Draft Feasibility Study

Lower Fox River, Wisconsin

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Prepared for:

Wisconsin Department of Natural Resources
1015 Webster Street
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List of Acronyms

2,3,7,8-TCDD	2,3,7,8-Tetrachlorodibenzo-*p*-dioxin
2,3,7,8-TCDF	2,3,7,8-Tetrachlorodibenzofuran
AOC	Area of Concern
APEG	Potassium Polyethylene Glycol
ARARs	Applicable or Relevant and Appropriate Requirements
ARCS	Assessment and Remediation of Contaminated Sediments
BCD	Base Catalyzed Decomposition
BLRA	Baseline Human Health and Ecological Risk Assessment
CAD	Confined Aquatic Disposal Facility
CDF	Confined Disposal Facility
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980 (Superfund Statute)
cm	Centimeter
COC	Chemical of Concern
COPC	Chemical of Potential Concern
CTF	Confined Treatment Facility
DC	Direct Current
DDD	4,4'-Dichlorodiphenyl dichloroethane
DDE	4,4'-Dichlorodiphenyl dichloroethylene
DDT	4,4'-Dichlorodiphenyl trichloroethane
DGPS	Differential Global Positioning System
DM	Data Management
DO	Dissolved Oxygen
DOD	Department of Defense
EPA	Environmental Protection Agency
FRDB	Fox River Data Base
FRM	Fox River Model
FS	Feasibility Study
ft	Foot or Feet
ft/s	Feet per Second
ft^2	Square Feet
ft^3	Cubic Feet
GBMSD	Green Bay Metropolitan Sewage District
g	Gram
g/year	Grams per Year
gpm	Gallons per Minute
GRA	General Response Action
HDPE	High Density Polyethylene
HTTD	High Treatment Thermal Destruction
IJC	International Joint Commission
in	Inch
K_d	Log Soil/Water Partition Coefficient
kg	Kilogram (one Kilogram is approximate equal to 2.2 pounds)

km	Kilometer (one kilometer is approximately equivalent to 0.6 miles)
km^2	Square Kilometer
K_{oc}	Organic Carbon Partitioning Coefficient
K_{ow}	Octanol Water Partitioning Coefficient
L	Liters (one Liter is approximately equivalent to 0.25 gallons)
LFRM	Lower Fox River Model
LLBdM	Little Lake Butte des Morts
LUST	Leaking Underground Storage Tank
m	Meter (one meter is approximately equivalent to 39 inches)
m^2	Square Meter
m^3	Cubic Meter
m^3/s	Cubic Meter per Second
mg	Milligram (1,000 mg is equivalent to 1 gram)
mg/kg	Milligrams per Kilogram
mg/L	Milligram per Liter
Mpa	Mega Pascal
NCP	National Contingency Plan
ng/kg	Nanograms per kilogram
ng/L	Nanogram per Liter
NPDES	National Pollutant Discharge Elimination System
NR	Natural Resource
NRC	National Cash Register
PAH	Polynuclear Aromatic Hydrocarbon
PCB	Polychlorinated Biphenyl
PCP	Pentachlorophenol
POTW	Publically Owned Treatment Works
ppb	Parts per Billion
PPE	Personal Protective Equipment
ppm	Parts per Million
ppt	Parts per Trillion
PRPs	Principal Responsible Parties
RA	Risk Assessment
RAOs	Remedial Alternative Options
RAP	Remedial Action Plan
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
ROD	Record of Decision
SLRA	Screening Level Risk Assessment
SMU	Sediment Management Unit
SVOC	Semi-Volatile Organic Compounds
SWAC	Surface Weighted Average Concentration
TBC	To Be Considered
TSCA	Toxic Substances Control Act
TSS	Total Suspended Solids
TWA	Time Weighted Average

UFRM	Upper Fox River Model
μg	Microgram
μg/kg	Micrograms per Kilogram
μm	Micrometer
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UV	Ultra-Violet
VOC	Volatile Organic Compound
w/w	Weight per Weight
WAC	Wisconsin Administrative Code
WDNR	Wisconsin Department of Natural Resources
WPSC	Wisconsin Public Service Corporation
WWTP	Wastewater Treatment Plan
yd	Yard
yd^3	Cubic Yard
yr	Year
°C	Degrees Celsius
°F	Degrees Fahrenheit

1 Introduction

This document presents the Feasibility Study Report (FS Report) to evaluate potential remedial alternatives and develop the necessary supporting information for the selection of a sediment remediation alternative for the Lower Fox River located in Wisconsin.

This FS Report was prepared by ThermoRetec Consulting Corporation (ThermoRetec, formerly RETEC) on behalf of the Wisconsin Department of Natural Resources (WDNR). The overall programmatic goal in preparing this FS Report is to provide WDNR with supporting information for the selection of the most appropriate remedial alternative for the Lower Fox River. This project is being conducted under the direction of WDNR, with funding and technical assistance from the United States Environmental Protection Agency (EPA) Region 5, and in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (NCP).

This FS Report is the final documentation of the remedial investigation and feasibility study (RI/FS) process. The RI/FS process conforms to the procedures outlined in the EPA guidance document; *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA* (EPA RI/FS Guidance) (EPA, 1988). Major components of the RI/FS process that have contributed to the completion of this document include the following:

- Data Management (DM) - DM involved the development of a usable database produced through the identification, acquisition, review (validation), catalog, classification and archive of known available data sources (electronic and hard copy) pertinent to the Lower Fox River Risk Assessment (RA) and RI/FS. Usable data includes water, sediment and fish tissue chemistry data. DM procedures and results are provided in the document; *Data Management Summary Report* prepared by EcoChem, Inc. (ThermoRetec, 1998)

- Remedial Investigation (RI) - The RI provides a compilation, review, and organization of physical, chemical and biological characteristics of the Lower Fox River. The RI involved: an assessment of the quality and usability of existing data; collection of additional sample data; and development of a description of the magnitude and extent of chemicals of concern (COC) in both sediment and water within the Lower Fox River. The RI is presented in the document; *Draft Remedial Investigation for the Lower Fox River* (RI Report)

(ThermoRetec, 1999b). A summary of the RI is presented in Section 2 of this FS Report.

- Risk Assessment (RA) - The RA involved the identification of COC and risk-based sediment clean-up goals based upon realistic assessments of potential risks to ecological and human receptors. The RA provides an assessment of risks to human health and the environment that will support selection of a remedy to eliminate, reduce, or control those risks. The RA is presented in two documents; *Screening Level Human Health and Ecological Risk Assessment* (SLRA) (RETEC, 1998) and *Draft Baseline Human Health and Ecological Risk Assessment* (BLRA) (ThermoRetec, 1999a). A summary of the RA is presented in Section 3 of this FS Report.

This section presents a description of the Lower Fox River and an outline of the primary components of the FS process, which coincide with Sections 2 through 10 of this FS Report.

1.1 Site Description

The Lower Fox River is located in northeastern Wisconsin within the eastern ridges and lowlands of the state. The Lower Fox River is defined as the 39-mile portion of the Fox River, beginning at the outlet of Lake Winnebago and terminating at the mouth of the river into Green Bay, Lake Michigan (Figure 1-1). The river flows north and drains approximately 6,330 square miles (USGS, 1998), making it a primary tributary to Green Bay and a part of the Great Lakes System.

The Lower Fox River is referred to in this FS Report in terms of the following four reaches:

- Little Lake Butte des Morts Reach (Figure 1-2)
- Appleton to Little Rapids Reach (Figure 1-3)
- Little Rapids to De Pere Reach (Figure 1-4)
- De Pere to Green Bay Reach (Figure 1-5)

Distinguishing river and sediment characteristics of each reach are summarized in Section 2.1.

Discharges from municipal, industrial, and agricultural entities located within the Lower Fox River region have resulted in the presence of numerous compounds in the sediments and water as well as the aquatic and wildlife species associated with the river ecosystem. Of the potentially toxic substances found, the RA concluded that Polychlorinated Biphenyls (PCBs) in river sediments are the primary COC. Additional contaminants include mercury and other heavy metals (arsenic, chromium, copper, lead, zinc), semivolatile and volatile organics (SVOCs and VOCs), chlorinated pesticides such as 4,4'-Dichlorodiphenyl trichloroethylene (DDT), dioxins and furans, and pentachlorophenol (PCP). Chlorinated pesticides (other than DDT) have not been found in significant concentrations within the river sediments (WDNR, 1996).

An estimated 90,720 kg (200,000 pounds) of PCBs were released into the Fox River between 1954 and the present (WDNR, 1998b). PCBs in the Lower Fox River pose a potential threat to human health and ecological receptors due to their tendency to sorb to sediments, persist in the environment, and bioaccumulate in aquatic organisms. Contaminated sediments acting as “sinks” for PCBs and other contaminants are also subject to physical and chemical processes that effect the overlying water column and adjoining water bodies in natural (uncontrolled) environments. For example, PCBs from sediment in the Lower Fox River are discharged into Green Bay at the mouth of the river through sediment transport and PCB dissolution in the water column. The RA and RI should be referred to for a complete description of human and ecological impacts as well as the fate and transport of PCBs, respectively. This FS Report considers contaminated sediments of the Lower Fox River to be the primary media for which all remedial alternatives developed herein will address.

1.2 Feasibility Study Process

The purpose of the FS was to evaluate remedial technologies and potential remedial alternatives for the Lower Fox River to provide the basis for the selection of an appropriate remedy that meets certain remedial action objectives. While this is a state-lead effort, the overall assessment follows the procedures and paradigms developed as part of CERCLA and the NCP. The primary steps of the FS process include:

- The establishment of remedial action objectives (RAOs)
- The identification and screening of general response actions (GRAs) and technologies that address the GRAs
- The development of and detailed analysis of remedial alternatives

Figure 1-6 provides a schematic view of the RI/FS process. Figure 1-6 also illustrates how each section of this FS Report relates to the steps of the FS process. By following the procedures of the EPA RI/FS Guidance, a list of potential remedial alternatives for the Lower Fox River was developed and evaluated. The remedial alternatives provide the basis for the development of a Record of Decision (ROD). The following subsections describe the organization and contents of this FS Report.

1.2.1 Summary of the Remedial Investigation - Section 2

Section 2 summarizes the RI Report in terms of the hydrological, physical, and biological characteristics of the river. The summary describes the following elements of the river system that are pertinent to the FS process:

- Environmental Setting - a detailed description of each of the four reaches of the Lower Fox River

- Site History - a chronology of major developments and regulatory actions in the Lower Fox River region that have impacted the quality of the river and the river ecosystem

- Sources of Contaminants - a description of both point and non-point sources that have impacted or continue to impact the Lower Fox River

- Fate and Transport - a generalized description of the processes by which chemical analytes are transported from their source(s) to potential human and environmental receptors

- Contaminant Distribution in the Lower Fox River - a summary of surface sediment chemical concentrations and vertical distributions across the four reaches.

1.2.2 Summary of the Baseline Human Health and Ecological Risk Assessment - Section 3

Section 3 summarizes the assessment of potential risks to ecological and human receptors that live, feed and play in the Lower Fox River and Green Bay. Results of the risk assessment provide the basis for setting risk-based sediment clean-up goals and determining an appropriate remedial alternative that will eliminate, reduce, or control those risks. The summary describes the following elements of the RA that are pertinent to the FS process:

- Overview of the Risk Assessment - a description of potential risks associated with the Lower Fox River and the primary components (i.e., chemicals of potential concern [COPC], sediment quality threshold [SQTs], etc.) that are identified as part of the process

- Ecological Risk Assessment - an outline of the general methodology used for assessing potential risks posed to ecological receptors, including a summary of the results

- Human Health Risk Assessment - an outline of the general methodology used for assessing potential risks posed to human health, including a summary of the results

- Conclusions - a summary of the results of the RA and conclusions based on these results that directly impact remediation of the Lower Fox River sediments and the FS process

Sections 2 and 3 precede Sections 4 through 10 in this FS Report since they were integral to the direction of the FS process described in the following subsections.

1.2.3 Development of Remedial Action Objectives and General Response Actions - Section 4

The first step in the FS process involves establishing RAOs, by integrating data from three key sources: site characteristics, human health and ecological risk, and applicable or relevant and appropriate requirements (ARARs).

The selection of GRAs to address the RAOs is developed from eight primary categories:

- No Action
- Institutional Controls
- Containment
- Removal
- *In Situ* Treatment
- *Ex Situ* Treatment
- Dewatering
- Disposal

Section 4 presents the RAOs and a discussion of the basis for establishing the RAOs for the Lower Fox River. This section also identifies and briefly describes the GRAs listed above.

1.2.4 Identification of Contaminated Sediment Areas - Section 5

Prior to the development of remedial alternatives, the extent (volumes and areas) of contaminated sediments are identified, to which the GRAs apply. This task was accomplished by identifying areas of contaminated sediment based on analytical data and modeling. Risk-based levels of acceptable contaminant concentrations within the sediments were used to define volumes and potential areas for remediation.

Section 5 identifies volumes and areas of impacted sediment and defines the extent of contaminated sediments to be addressed in the remedial alternatives.

1.2.5 Identification and Screening of Technologies - Section 6

A master list of remedial technology types and process options applicable to remediation of the Lower Fox River sediments was compiled for each GRA. An initial screening was performed to eliminate technology types and process options which technically could not be implemented. A second and final screening was performed to evaluate the various process options representing technology types that were retained from the initial screening. These were evaluated based on effectiveness, cost, and administrative (i.e., permitting issues, equipment availability, etc.) implementability.

Section 6 presents a description of the screening process and results of the screening. Additional criteria and other considerations that influence the development and analysis of remedial alternatives for the Lower Fox River are also presented in Section 6.

1.2.6 Reach-Specific Remedial Alternatives - Section 7

Technology types and process options that were retained after completion of the screening were combined to develop remedial alternatives for each of the four reaches. A range of alternatives was developed with the following purpose:

- Provide for no action as a baseline to which other remedial options are compared

- Contain the COCs in place to reduce and /or eliminate exposure to human and ecological receptors

- Remove and treat contaminated sediments to reduce the risk of human and ecological exposure to COCs

- Remove and contain contaminated sediments within a on-site or off-site disposal facility to reduce risk to human and ecological receptors and minimize long term management

Section 7 presents potential remedial alternatives for the four reaches of the Lower Fox River. Section 7 also provides a discussion of the basis for development of the remedial alternatives, considerations for implementation of the different process options incorporated into each remedial alternative, and costs associated with implementation of each remedial alternative.

1.2.7 Alternative Specific Risk Assessment - Section 8

The reach-specific remedial alternatives are further evaluated in terms of risk reduction and residual risks. This evaluation identifies residual ecological or human health risks based on estimates of the effective reduction of the concentrations of COCs in the Lower Fox River, attributable to a selected alternative.

Section 8 presents the alternative-specific risk assessment. This evaluation is intended to support risk based remedial alternative selection for the Lower Fox River. An alternative-specific risk assessment will provide further comparative data of each remedial alternative that can be used as an additional decision-making tool in the ROD.

1.2.8 Detailed Analysis of Remedial Alternatives - Section 9

Each of the remedial alternatives was evaluated using criteria specified in the EPA RI/FS Guidance. The criteria are divided into three categories as follows:

- Threshold Criteria
  - Overall Protection of Human Health
  - Compliance with ARARS

- Balancing Criteria
  - Long-Term Effectiveness and Permanence
  - Reduction of Toxicity, Mobility and Volume Through Treatment
  - Short-Term Effectiveness

  - Implementability
  - Cost

- Regulatory/Community Criteria
  - State Acceptance
  - Community Acceptance

The Regulatory/Community Criteria are typically addressed in the ROD and will be considered in the FS process during review by WDNR through public meetings held during the public comment period whereby comments are solicited by the WDNR on the contents of the RI and FS Reports.

Section 9 presents a detailed analysis of each remedial alternative developed for the four reaches.

1.2.9 Comparative Analysis of Alternatives - Section 10

A comparative analysis that focuses on synthesizing the detailed analysis of Section 9 into readily accessible decision-making tools was performed. This comparison is in contrast with the detailed analysis conducted in Section 9 in which each alternative was analyzed independently without a consideration of other alternatives. The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative relative to one another, so that the key tradeoffs the decision-maker must balance can be identified. To accomplish this, numerical measures were used to evaluate how each alternative compares relative to all others with respect to addressing each of the following questions:

- What is the residual human health risk after the implementation of the alternative?

- What is the level of disruption to local communities associated with the construction of each alternative?

- What is the administrative effort necessary to implement each alternative?

- What is the volume of contaminated sediment removed from the Lower Fox River?

- What is the cost of implementing each alternative?

- What is the incremental cost of reducing risk for each alternative?

Section 10 presents a synoptic comparison of the predicted performance of each of the reach-specific alternatives in relation to specific decision-making evaluation criteria.

1.3 Section 1 Figures

Figures for Section 1 follow this page, and include:

Figure 1-1 Lower Fox River Study Area
Figure 1-2 Little Lake Butte des Morts Reach
Figure 1-3 Appleton to Little Rapids Reach
Figure 1-4 Little Rapids to De Pere Reach
Figure 1-5 De Pere to Green Bay Reach
Figure 1-6 Overview of Feasibility Study Process

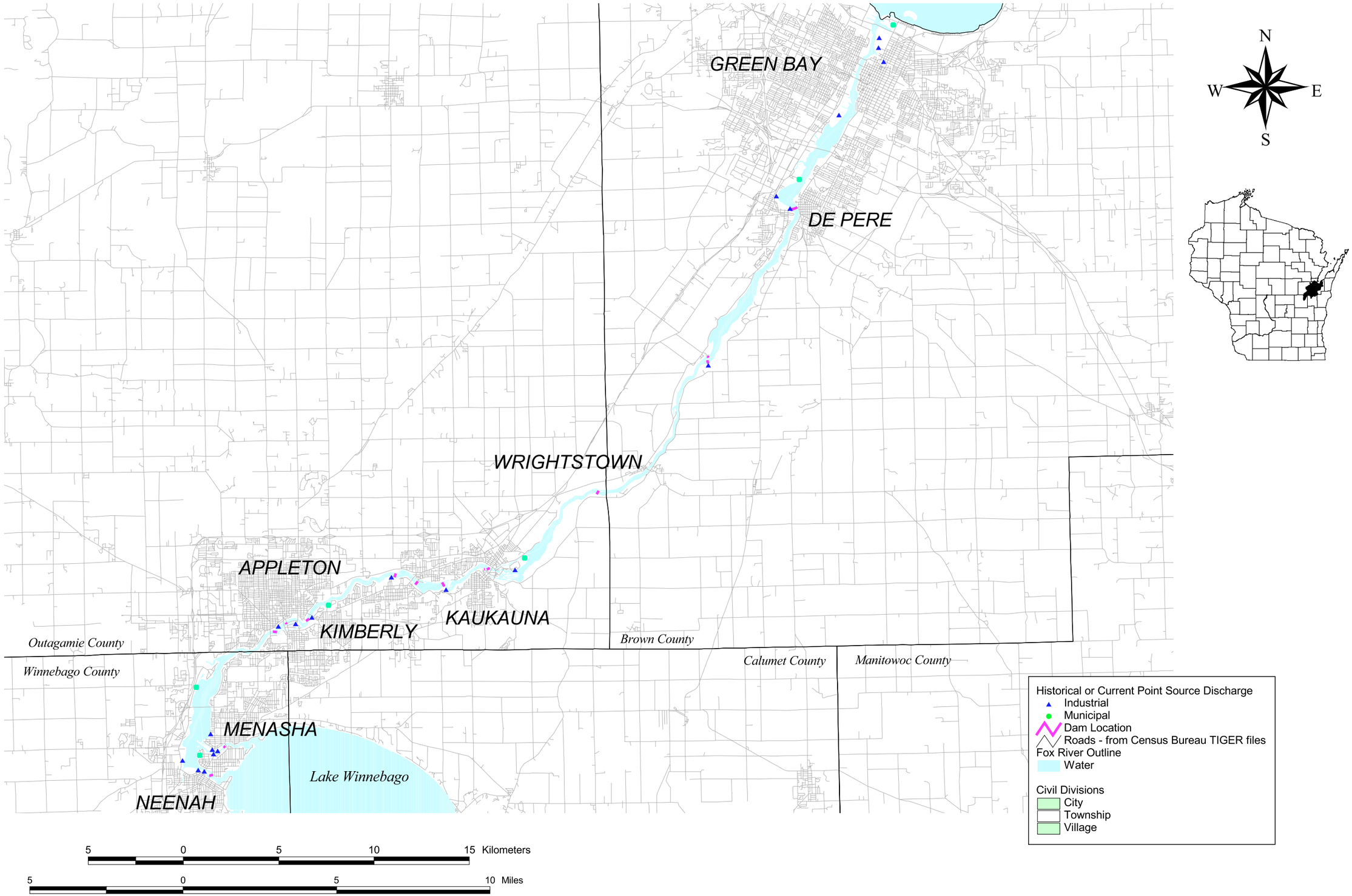

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FIGURE 1-1
LOWER FOX RIVER STUDY AREA

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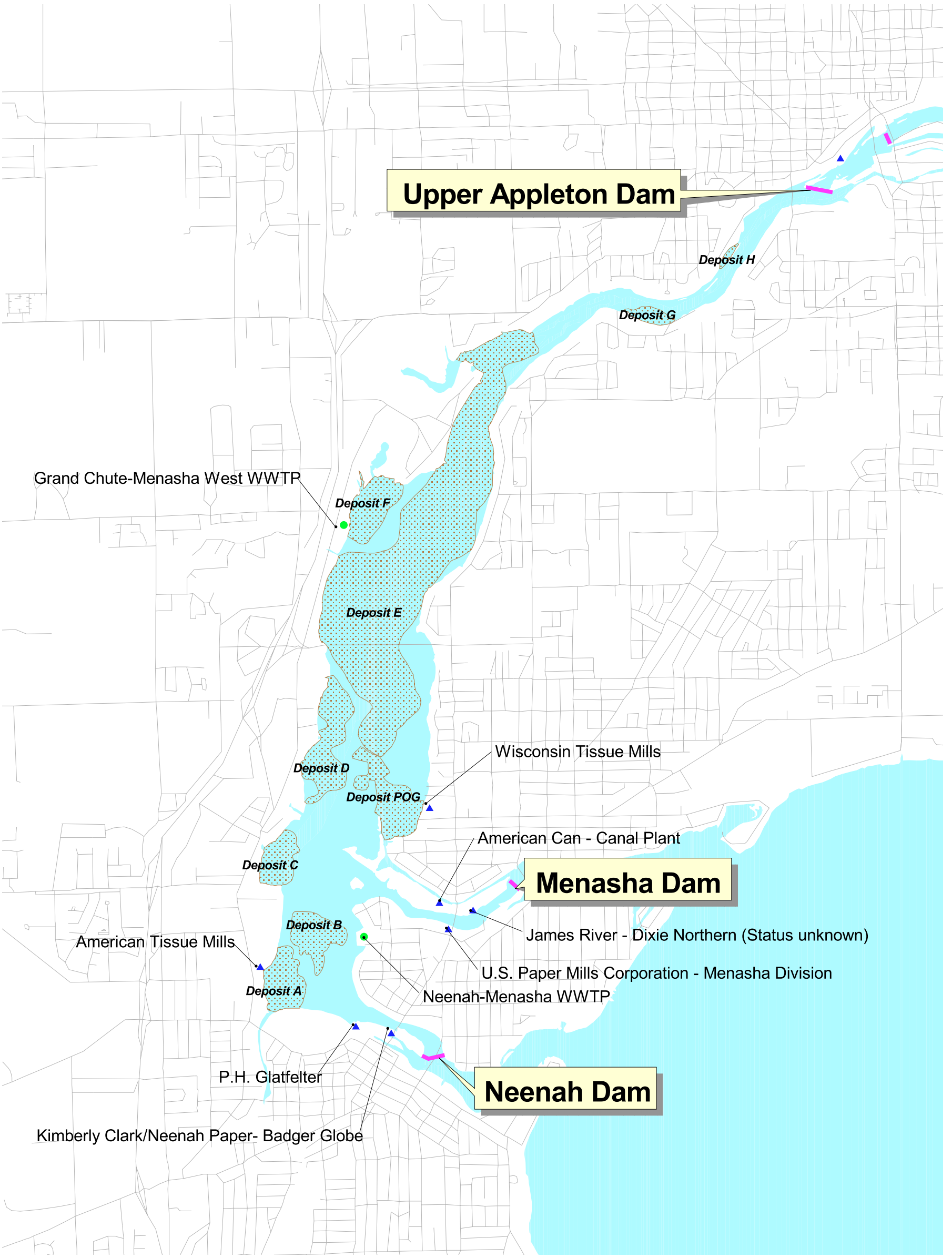

Deposit Outline - Mass Balance Study

Point Source Locations

- **Industrial**
- **Municipal**

Dam Locations

Roads - from Census Bureau TIGER files

Fox River Outline

Water

1 0 1 **Kilometers**

1 0 1 **Miles**

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FIGURE 1-2
LITTLE LAKE BUTTE DES MORTS REACH

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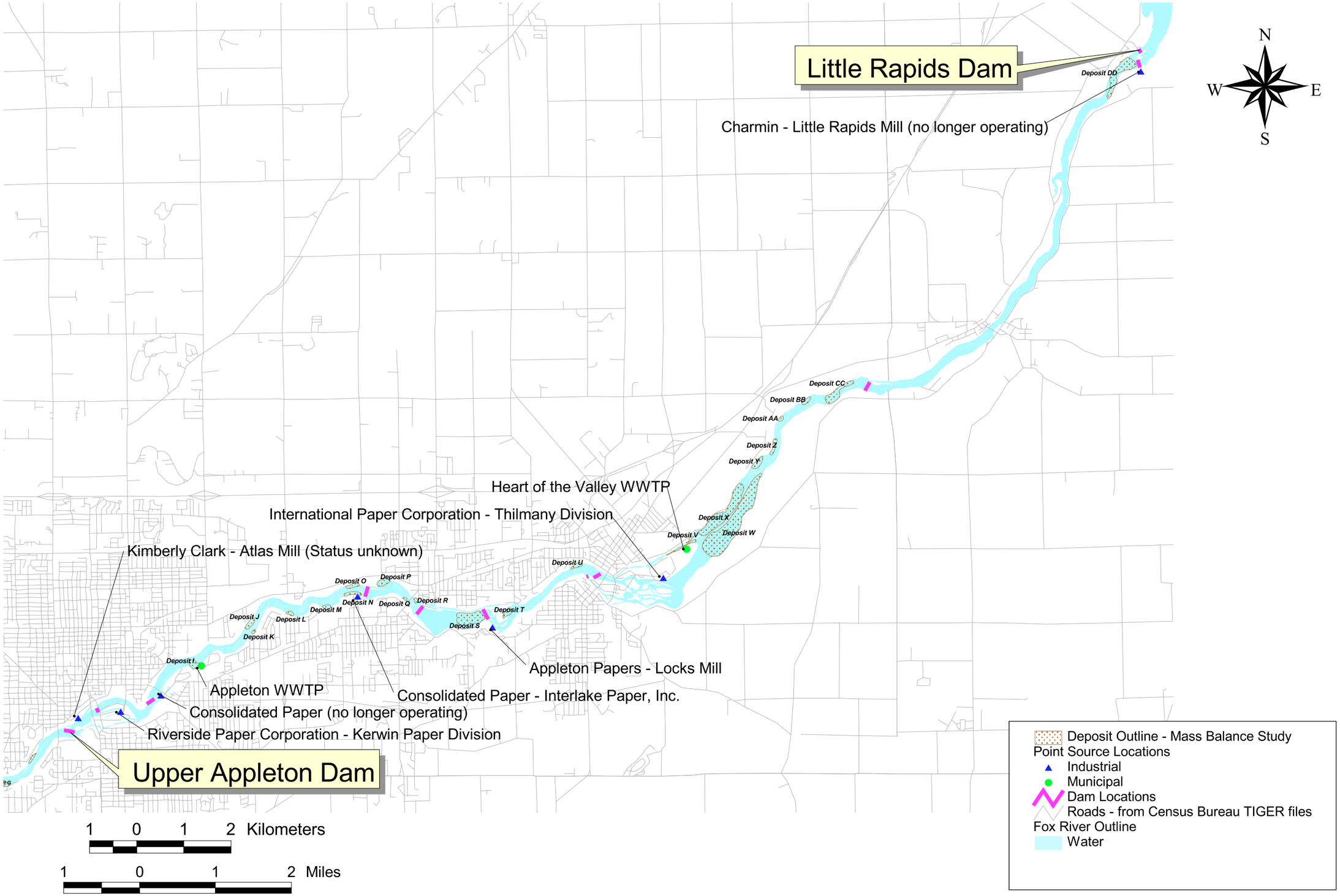

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FIGURE 1-3
APPLETON TO LITTLE RAPIDS REACH

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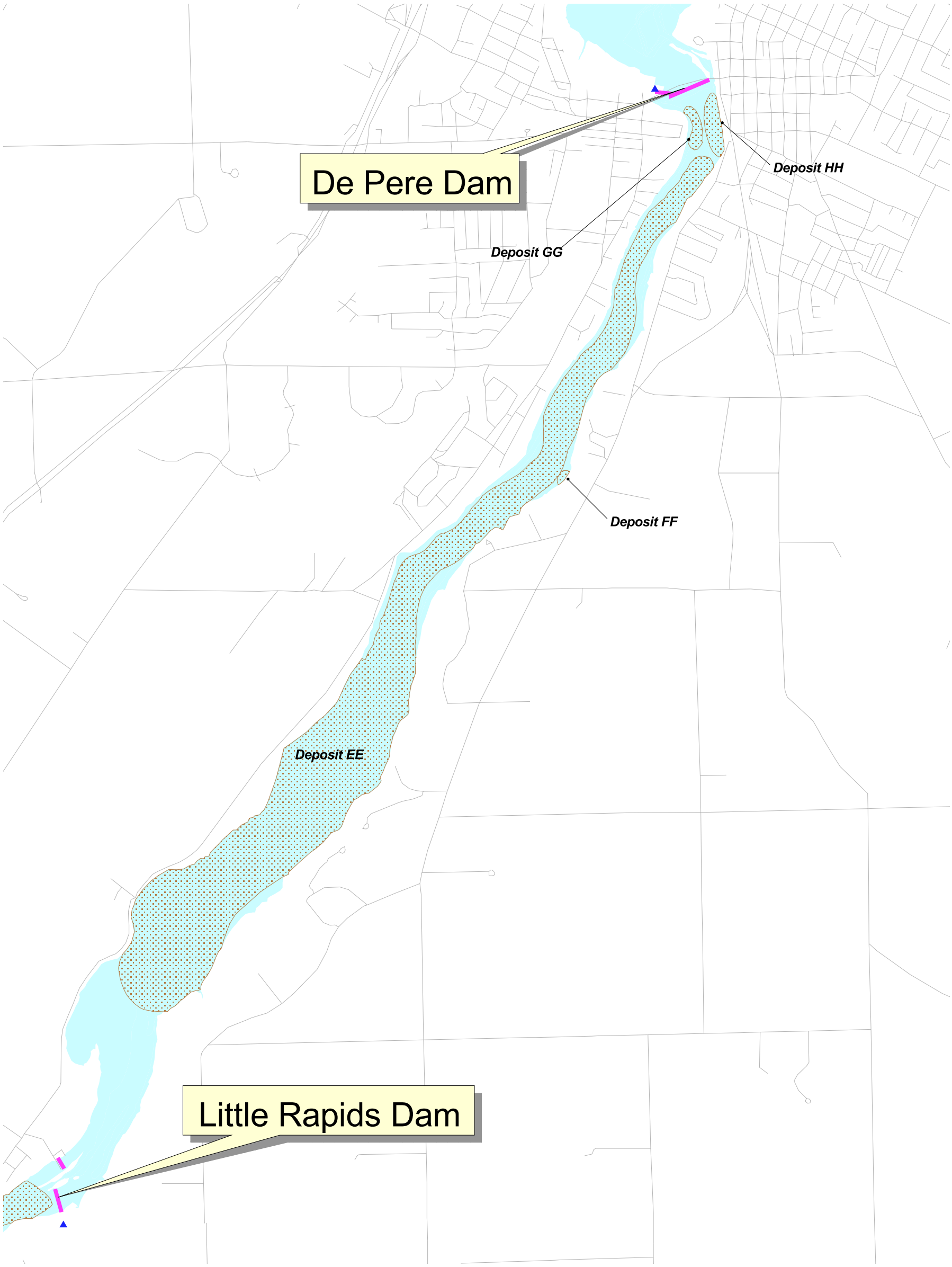

Deposit Outline - Mass Balance Study
Point Source Locations
Industrial
Municipal
Dam Locations
Roads - from Census Bureau TIGER files
Fox River Outline
Water

1 0 1 Kilometers

1 0 1 Miles

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FIGURE 1-4
LITTLE RAPIDS TO DE PERE

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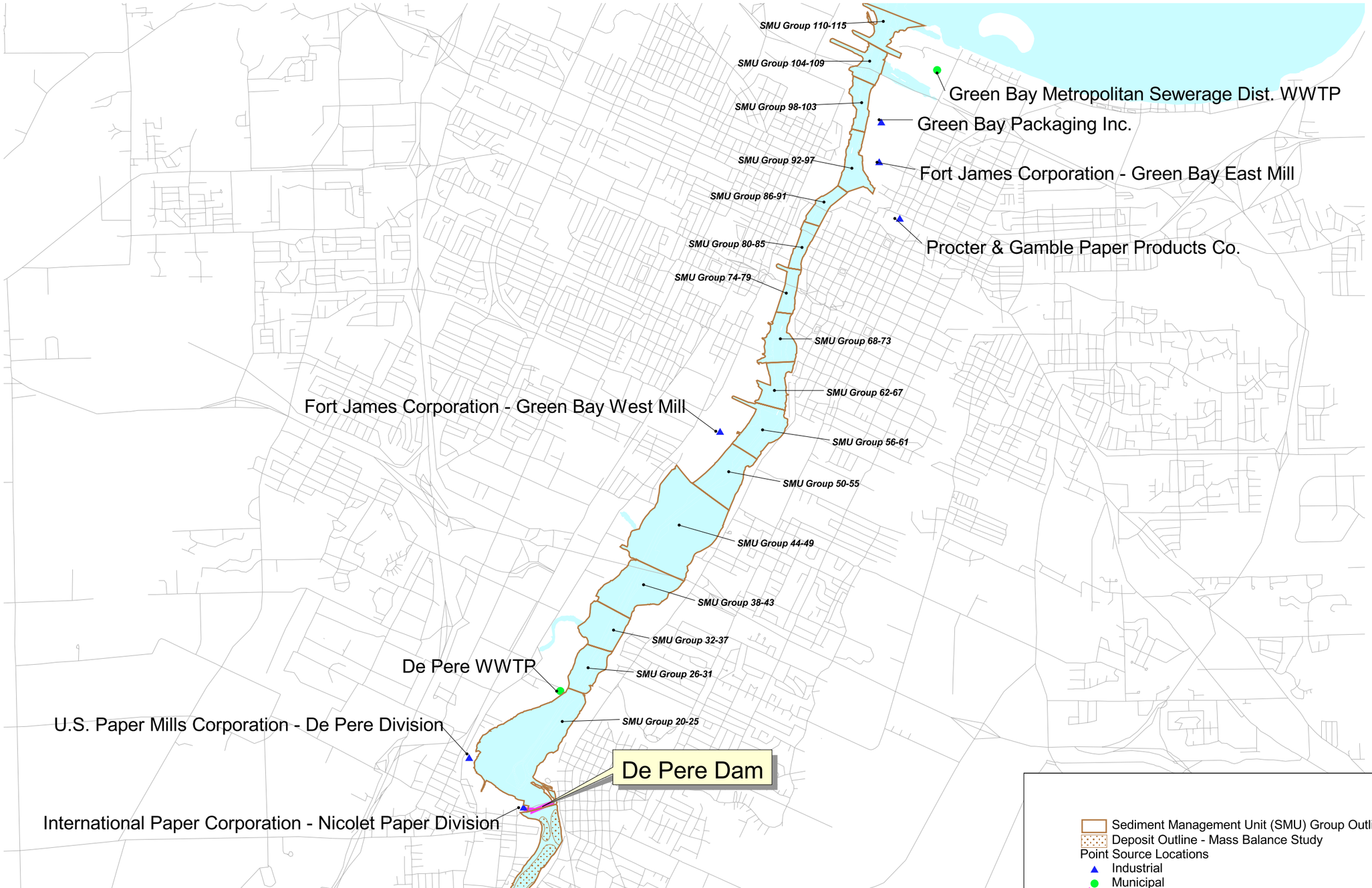

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FIGURE 1-5
DE PERE TO GREEN BAY REACH

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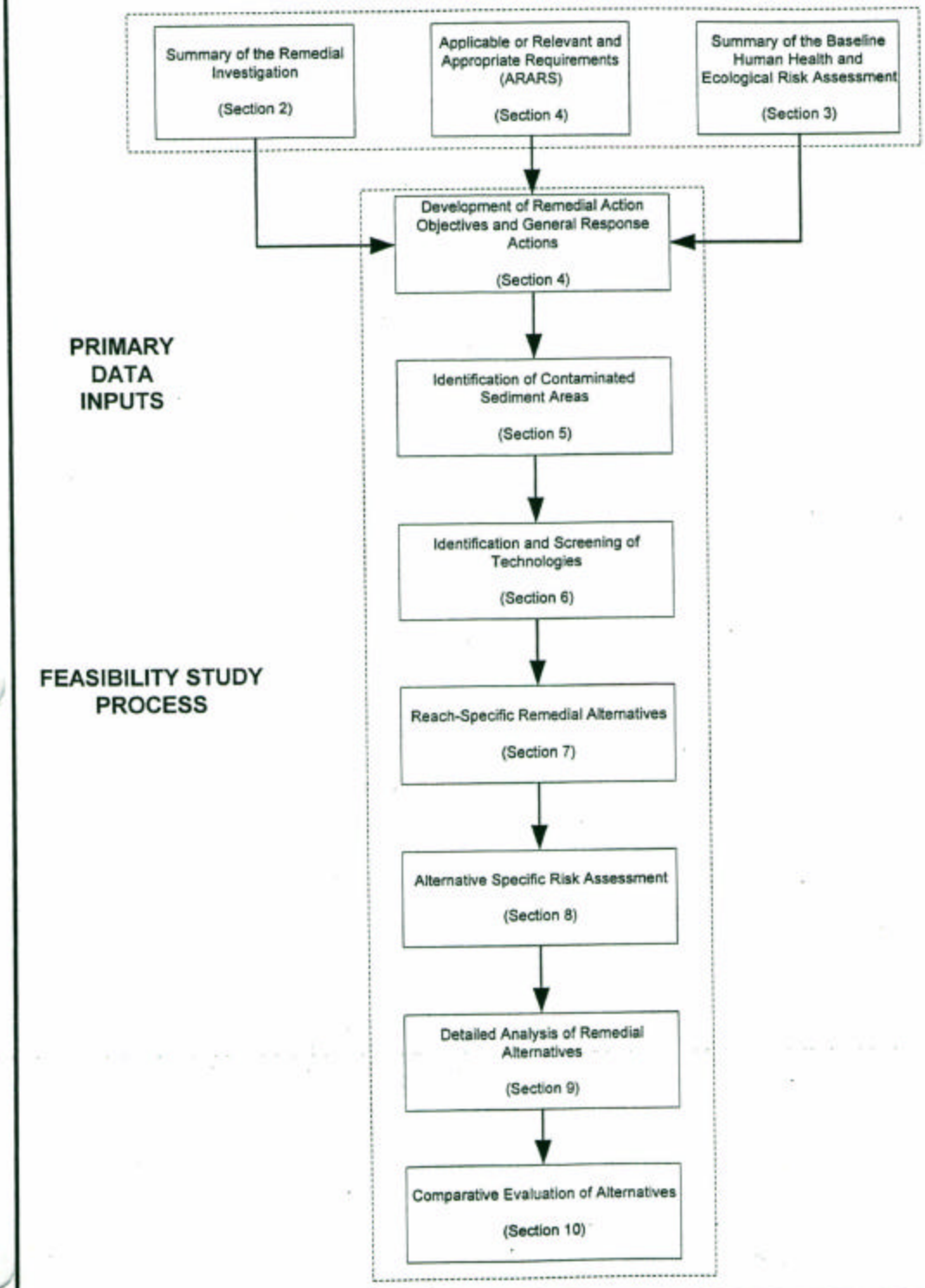

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LOWER FOX RIVER FEASIBILITY STUDY 3-3584-940				OVERVIEW OF FEASIBILITY STUDY PROCESS
CURRENT DATE	01-13-99	CADD FILE	3584C04S	FIGURE 1-6

2 Summary of the Remedial Investigation

This section summarizes the relevant hydrological, physical, and biological characteristics of the River from the Remedial Investigation for the Lower Fox River (ThermoRetec, 1999b). This section is not intended to provide a complete description of the system, nor sources of chemical compounds, but rather, a description of the elements of the system that are pertinent to the Feasibility Study.

The Lower Fox River RI that was conducted as part of the RI/FS process was primarily comprised of compiling, reviewing, and summarizing river sediment information from previous studies. Also, additional sediment samples were collected and analyzed for selected COC as part of the RI. The purpose of the RI was to evaluate the nature and extent of impacted sediments. Previously, 35 sediment deposits (labeled A through HH) upstream of the De Pere dam and 96 Sediment Management Units (SMUs 20 through 115) downstream of the De Pere dam were identified.

The scope of the RI was limited to the Lower Fox River and it describes the physical, chemical and biological characteristics of the river. The RI included the following activities:

- Compilation, review, and organization of existing data available for the Lower Fox River
- Assessment of the quality and usability of the existing data
- Collection of additional sample data in selected areas of the river
- Description of the physical characteristics of the river and sediment deposits
- Refinement of estimates of the occurrence, volume and mass of sediments which contain previously identified chemical parameters

The RI describes the magnitude and extent of COC in sediments and water only. A substantial amount of chemical data has been collected from a variety of biological organisms. Biological impacts and their implications within the river system are addressed in the RA. The RI should be referred to for detailed geographic and historic and current land use descriptions, as well as the evaluation

of sediment and water impacts. A summary of the RI Report is provided in this section.

2.1 Environmental Setting

The Lower Fox River flows northeast approximately 63 kilometers [km] (39 miles) from Lake Winnebago, the largest inland lake in Wisconsin, to its mouth, which discharges into lower Green Bay. The Fox River is the primary tributary to lower Green Bay, draining approximately 15,806 square kilometers [km^2] (6,330 square miles [mi^2]) (USGS, 1998f). The change in river elevation between Lake Winnebago and Green Bay is approximately 51 meters [m] (168 feet) (National Oceanic and Atmospheric Administration [NOAA], 1992).

The river, which was once navigable between Lake Winnebago and Green Bay, is now impounded by 12 dams and 17 locks. The river is still navigable to recreational boats but the Rapide Croche lock is permanently closed to restrict sea lamprey migration. The upstream reach of the Lower Fox River is bounded by two dams in the cities of Neenah and Menasha that control the pool elevation of Lake Winnebago and restrict river discharge.

The Neenah and Menasha channels connect Lake Winnebago with Little Lake Butte des Morts (LLBdM). LLBdM is a relatively shallow section of the Lower Fox River, approximately 1,070 m (3,500 feet) wide and extending approximately 4.8 km (3 miles) in length. Between the outlet of LLBdM and the Little Rapids dam, the Lower Fox River is generally less than 300 m (1,000 feet) wide and the channel meanders more in this stretch of the river than in other downstream reaches. Sediment is typically deposited on the inside portion of a meander bend, while the outer part of the meander bend (the cut bank) usually is non-depositional due to increased stream flow velocities. Between the Little Rapids and De Pere dams, the river is again relatively straight, although not as wide or as shallow as LLBdM.

Between the De Pere Dam to the river's mouth, the Lower Fox River is a large, channelized stream which is stabilized along much of this reach with either riprap or concrete reinforcement. Navigation for ocean bound vessels extends from Green Bay, upriver approximately 4.8 km (3 miles) to the Fort James Paper Company (formerly Fort Howard) turning basin via a shipping channel maintained to a water depth of approximately 7.3 m (24 feet). Flow in this reach of the river is sometimes reversed by wind-driven increases in Green Bay water levels.

The Lower Fox River is relatively narrow, generally less than 305 m (1,000 feet) wide over much of its length, and ranging up to approximately 6.1 m (20 feet) deep in some areas. Where the river widens significantly, the depth of the river generally decreases to less than 3 m (10 feet), and in the case of LLBdM, water depths range between 0.61 to 1.53 m (2 and 5 feet) except in the main channel. The main channel of the river ranges in depth from 1.8 to 6.1 m (6 to 20 feet). General and specific reach bathymetry information is listed in the NOAA (1992) recreational charts for Lake Winnebago and the Lower Fox River.

The lower 4.8 km (3 miles) of the river are dredged by the United States Army Corps of Engineers (USACE) in order to maintain a navigation channel. Prior to 1982, the navigation channel was maintained from the mouth of the river to the De Pere dam. Since 1982 this upper portion of the channel has been maintained to a depth of 1.8 m (6 feet). Between De Pere and the Fort James-West turning basin, the depth of water is generally less than 1.8 m (6 feet) outside of the navigation channel. Downstream of the Fort James-West turning basin, the river narrows so that the navigation channel almost encompasses the entire width of the river. According to USACE records, dredging activities in this reach and just downstream of the mouth of the river have removed 11.86 million cubic meters [m^3] (15.54 million cubic yards [yd^3]) of sediment between 1957 and 1997. USACE records indicated that between 1957 and 1965 the sediments were disposed of in Green Bay at locations without any containment. After 1965 most dredged sediments were disposed of at one of two confined disposal facilities (CDFs); the Bay Port facility, beginning in 1965, and the Renard Island (also known as Kidney Island) CDF after it opened in 1979.

2.2 Site History

The Fox River valley has long been home to many different Native Americans before European settlers arrived. In the late 1600s, Europeans had entered the region and used the river system for fur trading and as a route for exploration and transportation. Early settlements in the area included Fort Howard, which eventually became the city of Green Bay. By the early 1800s, timber, agricultural, fishing, fur trading, and other commercial activities were either well established or in the process of development. This region has long been used for transportation, commerce, energy, food (fish and waterfowl), and recreation, as well as habitat and a migration corridor for wildlife. Industries developed rapidly in the Fox River Valley due to the availability of water from Lake Winnebago, the Fox River, and Green Bay. Beginning in about 1820, lumber and flour industries came to the valley. The year 1850 marked the peak of the flour industry, which was followed by flour mill conversion to saw mills and/or pulp and paper mills. The earliest paper mill in Outagamie County was established in Appleton in 1853.

Fourteen hydro power sites were also located along the Fox River from Green Bay to Lake Winnebago. Today, industries and municipalities use the river for waste assimilation, industrial processing, cooling water, and power generation, while individuals use the river for food and recreation (WDNR, 1995).

Water quality degradation in the Lower Fox River has occurred over an extended period of time, largely beginning in the mid-1800s and continuing through the mid-1900s. By the mid-1800s, the Green Bay region experienced rapid growth (Smith et al., 1988). During this period, the fish and water of Green Bay, along with the timber and land of the region faced increased pressure from exploitation of the local resources. During the latter half of the 1800s, the regional forests were cut to feed the saw mills of the Lower Fox River and the lumber markets in the lower Midwest. The previously forested land was converted to agriculture and runoff from the surrounding farmlands and deforested areas added significantly to the nutrient and sediment loads of the Lower Fox River and Green Bay (Smith et al., 1988).

In addition to these nutrient and sediment loads, the introduction of untreated municipal sewage and industrial wastes also contributed to decline of the Lower Fox River and Green Bay water quality. The Lower Fox River saw and paper mills discharged saw dust and other fibrous material as well as waste sulfite liquors (chemical residues of the pulping operations). The saw dust and fibrous material formed large mats that floated on the water surface. In Green Bay, these mats reportedly covered several square kilometers of the water surface (Smith et al., 1988). The waste sulfite liquors and other industrial waste discharges severely lowered dissolved oxygen (DO) levels in the river and bay. This resulted in widespread fish die-offs in the 1920s and 1930s and low oxygen conditions extending into Green Bay as far as 30 km (19 miles) north of the mouth of the Fox River.

The degraded conditions of the Lower Fox River and Green Bay continued into the 1940s and 1950s. Due to high levels of fecal coliform bacteria, resulting from discharge of untreated municipal sewage, Green Bay's public swimming beach was permanently closed to swimming in 1943. Due to a declining water table and groundwater supplies and the pollution in the Lower Fox River and Green Bay, the city of Green Bay built a water supply pipeline in 1955 to bring Lake Michigan water from approximately 4 miles off shore of the city of Kewaunee.

During the late 1800s, a strong commercial fishing industry had been established in the Green Bay area. However, due to pollution and the introduction of exotic species in Green Bay, several of the bays most prized fisheries disappeared. These included lake sturgeon, herring, and lake trout. Additionally, the yellow perch

populations, which had been the mainstay of the local commercial fishing industry, declined significantly during this time period. In 1943, approximately 1.08 million kilograms [kg] (2.4 million pounds) of yellow perch were caught; by 1966 the catch had declined to 73,480 kg (162,000 pounds), a decrease of more than 90% (Smith et al., 1988). Although pollution levels have decreased, the introduction of exotic species into Green Bay continues to disrupt commercial fishing.

In addition to a decline in the commercial fishing catch, the populations of many piscivorous (fish-eating) birds also declined. Bird populations suffered from the effects of chlorinated pesticides, such as DDT and dieldrin. The EPA moved to ban these two pesticides in the early 1970s. The effects associated with chlorinated pesticides lead to concerns about other chlorinated compounds, including PCB, PCP and dioxins/furans. PCB, DDT and dieldrin were all detected in piscivorous birds in 1987 and 1988, years after the use and discharge of these compounds had been discontinued (Dale and Stromberg, 1993).

The historical discharges from municipal, industrial, and agricultural entities located within the Lower Fox River watershed occurred during an era of little environmental regulation and knowledge of the fate and effects of chemicals in the environment. As a result, numerous compounds can be detected in the sediments and water as well as the aquatic and wildlife species within or frequenting the river. During the early 1980s, more than 100 potentially toxic substances were found in Lower Fox River sediments, water, and fish tissue (Sullivan and Delfino, 1982). Recently, the list of parameters in the river and southern Green Bay have been estimated to include over 360 potentially toxic substances (International Joint Commission [IJC], 1992; WDNR, 1993a), including PCB, mercury, polynuclear aromatic hydrocarbons (PAHs) and ammonia. Other compounds found in some, but not all, deposits include the pesticides DDT, 4,4'-Dichlorodiphenyl dichloroethylene (DDE), 4,4'-Dichlorodiphenyl dichloroethane (DDD), and PCP. Of the potentially toxic substances found, the RA concludes that PCBs are the primary COC.

During the 1950s, 60s, and 70s, many industries throughout the United States used and produced products which contained PCB. In the early 1950s, National Cash Register (NCR) developed carbonless copy paper for office and business use. This paper used a coating of PCB emulsion, which released oils containing PCBs when struck or pressed, to produce the document copy. In 1954, local paper mills in the Lower Fox River Valley began manufacturing carbonless copy paper, resulting in the release of PCBs to the environment through process wastewaters and through the de-inking and recycling of waste carbonless paper. Aroclor 1242 was the PCB mixture used in the emulsion applied to the manufacture of

carbonless copy paper and approximately 30 million pounds of this emulsion were reportedly used in the Lower Fox River valley between about 1954 and 1971 (WDNR, 1998a). The use of PCBs was unregulated and the potential health effects were unknown during this time period.

The use of PCBs in carbonless paper manufacturing began in 1954 and ceased in 1971; however, recycling of the carbonless copy paper may have continued for a short time thereafter. It is estimated that by the end of 1971, over 98% of the PCB present within the Lower Fox River had been discharged, a portion of which settled into the river sediments (Fitzgerald & Steuer, 1996; WDNR 1998a).

In addition to the river sediments and water, PCBs have also been detected in many fish and bird species in the Lower Fox River and Green Bay. Evaluation of PCB-impacts in sediment, fish, and wildlife has been conducted by the WDNR, the EPA, and the United States Fish and Wildlife Service (USFWS). Due to bio-accumulation of PCBs in fish and fish-eating predators, consumption advisories have been in place since 1976. Therefore, eliminating sediments as a source of PCBs was one of the high priority items established in a Remedial Action Plan (RAP) for the Lower fox River and Lower Green Bay Area Of Concern (AOC) (WDNR, 1988).

An estimated 190,000 kg to 375,000 kg (418,000 to 825,000 pounds) of PCB were released into the Lower Fox River between 1954 and the present (WDNR, 1998a). PCBs from sediment deposits are discharged into Green Bay at the mouth of the Lower Fox River through sediment transport and PCB dissolution in the water column. Sediments are the most significant source of PCBs entering the water column (Fitzgerald and Steuer, 1996) and over 95% of the PCB load into Green Bay is derived from the Lower Fox River (WDNR, 1998a). It is estimated that approximately 72,500 kg (160,000 pounds) of PCBs have already escaped the Lower Fox River into Green Bay and Lake Michigan (EPA, 1998). In addition, up to 280 kg (620 pounds) of PCBs are estimated to be transported from the Fox River into Green Bay annually (Velleux and Endicott, 1994).

2.3 Current Land Use

The Lower Fox River Valley is the second largest urbanized region in the state of Wisconsin and supports a population of approximately 375,000, about 7% to 8% of the state's population. The Lower Fox River Valley, especially in the Appleton and Neenah-Menasha area, may still contain the largest concentration of pulp and paper industries in the world (20 mills in approximately 37 miles). The paper industry remains active within the valley and plays a vital role in the local and state economy. Between 1991 and 1996, an average of 101 pulp, paper, and

converting firms employed 26,716 people (Wisconsin Policy Research Institute and Wisconsin Paper Council, 1998). Other industries important to the region include metal working, printing, food and beverages, textiles, leather goods, wood products, and chemicals. In addition to heavy industrial land use, the region also supports a mixture of agricultural, residential, light industrial, conservancy, and wetland areas.

2.4 Sources of Detected Compounds

Potential sources of the detected compounds in the Lower Fox River include both point and non-point sources. Point sources are direct discharges or emissions from a discrete source, such as an outfall pipe, landfill, or spill. The chemical sources that are not specifically characterized and may encompass numerous individual discharges or emissions are non-point sources. Examples of non-point sources include agricultural and urban storm runoff as well as automobile emissions. Each of these types of sources contribute to the chemical impacts found in the Lower Fox River sediments.

2.4.1 Point Sources

The watershed area draining into the Lower Fox River is locally urbanized, particularly in areas adjacent to the river. Point sources of pollution within these urbanized areas include industries and municipalities that discharge directly into the Lower Fox River as well as releases from chemical spills, leaking underground storage tanks (LUSTs), and landfills.

Since the early 1970s, discharges to surface water require Wisconsin Pollutant Discharge Elimination System (WPDES) permits issued by the WDNR. The permit records indicate there are 44 major industrial and municipal WPDES dischargers in Brown, Outagamie, and Winnebago Counties. In 1990, there were 21 outfalls that discharged over 1 million gallons per day (MGD) to the Lower Fox River. The total discharge from these 21 outfalls was approximately 109 MGD.

Current major industrial/municipal discharges (exceeding 1 MGD) along each reach of the Lower Fox River include the following:

- LLBdM Reach: Badger Paper Mills; P.H. Glatfelter; Menasha Electric and Water Utility; Neenah/Menasha Wastewater Treatment Plant (WWTP); Kimberly-Clark Neenah/Badger Globe; U.S. Paper Mills; and Wisconsin Tissue mills

- Appleton to Little Rapids Reach: Appleton Papers; Appleton WWTP; Riverside Paper; International Paper-Thilmany Division; Interlake Papers; Appleton Paper; Heart of the Valley WWTP, and the Village of Wrightstown Sewer and Water Utility

- Little Rapids to De Pere Reach: None

- De Pere to Green Bay Reach: Nicolet Paper; Fort James; Procter & Gamble Paper; James River; Green Bay Packaging; U.S. Paper Mills; De Pere WWTP; and Green Bay Metropolitan Sewerage District (GBMSD)

WDNR completed a study to evaluate the source of PCBs in the Lower Fox River. Specific discharges were identified as the main source for some of the chemical parameters detected in the Lower Fox River. Although numerous contributors were recognized, seven entities ultimately were identified which are believed to have contributed over 98% of the PCBs discharged into the Lower Fox River between 1954 and 1971 (WDNR, 1998a). These include: P.H. Glatfelter Co. and the associated Arrowhead Park Site; Appleton Papers-Coating Mill; Appleton Papers-Locks Mill; Wisconsin Tissue; Fort James-Green Bay West; and the Appleton and Neenah/Menasha WWTPs, which accepted process water discharged from some of the entities listed above.

Similarly, elevated levels of mercury identified in Lower Fox River sediments have been attributed to mercuric slimicides (phenyl mercuric acetate) in paper manufacturing. This practice was discontinued in 1971 (Konrad, 1971). Sediments from above the Kaukauna dam to Green Bay were studied in 1970 and revealed elevated concentrations of mercury in river sediments. A number of studies completed in the late 1980s and 1990s to evaluate mercury concentrations in sediments and the water column indicated that mercury concentrations remain elevated more than 20 years after mercury use was discontinued.

Overall, pollutant loading of PCBs and many other chemicals have been reduced by at least 85% since the 1970s when effluent limits were imposed on facilities discharging more that one million gallons of wastewater per day. The discharge limits for many of the parameters discussed in this section, including the seven COPC identified in the SLRA, are listed in the Wisconsin Administrative Code (W.A.C.) NR 105 "Surface Water Quality Criteria and Secondary Values for Toxic Substances." The COPC include: PCBs, dioxin/furans, DDT and its metabolites (DDE and DDD), dieldrin, mercury, lead, and arsenic. Although PCBs have not been used in the Lower Fox River Valley in over 20 years, they are still detected in discharge at very low levels from previous point sources due to their ubiquitous nature and general persistence in the environment (WDNR,

1998a). Based on effluent discharge data from 1989/90, WDNR has estimated that current PCB discharge levels range from 3 to 5 kg annually and that there is little that can be done to further reduce these sources (Velleux and Endicott, 1994; WDNR, 1998a).

Few identifiable point sources exist for the other COPC in the Lower Fox River. Dioxin is not a manufactured compound; rather it is a by-product of various chlorinated organic compounds, such as PCBs. Therefore, it is often associated with PCBs but can also result from other sources. The pesticides, DDT and dieldrin, had widespread use in agriculture, but there is no point source associated with these compounds. Similarly, the metals lead and arsenic had widespread uses and are not associated with any specific point sources.

There are 17 closed municipal and industrial landfills that lie within a quarter mile of the Lower Fox River (Environmental Data Resources [EDR], 1996). Sixteen of these landfills are located below the De Pere dam in the Lower Green Bay AOC; the other is the former P.H. Glatfelter-Arrowhead Park Landfill (Arrowhead Park Site) at the southern end of LLBdM. This site was identified by as one of the potential PCB contributors (WDNR, 1998a). Three of these landfills, along with the Arrowhead Park Site, were studied during the Green Bay Mass Balance Groundwater Monitoring Study (WDNR, 1990 and 1992) for potential contributions of lead, cadmium, dieldrin, and PCBs to the Lower Fox River, and eventually Green Bay. These studies concluded that groundwater migration from these landfills does not adversely impact surface water bodies adjacent to these waste sites, especially with respect to lead, cadmium, or PCBs (Stohl and Erdmann, 1990 and 1992). The total PCB load from the Arrowhead Park Site is estimated not to exceed 12.8 grams [g] per year (g/year). The PCB load from the other 16 former municipal/industrial landfills located within the Green Bay city limits is estimated to range from 0.005 to 0.02 g/year, indicating that these would not likely contribute more than 1 gram of PCBs annually, combined (Stohl and Erdmann, 1990 and 1992). Therefore, the estimated daily PCB loads to groundwater from the Arrowhead Park Site (0.035 g/day) (Stohl and Erdmann, 1992) is minimal compared to the lowest winter daily PCB loading of 30 to 100 g/day as estimated from concentration data measured in the Lower Fox River below the De Pere dam (Steuer, 1990; WDNR, 1995).

Spills include surface releases of chemicals as well as leakage from underground storage tanks, pipelines and other structures. Spills of substances reported to WDNR include used motor oil, diesel and gasoline fuel, ammonia, and numerous industrial chemicals. From 1987 to 1991, there were 437 spills reported in the Lower Fox River basin and a response action was taken on 262 incidents. In 1992, there were 170 active cleanup cases for spills or leaking underground

storage tanks related to non-petroleum products in the Fox River basin. While many spill and LUST incidents have occurred within the Lower Fox River watershed, their potential effect on the river, if any, has not been specifically evaluated. However, spills are limited in volume and duration and the vast majority occur at locations are not likely to reach the river. Recent point source spills have relatively little impact on the river compared to the chemical parameters discharged directly to the river via the municipal and industrial dischargers. Therefore, they are not addressed further.

2.4.2 Nonpoint Sources

The Lower Fox River basin drains approximately 16,395 km^2 (6,330 mi^2). Due to the large size of the watershed, non-point sources have the potential to contribute significant pollutant loads from runoff and atmospheric deposition into the river.

The river sediments containing elevated concentrations of PCB as well as other compounds are dispersed along the entire Lower Fox River and are a continuing source of non-point pollution. PCB modeling studies (Velleux and Endicott, 1994; WDNR, 1995; WDNR, 1998a) were conducted to evaluate the sources, movement, and fate of PCBs in the Lower Fox River and Green Bay. It is estimated that over 99% of the PCBs in the river water is due to sediment resuspension, volatilization and/or dissolution of PCBs from the sediments (Fitzgerald and Steuer, 1996). These same processes control the occurrence of other organic and inorganic compounds within the sediments and water.

Soil eroded from agricultural land, construction sites, and street runoff as well as erosion from unstable stream banks is estimated to contribute 100,000 tons of solids to the Lower Fox River each year (WDNR, 1988). Only 5% of the solids load results from municipal/industrial dischargers; the remaining 95% is from non-point sources, such as agricultural and urban run-off.

Data from the early 1980s estimated PCB atmospheric deposition contributions to Lake Michigan of approximately 290 to 450 kg (640 to 990 pounds) annually. A Green Bay mass balance study (GBMBS) conducted in 1989 estimated atmospheric contributions of PCBs to Green Bay. The rain/snow flux of PCBs to Green Bay was approximately 2 to 16 kg (4.5 to 35 pounds) annually (Hornbuckle et. al., 1992). Due to the overall limited surface area of the Lower Fox River compared to the surface area of Green Bay, it is estimated that direct atmospheric contributions of the PCBs to the river are limited. Emissions of PAHs, lead and other compounds are also potential sources of these constituents in sediments. The fate of air emissions is dependent on many factors and their effects on the Lower Fox River are unknown.

2.5 Transport and Fate Processes

The transport and fate processes of the COC in the Lower Fox River define how these compounds behave in the natural environment and move from their sources to potential human and environmental receptors. Chemical transport is dependent on whether the chemical is present in a dissolved phase or particulate phase. The chemicals may move downstream in the water column, volatilize into the atmosphere, partition to sediment and be deposited or suspended in the water column, and/or be incorporated into the food chain. In general, PCBs tend to sorb to sediment particles, are resistant to biodegradation, volatilize slowly and bioaccumulate in aquatic organisms. Some chemical-specific properties that affect these tendencies include the following: organic carbon partitioning coefficient (Koc); octanol-water partitioning coefficient (Kow); water solubility; vapor pressure; Henry's Law constant; specific gravity; chemical formula; biodegradation rate; and bioaccumulation factor. These properties are usually the most important factors effecting the overall fate of a chemical in the environment and can be used to predict the mechanisms by which each chemical (or group of chemicals) will move through or transform in the environment.

Stream flow rate and sediment particle characteristics are the two main factors which influence the physical movement of sediment and sorbed chemical parameters in the river environment. Chemicals with low solubility in water (i.e., PCBs, PAHs, mercury) tend to sorb to fine-grained organic material in the water column, which may accumulate as deposits on the river bottom. After deposition, bottom sediments are subject to resuspension by river currents and transport as river bed load. Chemicals sorbed to fine-grained sediments and organic matter may be transported in suspension or as bed load by wind-driven and river water velocities. Sediment transport is the primary mechanism for chemical movement in the Lower Fox River and Green Bay.

In general, flowing water transport mechanisms in the Lower Fox River move impacted sediment downstream to Green Bay and Lake Michigan. Surface water transport characteristics are dependent on the type of water body present. In flowing water, as is the case throughout most of the Lower Fox River, the direction of chemical transport is typically downstream. In the case of marshes or lakes (i.e., LLBdM and Green Bay), chemical transport may be directed inland as well as downstream by wind or water driven currents. In stagnant water bodies, such as marshes, advective forces are less important, and primary attenuation may be through diffusion.

Other important processes that affect long-term chemical persistence include bioturbation of sediments and bioaccumulation. Sediment bioturbation will

generally improve degradation rates of organic compounds through oxygenation of surface sediments. However, bioturbation has little impact on the degradation rates of highly chlorinated organic compounds (i.e., PCBs and dioxin) or inorganic metals.

Bioaccumulation occurs in an organism when the uptake rate exceeds the organisms ability to remove the chemical through metabolic functions, dilution, or excretion, so that the excess chemical is stored in the body of the organism. One result of bioaccumulation may be biomagnification of the chemical up the food chain. Biomagnification occurs at the higher end of the food chain when the chemicals are passed from one organism to another through feeding processes (i.e., phytoplankton contain low levels of PCBs which are passed to the fish and ultimately to piscivorous birds or humans).

2.6 Extent Of Chemical Distribution

The following sections discuss the magnitude and distribution of the COC in the Lower Fox River. Therefore, this discussion is limited to PCBs, dioxin/furan, DDT, dieldrin, mercury, lead, and arsenic.

2.6.1 Lake Winnebago (Background) Results

Sediment samples were collected from three locations within Lake Winnebago to provide background concentrations of compounds entering the Lower Fox River. Lake Winnebago sediment samples were analyzed for PCBs (both Aroclors and congeners), SVOCs, pesticides, and metals. The results, indicate that only Aroclors 1242 and 1254 were present at concentrations from 10 to 20 micrograms per kilogram [µg/kg], whereas the three detected PCB congeners were below 5.5 µg/kg. The low concentrations suggest that PCBs in Lake Winnebago are not a concern and total PCB concentrations in Lake Winnebago sediments ranged as high as 36 µg/kg.

Dioxin/furan samples were not collected in Lake Winnebago and DDT and dieldrin were not detected.

Seven metals, including mercury, lead, and arsenic, were detected in Lake Winnebago sediments. Concentrations ranged up to 0.17 milligrams per kilogram [mg/kg] for mercury, 39 mg/kg for lead and 6 mg/kg for arsenic.

2.6.2 PCB Distribution

Distribution of total PCBs in the Lower Fox River sediments is described below for each reach of the river. Calculations indicate that the entire Lower Fox River

contains an average of approximately 3.17 g/m^3 in sediments with concentrations exceeding 50 µg/kg (0.05 parts per million [ppm]) and approximately 10.32 g/m^3 in sediments with concentrations exceeding 10,000 µg/kg. The analysis of PCB focuses on those volume and mass calculations for sediments containing over 50 µg/kg, which is slightly above total PCB concentrations observed in Lake Winnebago. Based on the calculated estimates, such sediments with less than 50 µg/kg total PCB concentrations account for less than 0.1% of the total calculated PCB mass.

LLBdM Reach PCB Results

The LLBdM reach of the Lower Fox River includes sediment deposits A through H and POG. Total PCB results for this reach indicate that concentrations range from 2 to 222,722 µg/kg in this reach. The sediment volume and mass estimates for the LLBdM reach indicate that approximately 1,830 kg (4,026 pounds) of PCBs are contained within about 1.64 million m^3 (2.14 million cy) of impacted sediment containing over 50 µg/kg PCB. This represents approximately 6.8% of the total PCB mass and about 19.3% of the sediment volume containing PCB in the river. Considering only sediments containing over 10,000 µg/kg (10 ppm), approximately 1,050 kg (2,315 pounds) of PCBs are contained within about 140,000 m^3 (183,000 yd^3). In sediments with concentrations exceeding 10,000 µg/kg, deposits A, B, and C, have between 9 and 12 g/m^3 of PCB. These results indicate that deposits A, B, and C contain the largest mass to volume ratio in this reach of the river. The PCB mass distribution in each sediment layer indicates that approximately 1,240 kg (2,734 pounds) of PCB (68% of the PCB mass in LLBdM) are present in the upper 30 centimeters [cm].

Appleton to Little Rapids Reach PCB Results

This section summarizes the sediment sampling results for the Appleton to Little Rapids reach of the river, which includes sediment deposits I through DD above the De Pere dam. Total PCB results for this reach indicate that concentrations range between 0.34 and 185,560 µg/kg.

The sediment volume and mass results for this reach indicate that approximately 302 kg (665 pounds) of PCBs are contained within about 418,800 m^3 (547,800 yd^3) of sediment containing over 50 µg/kg PCB. This represents just over 1% of the total PCB mass and about 5% of the sediment volume. Considering only sediments containing over 10,000 µg/kg (10 ppm), approximately 66 kg (145 pounds) of PCBs are contained within about 19,450 m^3 (25,540 yd^3). The mass to volume results indicate that Deposit N has the highest PCB mass ratio found in this reach of the river, with about 4 g/m^3 of PCB in sediments containing over 50 µg/kg. Considering only sediment with more than 10,000 µg/kg, deposits N,

X, and DD have mass ratios ranging from 4.6 to 7.5 g/m^3 of PCB. The distribution of PCB mass in each sediment layer in this reach indicates that more PCB is located in the 10 to 30 cm layer than in any other layer in this reach . Approximately 205 kg (450 pounds) of the 302 kg (665 pounds) of PCB are located in the upper 30 cm of sediment and there is a general decrease in PCB mass with depth.

Little Rapids to De Pere Reach PCB Results

This section summarizes the sediment sampling results for the Little Rapids to De Pere reach, which includes sediment deposits EE through HH. Total PCB results for this reach indicate that concentrations range between 3 and 54,000 µg/kg. Considering sediments with more that 50 µg/kg of total PCBs, approximately 1,447 kg (3,180 pounds) of PCB are contained within 1.14 million m^3 (1.5 million yd^3) of sediment. This is approximately 5.4% of the PCB mass contained in the Lower Fox River. Considering sediments exhibiting more than 10,000 µg/kg PCB, the mass decreases to 391 kg (860 pounds) in a volume of 50,000 m^3 (65,000 yd^3), or approximately 2.0% of the estimated total PCB mass in the Lower Fox River. The volume and mass results for this reach indicate that the mass to volume ratio ranges from 1.2 g/m^3 of PCB in Deposit EE to almost 4 g/m^3 of PCB in Deposit GG for sediments containing more than 50 µg/kg PCB. However, when considering sediment containing more than 10,000 µg/kg PCB, the ratios range from 4 to 8.5 g/m^3. As in both previous upstream reaches of the river, the majority of the PCB mass in this reach is located in the upper 30 cm of sediment. Approximately, 1,070 kg (2,355 pounds or 74%) of PCB are present in the two upper layers (0 to 30 cm) while the remaining 379 kg (834 pounds or 26%) of the PCB is located between 30 and 100 cm.

De Pere to Green Bay Reach PCB Results

This section summarizes the sediment sampling results for the De Pere to Green Bay reach. This reach includes the seven mile stretch of the river downstream of the De Pere dam where the 16 SMU groups (and 96 SMUs) are located. Total PCB concentrations in this reach range from 4 to 710,000 µg/kg. Based on the large number of SMUs in this reach, the PCB distribution analysis was completed for each SMU group (six SMUs per group), which correlates to a PCB transport model water column segment.

Considering sediments with more that 50 µg/kg total PCBs, approximately 23,440 kg (51,570 pounds) of PCB are contained within 5.3 million m^3 (7.0 million yd^3) of sediment. This is approximately 87% of the PCB mass and about 63% of the PCB impacted sediment volume contained within the entire Lower Fox River. Considering only sediments with more than 10,000 µg/kg, the PCB mass

decreases slightly to 17,655 kg (38,840 pounds) but the sediment volume decreases significantly to 1.65 million m^3 (2.2 million yd^3). This is approximately 70% of the estimated total PCB mass in the entire Lower Fox River.

Large volumes of sediments have collected in areas where the river width increases (i.e., SMUs 20-25 and 44-49), but these sediments generally have less than 5 g/m^3 of PCB or they do not contain sediments with PCB concentrations above 50,000 µg/kg. The PCB mass to volume ratios (for sediments with concentrations above 50 µg/kg) indicate that SMUs groups between the De Pere dam and the Fort James turning basins generally have about 3 to 4 g/m^3 of PCB. In the vicinity of the Fort James turning basin, this value rises significantly to approximately 5 to 12 g/m^3 of PCB, but then declines about 1 to 2 g/m^3 of PCB, except near the river mouth. It is assumed that historic dredging of the navigation channel in this downstream portion of the river has affected the PCB concentrations and mass compared to the other portions of this reach.

