxic to invertebrates, the MSC calculated by the toxicity test approach lacks a known toxicological mechanism, and was not considered further. In the absence of other alternatives, the MSC derived from the Cook et al. (1993) guideline for low risk of sediment-associated dioxin to birds was used.

PAHs: Table D.4 provides estimates of MSCs for PAHs (individual and total PAHs) based on the AET, ER-L, EqP-O, EPA SQC, SPAH model and toxicity test approaches. The SQC approach is identical to the EqP-O approach, except that the organic carbon-normalized PAH concentrations are set in EPA SQC documents (EPA 1993a, 1993b, 1993c), whereas EqP-O MSCs were calculated from first principles. Small differences in K_{oc} values used in the SQC and EqP-O calculations account for the differences in MSC values for acenaphthene, phenanthrene, and fluoranthene (Table D.4). The MSCs estimated from AET, ER-L, EqP-O, and toxicity tests followed the approaches described for metals and chlorinated phenols, and have the same advantages and disadvantages. The MSCs derived from the SPAH model use the Swartz et al. (1995) model to predict sediment criteria. The SPAH MSCs were calculated by 1) estimating the average, relative contribution of the toxic units (TU) for individual PAHs for OMS composites; 2) dividing each relative TU by 1000 to generate a sum of all TUs=0.10 (i.e., the non-toxic threshold from Swartz et al. 1995); and 3) calculating the dry weight sediment concentration for each PAH by changing the toxic unit prediction equation:

$$\text{Toxic Unit (TU)} = \frac{(C_{SED}/f_{oc}*K_{oc})}{\text{10d IW LC50}} \qquad \text{Equation D.1}$$

to:

$$C_{SED} = TU * 10d\ IW\ LC50 * f_{oc} * K_{oc} \qquad \text{Equation D.2}$$

where:

C_{SED} is measured sediment dry weight concentration of PAH mg/kg dry)
f_{oc} is the fractional concentration of organic matter (%TOC/100; kg/kg)
K_{oc} is the organic carbon-water partitioning coefficient for the PAH (L/kg organic carbon)
10d IW LC50 is the predicted porewater 10d LC50 for the PAH (mg/L).

This generates a prediction of the dry weight concentration of each PAH such that the combined toxicity of the PAH mixture is equal to 0.10 TU. The individual MSCs were then summed to generate MSCs for LPAH, HPAH and total PAH. Many assumptions were made using this model: 1) the toxicity database, derived from marine amphipods, was appropriate for freshwater biota; 2) the internal QSAR model, used to predict the porewater toxicity of most of the PAHs, was accurate; 3) the joint action of PAHs was additive; and 4) porewater concentrations of PAHs were appropriate predictors of toxicity to benthic invertebrates. The principal advantage of the SPAH approach was that differences between SQC- and SPAH-derived MSC values for acenaphthene, phenanthrene, and fluoranthene were due to the accommodation of the joint toxicity of the PAH mixture in the SPAH approach. The SPAH-derived MSC values were used because both the bioavailability of the compounds and their joint toxicological effects were taken into consideration, MSCs for the total mass of PAHs could be calculated, and the resulting criteria were site-specific, taking into consideration the PAH “fingerprint” and TOC content in Old Mormon Slough sediments. Thus, as with metals and PCP, the dry weight MSCs for PAHs will vary between sediments with low and high TOC contents.

Conclusion: Measured concentrations of the COCs were compared with the proposed MSC cleanup levels in Table D.5. By dividing the measured concentration by the MSC, the factor by which the most adverse COC would have to be reduced in order to be protective of aquatic biota was calculated. All other COCs in the sediment could be reduced to less than their respective MSCs if the sediment were reduced to the MSC cleanup level of the most adverse COC. For example, the measured LPAH concentration in OMS-OWP (253,437 mg/kg): if the sediment were cleaned up by a process that reduced LPAH by a factor of 77, concentrations of all of the other nonionic COCs could be reduced to below their MSC levels. The proposed cleanup level does not include any safety factors that are often used when setting environmental quality data (i.e., 10 times below NOECs).