The volume and mass results for this reach indicate that there are three SMU groups, SMUs 56-61, 62-67, and 68-73, which have a PCB mass to volume ratio of 5 g/m^3 or greater for sediments containing more than 50 µg/kg PCB. SMU group 56-61 has the highest PCB mass to volume ratio of any area in the Lower Fox River, with more than 12 g/m^3. For sediments with PCB concentrations exceeding 10,000 µg/kg four SMU groups have mass to volume ratios exceeding 11 g/m^3 and all SMU groups upstream of and including SMUs 86-91 have ratios exceeding 8 g/m^3 of PCB. However, focusing on these 13 SMU groups is similar to treating the entire reach as one large deposit. Therefore, by focusing on the six SMU groups (32-37, 38-43, 56-61, 62-67, 68-73, and 80-85) with either the highest PCB concentrations or greatest mass to volume ratios, the total PCB mass is approximately 11,800 kg (26,000 pounds), or about 44% of the PCB mass in the Lower Fox River. This mass is contained in approximately 1.74 million m^3 (2.27 million yd^3), or about 20% of the total impacted sediment volume in the river.

Over 8,323 kg (18,350 pounds) of PCBs are present in the 50 to 100 cm depth in this reach. The mass of PCB increases significantly between the upper 10 cm of sediments and the 50 to 100 cm layer. Approximately 850 kg (1,874 pounds) of PCBs are located in the surface sediments; however, the 10 to 30 cm layer has approximately 3,300 kg (7,275 pounds) of PCBs, about four times the mass located in the surface sediments. The estimated PCB mass in the 0 to 50 cm layers only represents approximately 35% of the mass in this reach. The remaining 65% of PCBs are buried at least 50 cm below the sediment surface and approximately 30% of the PCB mass is located at least 100 cm below surface sediments.

2.6.3 Dioxin/Furans

Six samples were collected in LLBdM from surface sediments in deposits D, E, and POG for analysis of 2,3,7,8-TCDD (dioxin) and 2,3,7,8-TCDF (furan). The SLRA indicated that furan concentrations above 2,000 nanograms per kilogram [ng/kg] are a potential concern; there is no established level for dioxins. Dioxin concentrations ranged up to 5.44 ng/kg while furan concentrations ranged up to 71.29 nanograms per kilogram [ng/kg]. Comparison of the dioxin/furan results with total PCB results indicates there is not a strong correlation between concentrations of the compounds.

In the Appleton to Little Rapids reach, three surface sediment samples were collected from Deposit N for analysis of dioxin and furan. Dioxin concentrations ranged between 0.51 and 16.7 ng/kg while the furan concentration was 333.05 ng/kg.

In the Little Rapids to De Pere reach, three samples were collected from deposits EE and HH. Dioxin concentrations ranged up to 6.82 ng/kg and furan concentrations ranged up to 117.09 ng/kg. In Deposit EE the dioxin and furan concentrations in the surface sediment were 24 times and four times greater than the subsurface results, respectively. These limited data suggest that dioxin/furan concentrations decrease with depth.

No sediment samples were analyzed for dioxin/furan compounds in the De Pere to Green Bay reach of the river.

2.6.4 Pesticides

The analyses of pesticides in the Lower Fox River detected 14 compounds. Of these, only dieldrin and DDT, were identified in the SLRA as being present at concentrations of potential concern.

LLBdM Reach Results

Deposit C is the only location throughout the river where dieldrin was detected and its extent appears to be very limited. The SLRA did not identify a concentration of concern for dieldrin. DDT was detected in deposits D, E, and POG. The SLRA indicated that total DDT concentrations above 1.6 µg/kg are a potential concern. DDT concentrations ranged between 5.5 and 50 µg/kg, with the highest concentration detected in Deposit POG. Previously collected samples indicate that DDT concentrations decrease with depth in Deposit D.

Appleton to Little Rapids Reach Results

DDT was detected in deposits N and X and the concentration found in Deposit N was the highest noted in any reach of the river at 360 μg/kg. Concentrations in Deposit X are all below 3.4 μg/kg. All the results are from surface samples such that pesticide concentrations at depth cannot be evaluated. The pesticide dieldrin was not detected in this reach of the river.

Little Rapids to De Pere Reach Results

Ten (10) pesticides were detected in 12 sediment samples collected in this reach of the river. Except for the two composite samples

DDT concentrations detected in three samples from Deposit EE and a composite sample from EE/GG ranged from 5.1 to 20 μg/kg. All but two of the pesticide samples analyzed for this reach of the river were collected during the supplemental data collection activities. Therefore, only surface sediment results are available for most of the samples. However, the composite samples were collected at a single location and suggest that DDT concentrations decrease with depth. The pesticide dieldrin was not detected in this reach of the river.

De Pere to Green Bay Reach Results

Neither DDT or dieldrin were detected in this reach of the river.

2.6.5 Inorganic Compounds

Mercury

Mercury background levels in Lake Winnebago averaged 0.14 mg/kg. Almost 99% of samples analyzed in the Lower Fox River exceeded this value. Mercury results for the 338 samples analyzed are as follows:

Summary of Mercury Results (mg/kg)

River Reach	Number of Samples	Minimum Concentration	Maximum Concentration	Average
LLBdM	102	ND	5.43	1.18
Appleton to Little Rapids	21	ND	5.45	2.14
Little Rapids to De Pere	138	ND	9.82	2.34
De Pere to Green Bay	77	ND	7.7	1.15
Entire River	338	ND	9.82	1.73

ND = Not Detected

The sediment sampling focused on specific deposits along the river; therefore, it is difficult to assess whether differences between reaches are meaningful. In the Little Rapids to De Pere reach, the large majority of samples were composite samples taken from within deposits EE/GG/HH. About one half of the mercury results exceeded 5 mg/kg, which significantly raised the average concentration for this reach.

Samples were collected at over 60 locations in deposits D, E, POG, N and EE/GG/HH to evaluate vertical distribution of mercury. With some exceptions, surface sediment concentrations exceeded those observed in deeper samples, typically by a factor of two to five times or more. However, results for Deposit POG indicate that in five of the six locations, the deeper sediment results are up to 2 times higher than the surface sediment results. Dredging in the vicinity of Deposit POG may be resulting in the burial of sediments impacted by mercury.

Samples collected from 45 locations in deposits EE/GG/HH to evaluate vertical distribution of mercury indicate that the upper sediment concentrations range from 1.5 to over 10 time greater than the lower sediment concentrations from 43 of these locations. Three or more samples were collected at 25 locations in deposits EE/GG/HH. In seven of these locations, mercury concentrations in the lowest sample exceeded concentrations of the middle sample.

The vertical trends in this reach of the river suggest that sediments with relatively low mercury levels, possibly from non-point sources, are covering sediments with higher concentrations at deposits behind the De Pere dam. Mercury transport maybe related to specific occurrences (i.e., high flow events), similar to PCBs, rather than as a continual process. Mercury use in paper production was discontinued in 1971 (WDNR, 1996), approximately the same time that PCB use ceased. Mercury is wide-spread throughout the Lower Fox River and likely extends to depths similar to PCBs. Specific point sources for mercury in sediments are not apparent from their distribution because mercury concentration ranges are not as large as PCB. The SLRA indicates that mercury values exceeding 0.15 mg/kg are a potential concern.

Lead

Lead background levels in Lake Winnebago averaged 35 mg/kg. Approximately 80% of samples analyzed in the Lower Fox River exceeded this value. Lead results for the 129 samples analyzed are as follows:

Summary of Lead Results (mg/kg)

River Reach	Number of Samples	Minimum Concentration	Maximum Concentration	Average
LLBdM	16	3.54	549	126
Appleton to Little Rapids	9	5.43	280	78
Little Rapids to De Pere	15	2.25	1,400	168
De Pere to Green Bay	89	5.3	350	91
Entire River	129	2.25	1,400	103

A limited number of sediment samples (40 or 31%) were collected and analyzed for lead above the De Pere dam. The results indicate that a number of samples in these reaches have very high concentrations, ranging from 280 to 1,400 mg/kg, respectively, in selected locations. Overall, the distribution of lead is sporadic and the average concentrations in all three of these reaches exceed the Lake Winnebago background level of 35 mg/kg. Additionally, the composite sample results, collected to evaluate vertical distribution, indicated that the deeper sediments in Deposit POG have higher concentrations than do the surface sediments, which is similar to that of mercury. However, in Deposit EE the vertical distribution results indicated surface sediments had higher concentrations and deeper sediment levels were well below Lake Winnebago background concentrations.

In the De Pere to Green Bay reach where the large majority of samples were collected, lead was detected in all 89 samples and concentrations ranged from 4.44 and 350 mg/kg. All but nine of the samples exceeded the background level of 35 mg/kg, indicating that elevated lead values are widespread in this reach of the river. Concentrations in this reach averaged 103 mg/kg.. Additionally, all samples were collected from surface sediments, therefore, the vertical distribution of lead in this reach is unknown. The results do not suggest any distribution pattern for lead within the surface sediment. The SLRA indicates that lead concentrations above 47 mg/kg are a potential concern.

Arsenic

Arsenic background levels in Lake Winnebago averaged 5.33 mg/kg. Arsenic was analyzed in 129 samples and was detected in 111. Approximately 63% of the samples analyzed in the Lower Fox River exceeded this value. The results are as follows:

Summary of Arsenic Results (mg/kg)

River Reach	Number of Samples	Minimum Concentration	Maximum Concentration	Average
LLBdM	16	1.27	6.8	4.65
Appleton to Little Rapids	9	2.46	9.7	4.93
Little Rapids to De Pere	15	2.17	7.6	4.99
De Pere to Green Bay	89	ND	385	12.6
Entire River	129	ND	385	9.8

Similar to lead, a limited number of sediment samples (40 or 31%) were collected and analyzed for arsenic above the De Pere dam. The average arsenic concentrations for the three reaches above the De Pere dam were below that observed in Lake Winnebago. Sediments exhibiting higher values may be within a normal range of variability near background. This is similar to the conclusion reached by the WDNR Triad Assessment (1996).

In the De Pere to Green Bay reach, arsenic was detected in 71 samples and 59 of these samples exceeded the background concentration of 5.3 mg/kg. Concentrations ranged up to 385.57 mg/kg, which was detected at this concentration in SMU 38. The same sample also exhibited the highest concentrations of cadmium, nickel, selenium, and silver. Based on the number and relatively high concentrations for parameters detected in this SMU, the results indicate point source impacts in this area. The remaining arsenic concentrations ranged between 0.8 and 13.35 mg/kg, and discarding the highest result, the average for this reach would be just over 7 mg/kg. The SLRA indicates that arsenic concentrations above 8.2 mg/kg are a potential concern.

2.6.6 Surface Water Sampling Results

Water samples collected during previous investigations indicate that 36 different parameters or physical properties of water in the Lower Fox River have been analyzed. The greatest number of samples have been analyzed for PCBs, followed by the inorganic parameters and physical properties of the water. The water sampling data is very limited in comparison to sediment sampling data. Therefore, the analysis focused on PCBs, mercury, and DDT. Using the water data collected in 1994/95 and an average discharge of 122 m^3/second, the annual average PCB load from the Lower Fox River into Green Bay was calculated to be about 210 kg (for 1994/95). Given seasonal variations in stream flow and chemical concentrations, this is similar to the results obtained by Velleux and

Endicott (1994). Additionally, the results obtained herein and from previous studies indicate that a significant portion of the PCB load is derived from sediments in the De Pere to Green Bay reach, suggesting that the large mass of PCB present within this reach is responsible for this increase.

Similarly, the estimated loads for mercury and DDT were calculated using the 1994/95 water sampling results and the average stream flow discharge. The mercury load may range between 10 and 300 kg (22 to 661 pounds) annually, with an average of about 100 kg. These results suggest that mercury load may, at times, be as great as the PCB load. Conversely, the estimated DDT load ranges from 0.23 to 0.81 kg (0.51 to 1.8 pounds) annually, which is much lower than the estimated loads for either PCBs or mercury.

3 Summary of the Baseline Human Health and Ecological Risk Assessment

A *Baseline Human Health and Ecological Risk Assessment for the Lower Fox River and Green Bay* has been prepared as a companion document to the RI and FS (ThermoRetec 1999a). This section summarizes the baseline assessment risks to both human health (BLRA, Section 5) and the environment (BLRA, Section 6) for the Lower Fox River and lower Green Bay, Wisconsin.

The BLRA for the Lower Fox River and Green Bay focused on defining the current (or baseline) human health and ecological risks associated with the COPC that had been previously identified as posing potential risk that were identified by the WDNR following the completion of the Screening Level Risk Assessment (RETEC, 1998). The COPC included PCBs (total and Aroclor 1242), dioxins/furans (2,3,7,8-Tetrachlorodibenzo-*p*-dioxin [2,3,7,8-TCDD] and 2,3,7,8-Tetrachlorodibenzofuran [2,3,7,8-TCDF]), DDT and its metabolites (DDE and DDD), dieldrin, and three metals (arsenic, lead, and mercury). The BLRA examined how contaminants move from the sediment and water into humans and ecological receptors within the Lower Fox River and the Lower Green Bay estuary. The BLRA further quantified the levels of risk, and distinguished those chemicals which pose the greatest potential for risks from those that pose negligible risks to human health and the environment.

For both assessments, risk was characterized for the four reaches of the Lower Fox River, including Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, and De Pere to Green Bay. Risks were also quantified within the lower Green Bay estuary - defined as the Bay from the mouth of the Fox River north to Chambers Island, although, this not a part of the feasibility study .

An additional objective of the BLRA was to identify what were “safe” (i.e., no risk) levels of total PCBs in fish, and determine what concentrations in the sediment would correspond to safe levels in fish. To that end, the BLRA developed and validated a mathematical model that could predict with acceptable accuracy what the safe levels of total PCBs in sediments were. These were called Sediment Quality Thresholds (SQT), and were developed for both human and ecological receptors. The SQTs have direct applicability to the FS in deriving the removal or containment alternatives that minimize exposure and risk.

A summary of the results of the BLRA are presented in the two sections below. In addition, the SQTs are presented in Section 3.3.

3.1 Ecological Risk Assessment

Important pathways and receptors were identified for the Lower Fox River. These include:

- Insects and other invertebrates that live in the water and are important prey items for fish and other insects.

- Insects and other invertebrates that live in or on the sediment ("benthic invertebrates") that are important in recycling nutrients and a principal part of fish diets.

- Fish, such as carp and catfish, that live on and forage in the sediments ("benthic fish"). These fish are in turn eaten by other fish, birds, mammals, and man.

- Fish, such as walleye and yellow perch, that live in the water column, and eat other fish or insects that live in the water or on the sediments. These fish may be in turn eaten by other fish, birds, mammals, and man.

- Birds, such as swallows, that eat insects that hatch from the sediments (insectivorous birds).

- Birds, such as cormorants or terns, that principally eat fish from the Lower Fox River or Green Bay (piscivorous birds).

- Birds, such as eagles, that will eat a variety of prey, including fish or small mammals (omnivorous birds).

- Mammals, such as mink, that eat fish as an important part of their diet (piscivorous mammals).

For each of these potential receptors, the Ecological Risk Assessment focused on reproduction, which is the most conservative endpoint. Risks were principally evaluated based upon whether or not the COPC were present at sufficiently high levels to cause reproductive dysfunction, death at birth, or deformities in the surviving offspring. Risks were evaluated by river reach, and are described below.

3.1.1 Little Lake Butte des Morts

Within the LLBdM reach, total PCBs and the dioxin-like coplanar PCBs (TCDD equivalents) were the only COPC that were identified as causing risk to the benthic invertebrates, benthic fish, and piscivorous mammals.

3.1.2 Appleton to Little Rapids

Within the Appleton to Little Rapids reach, only total PCBs and mercury were found to be at levels sufficient to cause risk to ecological receptors. Risks exist for the sediment-dwelling benthic invertebrates (PCBs and mercury), omnivorous birds (total PCBs), and piscivorous mammals (PCBs).

3.1.3 Little Rapids to De Pere

Within the Little Rapids to DePere reach, total PCBs, the dioxin-like PCB congeners, and mercury were identified as the principal chemicals posing risks to ecological receptors in this reach as well. Risks were identified for the benthic invertebrates (total PCBs and mercury) and piscivorous mammals (total PCBs, Aroclor 1242, and TCDD equivalents).

3.1.4 De Pere to Green Bay

Within the De Pere to Green Bay reach, only the total PCBs and the dioxin-like PCB congeners were identified as posing risks to receptors include benthic invertebrates (total PCBs and Aroclor 1242), benthic fish (total PCBs), pelagic fish (total PCBs), and piscivorous mammals (total PCBs, TCDD equivalents).

3.1.5 Green Bay

There are risks to multiple receptors at all trophic levels from exposure to total PCBs and TCDD equivalents throughout Green Bay. This includes impacts to benthic invertebrates, reproduction in benthic and pelagial fish, embryonic deformities in piscivorous birds, and highly significant effects to piscivorous mammals. Of the remaining COPCs, DDE was at sufficiently high levels to place benthic fish at risk, and a lower potential risk for hatching of double-crested cormorant eggs.

3.2 Human Health Risk Assessment

Using the results of the Screening Level Risk Assessment as a starting point, the human health risk assessment for the Lower Fox River and Green Bay calculated cancer risks and noncancer hazard indices for the following receptors:

- Recreational anglers
- Subsistence anglers
- Hunters
- Drinking water users
- Local residents
- Recreational water users (swimmers and waders)
- Marine construction workers

3.2.1 Risk to Anglers

The highest cancer risks and noncancer hazard indices were calculated for recreational anglers and subsistence anglers due primarily to consumption of fish containing PCBs. Using fish concentration data from 1990 on (and Walleye data from 1989 in Green Bay), the cancer risks were as high as 1.1×10^{-3} for recreational anglers and 1.5×10^{-3} for subsistence anglers. These risks are more than 1,000 times greater than the 10^{-6} cancer risk level, which is the point at which risk management decisions may be made under Superfund. The risks are more than 100 times greater than the 10^{-5} cancer risk level used by Wisconsin in evaluating sites under NR 700 W.A.C. The maximum risks for the recreational and subsistence anglers are about 23 times greater than the cancer risks calculated for these receptors using the fish concentrations from Lake Winnebago, which represents background.

The hazard indices were as high as 39 for the recreational angler and 56 for the subsistence angler, far in exceedance of the value of 1 established to protect people from long-term adverse noncancer health effects. The noncancer health effects associated with exposure to PCBs include reproductive effects (i.e., conception failure in highly exposed women [Courval et al., 1997]), developmental effects (i.e., neurological impairment in highly exposed infants and children [Lonky et al., 1996; Jacobson and Jacobson, 1996; Johnson et al., 1998]), and immune system suppression (i.e., increased incidence of infectious disease in highly exposed infants [Smith, 1984; Humphrey, 1988]). All of these noncancer health effects are extensively documented in animal studies (ATSDR, 1997). The maximum noncancer hazard indices for the recreational and subsistence anglers are about 23 times greater than the hazard indices calculated for these receptors using the fish concentrations from Lake Winnebago.

To provide perspective on the number of individuals who are potentially exposed, there are on the order of 47,000 recreational anglers, based on fish licenses, and between 2,000 and 5,000 subsistence anglers, based on a variety of surveys. The subsistence anglers include low income minority anglers, Native American anglers and Hmong anglers.

3.2.2 Risk by River Reach

Cancer risks and hazard indices were calculated by river reach and Green Bay zones. However, there was relatively little difference between the highest risk in any reach or zone, which occurred in the De Pere to Green Bay reach, and the lowest risk in any reach or zone, which occurred in the Little Rapids to De Pere reach. The risk in the De Pere to Green Bay reach is 2.6 times greater than the risk in the Little Rapids to De Pere reach.

3.2.3 Risk by Fish Species

The cancer risks and hazard indices were examined in detail in four fish species: carp, perch, walleye and white bass. Carp consistently had the highest concentrations of PCBs in each reach where data was available and so exhibited the highest cancer risks and hazard indices. The lowest concentrations of PCBs occurred for perch, walleye or white bass, depending on the river reach or Green Bay zone. The cancer risks and hazard indices for these three species are comparable.

3.2.4 Risk to Other Receptors

The only other receptors with cancer risks exceeding 10^{-6} were the hunters and drinking water users. The risks to the hunter were as high as 1.1×10^{-4}, but were at least 10 times lower than the risks to the anglers. The risk to the hunter was due to ingestion of PCBs in waterfowl. The risk to drinking water users exceeded 10^{-6} only in the De Pere to Green Bay reach. This exceedance was due to arsenic in surface water, where the arsenic value was from one detected value in a total of six samples. A more systematic sampling of this water for arsenic might show this single detected value to be anomalous. Additionally, the water in this reach is not currently used as a source of drinking water and there are no plans to use it as such in the foreseeable future (this reach of the Lower Fox River is not classified for use as a source of drinking water). The cancer risks to drinking water users in all other reaches and Green Bay were below the 10^{-6} level, as were the cancer risks for the local residents, recreational water users (swimmers and waders) and marine construction workers.

The only other receptor with noncancer hazard indices exceeding 1 was the hunter. The highest hazard index for this receptor was 4.3, which is more than ten times lower than the highest hazard index to the subsistence angler at 56. The hazard indices were below 1 for drinking water users, local residents, recreational water users (swimmers and waders) and marine construction workers.

3.2.5 Risk Summary

The BLRA concluded that recreational and subsistence anglers are at greatest risk for contracting cancer or experiencing noncancer health effects. The highest cancer risks are more than 20 times greater than background risks calculated for eating fish from Lake Winnebago. The primary reason for these elevated risks and noncancer hazard indices is ingestion of fish containing PCBs.

3.3 Sediment Quality Thresholds

For both human health and ecological risk, the BLRA concludes that the greatest potential risk is from the total PCBs that are found in the sediments of the Lower Fox River. For human health, the greatest risk comes from individuals who consume the fish caught in the Lower Fox River and Green Bay. For the ecological receptors, the greatest risks were from total PCBs in the fish themselves, as well as to the birds and mammals (i.e., mink) that rely principally on fish in the diet. Reducing total PCBs in fish by reducing the levels of total PCBs in the sediments was determined to be the most important means of reducing risks on the Lower Fox River.

The Fox River Bioaccumulation Model is a series of mathematical equations that describes a food web that includes an uptake routes from sediment and water to benthic infauna and ultimately fish. The mathematical model developed in the BLRA was constructed so that it could be used to either predict fish tissue concentrations from a given sediment concentration, or to predict sediment concentrations from a given fish tissue concentration. The model was validated by running the model “forward”; that is, fish tissue concentrations were predicted from existing sediment concentrations. When the predicted concentrations were compared to the actual measurements of total PCBs in fish collected in the Lower Fox River, the results were highly comparable. As a further check on the models use, existing fish tissue concentrations were fed into the model, and existing sediment concentrations were predicted with reasonable confidence.

To determine SQTs associated with the protection of human health, fish consumption limits were derived from the Great Lakes Sport Fish Consumption Advisory (GLSFA. This protocol is used by the WDNR for the Fish Consumption Advisory currently in place for the Lower Fox River and Green Bay. Unrestricted fish consumption has been identified as an RAO for the Lower Fox River. For unrestricted consumption (at a 10^{-4} health risk), the GLSFA is based upon consuming 225 meals of fish per year for 70 years, with no more than 0.05 mg/kg. Table 3-1 shows the unlimited consumption (column 1), and the additional advisory levels from the GLSFA. Table 3-1A shows the whole body concentrations of carp, yellow perch and walleye that would not exceed the

advisory threshold. Table 3-1B is the corresponding SQT; for unlimited consumption the SQT would be 27, 522, and 177 μg/kg in sediments for the three listed fish species.

SQTs protective of ecological receptors are shown in Table 3-2. These are based upon levels of total PCBs in fish either causing risk to the fish themselves (survival or reproduction), or to mink eating the fish. For carp and walleye, the SQT associated with egg survival was 170, and 190 μg/kg, respectively. The corresponding SQT that would be associated with fish death was 265 and 286 μg/kg, respectively. For mink, the SQT that has never been observed to cause risk to reproduction or kit survival was estimated at 6 μg/kg, while the SQT estimated for the lowest concentration observed to cause a statistically significant effect on reproduction and kit survival was 275 μg/kg.

Given these array of data, WDNR selected an SQT of 250 μg/kg as the risk-based remedial clean-up value for sediments on the Lower Fox River.

3.4 Section 3 Tables

Tables for Section 3 follow this page, and include:

Table 3-1 Sediment Quality Thresholds for the Protection of Human Health
Table 3-2 Sediment Quality Thresholds for the Protection of Ecological Receptors

Table 3-1 Sediment Quality Thresholds for the Protection of Human Health

A Calculated Whole Body Tissue Limit Concentrations Associated with the GLFSC Fish Fillet Consumption Advisories where Risk = 10^{-4} (ppb)

Fish Species	Eat No More than One Meal/Week or 52 Meals/Year (50-200 ppb PCBs in fish) [1]	Eat No More than One Meal/Month or 12 Meals/Year (200-1000 ppb PCBs in fish)	Eat No More than One Meal Every 2 Months or 6 Meals/Year (1000-1900 ppb PCBs in fish)	Do Not Eat (>1900 ppb PCBs in fish)
Carp (0.7) [2]	70	290	1430	2710
Yellow Perch (0.04) [2]	1250	5000	25000	47500
Walleye (0.1) [2]	500	2000	10000	19000

B Calculated Sediment Concentrations Associated with Whole Fish Consumption where Risk = 10^{-4} (ppb)

Fish Species	Eat No More than One Meal/Week or 52 Meals/Year (50-200 ppb PCBs in fish) [1]	Eat No More than One Meal/Month or 12 Meals/Year (200-1000 ppb PCBs in fish)	Eat No More than One Meal Every 2 Months or 6 Meals/Year (1000-1900 ppb PCBs in fish)	Do Not Eat (>1900 ppb PCBs in fish)
Carp	27	111	546	1030
Yellow Perch	522	2090	10440	19840
Walleye	177	707	3530	6710

1. Unrestricted consumption
2. Fillet to whole body conversions

Table 3-2 Sediment Quality Thresholds for the Protection of Ecological Receptors

SPECIES	RISK	MEASUREMENT POINT	TOTAL PCB CONCENTRATION	ESTIMATED SQT	UNITS
walleye	No risk to egg survival	egg	500	170	µg/kg
	No risk to adult survival	whole body	750	265	
carp	No risk to egg survival	egg	500	190	
	No risk to carp survival	whole body	750	286	
mink	No risk to reproduction and kit survival survival	carp in diet	15	6	µg/kg prey
	Lowest observed concetration that affected reproduction and kit survival survival		720	275	

4 Development of Remedial Action Objectives and General Response Actions

Defining remedial action objectives (RAOs) is a critical step in the FS process, and is the subject of this section. In addition, this section identifies a set of general response actions (GRAs), implementation of which may result in meeting the RAOs.

RAOs are general goals that must be identified for each contaminated medium for protection of human health and the environment. In the development of RAOs for the Lower Fox River, consideration was given to the following:

- The potential for chemical constituents to pose a risk to human and ecological health
- ARARs and "to be considered" standards (TBCs)
- The potential for activities in the Lower Fox River to influence the quality of the Great Lakes Basin
- RAOs that have been previously developed for the Lower Fox River and for other rivers within the Great Lakes Basin

Sediments of the Lower Fox River are the subject of this FS due to the risks that PCBs in the sediments pose to human health and ecological receptors. Therefore, GRAs are identified for remediation of contaminated sediments of the Lower Fox River. The GRAs provide the basis for development of remedial alternatives and attainment of the goals established in the RAOs.

4.1 Chemicals of Concern

Identifying COCs is necessary for screening remedial technologies and designing remedial alternatives that will allow for RAOs to be met. Investigations of the sediments and water quality and historical information of former process operations at facilities located along the Lower Fox River has resulted in the identification of over 300 potential contaminants in the Lower Fox River. These were identified prior to the RI that was completed for this FS. Contaminants that potentially pose risks to human and ecological receptors, referred to as COPCs, were identified by WDNR after a review of the SLRA (RETEC, 1998). The

procedure used to identify COPCs for the Lower Fox River is discussed in the previously referenced SLRA document. COPCs carried through to the BLRA (ThermoRetec, 1999a) were:

- PCBs (total and/or Aroclor 1242)
- Dioxins (2,3,7,8-TCDD) and Furans (2,3,7,8-TCDF)
- DDT, DDE, and DDD
- Dieldrin
- Arsenic
- Lead
- Mercury

The seven organic and inorganic COPCs listed above were carried forward and examined in more detail in the BLRA for the Lower Fox River. The analysis documented in the BLRA indicates that PCBs are the chemicals causing the greatest human health and ecological risks in the river.

4. Applicable or Relevant and Appropriate Requirements

Section 121 (d)(1) of CERCLA stipulates that remedial actions instituted under the Superfund program meet the standards and criteria that are ARARs. Consideration must also be given to relevant information that, while not legally binding, are collectively referred to as TBCs.

The identification of ARARs and TBCs is dependent on the constituents present in the media, site-specific characteristics and the technologies employed during remediation. ARARs and TBCs that may contribute to defining remedial action objectives and remedial alternatives for the Lower Fox River are provided in Table 4-1 and Table 4-2. ARARs are generally classified into three categories; chemical-specific, location-specific and action-specific.

4.2.1 Chemical-Specific ARARs

Chemical-specific requirements are based on health- or risk-based concentration limits or discharge limits for environmental media such as air and water for specific chemicals. Most chemical-specific ARARs have been developed for groundwater and surface water media. These requirements may be used to set clean-up levels for COCs or to set the safe level of discharge or emission where such a discharge or emission occurs during implementation of a remedial action.

4.2.2 Location-Specific ARARs

Location-specific ARARs are restrictions placed on the types of activities depending on the particular location where these activities are conducted. Location-specific ARARs include requirements for wetland protection, and management of certain chemicals or waste in areas with seismic activity or in flood plains.

4.2.3 Action-Specific ARARs

Action-specific requirements generally set performance, design, or other operational controls or restrictions on particular types of activities related to management of substances or pollutants. These requirements address the particular activities that are associated with the selected remedy. Action-specific requirements do not themselves determine the remedial alternatives, rather they indicate how a selected alternative must be designed, operated and managed.

4.3 Summary of Previous RAOs

As part of developing proposed RAOs for the Lower Fox River, a review was completed of certain documents that have previously established RAOs for contaminated sediments in rivers within the Great Lakes Basin. The following documents were reviewed to compile RAOs for this FS Report.

- *Polychlorinated Biphenyl (PCB) Contaminated Sediment in the Lower Fox River: Modeling Analysis of Selective Sediment Remediation* (WDNR - Bureau of Watershed Management, February 1997b).

- *Feasibility Study Report for Deposits POG and N on the Fox River* (Graef, Anhalt, Schloemer & Assoc. Inc., April 1997).

- *Remedial Investigation/Feasibility Study Little Lake Butte des Morts Sediment Deposit A* (Blasland, Bouck & Lee., Inc, July 1993).

- *Draft Feasibility Study Report for Sheboygan Harbor and River Superfund Site* (Blasland, Bouck & Lee, Inc., April 1998).

- *Draft Manistique River and Harbor Engineering Evaluation/Cost Analysis* (Blasland, Bouck & Lee, Inc., April 1994).

A detailed description of RAOs as they are presented in the documents listed above is provided Appendix A. The first three documents present RAOs for areas of contaminated sediments in the Lower Fox River. The latter two documents

present RAOs for rivers that have sediment impacts similar to those in the Lower Fox River. All of the documents reviewed address river systems with contaminated sediments with the potential to affect the Great Lakes.

The documents listed above contain RAOs which generally can be grouped into the following categories:

- Achieving surface water ARARs
- Reducing the bioavailability of COCs in all affected media to levels that are protective of human health and ecological receptors
- Minimizing transport of contaminants into the Great Lakes

A review of previous RAOs provided a basis for the development of RAOs for the Lower Fox River. However, these RAOs are not necessarily used in this FS Report.

4.4 RAOs for Lower Fox River FS

RAOs for the Lower Fox River are presented in Table 4-3. The classifying terms; local and global, are used to describe the potential for RAOs to impact specific sediment areas (local) and downstream transport (global). The classifying terms; short-term and long-term, are used to generally describe the length of time to meet the goals established in each RAO. The main subject addressed by each RAO is described in the following subsections.

4.4.1 Surface Water Quality

Achieve, to the extent practicable, surface water quality ARARs and TBCs throughout the Lower Fox River (RAO 1).

RAO 1 was established for the purpose of achieving surface water quality ARARs and TBCs for all COCs. ARARs and TBCs may vary, depending on location along the Lower Fox River. RAO 1 refers to meeting the relevant ARARs/TBCs at all reaches of the River.

The W.A.C. establishes human health standards for warm water sport fish and cold water aquatic communities, as well as wildlife criteria for certain of the specified COCs. For example, W.A.C. provides the following water quality standards:

- 0.01 ng/L (warm water fisheries)
- 0.003 ng/L (Great Lakes)
- 0.12 ng/L (wildlife)

These values will be applied as a baseline for achieving, to the extent practicable, water quality standards for PCBs.

4.4.2 Human Health Risks

Reduce, to the extent practicable, the potential for chemicals of concern in the Lower Fox River to cause adverse human health effects principally through exposure to PCBs from ingestion of fish by anglers (RAO 2).

RAO 2 refers to attaining all human health risk-based criteria in all locations of the river. The BLRA has determined SQTs for protection of human health. The BLRA has determined that exposure to PCBs by anglers through ingestion of fish caught from the Lower Fox River and Green Bay is the exposure pathway leading to the greatest potential for adverse health effects in the Lower Fox River and Green Bay. Another exposure pathway with the potential for significant adverse effects is exposure to PCBs by hunters through ingestion of waterfowl hunted along the Lower Fox River and Green Bay. The potential adverse health effects associated with this exposure pathway are significant, but less than those associated with ingestion of fish. Meeting the RAO for anglers for the fish ingestion pathway will also reduce risks associated with the waterfowl ingestion pathway since the source of PCBs for both fish and waterfowl is sediment. As with hunters and the waterfowl ingestion pathway, addressing the RAO for anglers for the fish ingestion pathway will also reduce risks associated with the other exposure pathways since the source for other exposure pathways is generally sediment.

4.4.3 Ecological Risks

Reduce, to the extent practicable, the potential for chemicals of concern in the Lower Fox River to cause adverse effects to environmental receptors in the Lower Fox River (RAO 3).

RAO 3 refers to attaining all ecological risk-based criteria in all reaches of the river. The BLRA has determined the receptors and exposure pathways identified in RAO 3 as potentially significant with respect to ecological risks. Only the receptors and exposure pathways for which the acceptable risk is exceeded are considered in achieving this objective.

As stated previously, PCBs have been identified as a principal risk contributor. The risks associated with all COCs are addressed by consideration of exposure pathways associated with PCBs only.

4.4.4 Transport of Contaminants to Green Bay

Reduce, to the extent practicable, future transport of PCBs from the Lower Fox River to Green Bay (RAO 4).

RAO 4 relates to improving environmental conditions in the Lower Fox River, with the intent to have beneficial effects on Green Bay. Existing levels of contamination in the Lower Fox River pose a significant threat to the environmental quality of Green Bay. The dynamics of the river flow and potential for increased sediment transport during rain events and flooding are of particular concern.

Based upon the scope of this FS, no remedial action is evaluated for Green Bay. However, improving environmental quality in the Lower Fox River will result in decreased transport of contaminants to Green Bay, which will ultimately decrease the rate of decay of environmental quality in Green Bay.

4.4.5 Contaminant Releases During Remediation

Minimize the potential for contaminant releases during any active remediation (RAO 5).

RAO 5 is included to ensure the short-term effectiveness of remedial alternatives. Contaminant releases may be enhanced through various mechanisms, such as volatilization and sediment resuspension during the remediation activities (i.e., dredging). Achieving the goals of RAO 5 may impact remedial design of alternatives by incorporation of measures to control contaminant releases during remediation.

These proposed RAOs, in conjunction with the RI and RA results provide the framework for the evaluation of remedial action technology types and process options, in the development of various remedial alternatives.

4.5 Development of General Response Actions

The first step in the identification of remedial technologies for the Lower Fox River, is to identify GRAs. GRAs describe those actions that will satisfy the remedial action objectives. The EPA RI/FS Guidance states that GRAs may include categories such as treatment, containment, and disposal, or a combination of these categories.

GRAs identified by ThermoRetec for contaminated Lower Fox River sediments are the following:

- No Action
- Institutional Controls
- Containment
- Removal
- *In Situ* Treatment
- Ex Situ Treatment
- Dewatering
- Disposal

4.5.1 No Action

No Action was selected as a GRA as required by the NCP, to serve as a baseline against which remedial alternatives can be compared. Under the No Action alternative, no remedial action would be implemented and any changes would be a result of natural processes such as erosion, sedimentation, biodegradation, and/or natural armoring.

4.5.2 Institutional Controls

Institutional Controls may include access restrictions and dredging moratoriums, fish consumption advisories, and/or domestic water supply restrictions. Institutional Controls are established to reduce exposure to the COCs. They involve the use of legal and administrative processes to implement the controls on a community and regional basis.

4.5.3 Containment

Containment involves the physical isolation and immobilization of contaminated sediment without treatment. Containment technologies can be used to effectively isolate the impacted sediment thereby immediately limiting the bioavailability and mobility of contaminants present in the sediments.

4.5.4 Removal

Removal of sediments from a river consists of utilizing dredging or excavating equipment to remove and relocate the impacted sediments. If necessary, the excavated sediment is treated to reduce the contaminant concentration or bioavailability and is then disposed of or managed in an appropriate facility.

4.5.5 *In Situ* Treatment

In Situ Treatment technologies can be used to reduce the contaminant concentration or bioavailability without removing or encapsulating the sediment to achieve the desired RAOs.

4.5.6 *Ex Situ* Treatment

Ex Situ Treatment requires removal of contaminated sediments prior to treatment. Removal/excavation generally increases costs; however, *ex situ* treatment may require shorter time periods and offer more controlled processes than *in situ* treatment. Numerous treatment technologies for sediments contaminated with hazardous substances are available and are continuously being developed.

4.5.7 Dewatering

Dewatering is a process to reduce the amount of water in dredged sediments. Water is removed, either passively or mechanically, in preparation for treatment or disposal. Water requirements and limitations are generally determined by the treatment or disposal method employed, which may influence the extent of dewatering.

4.5.8 Disposal

Disposal is the placement of material into a site, structure, or facility on a temporary or permanent basis. It is a major component associated with alternatives involving removal of sediments, which may include the disposal of the contaminated media or disposal of residues from pretreatment and treatment components.

In Section 6 of this FS Report, remedial action technologies are identified and screened for each GRA. In addition, process options within each technology type are identified and screened. The technology types and process options retained after screening are utilized in the development of remedial alternatives for the Lower Fox River, presented in Section 7.

4.6 Section 4 Tables

Tables for Section 4 follow this page, and include:

Table 4-1 Potential Federal ARARs and TBCs for the Lower Fox River
Table 4-2 Potential State ARARs and TBCs for the Lower Fox River
Table 4-3 ROAs for the Lower Fox River

Table 4-1 Potential Federal ARARs and TCBs for the Lower Fox River

REQUIREMENTS	CITATION	DESCRIPTION	APPLICATION	COMMENT
Federal				
Clean Water Act:	33 U.S.C.A. Sec. 1251-1387			
Ambient Water Quality Criteria	CWA Section 304 Quality Criteria for Water, U.S. EPA, 1986	Establishes nonenforceable guidelines for States to set water quality standards for surface water. Criteria based on protection of aquatic life and human health.	Chemical Action	Applicable only if concentrations of surface water above sediments exceed these criteria; otherwise becomes a cross-media check.
Water Quality Standards	CWA Section 303 40 CFR 131	Requires states to develop water quality standards based on federal guidelines.	Chemical Action	Applicable only if concentrations of surface water above sediments exceed these criteria; otherwise becomes a cross-media check.
National Pollutant Discharge Elimination System	CWA Section 401	Requires compliance with permit limitations for discharge to navigable waters, including water quality effluent limits, water quality standards, national performance standards, and toxic and pretreatment effluent standards.	Chemical Action	NPDES program is administered by the state. (see Wisconsin NPDES Permit Regulations.) Applicable for actions involving discharges of liquid effluent to surface water.
Effluent Standards - Technology- Based Discharge Requirements	CWA Section 301(b)	Requires all direct discharges to be treated with best control technology prior to discharge.	Chemical Action	Applicable if surface water is channeled directly to a surface water body via a ditch, culvert, storm sewer, or other means; or treated water is discharged.
Dredge and Fill Requirements	CWA Section 404 (Inland Testing Manual)	Regulates discharge of dredged or fill material to U.S. waters, including wetlands. Testing manual establishes procedures for determining the potential for contaminant-related impacts associated with discharge of dredged material in inland waters.	Chemical Action	Applicable for consideration of any practicable alternatives and may require protection of environmental values of the site.
Proposed Sediment Quality Criteria	CWA Section 304 Sediment Quality Criteria, U.S. EPA, 1991	Establishes sediment quality standards that will not unacceptably affect benthic organisms.	Chemical Action	Potentially applicable once promulgated.

Table 4-1 Potential Federal ARARs and TCBs for the Lower Fox River (Continued)

REQUIREMENTS	CITATION	DESCRIPTION	APPLICATION	COMMENT
Federal				
Great Lakes Critical Program Act of 1990 - Assessment and Remediation of Contaminated Sediments (ARCS) Program	CWA Section 118 (c)(7) 40 CFR Part 132 (Appendix E)	Provide environmental managers at AOCs and elsewhere with the tools and information necessary for making informed cost-effective, and environmentally sound decisions in addressing a local contaminated sediment problem.	Location	To be considered in addressing existing and possible pollutant problems in the Great Lakes and their tributaries.
Resource Conservation and Recovery Act:	42 U.S.C.A. 6901-6992k			
Definition of Hazardous Waste	40 CFR 261	Defines threshold levels and criteria to determine whether material is hazardous waste.	Chemical Action	Applicable in evaluating which wastes would be classified
Water Resources Development Act				
Toxic Substances Control Act (TSCA)	40 CFR Parts 750 and 761	Establishes requirements for handling, storage, and disposal of PCB-containing materials in excess of 50 ppm.	Chemical Action	Applicable to alternatives that address PCB-containing materials in excess of 50 ppm
Occupational Safety and Health Administration (OSHA)	29 CFR Parts 1910.120, 1910.132, 1910.134, 1910.138	Establishes 8-hour time-weighted average concentrations for protection of worker breathing zones, PPE requirements, medical monitoring requirements, respiratory protection requirements, HAZMAT training requirements.	Chemical Action	Applicable for workers near areas of contamination
Clean Air Act:	42 U.S.C. 7401-7642			
National Primary and Secondary Ambient Air Quality Standards (NAAQS)	40 CFR Part 50	Establishes ambient air quality standards for protection of public health.	Chemical Action	Applicable in evaluating air impacts prior to or during remediation
National Emissions Standards for hazardous Air Pollutants (NESHAP)	40 CFR Part 61	Establishes emission standards for sources emitting benzene, arsenic, asbestos, beryllium, mercury, radionuclides, and vinyl chloride	Chemical Action	Applicable in evaluating emission standards on treatment technologies.
International Joint Commission (IJC)	IJC, 1992	Protection of fish tissue	Location	To be Considered
Land Disposal of PCB Sediments	Valdas Adamkus 1/24/95 EPA Memorandum to WDNR	Outlines requirements for disposal of PCB sediments greater than 50 mg/Kg within Wisconsin NR-500 Landfills.	Location Action	Applicable in evaluating disposal options of sediments.

Table 4-2 Potential State ARARs and TCBs for the Lower Fox River

REQUIREMENTS	CITATION	DESCRIPTION	APPLICATION	COMMENT
State				
Wisconsin State Environmental Protection - General:	WAC NR 100-			
Water Quality Standards for Wisconsin Surface Waters	WAC NR 102 - 105	Establishes definition of water use and criteria for protection of public health and enjoyment and protection and propagation of fish, shellfish, and wildlife.	Chemical Action	Applicable only if concentrations of surface water above sediments exceed these criteria.
Groundwater Quality	WAC NR 140	Establishes groundwater quality standards for substances detected or having reasonable probability of entering groundwater resources.	Chemical Action	Applicable for removal, transport, and disposal of contaminated sediments (impacts to groundwater).
Management of PCBs and Products Containing PCBs	WAC NR 157	Establishes procedures for the storage, collection, transportation, processing, and final disposal of PCBs and materials containing PCBs.	Chemical Action	Applicable for removal, transport, and disposal of contaminated sediments.
Notification of the Discharge of Hazardous Substances	WAC NR 158	Notification procedures and responsibilities by discharger of hazardous substances including containment, cleanup, disposal, and restoration.	Chemical Action	Applicable for removal, transport, and disposal of contaminated sediments.
Plans and Specifications Review of Projects and Operations	WAC NR 108 Wis. Stats. 144	WDNR approval of any reviewable project, general operation and control of specific water/wastewater system.	Action	Applicable for Community Water Systems, Sewage Systems, and Industrial Wastewater Facilities.
Wisconsin State Environmental Protection - Hazardous Waste Management:	WAC NR 600-	Provides definitions, general permit application information, incorporation by reference citations and general information concerning the hazardous waste management program.	Action Location	Applicable for removal, transport, and disposal of contaminated sediments.
Identification and Listing of Hazardous Waste	WAC NR 605	Establishes criteria for identifying the characteristics of hazardous waste to determine if the waste is subject to regulation.	Chemical Action	Applicable for removal, transport, and disposal of contaminated sediments.
Wisconsin State Air Pollutant Control Regulations	WAC NR 400-	Establishes concentration levels, by chemical, for new sources.	Chemical Action	Applicable action-specific ARAR for removal and disposal of mercury- and PCB-contaminated sediments.
Wisconsin Pollutant Discharge Elimination System	WAC NR 200-	Requires compliance with permit limitations for discharge to navigable waters, including water quality effluent limits, water quality standards, national performance standards, and toxic and pretreatment effluent standards.	Chemical Action	Applicable action-specific ARAR for removal and disposal of mercury- and PCB-contaminated sediments.

Table 4-2 Potential State ARARs and TCBs for the Lower Fox River (Continued)

REQUIREMENTS	CITATION	DESCRIPTION	APPLICATION	COMMENT
State				
Wisconsin State Environmental Protection - Water Regulation:	WAC NR 300-			
Wisconsin's General Permit Program for Certain Water Regulatory Permits	WAC NR 322	Establishes minimum design standards and specifications for projects permitted under a general permit.	Action	Potentially applicable for implementation of a given remedial alternative.
Dredging Contract Fees	WAC NR 346	Establishes procedures applicable to the removal of material from the beds of natural lakes and outlying waters for which a contract is required between the State and person desiring to remove bed material.	Action	Potentially applicable for removal, transport, and disposal of sediments.
Sediment Sampling and Analysis, Monitoring Protocol, and Disposal Criteria for Dredging Projects	WAC NR 347	Establishes procedures and protocols for sediment sampling and analysis, disposal criteria, and monitoring requirements for dredging projects regulated by the State of Wisconsin.	Action	Potentially applicable for removal, transport, and disposal of sediments.
Wisconsin State Environmental Protection - Solid and Hazardous Waste Management:	WAC NR 500-520	Provides definitions, submittal requirements, exemptions and other general information relating to solid waste facilities which are subject to regulations under s. 144.43 to 144.47 and 227.11 Stats.	Action	Potentially applicable for implementation of a given remedial alternative.
Wisconsin State Environmental Protection - Investigation and Remediation of Environmental Contamination	WAC NR 700-	Establishes standards and procedures that allow for site-specific flexibility, pertaining to the identification, investigation, and remediation of sites and facilities which are subject to regulation under s. 144.442, 144.76, or 144.77, Stats.	Action	Potentially applicable for implementation of a given remedial alternative.
Dredge and Fill Requirements	WDNR, 1985, 1990	Report of the Technical Subcommittee on Determination of Dredge Material Suitability of In-Water Disposal.	Chemical Location Action	To be considered for alternatives involving in-water disposal, such confined aquatic disposal (CAD).

Table 4-2 Potential State ARARs and TCBs for the Lower Fox River (Continued)

REQUIREMENTS	CITATION	DESCRIPTION	APPLICATION	COMMENT
State				
Lower Green Bay Remedial Action Plan	WDNR, 1993a	Mercury limits	Chemical	To be considered
Wisconsin Environmental Policy Act:				
	WAC NR 150	Evaluation criteria to ascertain the effects of major projects on the environment.	Location Action	Potentially applicable for implementation of a given remedial alternative.
	WAC NR 157	On-site disposal of (sediments) material containing PCBs.	Location Action	Applicable for removal, transport, and disposal of contaminated sediments.
	WAC NR 220-297	Technology based effluent limits.	Location Action	Applicable for remedial alternatives involving discharges.
Water Quality Antidegradation	WAC NR 207	Establish implementation procedures for the antidegradation policy in s. NR 102.05 (1) (a).	Location Action	Applicable to proposed new or increased discharges.
Local Permits (building, zoning, other)		Construction in floodplain or wetland and miscellaneous construction activities.	Action Location	To be considered for implementation of a given remedial alternative.
Great Lakes Water Quality Initiative (GLI)	WAC 102 and 106 USEPA, 1995	Sets forth guidance for any remedial action in states bordering the Great Lakes. In general, minimize any lowering of water quality to the extent practicable.	Action	To be considered with regard to remedial alternatives involving wastewater discharge.
Sediment Remediation Implementation Guidance	Strategic Directions Report, WDNR 1995	Addresses the sediment remediation approach recommended by WDNR for sediment remediation projects.	Action	To be considered in risk management, technological feasibility and cost
Landfill siting and approval process	Wis. Stats. Ch. 289	Addresses the upland disposal of solid waste along with in-river disposal options.	Action Location	To be considered for implementation of any given remedial alternative disposal option.
Permit in navigable waters	Wis. Stats. Ch. 30	Substantive provisions that address minimizing adverse effects on navigable waterways resulting from work performed.	Action	Applicable for work performed in navigable waterways.

Table 4-3 RAOs for the Lower Fox River

Number	Classification		Definition
1	Local and Global	Long-Term	Achieve, to the extent practicable, surface water quality ARARs and TBCs throughout the Lower Fox River
2	Local and Global	Long-Term	Reduce, to the extent practicable, the potential for chemicals of concern in the Lower Fox River to cause adverse human health effects through the following exposure pathways: • direct use exposure for water as a result of using surface water as a drinking water source • direct contact exposure to surface water as a result of recreational activities in the Lower Fox River • ingestion of fish as a result of fishing by subsistence and recreational anglers • direct contact exposures to sediment as a result of construction activities in the Lower Fox River
3	Local and Global	Long-Term	Reduce, to the extent practicable, the potential for chemicals of concern in the Lower Fox River to cause adverse effects to environmental receptors in the Lower Fox River including: • adverse effects to the diversity and reproductive viability of aquatic organisms (fish and insects) in the Lower Fox River • adverse effects to fish and insect eating birds through ingestion of fish • adverse effects to fish eating mammals through ingestion of fish
4	Global and Local	Long-Term	Reduce, to the extent practicable, future transport of PCBs from the Lower Fox River to Green Bay.
5	Local	Short-Term	Minimize the potential for contaminant releases during any active remediation.

5 Identification of Contaminated Sediment Areas

The result of the analysis presented in this section is the identification of priority contaminated sediment areas (previously defined as deposits and sediment management units [SMUs]) within the four reaches of the Lower Fox River. Prioritization of contaminated sediment areas was based on measures of the RAOs as developed in Section 4. Remedial alternatives are developed in Section 7 for the contaminated sediment areas identified within the four reaches.

Contaminated sediments within the Lower Fox River were considered in the four, distinct reaches:

- Little Lake Butte des Morts reach
- Appleton to Little Rapids reach
- Little Rapids to De Pere reach
- De Pere to Green Bay reach

These reaches were developed as a way to refer to groups of contaminated sediment areas. Reaches were defined by considering the effect that local infrastructure would have on mobilization of remediation equipment. Infrastructure considered included the locations of dams, possible staging areas, and access to rail or roadways. The reach definitions given above are consistent with the definitions used in the RI and RA.

Areas to be remediated were identified by ranking contaminated sediment areas according to their potential contributions to water column and sediment PCB concentrations, and PCB transport to Green Bay. To identify remediation areas within each reach, the following methods were used.

- WDNR's PCB mass balance models were used to evaluate the effect of each contaminated sediment area on the following:
  - PCB concentrations in surface water (related to RAO 1)
  - Surface area weighted average PCB concentrations (SWAC) in sediment (related to RAO 2 and 3)
  - Transport of PCB from the Lower Fox River to Green Bay (related to RAO 4)

- Contaminated sediment areas within each reach were ranked according to their contribution to the quantitative measures identified above.

- The contaminated sediment areas that rank highest across some or all quantitative measures were identified.

- Remediation areas were formed by targeting a sufficient number of highly-ranked contaminated sediment areas from each reach to attempt to meet a PCB SWAC of 250 µg/kg. It was assumed that this target would not be met immediately, but rather, would be met ten years after any remediation takes place. Ten years is a typical horizon for evaluation of the effects of remedial actions under Superfund.

- The boundaries of remediation areas were further modified after examining the horizontal and vertical PCB distribution. The boundaries were modified by "bending" the boundaries to encompass "hot spots" (sediments with PCB concentrations exceeding 50 ppm) to the extent possible.

The remainder of this chapter contains the following:

- Presentation of the sediment ranking criteria
- Results and interpretations of the ranking procedures
- Descriptions of the remediation areas within each reach

5.1 Contaminated Sediment Ranking Criteria

The purpose of ranking the contaminated sediment areas identified in the Lower Fox River is to prioritize them according to their relative importance in meeting the RAOs within each reach. Higher ranked contaminated sediment areas are given higher priority. The ranking is used as a tool to select specific contaminated sediment areas for the development of remedial alternatives in the FS. A description of the criteria and methodology used in the sediment ranking exercise is provided below.

5.1.1 Relationship of the Ranking Criteria to RAOs

The criteria used in the ranking exercise are directly related to RAOs 1, 2, 3 and 4. The ranking is designed to identify which contaminated sediment areas in the Lower Fox River have the greatest impact on environmental conditions in both the river and Green Bay. The ranked lists generated by use of these criteria provide a useful quantitative tool to focus the FS, and to qualitatively predict how remediation of each contaminated sediment area contributes to meeting each RAO.

The RAOs and the corresponding sediment ranking criteria are summarized in Table 5-1.

The following should be noted:

- A ranking scheme based on the contribution of each sediment area to human health risk (RAO 2) and ecological risk (RAO 3) would provide essentially the same results. In other words, a sediment area that ranks high out of concern for human health would also rank high out of concern for environmental receptors, since the sediment/surface water to fish pathway drive both the human health and ecological risk. As such, the same ranking criterion is applied to RAOs 2 and 3.

- The ranking criterion that relates to RAOs 2 and 3 (human and ecological risk) considers only one chemical and one exposure pathway, namely: exposure of humans to PCBs via ingestion of contaminated fish. This is appropriate because the BLRA has identified this combination of contaminant and exposure pathway as the greatest relative concern in the Lower Fox River and Green Bay.

- A ranking criterion to address RAO 5 (short-term effects of remediation) is not used. Short-term effects of remediation will be addressed within the evaluation of various remedial technologies, and have little bearing on ranking the contaminated sediment areas.

5.1.2 Description of Ranking Criteria

In this section, the rationale, method, and measure for each of the three ranking criteria are identified. As discussed below, the WDNR Fox River PCB transport models were used along with interpolations of PCB data to produce the rankings.

Contribution to Surface Water PCB Concentration (RAO 1)

Rationale. This ranking criterion is focused on identifying which sediment areas have the greatest contribution to surface water concentrations within *any* reach of the river. Therefore, this criterion ranks the sediment areas based on their contribution to ARARs or TBCs potentially not being met *anywhere* within the Lower Fox River.

Method. The WDNR mass balance models were used to simulate a separate "type" of PCB for each of the distinct contaminated sediment areas. This provided an estimate of the contribution of each contaminated sediment area to overall surface water concentrations in the river.

Measure. The ranking of each contaminated sediment area was determined by tracking the maximum water column PCB concentration attributable to each contaminated sediment area, within a specified time interval, anywhere in the river. Ranking is obtained by sorting the maximum water column PCB concentrations from highest to lowest. Separate rankings were generated for contaminated sediment areas within each river reach.

Contribution to the Surface Area Weighted Average PCB Concentrations in Sediment (RAOs 2 and 3)

Rationale. This criterion focuses on PCB as the primary COC and human ingestion of fish as the primary exposure pathway to assess both human and ecological risk. This is based on the assumption that sediment areas that rank high out of concern for human health would also rank high out of concern for environmental receptors. Exposure to PCB-contaminated fish is believed to be the greatest human health and ecological concern. The SLRA has identified four reaches of the river within which separate fish consumption-related values of human and ecological risk were calculated in the BLRA. Based on the available Fox River food chain model, the greatest contribution to fish PCB concentration within each reach is due to PCB concentrations present in surficial sediments.

Method. Each sediment area was ranked according to its contribution to the SWAC. The BLRA has determined that the SWAC should be at or below 250 µg/kg in order to protect human health. Comparing the contributions to the SWAC relative to the human health criteria provides a way to prioritize contaminated sediment areas.

Two separate rankings were produced: one based entirely on interpolated PCB rankings (representing present conditions) and the other based on model predicted PCB concentrations (representing future conditions).

Measure. Contaminated sediment areas are ranked within each reach in decreasing order of their contribution to the SWAC (expressed in µg/kg).

Contribution to Transport of PCB from the Fox River to Green Bay (RAO 4)

Rationale. Reduction of PCB mass transport to Green Bay is one of the RAOs established for the Lower Fox River. The modeling tools available allow for the estimation of the contribution of each sediment area to this mass transport. A meaningful measure of PCB mass transport is the average mass transported from the Lower Fox River to Green Bay within a specified time interval.

Method. The WDNR models were used to simulate the contribution of PCB from each upstream sediment area to Green Bay.

Measure. The mass transport of PCB from each sediment area was tallied at the boundary between the Lower Fox River and Green Bay. The PCB mass transport into Green Bay (in mg/week) was integrated over a specified time period. Ranking was performed by sorting the total PCB mass transported from highest to lowest. Separate rankings were generated for sediment areas within each reach.

5.2 Interpretation of Rankings and Identification of Potential Remediation Areas

Potential remediation areas were identified within each of the four reaches of the Lower Fox River. Subsections 5.2.1 through 5.2.4 summarize the results of rankings and presents the resulting potential remediation areas by reach. Table 5-2 summarizes the potential remediation areas by reach.

5.2.1 Little Lake Butte des Morts Reach

The identification of the remediation areas within this reach is based on the rankings presented in Figures 5-1 through 5-4. Figure 5-1 presents contributions to the surface water PCB concentration. Figures 5-2 and 5-3 present contributions to the SWAC, based on interpolations of data and on model predicted concentrations, respectively. Figure 5-4 presents contributions to transport of PCB to Green Bay.

In these figures, deposits D, E, POG, C and A consistently rank highest in the three criteria used for selection. Conversely, the numerical contributions of deposits G, H and B within each ranked list are between two and three orders of magnitude lower than those of any other deposit within the LLBdM reach. As such, the remediation of these deposits is not considered relevant to the overall improvement of environmental conditions within the LLBdM reach.

Based on the rankings presented in Figures 5-2 through 5-4, the complete remediation of deposits D, POG, C and A, and partial remediation of Deposit E, would result in an approximate 80% reduction in the transport to Green Bay of PCB mass originating from the LLBdM reach, and in an approximate a 90% decrease in future (i.e. predicted concentrations ten years after remediation) SWAC within this reach. Similar quantitative estimates of the reduction of surface water PCB concentrations cannot be made based on the rankings presented in Figure 5-1, as the ranking in this figure do not necessarily refer to predicted surface water concentrations at the same location.

In summary, based on the discussion above, the following sediment deposits are included among the remediation areas for the LLBdM reach:

- Deposit A
- Deposit C
- Deposit D
- Deposit E
- Deposit POG

The potential remediation area boundaries are shown in Figure 5-17. A series of remedial alternatives will be developed in Section 7 of this FS Report for the remediation areas shown.

5.2.2 Appleton to Little Rapids Reach

The identification of the remediation areas within this reach was based on the rankings presented in Figures 5-5 through 5-8. Figure 5-5 presents contributions to surface water PCB concentrations. Figures 5-6 and 5-7 present contributions to the SWAC, based on interpolations of data and on model predicted concentrations, respectively. Figure 5-8 presents contributions to transport of PCB to Green Bay.

These figures show that Deposit N consistently ranks higher for all three ranking criteria than any other single deposit within the Appleton to Little Rapids reach. All other single deposits rank up to an order of magnitude lower in all three numerical criteria. Deposit N is currently being remediated in the Deposit N Demonstration Project, which is independent of this FS.

Based on the rankings presented in Figures 5-6 through 5-8, the complete remediation of Deposit N would result in a greater than 50% reduction in the transport to Green Bay of PCB mass originating from the Appleton to Little Rapids reach, and in a greater than 70% decrease in future (i.e., predicted concentrations ten years after remediation) SWAC within this reach. In order to meet a SWAC of 250 µg/kg ten years into the future, other areas would need to be remediated. Deposits L, M, G, P, Q and R contribute approximately 200 µg/kg to the SWAC. Deposits V, W, and X contribute approximately an additional 150 µg/kg. Thus, a strict interpretation of this ranking procedure suggests that other deposits should be included as remediation areas above and beyond Deposit N, which is currently being remediated.

This reach of the river, unlike any other on the Lower Fox River, consists of long reaches of river where no contaminants have been detected, interrupted periodically by small deposits, primarily located behind dams. The SWAC, as

typically applied by risk assessors, is calculated for the surface area of the entire river reach. The contributions to the SWAC, depicted in Figure 5-7, are calculated based only relative to the total surficial sediment area present. Thus, when the area of uncontaminated river is taken into account, the future SWAC, following completion of the Deposit N Demonstration Project, will approach the 250 µg/kg target. Therefore, no additional potential remediation areas are warranted.

In summary, no potential remediation areas are necessary with respect to the conditions applied for defining potential remediation areas for this FS. As such, no remedial alternatives besides Institutional Controls or No Action would be evaluated for this reach. However, an additional more pro-active remedial alternative is evaluated for this reach, as described in Section 7.

Figure 5-18 shows the distribution of PCB in the surface sediments for this reach.

5.2.3 Little Rapids to De Pere Reach

The identification of the potential remediation areas within this reach is based on the rankings presented in Figures 5-9 through 5-12. Figure 5-9 presents contributions to surface water PCB concentrations. Figures 5-10 and 5-11 present contributions to the SWAC, based on interpolations of data and on model predicted concentrations, respectively. Figure 5-12 presents contributions to transport of PCB to Green Bay.

Only four deposits, namely EE, FF, GG and HH are located in the Little Rapids to De Pere reach. Deposit EE extends over water columns segments 22 through 27. Sediments in deposits GG and HH encompass part of water column 27. Based on the rankings presented in Figures 5-9 through 5-12, sediment deposits EE(23), EE(24), EE(27)/GG/HH rank highest in all three criteria.

Based on the rankings presented in Figures 5-10 through 5-12, the complete remediation of deposits EE(23), EE(24), EE(27)/GG/HH would result in a greater than 60% reduction in the transport to Green Bay of PCB mass originating from the Little Rapids to De Pere reach, and in an approximate 70% decrease in the future (i.e., predicted concentrations ten years after remediation) SWAC within this reach.

In summary, based on the discussion above, the following sediment deposits are included as remediation areas for the Little Rapids to De Pere reach:

- Deposits EE(23), EE(24), EE(27), GG, HH.

The potential remediation area boundaries are shown in Figure 5-19. A series of remedial alternatives will be developed in Section 7 of this FS for this reach.

5.2.4 De Pere to Green Bay Reach

The identification of the remediation areas within this reach is based on the rankings presented in Figures 5-13 through 5-16. Figure 5-13 presents contributions to surface water PCB concentrations. Figures 5-14 and 5-15 present contributions to the SWAC, based on interpolations of data and on model predicted concentrations, respectively. Figure 5-16 presents contributions to transport of PCB to Green Bay.

Unlike the upstream reaches, there are no distinct sediment deposits in this reach. Instead, sediments have been referred to by "Sediment Management Units" or SMUs. Several numbering schemes have been used to identify SMUs. In this document we refer to SMUs by the numbering scheme which preserves the identity of SMU 56/57, which is another current WDNR/Fox River Group of Mills demonstration project currently under way. Under this scheme, SMUs are numbered 20 through 115, with low numbers indicative of sediments closest to the De Pere dam.

Based on the rankings presented in Figures 5-14 through 5-16, the complete remediation of SMUs 20-85 would be required in order to reach the target SWAC of 250 µg/kg in the future. Remediation of SMUs 20-85 would result in a greater than 90% reduction in the transport to Green Bay of PCB mass originating from the Little Rapids to De Pere reach, and a greater than 90% decrease in the future (i.e., predicted concentrations ten years after remediation) SWAC within this reach.

In summary, based on the discussion above, the following sediment deposits are included as remediation areas for the Little Rapids to De Pere reach:

- SMU 20-85

The location of the remediation areas within this reach is shown in Figure 5-20. A series of remedial alternatives will be developed in Section 7 of this FS for this reach.

5.3 Potential Remediation Area Volumes

This section summarizes volumes for the potential remediation areas. Two sets of tables are included in this section. Table 5-3 summarizes the total volume of sediment for which PCB concentrations exceed 250 µg/kg, and is presented here

to provide a comparison to the values in Table 5-4. Table 5-4 summarizes the volumes and surface areas for the remediation areas depicted in Figures 5-17 through 5-20.

The sediment volumes contained in Table 5-3 were generated by analyzing interpolated PCB values. The interpolated PCB values form the basis for the graphics contained in the remedial RI Report. The RI Report contains more detail about the interpolations.

Note that the volumes contained in Table 5-3 do not take into account the volume of sediment that is obtained through over-dredging.

Table 5-4 presents the volumes of potential sediment remediation areas. The volumes presented include 0.2 m of over-dredge in the vertical direction.

The volumes presented in Table 5-3 and 5-4 will be used in Section 7 through 10 of this document to evaluate and estimate costs of remedial alternatives.

5.4 Section 5 Tables and Figures

Tables and figures for Section 5 follow this page and include:

Tables

Table 5-1 Overview of Sediment Ranking Criteria
Table 5-2 Potential Remediation Areas by River Reach
Table 5-3 Volume of Sediment with PCB Exceeding 250 μg/kg
Table 5-4 Volumes for Potential Remediation Areas

Figures

Figure 5-1 Contributions to Surface Water PCB Concentrations: Model Year 10-12, Little Lake Butte des Morts
Figure 5-2 Contributions to PCB SWAC: Interpolated Data, Little Lake Butte des Morts
Figure 5-3 Contributions to PCB SWAC: Model Year 10-12, Little Lake Butte des Morts
Figure 5-4 Contributions to PCB Export to Green Bay: Model Year 10-12, Little Lake Butte des Morts
Figure 5-5 Contributions to Surface Water PCB Concentrations: Model Year 10-12, Appleton-Little Rapids
Figure 5-6 Contributions to PCB SWAC: Interpolated Data, Appleton to Little Rapids

Figure 5-7 Contributions to PCB SWAC:
Model Year 10-12, Appleton-Little Rapids
Figure 5-8 Contributions to PCB Export to Green Bay:
Model Year 10-12, Appleton-Little Rapids
Figure 5-9 Contributions to Surface Water PCB Concentrations:
Model Year 10-12, Little Rapids-De Pere
Figure 5-10 Contributions to PCB SWAC:
Interpolated Data, Little Rapids to De Pere
Figure 5-11 Contributions to PCB SWAC:
Model Year 10-12, Little Rapids-De Pere
Figure 5-12 Contributions to PCB Export to Green Bay:
Model Year 10-12, Little Rapids-De Pere
Figure 5-13 Contributions to Surface Water PCB Concentrations:
Model Year 10-12, De Pere-Green Bay
Figure 5-14 Contributions to PCB SWAC:
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Figure 5-15 Contributions to PCB SWAC:
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Figure 5-17 Little Lake Butte des Morts:
Potential Remediation Area Boundaries
Figure 5-19 Little Rapids to De Pere:
Potential Remediation Area Boundaries
Figure 5-20 De Pere to Green Bay:
Potential Remediation Area Boundaries

Table 5-1 Overview of Sediment Ranking Criteria

RAO Number	Remedial Action Objective (RAO)	Sediment Ranking Criteria	Ranking Criterion Source
1	Achieve, to the extent practicable, surface water quality ARARs and TBCs throughout the Lower Fox River.	Maximum river-wide surface water PCB concentration attributable to each sediment area.	Predicted water column concentrations.
2	Reduce the potential for chemicals-of-concern in the Lower Fox River to cause adverse human health effects through various pathways.	Contribution of each sediment area within a river reach to surficial sediment PCB concentrations.	Predict surface area weighted average sediment PCB concentrations.
3	Reduce the potential for chemicals-of-concern in the Lower Fox River to cause adverse effects to environmental receptors.	Contribution of each sediment area within a river reach to surficial sediment PCB concentrations.	Predict interpolated surface area weighted average sediment PCB concentration.
4	Reduce, to the extent practicable, future transport of PCBs from the Lower Fox River to Green Bay.	Mass transport of PCB to Green Bay attributable to each contaminated sediment area.	Predicted PCB mass transport to Green Bay.
5	Minimize the potential for contaminant releases from sediments during remediation in the area immediately adjacent to the remediation zone.	None.	N/A

Table 5-2 Potential Remediation Areas by River Reach

River Reach	Deposits or Sediment Managed Units (SMU) Included
Little Lake Butte De Morts	A, C, D, E, POG
Appleton to Little Rapids	None
Little Rapids to De Pere	EE(34), EE(24), EE(27), FF, GG, HH
De Pere to Green Bay	SMU 20-85

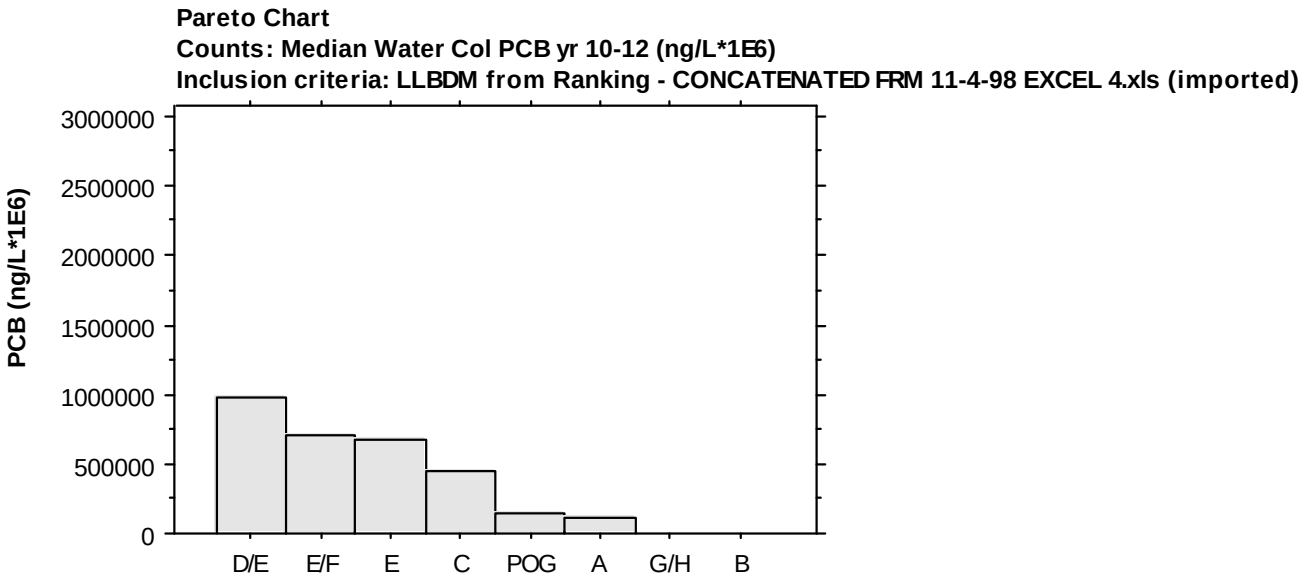
Table 5-3 Volume of Sediment with PCB Exceeding 250 μg/kg

Reach Name	Volume	
	TSCA, [PCB] >50,000 μg/kg	non-TSCA, [PCB] >250 μg/kg
Little Lake Butte des Morts	63,000 yd^3 48,150 m^3	1,563,000 yd^3 1,195,000 m^3
Appleton to Little Rapids	23,500 yd^3 17,975 m^3	337,250 yd^3 257,850 m^3
Little Rapids to De Pere	N/A	1,188,000 yd^3 908,350 m^3
De Pere to Green Bay	250,000 yd^3 191,150 m^3	5,440,000 yd^3 4,159,425 m^3

Table 5-4 Volumes for Potential Remediation Areas

Reach Name	Volume	
	TSCA	non-TSCA
Little Lake Butte des Morts	63,000 yd^3 48,150 m^3	1,065,000 yd^3 814,300 m^3
Appleton to Little Rapids	N/A	N/A
Little Rapids to De Pere	N/A	1,063,000 yd^3 812,800 m^3
De Pere to Green Bay	250,000 yd^3 191,150 m^3	4,817,800 yd^3 3,683,700 m^3

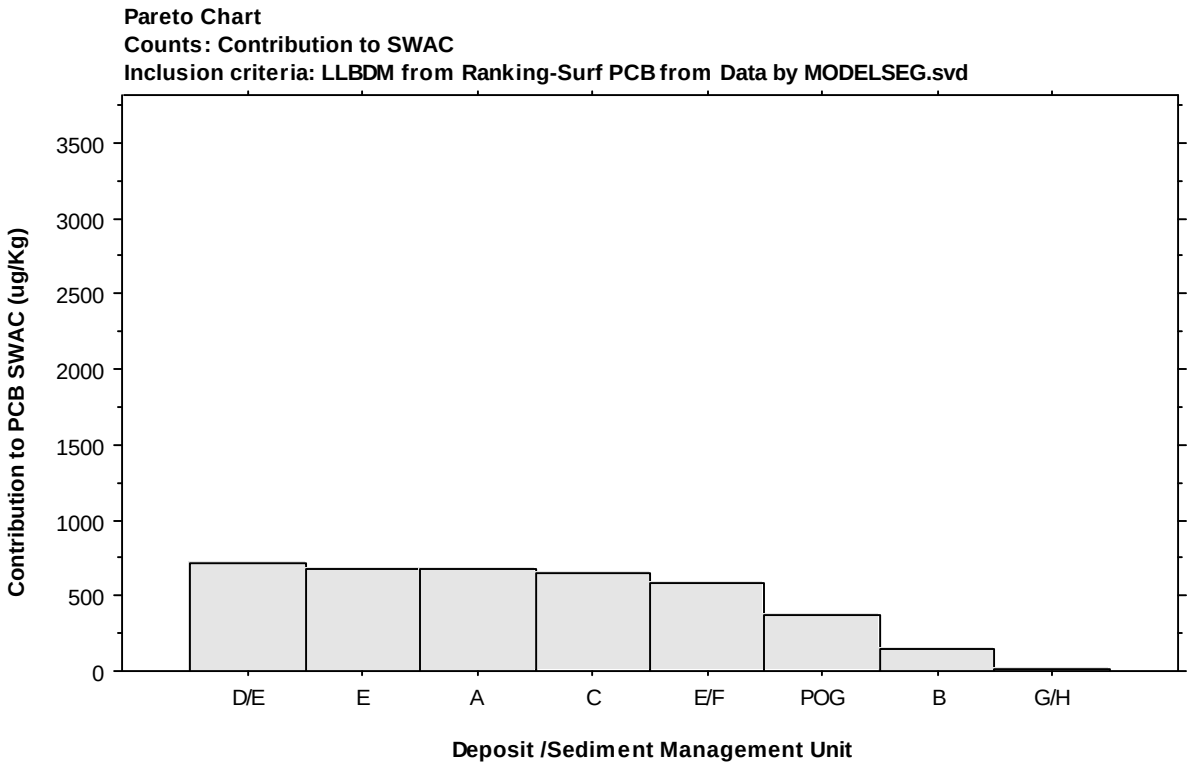
Figure 5-1. Contributions to Surface Water PCB Concentrations: Model Year 10-12, Little Lake Butte des Morts



Pareto Table for Descriptor
Counts: Median Water Col PCB yr 10-12 (ng/L*1E6)
Inclusion criteria: LLBDM from Ranking - CONCATENATED FRM 11-4-98 EXCEL 4.xls (imported)

	Count	Percent	Cum. Count	Cum. Percent
D/E	978000	31.733	978000	31.733
E/F	713000	23.134	1691000	54.867
E	681000	22.096	2372000	76.963
C	444000	14.406	2816000	91.369
POG	149000	4.835	2965000	96.204
A	114000	3.699	3079000	99.903
G/H	2000	.065	3081000	99.968
B	1000	.032	3082000	100.000

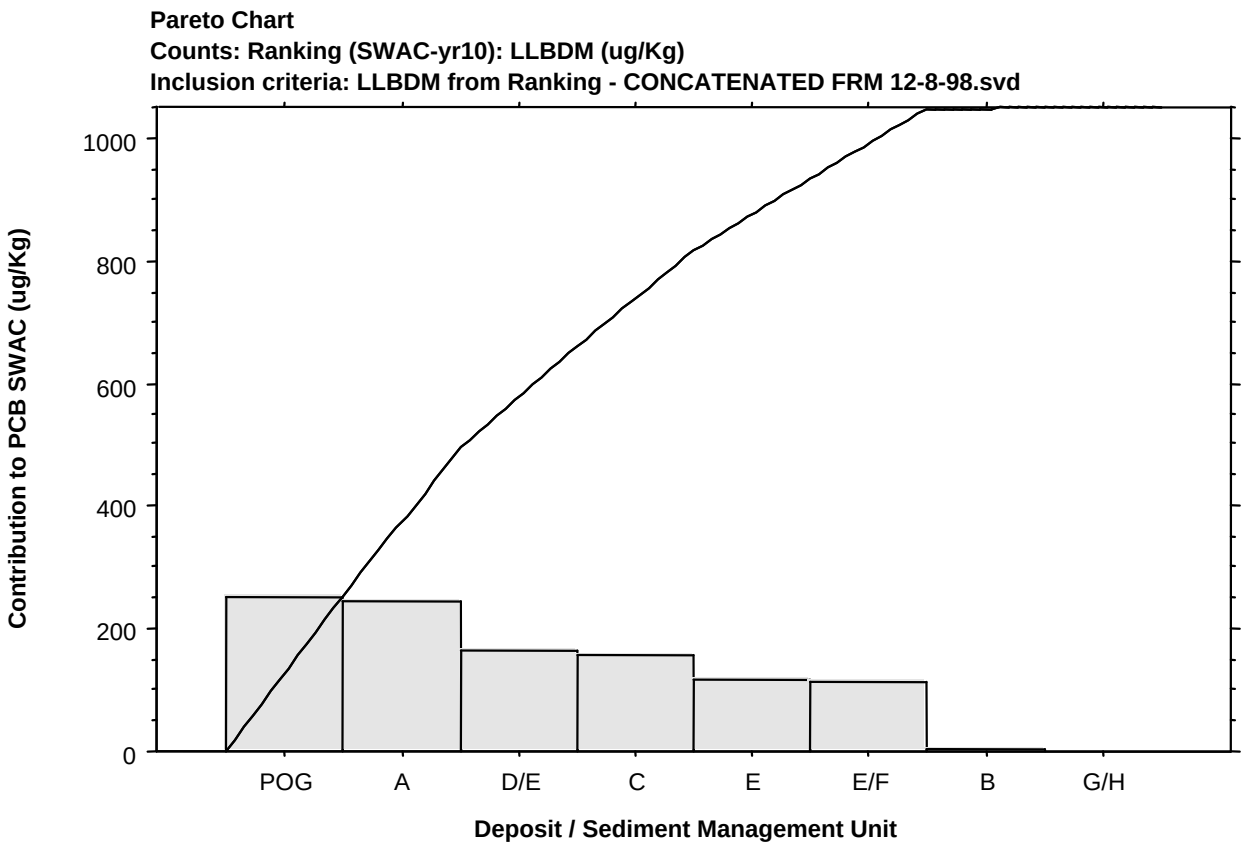
Figure 5-2. Contributions to PCB SWAC: Interpolated Data, Little Lake Butte des Morts



Pareto Table for Deposit /Sediment Management Unit
Counts: Contribution to SWAC
Inclusion criteria: LLBDM from Ranking-Surf PCB from Data by MODELSEG.svd

	Count	Percent	Cum. Count	Cum. Percent
D/E	713	18.670	713	18.670
E	681	17.832	1394	36.502
A	671	17.570	2065	54.072
C	656	17.177	2721	71.249
E/F	577	15.109	3298	86.358
POG	370	9.688	3668	96.046
B	144	3.771	3812	99.817
G/H	7	.183	3819	100.000

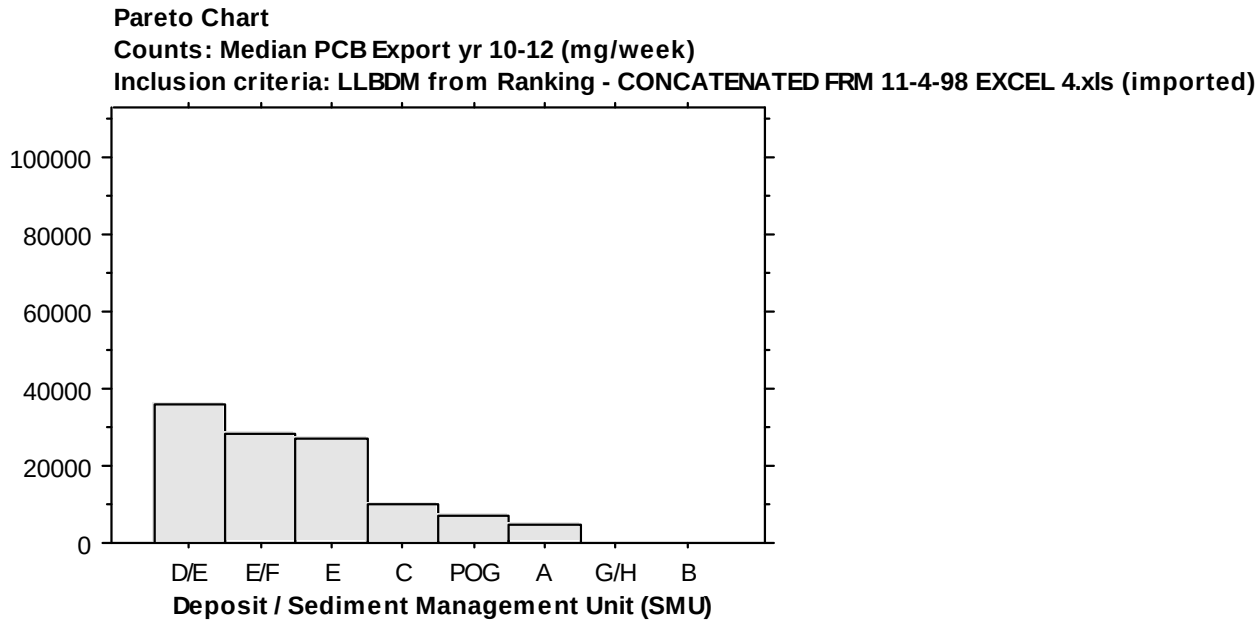
Figure 5-3. Contributions to PCB SWAC: Model Year 10-12, Litle Lake Butte des Morts



Pareto Table for Descriptor
Counts: Ranking (SWAC-yr10): LLBDM (ug/Kg)
Inclusion criteria: LLBDM from Ranking - CONCATENATED FRM 12-8-98.svd

	Count	Percent	Cum. Count	Cum. Percent
POG	253	24.072	253	24.072
A	243	23.121	496	47.193
D/E	165	15.699	661	62.892
C	156	14.843	817	77.735
E	117	11.132	934	88.868
E/F	114	10.847	1048	99.715
B	2	.190	1050	99.905
G/H	1	.095	1051	100.000

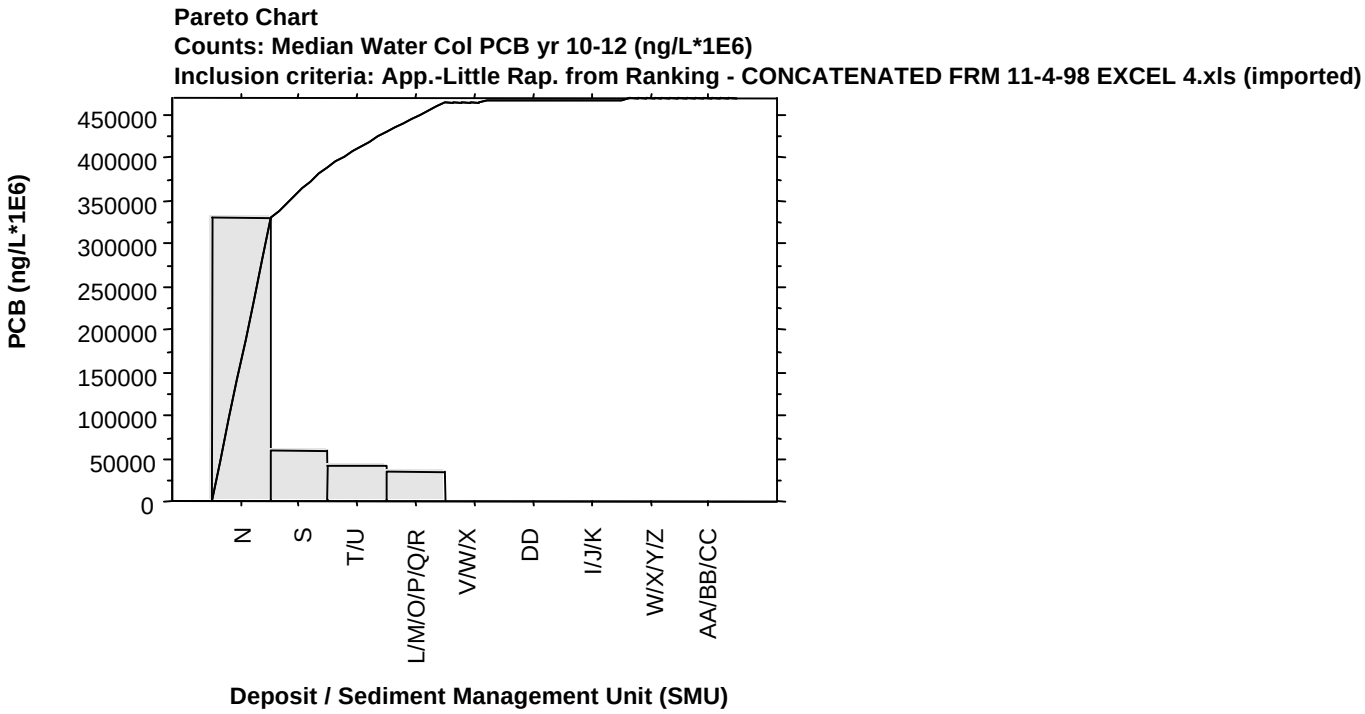
Figure 5-4. Contributions to PCB Export to Green Bay: Model Year 10-12, Little Lake Butte des Morts



Pareto Table for Descriptor
Counts: Median PCB Export yr 10-12 (mg/week)
Inclusion criteria: LLBDM from Ranking - CONCATENATED FRM 11-4-98 EXCEL 4.xls (imported)

	Count	Percent	Cum. Count	Cum. Percent
D/E	36000	31.826	36000	31.826
E/F	28000	24.754	64000	56.580
E	27000	23.870	91000	80.449
C	10000	8.841	101000	89.290
POG	7000	6.188	108000	95.478
A	5000	4.420	113000	99.898
G/H	71	.063	113071	99.961
B	44	.039	113115	100.000

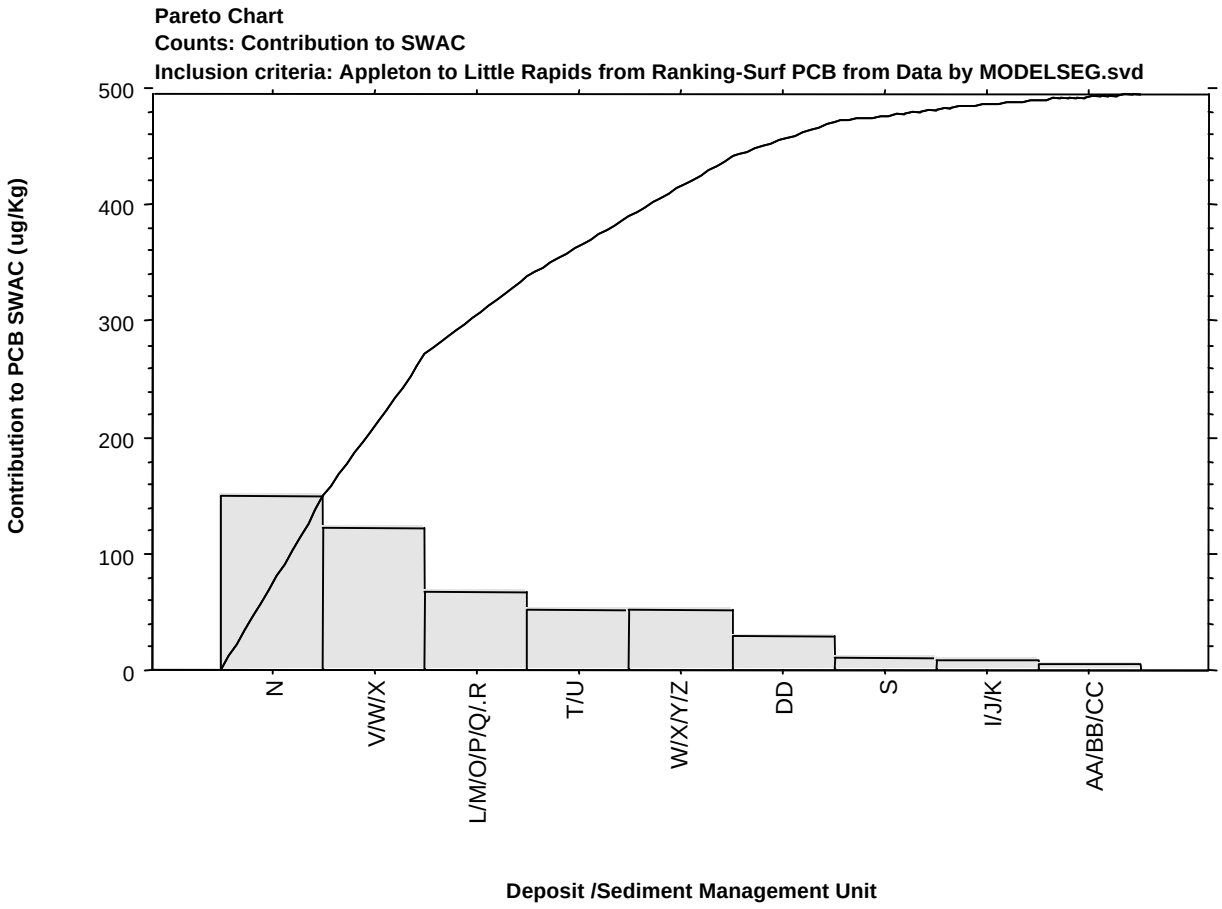
Figure 5-5. Contributions to Surface Water PCB Concentrations: Model Year 10-12, Appleton-Little Rapids



Pareto Table for Descriptor
Counts: Median Water Col PCB yr 10-12 (ng/L*1E6)
Inclusion criteria: App.-Little Rap. from Ranking - CONCATENATED FRM 11-4-98 EXCEL 4.xls (imported)

	Count	Percent	Cum. Count	Cum. Percent
N	330000	70.324	330000	70.324
S	59000	12.573	389000	82.898
T/U	42000	8.950	431000	91.848
L/M/O/P/Q/R	34000	7.246	465000	99.093
V/W/X	1000	.213	466000	99.307
DD	1000	.213	467000	99.520
I/J/K	1000	.213	468000	99.733
W/X/Y/Z	1000	.213	469000	99.946
AA/BB/CC	254	.054	469254	100.000

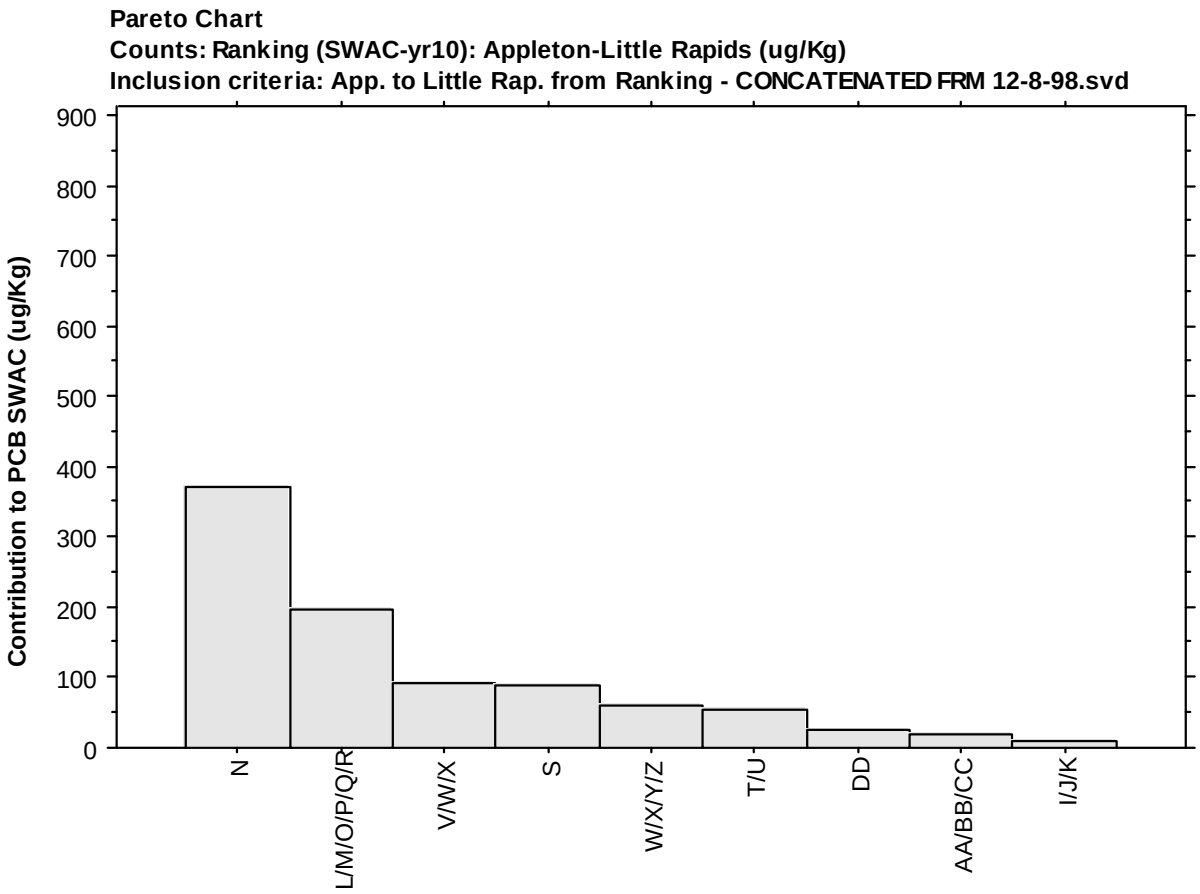
Figure 5-6. Contributions to PCB SWAC: Interpolated Data, Appleton to Little Rapids



Pareto Table for Deposit /Sediment Management Unit
Counts: Contribution to SWAC
Inclusion criteria: Appleton to Little Rapids from Ranking-Surf PCB from Data by MODELSEG.svd

	Count	Percent	Cum. Count	Cum. Percent
N	149	30.101	149	30.101
V/W/X	122	24.646	271	54.747
L/M/O/P/Q/R	67	13.535	338	68.283
T/U	52	10.505	390	78.788
W/X/Y/Z	51	10.303	441	89.091
DD	30	6.061	471	95.152
S	11	2.222	482	97.374
I/J/K	8	1.616	490	98.990
AA/BB/CC	5	1.010	495	100.000

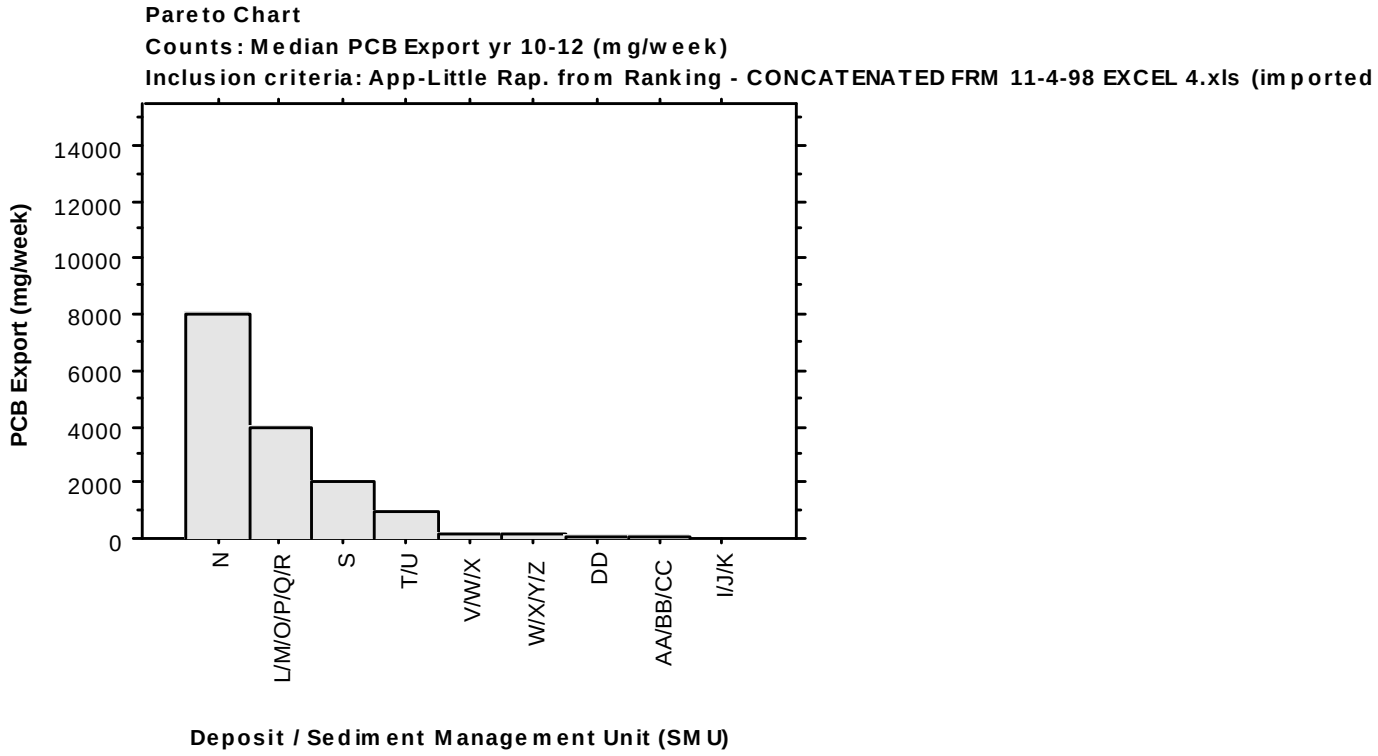
Figure 5-7. Contributions to PCB SWAC: Model Year 10-12, Appleton-Little Rapids



Pareto Table for Descriptor
Counts: Ranking (SWAC-yr10): Appleton-Little Rapids (ug/Kg)
Inclusion criteria: App. to Little Rap. from Ranking - CONCATENATED FRM 12-8-98.svd

	Count	Percent	Cum. Count	Cum. Percent
N	372	40.745	372	40.745
L/M/O/P/Q/R	196	21.468	568	62.212
V/W/X	93	10.186	661	72.399
S	90	9.858	751	82.256
W/X/Y/Z	59	6.462	810	88.719
T/U	53	5.805	863	94.524
DD	24	2.629	887	97.152
AA/BB/CC	18	1.972	905	99.124
I/J/K	8	.876	913	100.000

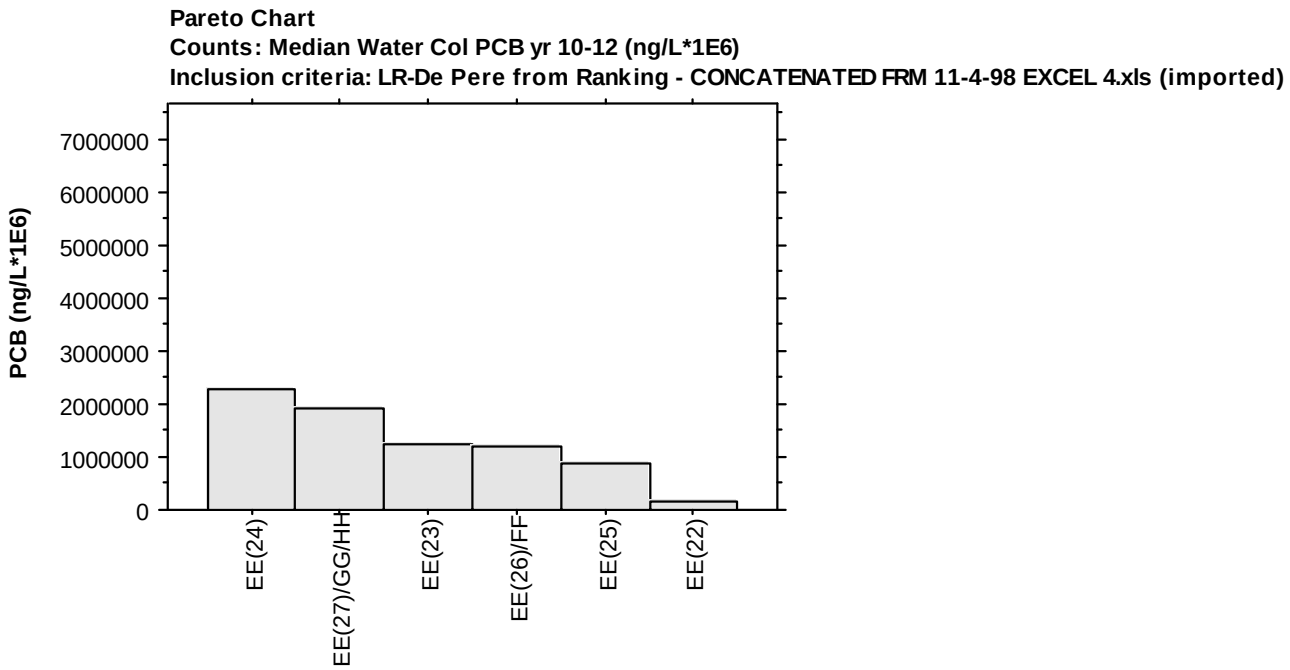
Figure 5-8. Contributions to PCB Export to Green Bay: Model Year 10-12, Appleton-Little Rapids



Pareto Table for Descriptor
Counts: Median PCB Export yr 10-12 (mg/week)
Inclusion criteria: App-Little Rap. from Ranking - CONCATENATED FRM 11-4-98 EXCEL 4.xls (imported)

	Count	Percent	Cum. Count	Cum. Percent
N	8000	51.507	8000	51.507
L/M/O/P/Q/R	4000	25.753	12000	77.260
S	2000	12.877	14000	90.136
T/U	1000	6.438	15000	96.575
V/W/X	191	1.230	15191	97.805
W/X/Y/Z	155	.998	15346	98.802
DD	99	.637	15445	99.440
AA/BB/CC	47	.303	15492	99.742
I/J/K	40	.258	15532	100.000

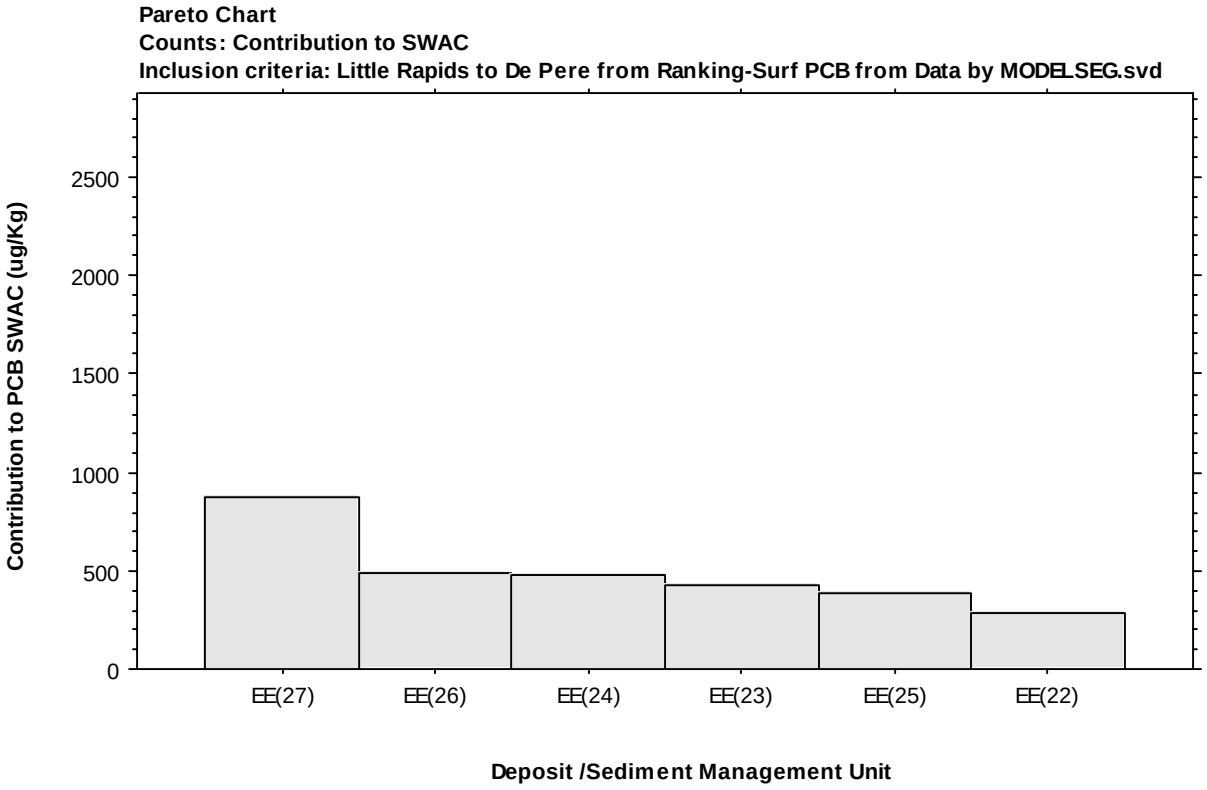
Figure 5-9. Contributions to Surface Water PCB Concentrations: Model Year 10-12, Little Rapids-De Pere



Pareto Table for Descriptor
Counts: Median Water Col PCB yr 10-12 (ng/L*1E6)
Inclusion criteria: LR-De Pere from Ranking - CONCATENATED FRM 11-4-98 EXCEL 4.xls (imported)

	Count	Percent	Cum. Count	Cum. Percent
EE(24)	2288000	29.792	2288000	29.792
EE(27)/GG/HH	1909000	24.857	4197000	54.648
EE(23)	1246000	16.224	5443000	70.872
EE(26)/FF	1197000	15.586	6640000	86.458
EE(25)	873000	11.367	7513000	97.826
EE(22)	167000	2.174	7680000	100.000

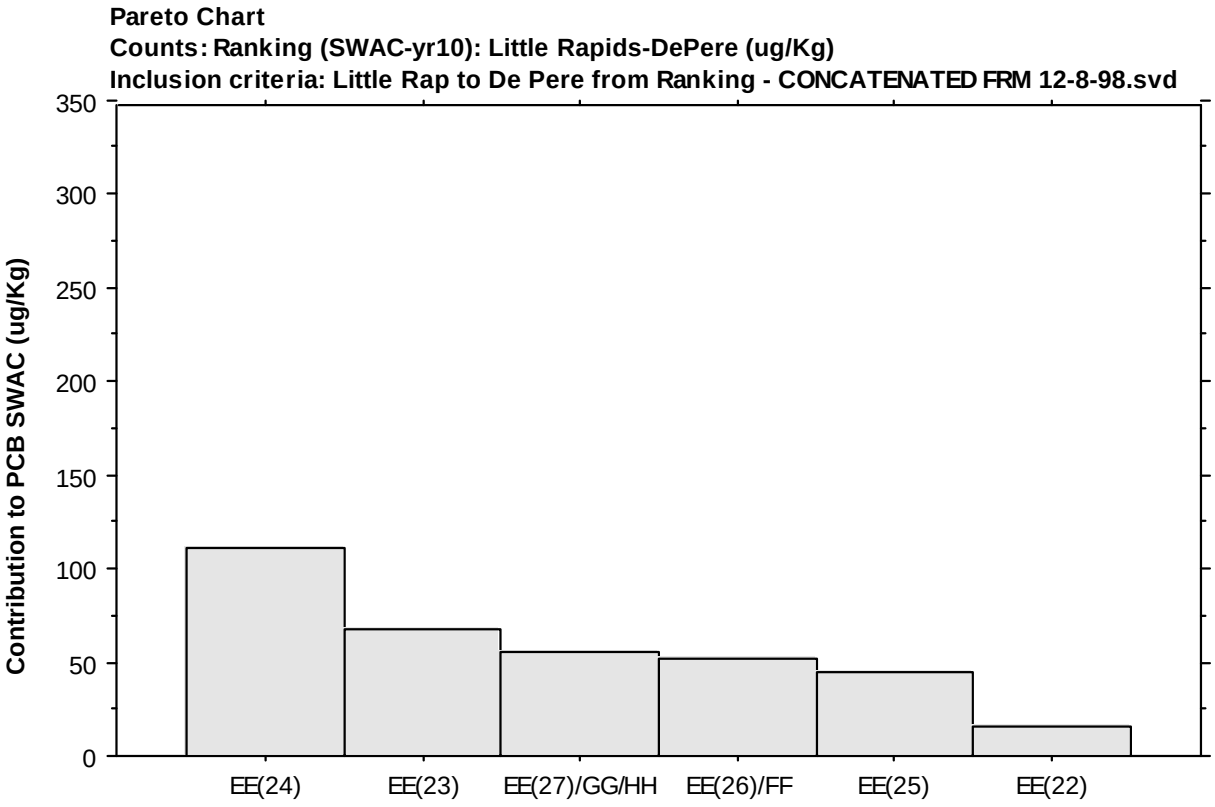
Figure 5-10. Contributions to PCB SWAC: Interpolated Data, Little Rapids to De Pere



Pareto Table for Deposit /Sediment Management Unit
Counts: Contribution to SWAC
Inclusion criteria: Little Rapids to De Pere from Ranking-Surf PCB from Data by MODELSEG.svd

	Count	Percent	Cum. Count	Cum. Percent
EE(27)	870	29.723	870	29.723
EE(26)	489	16.707	1359	46.430
EE(24)	475	16.228	1834	62.658
EE(23)	422	14.417	2256	77.076
EE(25)	387	13.222	2643	90.297
EE(22)	284	9.703	2927	100.000

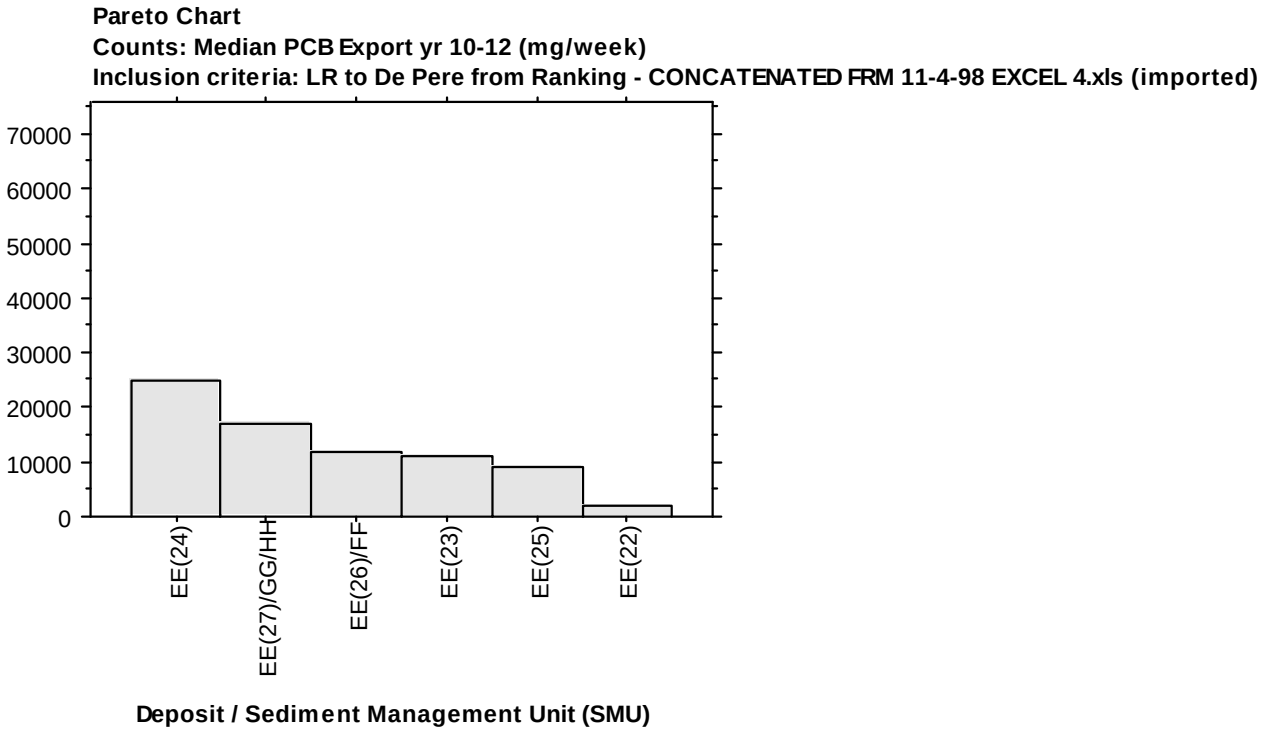
Figure 5-11. Contributions to PCB SWAC: Model Year 10-12, Little Rapids-De Pere



Pareto Table for Descriptor
Counts: Ranking (SWAC-yr10): Little Rapids-DePere (ug/Kg)
Inclusion criteria: Little Rap to De Pere from Ranking - CONCATENATED FRM 12-8-98.svd

	Count	Percent	Cum. Count	Cum. Percent
EE(24)	111	31.988	111	31.988
EE(23)	67	19.308	178	51.297
EE(27)/GG/HH	56	16.138	234	67.435
EE(26)/FF	52	14.986	286	82.421
EE(25)	45	12.968	331	95.389
EE(22)	16	4.611	347	100.000

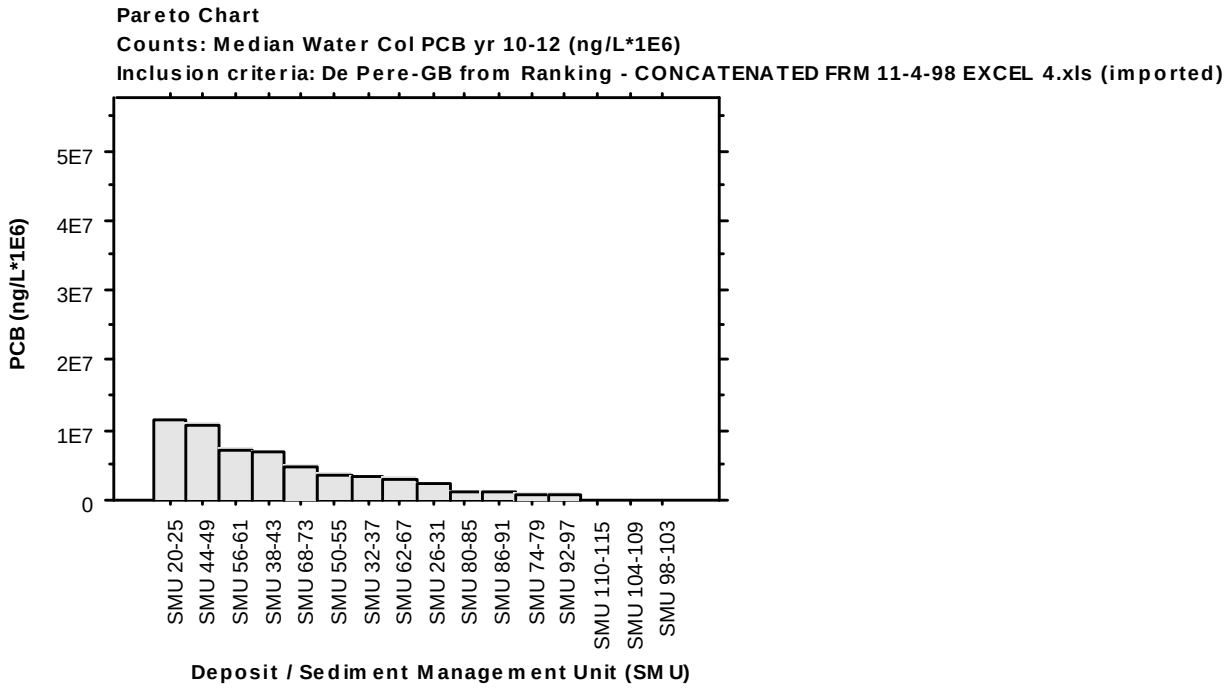
Figure 5-12. Contributions to PCB Export to Green Bay: Model Year 10-12, Little Rapids-De Pere



Pareto Table for Descriptor
Counts: Median PCB Export yr 10-12 (mg/week)
Inclusion criteria: LR to De Pere from Ranking - CONCATENATED FRM 11-4-98 EXCEL 4.xls (imported)

	Count	Percent	Cum. Count	Cum. Percent
EE(24)	25000	32.895	25000	32.895
EE(27)/GG/HH	17000	22.368	42000	55.263
EE(26)/FF	12000	15.789	54000	71.053
EE(23)	11000	14.474	65000	85.526
EE(25)	9000	11.842	74000	97.368
EE(22)	2000	2.632	76000	100.000

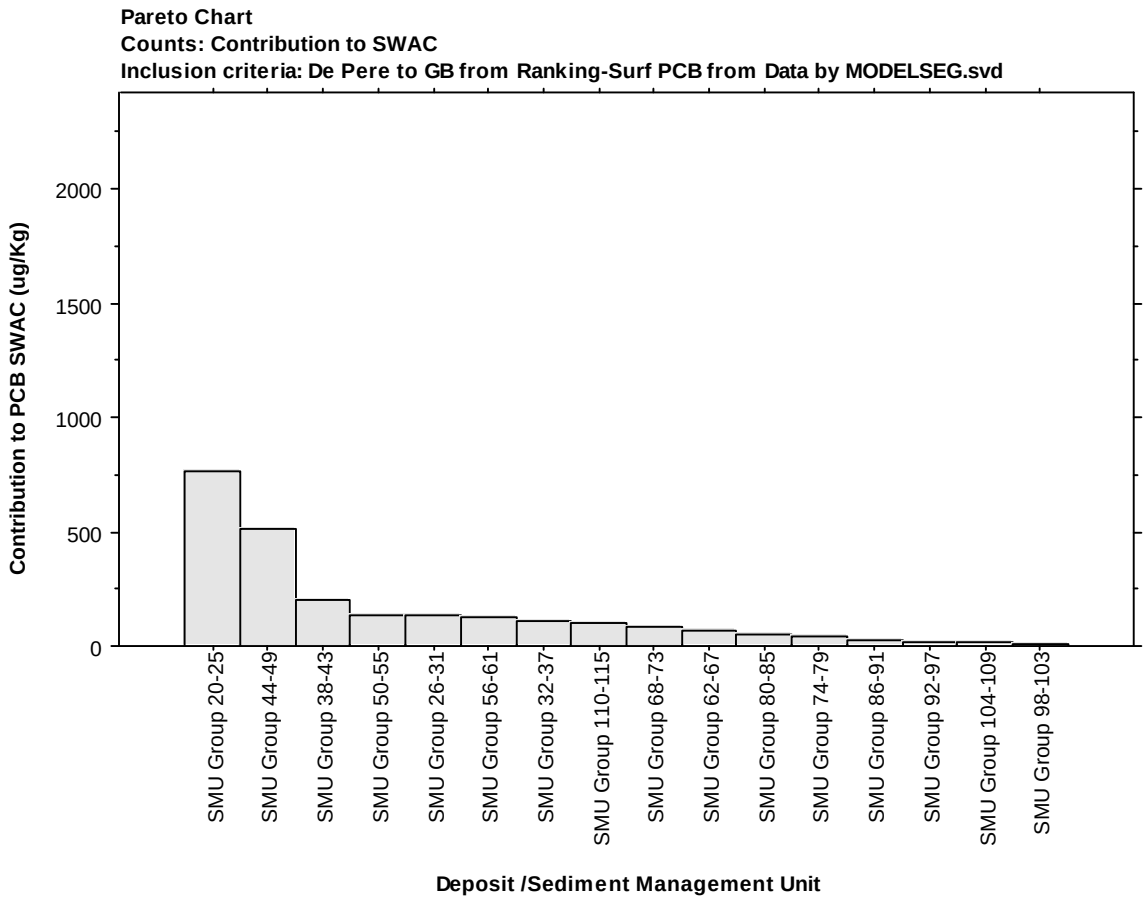
Figure 5-13. Contributions to Surface Water PCB Concentrations: Model Year 10-12, De Pere-Green Bay



Pareto Table for Descriptor
Counts: Median Water Col PCB yr 10-12 (ng/L*1E6)
Inclusion criteria: De Pere-GB from Ranking - CONCATENATED FRM 11-4-98 EXCEL 4.xls (imported)

	Count	Percent	Cum. Count	Cum. Percent
SMU 20-25	11350000	19.663	11350000	19.663
SMU 44-49	10960000	18.987	22310000	38.649
SMU 56-61	7075000	12.257	29385000	50.906
SMU 38-43	6904000	11.960	36289000	62.866
SMU 68-73	4812000	8.336	41101000	71.203
SMU 50-55	3544000	6.140	44645000	77.342
SMU 32-37	3202000	5.547	47847000	82.889
SMU 62-67	3078000	5.332	50925000	88.222
SMU 26-31	2420000	4.192	53345000	92.414
SMU 80-85	1237000	2.143	54582000	94.557
SMU 86-91	1097000	1.900	55679000	96.457
SMU 74-79	927000	1.606	56606000	98.063
SMU 92-97	783000	1.356	57389000	99.420
SMU 110-115	131000	.227	57520000	99.647
SMU 104-109	104000	.180	57624000	99.827
SMU 98-103	100000	.173	57724000	100.000

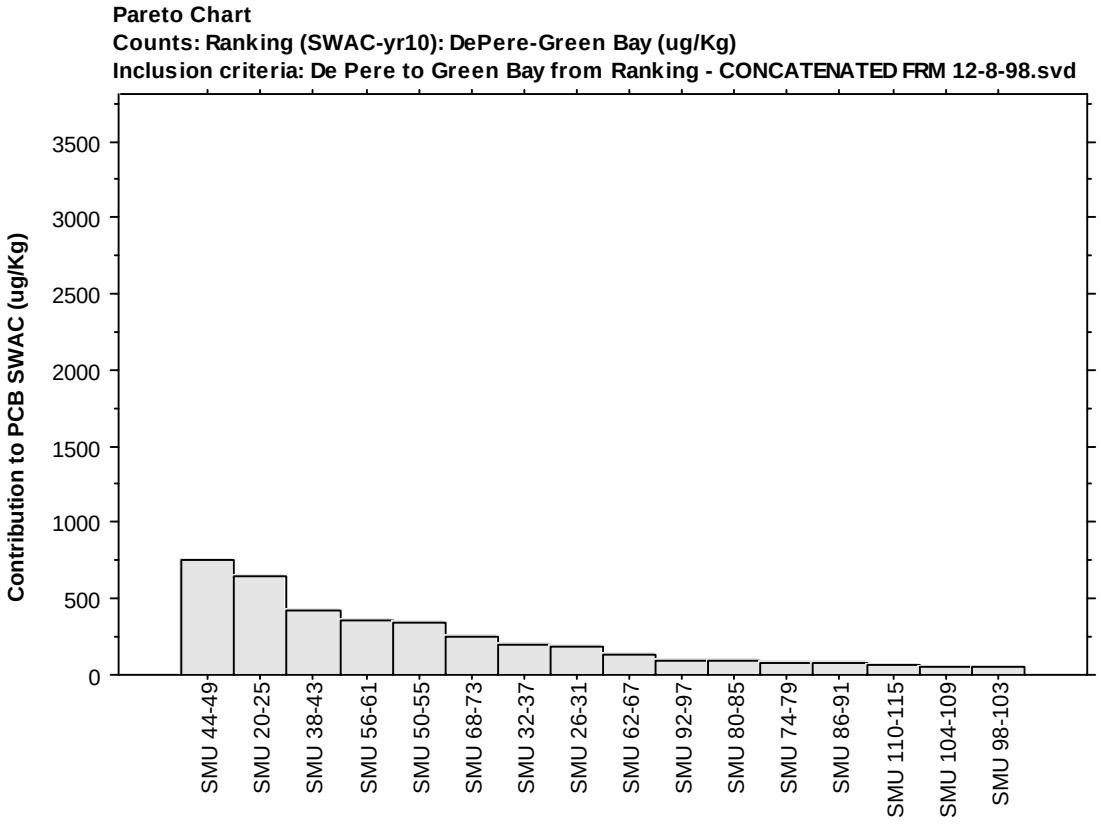
Figure 5-14. Contributions to PCB SWAC: Interpolated Data, De Pere-Green Bay



Pareto Table for Deposit /Sediment Management Unit
Counts: Contribution to SWAC
Inclusion criteria: De Pere to GB from Ranking-Surf PCB from Data by MODELSEG.svd

	Count	Percent	Cum. Count	Cum. Percent
SMU Group 20-25	770	31.766	770	31.766
SMU Group 44-49	515	21.246	1285	53.012
SMU Group 38-43	206	8.498	1491	61.510
SMU Group 50-55	134	5.528	1625	67.038
SMU Group 26-31	132	5.446	1757	72.483
SMU Group 56-61	130	5.363	1887	77.847
SMU Group 32-37	113	4.662	2000	82.508
SMU Group 110-115	100	4.125	2100	86.634
SMU Group 68-73	88	3.630	2188	90.264
SMU Group 62-67	67	2.764	2255	93.028
SMU Group 80-85	48	1.980	2303	95.008
SMU Group 74-79	46	1.898	2349	96.906
SMU Group 86-91	27	1.114	2376	98.020
SMU Group 92-97	21	.866	2397	98.886
SMU Group 104-109	21	.866	2418	99.752
SMU Group 98-103	6	.248	2424	100.000

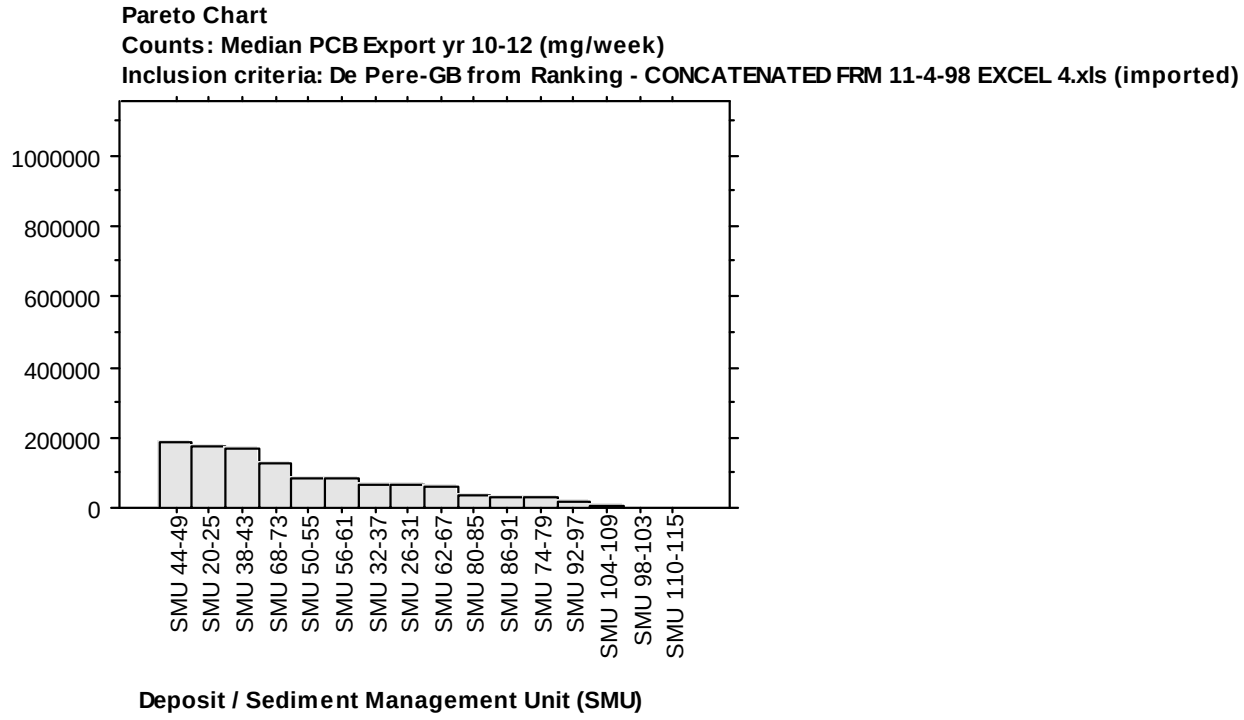
Figure 5-15. Contributions to PCB SWAC: Model Year 10-12, De Pere-Green Bay



Pareto Table for Descriptor
Counts: Ranking (SWAC-yr10): DePere-Green Bay (ug/Kg)
Inclusion criteria: De Pere to Green Bay from Ranking - CONCATENATED FRM 12-8-98.svd

	Count	Percent	Cum. Count	Cum. Percent
SMU 44-49	758	19.890	758	19.890
SMU 20-25	643	16.872	1401	36.762
SMU 38-43	425	11.152	1826	47.914
SMU 56-61	362	9.499	2188	57.413
SMU 50-55	348	9.131	2536	66.544
SMU 68-73	245	6.429	2781	72.973
SMU 32-37	199	5.222	2980	78.195
SMU 26-31	180	4.723	3160	82.918
SMU 62-67	137	3.595	3297	86.513
SMU 92-97	92	2.414	3389	88.927
SMU 80-85	89	2.335	3478	91.262
SMU 74-79	79	2.073	3557	93.335
SMU 86-91	76	1.994	3633	95.329
SMU 110-115	69	1.811	3702	97.140
SMU 104-109	59	1.548	3761	98.688
SMU 98-103	50	1.312	3811	100.000

Figure 5-16. Contributions to PCB Export to Green Bay: Model Year 10-12, De Pere-Green Bay



Pareto Table for Descriptor
Counts: Median PCB Export yr 10-12 (mg/week)
Inclusion criteria: De Pere-GB from Ranking - CONCATENATED FRM 11-4-98 EXCEL 4.xls (imported)

	Count	Percent	Cum. Count	Cum. Percent
SMU 44-49	187000	16.176	187000	16.176
SMU 20-25	177000	15.311	364000	31.488
SMU 38-43	171000	14.792	535000	46.280
SMU 68-73	129000	11.159	664000	57.439
SMU 50-55	86000	7.439	750000	64.879
SMU 56-61	85000	7.353	835000	72.232
SMU 32-37	68000	5.882	903000	78.114
SMU 26-31	67000	5.796	970000	83.910
SMU 62-67	63000	5.450	1033000	89.360
SMU 80-85	34000	2.941	1067000	92.301
SMU 86-91	31000	2.682	1098000	94.983
SMU 74-79	30000	2.595	1128000	97.578
SMU 92-97	21000	1.817	1149000	99.394
SMU 104-109	4000	.346	1153000	99.740
SMU 98-103	3000	.260	1156000	100.000
SMU 110-115	1	8.651E-5	1156001	100.000

Figure 5-17. Little Lake Butte des Morts: Potential Remediation Area Boundaries

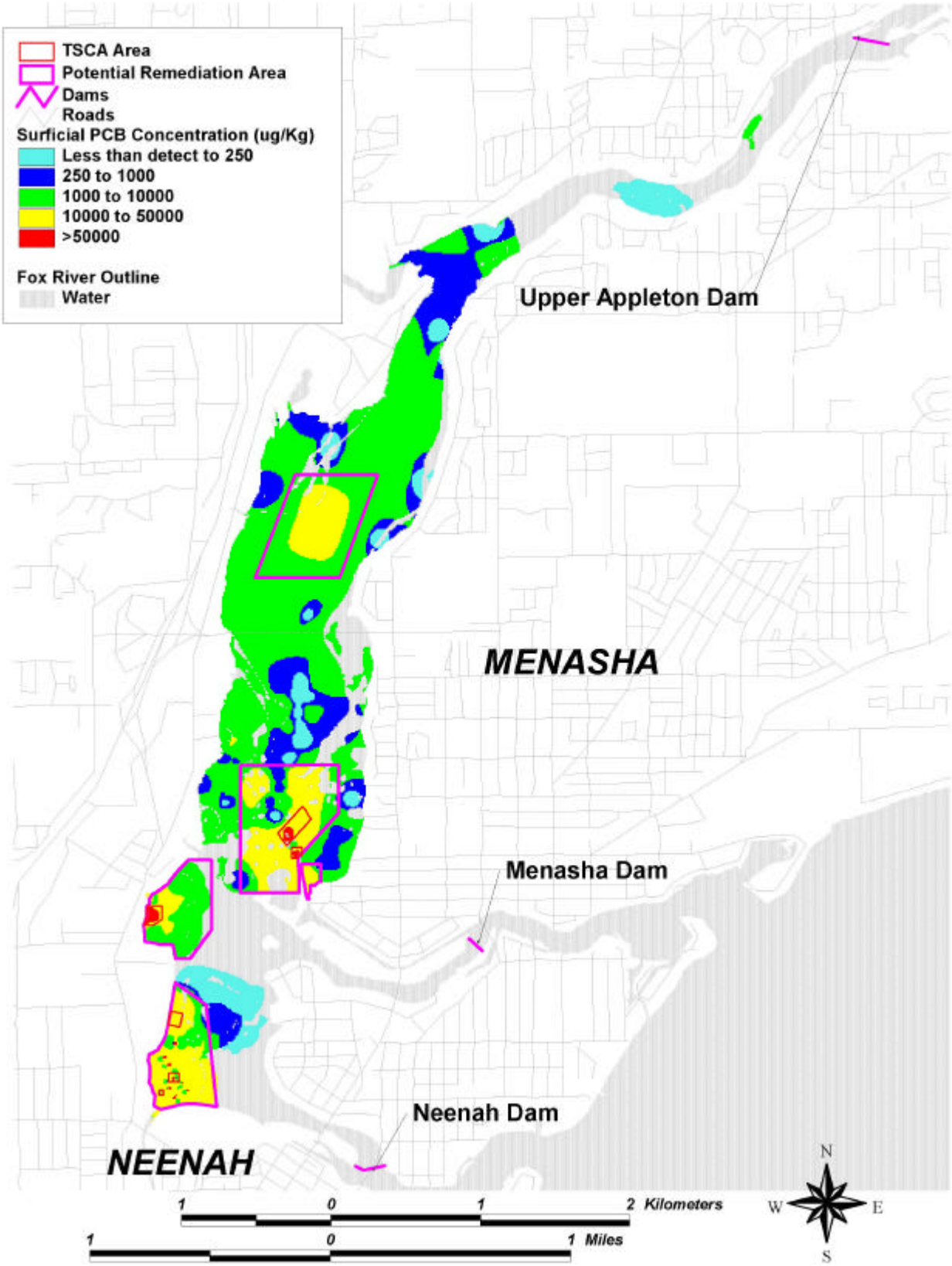


Figure 5-18. Appleton to Little Rapids: PCB Distribution

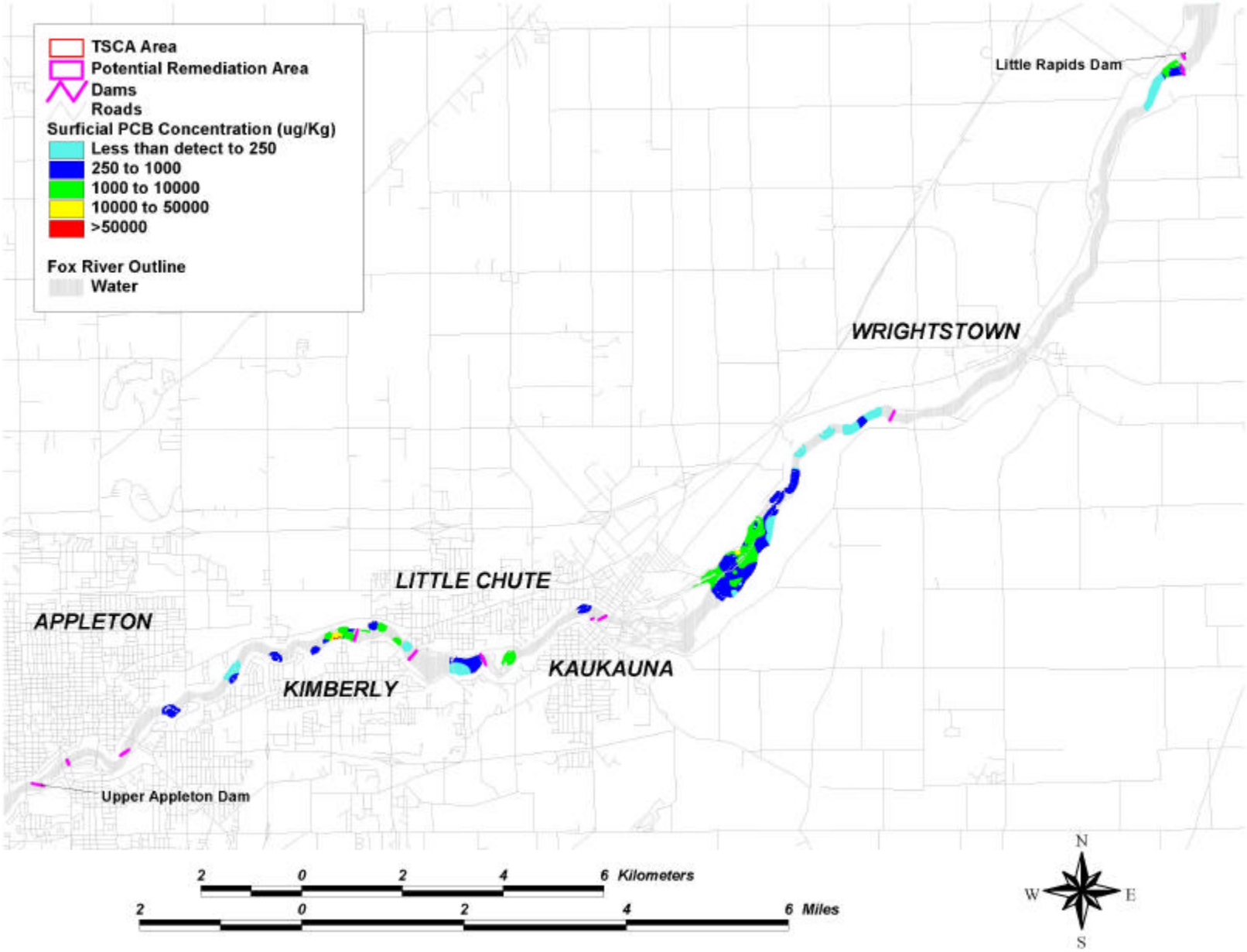


Figure 5-19. Little Rapids to De Pere: Potential Remediation Area Boundaries

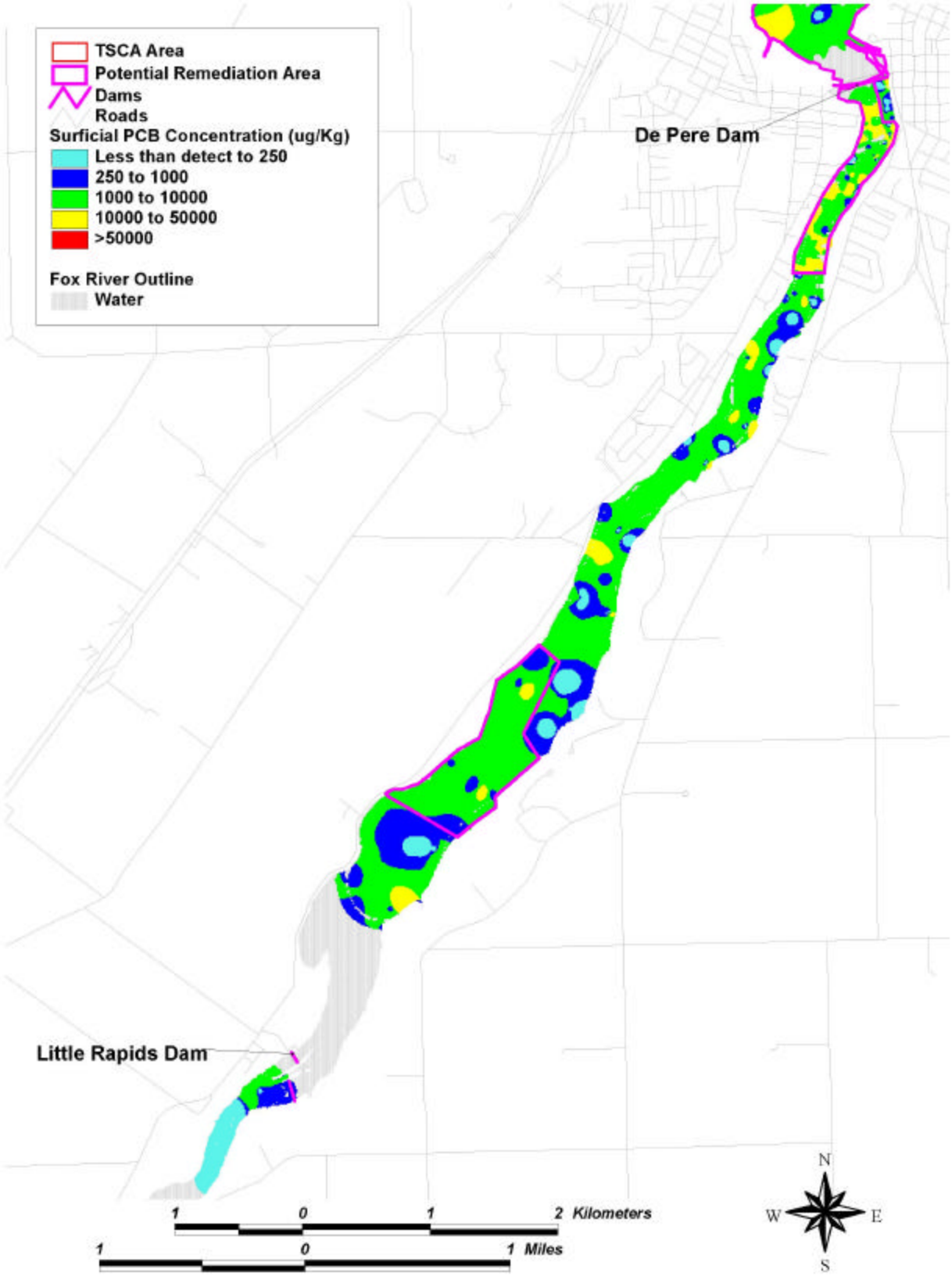
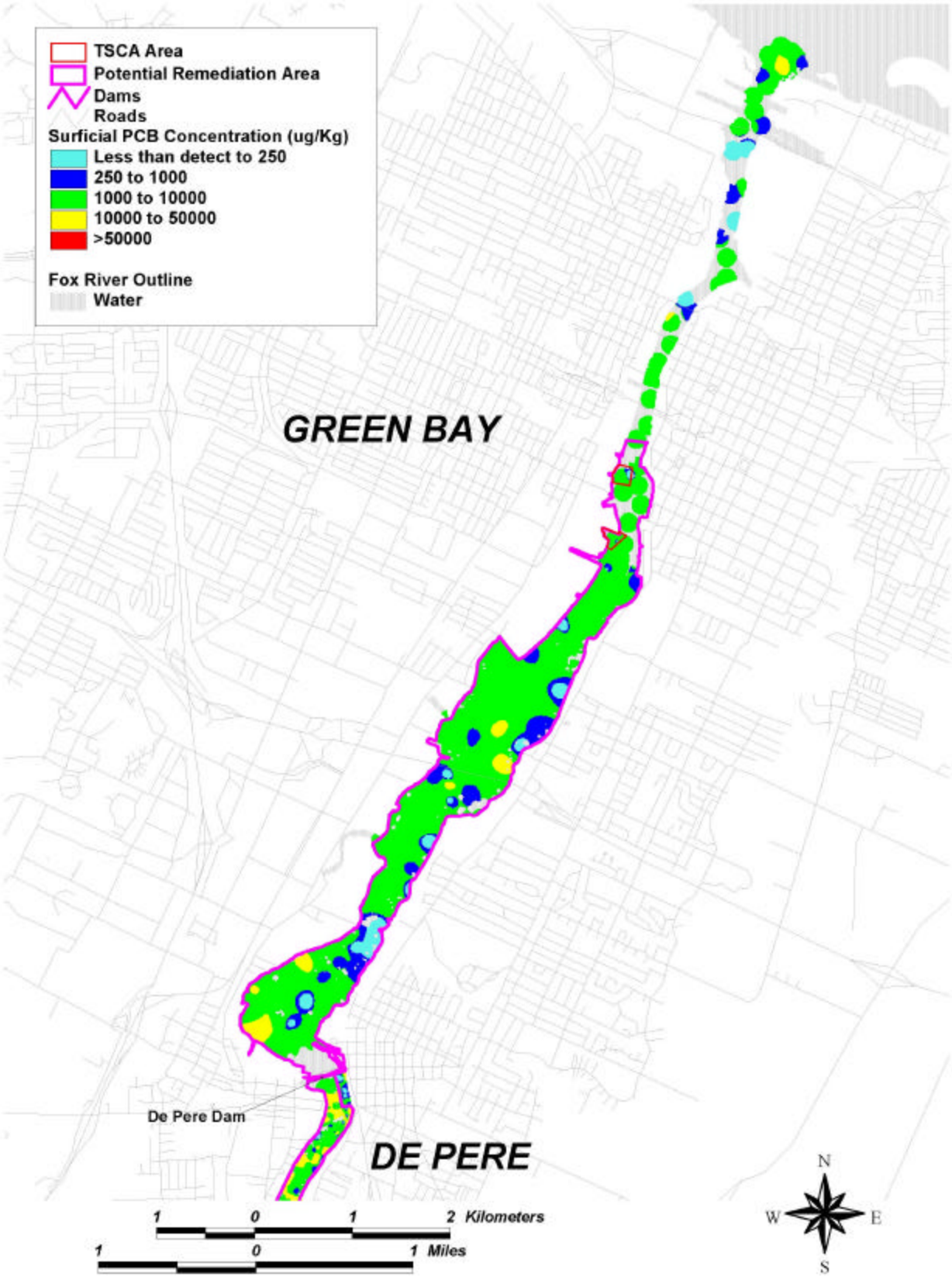


Figure 5-20. De Pere to Green Bay:
Potential Remediation Area Boundaries



6 Identification and Screening of Technologies

The purpose of this section is to identify and screen remedial action technology types and process options that are potentially applicable for management of contaminated sediments in the Lower Fox River. The screening process was conducted in accordance with the EPA RI/FS Guidance (EPA, 1988). The following provides a description of this section:

- Section 6.1 begins by the screening process with a presentation of the universe of general response actions, technology types, and specific process options that could be potentially brought to manage Lower Fox River sediments.