The information in Table D.5 allows consideration of cleanup goals by sample or by water body, using criteria derived for each COC. We have presented the cleanup levels according to the composites representing different sections of Old Mormon Slough (e.g., OMS-MTH, OMS-OWP); however, this compositing strategy was chosen based on known contaminant sources and expected levels of contamination, and it may not be the most appropriate for defining the areas for remediation. For comparison, cleanup levels using ER-L and AET values were provided in Table D.6. In general, the same COCs drive cleanup in each portion of Old Mormon

Slough (except dioxins, for which there is no reliable ER-L), as those indicated using MSCs in Table D.5. The most dramatic difference is that LPAHs dictate a cleanup by a factor of 77 using MSCs as compared to a factor of 459 in OMS-OWP using ER-Ls.

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Table D.1. Maximum Concentrations of Metals in Sediment Predicted to Cause No Adverse Effect

Metals (µg/g dry weight)	AET	ER-L	EqP-M (AVS = 3.6 µmole/g) [(a)]	EqP-M (AVS = 58.3 µmole/g) [(b)]	ToxicityTest NOEC[(c)]
Arsenic	130	8.2	NA[(d)]	NA	35.6
Chromium	96	81	NA	NA	118
Copper	390	34	***226***[(e)]	***3702***	147
Zinc	460	150	***233***	***3813***	1250

(a) Lowest AVS concentration measured in OMS-END.
(b) Highest AVS concentration measured in OMS-MTH.
(c) NOEC = No-observable-effects concentrations of metals are those measured in NMS-UPS sediments, which exhibited the highest non-significant percentage mortality.
(d) NA = AVS normalization not applicable for this metal.
(e) Sediment concentrations bolded and italicized are our recommendations for cleanup levels.

Table D.2. Maximum Concentrations of Pentachlorophenol (PCP) in Sediment Predicted to Cause No Adverse Effect

Pentachlorophenol (µg/kg dry weight)	AET	EqP-O Approach (3.6% TOC)[(a)]	EqP-O Approach (1.1% TOC)[(b)]
Pentachlorophenol	400	***10,506***[(c)] - 42,682[(d)]	***3210*** - 13,041[(d)]

(a) Highest %TOC measured in OMS East-END.
(b) Lowest %TOC measured in OMS-MTH.
(c) Sediment concentrations bolded and italicized are our recommendations for cleanup levels.
(d) High concentration based on EPA Freshwater Criteria, low concentration based on Eisler (1989).

Table D.3. Maximum Concentrations of TCDD-TEQs in Sediment that Would Pose Low Risk to Aquatic Life

Receptor Species to Protect	Cook (1993) Low Risk Values (pg/g dry weight)	ToxicityTest NOEC (pg/g dry weight)[(a)]
Benthos	NA[(b)]	249
Fish	60	NA
Birds	***21***[(c)]	NA

(a) NOEC No-observable-effects concentrations are the TEQs for NMS-UPS.
(b) NA Not available; guidelines not available, or data not available to make calculation.
(c) Sediment concentrations bolded and italicized are our recommendations for cleanup levels.

Table D.4. Maximum Concentrations of PAHs in Sediment Predicted to Cause No Adverse Effect