- Section 6.2 defines the screening process and the criteria used to screen the universe of technologies based upon their implementability, effectiveness, and relative costs. The section presents the results of the technology screening in a series of tables that describe the specific process options, and the rationale for retention or elimination.

- Section 6.3 presents the results of the technology screening and a brief description of the primary factors that influenced the screening decisions, which resulted in elimination or retention of specific process options. The section culminates in a list of retained process options.

- Section 6.4 provides a more detailed description of each of the retained process options that will be carried forward into the detailed reach-specific analysis in Section 7. The site-specific factors that will influence implementability or effectiveness (i.e., operational constraints) are also identified here, to be applied in Section 7.

- Section 6.5 discusses ancillary technologies (i.e., transportation of dredged sediments) that are required to implement specific management options for the Lower Fox River, but do not necessarily require screening.

- Section 6.6 provides information on water quality including protection of the water column during dredging and requirements for discharge of water from sediment handling activities.

The following literature sources and data bases were utilized to compile and evaluate a broad list of potentially applicable technology types and process options, as provided in Table 6-1:

- *Remediation Technologies Screening Matrix and Reference Guide, Second Edition* (DOD, 1994)
- *Assessment and Remediation of Contaminated Sediments (ARCS) Program, Final Summary Report* (EPA, 1994a)
- *Assessment and Remediation of Contaminated Sediments (ARCS) Program, Remediation Guidance Document* (EPA, 1994b)
- *Review of Removal, Containment and Treatment Technologies for Remediation of Contaminated Sediment in the Great Lakes* (Averett et al., 1990)
- *Dredging, Remediation, and Containment of Contaminated Sediments* (Demars et al., 1995)
- *SEDTEC: A Directory of Contaminated Sediment Removal and Treatment Technologies* (SEDTEC, 1997)

The following documents which evaluated technology types used or considered for use on the Fox River and at other similar sites were also used for reference:

- *Remedial Investigation Report for Contaminated Sediment Deposits on the Fox River Little Lake Butte des Mort to the De Pere Dam* (Graef et al., 1996)
- *Feasibility Study Report for Deposits POG and N on the Fox River* (Graef et al., 1997)
- *Remedial Investigation/Feasibility Study - Little Lake Butte Des Mort - Sediment Deposit A* (Blasland & Bouck Engineers, P.C., 1993)
- *Engineering Evaluation/Cost Analysis Manistique River and Harbor* (Blasland & Bouck, and Lee, Inc., 1994)
- *Sheboygan River and Harbor Feasibility Study* (Blasland, Bouck, and Lee, Inc., 1998)
- *Feasibility Study Report - Deposit A Little Lake Butte des Mort* (EWI Engineering Associated, Inc., 1992)

In addition to these sources, available site data, and specific criteria applicable to the process options were used in the screening process.

6.1 Identification of Technologies

The first step in the FS process involves the identification of General Response Actions (GRAs), remedial action technology types (i.e., dredging, chemical treatment, capping) and remedial action process options (i.e., horizontal auger dredge, electrochemical oxidation, sand cap). The following describes GRAs, technology types and process options:

- General Response Actions - These are selected to address the extent of contamination and the potential for migration of COC for a given medium. GRAs are described in broad terms in order to encompass all possible remedial actions for achieving the remedial action objectives. By identifying appropriate response actions which apply to contaminated sediments, the list of technologies to be reviewed can be substantially reduced.

- Technology Types - These are general categories that describe a means for achieving the GRAs. For example, removal is a GRA that can be achieved by excavation or dredging, while treatment is a GRA that can be achieved by biological and chemical treatment.

- Process Options - These are specific processes within each technology type. For example, chemical treatment, which is a technology type, includes such process options as solvent extraction and slurry oxidation. Process options are selected based on an understanding of the characteristics of the medium and technologies that are available to address the medium.

Table 6-1 presents potentially applicable technology types and process options that address remediation of contaminated sediments in the Lower Fox River. These technology types and process options are presented in Table 6-1 according to the following GRAs:

- No Action
- Institutional Controls
- Containment
- Removal
- *In situ* Treatment
- *Ex-situ* Treatment
- Dewatering
- Disposal

6.2 Screening of Technologies

The technology types and process options listed in Table 6-1 are screened in this section of the FS to determine which technologies may be appropriate for development of remedial alternatives to address the contaminated sediment in the Lower Fox River. The screening methodology used is consistent with that presented in the EPA RI/FS Guidance. The following subsections describe the process and screening criteria used for the identified technologies.

6.2.1 Screening Criteria

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

Implementability

Technical implementability places emphasis on general site characteristics and contaminant types and concentrations. These parameters are used to determine the technical feasibility of implementing a particular technology. Technologies that cannot be effectively implemented or are clearly unworkable are eliminated from further consideration in subsequent screening.

Administrative implementability is an evaluation tool that places emphasis on permitting issues and the availability of necessary services and equipment associated with the implementation of a particular technology.

Effectiveness

Effectiveness of a particular technology is evaluated relative to the other technologies identified in the screening. Consideration must be given to the many aspects that contribute to a technologies overall effectiveness. Some of these considerations are:

- How well the technology will handle the estimated areas or volumes of contaminated sediment to be remediated
- If the RAOs will be met through implementation of the technology
- How efficient is the technology at reducing or eliminating the COC
- To what scale (lab-, pilot-, full-) has the technology been tested
- Is the process option effective in protecting human health and the environment during the implementation phase of remediation

The feasibility of applying the process options for Lower Fox River sediment remediation was based primarily on the presence of PCBs, as opposed to the other COPCs. In other words, PCBs were the primary COPC considered in the screening process. Metals were also considered in the screening of certain process options for treatment.

Cost

Technologies were evaluated with respect to relative capital and operations and maintenance (O&M) costs. Detailed cost estimates of remedial alternatives are provided in Section 7 of this FS Report. Costs used for this phase of the screening process are defined in terms of high, moderate and low, rather than a specific dollar amount and are determined on the basis of engineering judgement. The cost of each process option is relative to other process options of the same technology type. Technologies are retained or eliminated based, to a lesser degree, on cost during this phase of the screening.

6.2.2 Screening Process

As specified in the EPA RI/FS Guidance, a two-step screening process was used to evaluate each process option listed in Table 6-1, with the exception of technology types or process options associated with the No Action GRA. The No Action GRA is retained as required by NCP for use as a baseline comparison against other technologies.

In the first step, referred to as the initial screening, process options determined to be technically implementable were retained for further evaluation. In the second step, the final screening, retained process options are evaluated further, based on three criteria; administrative implementability (if known), effectiveness and cost. In general, emphasis was placed on technical implementability in the initial screening and on effectiveness in the final screening, to be consistent with EPA RI/FS Guidance.

Tables 6-2 through 6-8 present the initial screening and Tables 6-9 through 6-15 present the final screening. Each table corresponds to the GRAs identified in Section 6.1.

Tables 6-2 through 6-15 identify the technology types and process options and provide brief descriptions of each process option. These tables also provide the screening comment and screening decision for each process option (i.e., retained or eliminated).

The screening comments reflect information about the technology that impact its use for remediation of contaminated sediments in the Lower Fox River. The screening comments provide pertinent information on the implementability, effectiveness, or cost that is relevant to each process option. The decision to retain or eliminate a process option is based on information summarized in the corresponding screening comment. Process options retained following the final screening represent feasible options among those originally subject to the screening.

6.3 Results of Technology Screening

A list of potentially applicable technology types and process options were subject to the two-step screening process described in Section 6.2.2. The screening criteria discussed in Section 6.2.1 and professional judgement were the basis for the final screening decision. Of the 67 remedial technology types and process options evaluated, 23 have been retained and are presented in Table 6-16. This condensed list provides a number of feasible options for the development of remedial alternatives.

A brief discussion of the primary factors that influenced the final decision to retain or eliminate specific process options is presented in the following subsections. Section 6.4 provides details of the retained process options including a description and selection criteria used in the screening. Section 6.4 through 6.6 provide relevant information about the retained process options to consider in the development of remedial alternatives, described in Section 7 of this FS Report.

6.3.1 No Action

The GRA of No Action was retained as required by NCP for use as a baseline comparison against other technologies. The “No Action” alternative requires no human intervention for river clean-up. For the No Action alternative, natural restoration is the only means of addressing the contaminated sediments in the Lower Fox River. Natural restoration may involve one or more processes that effectively reduce contaminant toxicity, mobility or volume. These processes include biodegradation, diffusion, dilution, sorption, volatilization, and/or chemical and biochemical stabilization of contaminants. The No Action alternative is unlikely to meet the RAOs. Selection of this process option requires at a minimum long term monitoring of the river to determine if natural restoration is occurring.

6.3.2 Institutional Controls

All institutional controls were retained as potentially applicable for use in remedial alternatives. Institutional controls may be employed during remedial operations or in areas where there is a low volume and a low mass of contaminated sediments. Long term monitoring is required with the use of institutional controls to determine if or when the controls may be eliminated.

6.3.3 Containment

Containment process options were limited to those that provide adequate protection against releases of and exposure to contaminants within the sediments. Consideration was given to placement of the cap over river bottom sediments, the potential for erosion of capping materials, future waterway uses and contaminant characteristics within the sediments to be capped. Depending upon the hydraulic conditions, the cap design may also include geotextiles to further restrict contaminant mobility, and/or engineering of erosion control layers (i.e., large rock cover as an armor) to prevent cap loss. The RAOs may be achieved with this option, provided long term hydraulic stability can be achieved. Capping requires the use of institutional controls, long term monitoring and maintenance, which may include cap replacement. Frequently, replacement of habitat is required to mitigate the loss of river bottom habitat caused by the cap.

6.3.4 Removal

Removal process options were limited to those that are expected to provide comparatively lower contaminant releases during operations, have the ability to handle debris and have demonstrated success. Both hydraulic and mechanical options were retained as removal options. Dry excavation with an excavator was also retained as potentially feasible for use at specific locations in the river. Removal options would require water quality monitoring during and after activities and management of materials following removal.

6.3.5 *In situ* Treatment

No *in situ* process options were retained for consideration in the development of remedial alternatives. *In situ* treatment process options, in general, have not been successfully demonstrated in field applications. Therefore, the process options screened do not constitute feasible technologies for implementation in the Lower Fox River.

6.3.6 *Ex situ* Treatment

Two *ex situ* treatment process options were retained. The elimination of other *ex situ* treatment options was primarily based on media-specific characteristics (i.e., high water content of sediments), contaminant composition, and the lack of full-scale demonstrations. The retained options are incineration and high temperature thermal destruction. Application of the retained *ex situ* treatment options will require residuals management (described in Section 6.5) and disposal of sediment after treatment.

6.3.7 Dewatering

Dewatering process options were limited to those which provide the best production rates for dewatering sediments, the best separation of fine particles and water, and energy efficient technologies. The dewatering technologies were confirmed in conversations with dredging contractors as the most practical and most widely used technologies. Dewatering process options are divided into two types of technologies: passive dewatering and mechanical dewatering. Passive dewatering is time dependent as the dredged sediments are placed into a holding facility, such as a pond or CDF, whereby water separates from the sediment by gravity. Passive dewatering is applicable in areas with large available space for construction of the holding facility. Mechanical dewatering is very energy dependent as it uses mechanical devices such as centrifuges, cyclones, or belt presses to remove moisture from the sediments. Mechanical dewatering is applicable in smaller areas where construction of a holding facility may not be practical. Passive and mechanical dewatering technologies require monitoring of air of effluent water during dewatering activities.

6.3.8 Disposal

Both on-site and off-site disposal process options were retained as potentially applicable. On-site disposal options include all nearshore or in-water options and involve the relocation and consolidation of sediments to an area within the river. All on-site disposal options will require institutional controls (i.e., dredging moratorium) and long term monitoring. Retained on-site disposal options include the level bottom cap and CDF. Off-site disposal involves the transportation of sediment out of the river. Off-site disposal options include all upland disposal options for relocation and consolidation of sediments in a landfill or for use as fill material. Off-site disposal options that were retained include all options that involve sediment disposal at a landfill.

6.4 Description and Selection Criteria for Retained Process Options

This section provides a detailed description of each of the retained process options and a review of pertinent selection criteria that influenced the screening process. The information presented in the following sections also provides the basis for development of the remedial alternatives in Section 7.

6.4.1 Containment Process Options

In situ capping is the containment and isolation of contaminated sediments by the placement of clean materials over the existing substrate. This alternative does not require removal of sediment; clean sediments are placed over old sediments as a barrier, effectively isolating contaminants within the substrate. Capping of subaqueous contaminated sediments has become an accepted engineering option for managing dredged materials of *in situ* remediation (NRC 1989; EPA 1991, 1994b, Palermo et al., 1998). There are multiple references that discuss physical considerations, design and monitoring requirements for capping. The following references were used in this FS Report to assess the applicability of containment technologies:

- *Review of Removal, Containment and Treatment Technologies for Remediation of Contaminated Sediment in the Great Lakes* (Averett et al., 1990)
- *Design Requirements for Capping* (Palermo et al., 1991)
- *Guidance for In Situ Subaqueous Capping of Contaminated Sediments* (Palermo et al., 1998)
- *Placement Techniques for Capping Contaminated Sediments* (Palermo et al., 1994)
- *WDOE, 1990 Standards for Confined Disposal of Contaminated Sediments Development Document* (WDOE, 1990)
- *Equipment and placement techniques for capping* (USACE, 1991)
- *Monitoring considerations for capping* (USACE, 1992)
- *Subaqueous Capping of Contaminated Sediments: Annotated Bibliography* (Zeeman, et al., 1992)

- *Design Considerations for Capping/Armoring of Contaminated Sediments In-Place* (Maynord et al., 1993)

The last two references describe capping design and structural considerations for capping in a riverine environment in the Great Lakes.

Description of Containment Process Options

Three types of caps were retained for consideration for the Lower Fox River. These are:

- Conventional Cap
- Armored Cap
- Composite Cap

These are described in more detail below.

Conventional Capping. Conventional caps involve the direct application of sand or other suitable cover material over the top of contaminated sediments. Sand or other earthen materials are used to contain contaminants. The design thickness is a function of both the chemical containment considerations and local hydraulic conditions. A cap of 30 to 50 cm is sufficient to chemically isolate PCBs and metals (Palermo et al., 1994). A summary of conventional capping projects in North America is provided in Appendix B.

There are a variety of potential methods for constructing a conventional cap in a riverine environment. These methods include hydraulic pipeline delivery of a sand slurry through a floating spreader box or submerged diffuser; dozing, clamming or washing of barged capping materials to settle through the water column; distribution by controlled discharge from hopper barges; mechanically fed tremie to the river bottom; high pressure spraying of a hydraulic sediment-water slurry across the water surface. Important factors in selecting the cap placement method are to assure minimum and even placement of material over the entire remedial area, limit resuspension and loss of contaminated sediment into the emerging cap layer. These factors are satisfied when the capping materials are allowed to settle through the water column rather than impacting the bottom with capping materials as a dumped mass or density-driven hydraulic flow.

Armored Capping. Armored caps are similar to sand caps in that sand is first placed over the contaminated sediments; however, that material is then covered so as to protect the cap (i.e., armoring material). Stone, or other suitable riprap materials are applied to the top of the cap to ensure the physical stability of the cap. Armored caps are more commonly used in environments where high water

velocities (i.e., flood-flow, propeller wash) can threaten the physical cap integrity. Examples of armored caps from Sheybogan Falls, Wisconsin and Manistique Harbor, Michigan are illustrated on Figure 6-1.

The contaminant containment portion of an armored cap within the Lower Fox River would be sand. This portion of the cap would be placed as described above in conventional capping. Armored stone may be obtained from local quarries, and is placed from a barge with either a conventional excavator or bucket. Methods for determining the appropriate armor stone grade and thickness can be found in the Assessment and Remediation of Contaminated Sediments (ARCS) Sediment Capping Study Final Report (Maynord et. al., 1993).

Composite Capping. A composite cap generally involves placement of a geotextile or flexible membrane liner directly over the contaminated sediments, which is then overlain with armored stone or riprap to ensure the physical integrity. Composite caps may also include a sand or activated carbon layer to capture any potential diffusive or advective migration of the underlying contaminants. For non-mobile contaminants, such as PCBs, the composite cap would likely only require a liner and armoring.

A demonstration project at Sheboygan Falls, Wisconsin, involved the construction of a composite cap consisting of layers of graded gravel and geotextiles over small areas of PCB contaminated sediments in a high velocity, shallow portion (<5 feet) of the stream bed. At the Manistique Harbor Superfund Site in Manistique, Michigan, an interim cap consisting of a 40-mil plastic liner with armoring was placed over a 0.5 acre PCB contaminated area of impacted sediment. The liner placement was intended only as a temporary structure to prevent resuspension and transport of PCBs until the final 17 acre armored cap could be constructed. Armoring was required since the cap is located within the navigational channel.

Criteria for Cap Selection

The criteria used for selection of a capping alternative are presence of sediments with PCB concentrations of 50 ppm or greater (referred to as TSCA level sediments, where the TSCA level is 50 ppm), site bathymetry, and current speed (median and 100 year flood). The latter two criteria are based upon general design guidance that caps should only be placed in a low-energy environment with little potential for erosion or disturbance of the cap (Palermo *et al*, 1998).

- *Contaminant Concentration - Capping is not considered for sediments where total PCB concentrations exceed the 50 ppm TSCA level, unless the alternative involves removal of all TSCA level material prior to capping.* Areas with sediment PCB concentrations exceeding the TSCA level of 50 ppm are unlikely to receive

regulatory approval for capping. EPA has determined that capping of PCB contaminated sediments is an action to contain and confine PCBs, though concentrations of 50 ppm or greater may not be approved by EPA (EPA Region 5 letter dated July 15, 1994, provided in Appendix C).

- *Site Bathymetry - The final constructed water depth shall be no less than three feet*. Site-specific water depth must be considered in selecting a cap as an option. To maintain physical integrity, the cap surface must be sufficiently below the water surface to minimize the potential for ice scour or wind-induced currents or waves. In general, a minimum constructed depth of 3 feet of water depth is sufficient to ensure integrity against weather erosion for potential locations in the Lower Fox River. Commercial and recreational boating use of an area must also be considered to ensure both adequate draft clearance, as well as the potential for scour from anchors or propeller wash. For recreational boating, a final water depth of > 3 feet should be sufficient for most vessels.

- *Currents - Capping is considered an alternative for a given river reach where the average current speed is less than 0.15 feet/second (ft/s), and the maximum (100 year flood) current speed is no greater than 0.7 ft/s.* Currents are important to consider from the standpoint of the potential to cause resuspension and physical erosion of the cap. Currents considerations should include both normal flow, flood events, and dramatic water fluctuation that may result from dam failure or dam drawdown. For a conventional sand cap, the site conditions should generally be non-dispersive in a relatively low-energy environment with low bottom current velocity. In addition, commercial boat-induced currents (propeller wash) should be considered. In the Lower Fox River, flood-flow velocities in the central river channels are expected to be the dominant potential erosional force within the Little Lake Butte des Morts reach, and the Little Rapids to De Pere reach. Below the De Pere dam, navigation-induced water movement from the wake of a large boat or propeller wash should be considered in any potential capping scenario. Detailed evaluation methods for quantifying erosional potential are given in Palermo et al., 1998.

Additional guidance that is applied in this FS concerning the placement of a cap in the Lower Fox River includes the following:

- Navigation Channels - Capping is not selected as an alternative within the designated federal navigation channel below the De Pere dam. Commercial vessels are limited to below the De Pere dam. While a constructed water depth of > 25 feet is sufficient for clearance for most vessels, cap placement within the channel would require substantial armoring to protect against

erosion by propeller wash, and would result in permanent deed restrictions prohibiting maintenance dredging and/or navigational improvements.

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

- Capping Materials - For thin layer capping, use of clean uniform granular materials (sands, fine gravels) enhances reliable application of the design layer thickness. Clumpy materials (cohesive silts/clays) and/or variable size gravels are more difficult to place evenly, and may only be placed by mechanical means.

- Placement Method - Both mechanical and hydraulic methods have been used for cap placement. Mechanical placement of capping material allows for greater placement accuracy while minimizing downstream turbidity. Restrictions to the mechanical application of capping material are related to the draft depths of the material barges, which are generally 8 to 10 feet. Hydraulic placement is not restricted by water depth, and has the advantage of minimizing the resuspension of contaminated sediment losses described above. Conversely, the placement activity itself will result in a temporary increase in downstream suspended solids due to the cap material.

- Impact to Riverine Habitat and Future Use - The impact to riverine habitat and long term use of the site must be considered in selection of a capping option. Creation of a cap will result in change of the site depth, which can significantly change the quality of the aquatic habitat. Conventional, armored, or composite caps result in significant change in substrate type, which can influence the functioning of the benthic community and food chain interactions.

- Institutional Notifications/Monitoring - All capping options result in permanent restrictions to future site use, as well as long term monitoring and maintenance of the cap.

6.4.2 Removal Process Options

Specific applications for the removal equipment identified in Table 6-11 are based upon integration of site knowledge, practical dredging experience, and demonstrated successful application under similar conditions found throughout the Lower Fox River. Wherever possible, Great Lakes practical experience was utilized to assess the applicability of a specific removal technology.

In assessing removal alternatives, there are four documents that provide practical implementation information for sediment remediation projects in the Great Lakes region. The are:

- *Assessment and Remediation of Contaminated Sediments (ARCS) Program, Remediation Guidance Document* (EPA, 1994b)

- *Review of Removal, Containment and Treatment Technologies for Remediation of Contaminated Sediment in the Great Lakes* (Averett et al., 1990)

- *Dredging, Remediation, and Containment of Contaminated Sediments* (Demars et al., 1995)

Description of Removal Process Options

There are three categories of removal technologies that were retained for consideration for the Lower Fox River. These are:

- Mechanical Dredging
- Excavators
- Hydraulic Dredging

These are described in more detail below.

Mechanical Dredging. Mechanical dredges remove sediment by applying mechanical force to dislodge and remove the dredged material. A mechanical dredge consists of a suspended or manipulated bucket lowered to the bottom that "bites" the dredge material and raises it to the surface (Figure 6-2). The dredged material is then deposited in a haul barge, as illustrated in Figure 6-3, or other contained conveyance for transport and re-handling to final disposition. This type of mechanical dredge and haul operation is currently used for routine maintenance dredging of approximately 100,000 to 200,000 cubic yards from the federal navigational channel for the Green Bay Port Authority.

Under suitable conditions, mechanical dredges are capable of removing dredged material at near *in situ* densities, with almost no additional water entrainment in the dredged mass and little free water in the filled bucket. This low water content is highly important if dewatering is required for ultimate sediment treatment or disposal. Mechanical dredges are also effective at removing large debris.

Types of mechanical dredges include: conventional (open) and environmental (closed) clamshell buckets; dragline bucket; dipper dredge; and bucket ladder dredge. The dragline, dipper and bucket ladder are open mouthed conveyances and are generally considered to not be applicable where sediment resuspension is undesirable due to contaminants present in the sediment (EPA, 1994b). Consequently, dragline, dipper and bucket ladder techniques are not considered further in this FS Report.

The clamshell bucket dredge, or grab-dredge, is widely used in the United States and throughout the world. It typically consists of a barge-mounted floating crane maneuvering a cable-suspended dredging bucket. The crane barge is held in place for stable accurate digging by deployable vertical spuds imbedded into the sediment. The operator lowers the clamshell bucket to the bottom, allowing it to sink into the sediment on contact. The bucket is then lifted through the water column to the surface, swung to the side, and emptied into a waiting haul barge. When loaded, the haul barge is moved to shore where a second clamshell unloads the barge for re-handling and/or transport to treatment or disposal facilities. Clamshell dredges can work in depths over 100 feet, and using advanced positioning equipment (i.e., differential global positioning systems [DGPS]) dredging accuracy is in the order of ± 1 foot horizontally and ± 0.5 foot vertically.

Clamshell buckets are designated by their digging capacity when full; (i.e., a 3 yd^3 bucket), and range in size from less than 1 yd^3 to more than 50 yd^3.

A conventional clamshell digging bucket may not be appropriate for removal of contaminated sediments from the Lower Fox River. Conventional buckets have a rounded cut that leaves a somewhat cratered sediment surface on the bottom. This irregular bottom surface results in need for over-dredging to achieve a minimum depth of cut, and can also encourage dense resuspended sediment losses to settle in the craters. Furthermore, the conventional open clamshell bucket is prone to sediment losses over the top during full bucket retrieval.

To minimize resuspension, recent innovations in bucket technologies have resulted in modified buckets with enclosed tops (Figure 6-2). Also, buckets can

be fitted with tongue-in-groove rubber seals to limit sediment losses through the bottom and sides.

A recent alternative bucket demonstrated in several tests and prototype sediment remediation projects is the proprietary Cable Arm® bucket (Figure 6-2). This bucket offers the advantages of a large footprint (i.e., 6 yd^3), a level cut, capability to remove even layers of sediment, and under careful operating conditions, reduced resuspension losses to the water column. The Cable Arm® bucket has been successfully demonstrated for contaminated sediment removal at a number of sites in the Great Lakes (Cleland, 1997; SEDTEC, 1997), and was used in a removal action in the summer of 1997 at a creosote-contaminated site in Thunder Bay, Ontario (I. Orchard, personal communication).

Production rates for clamshell dredging are highly project-specific. For navigation dredging a 5 yd^3 bucket might deliver more than 200 cubic yards per hour (yd^3/hr). This same bucket might only produce 20 to 30 yd^3/hr in controlled sediment remediation work where concerns include thorough removal, limiting resuspension, minimal water content, water quality compliance and limited over-dredging. Presence of large debris requiring separation and re-handling will also slow dredging progress.

At the disposal end, a barge load of dredged sediment will yield some amount of free water that was captured as the clamshell bucket closed. The free water is extruded to the surface of the barge load by consolidation of the sediment load. If removal of free water is required for disposal, it can be decanted by pumping and treated to meet water quality requirements prior to discharge. Solids removed in water treatment can be recycled to disposal. A common practice for optimizing extrusion of free water is to let the loaded barge stand idle to allow more complete short-term consolidation.

Excavators. This is a sub-set of mechanical dredges which includes the backhoe and loader, both of which are limited in reach-capability. Special closing buckets are available to reduce sediment losses and entrained water during excavation. Excavators are usually applied to dry or shallow water situations that can be accessed from shore-based or limited-draft floating equipment. Conventional excavating equipment can also be used for removing contaminated sediment and debris in shallow water. Although normally land-based, the excavator or backhoe can be positioned on a floating equipment spud-barge for dredging.

A conventional excavator bucket is open at the top and will result in sediment resuspension and loss during dredging, although careful operation can minimize losses. Various improved excavating buckets have been developed which

essentially enclose the dredged materials within the bucket prior to lifting through the water column. A special enclosed digging bucket was successfully used on the large excavator "Bonacavor" (C.F. Bean Corp.) for remediation of highly contaminated sediment in Slidell, Louisiana (NRC, 1997). Dredged material removed by backhoe would exhibit much the same characteristics as for clamshell dredging, including near *in situ* densities and limited free water.

For the Lower Fox River, excavators could be considered for dry dredged excavation. They would also be applicable to "dry" removal operations within, for example, a bermed and filled nearshore CDF.

Hydraulic Dredges. Hydraulic dredges remove and transport dredged materials as a pumped sediment-water slurry. The sediment is dislodged by mechanical agitation, for example, cutterhead, augers, or by high pressure water jets (Figure 6-4). In very soft sediment it may be possible to remove surface sediment by straight suction and/or by forcing the intake into the sediment without dislodgement. The loosened slurry is essentially then "vacuumed" into the intake pipe by the dredge pump and transported over long distances through the dredge discharge pipeline. Figure 6-5 provides an illustration of a hydraulic dredge with a pipeline to an upland gravity dewatering cell.

Types of hydraulic dredges include the conventional cutterhead, open suction, dust pan, and hopper dredges. The conventional cutterhead and horizontal auger dredges are illustrated in Figure 6-4. It also includes a variety of specialty hydraulic dredges adapted mainly to limit resuspension losses at the dredge head and increase the solids content of the dredged slurry for special dredging conditions of sediment and other site characteristics. These latter include the auger, cleanup, and refresher type dredges. Hydraulic dredges are rated by discharge pipe diameter, and those available in the Great Lakes range from smaller portable machines in the 6 to 16 inch category, to large 24 to 30 inch dredges. The most suitable and available hydraulic dredges for the Lower Fox River project are the open suction, cutterhead, and auger types. These are discussed below.

Suction dredges are open-ended hydraulic pipes. Suction dredges generate low levels of turbidity, but are limited to dredging soft, free-flowing and unconsolidated material. As suction dredges are not equipped with any kind of cutting devices, they produce very little resuspension of solids during dredging. However, the presence of trash, logs, or other debris in the dredged material will clog the suction and greatly reduce the effectiveness of the dredge (Averett et al., 1990).

The hydraulic pipeline cutterhead suction dredge is commonly used, with approximately 300 operating nationwide, and is generally the most efficient and versatile (Averett et al., 1990). It is similar to the open suction dredge, but is equipped with a rotating cutter surrounding the intake of the suction pipe. By combining the mechanical cutting action with hydraulic suction, the dredge has the capability to efficiently extract and remove materials.

Resuspension of sediments during cutterhead excavation is strongly dependent on operational parameters such as thickness of cut, rate of swing, and cutter rotation rate. Proper balance of operational parameters can result in suspended sediment concentrations as low as 10 mg/L in the vicinity of the cutterhead. More commonly cutterheads produce suspended solids in the 50 to 150 mg/L range.

The cutterhead dredge was evaluated for removing contaminated sediment during the New Bedford Harbor Superfund Pilot Study. Compared to two other suction types, the cutterhead was superior for minimizing sediment resuspension (USACE New England Division, 1990). A cutterhead dredge was also used for removal of Deposit N sediments. The document, *Fox River Deposit N Interim Project Report* (Foth & Van Dyke, 1999) reports that river turbidity measurements were consistently below background values during project operations. Turbidity data (i.e., range of turbidity measurements and the arithmetic mean) at five monitoring locations, where M-1 is considered to provide background levels, follows:

- M-1 Location (Upstream)
  Range: 3.7 ntu to 233 ntu
  Arithmetic Mean: 43.7 ntu

- M-2 Location (Adjacent to Barrier)
  Range: 0 ntu to 108 ntu
  Arithmetic Mean: 52 ntu

- M-3 Location (Downstream)
  Range: 2.6 ntu to 245 ntu
  Arithmetic Mean: 39.7 ntu

- M-4 Location (Mill Intake)
  Range: 1.3 ntu to 42.9 ntu
  Arithmetic Mean: 12.2 ntu

- M-5 Location (Mill Treated Water)
  Range: 0.1 ntu to 20.1 ntu
  Arithmetic Mean: 1.52 ntu

- M-6 Location (within Barrier)
  Range: 3.7 ntu to 310 ntu
  Arithmetic Mean: 41.5 ntu

The horizontal auger dredge is a relatively small portable hydraulic dredge designed for projects where a small (50 to 120 yd^3/hr) discharge rate is desired. In contrast to a cutterhead, the auger dredge is equipped with horizontal cutter knives and a spiral auger that cuts the material and moves it laterally toward the center of the auger where it is picked up by the suction. There are more than 500 horizontal auger dredges in operation. A specialized horizontal auger dredge has been used at the Manistique Harbor Superfund site.

The Toyo pump is a proprietary electrically-driven compact submerged pump assembly that is maneuvered into position using a derrick barge. This pump is capable of high solids production in uncohesive sediment and can be equipped with a rotating cutter or jet-ring to loosen sediment. This is a lower head pump that typically discharges through 6 to 12 inch diameter pipes and may require a booster pump for long pipeline distances. Typically slurry discharges are at a density of approximately one third the *in situ* density.

Criteria for Removal Selection

Operating water depth is the single criterion used for selection of a hydraulic or mechanical removal option.

- *Operating Depths - Hydraulic dredging is selected for alternatives in areas where the depth of water is less than 8 ft. A mechanical dredging option is considered where there is sufficient water depth (>8 ft.) and limited volume "hot spot" removals (i.e., small volume TSCA level sediments).* Small hydraulic dredges have been successfully utilized in river depths as shallow as 3 feet, whereas mechanical dredges are typically limited to depths of 8 to 10 feet, principally by the draw of the transport barges required to move the dredged materials to shore.

Other significant operating parameters and constraints considered in selecting and applying the appropriate dredging equipment for the Lower Fox River include:

- Removal Efficiency - Capability for removing the target contaminated sediment layer in a single (or minimum number of) pass(es) with the dredge equipment. This will insure successful remediation while minimizing the quantity of over-dredged material to be treated/disposed.

- Contaminant Resuspension - Capability for removing targeted sediments with minimum amount of sediment resuspension and loss during dredging.

Uncontrolled losses can re-contaminate areas already dredged and exceed water quality requirements at the dredging site.

- Water Management - Practicality of managing large volumes of water associated with dredged material that will require collection and treatment prior to discharge of return flow to the river. This ranges from moderate amounts of free water and drainage arising from mechanically dredged sediment to significant continuous volumes associated with return flow from a hydraulic dredge.

- Equipment Availability - Availability of dredging equipment is an important consideration. A number of floating clamshell dredges and small hydraulic dredges are available in the Great Lakes for use at the project site. Large construction backhoes and equipment barges are also available. However, many of the specialty dredges identified in the literature (i.e., pneumatic, refreshers, clean-up, matchbox dredges) are not available locally and/or would require fabrication of new dredging equipment and a period of operating experience.

- Project Duration - Ability to complete the project in a timely manner. A significant project constraint is the limited allowable work period for in-water construction activities. In-water work is presently considered to occur within the months of April through October (an approximate 200 day time period). In-water work near residential areas will be restricted to 10 hour work periods in order to minimize disturbance to the residents.

- Work Sequencing - Removal will proceed from upstream to downstream. Concurrent removal in the four reaches is not considered in order to prevent recontamination of remediated downstream areas due to resuspension from upstream removal activities.

6.4.3 Dewatering Process Options

Dewatering involves the removal of water from the dredged sediment to produce a material that is more easily handled by general construction equipment and to produce a material that would meet the disposal criteria, such as the paint filter test and strength specifications. The applicability of each dewatering technology is dependent upon the physical characteristics of the materials being dredged, the dredging method utilized, the required moisture content of the dewatered material, and any Total Suspended Solids (TSS) requirements for the effluent water.

Description of Dewatering Process Options

Dewatering technologies can be divided into three categories that are applicable to the Lower Fox River sediments. These are:

- Mechanical Dewatering
- Passive Dewatering
- Solidification

These are described in more detail below.

Mechanical Dewatering. Mechanical dewatering applies a force to the sediments which physically forces the water out of the sediments. Mechanical dewatering equipment sizes and capacities vary from small mobile units that are transported by semi-trailer to larger equipment assembled at fixed facilities. Mechanical dewatering also requires an energy source to operate the required equipment. Mechanical dewatering is used in conjunction with hydraulic dredging to dewater low percent solids slurries. Mechanical dewatering units are typically operated by one of two methods. In the first method the units are operated with a continuous throughput (i.e., the unit dewaters at the same rate as sediment is being removed from the water). In the second method an equalization pond is used for sediment slurry storage (i.e., the dewatering unit may operate 20 hours for every 10 hours of sediment removal). There are four mechanical dewatering techniques discussed in this subsection consisting of: centrifugation; diaphragm filter presses, belt presses; and hydrocyclones.

Centrifugation involves the spinning of the dredged slurry within a vessel at a high rate of speed. The water and the sediments are separated based upon the mass differences of the components. The use of a cloth filter or the addition of flocculent chemicals assist in the removal of finer particles. Centrifuges are suitable for areas along the Lower Fox River where room for larger dewatering systems are impractical. Centrifuges also work with oily sediments and can be used for either thickening or dewatering dredge slurries. Typical production rates of a single centrifuge vary from 20 to 500 gallons per minute (gpm). Assuming a dredged slurry solids content of 4% by volume and a dewatered solids content of 30% by volume, the typical production rates vary from approximately 1 to 21 yd^3/hr.

Hydrocyclones are a continuously operating device that use centrifugal force to accelerate the settling rate of particles within water. Hydrocyclones are cone shaped devices in which slurries are pumped at high velocities. The slurries enter near the top and spin downward toward the point of the cone. The particles settle out through a drain in the bottom of the cone while the effluent water exits

through an additional pipe exiting the top of the cone. The production rate and minimum particle size separated are both dependent upon the diameter of the hydrocyclone. Generally a wider hydrocyclone has a greater production rate, whereas narrower hydrocyclone will separate smaller particles. The typical production rate of a single unit will vary widely from 50 to 3,500 gpm, depending on the diameter of the unit. Assuming a dredged slurry solids content of 4% by volume and a dewatered solids content of 30% by volume, the typical production rates vary from approximately 2 to 150 yd^3/hr. Two hydroclones were used during the Deposit N demonstration project to remove +200 sieve material after removal of gravel-sized stones and debris.

Diaphragm filter presses are filter presses with an inflatable diaphragm which adds an additional force to the filter cake prior to removal of the dewatered sediments from the filter. Filter presses operate as a series of vertical filters which filter the sediments from the dredge slurry as the slurry is pumped past the filters. Once the filter's surface is covered by sediments, the flow of the slurry is stopped and the caked sediments are removed from the filter. Filter presses are available in portable units similar to the centrifuge units. Although very costly and labor intensive, production rates for a single unit vary from 1,200 to 6,000 gpm. Assuming a dredged slurry solids content of 4% by volume and a dewatered solids content of 30% by volume, the typical production rates vary from approximately 50 to 250 yd^3/hr.

Belt presses use belts to compress sediments against rollers to achieve high-pressure compression and shear to remove water from dredged sediments. Flocculants are often used to assist the removal of water from the sediments. Dewatering is generally conducted in three stages, gravity drain of excess water, a low pressure compression, and a high pressure compression. Belt presses are also very mobile and are common components in many municipal and industrial wastewater treatment plants throughout the Lower Fox River valley. Belt press efficiencies are dependent upon belt speeds, belt tensions and material composition, feed concentrations, and flocculent type and dosage. Typical production rates of a single unit vary from 40 to 100 gpm. Assuming a dredged slurry solids content of 4% by volume and a dewatered solids content of 30% by volume, the typical production rates vary from approximately 2 to 4 yd^3/hr. A type of belt press called the recessed chamber filter press was used for dewatering hydraulically dredged sediments from Deposit N. The filter press was used after removal of large particles and polymer additions. The filter cake produced was sufficiently dewatered for transport and disposal off-site.

Passive Dewatering. Passive dewatering uses gravity and time for sediment particles to settle out of the dredge spoils. Passive dewatering can occur on

sediment barges, within CDFs, and in specially built lagoons or ponds, with a retention time large enough to allow the sediment particles to settle. Passive dewatering is used for the mechanically-dredged navigation channel maintenance for the Green Bay Port Authority. In addition, a passive dewatering facility was considered feasible for the SMU 56/57 Demonstration Project (Montgomery Watson 1998).

Two passive dewatering technologies are discussed in this subsection consisting of on-barge dewatering and upland ponds.

On-barge dewatering is used in conjunction with mechanical dredging. On-barge dewatering involves gravity draining the water from the sediment while the material is inside the dredge barge. Typical dredge barges are equipped with side drains which allow the water to flow from the barge into the river. Dredge barges have been modified, in some cases, with a floor that slopes to a collection sump for treatment prior to discharge back to the river. These barges allow for water accumulation on one end of the barge. As a result, the sediment carrying capacity of these barges may be less, in certain situations, than typical dredge barges.

Upland pond dewatering is used in conjunction with hydraulic dredging, although it is possible to use it to dewater mechanically dredged sediments as well. The principal behind upland pond dewatering is to construct a retention pond which would contain approximately the amount of dredge slurry produced over a given period of time. The dredged sediments are allowed to settle out within the pond. Depending upon the size of the pond, the water is decanted off and sediment removed once the pond filled to a level that decreased the effective settling efficiency of the pond to an unacceptable level. The addition of baffles to the pond can increase the effective holding time and also increase the percent solids removed. In order to provide adequate retention time upland ponds may be quite large. Figure 6-6 provides the conceptual layout of a 4 acre dewatering pond that could be used for Lower Fox River sediments. This type of dewatering process is currently utilized at the Bayport facility in the Green Bay area.

Solidification. Solidification involves the addition of a chemical, powder, or mix to the dredged sediments to absorb excessive moisture. Solidification involves the addition of Portland cement, fly-ash, fly-ash/Portland cement mixtures and lime kiln dust to the dredged sediments. Solidification is commonly used for sediments that have been partially dewatered by another means, or on mechanical dredges that do not contain excess amounts of water. Solidification is not practical for dewatering dredge sludges generated from hydraulic dredging operations without implementation of another dewatering method, as the amount of Portland cement required would make the effort cost prohibitive (i.e., increase tonnages/volumes

for disposal and costs for additional Portland cement). The dewatering method used for hydraulically dredged Deposit N sediments did not require any additions of solidification agents prior to disposal. The solidification of dredged material can be done with anything from a pug mill to a roll-off box and track-hoe, depending upon sediment production rates and work space areas.

Criteria for Dewatering Selection

The principal criteria used are the type of removal options selected for a given river reach and available land for construction and operation of a passive dewatering facility.

- *Hydraulic Dredging - A passive dewatering facility is selected for all hydraulic dredging options where there are greater than 5 acres of land available for construction and operation of the settling ponds.* At least one alternative will include mechanical dewatering to provide a comparison in costs.

- *Mechanical Dredging - Passive on-barge dewatering is selected for all mechanical dredging options.*

Additional operating parameters and constraints which must be considered in selecting the appropriate dewatering technique for the Lower Fox River include:

- Production Rate - The selected dewatering technique should produce dewatered sediments at a rate equivalent to the sediment removal rate. This allows sediment to be removed by the dredges without concern for sediment storage prior to dewatering.

- Effectiveness - The selected dewatering technique must be capable of consistently meeting specific requirements for disposal. This is at least 50% solids without the addition of any solidification agents.

- Dewatering Barge Availability - Dredge barges with on board water collection sumps are not locally available. Such a barge may need to be constructed locally.

- Siting - Placing a dewatering pond a significant distance from the river may be impractical from a material handling standpoint. It may also be impractical to remove a large wooded area to install a dewatering pond.

- Discharge Water Quality - All water removed from the dredged sediments must meet certain regulatory requirements prior to discharge to a Publicly Owned Treatment Works (POTW) or to the river. The drain water from

standard dredge barges may not meet WPDES requirements to return to the Lower Fox River without further water treatment.

6.4.4 *Ex Situ* Treatment Process Options

Ex situ treatment involves treatment of contaminated sediments to reduce, condense and destroy the COC. *Ex situ* treatment processes are generally conducted on-site requiring construction or mobilization of treatment units and additional materials for use in the treatment process. Most treatment processes result in the production of residuals that are managed either on-site or off-site.

Description of *Ex Situ* Treatment Process

Two thermal treatment technologies were retained from the screening because they were determined to be applicable *ex situ* treatment processes for the Lower Fox River sediments. These are:

- Incineration
- High Temperature Thermal Destruction (HTTD)

These are described in more detail below.

Incineration. Incineration is a treatment technology in which high temperatures (1,400 to 2,200 degrees F) are used to volatilize and combust organic chemicals. Incinerators can be operated to meet the 99.9999% destruction and removal efficiency requirement for PCBs and dioxins as provided in the regulations at 40 CFR 761.70(b)(1). Various types of incinerators exist which obtain similar efficiency results while using different types of technologies and fuels. Commercial incinerator designs are rotary kilns equipped with an afterburner, a quench, and an air pollution control system. Incinerator off gas requires treatment to remove particulates and neutralize and remove acid gases. Baghouses, venturi scrubbers, and wet electrostatic precipitators remove particulates; packed-bed scrubbers and spray driers remove acid gases. Mobile incinerators are available for movement to a fixed location in close proximity to the contaminated sediments.

High-Temperature Thermal Destruction. HTTD is a full-scale technology in which temperatures in the range of 600 to 1,200 degrees F are used to volatilize organic chemicals. A carrier gas or vacuum system transports volatilized water and organics to a condenser or a gas treatment system. For the purposes of this FS, it will be assumed that a mobile rotary kiln desorption unit will be used. The volatilized organics are incinerated in an afterburner operating at approximately

2,000 degrees F. This treatment technique has been used successfully at several other sites with PCB contamination.

Criteria for *Ex Situ* Treatment Selection

There is only a single criterion for application of an *ex situ* alternative for the Lower Fox River:

- *Exceedance of the TSCA level - for TSCA level sediments, at least one alternative will include incineration or HTTD.*

The following factors are potential considerations for determining the applicability and effectiveness of thermal treatment processes for Lower Fox River Sediments:

- Availability - Incineration are less available than HTTD units. Adequate time will be needed to arrange for an incinerator.

- Feed Preparation - Thermal treatment units will require dewatering of the sediment prior to treatment to reduce the amount of energy needed to heat the sediment during the thermal treatment process.

- Emission Control - The thermal destruction of PCBs will likely produce acid gas emissions. Acid gas treatment will be required to treat acid gas emission.

- Sediment Particle Size - The presence of fine particulate in the sediment can adversely affect the operation of the thermal treatment. Sand, or another material, may need to be added to improve the flowability of the sediment.

- Regulatory Considerations - An EPA waiver for on-site treatment is required for PCB concentrations of 50 ppm or greater. Thermal processes must meet performance requirements in order to efficiently treat PCBs.

6.4.5 Disposal Process Options

Disposal is defined as the relocation and placement of removed sediments into a site, structure or facility. Disposal options are a major component of sediment remediation projects that involve the removal of sediments. In most cases, the disposal option is chosen as a permanent location for confinement and storage of the sediments.

Description of Disposal Process Options

PCB contaminated sediment removed from the Lower Fox River can be disposed of at a number of upland disposal facilities, and depending upon the PCB concentration, in "in-water" CDFs or level bottom caps.

Five general disposal options exist for the disposal of PCB impacted sediments removed from the Lower Fox River. These are:

- Level Bottom Cap
- Existing or Proposed Upland Landfill
- Construction of New, Dedicated Upland Landfill
- Confined Disposal Facility (CDF)
- Out-State Landfill

Each option is described in detail below.

Level Bottom Cap. Level-bottom capping involves the placement of contaminated sediment in a mound on a relatively flat surface. Capping material is then placed on top of the mound. The cap must be designed to prevent scour and erosion. Level-bottom caps are typically placed in larger water bodies such as oceans or lakes.

Existing or Proposed In-State Landfills. In-state landfills are typically classified as municipal or non-municipal. Municipal solid waste facilities are run privately or by local government to accept municipal solid waste. There are privately owned facilities that accept both municipal solid waste and industrial waste. Non-municipal or private industrial landfills typically only accept waste from their own operations, but may be permitted to accept waste from other generators. A non-municipal landfill may have to undergo significant permit modifications to accept waste from other generators or contaminated river sediment.

A landfill is an engineered facility which provides long term isolation and disposal, or degradation of waste material thereby minimizing the potential for release of contaminants to the environment. These landfills are designed to prevent the release of contaminants to the groundwater, control runoff to surface water, and limit dispersion into the air. Non-hazardous solid wastes may be disposed of in a solid waste landfill. A January 1995 agreement between EPA and the State of Wisconsin gives the WDNR authority to regulate the disposal of sediment with 50 ppm or greater PCBs in NR 500 W.A.C. approved landfills and the disposal of sediments with PCB concentrations of 500 ppm or greater in NR 500 W.A.C. approved landfills with EPA concurrence (EPA, 1995).

Landfill design requirements are provided in NR 500 W.A.C. NR 500 W.A.C. approved facilities meet location, hydrogeologic evaluation and groundwater performance standards. Landfill design requirements in Wisconsin also include: 1) a cover system, 2) a liner system, 3) a leachate collection and treatment system, 4) a water monitoring system, and 5) a gas monitoring system. Landfills cannot accept wastes containing free liquids. Wastes containing liquids must first be dewatered or stabilized. Contaminated sediment may also be placed within dedicated cells, or monofills, located within landfills. The monofill provides additional assurances that the contaminated sediment will not mix with other solid waste, and provides for more stable long term control of the material.

Appendix C contains a table listing municipal and non-municipal landfills located generally within the Lower Fox River valley. Information in the table was derived from records maintained by the WDNR (WDNR, 1998a). The list of landfills maintained by the WDNR is also included in Appendix C.

Approximately 14 existing and proposed municipal and non-municipal landfills have been identified within 40 miles of the Lower Fox River. Table 6-17 lists the landfills and provides information about existing and proposed capacities. Capacities for all the landfills were not available. Figure 6-7 shows the general location of these landfills.

Waste disposal capacity of landfills located within 40 miles of the river is in excess of 30,000,000 cubic yards, based upon WDNR data included in Appendix C. Although several municipalities banned disposal of contaminated sediment in landfills in the past, most local governments have either removed the bans or are in the process of removing the bans, opening the way to additional landfill capacity in the Lower Fox River valley.

One of the primary limitations to disposal of sediment in upland landfills located within the Lower Fox River valley is the need to dewater the material prior to disposal, as noted above. Dewatering options and technologies are further described in subsequent sections of this FS Report.

Based upon information received from the WDNR Sediment Remediation Demonstration projects, the cost to haul and dispose PCB contaminated sediment in a landfill located within 40 miles of the river is approximately $40 to $45 per cubic yard. This estimated cost for a “generic” landfill in the Lower Fox River valley is used in evaluating the cost of this disposal option presented in Section 7 of this FS Report. Landfill tipping fees for special wastes such as PCB contaminated sediments are variable, and react to many market conditions so the actual tipping fees may increase or decrease significantly over time.

Construction of New, Dedicated Landfill. Construction of a new publically owned, upland landfill dedicated to the disposal of the Lower Fox River sediments is another option. The dedicated landfill could be centrally located in an area to allow access from all areas of the river. Construction requirements for a dedicated landfill would generally be the same as the construction requirements for a municipal landfill. The disadvantage of constructing a dedicated landfill is the lengthy time required to site, design and construct.

Preliminary engineering work has been completed for at least one proposed landfill facility capable of accepting contaminated sediment from the Lower Fox River. The planned facility was located within 20 miles of the Lower Fox River in rural Brown County. Estimated costs to acquire and build the approximately 4 million cubic yard landfill to accept contaminated sediment is $14 million. Operation and maintenance costs for such a facility may exceed $2 million annually.

A newly constructed dedicated landfill could be designed to contain all PCB impacted sediments removed from the Lower Fox River. The total capacity required may be up to 9,000,000 cubic yards. The dedicated landfill would be constructed in small cells where each cell would be individually lined and each cell would contain the sediments removed in one year.

A dedicated landfill centrally located along the Lower Fox River would generally be most advantageous, given that siting conditions are appropriate. Additionally, locating the dedicated landfill close to the river may result in the lowest transportation costs. However, land and siting costs typically increase closer to the river. Siting would need to consider available transportation routes on the river and upland to the dedicated landfill.

Confined Disposal Facility. A confined disposal facility (CDF) is an engineered containment option that receives, de-waters, and provides a long term, or permanent placement of contaminated dredged material. Because of the nature of dredged material, a CDF must have features of both a wastewater treatment facility and a solid waste landfill (EPA, 1994b). Containment of contaminated sediments in CDFs is generally viewed as a cost effective remediation tool at Superfund Sites (EPA, 1996).

A CDF may serve as both a gravity settling pond for hydraulically dredged sediments, and as a containment facility that is permanently capped after dewatering and consolidation of the solids. A more complex CDF can include permanent peripheral and bottom liners to prevent contaminant leachate to the ground or surface water, a water capture and treatment system, a gas extraction

system, and an impervious hard-cap to prevent infusion of surface precipitation. In all cases, CDFs represent a long-term change in use of the affected property.

CDFs have been constructed both upland, and in-water. There are approximately 50 CDFs that have been constructed around the Great Lakes. These are primarily for dredged material from navigation projects. Most of these are in-water lakefills that were constructed using stone retention dikes and simple water return systems. The remainder are upland facilities constructed with earthen dikes, or placed within existing or excavated depressions.

As the need for contaminated dredged sediment disposal facilities developed, both the USACE and the EPA developed detailed guidance documents for the construction and management of those facilities. These include:

- *Engineering and Design - Confined Disposal of Dredged Material* (USACE 1987)
- *Design, Performance, and Monitoring of Dredged Material Confined Disposal Facilities in Region 5* (EPA, 1996)
- *Assessment and Remediation of Contaminated Sediments (ARCS) Program. Remediation Guidance Document* (EPA, 1994b)
- *Verification of Procedures for Designing Dredged Material Containment Areas for Solids Retention* (Averett et al., 1988)
- *Comprehensive Analysis of Migration Pathways (CAMP): Contaminant Migration Pathways at Confined Dredged Material Disposal Facilities* (Brannon et al., 1990)

There are two types of designs that are used in the construction of a CDF: solids retention and hydraulic isolation. Solid retention designs for CDFs physically isolate the sediment solids from the environment. Solid retention designs are appropriately used when the contaminants in the sediment are tightly bound to the retained solids and are not likely to leach and contaminate the surface or groundwater. Designs for these types of CDFs need only consider retention dikes or configurations such as geosynthetic liners placed between the inner wall of the retention dike and the dredged material. Water treatment consists of settling out the particulates prior to discharge. In contrast, hydraulic isolation designs isolate the solids and capture the associated water from the contaminated solids. Design of these facilities are similar to those for NR 500 W.A.C. landfills and often employ extensive water recovery and treatment operations.

Out-State Landfills. Disposal at an out-state landfill would be an option if in-state disposal was not possible. Two out-state landfills were evaluated. Both are permitted to accept sediment containing PCBs. Other disposal locations may become available in the future. Disposal at an out-state landfill would require either truck transport or rail transport. Sediments disposed at out-state landfills typically must also pass a free liquids test similar to the test required for disposal of sediments at a municipal landfill.

Out-state disposal is retained as a disposal alternative as it allows flexibility in disposal options. However, disposal of sediments at an out-state landfill are not considered further in this FS Report due to the following reasons:

- Transportation and disposal costs are approximately two to three times greater than disposal at a municipal landfill.

- Adequate space will most likely exist in municipal and non-municipal landfills within 40 miles of the Lower Fox River to accept all sediments removed from the river, if this option is selected.

Regulatory Considerations

Each of the disposal options are subject to regulatory considerations which impact their use with respect to the Lower Fox River contaminated sediments. A summary of the primary regulatory consideration are presented here.

Existing or Proposed Upland Landfill. One disposal option for contaminated sediment removed from the Lower Fox River is placement in a existing or new upland landfill.

Dredged sediment is classified as a solid waste in Wisconsin (Lynch, 1997; Lynch, 1998b). This determination has been made through statute and case law. Wis. Statute Chapter 289 and NR 500-520 of the W.A.C. provide most of the regulatory framework for handling and disposing of solid waste, and therefore, dredged contaminated sediments. Additionally, in a January 24, 1995 agreement, the EPA gave WDNR the authority to manage the disposal of sediment contaminated with PCB in concentrations of 50 ppm or greater in NR 500 W.A.C. approved landfills. Sediments containing PCBs of 500 ppm or greater may be disposed in an NR 500 W.A.C. approved landfill with EPA concurrence. A copy of the agreement (EPA, 1995) is included in Appendix C. The agreement also allows the WDNR to "select disposal facilities that comply with NR 500-520 W.A.C. for the disposal of sediments contaminated with PCBs at concentrations of 50 ppm or greater from sediment remediation projects conducted under the authority and supervision of the WDNR" (EPA, 1995). Any landfill approved for

disposal of contaminated sediment must meet the stringent state requirements for the design, operation and maintenance of a state-of-the-art disposal facility.

It is important to note that the process of gaining approval for the location of a new landfill (the siting process, as detailed in Wis. Statutes Chapter 289) is lengthy and may take many months or years to complete (Huebner, 1996).

WDNR has the authority to issue exemptions from regulation under Wis. Statutes Chapter 289, under some circumstances. The primary exemptions which cover dredged material exist in NR 500.08(3), W.A.C. The exemptions may not apply to sediment from the Lower Fox River (Lynch, 1998b) because of the large volumes of sediment and the concentrations of PCBs within the sediments.

Other exemptions from solid waste regulations for dredged material are found in NR 500.08(4) W.A.C. and Wis. Statutes Chapter 289.43(8), and NR 500.08(5) W.A.C.. The exemptions are know as The Low Hazard Exemption, and the Beneficial Reuse Exemption. The Low Hazard Exemption has been used for disposal of contaminated sediment from the Lower Fox River in the past; however, because of the large volumes expected and the concentration of PCBs, it is unlikely these exemptions can be used for large scale remediation efforts. No acceptable criteria for PCB concentrations in sediment have been established in NR 700 W.A.C. to date; therefore, the Beneficial Use Exemption cannot be used for material from the Lower Fox River.

New, Dedicated Upland Landfill. Regulatory considerations for the construction of a new disposal facility for upland disposal of contaminated sediment from the Lower Fox River are the same for a new or proposed solid waste landfill, as discussed above.

Confined Disposal Facility. Wisconsin has banned open water disposal of dredged material on the bed of all navigable waters for more than 25 years. The ban exists in Wis. Statutes Chapter 30.12(1)(a). There are, however, certain exceptions to the open water disposal prohibition. The exceptions include: 1) Legislative Authorization, 2) Lakebed Grants, 3) Bulkhead Lines, and 4) Leases. Obtaining any of these exceptions for disposal of dredged material into a navigatable water may be utilized for remediation of the Lower Fox River (Lynch, 1998b), but each could require substantial time to obtain. To obtain an exemption, the activity must still meet the conditions and limitations of the state's responsibilities for protection of water quality and other related issues.

In addition to the Wis. Statute Chapter 30 ban, NR 504 W.A.C. provides for certain set-back requirements when siting disposal facilities. Disposal facilities are

required to be set back certain distances from water ways and floodplains. The WDNR has the authority to waive this requirement under Wis. Statute Chapter 289.

CERCLA Exemptions. There is a "on-site permit exemption" as part of CERCLA. The exemption only applies if the EPA is conducting the remediation, or has issued an order or signed consent decree with the principal responsible parties (PRPs). The exemption does not apply if the State of Wisconsin conducts the work or issues the order or consent decree. For remediation of the Lower Fox River sediments, the WDNR position is that disposal units adjacent to the river or in-water could be considered "on-site". Additionally, WDNR does not believe that locational criteria ARARs for on-site disposal units could be exempted or waived even under a EPA lead CERCLA action (Lynch, 1998b).

Criteria for Disposal Selection

Off-site disposal is considered potentially feasible for alternatives at all the river reaches. Selection of a CDF alternative is dependent on two criteria:

- Location - In-water CDFs would be limited to areas of the Lower Fox River that are relatively wide with general construction access. Likewise, upland CDFs would be limited to large near-river acreages that could be permitted for landfill use.

- Upland Land Use - Location of an upland CDF is not likely to be appropriate in residential areas of the Lower Fox River valley. Likewise, in-water CDFs would need to consider site access, and potential losses of lake frontage to upland riparian landowners. Other potential uses of the Lower Fox River by upland owners, such as intake or permitted wastewater discharge pipes, electrical or other cable crossing, must be considered for in-water CDF location.

Additional factors that affect the disposal of PCB impacted sediments include the following:

- Landfill
  - Regulatory Considerations - As discussed above, landfilling of contaminated sediments in Wisconsin is highly regulated; however, the EPA has provided a mechanism for the state to manage sediment from the Lower Fox River in properly constructed and operated upland landfills. Any landfill disposal option must meet the stringent regulatory requirements.

- Current Landfill Capacity - The quantity of impacted sediment is relatively high when compared to typical one-time solid waste disposal projects. The current capacity of landfills will determine the amount of sediment that can be disposed of at any landfill.

- Length of Haul Route - The length of haul route will vary depending on highway weight restrictions, distances to different landfills, and origination point along the river. The length of the haul route has a direct bearing upon transportation costs and number of trucks required to maintain a steady state removal and disposal effort. If due to a limited number of trucks available within the Lower Fox River region, transportation costs may increase in order to maintain steady state sediment mass flow from the river to the disposal facility.

- Site Setting - Location of a newly constructed dedicated landfill, is dependant upon the hauling costs to the landfill, and the construction and long term monitoring costs of the facility. The topography can affect construction costs by increasing the amount of soil movement and preparation required to build the dedicated landfill. Soil conditions affect the feasibility of constructing the facility to the standards required by the WDNR waste program. The water table also affects the capacity as it dictates the disposal volume below ground surface.

- Roadway Surface Effects - Roadway surface effects of the haul route are an important consideration as any damage (i.e., asphalt, curb, gutter breakage, etc.) could become a project cost. Spring road restrictions on low tonnage roads may cause project delays if it is deemed necessary for the haul route to pass over the low tonnage roads.

- Residential Impacts - Residential impacts and safety issues are important considerations as the haul route involves moving a large number of trucks daily through highly residential areas or near schools or parks. It may be unsafe to move trucks on streets where residents are not accustomed to high traffic loads.

- Multiple Disposal Locations - The disposal of the sediments at multiple locations is important as the long term liability of the sediments is greater. Disposal at a single location presents a long term liability at a single facility. By disposing at numerous facilities, there is potential long term liability associated with the waste disposed at each facility.

- Confined Disposal Facilities
  - Regulatory Considerations - Obtaining approval and permits to construct a CDF would be difficult, as discussed previously. However, the mechanisms are available to permit this disposal option if there is a strong rationale to do so. One limitation to this option is the potential long period of time required to obtain the appropriate permits.

  - Contaminant Concentration - In-water CDFs are unlikely to be permitted for sediment with PCB concentrations exceeding the TSCA limit of 50 ppm. As described previously for capping, EPA to date has not permitted any permanent in-water containment facilities. However, TSCA materials could be considered for an upland CDF, provided that the facility met the design criteria for a TSCA chemical waste landfill.

  - CDF Design - Either an upland or in-water CDF would need to meet the substantive requirements for landfills defined in NR 500 W.A.C. While PCBs alone might be considered particulate-bound contaminants and a simple solids retention design might be suitable, dredged sediments in the Lower Fox River will also contain quantities of other metals, pesticides, and semivolatile organic compounds (i.e., polyaromatic hydrocarbons) that may require some consideration of hydraulic control (i.e., collection of internal leachate; physical isolation).

  - Flood and Erosion Control - For in-water CDFs, the design must consider a final construction height of at least 6 feet above the normal river level in order to maintain the surface above maximum expected flood height. External dike construction would need to consider the potential for flood or ice-induced damage.

6.5 Identification of Ancillary Technologies

Additional technologies and process options that are ancillary to the retained process options presented in Section 6.3 may be incorporated in the remedial alternatives. Incorporation of these technologies and process options is dependent on the process options chosen for a particular remedial alternative. For example, if removal and disposal in an off-site landfill is established as a remedial alternative, dewatering prior to transport of materials off-site and subsequent treatment of the water generated in the process will take place.

Potential ancillary technologies and process options are not subject to the same screening process described in Section 6.2. However, they are presented here as considerations for the development of remedial alternatives provided in the following sections of this FS Report. A description of ancillary technologies that are a part of certain of the remedial alternatives are described in following subsections.

6.5.1 Residuals Management

Residual management methods will be required for each remedial alternative. Residual management will vary depending upon the remedial alternative. The following provides a description of each of the residual management methods including a summary of the applicability of these methods:

- Off-Site Commercial Treatment - Publicly-owned treatment works (POTW) can be used for the treatment of effluent water from dredged sediments. This management option allows for the disposal of effluent waters. The discharge of water to a POTW is often dependent upon meeting certain discharge criteria as set by the municipality. This management method may be used in remedial alternatives where sediment dewatering is required.

- On-Site Treatment of Organic Compound - Carbon filtration and UV oxidation are commonly used management methods used to remove organic compounds from effluent water. Treatment of organic compounds, depending upon concentrations, may be required to discharge effluent water to either a POTW or to the Lower Fox River under a WPDES permit. This management method may be used in remedial alternatives where sediment dewatering is required.

- On-Site Treatment of Suspended Solids and Metals - Precipitation and froth tanks are commonly used management methods used to remove suspended solids and metals from effluent water. Treatment of suspended solids and metals, depending upon concentrations, may be required to discharge effluent water to either a POTW or the Fox River under a WPDES permit. This management method may be used in remedial alternatives where sediment dewatering is required.

- Off-Site Disposal of Non-Hazardous Wastes - Wastes such as personal protective equipment (PPE), filtration filters, construction debris that is not characterized hazardous waste can be disposed of at a local municipal landfill. This management method will be used in all remedial alternatives. The quantity generated will depend upon the remedial alternative.

6.5.2 Transportation

Transportation methods will be needed for any remedial alternative which involves removal of the contaminated sediments. The transportation methods included in each remedial alternative will be based upon the compatibility of that transportation method to the other process options. The following provides a description of each of the transportation methods including a summary of the compatibility of these methods:

- Truck - Transport of dewatered sediment over public roadways using dump trucks, roll-off boxes, or trailers. Includes associated loading facilities. This technology applies to transport for short distances. This technology will be used in remedial alternatives where dewatered sediment is transported to an in-state landfill.

- Rail - Transport of dewatered sediment by railroad using open gondolas. Includes associated loading facilities. This technology applies to transport over long distances (> 300 miles). This technology will be used in remedial alternatives where the dewatered sediment is transported to an out-state landfill.

- Barge - Transport of high-solids sediment through existing navigable waterways using barges. Includes associated unloading facilities on the river shore line. This technology applies to transport on the river in segments between dams or locks. This technology will be used in remedial alternatives where sediment removal is conducted using a mechanical dredge.

- Pipeline - Transport of low-solids sediment through pipeline directly from dredge equipment to a receiving point on the river shoreline. This technology applies to transport on the river and can be conducted along a river segment, or over a dam. This technology will be used in remedial alternatives where sediment removal is conducted using a hydraulic dredge.

6.6 Dredging Water Quality Management

A significant concern when selecting a removal technology is the effective management of water quality during the removal and dewatering operations. Water quality can be impacted during removal principally by resuspension of contaminated sediments. Controlling the rate and spread of the suspended solids load is an important consideration in technology selection. After removal, the dredged solids typically have moisture contents that must be reduced for effective treatment. Mechanically dredged sediments typically have a solids content of approximately 50 percent by weight. Hydraulically dredged sediments are in a

slurry with a solids content typically in the range of 10 to 20 percent (EPA 1994). Dewatering these sediments requires management of the contaminated water, which has direct cost implications.

6.6.1 In-Water Management

All removal technologies may increase the suspended solid load of the overlying waters, but vary in their overall impact. Solids loss or resuspension may or may not be significant in terms of environmental impact on the water column. In general, environmental impact is related to the magnitude of losses. However, the impact of low losses from environmental dredging techniques has not been proven and below some threshold these losses are likely to have no impact on the waterway. There are operational controls that can further reduce the impacts to water quality during dredging. For selection of the final removal technology(ies), these points must be considered for both environmental protectiveness and cost.

Water quality impacts can be controlled by the careful selection of dredging equipment as well as using specific operation and technical controls. These can include skilled operators working the dredging units at slower rates, careful placement of the dredging equipment, and use of sediment curtains or booms to control spread of suspended solids.

Field assessments have shown that sediment resuspension by hydraulic dredge can be minimized by careful operation of the dredge (USACE New England Division, 1990). This involves controlling the speed of cutterhead rotation, the swing speed, the rate of dredge advance and depth of cut. Recommendations for minimizing sediment resuspension at the dredge head include maintaining a slow to moderate cutter rotational speed at 15 to 20 revolutions per minute, a slow swing speed of 0.3 to 0.5 ft/s and limiting the minimum cut depth to the range of 50 to 100 percent of the suction pipe diameter.

Water quality impacts from sediment resuspension at the dredge can also be reduced by conducting the dredging within a silt curtain or silt screen enclosure in order to contain migration of the suspended solids/turbidity plume. The silt curtain is generally constructed of impermeable fabric and is suspended from the surface to the river bottom where it is anchored. The silt curtain can extend completely to the bottom with appropriate fringe weights and anchors. Gravity settling of the denser sediment plume and loose re-settled solids will seek the lowest point, resulting in some migration beneath the silt curtain. Experience elsewhere indicates more than 90 percent reduction in suspended concentrations across the silt curtain can be achieved under favorable conditions. Silt curtains are not effective in current speeds above approximately 0.5 ft/s or in high winds/waves (EPA, 1994b).

In comparison, the silt screen is constructed of permeable fabric designed to pass water but not the fine-grained resuspended sediment. Either the silt curtain or screen must be placed, managed and removed with care to avoid resuspension and release of contaminated sediment during operations. Silt curtains and screen placement and operation may be a source of resuspension of bed sediment due to dragging or alteration of local currents. The need for and benefit of containment systems during dredging must be weighed against the utility of and potential disadvantages of these systems.

6.6.2 Dredged Effluent Water Quality

Mechanical Dredging. Free water derived from mechanical dredging is principally within the transfer barges, or at the consolidation facility. Dredged sediment transfer barges are left idle before off-loading to allow for extrusion of free water to the surface of the load by sediment self-consolidation. Free water arising at the surface of the held barge load can then be decanted and pumped ashore to a water treatment system before unloading the dredged material. The water treatment could consist of a Baker tank(s) for primary sedimentation of solids, coagulant-aided secondary flocculent settling of remaining suspended solids, and filtration (i.e., sand, mixed media, activated carbon), if needed, to meet water quality requirements.

The shore side stockpile area can be lined and graded to contain and collect further sediment drainage and rainfall runoff. Site preparation could include a paved and curbed stockpile and re-handling area graded to collect drainage water. To minimize site size two low-wall cells could be constructed with nesting concrete ecology blocks (approximately 2 by 2 by 8 feet). Assuming a 4-foot thick sediment deposit within a cell, the approximate cell size for one day dredge production (one barge load) would be about 60 feet by 60 feet (3,600 square feet). The cell interiors could be lined with a filter fabric geotextile to promote continued water drainage while containing sediment particles. All drainage water and surface runoff would be collected and treated to meet water quality requirements prior to discharge back to the lake.

Dredged material would be removed from the cells by the off-load clam or by rubber-tired loader and loaded to sealed refuse containers for transport to treatment or disposal.

Where gravity separation is proposed, water treatment will be required to meet water quality requirements for discharge back to the river. Water already within the cell during the disposal operation will be displaced by the emerging deposition of contaminated dredged materials. Free water and drainage water from the dredged material and rainfall/runoff will also collect within the cell. This

discharge rate is capable of treatment by a package/portable treatment plant that could include gravity sedimentation and filtration for solids removal. Alternatively, the disposal cell could provide opportunity for cost-effective flow management within a small constructed (diked) final sedimentation cell dedicated to quiescent settling with or without coagulant addition, and with discharge skimmed from the clarified surface waters. Free water present at the surface of the haul barge would be pumped ashore to the disposal cell/water treatment system before off-loading in order to minimize tendency for washout/spillage during the off-load swing.

In the past, WDNR has authorized a minimum dilution zone for dredging return flow. For the purposes of this FS Report, it is assumed that acute water quality criteria must be met at the point of discharge and a mixing zone or zone of initial dilution is allowed to satisfy chronic criteria.

Hydraulic Dredging. Hydraulic dredging results in a large volume of sediment-water slurry to be managed. Flow rates in small dredges can range from as little as 900 gpm (80 yd^3/hr) for a 6-inch dredge, to more than 3,500 gpm (310 yd^3/hr) for a 10-inch dredge. Hydraulic dredging rates in contaminated sediment removal are frequently limited by the capacity and treatment rates of the water quality system.

Conventional separation of solids from the dredged slurry is by gravity sedimentation in a suitably sized quiescent retention pond. The return flow is decanted over a weir to skim the clarified water from the surface in order to meet water quality requirements before discharge.

Other means of solids removal for hydraulic dredging have been tested (EPA, 1994b; SEDTEC, 1997). In 1995-96 approximately 100,000 yd^3 of hydraulically dredged contaminated sediment was dewatered by adding a coagulant aid to the slurry stream and routing the flow through a set of two clarifiers for thickening and then through belt presses for land filling (Ohio River Dredge and Dock, Inc.). A proprietary process (Solomon Venture, Lakewood, Colorado) reports success in using a system of screens and grids to remove particles down to 1 micron size at dredge flows of 1,200 gpm (approximately a 6-inch dredge size). An emerging solids separation technology is the use of geomembrane tubes designed to pass water, but not selected sediment sizes. Sandy sediments have been pumped into such tubes for separation of solids. However, the membranes may be subject to blinding (plugging) for high concentrations of fine grained materials.

Given the physical limitations on ponding cell sizes, it is likely that the hydraulic dredge used for the Lower Fox River in Little Lake Butte des Morts and between

Little Rapids and De Pere, would be limited to the small dredge sizes; 6 to 8 inches.

Ponding cells would be sized to at least provide the required hydraulic retention capacity. However, the minimum cell size would also need to be balanced with the sediment storage capacity required for deposition of the affected fractions of dredged materials. For Lower Fox River sediment removal the requirement for cell storage capacity for sediment deposition would dominate the primary cell sizing. A properly designed coagulant-aided solids separation system would be expected to produce return flow effluent with less than 200 mg/L total suspended solids.

An alternative would be a constructed gravity thickener, or clarifier, in place of the above secondary settling cell. As the flocculated sediment settles toward the bottom of the clarifier, the thickened underflow would be collected and pumped to a mechanical filtration system (i.e., belt press) to produce a dewatered solids cake. The withdrawn water is cycled back to the clarifier inflow. Clarifier overflow water (i.e., the clarified dredge flow) is discharged back to the waterway if it meets water quality requirements or is provided additional treatment as needed for water quality compliance. Additional treatment at this stage might include sand, mixed media and/or activated carbon filtration. If needed, such end-stage treatment will be expensive and may result in selecting an alternate dredging/disposal method.

A alternative to gravity sedimentation would be to import or construct a mechanical filtration system on-site. Proprietary commercial installations have reported success in solids removal and dewatering the full slurry stream from a small hydraulic dredge (i.e., Solomon Liquids, Lakewood, Colorado; Global Dewatering, Edmonton, Canada.). Such systems can be utilized in tandem to increase overall flow capacity if needed for a project of this size (2,000 gpm). A typical system utilizes screens and centrifuges for solids removal, in some cases aided by chemical coagulants and short-term gravity separation. A properly designed and operated system would be expected to produce a return flow with less than 200 mg/L total suspended solids.

A multi-cell settling/treatment pond would allow addition of a coagulating agent to assist in secondary (final) sedimentation before discharge (USACE, 1987). The primary (first) cell would settle and retain the coarser grained sediment within the first few hours of retention. The overlying suspended fine-grained supernatant would be discharged to the secondary settling cell after mixing with a chemical coagulant to aid in flocculent settling. Addition of the coagulating agent would be mixed by turbulence within the gravity flow discharge pipe(s) from the primary

cell into the secondary cell, or a static mixing tank could be added between the cells if the gravity flow energy was not sufficient to result in proper mixing. Final design of the system would require additional testing to identify an optimum coagulant and concentration.

6.7 Section 6 Tables and Figures

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Table 6-1 Summary of Reviewed Technologies

General Response Action	Remedial Technology	Process Option
No Action	None	Not Applicable
Institutional Controls	Physical, Engineering or Legislative Restrictions	Consumption Advisories Access Restriction Dredging Moratorium
Containment	Capping	Sand Cap Sediment/Clay Cap Armored Composite Cap Thin Layer Cap Enhanced Cap
	Rechannelization	Construction of New Channels
Removal	Dredging	Hydraulic Dredging Mechanical Dredging
		Excavator
In Situ Treatment	Biological	In situ Slurry Biodegradation In situ Aerobic Biodegradation In situ Anaerobic Biodegradation
	Chemical	In situ Slurry Oxidation Aqua MecTool Oxidation In situ Oxidation Electrochemical Oxidation
	Physical Extractive Processes	Sediment Fushing SVE/Thermally Enhanced SVE/Bioventing Air Sparging
	Physical- Immobilization	Air Sparging MecTool Stabilization Vitrification Imbiber Beads Ground Freezing

Table 6-1 Summary of Reviewed Technologies (Continued)

General Response Action	Remedial Technology	Process Option
Ex Situ Treatment	Biological	Landfarming/Composting Biopiler Fungal Biodegradation Slurry Phase Biological Treatment Enhanced Biodegradatin
	Chemical	Acid Extraction Solvent Extraction Slurry Oxidation Reduction/Oxidation
	Chemical/Physical	Dehalogenation Sediment Washing Radiolytic Dechlorination
	Physical	Separation Solar Detoxification Solidification Vitrification
	Thermal	Incineration High Temperature Thermal Destruction Low Temperature Thermal Destruction Pyrolysis Thermal Desorption High-Pressure Oxidation
Dewatering	Mechanical	Centrifugation Belt Press Hydroclone Dighagm Filter Press
	Gravity	On-Barge Dewatering Lagoons/Ponds Solidification

Table 6-1 Summary of Reviewed Technologies (Continued)

General Response Action	Remedial Technology	Process Option
Disposal	On-Site Disposal	Level Bottom Cap Confined Aquatic Disposal (CAD) Confined Disposal Facility (CDF) Nearshore Biofiltration Cell Upland Confined Fill
	Off-Site Disposal	Dedicated New Upland Landfill NR 500 Landfill (county, private, industrial landfills) TSCA Subtitle C Landfill Upland confined Fill (Commercial/Industrial) Upland Fill (Residential/Clean)

Table 6-2 Initial Screening: Institutional Controls

Technology	Process Option	Description	Implementability	Screening Decision
Physical, Engineering, or Legislative Restrictions	Consumption Advisories	Advisories to indicate that consumption of fish in the area may present a health risk	Potentially applicable	Retained
	Access Restrictions	Constraints, such as fencing and signs, placed on property access	Potentially applicable	Retained
	Dredging Moratorium	Restricts dredging operations	Potentially applicable	Retained

Table 6-3 Initial Screening: Containment

Technology	Process Option	Description	Screening Comment Implementability	Screening Decision
Capping	Sand Cap	Placement of clean sand over existing contaminated bottom to physically isolate contaminants.	Easily applied in situ, however scouring must be considered. Decreased water depth may limit future uses of waterway and may impact flooding, stream bank erosion, navigation and recreation.	Retained
	Sediment/ Clay Cap	Use of dredged fine-grained sediments or commercially obtained clay materials to achieve contaminant isolation.	Placement of cap within the waterway may require special engineering controls. Difficult to place clay portion of a cap. Minimizes cap thickness in areas with shallow water depth.	Retained
	Armored Cap	Cobbles, pebbles or larger material are incorporated into the cap to prevent erosion in high-energy environments, or to prevent cap breaching by bioturbators. (Example: membrane gabions)	Decreased water depth may limit future uses of waterway and may impact flooding, stream bank erosion, navigation and recreation.	Retained
	Composite Cap	Soil, media and geotextile cap over contaminated material to inhibit contaminated pore-water migration and/or inhibit bioturbators.	Decreased water depth may limit future uses of waterway and may impact flooding, stream bank erosion, navigation and recreation.	Retained
	Thin Layer Cap	Application of a thin (1- to 3-inch) layer of clean sediments and allowing natural resorting or bioturbation to mix the contaminated and clean sediments, which results in a surface layer of impacted material within acceptable levels.	Minimizes reduction in water depth that may limit future use of river and may impact flooding, streambank erosion, navigation, and recreation.	Retained
	Enhanced Cap	Incorporation of materials such as granular activated carbon or iron filings to provide chemical binding or destruction of contaminants migrating in pore water.	Decreased water depth may limit future uses of waterway and may impact flooding, stream bank erosion, navigation and recreation.	Retained

Table 6-3 Initial Screening: Containment (Continued)

Technology	Process Option	Description	Screening Comment Implementability	Screening Decision
Rechannelization	Construction of New Channels	Construction of new channels to reroute surface water through non-impacted sediments or soils.	Rerouting channels is often not feasible.	Eliminated

Table 6-4 Initial Screening: Removal

Technology	Process Option	Description	Screening Comment Implementability	Screening Decision
Dredging	Hydraulic Dredging	A rotating cutter head loosens sediment at the suction mouth, where a centrifugal pump draws the sediment/water slurry through the pipeline. Performs efficiently in most sediments. Resuspension losses can be minimized by operational controls.	Produces low slurry density and results in high water treatment costs. Ability to remove debris.	Retained
	Mechanical Dredging	A mechanical dredge consists of a barge-mounted floating crane that maneuvers a cable-suspended dredging bucket. The bucket is lowered into the sediment, and when withdrawn the cable closes the jaws of the bucket, retaining dredged material.	Readily available in the U.S. Vessel draft precludes operations in water with depths less than 6 feet. May be difficult to implement upstream of the De Pere Dam due to barge access/construction issues.	Retained
Dry Excavation	Excavator	This removal option includes erecting sheet piles, or a coffer dam, around the contaminated sediments to dewater. Removal would then involve conventional excavation (backhoe) equipment.	An enclosed and drained sheet pile wall would need to be constructed to be water impervious. Difficult to implement.	Retained

Table 6-5 Initial Screening: *In situ* Treatment

Technology	Process Option	Description	Screening Comment Implementability	Screening Decision
Biological	*In situ* Slurry Biodegradation	Anaerobic, aerobic, or sequential anaerobic/aerobic degradation of organic compounds with indigenous or exogenous microorganisms. Oxygen levels, nutrients, and pH are controlled to enhance degradation. Would require sheet piling around entire area and slurry treatment would be performed using aerators and possibly mixers.	Requires in-water steel piling around treatment area and extensive water quality monitoring outside piles. Biodegradation has not been demonstrated to effectively remediate PCBs. No known full-scale applications.	Eliminated
	In situ Aerobic Biodegradation	Aerobic degradation of sediment *in situ* with the injection of aerobic biphenyl enrichments or other co-metabolites. Oxygen levels, nutrients, and pH are controlled to enhance degradation.	Work performed to date has only been performed in the laboratory. Contaminants generally not amenable to aerobic degradation.	Eliminated
	In situ Anaerobic Biodegradation	Anaerobic degradation *in situ* with the injection of a methanogenic culture, anaerobic mineral medium, and routine supplements of glucose to maintain methanogenic activity. Nutrients, and pH are controlled to enhance degradation.	Work performed to date has only been performed in the laboratory. Laboratory testing data has indicated only minor removal is achievable.	Eliminated
Chemical	*In situ* Slurry Oxidation	Oxidation of organics using oxidizing agents such as ozone, peroxide, or Fenton s Reagent.	Requires in-water steel piling around treatment area and extensive water quality monitoring outside piles. No known full-scale applications.	Eliminated
	Aqua MecTool Oxidation	A caisson (18 feet by 18 feet) is driven into the sediment and a rotary blade is used to mix sediment and add oxidizing agents such as ozone, peroxide, or Fenton s Reagent. A bladder is placed in the caisson to reduce TSS and the vapors may be collected at the surface and treated.	May have difficulty injecting high air flows into caisson with standing water while preventing generation of TSS. No known completed full- or pilot-scale projects.	Eliminated
	In situ Oxidation	An array of injection wells is used to introduce oxidizing agents such as ozone to degrade organics.	Requires in-water steel piling around treatment area and extensive water quality monitoring outside piles. No known full-scale applications.	Eliminated
	Electrochemical Oxidation	Proprietary technology in which an array of single steel piles is installed and low current is applied to stimulate oxidation of organics.	Applicability for use in water is not known. No demonstrated sediment application.	Eliminated

Table 6-5 Initial Screening: *In situ* Treatment (Continued)

Technology	Process Option	Description	Screening Comment Implementability	Screening Decision
Physical-Extractive Processes	Sediment Flushing	Water or other aqueous solution is circulated through impacted sediment. An injection or infiltration process introduces the solution to the impacted area and the solution is later extracted along with dissolved contaminants. Extraction fluid must be treated and is often recycled.	Requires in-water steel piling around treatment area and extensive water quality monitoring outside piles. No known full-scale applications.	Eliminated
	SVE/Thermally Enhanced SVE/ Bioventing	An array of extraction and injection wells is used to physically strip volatile contaminants or to stimulate biodegradation in unsaturated soil. Oxygen levels, nutrients, and pH can be controlled in bioventing applications. Removal may be enhanced by heating the system.	Technology is applicable to vadose zone soil or dewatered soil.	Eliminated
	Air Sparging	An array of injection wells is used to physically strip volatile contaminants or to stimulate biodegradation in unsaturated soil. Oxygen levels, nutrients, and pH can be controlled to enhance biological activity.	Requires in-water steel piling around treatment area and extensive water quality monitoring outside piles. Possible generation of exceedances through leakage from sheet pile. Targets VOCs and other readily degradable organics rather than PCBs. No known sediment applications.	Eliminated

Table 6-5 Initial Screening: *In situ* Treatment (Continued)

Technology	Process Option	Description	Screening Comment Implementability	Screening Decision
Physical-Immobilization	Aqua MecTool Stabilization	A caisson (18 feet by 18 feet) is driven into the sediment and a rotary blade is used to mix sediment and add stabilizing agents. A bladder is placed in the caisson to reduce TSS and the vapors may be collected at the surface and treated.	Proprietary technology that has been used in a pilot scale application in Wisconsin with coal tar contaminated sediments and in a bench-scale application in the Manistique River, Michigan. Previous trials with this technology created water treatment problems inside the caisson.	Eliminated
	Vitrification	Uses and electric current to melt soil or other earthen materials at extremely high temperatures (2,900 to 3,650 degrees F). Inorganic compounds are incorporated into the vitrified glass and crystalline mass and organic pollutants are destroyed by pyrolysis. *In situ* applications use graphite electrodes to heat soil.	Requires less than 60 percent water content. Remaining sediment surface may not provide suitable habitat. No known sediment applications.	Eliminated
	Imbiber Beads	A cover blanket of Imbiber Beads placed over contaminated sediments to enhance anaerobic microbial degradation processes and allow exchange of gases between sediments and surface water. The beads are spherical plastic particles that would absorb PCB vapors generated.	Not well demonstrated for remediation of bottom sediments. Removal and disposal of the blanket is not well demonstrated.	Eliminated
	Ground Freezing	An array of pipes is placed in the ground and brine at a temperature of - 20 to - 40 degrees C is circulated to freeze soil. Is only recommended for short duration applications and to assist with excavation.	Application in presence of standing water has not been tested. Standing water likely provides a significant sink for cold temperatures and would substantially increase cost.	Eliminated

Table 6-6 Initial Screening: *Ex-situ* Treatment

Technology	Process Option	Description	Screening Comment Implementability	Screening Decision
Biological	Landfarming/ Composting	Sediment is mixed with amendments and placed on a treatment area that typically includes leachate collection. The soil and amendments are mixed using a windrow composter, conventional tilling equipment, or other means to provide aeration. Moisture, heat, nutrients, oxygen, and pH can be controlled to enhance biodegradation. Other organic amendments such as wood chips, potato waste, or alfalfa are added to composting systems.	Requires a large amount of space. Contaminants generally not amenable to aerobic degradation. Inorganic contaminants will not be degraded.	Eliminated
	Biopiles	Excavated sediments are mixed with amendments and placed in aboveground enclosures. It is an aerated static pile composting process in which compost is formed into piles and aerated with blowers or vacuum pumps. Moisture, heat, nutrients, oxygen, and pH can be controlled to enhance biodegradation.	Requires large upland area. Used for reducing concentrations of petroleum constituents in soils. Applied to treatment of nonhalogenated VOCs and fuel hydrocarbons. Contaminants generally not amenable to aerobic degradation.	Eliminated
	Fungal Biodegradation	Fungal biodegradation refers to the degradation of a wide variety of organopollutants by using their lignin-degrading or wood-rotting enzyme system. (Example: White Rot Fungus)	No known full-scale applications. High concentrations of contaminants may inhibit growth. The technology has been tested only at bench-scale.	Eliminated

Table 6-6 Initial Screening: *Ex-situ* Treatment (Continued)

Technology	Process Option	Description	Screening Comment Implementability	Screening Decision
Biological (Continued)	Slurry Phase Biological Treatment	An aqueous slurry is created by combining sediment with water and other additives. The slurry is mixed to keep solids suspended and microorganisms in contact with the contaminants. Upon completion of the process, the slurry is dewatered and the treated sediment is removed for disposal. (Example: Sequential Anaerobic/Aerobic Slurry-Phase Bioreactors)	Large volume of tankage required. No known full-scale applications. Contaminants generally not amenable to biodegradation. Inorganic constituents will not be degraded.	Eliminated
	Enhanced Biodegradation	Addition of nutrients (oxygen, minerals, etc.) to the sediment to improve the rate of natural biodegradation. Use of heat to break carbon-halogen bonds and to volatilize light organic compounds. (Example: D-Plus (Sinre/DRAT))	Not available on a commercial scale. PCB not amenable to biodegradation. Inorganic constituents will not be degraded.	Eliminated

Table 6-6 Initial Screening: *Ex-situ* Treatment (Continued)

Technology	Process Option	Description	Screening Comment Implementability	Screening Decision
Chemical	Acid Extraction	Waste contaminated sediment and acid extractant are mixed in an extractor, dissolving the contaminants. The extracted solution is then placed in a separator, where the contaminants and extractant are separated for treatment and further use.	Commercial-scale units are in operation. Suitable for sediments contaminated with heavy metals. Not applicable to PCB-impacted sediment.	Retained for metals treatment
	Solvent Extraction	Waste contaminated sediment and solvent extractant are mixed in an extractor, dissolving the contaminants. The extracted solution is then placed in a separator, where the contaminants and extractant are separated for treatment and further use. (Example: B.E.S.T. and propane extraction process)	At least one commercial unit available. Process may have difficulty with fine-grained sediment and high moisture content.	Retained
	Slurry Oxidation	The same as slurry-phase biological treatment with the exception that oxidizing agents are added to decompose organics. Oxidizing agents may include ozone, hydrogen peroxide, and Fenton s Reagent.	Large volume of tankage required. No known full-scale applications. High organic carbon content in sediment will increase volume of reagent and cost.	Eliminated
	Reduction/ Oxidation	Reduction/Oxidation chemically converts hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are hypochlorites, chlorine, and chlorine dioxide.	Target contaminant group for chemical redox is inorganics. Less effective against nonhalogenated VOCs, SVOCs, fuel hydrocarbons and pesticides. Not cost-effective for high contaminant concentrations because of large amounts of oxidizing agent required.	Retained for metals treatment

Table 6-6 Initial Screening: *Ex-situ* Treatment (Continued)

Technology	Process Option	Description	Screening Comment Implementability	Screening Decision
Chemical/Physical	Dehalogenation	Dehalogenation process in which sediment is screened, processed with a crusher and pug mill, and mixed with sodium bicarbonate (Base Catalyzed Decomposition or BCD) or potassium polyethylene glycol (APEG). The mixture is heated to above 630 degrees F in a rotary reactor to decompose and volatilize contaminants. Process produces biphenyls, olefins, and sodium chloride.	Generates secondary waste streams of air, water, and sludge. Similar to thermal desorption but more expensive. Solids content above 80 percent is preferred. Technology is generally not cost-effective for large volumes.	Retained
	Sediment Washing	Contaminants sorbed onto fine soil particles are separated form bulk soil in an aqueous-based system on the basis of particle size. The wash water may be augmented with a basic leaching agent, surfactant, pH adjustment, or chelating agent to help remove organics and heavy metals.	Not an easily accessible commercial process (limited use in the United States). Process has difficulty with fine-grained sediment. Not effective for PCBs.	Eliminated
	Radiolytic Dechlorination	Sediment is placed in alkaline iso-propanol solution and gamma irradiated to a dose of <10 (~1% solution). Products of this dechlorination process are biphenyl, acetone, and inorganic chloride. Process must be carried out under inert atmosphere.	Only bench-scale testing has been performed. Difficult and expensive to create inert atmosphere for full-scale project.	Eliminated

Table 6-6 Initial Screening: *Ex-situ* Treatment (Continued)

Technology	Process Option	Description	Screening Comment Implementability	Screening Decision
Physical	Separation	Contaminated fraction of solids are concentrated through gravity, magnetic or sieving separation processes.	Not effective on fine-grained sediment and in presence of high moisture content. Target compounds are SVOCs, fuels, and inorganics. Previous tests on Fox River sediments have shown no benefit in reducing contaminated sediment volumes, but it has been demonstrated as effective in improving the efficiencies of the dewatering process.	Eliminated
	Solar Detoxification	Through photochemical and thermal reactions the ultraviolet energy in sunlight destroys contaminants.	The process has been successfully demonstrated at pilot scale. The target contaminant group is VOCs, SVOCs, solvents, pesticides, and dyes. Some heavy metals may be removed. Only effective during daytime with normal intensity of sunlight.	Eliminated
	Vitrification	Uses an electric current to melt soil or other earthen materials at extremely high temperatures (2,900 to 3,650°F). Inorganic compounds are incorporated into the vitrified glass and crystalline mass and organic pollutants are destroyed by pyrolysis. Off-gas collection and treatment are required.	Requires less than 60 percent water content. Fundamentally thermally treats PCBs and stabilizes metals but at a much higher cost.	Retained
Thermal	Incineration	Temperatures greater than 1,400°F are used to volatilize and combust organic chemicals. Commercial incinerator designs are rotary kilns equipped with an afterburner, a quench and an air pollution control system.	Only one off-site fixed facility incinerator is permitted to burn PCBs and dioxins. Mobile incinerators are available for movement to a fixed location in close proximity to the contaminated sediments. May require an acid gas scrubber for treatment of air emissions.	Retained
	On-Site High-Temperature Thermal Destruction	Temperatures in the range of 600 to 1,200°F are used to volatilize and combust organic chemicals. These thermal units are typically equipped with an after burner and baghouse for treatment of air emissions.	Technology readily available as mobile units which would need to be set up at a fixed location in close proximity to the contaminated sediments.	Retained

Table 6-6 Initial Screening: *Ex-situ* Treatment (Continued)

Technology	Process Option	Description	Screening Comment Implementability	Screening Decision
	Low-Temperature Thermal Destruction	Temperatures in the range of 200 to 600°F are used to volatilize and combust organic chemicals. These thermal units are typically equipped with an after burner and baghouse for treatment of air emissions.	Technology readily available as mobile units which would need to be set up at a fixed location in close proximity to the contaminated sediments. Thermal desorption and combustion is effective with a range of SVOCs. Typically not employed with chlorinated compounds or VOCs.	Eliminated
	Pyrolysis	Chemical decomposition is induced in organic materials by heat in the absence of oxygen. Organic materials are transformed into gaseous components and a solid residue (coke) containing fixed carbon and ash.	High moisture content increases treatment cost. Generates air and coke waste streams. Target contaminant groups are SVOCs and pesticides. It is not effective in either destroying or physically separating inorganics from the contaminated medium. Limited performance data are available for pyrolytic systems treating hazardous wastes containing PCBs, dioxins, and other organics.	Eliminated
Thermal (Continued)	Thermal Desorption	Wastes are heated to volatilize water and organic contaminants. A carrier gas or vacuum system transports volatilized water and organics to the gas treatment system. X*TRAX , DAVES, Taciuk Process and Holoflite Dryer	Fine-grained sediment and high moisture content will increase retention times. Widely available commercial technology for both on-site and off-site applications. Acid scrubber will be added to treat off-gas.	Retained
	High-Pressure Oxidation	High temperature and pressure used to break down organic compounds. Operating temperatures range from 150 to 600°C and pressures range from 2,000 to 22,300 MPa. (Examples: Wet Air Oxidation and Supercritical Water Oxidation)	Predominantly for aqueous-phase contaminants. Wet Air Oxidation is a commercially proven technology for municipal wastewater sludges and destruction of PCBs is poor. Supercritical Water Oxidation has demonstrated success for PCB destruction in bench- and pilot-scale testing.	Eliminated

Table 6-7 Initial Screening: Dewatering

Technology	Process Option	Description	Screening Comment Implementability	Screening Decision
Mechanical Dewatering	Centrifugation	Rapidly rotates fluid mixture to separate the components based upon mass. Flocculents are often used to increase effectiveness.	Production rate is based on size and quantity of centrifuges used to dewater. Typical production rate of a single centrifuge is 20 to 500 gpm. Due to handling issues, more effective on dredge spoils containing a low percent of solids.	Retained
	Belt Press	Uses belts that compress sediments against rollers to achieve high-pressure compression and shear to remove water from dredged sediments.	Production rate is based on the size and quantity of belt presses used. Typical production rate of a single belt press is 40 to 100 gpm. Sediments are initially gravity drained which could produce high concentration of TSS.	Retained
	Hydrocyclone	Continuous operating cone shaped device which uses centrifugal force to accelerate settling.	Production rate and minimum separation size depended upon size of hydrocyclone (larger capacity provides a larger minimum separation size). Typical production rate of a single hydrocyclone is 50 to 3,500 gpm.	Retained
	Diaphragm Filter Press	Dewaters dredged sediments by passing slurry through a vertical filter. Uses inflatable diaphragms to increase pressures on sediments prior to removing sediments from filter.	Production rate is based on the size and quantity of filter presses used. Typical production rate of a single filter press is 1,200 to 6,000 gpm. Due to nature of operation, does not allow for continuous operation.	Retained

Table 6-7 Initial Screening: Dewatering (Continued)

Technology	Process Option	Description	Screening Comment Implementability	Screening Decision
Passive Dewatering	On Barge	Mechanically dredged sediments are placed within a barge which either allows excess water to flow into river, or to accumulate in an on-board sump where it is removed and treated.	Water drained from sediment on barge into river may not meet NPDES discharge standards. Gravity drained water may contain high concentrations of TSS. Not all river segments may be accessible to a barge.	Retained
	Dewatering Lagoons/Ponds	Dredged sediments are placed within constructed lagoons where sediments are allowed to gravity settle.	Construction area of ponds near river may involve removal of wooded areas. Construction costs involved in constructing contingencies to address potential spills and leaks. Effluent water may contain high concentrations of TSS. Average annual rainfall and evaporation approximately equal.	Retained
	Solidification	Dredged sediments are mixed with a Portland cement and/or fly ash mixture to produce a product which passes paint filter test.	Staging, mixing, and curing areas required. Solidified sediments have increased mass of unsolidified sediments. Practical only with sediments with high solids concentrations.	Retained

Table 6-8 Initial Screening: Disposal

Technology	Process Option	Description	Screening Comment Implementability	Screening Decision
On-site Disposal	Level Bottom Cap	Relocation of impacted sediment to discrete area and capping with a layer of clean sediments. Provides similar protection as capping but requires substantially more sediment handling that may cause increased releases to surface water.	Decreased water depth may limit future use of river and may impact flooding, streambank erosion, navigation, and recreation.	Retained
	Confined Aquatic Disposal (CAD)	Place untreated sediment within a lateral containment structure (i.e., Bottom depression or subaqueous berm) and cap with clean sediment.	CAD cannot be implemented due to ban on open water disposal in the Great Lakes.	Eliminated
	Confined Disposal Facility (CDF)	Place untreated sediment in a nearshore confined disposal facility that is separated from the river by an earthen berm or other physical barrier and capped to prevent dermal contact.	Portion of river to be used must be expendable. Potential impacts on flooding, stream bank erosion, navigation, and recreation. Requires Army Corps of Engineers 404 permit.	Retained
	Nearshore Biofiltration Cell	Contaminated sediment is placed in a nearshore confined treatment facility (CTF) where the contents are manipulated to enhance naturally occurring biodegradation.	Portion of river to be used must be expendable. Potential impacts on flooding, stream bank erosion, navigation, and recreation. Requires Army Corps of Engineers 404 permit. Engineering design of a full-scale system may be difficult to implement due to the potential need for oxygen additions. Demonstration project on Sheboygan River sediments resulted in incomplete degradation of PCBs and concerns about full-scale engineering design.	Eliminated
	Upland Confined Fill	Placed treated or untreated sediment at an on-site location. Location may require cap or other containment devices based on analytical data.	Standard construction techniques. Requires available upland space.	Retained

Table 6-8 Initial Screening: Containment (Continued)

Technology	Process Option	Description	Screening Comment Implementability	Screening Decision
Off-site Disposal	NR 500 Landfill (county, private, industrial landfills)	Off-site disposal at a licensed commercial facility that can accept nonhazardous dewatered sediment. Depends on analytical data from dredged sediment. Dewatering required to reduce water content for transportation.	Sediment must pass paint filter test for transport and disposal. Sediment must also pass strength test and be able to support slopes for disposal, especially with large quantities. WDNR has authority to dispose of PCB sediment in NR 500 W.A.C. facilities.	Retained
	Dedicated New Upland Landfill	A newly constructed dedicated landfill designed to contain all PCB impacted sediments removed from the Lower Fox River. The dedicated landfill would be constructed in small cells where each cell would be individually lined and each cell would contain the sediments removed in one year.	Construction requirements for a dedicated landfill would generally be the same as the construction requirements for a municipal landfill. Time required to site, design and construct is a consideration.	Retained
	TSCA Subtitle C Landfill	Off-site disposal at a licensed commercial facility that can accept hazardous dewatered sediment. Depends on analytical data from dredged sediment. Dewatering required to reduce water content for transportation.	Sediment must pass paint filter test for transport and disposal sediment must also pass strength test and be able to support slopes for disposal, especially with large quantities. WDNR has authority to dispose of PCB sediment in NR 500 W.A.C. facilities.	Retained
	Upland Confined Fill (Commercial/ Industrial)	Placed treated or untreated sediment at an off-site location. Location may require cap or other containment devices based on analytical data.	Standard construction techniques. Sediment must pass paint filter test for transport and disposal. Treatment to Wisconsin commercial/industrial criteria.	Retained
	Upland Fill (Residential/ Clean)	Place treated sediment at an off-site location. Requires that sediment be treated to a level that allows no restriction reuse.	Standard construction techniques. Sediment must pass paint filter test for transport and disposal. Treatment to Wisconsin clean fill criteria.	Retained

Table 6-9 Final Screening: Institutional Controls

Technology	Process Option	Description	Screening Comment		Screening Decision
			Effectiveness	Cost	
Physical, Engineering or Legislative Restrictions	Consumption Advisories	Advisories to indicate that consumption of fish in the area may present a health risk.	Provides limited protection	Low	Retained
	Access Restrictions	Constraints, such as fencing and signs, placed on property access.	Provides limited protection	Low	Retained
	Dredging Moratorium	Restricts dredging operations.	Provides limited protection	Low	Retained

Table 6-10 Final Screening: Containment

Technology	Process Option	Description	Screening Comment		Screening Decison
			Effectiveness	Cost	
Capping	Sand Cap	Placement of clean sand over existing contaminated bottom to physically isolate contaminants.	Isolates contaminants from the overlying water column and prevents direct contact between aquatic biota and contaminants. Effective for contaminants such as PCBs with low solubility and high sorption where the main concern is resuspension and direct contact. Modeling will be necessary to determine if a thin-layer cap will provide adequate protection of the water column from dissolved PCBs.	Low	Retained
	Sediment/ Clay Cap	Use of dredged fine-grained sediments or commercially obtained clay materials to achieve contaminant isolation.	Sediment with silt and clay is effective in limiting diffusion of contaminants. Effective for contaminants such as PCBs with low solubility and high sorption where the main concern is resuspension and direct contact. Clay caps are generally more effective than sand caps for containment of contaminants with high solubility and low sorption. These properties increase dissolution to the overlying water column and/or recontamination of sediment within the bioactive zone (upper 10 cm).	Low	Eliminated
	Armored Cap	Cobbles, pebbles or larger material are incorporated into the cap to prevent erosion in high-energy environments, or to prevent cap breaching by bioturbators. (Example: membrane gabions)	Isolates contaminants from the overlying water column and prevents direct contact between aquatic biota and contaminants. Effective for contaminants such as PCBs with low solubility and high sorption where the main concern is resuspension and direct contact. Armoring minimizes scouring.	Low to Moderate	Retained for limited use in high-energy sections of river
	Composite Cap	Soil, media and geotextile cap over contaminated material to inhibit contaminated pore-water migration and/or inhibit bioturbators.	Isolates contaminants from the overlying water column and prevents direct contact between aquatic biota and contaminants. Use of geotextiles may not be necessary for contaminants such as PCBs with low solubility and high sorption where the main concern is resuspension and direct contact.	Low to Moderate	Retained

Table 6-10 Final Screening: Containment (Continued)

Technology	Process Option	Description	Screening Comment		Screening Decison
			Effectiveness	Cost	
Capping (Continued)	Thin Layer Cap	Application of a thin (1- to 3-inch) layer of clean sediments and allowing natural resorting or bioturbation to mix the contaminated and clean sediments, which results in a surface layer of impacted material within acceptable levels.	Effective for contaminants that are amenable to natural attenuation. PCBs are not amenable to natural attenuation.	Low	Eliminated
	Enhanced Cap	Incorporation of materials such as granular activated carbon or iron filings to provide chemical binding or destruction of contaminants migrating in pore water.	Provides similar direct contact protection as sand cap, but additives are designed to increase retention time in the cap or treat pore water. Additives used for the purpose of increasing retention time and treating pore water would have little effect on PCBs with low solubility and high sorption.	Low to Moderate	Eliminated

Table 6-11 Final Screening: Removal

Technology	Process Option	Description	Screening Comment		Screening Decision
			Effectiveness	Cost	
Dredging	Hydraulic Dredging	A rotating cutter head loosens sediment at the suction mouth, where a centrifugal pump draws the sediment/water slurry through the pipeline. Performs efficiently in most sediments. Resuspension losses can be minimized by operational controls.	Can effectively dredge all types of materials. Superior in minimizing sediment resuspension compared to other dredges. Low slurry density.	Low	Retained
	Mechanical Dredging	A mechanical dredge consists of a barge-mounted floating crane that maneuvers a cable-suspended dredging bucket. The bucket is lowered into the sediment, and when withdrawn the cable closes the jaws of the bucket, retaining dredged material.	Can be operated to produce low suspended solids in the water column, thereby reducing water quality impacts. Level cut and low suspended solids also provide less opportunity for recontamination of dredged areas.	Low	Retained
Dry Excavation	Excavator	This removal option includes erecting sheet piles, or a coffer dam, around the contaminated sediments to dewater. Removal would then involve conventional excavation (backhoe) equipment.	Sheet pile isolates contaminated area during removal activities to minimize contamination of nearby sediments and water.	High	Retained

Table 6-12 Final Screening: *In situ* Treatment

Technology	Process Option	Description	Screening Comment		Screening Decision
			Effectiveness	Cost	
No *In Situ* Treatment process options were retained in the initial screening.					

Table 6-13 Final Screening: *Ex-situ* Treatment

Technology	Process Option	Description	Screening Comment		Screening Decision
			Effectiveness	Cost	
Chemical	Acid Extraction	Waste contaminated sediment and acid extractant are mixed in an extractor, dissolving the contaminants. The extracted solution is then placed in a separator, where the contaminants and extractant are separated for treatment and further use.	Suitable for sediments contaminated with heavy metals. Metals are concentrated in form potentially suitable for recovery. Not applicable to PCB-impacted sediment. Commercial-scale units are in operation.	Moderate	Eliminated
	Solvent Extraction	Waste contaminated sediment and solvent extractant are mixed in an extractor, dissolving the contaminants. The extracted solution is then placed in a separator, where the contaminants and extractant are separated for treatment and further use. (Example: B.E.S.T.™ and propane extraction process)	Effective for treating sediments containing PCBs. Extraction of organically bound metals and organic contaminants creating residuals with special handling requirements. The process is sensitive to sediment characteristics (i.e., clay content, pH). PCBs are not destroyed and may require further treatment by another technology.	Moderate	Eliminated
	Reduction/ Oxidation	Reduction/Oxidation chemically converts hazardous contaminants to nonhazardous or less toxic compounds that are more stable, less mobile, and/or inert. The oxidizing agents most commonly used are hypochlorites, chlorine, and chlorine dioxide.	Target contaminant group for chemical redox is inorganics. Less effective against nonhalogenated VOCs, SVOCs, fuel hydrocarbons and pesticides.	Moderate	Eliminated
Chemical/Physical	Dehalogenation	Dehalogenation process in which sediment is screened, processed with a crusher and pug mill, and mixed with sodium bicarbonate (Base Catalyzed Decomposition or BCD) or potassium polyethylene glycol (APEG). The mixture is heated to above 630°F in a rotary reactor to decompose and volatilize contaminants. Process produces biphenyls, olefins, and sodium chloride.	Effective for treating sediments containing PCBs. The presence of metals may affect performance. High moisture content adversely effects treatment. The process is sensitive to sediments characteristics (i.e., clay content, pH). The APEG process often needs to cycle numerous times to achieve the desired results and may cause the formation of dioxins and furans.	Moderate	Eliminated

Table 6-13 Final Screening: *Ex-situ* Treatment (Continued)

Technology	Process Option	Description	Screening Comment		Screening Decision
			Effectiveness	Cost	
Physical	Vitrification	Uses an electric current to melt soil or other earthen materials at extremely high temperatures (2,900 to 3,650°F). Inorganic compounds are incorporated into the vitrified glass and crystalline mass and organic pollutants are destroyed by pyrolysis. Off-gas collection and treatment are required.	Destroys PCBs and immobilizes metals. Fundamentally thermally treats PCBs and stabilizes metals. High moisture content adversly effects the treatment. Residuals are produced that must be treated and/or disposed. Effectiveness is difficult to assess.	High	Eliminated
Thermal	Incineration	Temperatures greater than 1,400°F are used to volatilize and combust organic chemicals. Commercial incinerator designs are rotary kilns equipped with an afterburner, a quench and an air pollution control system.	High temperatures result in generally complete decomposition of PCBs and other organic chemicals. Effective across wide range of sediment characteristics.	Very High	Retained as high-cost alternative
	High-Temperature Thermal Destruction (HTTD)	Temperatures in the range of 600 to 1,200°F are used to volatilize and combust organic chemicals. These thermal units are typically equipped with an after burner and baghouse for treatment of air emissions.	Thermal desorption and combustion is effective with a range of SVOCs. Target contaminants for HTTD are SVOCs, PAHs, PCBs and pesticides. Destruction of organic compounds occurs within an offgas chamber or unit that is integrated into the thermal desorption system.	High	Retained
	Thermal Desorption	Wastes are heated to volatilize water and organic contaminants. A carrier gas or vacuum system transports volatilized water and organics to the gas treatment system. X*TRAX™, DAVES, Taciuk Process and Holoflite™ Dryer	Demonstrated effectiveness at several other sediment remediation sites. Vaporized organic Contaminants that are captured and condensed need to be destroyed by another technology. The resulting water stream from the condensation process may require further treatment as well.	Low	Eliminated

Table 6-14 Final Screening: Dewatering

Technology	Process Option	Description	Screening Comment		Screening Decision
			Effectiveness	Cost	
Mechanical Dewatering	Centrifugation	Rapidly rotates fluid mixture to separate the components based upon mass. Flocculents are often used to increase effectiveness.	Fines build up in effluent. Able to handle slurries.	Moderate	Retained
	Belt Press	Uses belts that compress sediments against rollers to achieve high-pressure compression and shear to remove water from dredged sediments.	Requires dredged sediments at approximately 30% solids. Some clogging occurs.	Moderate	Retained
	Hydrocyclone	Continuous operating cone shaped device which uses centrifugal force to accelerate settling	Can remove sediments as small as 5 um.		Retained
	Diaphragm Filter Press	Dewaters dredged sediments by passing slurry through a vertical filter. Uses inflatable diaphragms to increase pressures on sediments prior to removing sediments from filter.	Filters may clog with fines. Extremely energy intensive and generates additional wash water.	Moderate to High	Retained
Passive Dewatering	On-Barge	Mechanically dredged sediments are placed within a barge which either allows excess water to flow into river, or to accumulate in an on-board sump where it is removed and treated.	Sediments could require additional treatment to pass paint filter test.	Low	Retained
	Dewatering Lagoons/Ponds	Dredged sediments are placed within constructed lagoons where sediments are allowed to gravity settle.	Retention times affect production rates. Sediments could require additional treatment to pass paint filter test.	Moderate	Retained
Passive Dewatering	Solidification	Dredged sediments are mixed with a Portland cement and/or fly ash mixture to produce a product which passes paint filter test.	Most effective on partially dewatered/ high solid sediments	Moderate	Retained

Table 6-15 Final Screening: Disposal

Technology	Process Option	Description	Screening Comment		Screening Decision
			Effectiveness	Cost	
On-site Disposal	Level Bottom Cap	Relocation of impacted sediment to discrete area and capping with a layer of clean sediments. Provides similar protection as capping but requires substantially more sediment handling that may cause increased releases to surface water.	Isolates contaminants from the overlying water column and prevents direct contact between aquatic biota and contaminants. Effective for contaminants such as PCBs with low solubility and high sorption where the main concern is resuspension and direct contact. Releases from impacted sediment may occur during consolidation.	Moderate	Retained
	Confined Disposal Facility (CDF)	Place untreated sediment in a confined disposal facility that is separated from the river or bay by an earthen berm or other physical barrier and capped to prevent dermal contact.	Risk of discharge to river or bay through outer berm or containment wall.	Moderate	Retained
	Upland Confined Fill (Commercial/ Industrial)	Placed treated or untreated sediment at an on-site location. Location may require cap or other containment devices based on analytical data.	Sediments must be treated to commercial/industrial criteria. May require liner and cap depending on constituent concentrations.	Low to Moderate	Eliminated
	Upland Fill (Residential/Clean)	Place treated sediment at an off-site location. Requires that sediment be treated to a level that allows no restriction reuse.	Sediment must meet residential fill criteria.	Low	
Off-site Disposal	NR 500 Landfill (county, private, industrial landfills)	Off-site disposal at a licensed facility that can accept dewatered sediment. Dewatering required to reduce water content for transportation. This may be a municipal or non-municipal landfill.	EPA waiver allows WDNR to regulate disposal of PCB contaminated sediments in NR 500 landfills. Some non-municipal landfills may require upgrades to meet NR 500 criteria.	Low to Moderate	Retained

Table 6-15 Final Screening: Disposal (Continued)

Technology	Process Option	Description	Screening Comment		Screening Decision
			Effectiveness	Cost	
Off-site Disposal	Dedicated New Upland Landfill	A newly constructed dedicated landfill designed to contain all PCB impacted sediments removed from the Lower Fox River. The dedicated landfill would be constructed in small cells where each cell would be individually lined and each cell would contain the sediments removed in one year.	EPA waiver allows WDNR to regulate disposal of PCB contaminated sediments in NR 500 landfills. The dedicated landfill could be centrally located in an area to allow access from all areas of the river.	Moderate to High	Retained
	TSCA Subtitle C Landfill	Off-site disposal at a licensed commercial facility that can accept hazardous dewatered sediment. Depends on analytical data from dredged sediment. Dewatering required to reduce water content for transportation. (PCBs >50)	Commercial permitted landfill.	High	Retained

Table 6-16 Summary of Technologies Retained

General Response Action	Remedial Technology	Process Option
No Action	None	None
Institutional Controls	Physical, Engineering or Legislative Restrictions	Consumption Advisories Access Restrictions Dredging Moratorium
Containment	Capping	Sand Cap Composite Cap Armored Cap
Removal	Dredging	Hydraulic Dredging Mechanical Dredging
	Dry Excavation	Excavator
Ex-situ Treatment	Thermal	Incineration High-temperature Thermal Destruction
Disposal	On-Site Disposal	Level Bottom Cap Confined Disposal Facility (CDF)
	Off-Site Disposal	NR 500 Landfill (county, private, industrial landfills) Dedicated New Upland Landfill TSCA Subtitle C Landfill
Dewatering	Mechanical	Belt Filters Centrifuges Hydrocyclone Solidification
	Gravity	On Barge Dewatering Lagoons/Ponds

Table 6-17 Summary of Selected Wisconsin Landfills within Approximately 40 Miles of the Lower Fox River

Facility Name	No.[4]	County	Status		Remaining Capacity [3]	Notes
			Existing Landfill	Proposed Landfill	CY	
Municipal [1]						
Brown County East	1	Brown	X		934,875	
Brown County South	2	Brown		X	8,025,000	b
Superior Services - Hickory Meadows	3	Calumet		X	7,500,000	
Kewaunee County SW	4	Kewaunee	X		259,367	d
Mar-Oco	5	Marinette	X		1,080,754	
Outagamie County SW Div	6	Outagamie	X		5,600,000 - 6,600,000	a
Shawano Cty Phase 2	7	Shawano	X		716,500	a
W M W I - Ridgeview Recycling	8	Manitowoc	X		4,770,000	a
W M W I - Valley Trail	9	Green Lake	X		4,905,300	a
Winnebago County Sunnyview	10	Winnebago	X		5,015,557	
Non Municipal [2]						
Appleton Papers Inc. Tn of HA	11	Calumet	X		unknown	
Appleton Papers Inc-Locks MI	12	Outagamie	X		65,800	c
Fort James Corp Green Bay West	13	Brown	X		3,972,984	
Wisconsin Tissue Mills North	14	Winnebago	X		312,569	

revised: 02/05/99

Notes: 1) - Landfill is operated for the disposal of municipal solid waste and some industrial waste. May be either publicly or privately owned.

2) - Landfill is operated for the disposal of industrial waste and is privately owned.

3) - Remaining Capacity as of January 1998 and proposed capacity

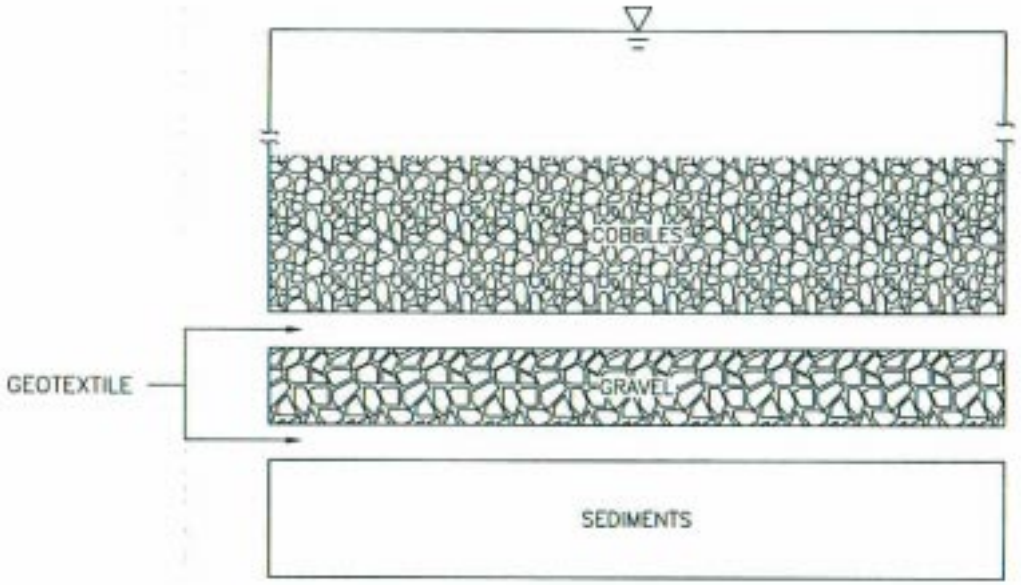
4) - Landfill identification for Figure 6-7, Lower Fox River Feasibility Study

a) - Proposed or existing facilities which are expansions to an existing facility

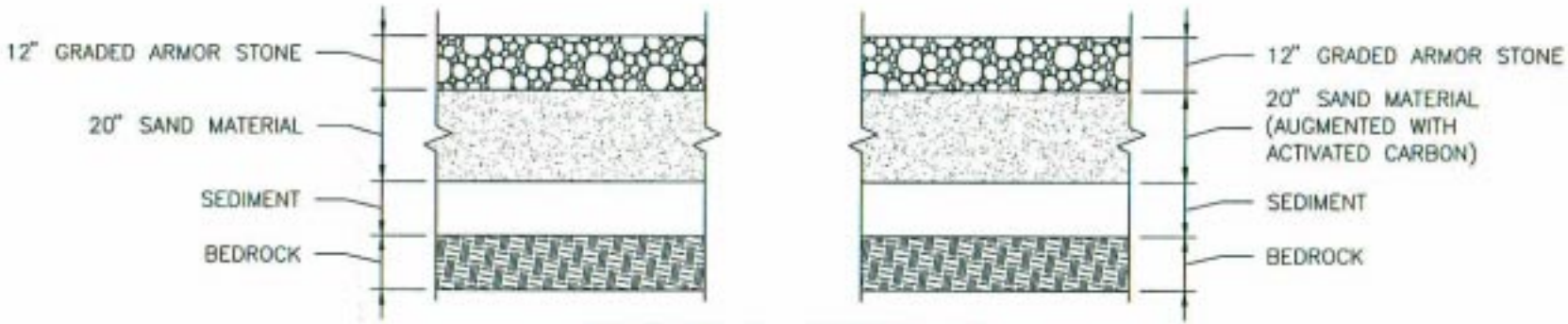
b) - A 3,700,000 CY monofill was approved as part of this site's Feasibility Study, but this monofill is not proposed or being developed at this time.

c) - Not an NR 500 approved facility, landfill modifications required prior to the acceptance of sediments

d) - Facility is a balefill, landfill modifications required prior to the acceptance of sediments



SHEBOYGAN FALLS, WI

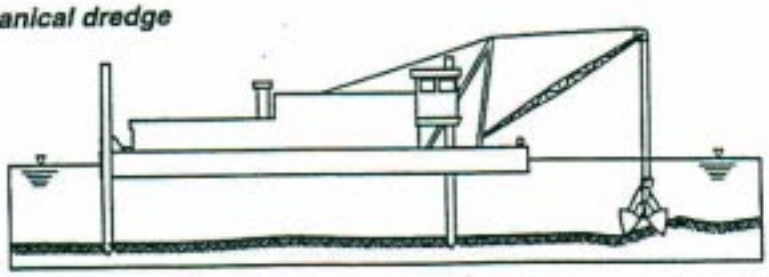


MANISTIQUE HARBOR, MI

ThermoRetec

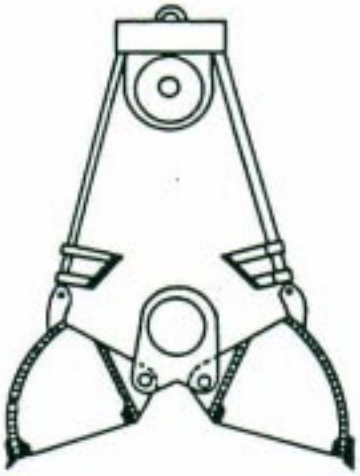
EC-SEA-03924				EXAMPLES OF ARMORED CAPS
CURRENT DATE	1/12/99	CADD FILE	3924D004	FIGURE 6-1

Mechanical dredge



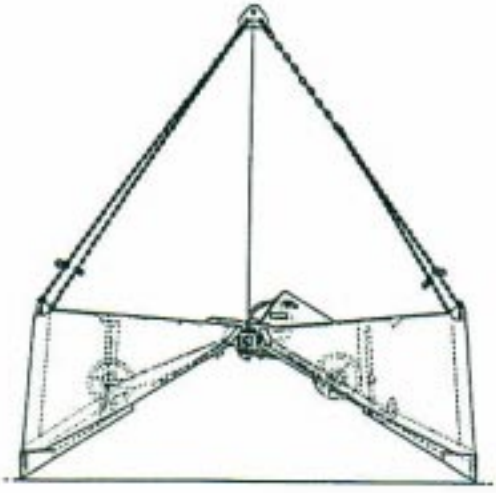
Source: USACE/USEPA (1992)

Enclosed Bucket



Source: Herbich and Brahme (1991).

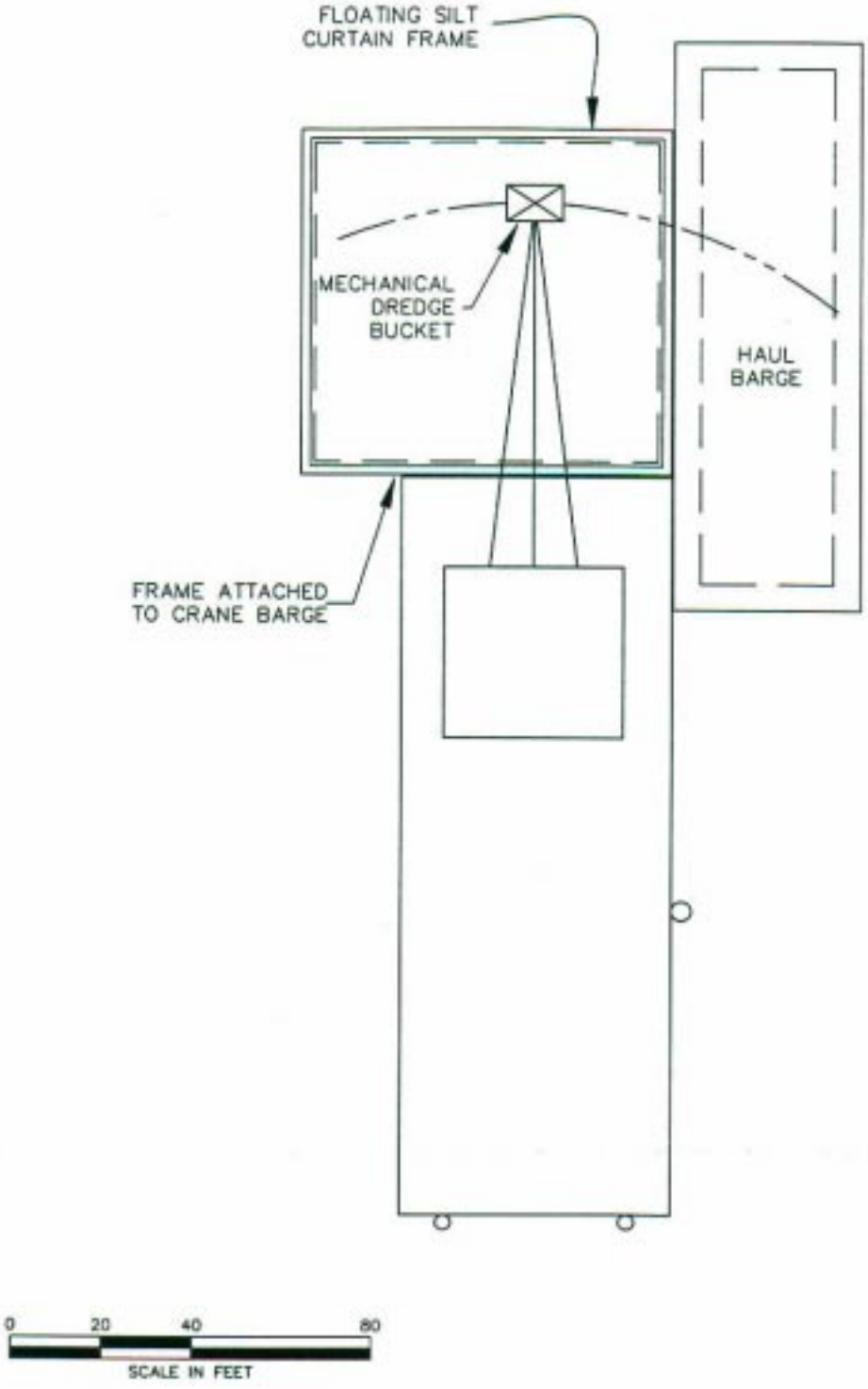
Cable Arm Bucket



Source: Cable Arm, Inc.

ThermoRetec

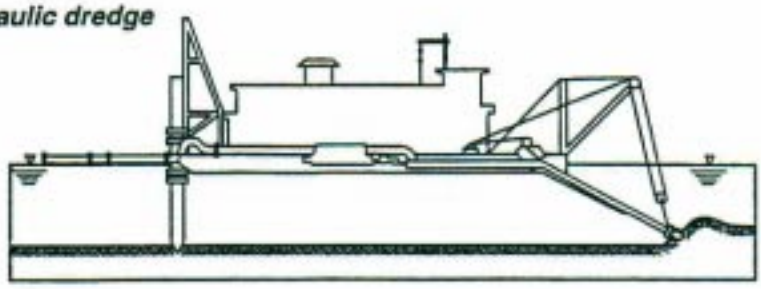
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-900	EXAMPLES OF MECHANICAL DREDGES
CURRENT DATE 01-13-99 CADD FILE	FIGURE 6-2



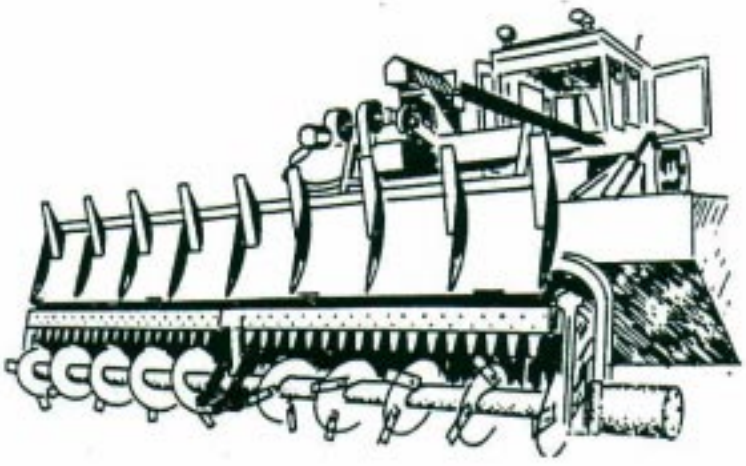
ThermoRetec

3-2438-571				TYPICAL MECHANICAL OPERATIONS
CURRENT DATE	1/11/99	CADD FILE	24385179	FIGURE 6-3

Hydraulic dredge

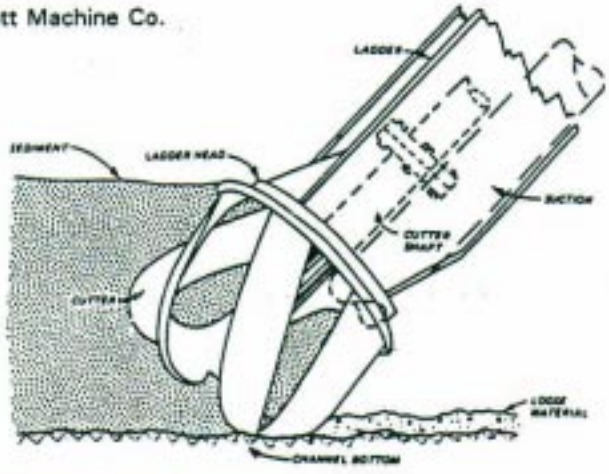


Source: USACE/USEPA (1992)



Horizontal Auger Dredge

Source: Ellicott Machine Co.

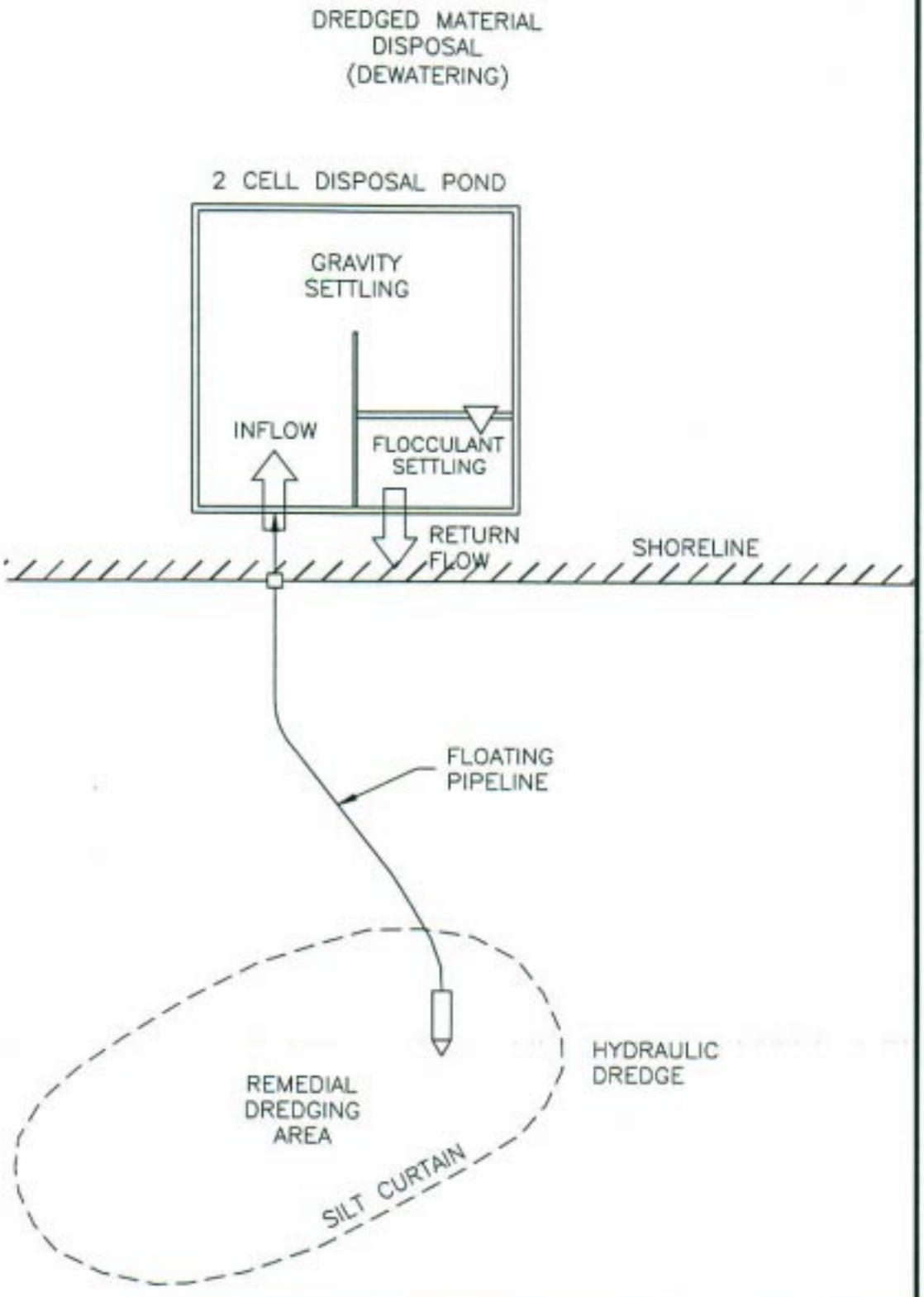


Conventional (Open Basket) Dredgehead

Source: Zappi and Hayes (1991)

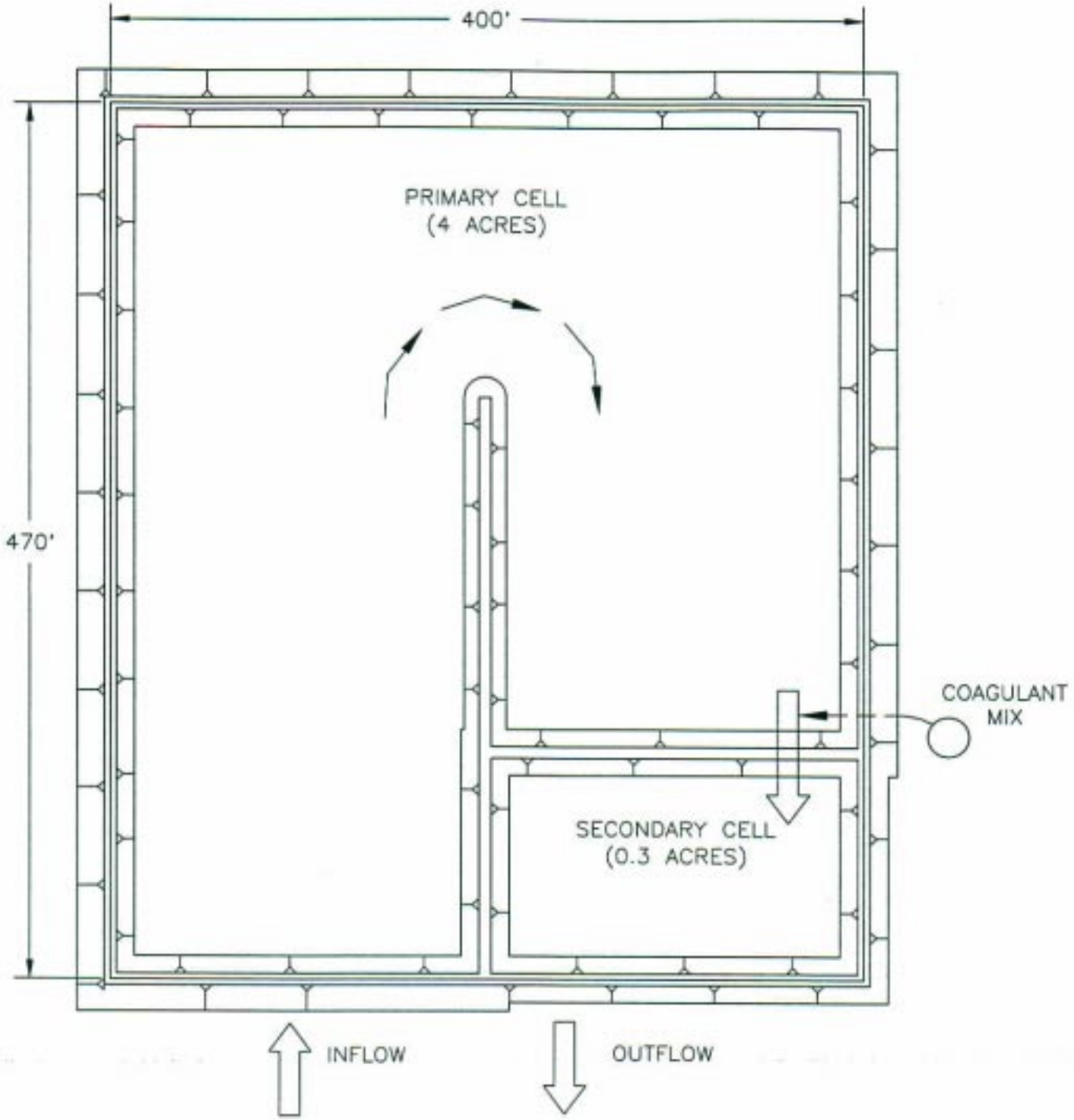
ThermoRetec

LOWER FOX RIVER FEASIBILITY STUDY 3-3584-900	EXAMPLES OF HYDRAULIC DREDGES
CURRENT DATE 01-13-99 CADD FILE	FIGURE 6-4



ThermoRetec

3-3584-542	CONCEPTUAL HYDRAULIC DREDGING TO DEWATERING POND
CURRENT DATE 1/12/99 CADD FILE 2438D025	FIGURE 6-5



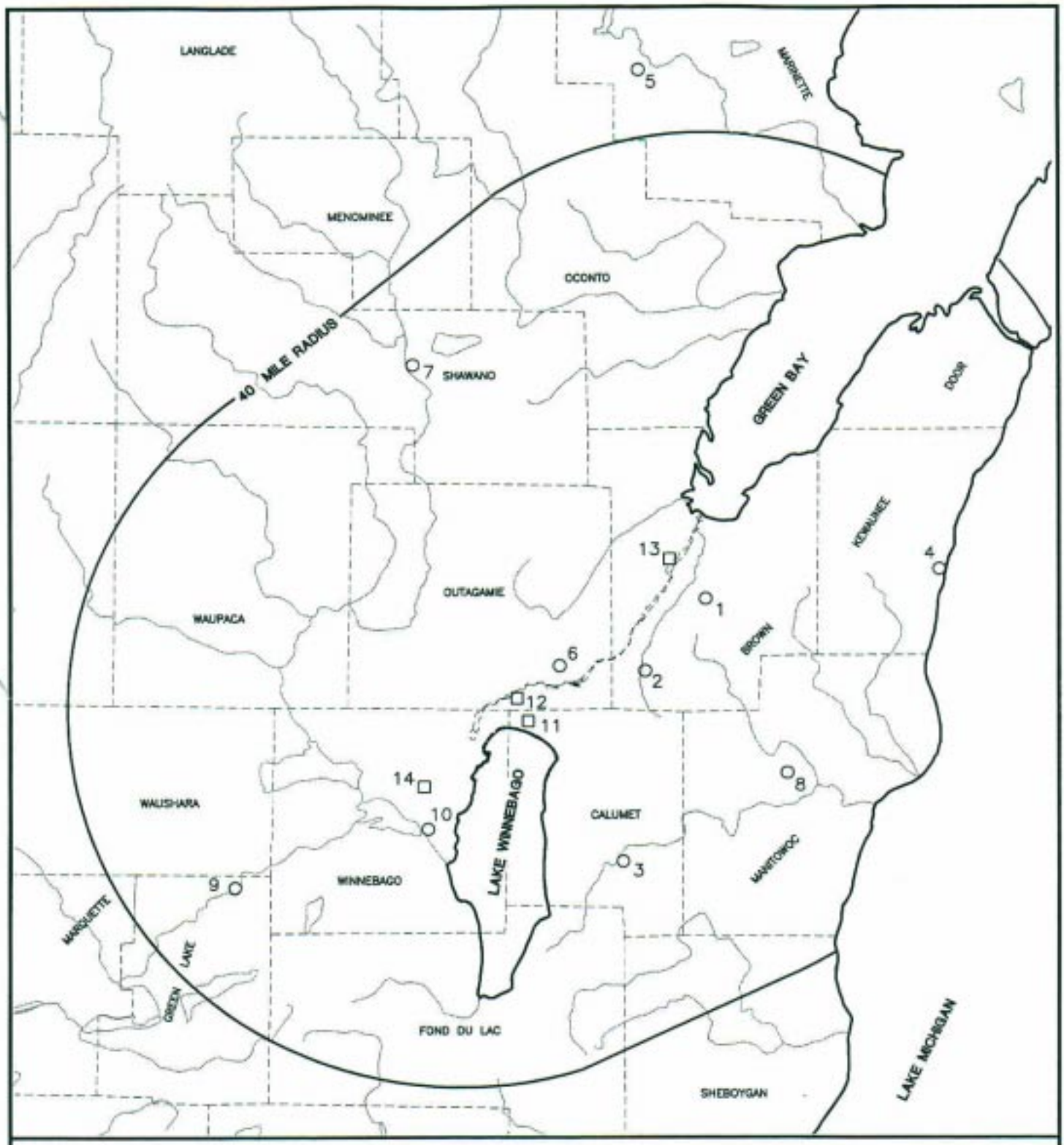
ThermoRetec

3-3584-542

CURRENT DATE	1/11/99	CADD FILE	2438006S

CONCEPTUAL LAYOUT OF A GRAVITY DEWATERING POND

FIGURE 6-6



LOWER FOX RIVER GENERAL LANDFILL LOCATION MAP

N
W E
S

3500' 0 7000'

SCALE 1"=7000'

LEGEND

○ 21 GENERAL LOCATION MUNICIPAL LANDFILL

□ 15 GENERAL LOCATION NON MUNICIPAL LANDFILL

(NUMBERS CORRESPOND TO LANDFILLS LISTED ON TABLE 6-17 OF FEASIBILITY STUDY)

LOCATION KEY

ThermoRetec

LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500				GENERAL LANDFILL LOCATION MAP
CURRENT DATE	12-04-98	CADD FILE	3584C035	FIGURE 6-7

7 Reach-Specific Remedial Alternatives

This section of the FS develops and describes a set of potential remedial alternatives for management of contaminated sediment at each of the four river reaches identified for the Lower Fox River. The alternatives were formed based upon an integration of the information and data presented in the RI Report, the BLRA Report, and Section 5 of this FS Report. The remedial alternatives described in this section were developed by assembling certain retained process options identified in Section 6.

In each of the subsections below, reach-specific alternatives and process options are developed and justified, and a detailed cost analysis for each alternative is presented. Selection of reach-specific alternatives and process options is dependent upon the general and physical constraints found in each of the four river reaches. For example, river depth can affect the feasibility of implementing mechanical dredging or the placement of a cap. Physical impediments in or on the water can also affect whether a specific piece of equipment or process option will be applicable to that reach. The reach-specific alternatives must be developed with these limitations in mind. Accordingly, the alternative development begins with a summary of the general and physical site characteristics by reach that were presented in the RI Report. This discussion focuses on those characteristics that may affect the implementability of a specific process option or remedial alternative.

Following the discussion of river reach characteristics, the site-specific alternatives and process options are described in detail. For each river reach, a series of three to eight alternatives are presented, along with the justification for the specific alternatives and the process options used to achieve those alternatives. This section is the integration of the defined areas and volumes of contaminated sediments presented in Section 5, the process option selection criteria of Section 6, and the relevant general and physical site conditions, described in this section.

Finally, a discussion of each alternative and the associated costs is presented. For each alternative, the corresponding specific set of process options, including pertinent assumptions concerning the staging and timing of those options, is described. A detailed process flow diagram is developed, and specific costs associated with implementation are given. The detailed analysis of the alternatives in accordance with CERCLA criteria is presented in Section 8.

7.1 Little Lake Butte des Morts

7.1.1 General Site Characteristics

LLBdM is located principally within Winnebago County, and is bordered by the communities of Neenah, Menasha, and Appleton. Land use in the vicinity of the Lake is a combination of both industrial and residential.

The river within this reach is generally broad and shallow at the southern end, narrowing and deepening as the river flows north and constricts near Stroebe Island nearby Appleton. As discussed in Section 5, most of the depositional areas identified as requiring remediation are in the southern part of the reach (deposits A, C, POG, and D) where water depths are shallow, generally between 3 and 7 feet, and flow is reduced. Water depths average about 4 to 5 feet at deposits A and B. North (downstream) of the railroad bridge, the water depth ranges from 2 feet nearshore to 13 feet in the federal channel near Stroebe Island, and then deepens to 23 feet as the river narrows at Appleton. General water depths are presented in Ocean Surveys (1998).

Average stream velocity in LLBdM is 0.16 ft/s (0.05 m/s), with 100-year maximum flows predicted at 0.83 ft/s (0.27 m/s). Average and 100-year flows are also given in Table 7-1.

Physical impediments to sediment management on LLBdM include the railroad bridge that transects the river between the Menasha Lock on the eastern shore and Fritse Park on the west. The railroad bridge is sufficiently low to prevent the on-water movement of dredging equipment between the southern and northern portions. Underwater structures that must be considered include existing water intake lines for Eggers Industries and Kimberly-Clark, located through Deposit A. The Eggers Industries line is abandoned, but the Kimberly-Clark line is still active. Neenah Slough flows through Arrowhead Park, and must be considered with any action involving deposits A, B or C.