PAHs (µg/kg dry weight)	AET	ER-L	SQC (3.6%TOC)[a]	SQC (1.1%TOC)[b]	EqP-O (3.6%TOC)[a]	EqP-O (1.1%TOC)[b]	SumPAH Model (3.6%TOC)[a]	SumPAH Model (1.1%TOC)[b]	Toxicity Test NOEC[c]
Naphthalene	230	160	NA[d]	NA	45,572	22,574	***5,527***[e]	***1,689***	520
Acenaphthylene	71	44	NA	NA	NA	NA	***46***	***14***	67.9
Acenaphthene	130	16	4,680	1,430	4,989	1,524	***552***	***169***	122
Fluorene	120	19	NA	NA	NA	NA	***399***	***122***	161
Phenanthrene	660	240	6,480	1,980	4,436	1,356	***597***	***182***	832
Anthracene	280	85.3	NA	NA	NA	NA	***270***	***83***	196
Fluoranthene	1,300	600	22,320	6,820	22,176	6,776	***1,190***	***363***	3,560
Pyrene	2,400	665	NA	NA	NA	NA	***1,157***	***353***	3,450
Benzo(a)anthracene	960	261	NA	NA	NA	NA	***514***	***157***	756
Chrysene	950	384	NA	NA	NA	NA	***587***	***179***	1,150
Benzo(b)fluoranthene	1,800	NA	NA	NA	NA	NA	***587***	***179***	1,510
Benzo(k)fluoranthene	1,800	NA	NA	NA	NA	NA	***234***	***72***	546
Benzo(a)pyrene	1,100	430	NA	NA	NA	NA	***340***	***104***	830
Indeno(1,2,3-cd)pyrene	760	NA	NA	NA	NA	NA	NA	NA	786
Dibenz-(a,h)anthracene	240	63.4	NA	NA	NA	NA	NA	NA	165
Benzo(g,h,i)perylene	920	NA	NA	NA	NA	NA	NA	NA	869
Total LPAH	1,200	552	NA	NA	NA	NA	***7,391***	***2,258***	1,899
Total HPAH	7,900	1,700	NA	NA	NA	NA	***4,609***	***1,408***	13,622
Total PAH	NA	4,022	NA	NA	NA	NA	***12,000***	***3,667***	15,521

(a) HIghest %TOC measured in OMS-END.
(b) Lowest %TOC measured in OMS Mouth.
(c) NOEC = No-observable-effects concentrations of PAHs are those measured in NMS-UPS.
(d) NA = Not available; criteria or guidelines not available, or data not available to make calculation.
(e) Sediment concentrations bolded and italicized are our recommendations for cleanup levels.

Table D.5. Comparisons with and Ratios of Measured and Maximum Sediment Concentrations (MSCs) of COCs in Old Mormon Slough, New Mormon Slough, Stockton Channel Reference, and San Joaquin Reference

Contaminant of Concern		Old Mormon Slough				New Mormon Slough		Stockton Channel Reference	San Joaquin River Reference
		OMS-END	OMS-CPA	OMS-OWP	OMS-MTH	NMS-DNS	NMS-UPS		
PCDD/PCDF TEQs	Measured	677	1,073	114	37	44	252	92	18.0
(pg/g dry weight)	MSC	21	21	21	21	21	21	21	21
	Ratio	***32***(a)	***51***	5	2	2	12	4	0.9
LPAHs	Measured	1,890	10,865	253,437	7,958	1,060	1,900	904	ND(b)
(ug/kg dry weight)	MSC	7,391	3,080	3,285	2,258	3,080	9,650	6,570	1,396
	Ratio	0	4	***77***	4	0	0	0	NA(c)
HPAHs	Measured	12,475	45,467	12,450	7,699	2,830	13,600	9,500	60.1
(ug/kg dry weight)	MSC	4,609	1,921	2,049	1,408	1,921	6018	4,097	871
	Ratio	3	24	6	***5***	1	2	2	0.1
Total PAHs	Measured	14,365	56,332	265,887	15,657	3,880	15,500	10,400	60.1
(ug/kg dry weight)	MSC	12,000	5,000	5,334	3,667	5,000	15,667	10,667	2,267
	Ratio	1	11	50	4	1	1	1	0.0
PCP	Measured	ND	400	ND	ND	ND	ND	ND	ND
(ug/kg dry weight)	MSC		4,378						
	Ratio	NA	0	NA	NA	NA	NA	NA	NA
Arsenic	Measured	17.6	33.0	10.1	7.70	22.8	35.6	25.9	7.10
(mg/kg dry weight)	MSC	NE(d)	NE(d)	NE(d)	NE(d)	NE(d)	NE(d)	NE(e)	NE(e)
	Ratio	NA	NA	NA	NA	NA	NA	NA	NA
Chromium	Measured	145	124	126	105	116	118	128	84.3
(mg/kg dry weight)	MSC	NE(d)	NE(d)	NE(d)	NE(d)	NE(d)	NE(d)	NE(e)	NE(e)
	Ratio	NA	NA	NA	NA	NA	NA	NA	NA
Copper	Measured	114	73.5	58.9	33.1	70.9	147	153	31.9
(mg/kg dry weight)	MSC	3,702	1,772	1,492	226	1,765	2,057	NE(e)	NE(e)
	Ratio	0	0	0	0	0.0	0	NA	NA
Zinc	Measured	274	173	154	123	811	1,250	767	82.2
(mg/kg dry weight)	MSC	3,813	1,825	1,537	233	1,818	2,119	NE(e)	NE(d)
	Ratio	0	0	0	1	0	1	NA	NA