7.1.2 Description of Remedial Alternatives and Process Options

This section defines the remedial alternatives for the LLBdM reach, and then describes the technologies that would be applied based upon application of the criteria defined in Section 6. The remedial alternatives for LLBdM include the following:

- Alternative A - Remove all river sediment with PCB concentrations greater than 250 μg/kg and dispose of the sediment off site.

- Alternative B - Remove the most highly contaminated river sediment to achieve a reach-wide sediment surface weighted average concentration (SWAC) of 250 μg/kg. Dispose of dredged sediment off site.

- Alternative C - Selectively remove sediment with PCB concentrations exceeding the TSCA threshold of 50 ppm (TSCA level sediment) and treat this sediment using HTTD. Remove remaining river sediment to achieve a SWAC of 250 μg/kg. Place all sediments in an on-site nearshore CDF.

- Alternative D - Selectively remove sediment with PCB concentrations exceeding the TSCA threshold of 50 ppm and dispose of this sediment off site. Remove remaining river sediment to achieve a SWAC of 250 μg/kg and place in an on-site nearshore CDF.

- Alternative E - Cap all sediments to the maximum extent practicable, and dredge the remaining sediment to achieve a SWAC of 250 μg/kg. Mechanically dredge all TSCA level sediment. Dispose of dredged sediment off site.

- Alternative F - Establish institutional controls.

- Alternative G - No action.

Table 7-2 presents a summary of the remedial alternatives for LLBdM. The process options that can be applied to the remedial alternatives are described below.

Removal Process Options

Sediment removal is identified for Alternatives A through E. Remediation area boundaries and sediment management areas are shown in Figures 5-15 and 7-1. For the LLBdM reach, the most practicable dredging option for large scale removal is hydraulic dredging. The relatively shallow water depths within the reach preclude wide scale application of a mechanical dredge. However, mechanical dredging is practicable and better suited to remove the relatively small volumes (63,000 cubic yards or less) of sediment exceeding 50 mg/kg PCBs identified as part of Alternatives C, D, and E.

A horizontal auger hydraulic dredge with a 10-inch pipeline has been selected for the remedial alternatives identified in this reach where a hydraulic dredge would be employed. While larger dredges are available, use of the 10-inch pipeline allows a greater degree of control over resuspension of contaminated sediments during removal operations, provides for a removal time frame of less than 10

years, and limits the size required of a gravity dewatering pond or structure. The operating assumption is that dredging would occur only during normal daylight hours (10 hours/day) during a normal work week (5 days/week), since LLBdM includes residential areas. Winter weather conditions are likely to preclude operations; as a result, dredging is assumed to occur only between March and October (26 weeks/year).

The horizontal auger is a commonly employed hydraulic dredge, with multiple capable portable dredges in the small to medium size range available in the Great Lakes region. Required operator experience and skills are also available in the region. Sediment remedial demonstrations by others (i.e., USACE, EPA, Environment Canada) have highly rated the small horizontal auger dredge for contaminated sediment removal. A horizontal auger equipped with two 10-inch pipelines, for example, has been successfully employed at the Manistique Superfund site. A suitable alternative is the small cutterhead dredge; the cutterhead is the only hydraulic dredge capable of effective operations if debris or compacted sediments are present. A ladder cutterhead is currently being used at the Deposit N Demonstration Project on the Lower Fox River.

A mechanical dredge would be employed locally in Alternatives C and E for removal of sediments with greater than 50 mg/kg PCBs. A mechanical bucket can be deployed with greater accuracy and precision to minimize the volume of sediments and free water that must be managed. For this river reach, a small (3 yd^3) closed clamshell environmental bucket mounted on a shallow draft (3 feet) barge could be used in the remedial alternatives. To move the sediments to shore, shallow deck barges fitted with side boards to contain contaminated sediments and associated water would be used in Alternatives C and E.

All dredging is assumed to occur within a defined footprint to a fixed cut depth of 8 inches over-dredge of material.

Dewatering Process Options

For the majority of the alternatives utilizing hydraulic dredging in the LLBdM reach, dewatering has been configured using a gravity settling pond. The water would be treated using flocculants, a clarifier, and sand filtration prior to discharge back to the river. For the alternatives involving upland disposal (Alternatives A, B, and E), the gravity settling pond would be located in Arrowhead Park. For the dredge to CDF alternatives (Alternatives C and D), dewatering would be conducted directly within the CDF and is discussed in more detail below. A hydraulic dredge with mechanical dewatering of TSCA level sediments has also been included (Alternative D).

The proposed dewatering system would meet the criteria defined in Section 6 of this FS Report, in terms of production rate, effectiveness, practicability, and discharge water quality. The dewatering system would operate 24 hours/day near residential areas. The largely passive system is preferable to mechanical dewatering, from a noise production standpoint.

Alternatives A, B, and E would include the construction of two approximately 4-acre gravity separation ponds in Arrowhead Park. The ponds would be enclosed laterally with berms to allow a ponding depth of 5 feet, and lined with 80 mil HDPE. Each settling pond would receive dredged sediment in three week increments. After a pond is filled, the sediment would be allowed to dewater to 50 percent solids. Residual water would be drained, treated, and discharged. The sediment will be solidified using cement or other agents prior to off-site disposal, since dewatered sediment may still be difficult to manage due to high moisture content. Sediment would be removed in preparation for the next three week period.

For the mechanical dredging operations in Alternatives C and E, limited capacity barges (500 cubic yards) would be used. Dewatering of sediments would occur by allowing the solids to gravity settle in the barge, and collecting the free water for treatment and discharge.

The solids content after dewatering for the hydraulic or mechanical dredging is assumed to be 50% (w/w). Prior to any off-site shipment, the sediment would be solidified to improve handling and to satisfy requirements for solid waste hauling on public roads and disposal, if necessary. For cost estimating purposes, it was assumed that solidification was necessary and that the sediment would be solidified with the addition of 5% (w/w) Type I Normal Portland Cement as the reagent. The sediment will be removed from the pond using standard earth moving equipment and mixed with the reagent in a pug mill. Numerous other cost effective reagents are available that may be tested and used for implementation of a remedial action.

A mechanical dewatering option is included for Alternative D for hydraulically dredged TSCA level sediments. Mechanical dewatering of the hydraulically dredged slurry will require the partitioning off of two, approximately 0.5 acre cells within the CDF constructed under this alternative to serve as an equalization basin to hold the slurry removed during a single dredging cycle. The slurry is pumped into a cell, allowed to settle for approximately 4 to 6 hours, and then fed to the dewatering equipment and water treatment facilities to process the sediment. For the purposes of costing, a centrifugation system was used. The

design proposed here is similar to that evaluated in the basis of design report for the demonstration project at SMU 56/57 (Montgomery Watson, 1998)

Treatment Process Options

The only on-site treatment process option retained from the screening process in Section 6 to include in the remedial alternatives is HTTD. The only sediment to be considered for on-site treatment is that sediment with PCB concentrations greater than 50 mg/kg.

Several commercial mobile HTTD units are available throughout the country and at least one unit is available from Minnesota. These units typically require a working area of about 200 by 200 feet. The working pad would be constructed of crushed rock, but may include asphalt. Due to the high fines content of much of the sediment, clean sand will be added to increase the sand content to 25 percent. Material with a high fines content may hinder system operations by sticking to the kiln walls and requiring increased retention times.

The HTTD treatment unit would have to be mobilized on at least two occasions: for sediment removal both south and north of the railroad trestle. Ideally, the working pad would be located adjacent to the proposed CDFs to minimize sediment handling.

CDF Process Options

Two CDFs are proposed for the LLBdM reach. The first CDF is proposed as a nearshore facility at the south end of the Lake at Arrowhead Park (Figure 7-2). The second CDF is proposed as a peninsula built into the river over most of Deposit POG to the northeast edge of the railroad bridge at Menasha (Figure 7-3). In both cases, the CDF design and location were selected to minimize impacts to upland riparian landowners.

The CDF at Arrowhead Park would consist of two contained structures: one on Arrowhead Park and the other encompassing Deposit A at Menasha, in front of the Kimberly-Clark facility. This arrangement accommodates a channel for the Neenah Slough. Contaminated sediments from within the slough area would be dredged into the CDF, and the shoreline backfilled with clean sediments to create a potential wetland area. Dredged sediment capacity at the Arrowhead CDF is estimated to be 750,000 cubic yards.

The second facility at Menasha would be placed completely in-water, and would require rubblemound jetties at the southern and northern ends to protect the backwater areas from erosion. A peninsula CDF was selected in order to allow for

maintenance of the existing navigation channel from the Menasha Lock. The dredged sediment capacity at the Menasha CDF is approximately 1 million cubic yards.

The concept for all Lower Fox River CDFs is a hybrid of the solid retention and hydraulic isolation designs discussed in Section 6. PCBs are predominately tied to the solids fraction of the sediments, but may dissolve and be carried at low concentrations in pore water. As such, the design includes placement of a stainless sheet pile wall driven to 30 feet below the final grade elevation into the relatively impervious clay layer underlying much of the soft sediments. Using this configuration, it should not be necessary to line the bottom of the CDF. The overall height of the CDF would be above the 100-year flood level—approximately 6 feet above the normal elevation of the river. The retention berms would be constructed with riprap to prevent flood or ice damage to the CDF.

As stated in Section 6, in-water CDFs are unlikely to be permitted for the placement of untreated TSCA level sediments. In Alternative C, dredged TSCA level sediments will be first treated by HTTD prior to placement in the CDF.

During hydraulic dredging, the CDF would be utilized to provide a gravity settling pond, with the overflow water decanted and filtered. Upon completion of dredging, the sediment would be allowed to further settle, and would then be capped with 3 feet of clean sediment and revegetated. Long-term use of CDF surface could include a park or multi-use open space. As the Lower Fox River sediments are relatively low in organic debris, a methane collection system is not expected to be needed for the CDF.

Disposal Process Options

All sediment samples to date in LLBdM indicate that the PCB concentrations are below 500 ppm. Based upon this, all sediment could be shipped to a landfill that conforms to the NR 500 W.A.C. requirements and has received an approval per DNR's agreement with EPA for the disposal of TSCA level sediments. Local landfill options and unit costs were defined in Section 6.5.5 of this FS Report.

Capping Process Options

Within the LLBdM reach, only two areas (Deposit C and a portion of Deposit E) met the criteria defined in Section 6.5.1 of this FS Report for placement of a cap. These areas are shown on Figure 7-1. These locations were selected principally based on levels of contaminants, site bathymetry, and location of navigational channels. The proposed caps at Deposit C and over the "hot spot" at Deposit E

would be constructed so that the TSCA level sediments are mechanically dredged prior to capping. While a cap had been proposed previously over Deposit POG (Graef et. al, 1996), it was not included as an alternative in this FS Report for the following reasons:

- The presence of TSCA level sediments within POG
- Site bathymetry is too shallow (3 to 6 feet)
- Any cap would interfere with potential future navigational uses of the boat channel from the Menasha Lock

The cap in LLBdM is planned to be a composite cap composed of an 80 mil HDPE cover and overlain with large cobbles, or equivalent, to secure the geotextile and provide erosion protection.

Institutional Control Options

Institutional controls appropriate to LLBDM include:

- Maintenance of the fish consumption advisory
- A moratorium on any future dredging within the federal navigation channel
- Deed restrictions on any in-water activities that could result in sediment disturbance (i.e., marina construction or over-water development)
- Access restrictions to contaminated areas (i.e., Arrowhead Park)
- Continued restriction on the use of the Fox River for domestic water supplies
- Long-term (40-year) monitoring program for sediments, water, and fish PCB levels.

Implementation of these institutional controls will likely require an active public education program for the fish and domestic water advisories. Deed and access restrictions may require local or state legislative action to prevent any development in contaminated areas of the river. Finally, federal action may be necessary on any dredging moratoriums within the federal navigation channel.

A long-term monitoring program would include annual surface sediment sampling to determine if/when conditions change within the Lake. In addition, both water and sport fish (i.e., catfish, perch, walleye) should be sampled annually to

determine if more restrictive controls are necessary. The sampling program may continue indefinitely under this process option, but for the purposes of the FS it has been costed at 40 years.

7.1.3 Development of Alternatives and Associated Costs

This section describes the remedial alternatives developed for the LLBdM reach. Each remedial alternative includes a description, a process flow diagram, and a summary cost table. Summary costs presented in this FS do not include a line item for contingency costs. The cost contingency typically added in feasibility studies is +30% of the as-built costs, and may be added by the reader. Details used to develop each cost estimate are provided in Appendix D.

The following components are discussed, when applicable, within the development:

- Site Mobilization and Preparation
- Sediment Removal
- Sediment Dewatering
- Water Treatment
- Sediment Disposal
- Demobilization and Site Restoration
- Long-term Monitoring

Alternative A: Dredge with Off-Site Disposal of all Sediments Greater than 250 ppb PCBs

Alternative A includes the removal of sediments with a hydraulic dredge and off-site disposal of the sediments. Figure 7-4 provides a process flow diagram describing the process options included in this remedial alternative. Table 7-3 contains the summary costs to implement Alternative A. Detailed supporting costs are provided in Appendix D. The total volume of sediment to be dredged in this alternative is 1,626,350 cubic yards.

Site Mobilization and Preparation. Staging for the dredging of the sediments south of the railroad bridge would be conducted at Arrowhead Park. Site mobilization and preparation at Arrowhead Park includes securing the onshore property area for equipment staging, constructing the sediment dewatering ponds, water treatment, sediment storage, and truck loading. Offshore, a docking facility for the hydraulic dredges would be constructed. Property purchase and preparation are included in the cost of the process components.

For the purposes of the FS, staging for the dredging of the sediments north of the railroad bridge will be on property located adjacent to the Menasha Locks. This facility is solely for the purpose of docking the hydraulic dredging equipment - the dredge slurry will still be pumped to Arrowhead Park. Property purchase and construction of the docking facility are included in the cost of the process components.

Sediment Removal. Sediment removal would be done using a 10-inch horizontal auger hydraulic dredge. Given the volumes and operating assumptions described in Section 7.1.2, the complete removal effort would require approximately 4.9 years. Pipelines would be extended from the dredging area to Arrowhead Park for dewatering. For longer pipeline runs, it may be necessary to utilize in-line booster pumps to pump the slurry to the Arrowhead Park dewatering facility. Silt curtains around the dredging area are included to minimize sediment resuspension downstream of the dredging operation. Buoys and other waterway markers would be installed around the perimeter of the work area to prevent entry of unauthorized boats within the removal work zone. Other capital items included in the sediment removal costs are water quality monitoring, post- removal sediment bathymetric surveys to ensure achievement of the removal action, and site restoration at the conclusion of operations.

Sediment removal costs are estimated at $5,600,000.

Sediment Dewatering. Gravity dewatering includes land purchase, site clearing, and dewatering pond construction. Key assumptions include an approximate 4 percent dredged solids concentration and an approximate 2,917 gpm water production for the dredge. Sediment dewatering would be done in a two-cell passive filtration system at Arrowhead Park. The system would accommodate the 3 weeks of solids dredge production rate, plus a maximum water surge storage capacity. It is assumed that the final sediment would require solidification with 5% (w/w) cement to satisfy hauling and disposal requirements. Dewatering costs also include pond decommissioning and site restoration at the completion of the project.

Sediment dewatering costs are estimated at $1,200,000.

Water Treatment. Water treatment includes purchase of equipment and materials for flocculation, clarifiers, and sand filters. Water treatment would be conducted 24 hours/day, 7 days/week during the dredging season. Discharge water is estimated at 1,000,000 gallons/day. Daily discharge water quality monitoring is included in the cost estimate. Treated water would be sampled and analyzed to verify compliance with the appropriate discharge requirements prior to discharge

back to the river. Water treatment costs also include pad and equipment demobilization and site restoration.

Water treatment costs are estimated at $1,800,000.

Sediment Disposal. Sediment disposal includes the loading and transportation of the sediment to a facility listed in Section 6.5.5. The sediments would be loaded into tractor-trailer end dumps with bed liners or sealed gates with a front-end loader. Each load would be manifested and weighed. Each tractor-trailer would be decontaminated prior to leaving the staging area to prevent tracking excess soils onto nearby streets and highways. After unloading at the designated disposal facility, each tractor-trailer would be decontaminated and returned to the staging area for another load.

Costs of sediment disposal at an NR 500 W.A.C. landfill are estimated at $84,900,000.

Demobilization and Site Restoration. Demobilization and site restoration involves removing all equipment, (i.e., fencing, facilities), from the staging and work areas. All work pads and other permanent structures would be removed and the site would be graded to its original condition. Vegetated areas would be replanted to a state similar to that of the pre-construction. Demobilization and restoration costs are included within the above dredging, dewatering, and treatment estimates.

Long Term Monitoring. Long-term monitoring is not required under this alternative.

Alternative B: Dredge with Off-Site Disposal of Sediments to a SWAC of 250 ppb PCB

Alternative B includes the removal of sediment with a hydraulic dredge and off-site disposal of the sediments. Alternative A removes *all* sediment greater than 250 parts per billion (ppb): however, Alternative B removes only sufficient sediment to yield a sediment SWAC of less than 250 ppb PCBs. The sediment to be managed to attain the SWAC in the LLBdM reach was identified (Section 5) and is presented in Figure 7-1. Other than the volumes removed, all technologies and implementation procedures described for Alternative A are applicable to Alternative B. The process flow diagram is given in Figure 7-5 and the estimated costs are presented in Table 7-3. Detailed supporting costs are provided in Appendix D.

Site Mobilization and Preparation. Same as Alternative A with costs included in the following process components.

Sediment Removal. Sediment removal would be done using a 10-inch horizontal auger dredge. Removal volumes for this alternative are 1,128,565 cubic yards, and the complete removal effort is estimated to require 3.4 years.

Sediment removal costs are estimated at $4,100,000.

Sediment Dewatering. The approximately 4-acre gravity dewatering ponds previously described in Section 7.1.2 and for Alternative A are also included in Alternative B.

Sediment dewatering costs are estimated at $1,200,000.

Water Treatment. Treated discharge water is estimated at 1,000,000 gallons/day.

Water treatment costs are estimated at $1,600,000.

Sediment Disposal. Sediment disposal includes the loading and transportation of the sediments to a facility listed in Section 6.5.5.

Costs of off-site sediment disposal at an NR 500 W.A.C. landfill are estimated at $59,100,000.

Demobilization and Site Restoration. Same as Alternative A with costs included in the above dredging, dewatering, and treatment estimates.

Long Term Monitoring. As not all of the PCB mass is removed under Alternative B, long-term monitoring is required for this alternative. The basis for the SWAC removal option is to maintain fish tissue concentrations below a human health risk of 1×10^{-4}. Under the SWAC alternative, the long-term monitoring would focus on annual sport fish (i.e., catfish, perch, walleye) sampling to ensure that human health thresholds are not exceeded. This sampling program may continue indefinitely under this process option, but for the purposes of the FS it has been costed at 40 years.

The estimated cost for institutional controls and long-term monitoring is $1,000,000.

Alternative C: Dredge to the SWAC, with On-Site Thermal Treatment (HTTD) of TSCA Sediments, and Disposal in On-Site CDFs

Alternative C addresses the same sediment volumes as identified for Alternative B, but includes construction of on-site CDFs for long-term disposal of the materials. As previously noted, sediments with PCB concentrations exceeding 50 ppm are not to be disposed of in a nearshore CDF. As such, this alternative utilizes mechanical dredging to remove those smaller volumes of sediment greater than 50 ppm, treats the sediment with HTTD, and then safely disposes of the sediment in the CDF.

Figure 7-6 provides a process flow diagram describing the process options included in this remedial alternative. Table 7-3 contains the summary costs to implement Alternative C. Detailed supporting costs are provided in Appendix D. The total volume of sediments to be dredged in this alternative is 867,600 cubic yards.

Site Mobilization and CDF Construction. The process is staged to construct and complete dredging to the Arrowhead Park CDF, south of the railroad tracks, before proceeding to construction and dredging at the Menasha CDF. Site mobilization and preparation includes securing the onshore property area for equipment staging, constructing both the onshore and in-water CDFs, water treatment, and offshore docking facility for both the mechanical and hydraulic dredges. Site preparation would also include setting a 200 by 200 foot asphalt pad for the HTTD unit.

In addition to physical construction costs, the estimates for both CDFs include long-term (40-year) monitoring and maintenance costs, and mitigation costs for the loss of river bottom habitat at the Arrowhead Park and Menasha CDFs (110 acres). Property purchase and preparation are included in the costs of the following process components.

CDF construction is estimated at $39,300,000.

Sediment Removal. Mechanical dredging of the limited TSCA level sediment volumes would occur at both sites prior to initiation of hydraulic dredging. For the Arrowhead Park CDF, mechanical dredging of the TSCA level sediment hot spots in Deposit A would occur *before* construction of that portion of the in-water CDF. Those materials would be thermally treated and placed into the base of the upland cell on the Arrowhead Park CDF. In addition, the sediments from the Neenah Slough channel would also be removed and placed into the upland CDF.

Mechanical removal of the approximately 63,000 cubic yards would require approximately 1 year.

Hydraulic sediment removal techniques for this alternative are equivalent to that described for Alternatives A and B. The estimated time to complete hydraulic dredging is 2.4 years.

Sediment removal costs are estimated at $3,100,000 for hydraulic dredging, and $3,000,000 for the mechanical dredging.

Sediment Dewatering. Passive dewatering will occur directly within the CDF berms for hydraulic dredging. Mechanically dredged sediment will dewater on-barge for two days prior to off-loading. As a result, there are no separate dewatering costs in this alternative.

Water Treatment. Overflow return water from the CDFs would be treated before discharge to the river. Monitoring requirements are expected to be the same as those for Alternative A.

Water treatment costs for Alternative C are estimated at $1,400,000.

Sediment Treatment. Thermal destruction of the dewatered TSCA level sediments would involve blending the high silt/clay sediments with sand to improve HTTD performance. The total volume of material (sediments and sand) post-treatment is 43,750 cubic yards. The HTTD would include appropriate treatment of air emissions. Additional costs included in this option are for air emissions and treated sediment quality testing.

The cost for HTTD and placement in the CDF is $10,400,000.

Sediment Disposal. No sediment disposal is necessary with use of a CDF, as sediment is disposed within the facility.

Demobilization and Site Restoration. Demobilization and site restoration involves removing all equipment, (i.e., fencing, facilities), from the staging and work areas. The CDFs would be finished with a 3 foot cap of clean soils, and seeded and planted. Additional amenities (i.e., bike paths, wildlife habitat) were not included in the cost estimates. Demobilization and site restoration costs are included under the dredging and dewatering estimates.

Long Term Monitoring. As described for Alternative B, the “SWAC” monitoring program is applicable here. The long-term monitoring would focus on annual

sport fish (i.e., catfish, perch, walleye) sampling to ensure that human health thresholds are not exceeded. To ensure that the CDF is functioning as designed, near-site sediment and water sampling would be conducted on an annual basis. Again, this monitoring program has been costed at 40 years.

The estimated cost for institutional controls and long-term monitoring is $1,000,000.

Alternative D: Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments, and Disposal of Remaining Sediments in On-Site CDFs

This alternative addresses the same sediment volumes as Alternative C, except that the TSCA level sediments would be removed with a hydraulic dredge, mechanically dewatered, and disposed of off site at a NR 500 W.A.C. landfill. A process flow diagram is provided in Figure 7-7 and the estimated costs are presented in Table 7-3. Detailed supporting costs are provided in Appendix D.

Site Preparation and CDF Construction. In addition to the site preparation and CDF construction described for Alternative C, Alternative D would require a staging area for mechanical dewatering and for the mechanically dredged sediments to be offloaded and transported off site. The cost for constructing the upland staging area is included in dewatering and disposal. All other elements of Alternative D are the same as those described for Alternative C.

CDF construction is estimated at $39,300,000.

Sediment Removal. Hydraulic dredging of the limited TSCA level sediment volumes would occur at both sites prior to dredging the material below the TSCA level. For the Arrowhead Park CDF, dredging of the TSCA level sediment hot spots in Deposit A would occur *before* construction of that portion of the in-water CDF. Hydraulic removal of the approximately 63,000 cubic yards with a 6-inch horizontal auger dredge would require approximately 1 year.

Hydraulic sediment removal techniques for this alternative are equivalent to that described for Alternatives A and B. A 10-inch horizontal auger dredge would be used. The estimated time to complete for hydraulic dredging of material below the TSCA level is 2.4 years.

Sediment removal costs are estimated at $4,200,000 for hydraulic dredging.

Sediment Dewatering. Passive dewatering will occur directly within the CDF berms for hydraulic dredging. TSCA level material will be mechanically dewatered prior to off site disposal.

Mechanical dewatering costs for Alternative D are estimated at $1,700,000.

Water Treatment. Overflow return water from the CDFs and the mechanical dewatering system would be treated before discharge to the river. Monitoring requirements are the same as all previous alternatives.

Water treatment costs for Alternative D are estimated at $1,500,000.

Sediment Disposal. Sediment disposal includes the loading and transportation of the sediments to a facility listed in Section 6.5.5.

The cost for off-site sediment disposal at an NR 500 W.A.C. landfill is estimated at $3,800,000.

Demobilization and Site Restoration. Demobilization and site restoration involves removing all equipment, (i.e., fencing, facilities), from the staging and work areas. The CDFs would be finished with a 3 foot cap of clean soils, and seeded and planted. Additional amenities (i.e., bike paths, wildlife habitat) were not included in the cost estimates. Demobilization and site restoration costs are included under the dredging and water treatment estimates.

Long Term Monitoring. As described for Alternative B, the "SWAC" monitoring program is also applicable here. The long-term monitoring would focus on annual sport fish (i.e., catfish, perch, walleye) sampling to ensure that human health thresholds are not exceeded.

The estimated cost for institutional controls and long-term monitoring is $1,000,000.

Alternative E: Cap to the Maximum Extent Practicable; Dredge to the SWAC, with Off-Site Disposal of Sediments

Alternative E includes capping and dredging of sediments to attain the SWAC. As stated in Section 7.1.2, only two areas meet the cap criteria defined in Section 6.5.1. The first capping area encompasses Deposit C, which has TSCA level sediments, and depths ranging from less than 3 feet to 9 feet. Those TSCA level sediments require mechanical dredging prior to cap placement, and the post-dredging depth in the shallow area would increase to at least 4.5 feet. The second

area is a portion of Deposit E within the main river channel near Stroebe Island, and is over 9 feet in depth. A process flow diagram is given in Figure 7-8 and the estimated costs are presented in Table 7-3. Detailed supporting costs are provided in Appendix D.

Site Preparation and Cap Construction. Site preparation for dredging would include the gravity dewatering ponds discussed in Alternative A. Cap construction would require an upland staging area for the HDPE liner, as well as for the receipt and placement of the armoring stone. Cobble placement would be done by mechanical bucket. All other unit costs are similar to those described for the prior alternatives for the river reach. Site preparation costs in this alternative are included under the dredging and capping costs.

Capping costs at both sites under this alternative are estimated to be $9,600,000.

Sediment Removal. Mechanical dredging of the limited TSCA level sediment volumes in Deposit C would occur prior to initiation of hydraulic dredging. Mechanical removal of the approximately 8,000 cubic yards would require approximately 0.2 years.

Hydraulic sediment removal techniques for this alternative are equivalent to that described for Alternatives A and B. The estimated time to complete hydraulic dredging is 2.2 years.

Sediment removal costs are estimated at $2,900,000 for hydraulic and $1,500,000 for mechanical dredging.

Sediment Dewatering. The approximately 4-acre gravity dewatering ponds previously described in Section 7.1.2 and for Alternatives A and B are also included in Alternative E. Mechanically dredged sediment will dewater on-barge for two days prior to off-loading.

Sediment dewatering costs are estimated at $1,200,000.

Water Treatment. Overflow return water from the gravity dewatering ponds would be treated before discharge to the river. Monitoring requirements are the same as for the prior remedial alternatives.

Water treatment costs for Alternative E are estimated at $1,400,000.

Sediment Disposal. Assumptions and unit costs for off-site sediment disposal are the same as described for Alternative A.

The estimated cost for off-site disposal is estimated at $39,000,000.

Demobilization and Site Restoration. Demobilization and site restoration involves removing all equipment, fencing, facilities, etc., from the staging and work areas. Demobilization and site restoration costs are included under the dredging and capping estimates.

Long Term Monitoring. As described for Alternative B, the "SWAC" monitoring program is applicable here. The long-term monitoring would focus on annual sport fish (i.e., catfish, perch, walleye) sampling to ensure that human health thresholds are not exceeded.

Additional monitoring would be required to ensure the maintenance of cap integrity. For this type of armored composite capping, the annual monitoring would include bathymetric or side scan sonar profiling, as well as diver inspections to ensure that the cap and armor remained in place.

The estimated cost for institutional controls and long-term monitoring is $1,000,000.

Alternative F: Establishing Institutional Controls

Institutional controls may be implemented in combination with any of the proposed remedial alternatives. These controls include monitoring, access restrictions, dredging moratoriums, fish consumption advisories, and domestic water supply restrictions. Items included in costs for institutional controls are public education programs for fish or health advisories and deed restrictions.

The estimated cost for institutional controls and long-term monitoring is $1,200,000.

Alternative G: No Action

As required under the NCP, a no action alternative is included for the LLBdM reach. This alternative involves taking no action and relying on natural processes, such as natural attenuation, dispersion, dilution, and sedimentation to reduce contaminant quantities and/or concentrations and control contaminant migration processes. This alternative implies that no active management or remediation is employed; however, some institutional controls, such as access or resource use restrictions, may be employed to reduce risks until the RAOs are achieved.

7.2 Appleton to Little Rapids

7.2.1 General Site Characteristics

The Appleton to Little Rapids reach is approximately 20 miles long, and is the divider between Outagamie County on the west, and Brown County on the east. Much of this section of the river is agrarian, but, in addition to Appleton, includes the communities of Kimberly, Kaukauna, Little Chute, and Wrightstown.

Throughout this reach, the river is characterized by a series of channels and pools controlled largely by the seven dams/locks found between the Appleton dam and the Little Rapids dam at Kaukauna. The contaminated sediment deposits are largely found in quiescent depositional pools (see Section 4). This section of the river ranges from relatively deep (8 to 12 feet), where the river narrows (i.e., the segment from Appleton to Cedars Locks), to shallow and unnavigable (i.e., at the Thousand Island Conservancy).

This reach has an average stream flow velocity of 0.33 ft/s with an average maximum velocity of 1.2 ft/s (Table 7-1).

The single most important impediment to sediment management in this reach is the dams/locks, which prevent free movement of equipment between the 22 separate sediment deposits. In this segment, only the Little Rapids Lock is operable, with the exception of the Rapide Croche Lock, which is permanently closed to restrict sea lamprey movement, all locks would require maintenance and renovation before they could be made operational. Several are too small to accommodate larger equipment barges. As a result, remedial actions in this reach would require multiple mobilization of equipment around the dams.

7.2.2 Description of Remedial Alternatives and Process Options

This section defines the remedial alternatives for the Appleton to Little Rapids reach, and then describes the technologies that would be applied based upon application of the criteria defined in Section 6. The remedial alternatives for the Appleton to Little Rapids reach include the following:

- Alternative A - Remove all river sediment with PCB concentrations greater than 250 μg/kg and dispose of the sediment off-site.

- Alternative B - Establish institutional controls.

- Alternative C - No action.

A "dredge to SWAC" alternative is not included in this reach as the SWAC has been achieved with the removal of Deposit N during the demonstration project. A CDF was not considered for this reach due to lack of suitable and available in-water space. The process options that can be applied to the remedial alternatives are described below.

Removal Process Options

Sediment removal is identified for Alternative A. Sediment management areas are shown in Figure 7-9. For the Appleton to Little Rapids reach, the only practicable dredging option for removal is hydraulic dredging. The relatively shallow water depths within the reach and inaccessibility of the river preclude application of a mechanical dredge.

A horizontal auger hydraulic dredge with a 6-inch pipeline has been selected for the remedial alternative in this reach where a hydraulic dredge would be employed. While larger dredges are available, use of the 6-inch pipeline allows for a greater degree of control over resuspension of contaminated sediments during removal operations, provides for a removal time frame of less than 10 years, and limits the size required of a gravity dewatering pond. Because the Appleton to Little Rapids reach includes residential areas, an operating assumption is that dredging would occur only during normal daylight hours (10 hours/day) during a normal work week (5 days/week). Winter weather conditions are likely to preclude operations; as a result, dredging is assumed to occur only between March and October (26 weeks/year).

The horizontal auger is a commonly employed hydraulic dredge, with multiple capable portable dredges in the small to medium size range available in the Great Lakes region. Required operator experience and skills are also available in the region. Sediment remedial demonstrations by others (i.e., USACE, EPA, Environment Canada) have rated highly the small horizontal auger dredge for contaminated sediment removal. A suitable alternative is the small cutterhead dredge; the cutterhead is the only hydraulic dredge capable of effective operations if debris or compacted sand are present. A ladder cutterhead dredge is currently being used at the Deposit N Demonstration Project on the Lower Fox River.

All dredging is assumed to occur within a defined footprint to a fixed cut depth of 8 inches over-dredge of material.

Dewatering Process Options

For the alternative utilizing hydraulic dredging in the Appleton to Little Rapids reach, dewatering has been configured using a gravity settling pond. The water

would be treated using flocculents, a clarifier, and sand filtration prior to discharge back to the river. For the dredge and off-site disposal alternative, the gravity settling pond is assumed to be located off site in nearby farm fields leased or purchased for the project Given that much of the upriver portion of this reach is residential, the most likely area for facility construction would outside Wrightstown, at the downstream end of deposits W and X (Figure 7-9). The hydraulic slurry from the upstream deposits would be transported via pipeline either on the river, or overland around the dams and locks.

The proposed dewatering system would meet the criteria defined in Section 6 of this FS Report, in terms of production rate, effectiveness, practicability, and discharge water quality. The dewatering system would operate 24 hours/day potentially near residential areas. The largely passive system is preferable to mechanical dewatering from a noise production standpoint.

Alternative A would include the construction of two approximately 1-acre gravity separation ponds. The ponds would be enclosed laterally with berms to allow a ponding depth of 5 feet, and lined with 80 mil HDPE. Each settling pond would receive dredged sediment in three week increments. After a pond is filled, the sediment would be allowed to dewater to 50 percent solids. Residual water would be drained, treated, and discharged. The sediment will be solidified using cement or other agents prior to off-site disposal, since dewatered sediment may still be difficult to manage due to high moisture content. Sediment would be removed in preparation for the next three week period.

The solids content after dewatering for the hydraulic dredging is assumed to be 50% (w/w). Prior to any off-site shipment, the sediment would be solidified to improve handling and to satisfy requirements for solid waste hauling on public roads.

Treatment Process Options

No treatment would be performed for remedial alternatives in the Appleton to Little Rapids reach of the river since sediment PCB concentrations in this reach do not exceed 50 mg/kg.

CDF Process Options

No CDFs are proposed for the Appleton to Little Rapids reach of the river. The small volume of contaminated material does not justify construction of a CDF.

Disposal Process Options

All sediment samples to date in this reach indicate that the PCB concentrations are below 500 ppm. Based upon this, all sediment could be shipped to a landfill that conforms to the NR 500 W.A.C. requirements. Local landfill options and unit costs were defined in Section 6.5.5 of this FS Report.

Capping Process Options

No capping is proposed for the Appleton to Little Rapids reach of the river as contaminated sediment depths are generally less than 4 feet and would be exposed to flood and/or ice scaring.

Institutional Control Options

Institutional control options are the same as those described for LLBDM.

7.2.3 Development of Alternatives and Associated Costs

This section describes the remedial alternatives developed for the Appleton to Little Rapids reach. Each remedial alternative includes a description, a process flow diagram, and a summary cost table. Contingency costs are not included in these estimated, but may be added by the reader as +30% of the as-built costs. Details used to develop each cost estimate are provided in Appendix D.

The following components are discussed, when applicable, within the development of each alternative:

- Site Mobilization and Preparation
- Sediment Removal
- Sediment Dewatering
- Water Treatment
- Sediment Disposal
- Demobilization and Site Restoration
- Long-Term Monitoring

Alternative A: Dredge with Off-Site Disposal of all Sediments Greater than 250 ppb PCBs

Alternative A includes the removal of sediment with a hydraulic dredge and off-site disposal of the sediment. Figure 7-10 provides a process flow diagram describing the process options included in this remedial alternative. Table 7-4 contains the summary costs to implement Alternative A. Detailed supporting costs are provided in Appendix D. The total volume of sediment to be dredged

in this alternative is 337,800 cubic yards, which results in the removal of approximately 640 pounds of PCBs.

Site Mobilization and Preparation. Staging for the dredging of the sediments would be conducted at several locations due to the interference of inoperable locks. Approximately five separate areas would be required for staging. Site mobilization and preparation includes securing the onshore property area for equipment staging, constructing the sediment dewatering ponds, water treatment, sediment storage, and truck loading. Offshore, a docking facility for the hydraulic dredges would be constructed. Purchase and property preparation are included in the costs of the following process components.

Sediment Removal. Sediment removal would be done using a 6-inch horizontal hydraulic auger dredge. Given the volumes and operating assumptions described in Section 7.2.2, the complete removal effort would require approximately 4.4 years. Pipelines would extend from the dredging area to the dewatering area. For longer pipeline runs, it may be necessary to utilize in-line booster pumps to pump the slurry to the dewatering facility. Silt curtains around the dredging area are included to minimize sediment resuspension downstream of the dredging operation. Buoys and other waterway markers would be installed around the perimeter of the work area to prevent entry of unauthorized boats. Other capital items included in the sediment removal costs are water quality monitoring, post-removal sediment bathymetric surveys to ensure achievement of the removal action, and site restoration at the conclusion of operations.

Sediment removal costs are estimated at $6,200,000.

Sediment Dewatering. Gravity dewatering includes land purchase, site clearing, and dewatering pond construction. Key assumptions include an approximate 4 percent dredged solids concentration and an approximate 673 gpm water production for the dredge. Sediment dewatering would be done in a two-cell passive filtration system. The system would accommodate the 3 weeks of solids dredge production rate, plus a maximum water surge storage capacity. One set of centrally located dewatering ponds may be more than 10 miles from either end of the dredging area. Booster pumps may be required to pump dredged material to the dewatering ponds. It is assumed that the final sediment would require solidification with 5% (w/w) cement to satisfy hauling and disposal requirements. Dewatering costs also include pond demobilization and site restoration at the completion of the project.

Sediment dewatering costs are estimated at $320,000.

Water Treatment. Water treatment includes purchase of equipment and materials for flocculation, clarifiers, and sand filters. Water treatment would be conducted 24 hours/day, 7 days/week during the dredging season. Discharge water is estimated at 249,120 gallons/day. Daily discharge water quality monitoring is included in the cost estimate. Treated water would be sampled and analyzed to verify compliance with the appropriate discharge requirements. Water treatment costs also include pad and equipment demobilization and site restoration.

Water treatment costs are estimated at $740,000.

Sediment Disposal. Sediment disposal includes the loading and transportation of the sediments to a facility listed in Section 6.5.5. Sediments would be loaded into tractor-trailer end dumps with bed liners or sealed gates with a front-end loader. Each load would be manifested and weighed. Each tractor-trailer would be decontaminated prior to leaving the staging area to prevent tracking excess soils onto nearby streets and highways. After unloading at the designated disposal facility, each tractor-trailer would be decontaminated and returned to the staging area for another load.

Costs of sediment disposal at an NR 500 W.A.C. landfill are estimated at $16,400,000.

Demobilization and Site Restoration. Demobilization and site restoration involves removing all equipment (i.e., fencing, facilities) from the staging and work areas. All work pads and other permanent structures would be removed and the site would be graded to its original condition. Any vegetated areas would be replanted to a state similar to that of the pre-construction. Demobilization and restoration costs are included under the above dredging, dewatering, and treatment estimates.

Long Term Monitoring. Long-term monitoring is not required under this alternative.

Alternative B: Establish Institutional Controls

Institutional controls may be implemented in combination with any of the proposed remedial alternatives. These controls include monitoring, access restrictions, dredging moratoriums, fish consumption advisories, and domestic water supply restrictions. Items included in costs for institutional controls are public education programs for fish or health advisories, and deed restrictions.

The estimated cost for institutional controls and long-term monitoring is $1,200,000.

Alternative C: No Action

As required under the NCP, a no action alternative is included for the Appleton to Little Rapids reach. This alternative involves taking no action and relying on natural processes, such as natural attenuation, dispersion, dilution, and sedimentation to reduce contaminant quantities and/or concentrations and control contaminant migration processes. This alternative implies that no active management or remediation is employed; however, some institutional controls, such as access or resource use restrictions, may be employed to reduce risks until the RAOs are achieved.

7.3 Little Rapids to De Pere

7.3.1 General Site Characteristics

The Little Rapids to De Pere reach lies wholly within Brown County, and is largely agricultural for much of the upper segment. In the area of the De Pere dam, property use is principally residential, with the community of De Pere on both sides of the river and St. Norbert's College on the west bank. Most of the contaminated sediments exist in a single contiguous depositional zone (Deposit EE), approximately 5 miles in length. The entire reach is approximately 7 miles in length.

Depths throughout this reach are greater than the two upstream reaches of LLBdM and Appleton to Little Rapids. The main channel depth is generally greater than 6 feet throughout most of the reach, and as deep as 18 feet at the De Pere dam. The shoreline is less than 4 feet in depth and drops off abruptly close to the shore. General water depths by river reach are given in Ocean Surveys (1998).

The average stream velocity for the Little Rapids to De Pere reach is 0.12 ft/s. The maximum flood velocity noted here is 0.68 ft/s. Average and 100 year flows are given in Table 7-1.

There are generally no physical impediments to sediment management in this reach. Currently, there is no access to the river that would support remedial efforts, but there are opportunities suitable for construction and maintenance of a dock and nearshore support facilities.

7.3.2 Description of Remedial Alternatives and Process Options

This section defines the remedial alternatives for the Little Rapids to De Pere reach, and then describes the technologies that would be applied based upon application of the criteria defined in Section 6. The remedial alternatives for the Little Rapids to De Pere reach include the following:

- Alternative A - Remove all river sediment with PCB concentrations greater than 250 μg/kg and dispose of the sediment off-site.

- Alternative B - Remove all river sediment with PCB concentrations greater than 250 μg/kg. Hydraulically dredge sediment and pump directly to a new off-site landfill.

- Alternative C - Remove the most highly contaminated river sediment to achieve a reach-wide sediment SWAC of 250 μg/kg. Dispose of dredged sediment off-site.

- Alternative D - Remove the most highly contaminated river sediment to achieve a reach-wide sediment SWAC of 250 μg/kg. Place dredged sediment in a nearshore CDF located downstream of the De Pere dam.

- Alternative E - Cap and remove river sediment to achieve a reach-wide sediment SWAC of 250 μg/kg. Cap Deposit EE through Segments 22, 23, and 24. Dredge Segments 26 and 27 (including EE, GG, and HH) and place dredged sediment in a nearshore CDF downstream of the De Pere dam.

- Alternative F - Cap all sediment in river Segments 22 through 27.

- Alternative G - Establish institutional controls.

- Alternative H - No action.

Table 7-5 presents a summary of the remedial alternatives for the Little Rapids to De Pere reach. The process options that can be applied to the remedial alternatives are described below.

Removal Process Options

Sediment removal is identified for Alternatives A through E. Remediation area boundaries and sediment management areas are shown in Figures 5-17 and 7-11. For the Little Rapids to De Pere reach, the only practicable dredging option for

large scale removal is hydraulic dredging. The relatively shallow water depths within the reach and accessibility concerns preclude application of a mechanical dredge.

A horizontal hydraulic auger dredge with a 10-inch pipeline has been selected for the remedial alternatives identified in this FS Report where a hydraulic dredge would be employed. While larger dredges are available, use of the 10-inch pipeline allows for a greater degree of control over resuspension of contaminated sediments during removal operations, provides for a removal time frame of less than 10 years, and limits the size required of a gravity dewatering pond. Because the Little Rapids to De Pere reach includes residential areas, an operating assumption is that dredging would occur only during normal daylight hours (10 hours/day) during a normal work week (5 days/week). Winter weather conditions are likely to preclude operations; as a result, dredging is assumed to occur only between March and October (26 weeks/year).

The horizontal auger is a commonly employed hydraulic dredge, with multiple capable portable dredges in the small to medium size range available in the Great Lakes region. Required operator experience and skills are also available in this region. Sediment remedial demonstrations by others (i.e., USACE, EPA, Environment Canada) have rated highly the small horizontal auger dredge for contaminated sediment removal. A suitable alternative is the small cutterhead dredge; the cutterhead is the only hydraulic dredge capable of effective operations if debris or compacted sand are present. A ladder cutterhead dredge is currently being used at the Deposit N Demonstration Project on the Lower Fox River.

All dredging is assumed to occur within a defined footprint to a fixed cut depth of 8 inches over-dredge of material.

Dewatering Process Options

For all alternatives utilizing hydraulic dredging in the Little Rapids to De Pere reach, dewatering has been configured using a gravity settling pond, with water treated using flocculents, a clarifier, and sand filtration prior to discharge back to the river. For the dredge and off site disposal alternatives (Alternatives A and C), the gravity settling pond would be located on nearby property. For the dredge to CDF/landfill alternatives (Alternatives B, D, and E), dewatering would be conducted directly within the CDF/landfill and is discussed in more detail below.

The proposed dewatering system would meet the criteria defined in Section 6 of this FS Report, in terms of production rate, effectiveness, practicality, and discharge water quality. The dewatering system would operate 24 hours/day near

residential areas. The largely passive system is preferable to mechanical dewatering from a noise production standpoint.

Alternatives A and C would include the construction of two approximately 4-acre gravity separation ponds. The ponds would be enclosed laterally with berms to allow a ponding depth of 5 feet, and lined with 80 mil HDPE. Each settling pond would receive dredged sediment in three week increments. After a pond is filled, the sediment would be allowed to dewater to 50 percent solids. The residual water would be drained, treated, and discharged. The sediment will be solidified using cement or other agents prior to off-site disposal, since dewatered sediment may still be difficult to manage due to high moisture content. Sediment would be removed in preparation for the next three week period.

The solids content after dewatering is assumed to be 50% (w/w). Prior to any off-site shipment, the sediment would be solidified to improve handling and to satisfy requirements for solid waste hauling on public roads and disposal.

Treatment Process Options

No treatment would be performed for remedial alternatives in the Little Rapids to De Pere reach of the river since sediment PCB concentrations in this reach do not exceed 50 mg/kg.

CDF Process Options

The CDFs considered for placement of sediment from the Little Rapids to De Pere reach would be located downstream of the De Pere dam. The Little Rapids to De Pere reach is relatively narrow and contains a large number of residences at the northern end of the reach. As a result, it is not considered practicable to place a CDF in this reach. CDFs constructed downstream of De Pere would be designed to allow sufficient capacities for dredged sediment. Further discussion regarding these CDFs is contained in Section 7.4.

Disposal Process Options

All sediment samples to date in this reach indicate that the PCB concentrations are below 500 ppm. Based upon this, all sediment could be shipped to a landfill that conforms to the NR 500 W.A.C. requirements. Local landfill options and unit costs were defined in Section 6.5.5 of this FS Report.

Capping Process Options

Sediment in all of the river segments within this reach is amenable to capping (Figure 7-11). Capping is a viable alternative for portions, or all, of the reach due to the greater depths to sediment, relatively slow currents, and the lack of TSCA

level sediment. Furthermore, the reach has been identified as a depositional zone rather than an erosional zone (ThermoRetec, 1999b), which further supports the potential for capping in this reach.

A cap in the Little Rapids to De Pere reach would be a sand cap overlain with large cobble to provide erosion protection. The sand cap would be placed with a 10-inch tremie pipeline. Use of a tremie is preferable to placement with a split hull barge in this reach to minimize the potential for resuspension of contaminated sediments. Placement of armor is also proposed using a barge-floated bucket.

Institutional Control Options

Institutional controls for this reach are the same as those described previously for LLBDM.

7.3.3 Development of Alternatives and Associated Costs

This section describes the remedial alternatives developed for the Little Rapids to De Pere reach. Each remedial alternative includes a description, a process flow diagram, and a summary cost table. Contingency costs may be added in separately by the reader as +30% of the as-built cost presented in this section. Details used to develop each cost estimate are provided in Appendix D.

The following components are discussed, when applicable, within the development of each alternative:

- Site Mobilization and Preparation
- Sediment Removal
- Sediment Dewatering
- Water Treatment
- Sediment Disposal
- Demobilization and Site Restoration
- Long-Term Monitoring

Alternative A: Dredge with Off-Site Disposal of all Sediments Greater than 250 ppb PCBs

Alternative A includes the removal of sediment with a hydraulic dredge and off-site disposal of the sediment. Figure 7-12 provides a process flow diagram describing the process options included in this remedial alternative. Table 7-6 contains the summary costs to implement Alternative A. Detailed supporting costs are provided in Appendix D. The total volume of sediment to be dredged in this alternative is 1,188,000 cubic yards.

Site Mobilization and Preparation. Staging for the dredging of sediment would be conducted at an undetermined location. Site mobilization and preparation includes securing the onshore property area for equipment staging, constructing the sediment dewatering ponds, water treatment, sediment storage, and truck loading. Offshore, a docking facility for the hydraulic dredges would be constructed. Property purchase and preparation are included in the costs of the following process components.

Sediment Removal. Sediment removal would be done using a 10-inch horizontal auger hydraulic dredge. Given the volumes and operating assumptions described in Section 7.3.2, the complete removal effort would require approximately 3.6 years. Pipelines would extend from the dredging area to the dewatering area. For longer pipeline runs, it may be necessary to utilize in-line booster pumps to pump the slurry to the dewatering facility. Silt curtains around the dredging area are included to minimize sediment resuspension downstream of dredging operation. Buoys and other waterway markers would be installed around the perimeter of the work area to prevent entry of unauthorized boats within the removal work zone. Other capital items included in the sediment removal costs are water quality monitoring, post-removal sediment bathymetric surveys to ensure achievement of the removal action, and site restoration at the conclusion of operations.

Sediment removal costs are estimated at $4,100,000.

Sediment Dewatering. Gravity dewatering includes land purchase, site clearing, and dewatering pond construction. Key assumptions include an approximate 7 percent dredged solids concentration and an approximate 2,917 gpm water production for the dredge. Sediment dewatering would be done in a two-cell passive filtration system. The system would accommodate the 3 weeks of solids dredge production rate, plus a maximum water surge storage capacity. It is assumed that the final sediment would require solidification with 5% (w/w) cement to satisfy hauling and disposal requirements. Dewatering costs also include pond demobilization and site restoration at the completion of the project.

Sediment dewatering costs are estimated at $1,200,000.

Water Treatment. Water treatment includes purchase of equipment and materials for flocculation, clarifiers, and sand filters. Water treatment would be conducted 24 hours/day, 7 days/week during the dredging season. Discharge water is estimated at 947,520 gallons/day. Daily discharge water quality monitoring is included in the cost estimate. Treated water would be sampled and analyzed to verify compliance with the appropriate discharge requirements. Water treatment costs also include pad and equipment demobilization and site restoration.

Water treatment costs are estimated at $1,500,000.

Sediment Disposal. Sediment disposal includes the loading and transportation of the sediments to a facility listed in Section 6.5.5. Sediments would be loaded into tractor-trailer end dumps with bed liners or sealed gates with a front-end loader. Each load would be manifested and weighed. Each tractor-trailer would be decontaminated prior to leaving the staging area to prevent tracking excess soils onto nearby streets and highways. After unloading at the designated disposal facility, each tractor-trailer would be decontaminated and returned to the staging area for another load.

Costs of sediment disposal at an NR 500 W.A.C. landfill are estimated at $107,000,000.

Demobilization and Site Restoration. Demobilization and site restoration involves removing all equipment (i.e., fencing, facilities) from the staging and work areas. All work pads and other permanent structures would be removed and the site would be graded to its original condition. Any vegetated areas would be replanted to a state similar to that of the pre-construction. Demobilization and restoration costs are included under the above dredging, dewatering, and treatment estimates.

Long Term Monitoring. Long-term monitoring is not required under this alternative.

Alternative B: Dredge and Pump to Off-Site Disposal All Sediments Greater than 250 ppb PCB

Alternative B removes the same sediment volumes as identified for Alternative A, but includes construction of a new NR 500 W.A.C. landfill for long-term disposal of the materials. Sediment would be pumped directly to the landfill. The process flow diagram is provided in Figure 7-13 and costs are presented in Table 7-6.

Site Mobilization and Preparation. Staging for the dredging of sediment would be conducted at an undetermined location. Site mobilization and preparation includes securing the onshore property area for equipment staging, water treatment, sediment storage, and truck loading. Offshore, a docking facility for the hydraulic dredges would be constructed. Property purchase and preparation are included in the costs of the following process components.

Sediment Removal. Sediment removal would be done using a 10-inch horizontal auger dredge. Dredged material would be pumped directly to the disposal area.

Removal volumes for this alternative are 1,188,000 cubic yards, and the complete removal effort is estimated to require 3.6 years.

Sediment removal costs are estimated at $5,000,000.

Sediment Dewatering. Passive dewatering would be conducted directly within the landfill berms. Therefore, no dewatering costs are associated with this alternative.

Water Treatment. Treated discharge water is estimated at 950,000 gallons/day.

Water treatment costs are estimated at $1,500,000.

Sediment Disposal. Sediment disposal includes the cost of construction of a new NR 500 W.A.C. landfill in rural Brown County. Landfill operations, closure, long-term monitoring, and profit for the operator are not included in the disposal cost. Transportation costs are not required since dredged material is pumped directly to the landfill.

The cost for off-site sediment disposal at a new NR 500 W.A.C. landfill is estimated at $15,700,000.

Demobilization and Site Restoration. Demobilization and site restoration involves removing all equipment, fencing, facilities, etc., from the staging and work areas. All work pads and other permanent structures would be removed and the site would be graded to its original condition. Any vegetated areas would be replanted to a state similar to that of pre-construction. Demobilization and restoration costs are included under the above dredging and treatment estimates.

Long Term Monitoring. Long-term monitoring is not required under this alternative.

Alternative C: Dredge with Off-Site Disposal of Sediments to a SWAC of 250 ppb PCB

Alternative C also includes the removal of sediment with a hydraulic dredge and off-site disposal of the sediments. Alternatives A and B remove *all* sediment greater than 250 ppb PCBs; however, Alternative C removes only sufficient sediment to yield a SWAC of less than 250 ppb PCBs. The sediment to be managed to attain the SWAC in the Little Rapids to De Pere reach was identified (Section 5) and is presented in Figure 7-11. Other than the volumes removed, all technologies and implementation procedures described for Alternative A are

applicable to Alternative C. The process flow diagram is given in Figure 7-14 and the estimated costs are presented in Table 7-6. Detailed supporting costs are provided in Appendix D.

Site Mobilization and Preparation. Staging for the dredging of sediment would be conducted at an undetermined location. Site mobilization and preparation includes securing the onshore property area for equipment staging, constructing the sediment dewatering ponds, water treatment, sediment storage, and truck loading. Offshore, a docking facility for the hydraulic dredges would be constructed. Property purchase and preparation are included in the costs of the following process components.

Sediment Removal. Sediment removal would be done using a 10-inch horizontal auger dredge. Removal volumes for this alternative are 1,065,000 cubic yards, and the complete removal effort is estimated to require 3.2 years.

Sediment removal costs are estimated at $3,700,000.

Sediment Dewatering. The approximate 4-acre gravity dewatering ponds previously described are also included in Alternative C.

Sediment dewatering costs are estimated at $1,200,000.

Water Treatment. Treated discharge water is estimated at 950,000 gallons/day.

Water treatment costs are estimated at $1,400,000.

Sediment Disposal. Sediment disposal includes the loading and transportation of the sediment to a facility listed in Section 6.5.5.

Costs of off-site sediment disposal at an NR 500 W.A.C. landfill are estimated at $95,900,000.

Demobilization and Site Restoration. Demobilization and site restoration involves removing all equipment, fencing, facilities, etc., from the staging and work areas. All work pads and other permanent structures would be removed and the site would be graded to its original condition. Any vegetated areas would be replanted to a state similar to that of pre-construction. Demobilization and restoration costs are included under the above dredging, dewatering, and treatment estimates.

Long Term Monitoring. As described previously for LLBdM, the "SWAC" monitoring program is applicable here. The long-term monitoring would focus on annual sport fish (i.e., catfish, perch, walleye) sampling to ensure that human health thresholds are not exceeded.

The estimated cost for institutional controls and long-term monitoring is $1,000,000.

Alternative D: Dredge to the SWAC and Placement of Sediment in CDFs

Alternative D removes the same sediment volumes as identified for Alternative C, but includes construction of on-site CDFs for long-term disposal of the materials; these CDFs are proposed to be located downstream of the De Pere dam. Figure 7-15 provides a process flow diagram describing the process options included in this remedial alternative. Table 7-6 contains the summary costs to implement Alternative D. Detailed supporting costs are provided in Appendix D. The total volume of sediment to be dredged in this alternative is 1,065,000 cubic yards.

Site Mobilization and CDF Construction. The process is staged to construct and complete dredging to a CDF located below the De Pere dam. Site mobilization and preparation includes securing the onshore property area for equipment staging, constructing the CDFs, water treatment, and offshore docking facility for the hydraulic dredge. Property purchase and preparation are included in the costs of the following components.

In addition to physical construction costs, the estimates for the CDFs include long-term (40-year) monitoring and maintenance costs, and mitigation costs for the loss of river bottom habitat.

CDF construction is estimated at $23,200,000.

Sediment Removal. Hydraulic dredging of sediment will be conducted using the same methods described for Alternatives A and C. The complete removal effort is estimated to require 3.2 years.

Sediment removal costs are estimated at $3,700,000.

Sediment Dewatering. Passive dewatering would be conducted directly within the CDF berms. Therefore, no separate dewatering costs are associated with this alternative.

Water Treatment. Overflow return water from the CDFs would be treated before discharge to the river. Monitoring requirements are expected to be the same as Alternatives A and C.

Water treatment costs are estimated at $1,400,000.

Sediment Disposal. All dredged sediment will be placed in CDFs. All costs for the CDF are included under Site Mobilization and CDF Construction.

Demobilization and Site Restoration. Demobilization and site restoration involves removing all equipment, fencing, facilities, etc., from the staging and work areas. The CDFs would be finished with a 3 foot cap of clean soils, and seeded and planted. Demobilization and site restoration costs are included under the dredging, water treatment, and CDF construction estimates.

Long Term Monitoring. As described previously for LLBdM, the "SWAC" monitoring program is applicable here. The long-term monitoring would focus on annual sport fish (i.e., catfish, perch, walleye) sampling to ensure that human health thresholds are not exceeded. To ensure that the CDF is functioning as designed, near-site sediment and water sampling would be conducted on an annual basis for 40 years.

The estimated cost for institutional controls and long-term monitoring is $1,000,000.

Alternative E: Cap and Dredge to the SWAC, with Placement of Sediment in CDFs

Alternative E includes capping and dredging of sediment to attain the SWAC. The capping area encompasses Deposit EE in river Segments 22 through 24, with depths ranging from less than 6 feet to 12 feet. Figure 7-16 provides a process flow diagram describing the process options included in this remedial alternative. Table 7-6 contains the summary costs to implement Alternative E. Detailed supporting costs are provided in Appendix D. The total volume of sediment to be dredged in this alternative is 593,220 cubic yards.

Site Mobilization and CDF Construction. The process is staged to construct and complete dredging to a CDF located below the De Pere dam. Site mobilization and preparation includes securing the onshore property area for equipment staging, constructing the CDFs, water treatment, and offshore docking facility for the hydraulic dredge. Property purchase and preparation are included in the costs of the following components.

In addition to physical construction costs, the estimates for the CDFs include long-term (40-year) monitoring and maintenance costs, and mitigation costs for the loss of river bottom habitat.

CDF construction is estimated at $23,200,000.

Cap Construction. Cap construction would require an upland staging area for the receipt and placement of the sand and armoring stone. Sand would be placed with a tremie; cobble would be placed with a mechanical bucket. All other cost factors include the same unit costs as those described previously for LLBdM.

Capping costs are estimated at $14,300,000.

Sediment Removal. Hydraulic dredging of sediment would be conducted using the same methods described for Alternatives A and C.

Sediment removal costs are estimated at $2,300,000.

Sediment Dewatering. Passive dewatering would be conducted directly within the CDF berms. Therefore, no separate dewatering costs are associated with this alternative.

Water Treatment. Overflow return water from the CDFs would be treated before discharge to the river. Monitoring requirements are expected to be the same. Water treatment costs are estimated at $1,300,000.

Demobilization and Site Restoration. Demobilization and site restoration involves removing all equipment, fencing, facilities, etc., from the staging and work areas. The CDFs would be finished with a 3 foot cap of clean soils, and seeded and planted. Demobilization and site restoration costs are included under the dredging, water treatment, and CDF construction estimates.

Long Term Monitoring. As described for Alternative B, the "SWAC" monitoring program is applicable here. The long-term monitoring would focus on annual sport fish (i.e., catfish, perch, walleye) sampling to ensure that human health thresholds are not exceeded.

Additional monitoring would be required to ensure the maintenance of cap integrity. For this type of sand cap, the annual monitoring would include bathymetric or side scan sonar profiling. Diver inspections would be conducted only if holes or erosion was indicated in the sonar surveys. Annual vertical cores would be collected in select places of the cap to ensure there is no vertical

migration of contaminants toward the cap surface. Cores are punched through the cap into the native, contaminated sediments, and the core is sectioned into 10 cm increments for analysis. Split spoon samplers are recommended, and the hole is back-grouted to ensure cap integrity after sampling.

The estimated cost for institutional controls and long-term monitoring is $1,000,000.

Alternative F: Cap All Deposits

Alternative F includes capping of sediment to attain the SWAC. The first capping area encompasses Deposit EE in river Segments 22 through 24, with depths ranging from less than 6 feet to 12 feet. The second capping area encompasses river Segments 26 and 27 (deposits EE, GG, and HH), with depths ranging from less than 6 feet to 18 feet.

Site Preparation and Cap Construction. Cap construction would require an upland staging area for the receipt and placement of the sand and armoring stone. Sand would be placed with a tremie and cobble would be placed with a mechanical bucket. All other costs include the same as those described previously. Site preparation costs in this alternative are included under the capping total costs.

Capping costs are estimated at $21,100,000.

Long Term Monitoring. Additional monitoring would be required to ensure the maintenance of cap integrity. Annual monitoring would be the same as described for Alternative D.

The estimated cost for institutional controls and long-term monitoring is $1,000,000.

Alternative G: Establish Institutional Controls

Institutional controls may be implemented in combination with any of the proposed remedial alternatives. These include monitoring, access restrictions, dredging moratoriums, fish consumption advisories, and domestic water supply restrictions. Items included in costs for institutional controls are public education programs for fish or health advisories, and deed restrictions.

The estimated cost for institutional controls and long-term monitoring is $1,200,000.

Alternative H: No Action

As required under the NCP, a no action alternative is included for the Little Rapids to De Pere reach. This alternative involves taking no action and relying on natural processes, such as natural attenuation, dispersion, dilution and sedimentation to reduce contaminant quantities and/or concentrations and control contaminant migration processes. This alternative implies that no active management or remediation is employed; however, some institutional controls, such as access or resource use restrictions, may be employed to reduce risks until the RAOs are achieved.

7.4 De Pere to Green Bay

7.4.1 General Site Characteristics

This section of the lower Fox River is the most heavily developed, and includes numerous communities. The river reach between the De Pere dam and the mouth of the river at Green Bay is a combination of both residential and industrial development.

The river is broad and shallow at the upper end, becoming narrow and deep as it approaches the mouth of the river. In the downstream portion, the federal channel has been routinely dredged to maintain a project depth of 24 feet. River depths outside of the federal channel, from De Pere to the Fort James-West facility, range from 4 to 12 feet, and between the Fort James-West facility and the mouth of the river, reach depths of 20 feet. General water depths by river reach are given in Ocean Surveys (1998).

Stream velocity in this reach is the lowest of the four reaches, with an average stream velocity of 0.08 ft/s (Table 7-1). This slow river flow is likely, in part, responsible for the depositional characteristic of the river below the De Pere dam.

Below the De Pere dam there are no locks or dams that would impede dredging equipment. There are seven bridges over the river to Green Bay. However, none of the bridges represent an impediment to vessel and equipment movement within the reach. Other physical impediments to removal actions in this reach include the numerous bulkhead lines, old docks, and potential underwater archeological sites (i.e., historic barges—indicated as “ruins” on the navigational charts). Costs of removing these impediments were not estimated. Any future specific action plans must consider the potential for impact to operations due to such impediments.

7.4.2 Description of Remedial Alternatives and Process Options

This section defines the remedial alternatives for the De Pere to Green Bay reach, and then describes the technologies that will be applied based upon application of the criteria defined in Section 6. The remedial alternatives for the De Pere to Green Bay reach include the following:

- Alternative A - Remove all river sediments with PCB concentrations greater than 250 μg/kg and dispose of the sediment off-site.

- Alternative B - Remove all river sediments with PCB concentrations greater than 250 μg/kg and pump directly to a new NR 500 W.A.C. landfill.

- Alternative C - Remove the most highly contaminated river sediment to achieve a reach-wide SWAC of 250 μg/kg. Dispose of dredged sediment off-site.

- Alternative D - Selectively remove sediment with PCB concentrations exceeding the TSCA threshold of 50 ppm and treat this sediment using HTTD. Remove remaining river sediment to achieve a SWAC of 250 μg/kg. Place all sediments in an on-site nearshore CDF.

- Alternative E - Selectively remove sediment with PCB concentrations exceeding the TSCA threshold of 50 ppm and dispose of off-site. Remove remaining river sediment to achieve a SWAC of 250 μg/kg and place in an on-site nearshore CDF.

- Alternative F - Cap sediments to the maximum extent practicable and dredge remaining sediments to achieve a SWAC of 250 μg/kg. Mechanically remove and dispose of off-site all TSCA level sediments. Mechanically dredged sediment to be placed in nearshore CDF.

- Alternative G - Institutional controls consisting of fish consumption advisories.

- Alternative H - No action.

Table 7-7 presents a summary of the remedial alternatives for the De Pere to Green Bay reach. The process options that can be applied to the remedial alternatives are described below.

Removal Process Options

Sediment removal is identified for Alternatives A through F. Remediation area boundaries and sediment management areas are shown on Figures 5-18 and 7-17. For the De Pere to Green Bay reach, both mechanical and hydraulic dredging are practicable. Mechanical dredging is better suited to remove the relatively small volumes (248,000 cubic yards) exceeding 50 mg/kg PCBs identified as part of Alternatives D, E, and F. It has been proposed that all dredging in the De Pere to Green Bay reach be performed with a mechanical dredge with the exception of Alternative B, which includes hydraulic dredging and pumping sediment directly to a new NR 500 W.A.C. landfill. Mechanical dredging significantly reduces the water management needs which is necessary due to the limited upland space availability on this reach.

A 6 yd^3 Cable Arm™ bucket has been selected for the remedial alternatives identified in this reach where a mechanical dredge is employed. The De Pere to Green Bay reach includes both residential and industrial areas. In residential areas, immediately downstream of the De Pere dam, the operating assumption is that dredging will occur only during normal daylight hours (12 hours/day) during a normal work week (5 days/week). In industrial areas, dredging may occur 24 hours/day and 6 days per week; however, this option was not included in the FS. Winter weather conditions are likely to preclude operations; as a result, dredging is assumed to occur only between March and October (26 weeks/year).

Hydraulic dredging for Alternative B will be performed using two 10-inch pipeline dredges with a cutterhead. A floating pipeline from the dredges will connect to a shore-based pipeline that will pump the sediment directly to an NR 500 W.A.C. landfill. This operation will minimize the need for upland off-loading, staging, and truck loading facilities. The operating assumption is that dredging will occur only during normal daylight hours (12 hours/day) during a normal work week (5 days/week). In industrial areas, dredging may occur 24 hours/day and 6 days per week; however, this option was not included in the FS. Winter weather conditions are likely to preclude operations; as a result, dredging is assumed to occur only between March and October (26 weeks/year).

Dewatering Process Options

For all mechanical dredging alternatives, it is proposed that dewatering be conducted on-barge and in upland staging areas. Each 2,000 yd^3 barge load of dredged sediment will be filled in 1 day and will dewater for 2 days on the barge. Free water will be pumped from the watertight barges and managed. Sediment will then be transferred onto an asphalt paved upland staging area where any additional free water will be collected. All water collected from the barges and the

upland staging area will be treated using flocculents, a clarifier, and sand filtration prior to discharge back to the river. The upland staging areas may be located at the Bayport facility near the mouth of the Fox River or at the former Shell facility near the middle of this reach. For the dredge to CDF alternatives (Alternatives D, E, and F), dewatering will occur directly within the CDF.

The proposed dewatering system will meet the criteria defined in Section 6 of this FS Report, in terms of production rate, effectiveness, practicality, and discharge water quality.

A single 1-acre asphalt lined upland staging area will be constructed with 6-inch asphalt berms and a water collection sump.

The solids content after dewatering is assumed to be 50% (w/w). Prior to any off-site shipment, the sediment will be solidified to improve handling and to satisfy requirements for solid waste hauling on public roads and disposal.

For Alternative B, hydraulically dredged sediment will be pumped directly to a new NR 500 W.A.C. landfill. Dewatering will occur within the PCB sediment landfill and water will be treated and returned to the river.

Treatment Process Options

The only on-site treatment process option retained from the screening process in Section 6 that will be included in the remedial alternatives is HTTD. The only sediment to be considered for on-site treatment is that sediment with PCB concentrations greater than 50 mg/kg.

Several commercial mobile HTTD units are available throughout the country and at least one unit is available from Minnesota. These units typically require a working area of about 200 by 200 feet. The working pad will be constructed of crushed rock, but may include asphalt. Due to the high fines content of much of the sediment, clean sand will be added to increase the sand content to 25 percent. Material with a high fines content may hinder system operations by sticking to the kiln walls and requiring increased retention times.

The HTTD treatment units will have to be mobilized each year and the working pad will be located adjacent to the proposed CDFs or the upland staging areas.

CDF Process Options

Three CDFs are currently proposed for the De Pere to Green Bay reach. All three CDFs are nearshore facilities located immediately downstream of the De Pere dam

(Figure 7-18). In all cases, the CDF location was selected to minimize impacts to upland riparian landowners. The total capacity of these facilities is 1,275,000 cubic yards, which is lower than the proposed dredge volumes of about 3,100,000 to 3,500,000 cubic yards. Other possible CDF locations could include within the bulkhead line just south of the Former Shell facility and at the Cat Islands. Rough costs for additional CDFs to make up the required CDF capacity have been estimated.

The concept for all Lower Fox River CDFs is a hybrid of the solid retention and hydraulic isolation designs discussed in Section 6. PCBs are predominately tied to the solids fraction of the sediments, but may dissolve and be carried at low concentrations in pore water. As such, the construction includes placement of a stainless sheet pile wall driven to 30 feet below the final grade elevation into the relatively impervious clay layer underlying much of the soft sediments. Using this configuration, it should not be necessary to line the bottom of the CDF. The overall height of the CDF will be above the 100-year flood level—approximately 6 feet above the normal river elevation. The retention berms will be constructed with appropriately sized shot rock and riprap to prevent flood or ice damage to the CDF.

In keeping with design criteria given in Section 6, there will be no placement of untreated TSCA level sediments in any CDF. Dredged TSCA level sediments must first be treated by HTTD prior to placement in the CDF.

During mechanical dredging, the CDF itself will act as a collection system for excess water, with the overflow water decanted and filtered. Upon completion of dredging, the sediment is allowed to further settle, and is then capped with 3 feet of clean sediments and revegetated. Long-term use of CDF surface can include a park or multi-use open space. As the Lower Fox River sediments are relatively low in organic debris, a methane collection system has not been included as part of the concept design.

Disposal Process Options

Total PCB concentrations in sediment within this reach generally are below 500 ppm. All sediment below 500 ppm may be disposed of at landfills which conform to the NR 500 W.A.C. requirements. The exception to this is SMU 56/57 which has sediment over 500 ppm. These sediments can be accepted at NR 500 W.A.C. landfills, but must have EPA concurrence (see Section 6.5.5). Local landfill options and unit costs were defined in Section 6.5.5 of this FS Report.

Capping Process Options

Within the De Pere to Green Bay reach, only one area met the criteria defined in Section 6.5.1 of this FS Report for placement of a cap. This area is shown on Figure 7-17. This location was selected principally based on levels of contaminants, site bathymetry, and location of navigational channels. The proposed cap shown on Figure 7-17 will be constructed so that the TSCA level sediments are mechanically dredged prior to capping.

The cap in the De Pere to Green Bay reach is planned to be an armored cap composed of 18 inches of sand overlain with 6 inches of large cobble to provide erosion protection.

Institutional Controls

Institutional controls in this reach are the same as those described previously for LLBdM and the Little Rapids to De Pere reach.

7.4.3 Development of Alternatives and Associated Costs

This section describes the remedial alternatives developed for the De Pere to Green Bay reach. Each remedial alternative includes a description, a process flow diagram and a summary cost table. Contingency costs may be added as +30% of the as-built cost by the reader. Details used to develop each cost estimate are provided in Appendix D.