(a) Bolded, italicized type indicates the COC with the highest ratio for each Old Mormon Slough composite.
(b) ND = Not detected.
(c) NA = Not applicable.
(d) NE = Not established, MSC value not given because equilibrium partioning models did not exist.
(e) NE = Not established, MSC value not given because AVS data not available.

Table D.6. Comparisons with and Ratios of Measured and Effects Range-Low (ER-Ls) or Apparent Effects Threshold (AET) of COCs in Old Mormon Slough, New Mormon Slough, Stockton Channel Reference, and San Joaquin Reference

Contaminant of Concern		Old Mormon Slough				New Mormon Slough		Stockton Channel Reference	San Joaquin River Reference
		OMS-END	OMS-CPA	OMS-OWP	OMS-MTH	NMS-DNS	NMS-UPS		
PCDD/PCDF TEQs	Measured	677	1,073	114	37	44	252	92	18
(pg/g dry weight)	ER-L/AET	NE(a)	NE	NE	NE	NE	NE	NE	NE
	Ratio	NA(b)	NA	NA	NA	NA	NA	NA	NA
LPAHs	Measured	1,890	10,865	253,437	7,958	1,060	1,900	904	ND(c)
(ug/kg dry weight)	ER-L	552	552	552	552	552	552	552	552
	Ratio	3	20	***459***	***14***	2	3	2	NA
HPAHs	Measured	12,475	45,467	12,450	7,699	2,830	13,600	9,500	60.1
(ug/kg dry weight)	ER-L	1,700	1,700	1,700	1,700	1,700	1,700	1,700	1700
	Ratio	***7***(d)	***27***	7	5	2	8	6	0.0
Total PAHs	Measured	14,365	56,332	265,887	15,657	3,880	15,500	10,400	60.1
(ug/kg dry weight)	ER-L	4,022	4,022	4,022	4022	4,022	4,022	4,022	4022
	Ratio	4	14	66	4	1	4	3	0.0
PCP	Measured	ND	400	ND	ND	ND	ND	ND	ND
(ug/kg dry weight)	AET	400	400	400	400	400	400	400	400
	Ratio	NA	1	NA	NA	NA	NA	NA	NA
Arsenic	Measured	17.6	33.0	10.1	7.70	22.8	35.6	25.9	7.10
(mg/kg dry weight)	ER-L	8.2	8.2	8.2	8.2	8.2	8.2	8.2	8.2
	Ratio	2.1	4.0	1.2	0.94	2.8	4.3	3.2	0.87
Chromium	Measured	145	124	126	105	116	118	128	84.3
(mg/kg dry weight)	ER-L	81	81	81	81	81	81	81	81
	Ratio	2	2	2	1	1	1	2	1.0
Copper	Measured	114	73.5	58.9	33.1	70.9	147	153	31.9
(mg/kg dry weight)	ER-L	34	34	34	34	34	34	34	34
	Ratio	3	2.2	1.7	1.0	2.1	4	5	0.9
Zinc	Measured	274	173	154	123	811	1,250	767	82.2
(mg/kg dry weight)	ER-L	150	150	150	150	150	150	150	150
	Ratio	2	1	1	1	5	8	5	0.5

(a) NE = Not established.
(b) NA = Not applicable.
(c) ND = Not detected.
(d) Bolded, italicized type indicates the COC with the highest ratio for each Old Mormon Slough composite.

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