The following components are discussed, when applicable, within the development of each alternative:

- Site Mobilization and Preparation
- Sediment Removal
- Sediment Dewatering
- Water Treatment
- Sediment Disposal
- Demobilization and Site Restoration
- Long-Term Monitoring

Alternative A: Dredge with Off-Site Disposal all Sediments Greater than 250 ppb PCBs

Alternative A includes the removal of sediments with a mechanical dredge and off-site disposal of the sediments. Figure 7-19 provides a process flow diagram describing the process options included in this remedial alternative. Table 7-8 contains the summary costs to implement Alternative A. Detailed supporting

costs are provided in Appendix D. The total volume of sediments to be dredged in this alternative is 5,690,000 cubic yards.

Site Mobilization and Preparation. Staging for the dredging of sediments will be conducted at the Bayport or former Shell facilities. Site mobilization and preparation includes securing the onshore property area for equipment staging, constructing the sediment staging areas, water treatment, sediment solidification, and truck loading. It is assumed that docking facilities for the mechanical dredge and barges already exist at these locations. Purchase and property preparation are included in the costs.

Sediment Removal. Sediment removal will be done using a 6 yd^3 mechanical Cable Arm™ dredge. Given the volumes and operating assumptions described in Section 7.1.2, the complete removal effort would require approximately 6.1 years using four dredges. Silt curtains around the dredging area are included to minimize sediment resuspension downstream of the dredging operation. Buoys and other waterway markers will be installed around the perimeter of the work area to prevent entry of unauthorized boats. Other capital items included in the sediment removal cost are air and water quality monitoring, post-removal sediment bathymetric surveys to ensure achievement of the final design cut for the removal action and site restoration at the conclusion of operations.

Sediment removal costs are estimated at $44,900,000.

Sediment Dewatering. Barge rental and movement costs and upland staging are included under Sediment Removal. Dewatering will be conducted by allowing the sediment to remain on the barge for 2 days for removal of free water. The collection of any additional free water will occur at the upland staging facility. Solidification of the sediment with 5% (w/w) Portland cement will be conducted prior to any off-site shipment of the material. The costs for solidification are included under off-site disposal. As a result, no separate costs are included for dewatering.

Water Treatment. Water treatment includes purchase of equipment and materials for flocculation, clarifiers, and sand filters. Water treatment will be conducted 24 hours/day, 7 days/week during the dredging season. Discharge water is estimated as approximately 413,000 gallons/day. Daily discharge water quality monitoring is included as a cost in the estimate. Treated water would be sampled and analyzed to verify compliance with the appropriate discharge requirements.

Water treatment costs are estimated at $1,100,000.

Sediment Disposal. Sediment disposal includes the loading and transportation of the sediments to a facility listed in Section 6.5.5. Sediments will be loaded into tractor-trailer end dumps with bed liners or sealed gates with a front-end loader. Each load will be manifested and weighed. Each tractor-trailer will be decontaminated prior to leaving the staging area to prevent tracking excess soils onto nearby streets and highways. After unloading at the designated disposal facility, each tractor-trailer will be decontaminated and returned to the staging area for another load.

The estimated cost for off-site sediment disposal at an NR 500 W.A.C. landfill is $444,000,000.

Demobilization and Site Restoration. Demobilization and site restoration involves removing all equipment (i.e., fencing, facilities) from the staging and work areas. All work pads and other permanent structures will be removed and the site will be graded to its original condition. Any vegetated areas will be replanted to a state similar to that of the pre-construction. Demobilization and restoration costs are included under the dredging and dewatering estimates.

Long Term Monitoring. Long-term monitoring is not required under this alternative.

Alternative B: Dredge and Pump to Off-Site Disposal All Sediments Greater than 250 ppb PCB

Alternative B removes the same sediment volumes as identified for Alternative A, but includes construction of a new NR 500 W.A.C. landfill for long-term disposal of the materials. Sediment would be pumped directly to the landfill. The process flow diagram is provided in Figure 7-20 and costs are presented in Table 7-8.

Site Mobilization and Preparation. Staging for the dredging of sediment would be conducted at the Bayport or former Shell facilities. Site mobilization and preparation includes securing the onshore property area for equipment staging, constructing the pipeline and booster stations, and water treatment. Offshore, a docking facility for the hydraulic dredges would be constructed. Property purchase and preparation are included in the costs of the following process components.

Sediment Removal. Sediment removal would be done using two 10-inch cutterhead dredges. Dredged material would be pumped directly to the disposal area through a 16-inch pipeline. It has been assumed that the pipeline will have an average length of 132,000 feet and will require seven booster stations

(approximately one every three miles). Removal volumes for this alternative are 5,690,000 cubic yards, and the complete removal effort is estimated to require 8.5 years.

Sediment removal costs are estimated at $21,600,000.

Sediment Dewatering. Passive dewatering would be conducted directly within the landfill berms. Therefore, no dewatering costs are associated with this alternative.

Water Treatment. Treated discharge water is estimated at 4,474,000 gallons/day.

Water treatment costs are estimated at $8,600,000.

Sediment Disposal. Sediment disposal includes the cost of construction of a new NR 500 W.A.C. landfill in rural Brown County. Landfill operations, closure, long-term monitoring, and profit for the operator are not included in the disposal cost. Transportation costs are not required since dredged material is pumped directly to the landfill.

The cost for off-site sediment disposal at a new NR 500 W.A.C. landfill is estimated at $15,700,000.

Demobilization and Site Restoration. Demobilization and site restoration involves removing all equipment, fencing, facilities, etc., from the staging and work areas. All work pads and other permanent structures (i.e., pipelines and booster stations) would be removed and the site would be graded to its original condition. Any vegetated areas would be replanted to a state similar to that of pre-construction. Demobilization and restoration costs are included under the above dredging and treatment estimates.

Long Term Monitoring. Long-term monitoring is not required under this alternative.

Alternative C: Dredge with Off-Site Disposal of Sediments to a SWAC of 250 ppb PCB

Alternative C also includes the removal of sediments with a hydraulic dredge and off-site disposal of the sediments. Alternatives A and B remove *all* sediments greater than 250 ppb PCBs; however, Alternative C removes only sufficient sediment to yield a surface sediment area weighted average concentration of less than 250 ppb PCBs. The sediments to be managed to attain the SWAC in the

De Pere to Green Bay reach were developed and are identified in Section 5, and are presented on Figure 7-17. Other than the volumes removed, all technologies and implementation procedures described for Alternative A are applicable to Alternative C. The process flow diagram is given on Figure 7-21 costs are presented in Table 7-8. Detailed supporting costs are provided in Appendix D.

Sediment Removal. Sediment removal will be done using a 6 yd^3 Cable Arm™ dredge. Removal volumes for this alternative are 5,066,000 cubic yards, and the complete removal effort is estimated to require 7.3 years; assuming three dredges are actively employed.

Sediment removal costs are estimated at $40,000,000.

Sediment Dewatering. The upland staging areas previously described are also envisioned for Alternative C. Costs are included within Sediment Removal and Off-Site Disposal.

Water Treatment. Water treatment is estimated as approximately 310,000 gallons/day. Water treatment costs for Alternative C are $1,000,000.

Sediment Disposal. Sediment disposal includes the loading and transportation of the sediments to a facility listed in Section 6.5.5. The cost for off-site sediment disposal at an NR 500 W.A.C. landfill is estimated at $395,600,000.

Long Term Monitoring. As some PCB residuals will remain after dredging, long-term monitoring is necessary to ensure fish tissue concentrations below a human health risk of 1×10^{-4}. The long-term monitoring would focus on annual sport fish (i.e., catfish, perch, walleye) sampling to ensure that human health thresholds are not exceeded. This sampling program may continue indefinitely under this process option, but for the purposes of the FS it has been costed at 40 years.

The estimated cost for institutional controls and long-term monitoring is $1,000,000.

Alternative D: Dredge to the SWAC, with On-Site Thermal Treatment (HTTD) of TSCA Sediments, and Disposal in On-Site CDFs

Alternative D addresses the same sediment volumes as identified for Alternative C, but includes construction of on-site CDFs for long-term disposal of the materials. As previously noted, sediments with PCB concentrations exceeding 50 ppm are not disposed of in a nearshore CDF. As such, this

alternative utilizes mechanical dredging to remove those smaller volumes of sediment greater than 50 ppm, treats the sediments with HTTD, and then safely disposes of the sediments in the CDF.

Figure 7-22 provides a process flow diagram describing the process options included in this remedial alternative. Table 7-8 contains the summary costs to implement Alternative D. Detailed supporting costs are provided in Appendix D. The total volume of sediments to be dredged in this alternative is 4,720,000 cubic yards.

Site Mobilization and CDF Construction. For the concept level FS, the process is staged to construct and complete dredging to the De Pere dam and other CDFs. Site mobilization and preparation includes securing the onshore property area for equipment staging, constructing the CDFs, water treatment, and offshore docking facility for both the mechanical and hydraulic dredges. Site preparation will also include setting a 200 by 200 foot asphalt pad for the HTTD unit.

In addition to physical construction costs, the estimates for the CDFs include long-term (40-year) monitoring and maintenance costs, and mitigation costs for the loss of river bottom habitat.

CDF construction is estimated at $61,300,000.

Sediment Removal. Mechanical dredging of the limited TSCA level volumes will occur prior to initiation of dredging material below the TSCA level. The TSCA level sediment will be thermally treated and placed into the CDF.

Mechanical sediment removal will be conducted using the same methods described for Alternatives A and C. The estimated time to complete dredging is 6.8 years using three dredges.

Sediment removal costs are estimated at $37,300,000.

Sediment Dewatering. There are no separate dewatering costs associated with this alternative. Any dredged sediment from the De Pere to Green Bay reach will be dewatered on barges or within the CDFs.

Water Treatment. Overflow return water from the CDFs will be filtered before discharge to the river, as described previously. Monitoring requirements are expected to be the same as Alternatives A and C. Water treatment costs for Alternative D are $1,000,000.

Sediment Treatment. Thermal destruction of the dewatered TSCA level sediments will involve blending of the high silt/clay sediments with sand to improve HTTD performance. Moisture content of the *in situ* sediment (248,000 cubic yards) is assumed to be 66% (w/w); treated sediment moisture content is assumed to be 10% (w/w). Therefore, the total volume of material (sediments and sand) after treatment is 75,000 cubic yards. The total volume of material (sediments and sand) post-treatment is 75,000 cubic yards. The HTTD will include appropriate treatment of air emissions. Additional costs included in this option are for air emissions and sediment quality testing.

The cost for HTTD destruction and placement in the CDF is $30,400,000.

Demobilization and Site Restoration. Demobilization and site restoration involves removing all equipment, fencing, facilities, etc., from the staging and work areas. The CDFs will be finished with a 3 foot cap of clean soils, and seeded and planted. Additional amenities (i.e., bike paths, wildlife habitat) were not included in the cost estimates.

Long Term Monitoring. As described previously for LLBdM, the "SWAC" monitoring program is applicable here. The long-term monitoring would focus on annual sport fish (i.e., catfish, perch, walleye) sampling to ensure that human health thresholds are not exceeded. To ensure that the CDF is functioning as designed, near-site sediment and water sampling would be conducted on an annual basis for 40 years.

The estimated cost for institutional controls and long-term monitoring is $1,000,000.

Alternative E: Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments, and Disposal of Remaining Sediments in On-Site CDFs

This alternative is similar to Alternative D, except that the TSCA level sediments will be removed and disposed of off-site at a NR 500 W.A.C. landfill. A process flow diagram is provided in Figure 7-23 and the estimated costs are presented in Table 7-8.

Site Preparation and CDF Construction. In addition to the site preparation and CDF construction described in Alternative D, Alternative E will require an upland staging area for the mechanically dredged sediments to be transported off site. All other elements of Alternative E are the same as those described for Alternative D.

CDF construction is estimated at $61,300,000.

Sediment Removal. Mechanical dredging will be the same as described in Alternative D.
Sediment removal costs are estimated at $37,300,000.

Sediment Dewatering. There are no separate dewatering costs associated with this alternative. Any dredged sediment from the De Pere to Green Bay reach will be dewatered on barges or within the CDFs.

Water Treatment. Overflow return water from the CDFs will be filtered before discharge to the river, as described previously. Monitoring requirements are expected to be the same as Alternatives A and C. Water treatment costs for Alternative E are $1,000,000.

Sediment Disposal. Assumptions and unit costs for off-site sediment disposal are similar to those described for Alternative A. The cost for off-site disposal in this alternative is $22,100,000.

Demobilization and Site Restoration. Demobilization and site restoration involves removing all equipment, fencing, facilities, etc., from the staging and work areas. The CDFs will be finished with a 3 foot cap of clean soils, and seeded and planted. Additional amenities (i.e., bike paths, wildlife habitat) were not included in the cost estimates.

Long Term Monitoring. As described previously for LLBdM, the "SWAC" monitoring program is applicable here. The long-term monitoring would focus on annual sport fish (i.e., catfish, perch, walleye) sampling to ensure that human health thresholds are not exceeded. To ensure that the CDF is functioning as designed, near-site sediment and water sampling would be conducted on an annual basis for 40 years.

The estimated cost for institutional controls and long-term monitoring is $1,000,000.

Alternative F: Cap to the Maximum Extent Practicable; Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments

Alternative F includes capping and dredging of sediments to attain the SWAC. The only area that meets the cap criteria defined in Section 6.5.1, is shown in Figure 7-17. The capping area encompasses sediment that has TSCA level

sediments, and depths ranging from less than 3 feet to 9 feet. Those TSCA level sediments require mechanical dredging prior to cap placement, and the post-dredging depth in the shallow area will be increased to at least 4.5 meters. Figure 7-24 provides a process flow diagram describing the process options included in this remedial alternative. Costs for Alternative F are summarized in Table 7-8.

Site Preparation and Cap Construction. Site preparation for dredging will include the upland staging areas discussed in Alternative A and CDF construction described in Alternatives D and E. Cap construction will require an upland staging area for receipt of the armoring stone. Cobble will be placed using a mechanical bucket. All other unit costs are the same as those described previously.

Site preparation costs in this alternative are included under the dredging and capping total costs.

Capping costs under this alternative are estimated to be at $11,500,000. CDF construction is estimated at $61,300,000.

Sediment Removal. Mechanical dredging operations will be conducted using the same techniques described in Alternative E. Sediment removal costs are estimated at $33,700,000.

Sediment Dewatering. Dewatering will be conducted as described for previous alternatives. Costs for dewatering are included in Sediment Removal.

Water Treatment. Overflow return water from the CDF will be filtered before discharge to river, as described previously. Monitoring requirements are expected to be the same as Alternatives A and C. Water treatment costs for Alternative F are $900,000.

Sediment Disposal. Assumptions and unit costs for off-site sediment disposal are similar to those described for Alternative A. The cost for off-site disposal in this alternative is $22,100,000.

Long Term Monitoring. Long-term monitoring would be required to ensure that fish tissue PCB levels remain below the consumption advisory levels and to ensure cap integrity and chemical isolation. The program would involve annual fish tissue sampling, as well as bathymetric or side scan sonar profiling. Diver inspections would also be required to ensure that the cap and armor remained in place.

The estimated cost for institutional controls and long-term monitoring is $1,000,000.

Alternative G: Institutional Controls

Institutional controls may be implemented in combination with any of the proposed remedial alternatives. These include monitoring, access restrictions, dredging moratoriums, fish consumption advisories, and domestic water supply restrictions. Items included in costs for institutional controls are public education programs for fish or health advisories and deed restrictions.

The estimated cost for institutional controls and long-term monitoring is $1,200,000.

Alternative H: No Action

As required under the NCP, a no action alternative is included for the De Pere to Green Bay reach. This alternative involves taking no action and relying on natural processes, such as natural attenuation, dispersion, dilution and sedimentation to reduce contaminant quantities and/or concentrations and control contaminant migration processes. This alternative implies that no active management of remediation is employed; however, some institutional controls, such as access or resource use restrictions, may be employed to reduce risks until RAOs are achieved.

7.5 Section 7 Tables and Figures

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Table 7-1 Physical Characteristics of the Lower Fox River

River Reach	Deposit/ SMU	Total PCB Mass (kg)	Areal Extent			Hydraulic Parameters		Grain Size					
			Surface Area (m^2)	Thickness (m)	Volume (m^3)	Avg. Flow (122 m^3/s) (ft/sec)	100-year Peak (680 m^3/s) (ft/sec)	Sand (%)	Silt (%)	Clay (%)	Percent Moisture	Bulk Density	Specific Gravity
Little Lake Butte Des Morts					2,174,361			36	46	18	64	33.03	2.51
	A	667	151,800	0.82	124,360	0.19	1.10	38	45	17		32.81	
	B	1	147,200	0.42	62,293	0.15	0.85	65	29	10		62.18	
	C	127	118,000	0.67	79,614	0.09	0.50	27	52	21		26.50	2.59
	D	89	251,100	0.27	101,503	0.08	0.44	44	44	12		38.96	
	E	566	2,022,900	0.66	1,541,363	0.08	0.45	28	50	22		33.48	2.43
	F	14	169,000	0.70	118,015	0.10	0.56	27	51	22		19.40	
	G	1	41,400	0.57	23,514	0.35	1.10	56	31	13		42.65	
	H	1	11,300	0.16	1,794	0.35	1.95	68	20	12		56.86	
	POG	328	212,700	0.57	121,905	0.09	0.50	57	34	6		25.26	
Appleton to Little Rapids					982,354			41	43	18	55	36.57	2.38
	I	1	29,800	0.34	10,173	0.30	1.68	35	60	20		50.76	
	J	0	24,900	0.26	6,581	0.30	1.68	15	66	19		40.66	
	K	0	5,400	0.18	995	0.30	1.68	63	22	15		47.85	
	L	0	10,700	0.16	1,753	0.21	1.17	45	45	21		63.90	
	M	0	13,200	0.26	3,473	0.21	1.17	11	63	29		28.78	
	N	86	22,300	0.53	11,853	0.21	1.17	41	45	13		30.41	2.35
	O	3	18,900	0.76	23,684	0.21	1.17	46	44	17		35.40	
	P	45	31,000	0.16	632	0.21	1.17	36	50	14		41.75	
	Q	0	4,000	0.35	2,631	0.21	1.17	49	40	11		30.70	
	R	2	7,600	0.31	2,370	0.21	1.17	12	56	32		61.78	
	S	4	166,100	0.66	109,292	0.23	1.26	47	36	18		45.22	
	T	12	20,600	0.67	13,817	0.21	1.18	88	11	5		28.97	
	U	1	17,700	0.36	6,379	0.21	1.18	52	48	13		47.54	
	V	2	24,000	0.54	13,040	0.65	0.82	32	52	16		25.90	
	W	53	562,700	0.72	407,114	0.65	0.82	48	35	17		42.64	2.34
	X	41	255,500	0.68	173,366	0.65	0.82	34	53	14		32.86	2.54
	Y	0	31,600	0.24	7,441	0.65	0.93	45	40	15		41.65	
	Z	0	24,500	0.51	12,415	0.65	0.93	35	43	23		47.64	
	AA	0	8,400	0.15	1,284	0.27	1.49	55	21	25		73.66	
	BB	0	15,800	0.18	2,918	0.27	1.49	48	33	19		58.06	
	CC	2	83,300	0.72	59,864	0.27	1.49	31	26	43		57.41	
	DD	96	148,400	0.75	111,279	0.19	1.04	34	42	25		40.37	
Little Rapids to DePere					2,266,126			26	51	22	64	33.36	2.47
	EE	1,422	2,586,300	0.86	2,224,176	0.12	0.68	28	50	23		31.54	2.47
	FF	5	4,900	0.43	2,115	0.12	0.68	27	52	21		45.11	
	GG	70	24,200	0.59	14,350	0.12	0.68	18	58	23		29.85	
	HH	51	44,600	0.57	25,485	0.12	0.68	22	57	18		32.83	
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Table 7-1 Physical Characteristics of the Lower Fox River (Continued)

River Reach	Deposit/ SMU	Total PCB Mass (kg)	Areal Extent			Hydraulic Parameters		Grain Size					
			Surface Area (m^2)	Thickness (m)	Volume (m^3)	Avg. Flow (122 m^3/s) (ft/sec)	100-year Peak (680 m^3/s) (ft/sec)	Sand (%)	Silt (%)	Clay (%)	Percent Moisture	Bulk Density	Specific Gravity
DePere to Green Bay					5,778,259			37	47	17	51	36.54	2.36
	20	1,449	384,200	1.16	446,433	0.07	0.39						
	21	487	151,200	1.15	173,648	0.07	0.39						
	22	521	102,200	1.50	153,385	0.07	0.39						
	23	60	142,100	0.71	100,496	0.07	0.39						
	24	776	106,500	1.22	130,199	0.07	0.39						
	25	474	134,400	0.85	114,764	0.11	0.39						
	26	23	16,200	0.57	9,247	0.11	0.61						
	27	32	18,900	0.34	6,332	0.11	0.61						
	28	205	70,000	0.59	41,230	0.11	0.61						
	29	406	80,300	1.26	101,180	0.11	0.61						
	30	16	13,500	0.26	3,481	0.11	0.61						
	31	9	18,900	0.21	4,016	0.11	0.61						
	32	144	46,200	0.57	26,539	0.10	0.53						
	33	40	53,000	0.25	13,499	0.10	0.53						
	34	368	62,800	1.34	84,199	0.10	0.53						
	35	440	73,600	1.36	100,080	0.10	0.53						
	36	9	14,600	0.15	2,222	0.10	0.53						
	37	8	19,900	0.50	9,986	0.10	0.53						
	38	117	50,000	0.69	34,697	0.08	0.43						
	39	25	26,900	0.56	15,110	0.08	0.43						
	40	629	96,100	1.26	121,476	0.08	0.43						
	41	836	133,200	1.16	154,894	0.08	0.43						
	42	88	55,000	0.26	14,222	0.08	0.43						
	43	43	104,900	0.60	63,167	0.08	0.43						
	44	111	116,900	0.77	90,377	0.07	0.37						
	45	819	186,800	1.13	210,898	0.07	0.37						
	46	383	174,100	1.21	210,718	0.07	0.37						
	47	1,008	151,500	1.83	277,438	0.07	0.37						
	48	495	187,900	1.23	231,572	0.07	0.37						
	49	1,305	250,900	1.46	366,314	0.07	0.37						

Table 7-1 Physical Characteristics of the Lower Fox River (Continued)

River Reach	Deposit/ SMU	Total PCB Mass (kg)	Areal Extent			Hydraulic Parameters		Grain Size					
			Surface Area (m^2)	Thickness (m)	Volume (m^3)	Avg. Flow (122 m^3/s) (ft/sec)	100-year Peak (680 m^3/s) (ft/sec)	Sand (%)	Silt (%)	Clay (%)	Percent Moisture	Bulk Density	Specific Gravity
	50	41	26,200	0.97	25,345	0.08	0.47						
	51	46	24,400	1.30	31,687	0.08	0.47						
	52	875	103,100	1.74	178,971	0.08	0.47						
	53	148	97,700	1.35	131,801	0.08	0.47						
	54	121	58,700	0.61	35,633	0.08	0.47						
	55	5	20,500	0.17	3,550	0.08	0.47						
	56	2,005	66,900	2.15	143,841	0.06	0.36						
	57	2,667	86,200	2.16	186,034	0.06	0.36						
	58	422	30,800	2.12	65,198	0.06	0.36						
	59	213	26,700	1.31	35,052	0.06	0.36						
	60	41	31,400	0.35	10,875	0.06	0.36						
	61	225	43,700	1.01	44,284	0.06	0.36						
	62	661	49,400	1.69	83,431	0.07	0.37						
	63	14	4,900	2.60	12,740	0.07	0.37						
	64	19	18,200	0.30	5,484	0.07	0.37						
	65	183	36,100	2.40	86,720	0.07	0.37						
	66	0	8,100	1.94	15,740	0.07	0.37						
	67	71	4,800	2.76	13,240	0.07	0.37						
	68	48	400	2.73	1,090	0.06	0.37						
	69	3	85,200	2.84	241,585	0.06	0.37						
	70	1,464	38,300	2.80	107,218	0.06	0.37						
	71	540	2,500	1.90	4,750	0.06	0.37						
	72	17	4,200	2.60	10,920	0.06	0.37						
	73	50	500	2.10	1,050	0.07	0.38						
	74	3	500	1.50	750	0.07	0.38						
	75	0	36,700	2.96	108,658	0.07	0.38						
	76	300	27,900	1.33	37,050	0.07	0.38						
	77	56	2,600	3.70	9,620	0.07	0.38						
	78	19	2,200	1.31	2,890	0.07	0.38						
	79	2	5,300	2.20	11,670	0.07	0.38						
	80	7	1,300	3.11	4,040	0.09	0.49						
	81	10	36,100	1.85	66,743	0.09	0.49						
	82	43	29,600	2.93	86,610	0.09	0.49						
	83	295	5,200	1.37	7,131	0.09	0.49						
	84	3	3,600	3.00	10,800	0.09	0.49						
	85	34	8,600	2.58	22,200	0.09	0.49						
	86	39	3,900	1.80	7,020	0.08	0.45						
	87	3	32,600	2.05	66,694	0.08	0.45						
	88	144	11,300	1.57	17,757	0.08	0.45						
	89	34	4,700	0.50	2,350	0.08	0.45						

Table 7-1 Physical Characteristics of the Lower Fox River (Continued)

River Reach	Deposit/ SMU	Total PCB Mass (kg)	Areal Extent			Hydraulic Parameters		Grain Size					
			Surface Area (m^2)	Thickness (m)	Volume (m^3)	Avg. Flow (122 m^3/s) (ft/sec)	100-year Peak (680 m^3/s) (ft/sec)	Sand (%)	Silt (%)	Clay (%)	Percent Moisture	Bulk Density	Specific Gravity
	90	4	1,400	0.89	1,240	0.08	0.45						
	91	3	300	1.10	330	0.08	0.45						
	92	1	3,600	1.10	3,960	no data	no data						
	93	5	50,900	1.21	61,746	no data	no data						
	94	104	29,400	1.14	33,660	no data	no data						
	95	31	11,800	1.58	18,702	no data	no data						
	96	18	5,100	1.20	6,120	no data	no data						
	97	2	3,200	1.20	3,840	no data	no data						
	98	0	9,600	1.50	14,400	no data	no data						
	99	14	29,700	1.20	35,640	no data	no data						
	100	3	27,700	1.50	41,550	no data	no data						
	101	56	2,700	1.20	3,240	no data	no data						
	102	0	3,600	1.50	5,400	no data	no data						
	103	11	10,600	0.30	3,180	no data	no data						
	104	1	4,000	1.16	4,640	no data	no data						
	105	18	28,600	0.63	18,120	no data	no data						
	106	41	35,600	0.77	27,408	no data	no data						
	107	46	11,500	1.13	13,050	no data	no data						
	108	32	8,600	0.85	7,269	no data	no data						
	109	7	7,400	1.42	10,492	no data	no data						
	110	36	5,700	2.53	14,442	no data	no data						
	111	52	40,100	1.65	66,119	no data	no data						
	112	195	52,400	2.09	109,601	no data	no data						
	113	456	4,500	1.35	6,090	no data	no data						
	114	10	32,100	0.56	17,980	no data	no data						

Table 7-2 Summary of Remedial Alternatives - Little Lake Butte des Morts

	Alternative A		Alternative B		Alternative C		Alternative D		Alternative E	
	Non-TSCA	TSCA	Non-TSCA	TSCA	Non-TSCA	TSCA	Non-TSCA	TSCA	Non-TSCA	TSCA
Sediment Removal Volume (1000 cy)	1563	63	1066	63	805	63	805	63	679	63
Mass of PCB (kg)										
Removal										
Hydraulic	✔	✔	✔	✔	✔		✔	✔	✔	✔
Mechanical						✔				✔ (8000 cy)
Dewatering										
Mechanical								✔		
Passive (ponds on Arrowhead Park)	✔	✔	✔	✔					✔	✔
Passive (on barge)						✔				✔
Passive (in on-site CDFs)					✔		✔			
Treatment (HTTD)						✔				
Disposal										
Off-site (NR 500 Landfill)	✔	✔	✔	✔				✔	✔	✔
On-site CDF					✔	✔	✔			
Capping										
Armored									✔ (6 mil ft^2)	

Table 7-3 Cost Summary for Remedial Alternatives - Little Lake Butte des Morts

Alternative	Hydraulic Dredging	Mechanical Dredging	Capping	Dewatering	Water Treatment	Sediment Treatment	CDF Construction	Off-site Disposal	Institutional Controls	TOTAL
A	$5,600,000	---	---	$1,200,000	$1,800,000	---	---	$84,900,000	---	$93,500,000
B	$4,100,000	---	---	$1,200,000	$1,600,000	---	---	$59,100,000	$1,000,000	$67,000,000
C	$3,100,000	$3,000,000	---	---	$1,400,000	$10,400,000	$39,300,000	---	$1,000,000	$58,200,000
D	$4,200,000	---	---	$1,700,000	$1,500,000	---	$39,300,000	$3,800,000	$1,000,000	$51,500,000
E	$2,900,000	$1,500,000	$9,600,000	$1,200,000	$1,400,000	---	---	$39,000,000	$1,000,000	$56,600,000
F	---	---	---	---	---	---	---	---	$1,200,000	$1,200,000
G	---	---	---	---	---	---	---	---	---	$0

Table 7-4 Cost Summary for Remedial Alternatives - Appleton to Little Rapids

Alternative	Hydraulic Dredging	Dewatering	Water Treatment	Off-site Disposal	Institutional Controls	TOTAL
A	$6,200,000	$320,000	$740,000	$16,400,000	---	$23,660,000
B	---	---	---	---	$1,200,000	$1,200,000
C	---	---	---	---	---	$0

Table 7-5 Summary of Remedial Alternatives - Little Rapids to De Pere Dam

	Alternative A		Alternative B		Alternative C		Alternative D		Alternative E		Alternative F	
	Non-TSCA	TSCA	Non-TSCA	TSCA	Non-TSCA	TSCA	Non-TSCA	TSCA	Non-TSCA	TSCA	Non-TSCA	TSCA
Sediment Removal Volume (1000 cy)	1188	0	1188	0	1065	0	1065	0	593	0	0	0
Mass of PCB (kg)												
Removal												
Hydraulic	✔		✔		✔		✔		✔			
Mechanical												
Dewatering												
Passive (gravity dewatering ponds)	✔				✔							
Passive (in Monofill)			✔									
Treatment (HTTD)												
Disposal												
Off-site (NR 500 Landfill)	✔				✔							
Off-site (new NR 500 Monofill			✔									
On-site CDF							✔		✔			
Capping												
Sand									✔ (8 mil ft^2)		✔ (12 mil ft^2)	

Table 7-6 Cost Summary for Remedial Alternatives - Little Rapids to De Pere Dam

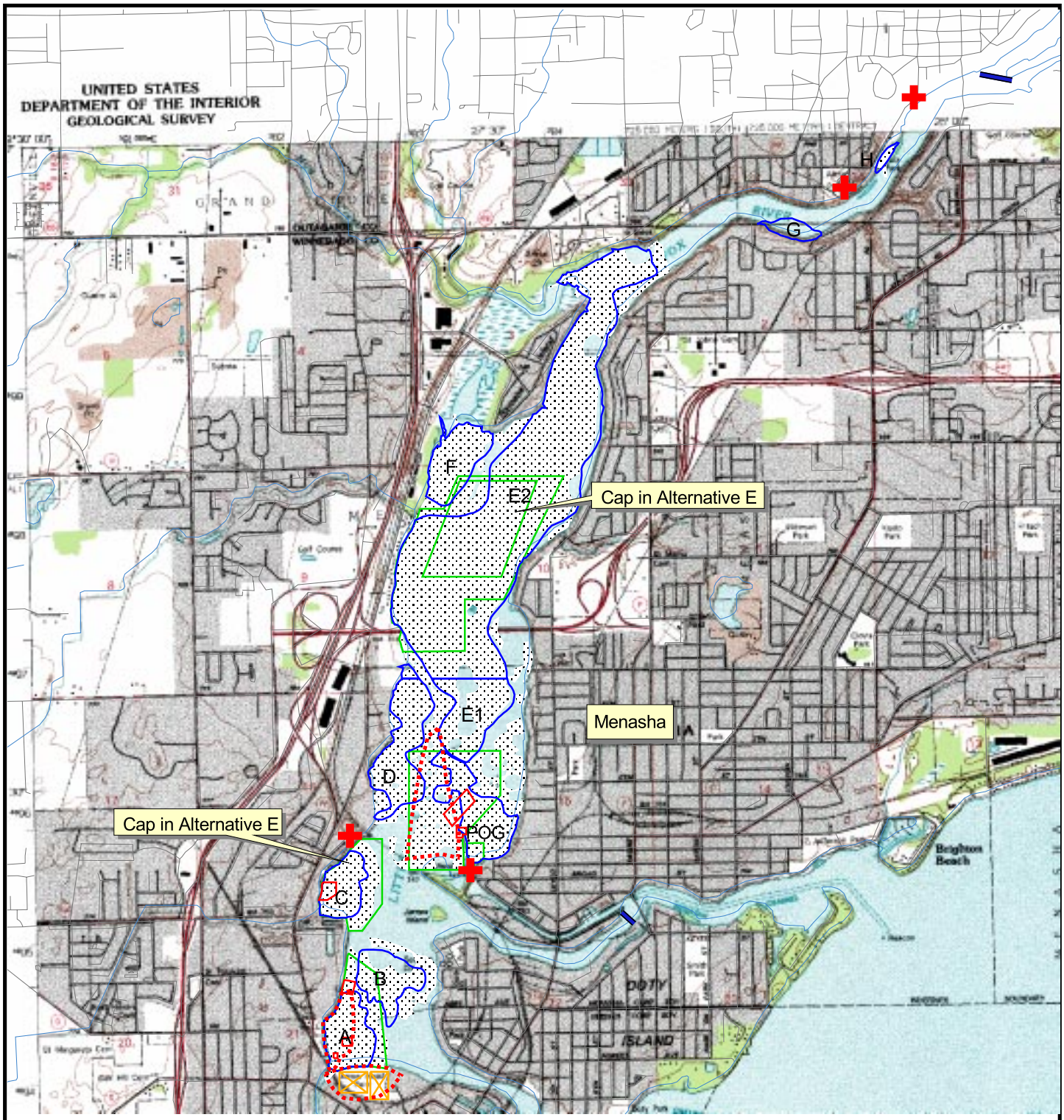
Alternative	Hydraulic Dredging	Capping	Dewatering	Water Treatment	Off-site Disposal	Institutional Controls	TOTAL
A	$4,100,000	---	$1,200,000	$1,500,000	$107,000,000	---	$113,800,000
B	$5,000,000	---	---	$1,500,000	$15,700,000	---	$22,200,000
C	$3,700,000	---	$1,200,000	$1,400,000	$95,900,000	$1,000,000	$103,200,000
D	$3,700,000	---	---	$1,400,000	$23,200,000	$1,000,000	$29,300,000
E	$2,300,000	$14,300,000	---	$1,300,000	$23,200,000	$1,000,000	$42,100,000
F	---	$21,000,000	---	---	---	$1,000,000	$22,000,000
G	---	---	---	---	---	$1,200,000	$1,200,000
H	---	---	---	---	---	---	$0

Table 7-7 Summary of Remedial Alternatives - De Pere Dam to Green Bay

	Alternative A		Alternative B		Alternative C		Alternative D		Alternative E		Alternative F	
	Non-TSCA	TSCA	Non-TSCA	TSCA	Non-TSCA	TSCA	Non-TSCA	TSCA	Non-TSCA	TSCA	Non-TSCA	TSCA
Sediment Removal Volume (1000 cy)	5440	250	5440	250	4815	250	4471	250	4471	250	4011	250
Mass of PCB (kg)												
Removal												
Hydraulic			✔	✔								
Mechanical	✔	✔			✔	✔	✔	✔	✔	✔	✔	✔
Dewatering												
Passive (on barge)	✔	✔			✔	✔	✔	✔	✔	✔	✔	✔
Passive (in Monofill)			✔	✔								
Passive (in on-site CDFs)							✔		✔		✔	
Treatment (HTTD)								✔				
Disposal												
Off-site (NR 500 Landfill)	✔	✔			✔	✔				✔		✔
Off-site (new NR 500 Monofill			✔	✔								
On-site CDF							✔	✔	✔		✔	
Capping												
Sand											✔ (6 mil ft^2)	

Table 7-8 Cost Summary for Remedial Alternatives - De Pere Dam to Green Bay

Alternative	Hydraulic Dredging	Mechanical Dredging	Capping	Water Treatment	Sediment Treatment	CDF Construction	Off-site Disposal	Institutional Controls	TOTAL
A	---	$44,900,000	---	$1,100,000	---	---	$444,000,000	---	$490,000,000
B	$21,600,000	---	---	$8,600,000	---	---	$15,700,000	---	$45,900,000
C	---	$40,000,000	---	$1,000,000	---	---	$395,600,000	$1,000,000	$437,600,000
D	---	$37,300,000	---	$1,000,000	$30,400,000	$61,300,000	---	$1,000,000	$131,000,000
E	---	$37,300,000	---	$1,000,000	---	$61,300,000	$22,100,000	$1,000,000	$122,700,000
F	---	$33,700,000	$11,500,000	$900,000	---	$61,300,000	$22,100,000	$1,000,000	$130,500,000
G	---	---	---	---	---	---	---	$1,200,000	$1,200,000
H	---	---	---	---	---	---	---	---	$0



N

1 0 1 Miles

Possible nearshore confined disposal facility
Upland staging
TSCA Areas
Possible Equipment Access
Deposits
SWAC Remediation Areas
Dam Locations
Water
Target Remediation Areas
PCB Concentrations >250 ug/kg

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LOWER FOX RIVER FEASIBILITY STUDY 3-3584-999		LITTLE LAKE BUTTE DES MORTES SEDIMENT MANAGEMENT AREAS	
DATE: 2/12/1999	FOXRIVER.APR		FIGURE 7-1

Figure 7-2 Preliminary Concept Design for the Arrowhead Confined Disposal Facility

Figure 7-3 Preliminary Concept Design for the Menasha Confined Disposal Facility

Figure 7-4
Little Lake Butte des Morts, Alternative A: Dredge Sediment >250 ppb With Off-site Disposal

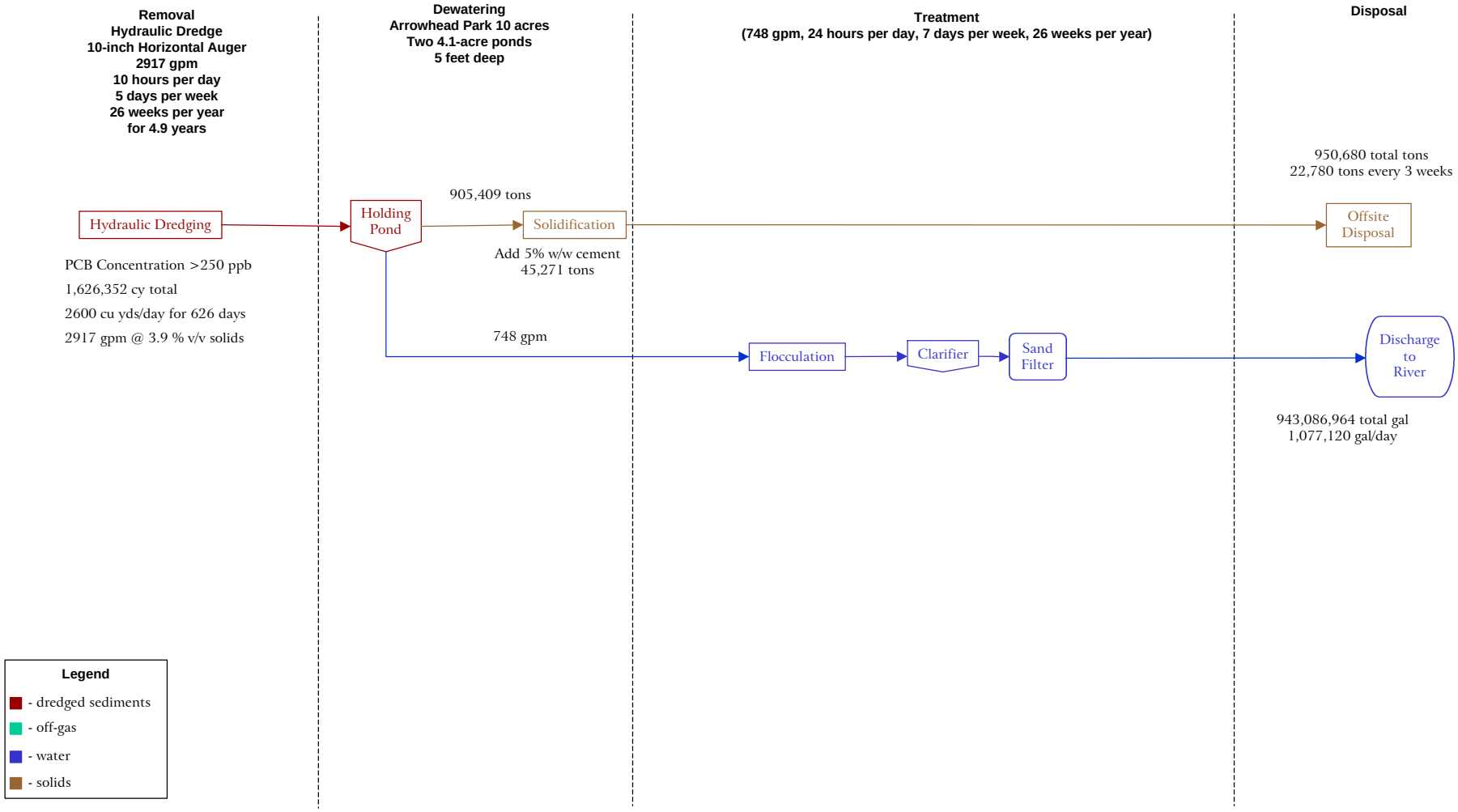


Figure 7-5
Little Lake Butte des Morts, Alternative B: Dredge Sediment to SWAC With Off-site Disposal

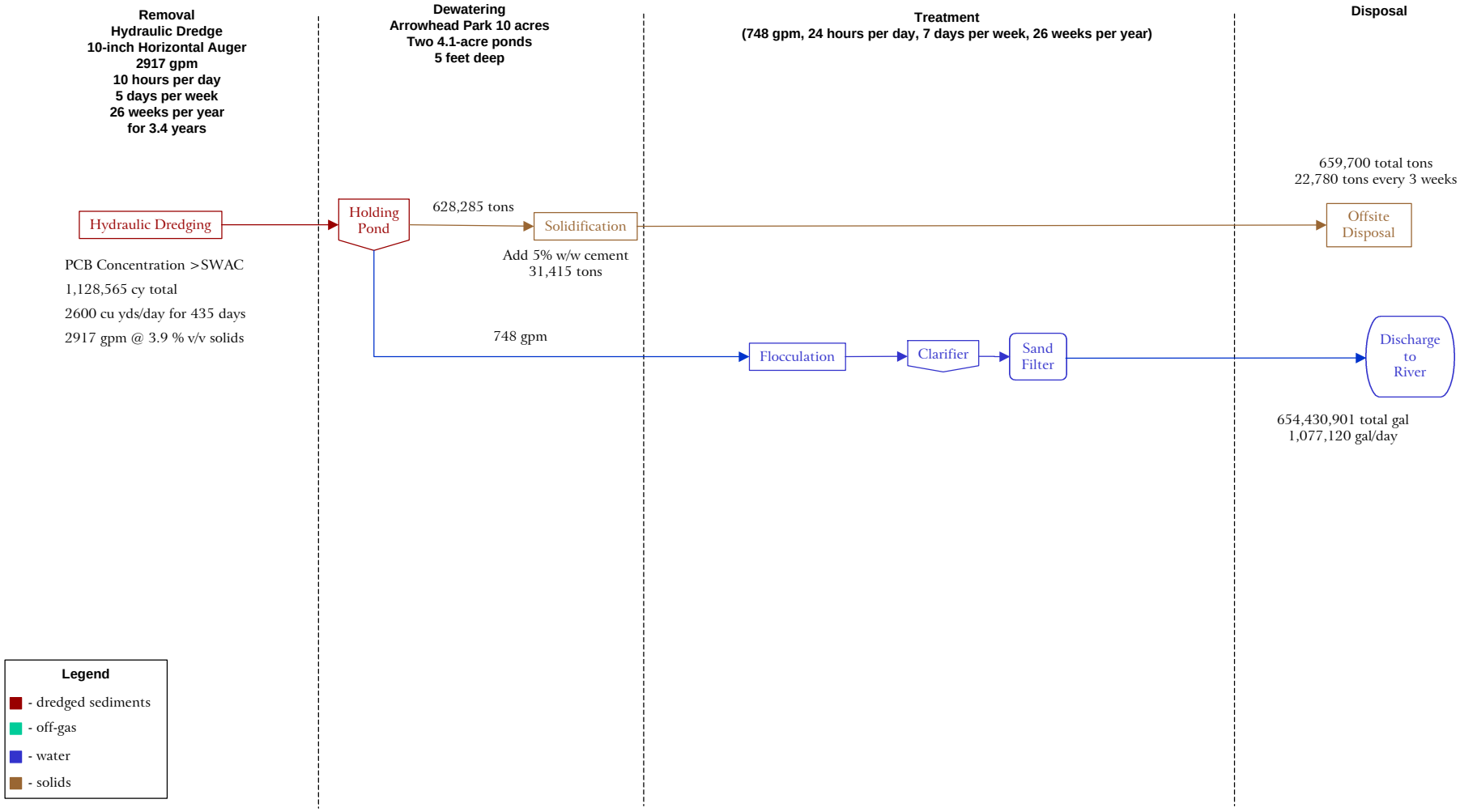


Figure 7-6
Little Lake Butte des Morts, Alternative C: Dredge Sediment to SWAC, On-site HTTD, Dispose in On-site CDF

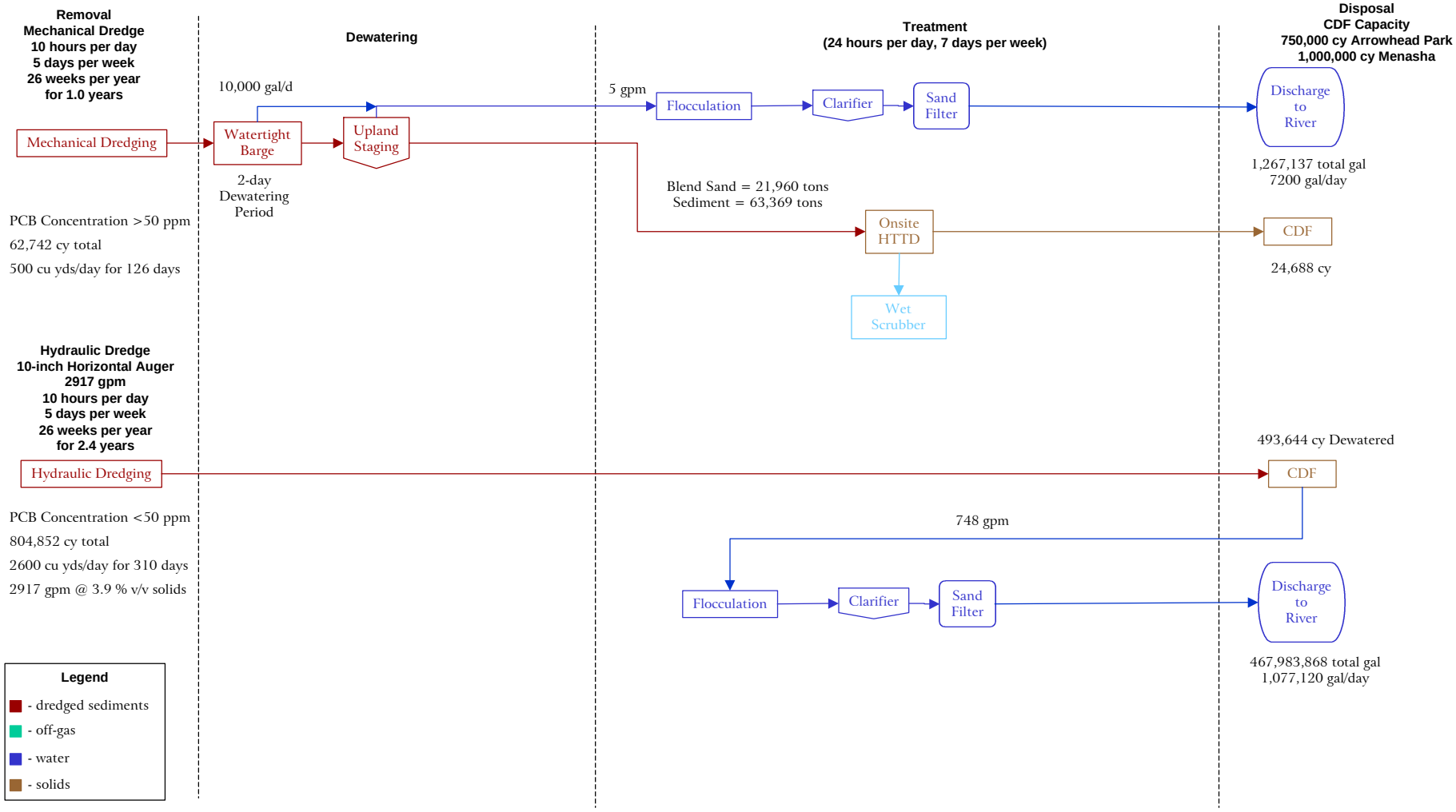


Figure 7-7
Little Lake Butte des Morts, Alternative D: Dredge Sediment to SWAC With Off-site Disposal of TSCA Materials and On-site CDF

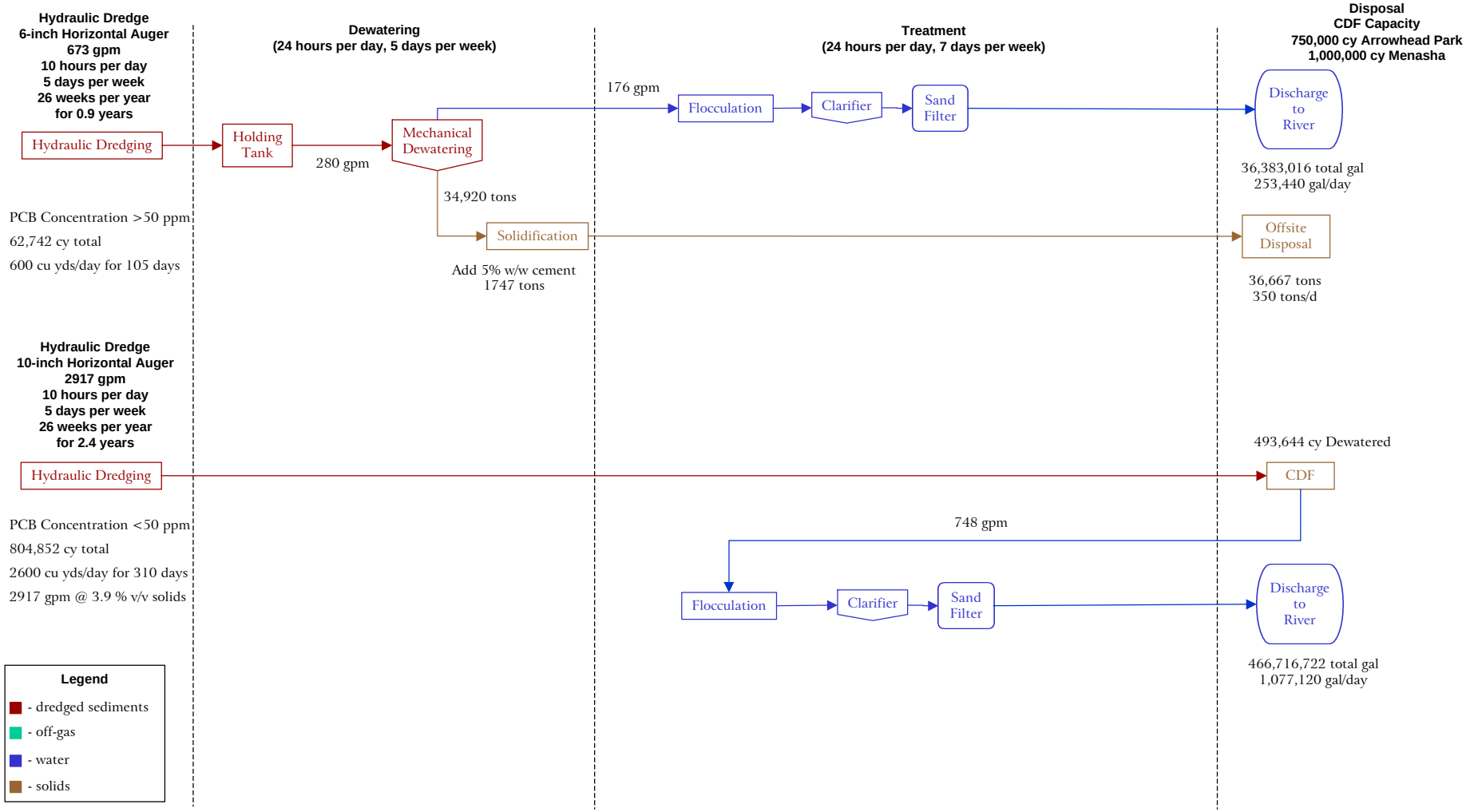
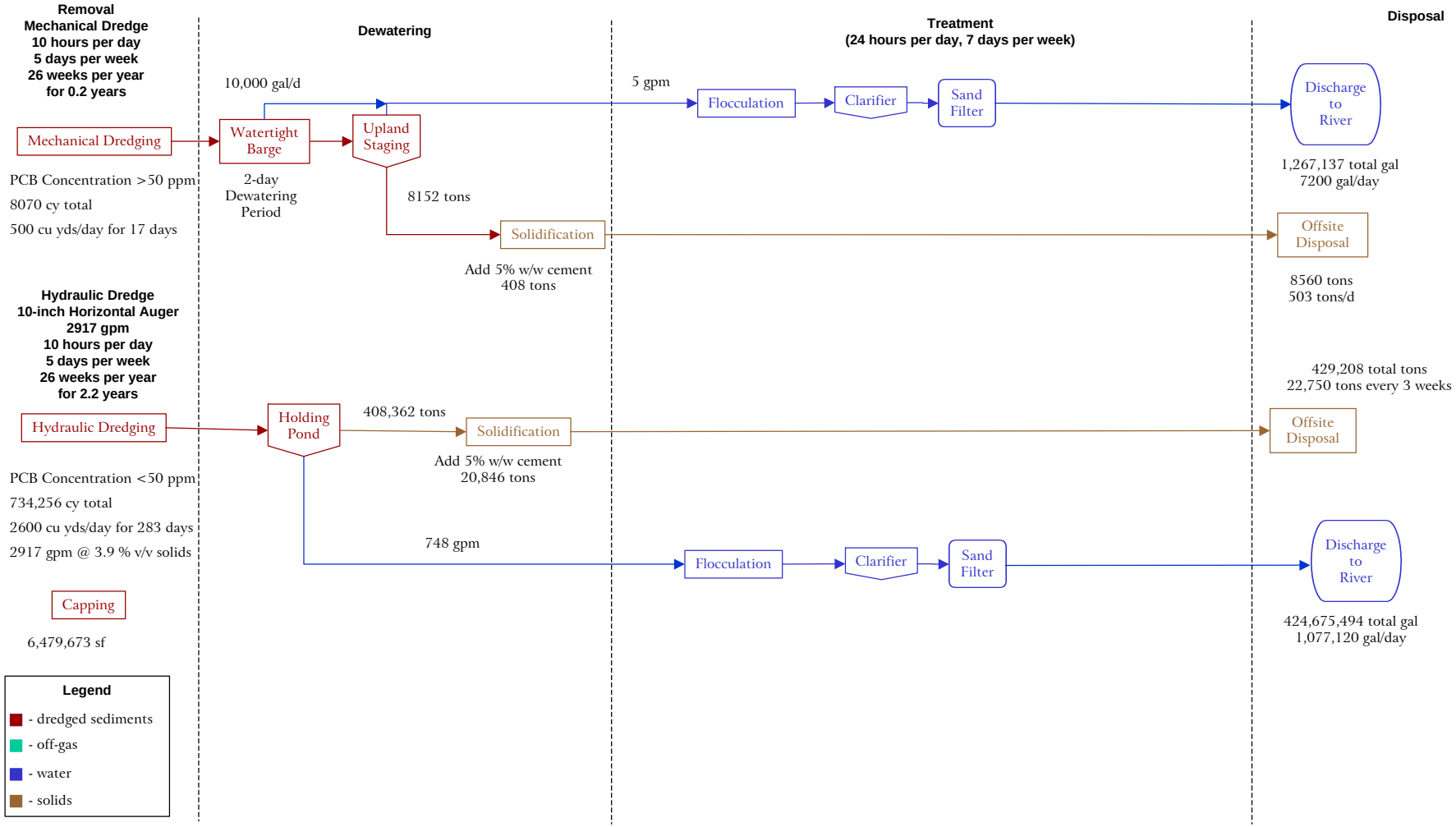
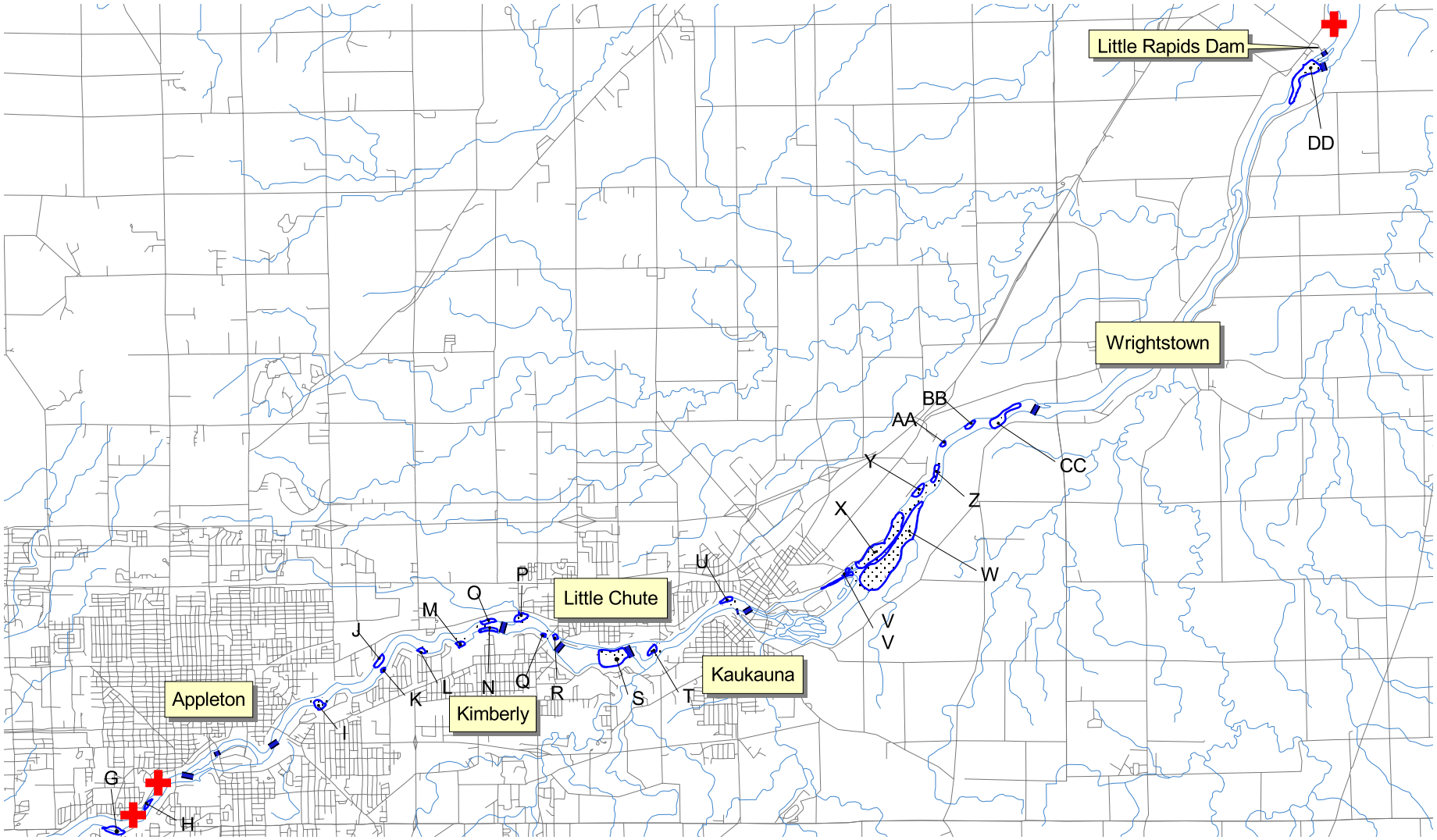


Figure 7-8
Little Lake Butte des Morts, Alternative E: Cap Sediment to the Maximum Extent Possible and Dredge to Attain SWAC With Off-site Disposal





N

1 0 1 2 Miles

Possible nearshore confined disposal facility
Upland staging
TSCA Areas
Possible Equipment Access
Deposits
SWAC Remediation Areas
Dam Locations
Water
Target Remediation Areas
PCB Concentrations >250 ug/kg

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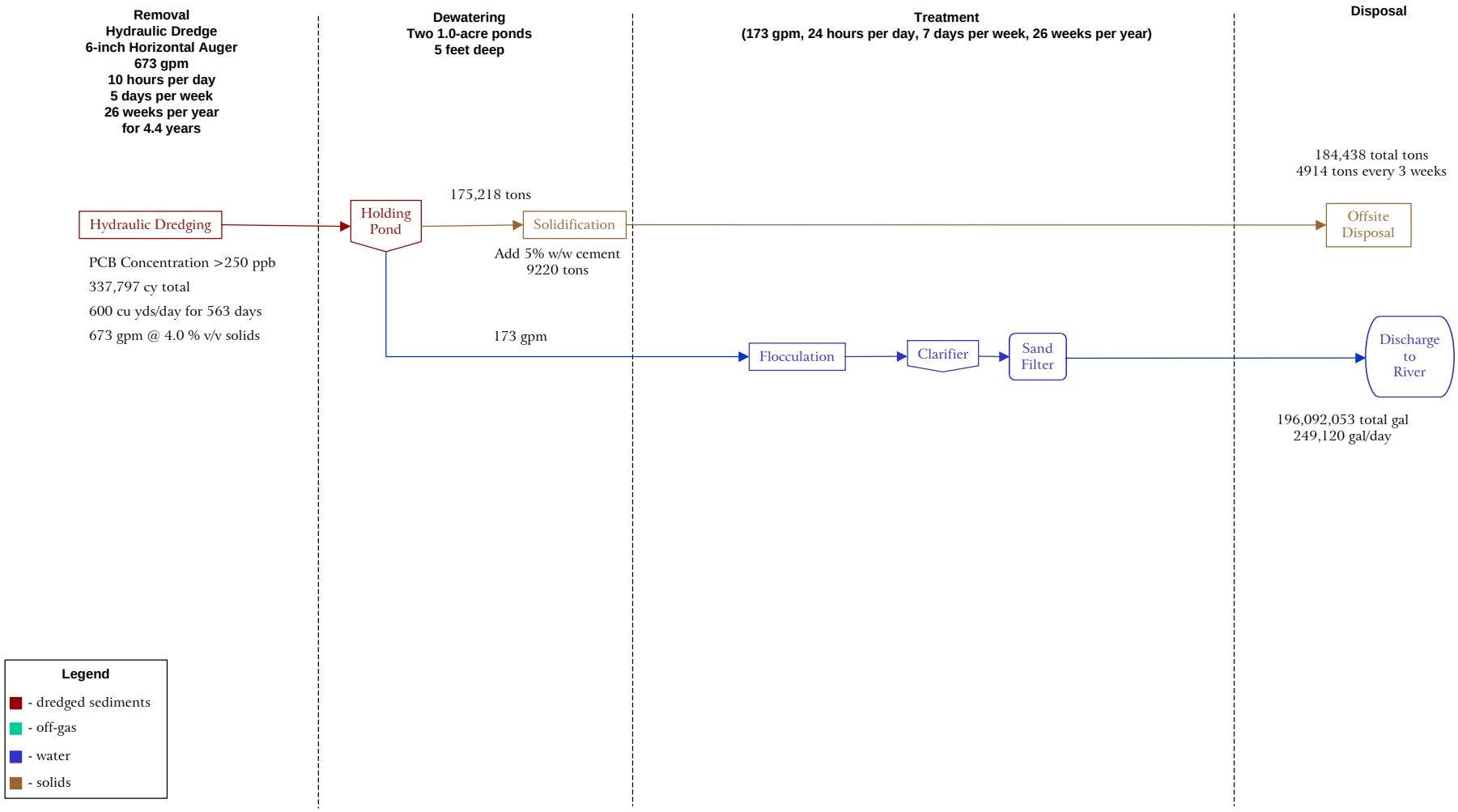
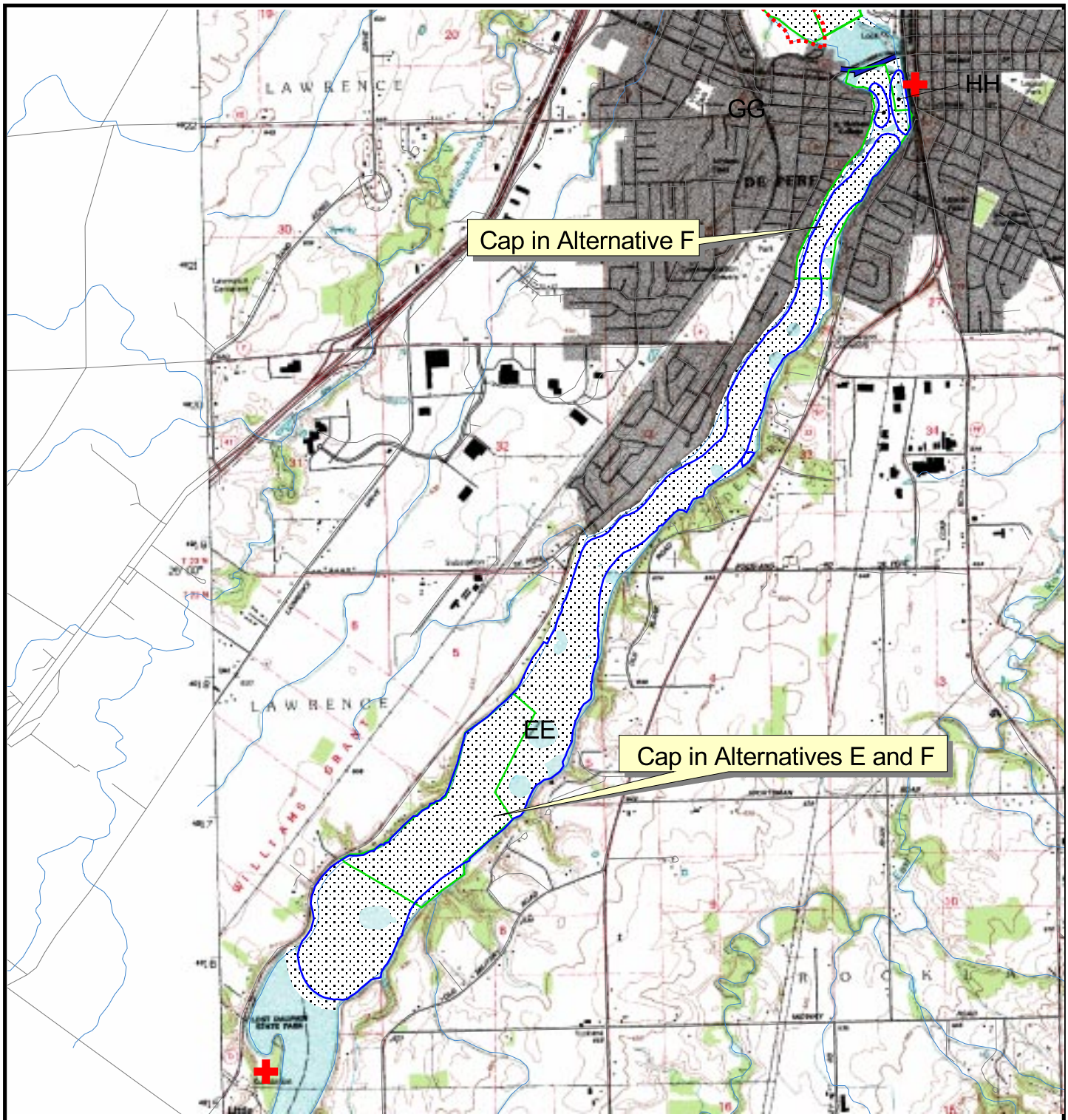
Figure 7-10
Appleton to Little Rapids, Alternative A: Dredge Sediment >250 ppb With Off-site Disposal





N

0.6 0 0.6 1.2 Miles

Possible nearshore confined disposal facility
Upland staging
TSCA Areas
Possible Equipment Access
Deposits
SCAW Remediation Areas
Dam Locations
Water
Target Remediations Areas
PCB Concentrations >250 ug/kg

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LOWER FOX RIVER FEASIBILITY STUDY 3-3584-999		LITTLE RAPIDS TO DePERE SEDIMENT MANAGEMENT AREAS	
DATE: 2/12/1999	FOXRIVER.APR		FIGURE 7-11

Figure 7-12
Little Rapids to De Pere Dam, Alternative A: Dredge Sediment >250 ppb With Off-site Disposal

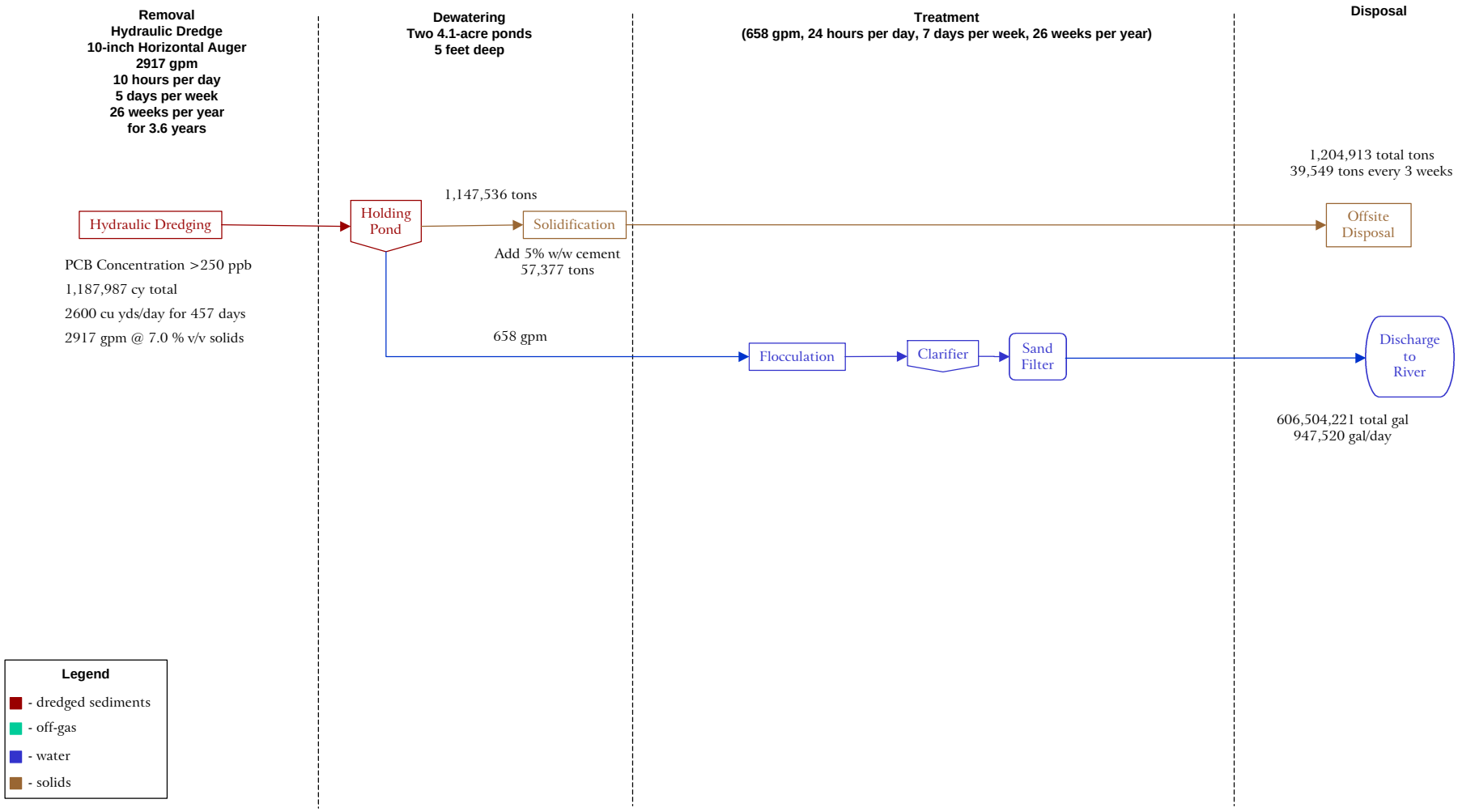


Figure 7-13
Little Rapids to De Pere Dam, Alternative B: Dredge Sediment >250 ppb and Pump Dredged Sediments to Off-site Landfill

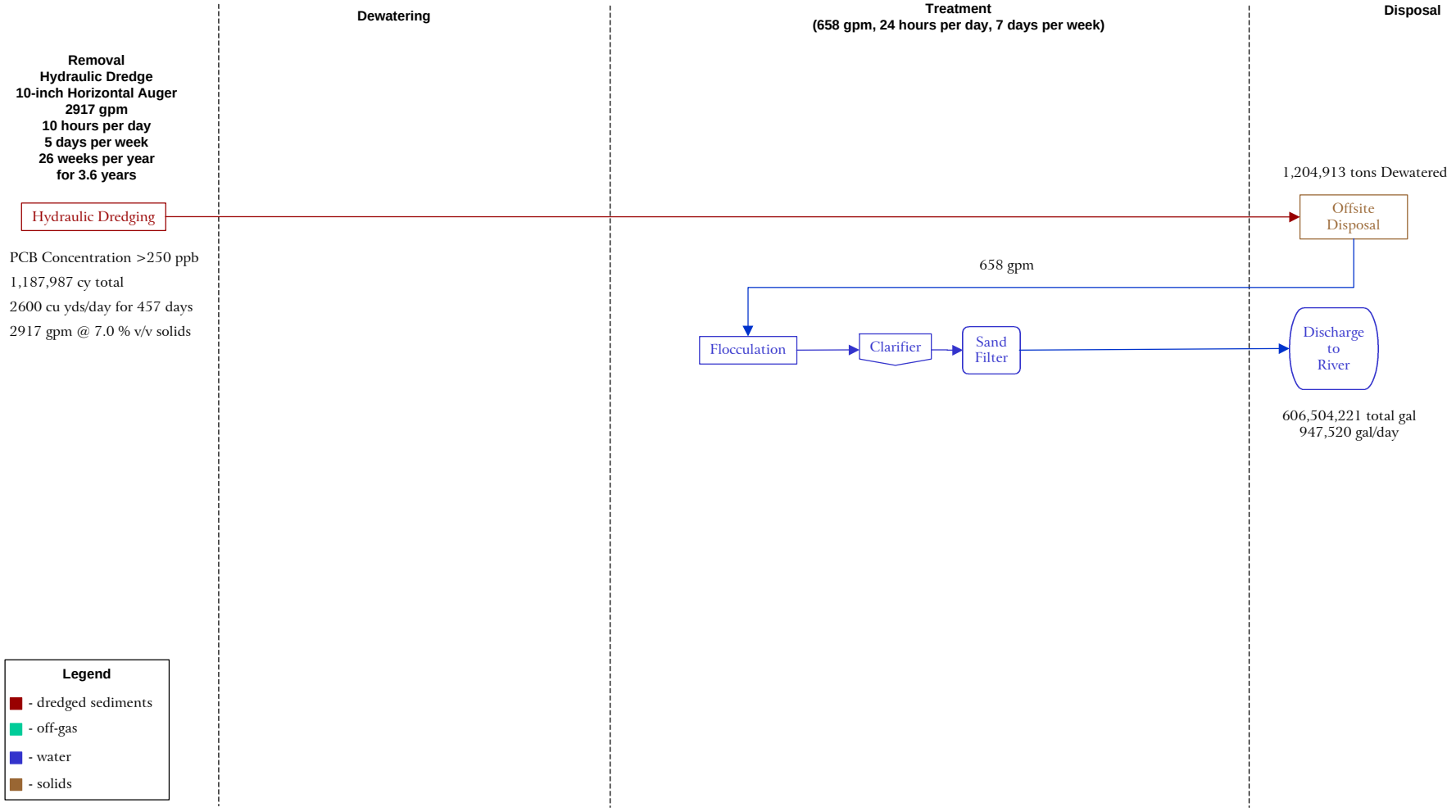


Figure 7-14
Little Rapids to De Pere Dam, Alternative C: Dredge Sediment to SWAC With Off-site Disposal

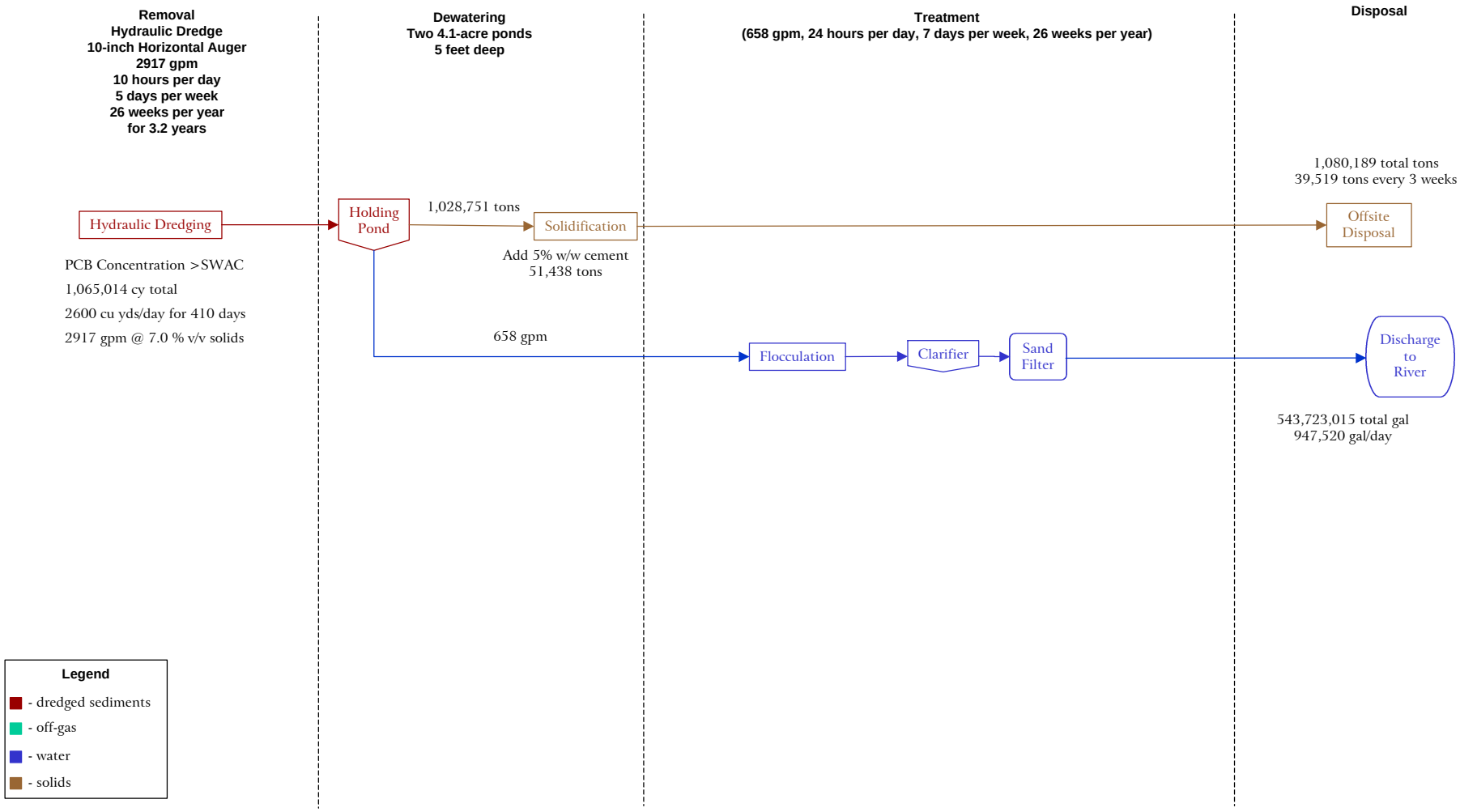


Figure 7-15
Little Rapids to De Pere Dam, Alternative D: Dredge Sediment to SWAC With On-site CDF

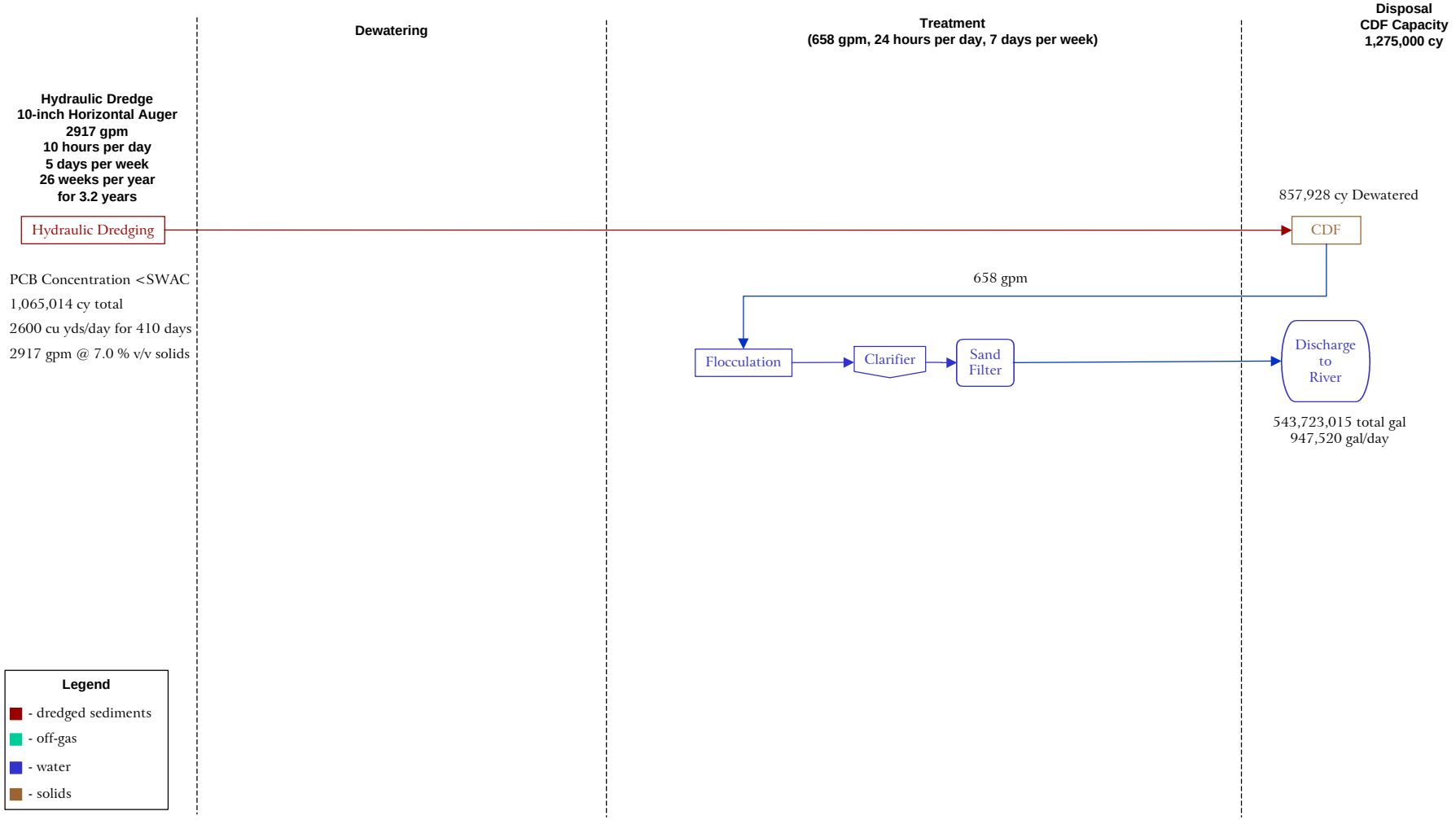
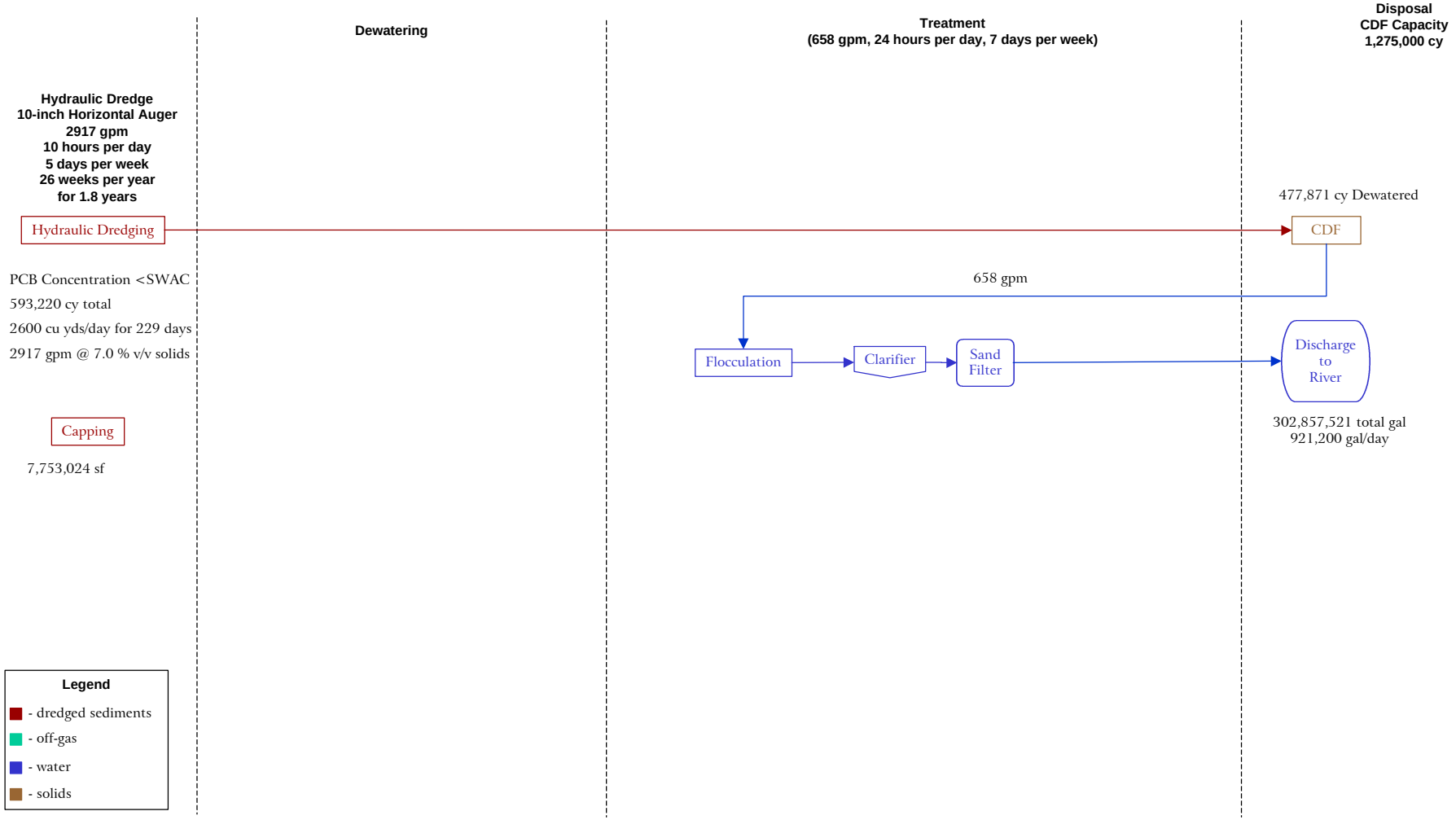
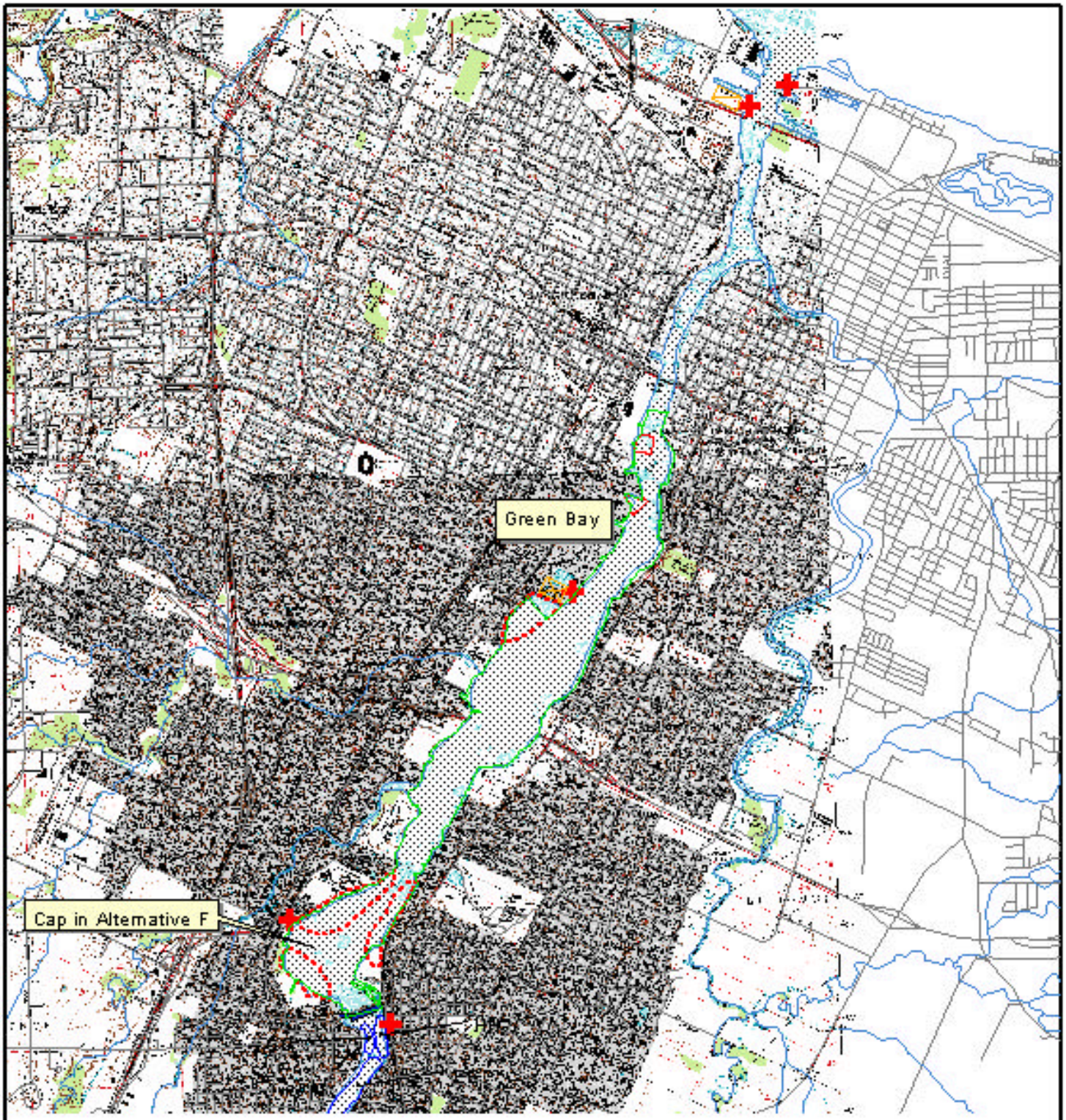


Figure 7-16
Little Rapids to De Pere Dam, Alternative E: Cap Sediment to the Maximum Extent Possible and Dredge to Attain SWAC With On-site CDF





N

1 0 1 2 Miles

Remediation_areas_depere.shp
Possible nearshore confined disposal facility
Upland staging
TSCA Areas
Possible Equipment Access
Deposits
Dam Locations
Water
Target Remediation Areas
PCB Concentrations >250 ug/kg

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DePERE TO GREEN BAY
SEDIMENT MANAGEMENT AREAS

FIGURE 7-17

Figure 7-18 DePere to Green Bay: Preliminary Concept Design for the DePere Confined Disposal Facility

Figure 7-19
De Pere Dam to Green Bay, Alternative A: Dredge Sediment to >250 ppb With Off-site Disposal

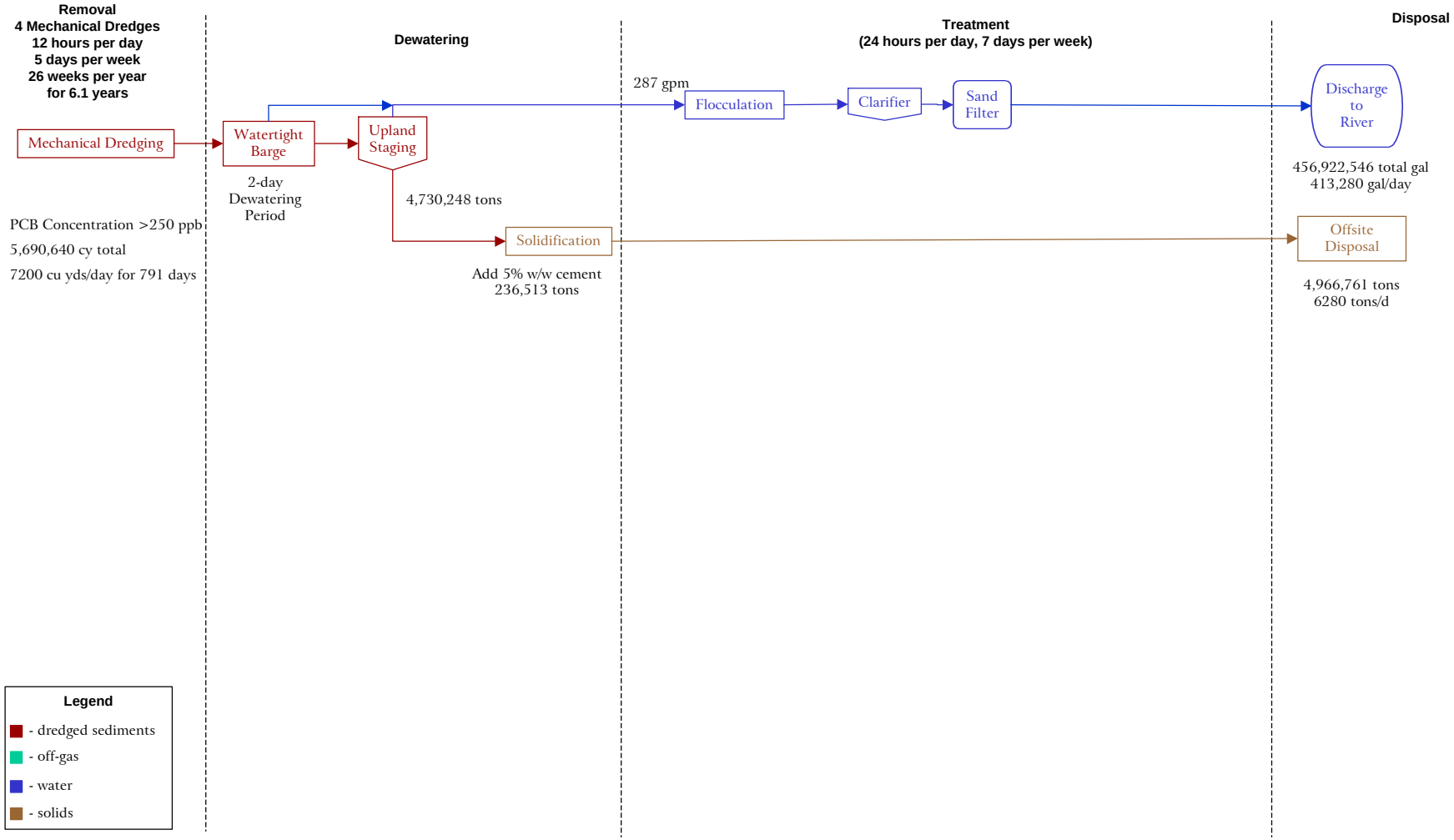


Figure 7-20
De Pere Dam to Green Bay, Alternative B: Dredge Sediment >250 ppb and Pump Dredged Sediments to Off-site Landfill

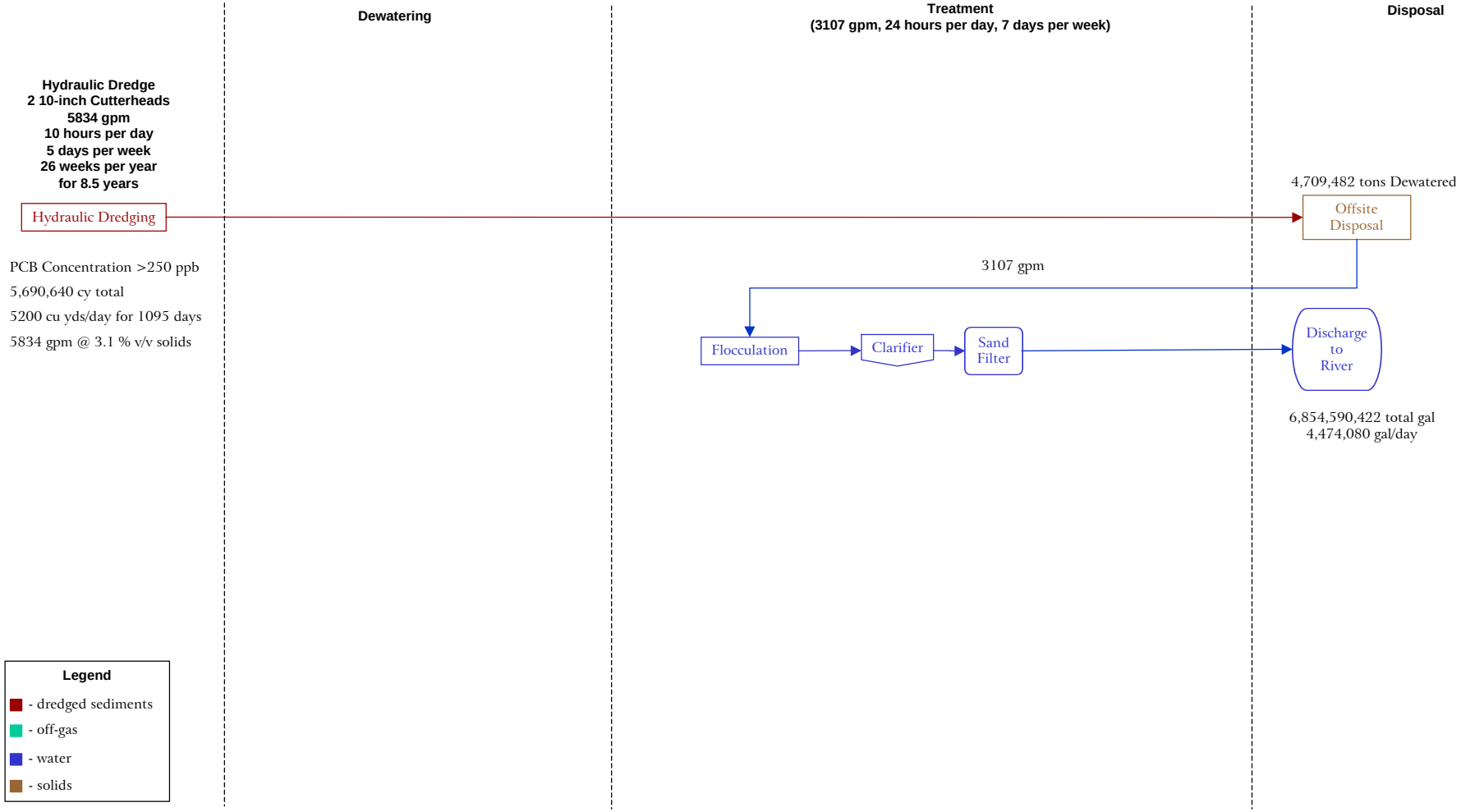


Figure 7-21
De Pere Dam to Green Bay, Alternative C: Dredge Sediment to SWAC With Off-site Disposal

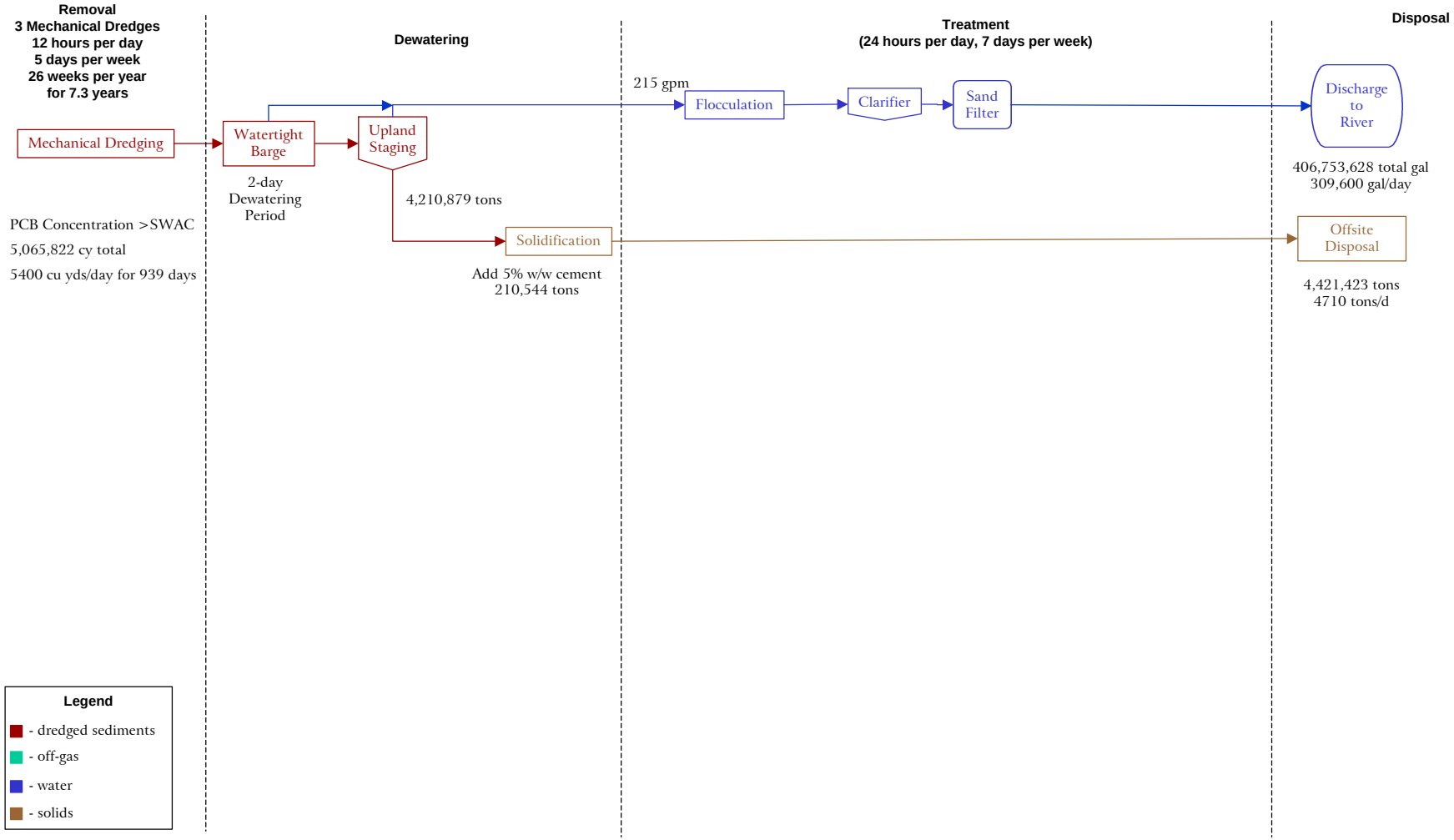


Figure 7-22
De Pere Dam to Green Bay, Alternative D: Dredge Sediment to SWAC, On-site HTTD, Dispose in On-site CDF

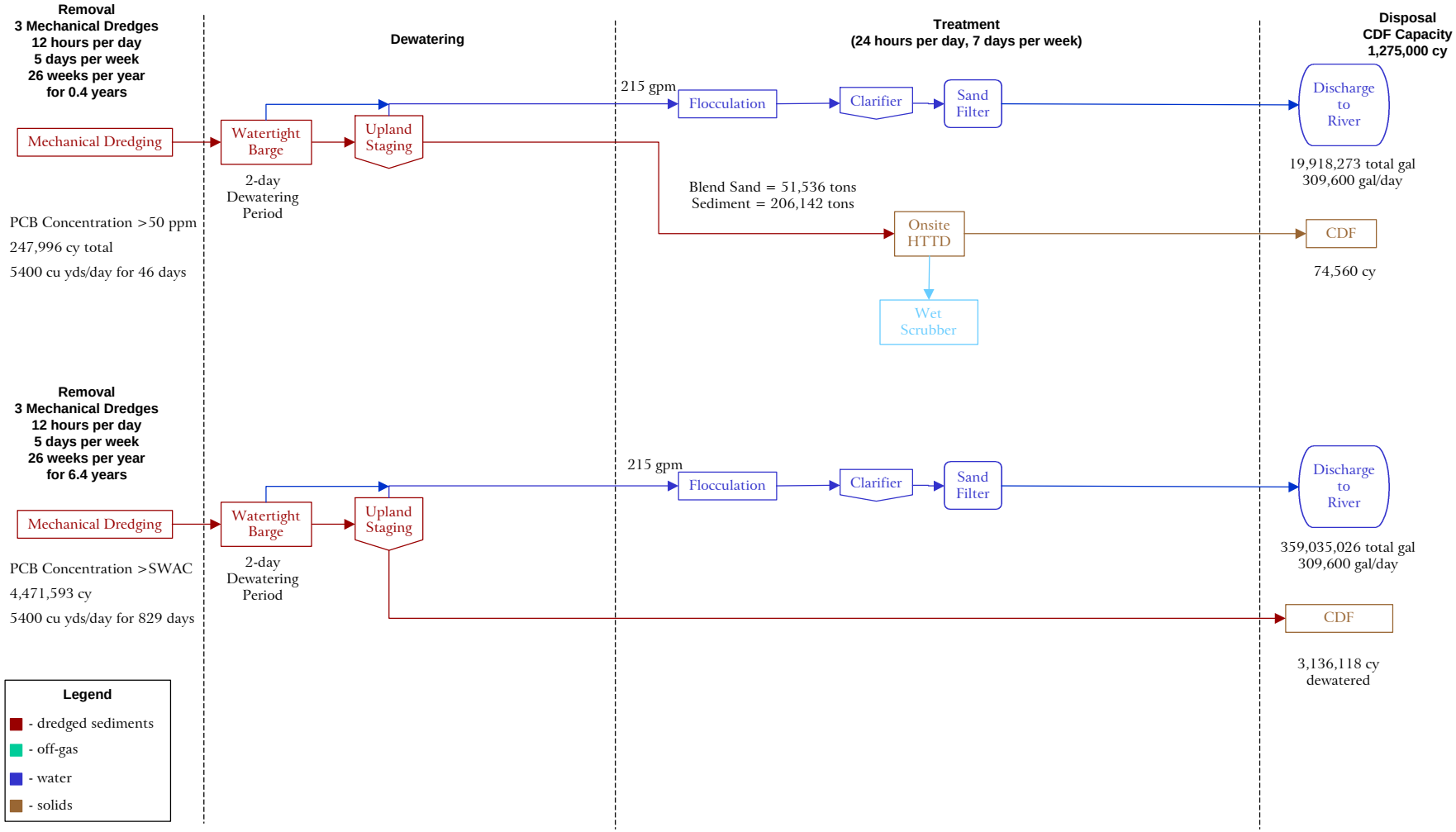


Figure 7-23
De Pere Dam to Green Bay, Alternative E: Dredge Sediment to SWAC With Off-site Disposal of TSCA Materials and On-site CDF

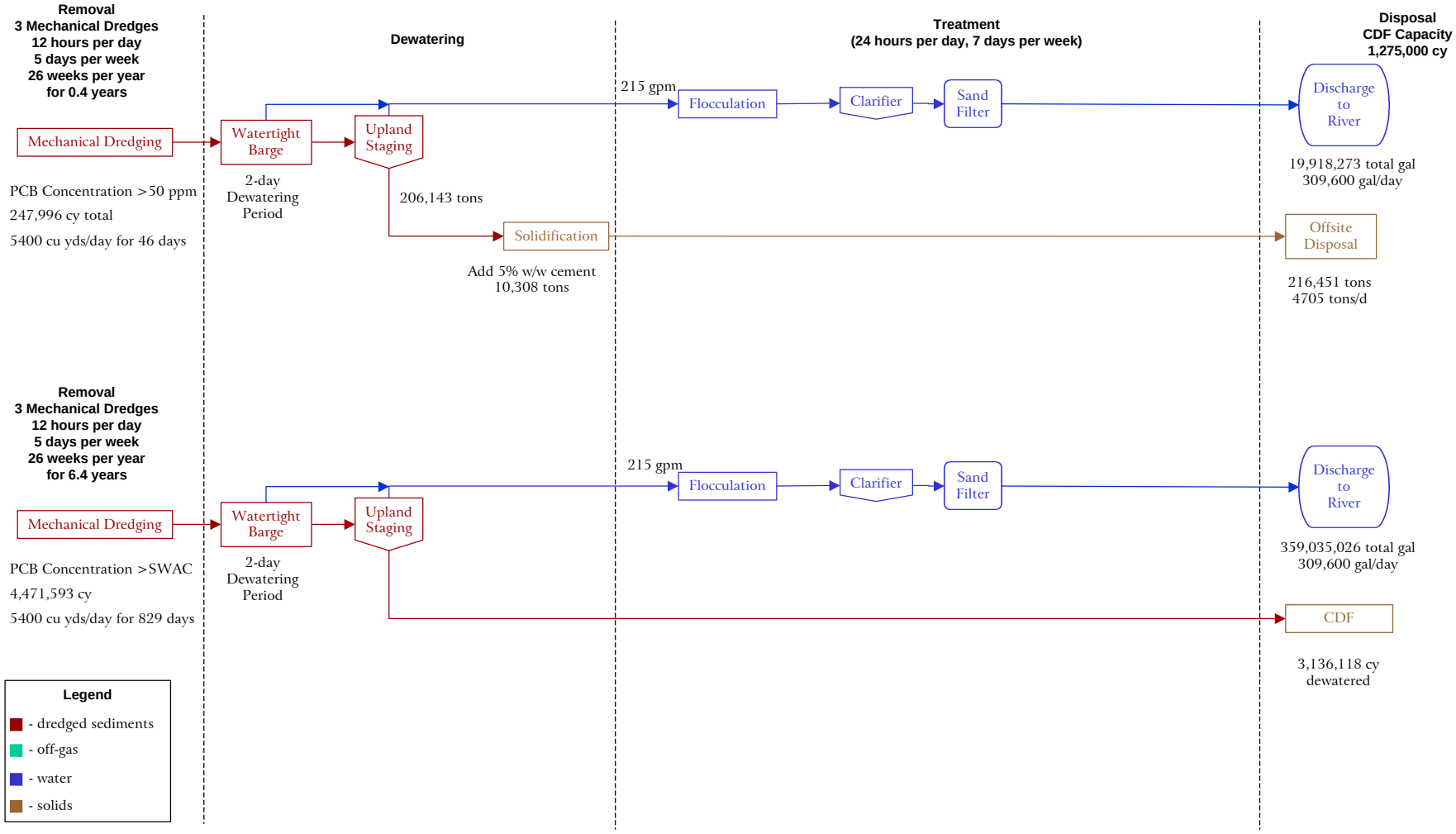
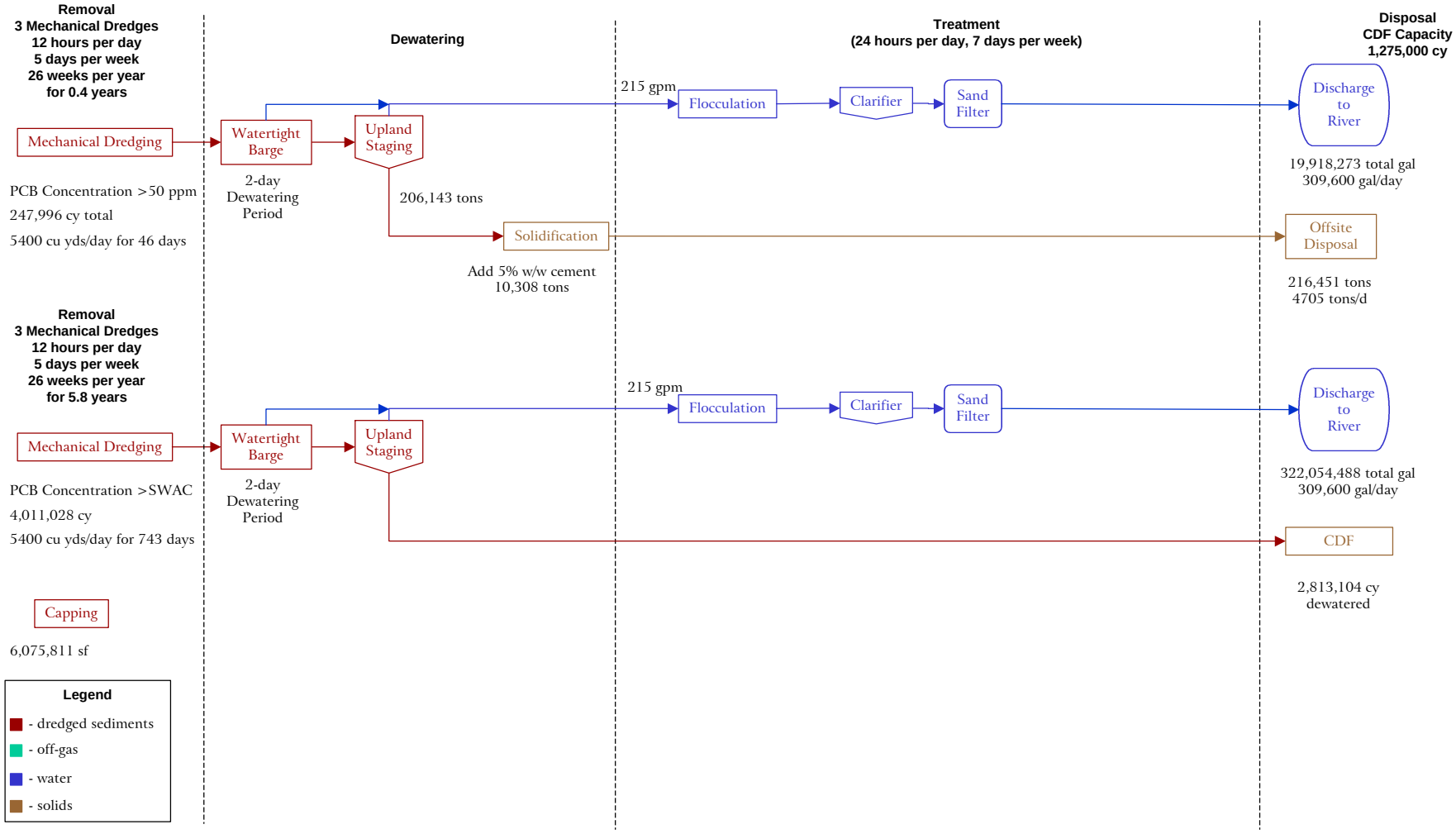


Figure 7-24
De Pere Dam to Green Bay, Alternative F:Cap Sediment to the Maximum Extent Possible and Dredge to Attain SWAC With Off-site Disposal of TSCA Materials and On-site CDF



8 Alternative-Specific Risk Assessment

This section presents an analysis of the risk reduction achieved with the remedial alternatives developed and presented in Section 7. This evaluation has been conducted to determine the degree to which a specific alternative meets the following RAOs that were established in Section 4.0 of this FS Report:

- *RAO 1* - Achieve, to the extent practicable, surface water quality ARARs
- *RAO 2* - Reduce the potential for COCs to cause adverse human health effects principally through exposure to PCBs from ingestion of fish by anglers
- *RAO 3* - Reduce the potential for COCs to cause adverse effects to ecological receptors
- *RAO 4* - Reduce, to the extent practicable, future transport of PCBs to Green Bay

This section provides an evaluation of risk reduction for functional alternatives; complete removal, partial removal or containment, or no action.
The ARAR used for surface water quality is NR 105 W.A.C. for drinking water and wildlife; 0.003 and 0.12 ng/L PCBs, respectively. The reductions in total PCBs in the surface water are evaluated in this section. Risks to humans through fish consumption are principally addressed through RAO 2 and RAO 3.

To address RAO 2 and RAO 3, sediment quality thresholds were established and discussed in Section 3. A remedial goal of 250 μg/kg total PCBs in sediment was established that would allow for removal of the fish consumption advisory at the earliest possible date, while providing risk reduction for 50% of the ecological receptors identified for the river. None of the remedial alternatives identified provide 100% protection immediately for all of the human or ecological receptors in the Lower Fox River system. The key assumption for this cleanup value is that sediment transport and burial over time would achieve further reductions in PCB mass, and thus concomitant reductions in risk. At some point in the future this would result in restoration of the river to unrestricted use and all receptors. Time and the level of risk reduction become the metrics for assessing the efficacy of a specific remedial alternative.

In addition to PCBs, the remedial-specific risk assessment considers the potential residual risks associated with other contaminants identified in the risk assessment process. The risks to human health and the environment from other

contaminants were typically 100 to 10,000 times less than those posed by PCBs; however, the additional COPCs are considered in the evaluation of risk reduction associated with the remedial alternatives.

Risk reduction must also be evaluated based upon the long-term effect on Green Bay. An alternative which is acceptable based solely upon meeting risk levels or meeting RAOs 1 through 3 in the river, may not account for the mass transport of PCBs to Green Bay. Mass transport is used here as a surrogate for risk in Green Bay. As the physical sediment settling and biological uptake is not as well understood in Green Bay as it is in the Lower Fox River, the total mass transported to the Green Bay over time is the best indicator of continued risks.

Finally, the uncertainties associated with the predictions of long-term residual risks should also be considered. The uncertainties associated with the selection of specific receptors and the values at which those receptors are thought to be placed at risk are discussed in the BLRA. Uncertainties in this section include the assumptions built into the mass transport models used to predict long-term sediment trends, and the associated risks for those river reaches. These are also discussed below.

8.1 Description of Detailed Analysis Process

8.1.1 Total PCB Residual Risk Evaluation

The process of evaluating risks associated with the river reach remedial alternatives uses predictions of the post-remediation surface sediment concentrations over time, in comparison to surface water ARARs, sediment-based risk thresholds, and mass transport of contaminated sediments to Green Bay.

There are 3 to 7 remedial alternatives for each of the river reaches. The alternatives vary based upon the process options (i.e., hydraulic dredging, cap, etc) and the quantity of contaminated sediment addressed in the alternative. The quantity of contaminated sediment varies based upon the following three management approaches, referred to in this section as functional alternatives:

- Complete Remediation - Remove and dispose of all River sediments with total PCB concentration exceeding 250 μg/kg

- Partial Remediation - Remove or contain the river sediments so that the reach-wide surface SWAC of total PCBs is less than or equal to 250 μg/kg

- No Action - Leave all sediment in place with either no action, or institutional controls to limit exposure to the sediments

The remedial alternative-specific risk assessment considers the impacts over time to changes in surface water and surface sediment concentrations, as well as mass transport, for these three functional alternatives.

The remedial alternative-specific risk assessment also considers post-remediation changes to surface water and sediment concentrations based upon transport of the contaminated sediments through and out of the Lower Fox River. To predict changes in surface water and sediment PCB concentrations over time, 100-year runs of the concatenated Fox River Model (FRM) described in Section 5 of this FS Report were performed for each of the three functional alternatives[1]. The three functional alternatives bracket the range of expected river responses to remediation. The assumptions used for each run are described in the following subsections.

- No Action - The functional alternative assumes that no remediation is conducted to address contaminated sediments. The concatenated FRM was set to run for 100 years using the same initial conditions as described in Section 5 of this FS Report.

- Partial Remediation - This functional alternative assumes that post-remediation PCB concentrations of 2 mg/kg remain in surface sediments following remediation (i.e., dredging). Temporary increases in surface sediment chemical concentrations have been observed following numerous sediment removal projects. For this exercise, the assumed post-remediation value of 2 mg/kg falls between the median and geometric mean total PCB concentration calculated using all the PCB data in the Fox River Database (FRDB), and thus is an appropriately conservative value. It should be noted that the volume of post-remediated surface sediment with a concentration of 2 mg/kg is much smaller than the initial volume of sediment, so significant reduction of the total mass of PCBs would result from remediation even if significant reductions of surface sediment concentrations has not been immediately achieved.

  The model run that simulates partial remediation was completed by zeroing out the PCB initial conditions for all sediment layers except the surficial sediment layer beneath water column segments 2, 4, 5, 7, 13, 23, 24, 27, 28, 30, 31, 32, 36. The sediments below these water column segments correspond

[1]This approach was somewhat different than the calculations used to rank the deposits in Section 5, where the denominator was the total sediment "deposit" surface area, as opposed to the total "reach" surface area. The net result here is that the initial SWAC concentrations were lower than those used to estimate sediment in Chapter 5.

approximately to the potential remediation areas discussed in Section 5 and 7 of this FS Report. This simulation also assumes completion of the Deposit N project.

- Complete Remediation - For this functional alternative, the initial PCB conditions were zeroed out for all of the model segments, except for the surficial sediment layer which was given a value of 250 μg/kg. While the assumption that the residual post-dredging surface sediment concentration would be 250 μg/kg requires an optional result, this model run represents a best case response of the Lower Fox River to remediation.

For surface water comparisons, the total PCB concentration in each model segment was estimated, and the cumulative concentration at the downstream end of a specific reach was used to plot changes over time.

Reach-wide SWAC were calculated by determining the model output for each segment in a reach, multiplying it by the area of the individual sediment segment, summing those segments, and then dividing that sum by the total surface area in that reach. The model runs were set to begin in the year 2010, and assumes that all remediation has been completed at that point in time.

The model output was used to evaluate PCB risk reduction by comparing the surface sediment concentration of total PCBs over time to the SQT described in Section 3. SQTs were developed that were protective of human and ecological receptors identified in the BLRA. The basis for the selection of these receptors, and the toxicity reference values from which the SQTs were developed, are detailed in the BLRA. Risk is considered to be abated once the surface sediment concentration is below the SQT.

8.1.2 Non-PCB COPC Residual Risk Evaluation

The risk evaluation for the COPCs, other than PCBs, was conducted by plotting the distribution of the compounds in the FRDB relative to the total PCB base maps and the locations of sediments to be addressed as identified in Section 5. The complete remediation functional alternatives described in Section 7, result in the removal of the non-PCB contaminants along with the PCBs. As a result of this removal, the non-PCB COPCs would have no residual risk. The no action functional alternatives, result in the same residual risks as those identified in the BLRA. Residual risks to human health and the environment may remain in the alternatives that do not remove all of the contaminated sediment deposits, and these are discussed in the reach discussions below.

The chemicals identified in both the SLRA and the BLRA that are evaluated in this section include arsenic, copper, DDE, lead, mercury, and total PAHs. While dioxins and the dioxin-like PCB congeners were also identified as COPCs in the BLRA, these co-occur with the PCBs, and residual risk would be the same as the residual PCB risks. As a result of this co-location, these COPCs are discussed with PCBs.

8.1.3 Green Bay Residual Risks Evaluation

Residual risks to Green Bay are based simply upon mass transport over time of the residual (non-remediated) sediments from the four Lower Fox River reaches. The cumulative mass transport over 100 years from the three functional alternative model runs are graphed and discussed in the following sections.

8.2 Reach Specific Risk Assessment

8.2.1 Little Lake Butte des Morts

Seven remedial alternatives were presented for LLBdM in Section 7. These included one complete removal alternative (Alternative A), four alternatives that included partial removal and capping (Alternatives B, C, D, and E) and two alternatives that are functionally no action alternatives (Alternatives F and G).

Reductions in surface water total PCBs are shown in Figure 8-1. The greatest reductions in total PCBs occur in the complete remediation alternative. In these functional alternatives surface water quality PCB concentrations are below 1 ng/L within 5 years post-remediation, and remain relatively constant throughout the entire 100-year model run. The lowest surface water total PCB concentration achieved under this alternative is 0.10 ng/L, which is still ten to 100 times above the surface water ARARs, and thus represents residual total PCB risk. This failure to achieve lower levels of total PCBs is principally due to low-level continued inputs of total PCBs from external sources. Thus, in the absence of controlling those additional inputs, this likely represents the greatest practicable reduction in concentrations of PCBs in surface water. Surface water total PCB concentrations for both the partial removal and no action functional alternatives also decrease rapidly over the first 35 years post-remediation, and then remain constant over the remaining 70 years of the model run. Both of these functional alternatives produce similar water quality PCB concentrations at the end of 100 years of 0.10 and 0.15 ng/L, respectively.

Sediment-based alternative-specific residual risks from total PCBs to human health and the environment are shown in Table 8-1 and Figure 8-2. In the complete removal alternative (Alternative A) the SWAC surface sediment total

PCB concentration falls below 120 μg/kg in the first year post-remediation (Table 8-1), which is sufficiently low to be protective of 90% of the receptor species identified for LLBdM (Figure 8-2). In the absence of additional inputs of PCBs, residual risks to benthic infauna and mink would not exist 17 years post-remediation.

In the partial removal alternatives for LLBdM, (Alternatives B through E) removal and disposal and/or capping is conducted for sufficient sediment quantities so that the surface the SWAC for the entire lake would be less than or equal to 250 μg/kg. Using the FRM assumptions described above for partial removal, there would be a temporary increase in the surface sediment concentration, and the SWAC of 250 μg/kg would not be achieved until approximately 8 years post-remediation. Under these alternatives, there would be a need to maintain the fish consumption advisories and continue fish tissue monitoring until PCB levels in consumed fish decreased below the 10^{-4} cancer risk level. Thereafter, surface sediment PCB concentrations decrease relatively rapidly. Moderate risks to benthic infauna (hazard quotients <10) remain until approximately 27 years post-remediation. Sediment total PCB concentrations decrease below levels that would not effect mink reproduction within 44 years of final sediment management in the lake.

The no action alternatives for LLBdM (Alternatives F and G) would result in human health risks from fish consumption until approximately the year 2030. Elevated risks to fish and birds would remain until approximately the middle of the next century, while risks to mink would continue until the 22nd century.

The distribution and concentrations of COPCs other than PCBs are shown on Figures 8-3 through 8-8. Under the complete removal alternatives, all other COPC would also be removed from LLBdM, and thus would be removed as risks to human health or the environment. All of the metals, DDE, and total PAHs are found co-located in the same deposits as the PCBs. Under the partial removal alternatives (Alternatives B, C, D, and E), with the exception of mercury, the proposed remedial actions (removal or capping) would also remove or isolate the remaining contaminants. Under these partial removal alternatives, residual mercury would remain at sufficiently high concentrations to cause risk to the benthic infauna in sediments (hazard quotient = 7)(Figure 8-7). These residual mercury risks would presumably abate at the same rate as the total PCBs. The time to complete elimination of mercury risks was not estimated.

8.2.2 Appleton to Little Rapids

Three remedial alternatives were presented for this reach in Section 7. These included one complete removal alternative (Alternative A), and two alternatives that are functionally no action alternatives (Alternatives B and C).

Changes in surface water total PCB concentrations are shown in Figure 8-9. The pattern observed in this reach is the same as that observed for LLBdM. Under the complete removal alternatives, total PCBs are reduced to under 1 ng/L in the first four years post-remediation, but then decrease slowly to the lowest level, 0.13 ng/L, over the next 100 years. For the no action alternative, total PCBs are at 1 ng/L 30 years post-remediation, and are at 0.17 ng/L after 100 years. The lowest surface water total PCB concentration achieved under this alternative is 0.10 ng/L, which is still 10 to 100 times above the surface water ARARs, and thus represents residual total PCB risk.

Table 8-1 and Figure 8-10 present the post-remediation projected surface sediment PCB concentrations. Given the large areas of this reach of the river that are not depositional, the initial weighted average concentrations under both functional alternatives are below the levels necessary to restore full fish consumption. It should be noted that the no action is in a large part reduced because of the completion of the Deposit N removal. The complete removal alternative for this reach would result in a complete reduction of risk to all identified receptor species within 10 years post-remediation. Under the no action alternative, low level risks (hazard quotients < 4) would remain for up to 20 years for benthic infauna, based upon the area-wide average concentration. However, given the large surface area this may not be a realistic assessment since localized areas of elevated PCB concentrations (i.e., deposits W or X) may remain elevated for longer time frames.

The distribution and concentrations of COPCs other than PCBs are shown in Figures 8-11 through 8-16. Principally these chemicals are found elevated at Deposit N, and at deposits W and X. Residual levels of arsenic, copper, lead and mercury in the sediments are not sufficiently high to cause reach-wide risks to humans, fish, birds, or mammals, but are present in that localized area at levels that could impact benthic infaunal populations. This is also true for total PAHs in deposits W and X. The levels of DDE in that same area have not been demonstrated to bioaccumulate and pose risks to human health or the environment.

8.2.3 Little Rapids to DePere

Eight remedial alternatives were presented for the Little Rapids to De Pere reach in Section 7. Alternatives A and B are functionally complete removals, differing only in the process options for removal and disposal of the sediment. Alternatives C and D are partial removals to a SWAC of 250 μg/kg, while Alternative E combines both partial removal and a sediment cap to achieve a SWAC of 250 μg/kg. Alternative F consists of capping all the contaminated sediments in this reach. Functionally, this is equivalent to the complete removal alternatives, except that this alternative requires long-term monitoring and on-going maintenance of the cap to ensure integrity and chemical isolation. Alternatives G and H are functionally no action alternatives.

Changes in surface water concentrations of total PCBs are shown in Figure 8-17. For the complete removal alternatives, total PCBs decrease to below 1 ng/L in the first five years post-remediation, and then slowly decrease to a low of 0.1 ng/L 100 years post-remediation. For the partial removal alternatives, total PCBs fall below 1 ng/L in 30 years, and are also at 0.1 ng/L after 100 years. These values are still 10 to 100 times above the surface water ARARs, and thus represent residual total PCB risk. In the no action alternatives, total PCBs never decrease below 1 ng/L in the 100 years of model runs, which is 100 to 1,000 times the ARARs, and represents a greater residual risk than either the full or partial removal alternatives.

Changes in surface sediment PCB concentrations are presented in Table 8-1 and Figure 8-18. Under the complete removal alternatives (Alternatives A, B, and F), risk reduction to almost all of the important receptors are realized within the first 5 years post-remediation. Given the proposed volumes that would be removed or isolated, the SWAC is predicted to fall to below levels that would allow a removal of the fish consumption advisory, as well as to minimize or eliminate risks to fish or bird reproduction within 3 years post-remediation. An additional three years would be required (total of seven) before mass transport would redistribute and remove the sediments to below the level that would not pose any risks to benthic infauna. During that period of time recovery should begin (hazard quotient <4). In the absence of additional inputs, sediment PCB quality under these alternatives would fall to a no risk level in approximately 17 years post-remediation.

Under the partial removal alternatives, a temporary increase would occur in the surface sediment concentration, and the SWAC of 250 μg/kg would not be achieved until approximately 6 years post-remediation (Figure 8-18). Under these alternatives, there would be a need to maintain the fish consumption advisories and continue fish tissue monitoring until PCB levels in consumed fish decreased

below the 10^{-4} cancer risk level. Thereafter, changes to surface sediment PCB concentrations decrease relatively slowly (Table 8-1). Moderate risks to benthic infauna (hazard quotients < 10) remain until approximately 27 years post-remediation, while surface sediment total PCB concentrations remain at levels that could potentially effect mink reproduction until 66 years (Year 2076) after all remediation is completed.

The no action alternatives for the Little Rapids to De Pere reach (Alternatives G and H) would result in human health risks from fish consumption until approximately the year 2035. Elevated risks to fish and birds would remain until approximately the middle of the next century, while risks to mink would continue well into the 22nd century.

The distribution and concentrations of COPCs other than PCBs are shown on Figures 8-19 through 8-24. Under the complete removal or isolation alternatives (Alternatives A, B, and F), all other COPC would also be removed or isolated from the river, and thus would not pose continued risks to human health or the environment. All of the metals, DDE, and total PAHs are found co-located in the same deposits as the PCBs. Under the partial removal alternatives (Alternatives C, D, and E), the proposed remedial actions (removal or capping) would also remove or isolate the remaining contaminants. This is especially true for mercury, where the FRDB shows that most of the mercury is found immediately behind the De Pere dam (Figure 8-23); within the area that is proposed for dredge and removal under all of the partial alternatives. Under the no action alternatives, the residual risks would be the same as those defined in the BLRA.

8.2.4 De Pere to Green Bay

Eight alternatives were presented for the De Pere to Green Bay reach in Section 7. Alternatives A and B are functionally complete removals, differing only in the sediment removal and disposal process options. Alternatives C, D, and E are partial removals to a SWAC of 250 μg/kg, while Alternative F combines both partial removal and a sediment cap to achieve the SWAC of 250 μg/kg. Alternatives G and H are functionally no action alternatives.

Changes in surface water concentrations of total PCBs are shown in Figure 8-25. Water column PCB concentrations are higher in this reach than any of the other reaches, and the relative differences between the three functional alternatives are the most striking in this reach of the river. Under the complete (Alternatives A and B) removal alternatives, total PCBs post-remediation remain at approximately 1 ng/L for the entire 100-year run of the model. For the partial removal alternatives, the water column concentration of total PCBs remains above 10 ng/L for the first 20 years, and then slowly levels off to approximately 4 to 5 ng/L over

the next 80 years. For the no action alternative, total PCBs remain at or above 100 ng/L for 65 years post-remediation, and then drop only to approximately 10 to 20 ng/L.

Changes in surface sediment PCB concentrations are presented in Table 8-1 and Figure 8-26. Under the complete removal alternatives (Alternatives A and B), risk reduction to almost all of the important receptors are realized within the first two years post-remediation. Given the proposed volumes that would be removed or isolated, the SWAC is predicted to decrease to below levels that would allow a removal of the fish consumption advisory, as well as to minimize or eliminate risks to fish or bird reproduction within 10 years post-remediation. In the absence of additional inputs, sediment PCB quality under these alternatives would fall to a no risk level in approximately 27 years post-remediation.

None of the partial removal strategies effectively reduce all the risks to human health and the environment within 100 years post-remediation. Under the partial removal alternatives, there would be a temporary increase in the surface sediment concentration, and the SWAC of 250 μg/kg would not be achieved until approximately 12 years post-remediation (Figure 8-26). Thereafter, changes to surface sediment PCB concentrations decrease relatively slowly (Table 8-1). Risks to benthic infauna (hazard quotients < 10) would remain until approximately 95 years post-remediation, while surface sediment total PCB concentrations remain at levels that could potentially effect mink reproduction until some point beyond 100 years post-remediation.

Under the no action alternatives (Alternatives G and H), there would be little risk reduction in this reach until well into the 22nd century.

The distribution and concentrations of COPCs other than PCBs are shown on Figures 8-27 through 8-32. The distribution of the metals is relatively ubiquitous throughout the reach, and would be removed along with the PCBs under any of the complete removal alternatives. The partial removal alternatives would capture most of the metals, but would leave behind sufficient concentrations in the furthest downstream points of the river to at least pose a risk to the sediment-dwelling insects. The few samples where DDE and total PAHs were measured in this reach, occur within the areas delineated for removal or isolation under the partial removal alternatives.

8.3 Residual Risks to Green Bay

Residual risks to Green Bay are discussed in the context of mass export over time of the residual (non-remediated) PCB-contaminated sediments from the four

Lower Fox River reaches. RAO 4 is the reduction of the PCB mass transport to Green Bay to the greatest degree practicable. The greater the cumulative transport of PCBs to Green Bay, the greater the risk. The cumulative mass transport over 100 years by functional alternative is given in Figure 8-33.

Under the combined (four reach) complete removal alternatives, the predicted net yearly transport to Green Bay of PCBs under the no action alternative is between 200 to 300 kg (440 to 660 pounds), for a cumulative 100-year total of 26,100 kg (57,400 pounds). This is consistent with current release levels to Green Bay, and thus current risks described in the BLRA for Green Bay are expected to remain through the next 100 years.

Significant reduction in the export of total PCBs is achieved under the partial removal/isolation scenarios. The cumulative 100-year export of PCBs to Green Bay is 2,700 kg (5,940 pounds). This represents approximately 10% of the no action alternative. It is not possible to predict with the tools used in this analysis if this will result in a direct 90% reduction in risk to Green Bay receptors, but it is reasonable to assume that this will result in a substantial reduction in Green Bay surface sediment and water column total PCBs, and will result in some measurable reduction in risk.

Finally, the average total PCB transport under the complete removal or isolation alternatives is less than 3 kilograms (6.6 pounds) per year, with cumulative 100 year total of approximately 320 kg (704 pounds). This 100-year cumulative amount is less than or equal to a single year output under the no action alternatives. Again, it is not possible to quantify the degree of risk reduction to Green Bay based upon these tools, but it can be qualitatively stated that risk reduction will be substantial, relative to the two other functional alternatives.

8.4 Uncertainty Analysis

There is always considerable uncertainty in using a long-term predictive model to forecast risks to human health and the environment. While the FRM has been shown to be a reasonably accurate tool for forecasting changes to surface sediment concentrations and mass export of PCBs to Green Bay (WDNR, 1997b), there remains uncertainty in the actual magnitude of the changes predicted by the model. These uncertainties reside in the model itself, the assumptions used for each of the functional alternatives, and the application of the actual data to the model. However, the uncertainties are mitigated by the fact that the alternative-specific risk assessment is intended solely to provide a relative level of residual risk between each of the proposed alternatives, and not necessarily to provide 100%

accurate predictions. Within this context, the FRM and the accompanying assumptions are adequate for the purposes of this FS.

Additional uncertainty results from the time between achieving a sediment quality threshold, and the time until risk reduction is actually observed. While total PCB concentrations in sediments will achieve 250 μg/kg, it may be several years before fish show changes in total PCB body concentrations/mass. This uncertainty can be mitigated by a well designed post-remediation sediment and fish tissue sampling program.

Use of a reach-wide weighted-average concentration may in some reaches allow for higher risks in localized areas. Large sections of non-depositional areas can skew the SWAC low, and not take into account localized risks to less mobile organisms (i.e., benthic infauna). While some pelagic fish, such as walleye or pike, may have large forage ranges and be appropriately represented by the SWAC, benthic fish such as carp have smaller home ranges and thus may be subjected to localized higher risks than predicted.

Use of the FRM shows that over time most of the sediment is transported downstream, but this may still result in short-term increased risks to some organisms.

Finally, residual risks posed by the COPCs other than total PCBs, are based upon the data in the FRDB. The distribution plots may be skewed by uneven, biased sampling, for these other constituents. However, with the exception of mercury in Little Lake Butte des Morts, risks from these constituents were below all ecological and human health thresholds.

8.5 Section 8 Tables and Figures

Tables and figures for Section 8 follow this page and include:

Tables

Table 8-1 Alternative Specific Risk Assessment: Years Post-remediation to Achieve Protective Sediment Quality Threshold for Total PCBs

Figures

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Figure 8-32 De Pere to Green Bay Surface Sediment Total PCB and Total PAHs Distribution
Figure 8-33 PCB Export to Green Bay under the Remedial Alternatives

Table 8-1. Alternative Specific Risk Assessment. Years post-remediation to achieve protective sediment quality threshold for total PCBs

			Little Lake Butte des Morts			Appleton to Little Rapids	
			Complete Removal	Partial Removal	No Action	Complete Removal	No Action
Protective Threshold	**SQT (µg/kg)**	FS Alternatives	A	B,C,D,E	F,G	A	B,C
Forster's tern reproductive impairment NOEL	1491		0	0	0	0	0
Common tern reproductive impairment NOEL	1454		0	0	0	0	0
Double-crested cormorant reproductive impairment NOEL	611		0	2	7	0	0
Yellow Perch Unrestricted Human Consumption	522		0	3	9	0	0
Forster's tern LOEL for deformities	296		0	7	18	0	0
Common tern LOEL for deformities	287		0	7	18	0	0
Carp adult survival NOEL	286		0	7	18	0	0
Mink LOEL reproduction and survival	275		0	7.5	19	0	0
Walleye adult survival NOEL	265		0	8	19	0	0
Carp egg survival NOEL	190		0	11	25	0	0
Walleye Unrestricted Human Consumption	177		0.5	11	25	0	0
Walleye egg survival NOEL	170		0.5	11	26	0	0
Double-crested cormorant LOEL for deformities	120		0.5	14.5	34	0	0
Benthic Infauna Growth and Reproduction (ARCS)	33		6	26.5	77	3	18
Carp Unrestricted Human Consumption	27		6	29	88.5	3	20
Mink reproduction and survival NOEL	6		17	44	>100	10	37

			Little Rapids to DePere			DePere to Green Bay		
			Complete Removal	Partial Removal	No Action	Complete Removal	Partial Removal	No Action
Protective Threshold	**SQT (µg/kg)**	FS Alternatives	A, B, F	C,D,E	G,H	A,B	C,D,E,F	G,H
Forster's tern reproductive impairment NOEL	1491		0	0	0	0	1	70.5
Common tern reproductive impairment NOEL	1454		0	0	0	0	1	70.5
Double-crested cormorant reproductive impairment NOEL	611		0	2.5	11	0	4.5	>100
Yellow Perch Unrestricted Human Consumption	522		0	3	16.5	0	5.5	>100
Forster's tern LOEL for deformities	296		0	5	22.5	0	11.5	>100
Common tern LOEL for deformities	287		0	5	23	0	11.5	>100
Carp adult survival NOEL	286		0	5	23	0	11.5	>100
Mink LOEL reproduction and survival	275		0	5.5	23	0	12	>100
Walleye adult survival NOEL	265		0	5.5	23	0	12	>100
Carp egg survival NOEL	190		0	6.5	35	0	20.5	>100
Walleye Unrestricted Human Consumption	177		0.5	8.5	35.5	1.3	28	>100
Walleye egg survival NOEL	170		0.5	8.5	35.5	1.3	28	>100
Double-crested cormorant LOEL for deformities	120		2.5	10	41	2.5	40	>100
Benthic Infauna Growth and Reproduction (ARCS)	33		6.5	26.5	>100	6.5	95	>100
Carp Unrestricted Human Consumption	27		7	26.5	>100	6.5	99	>100
Mink reproduction and survival NOEL	6		10	61	>100	19.3	>100	>100

Figure 8- 1. Projected Surface Water PCB Concentrations
Little Lake Butte des Morts

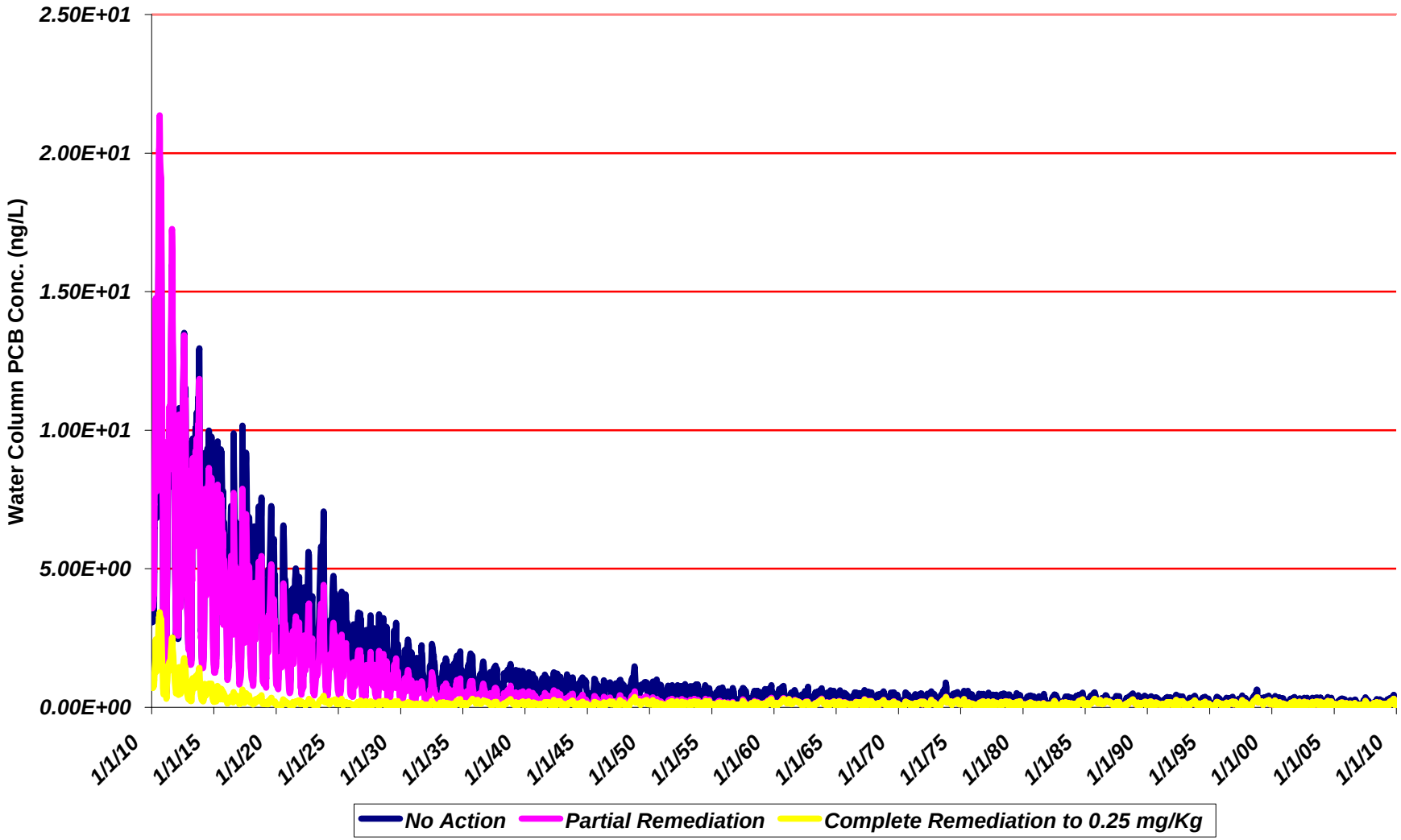
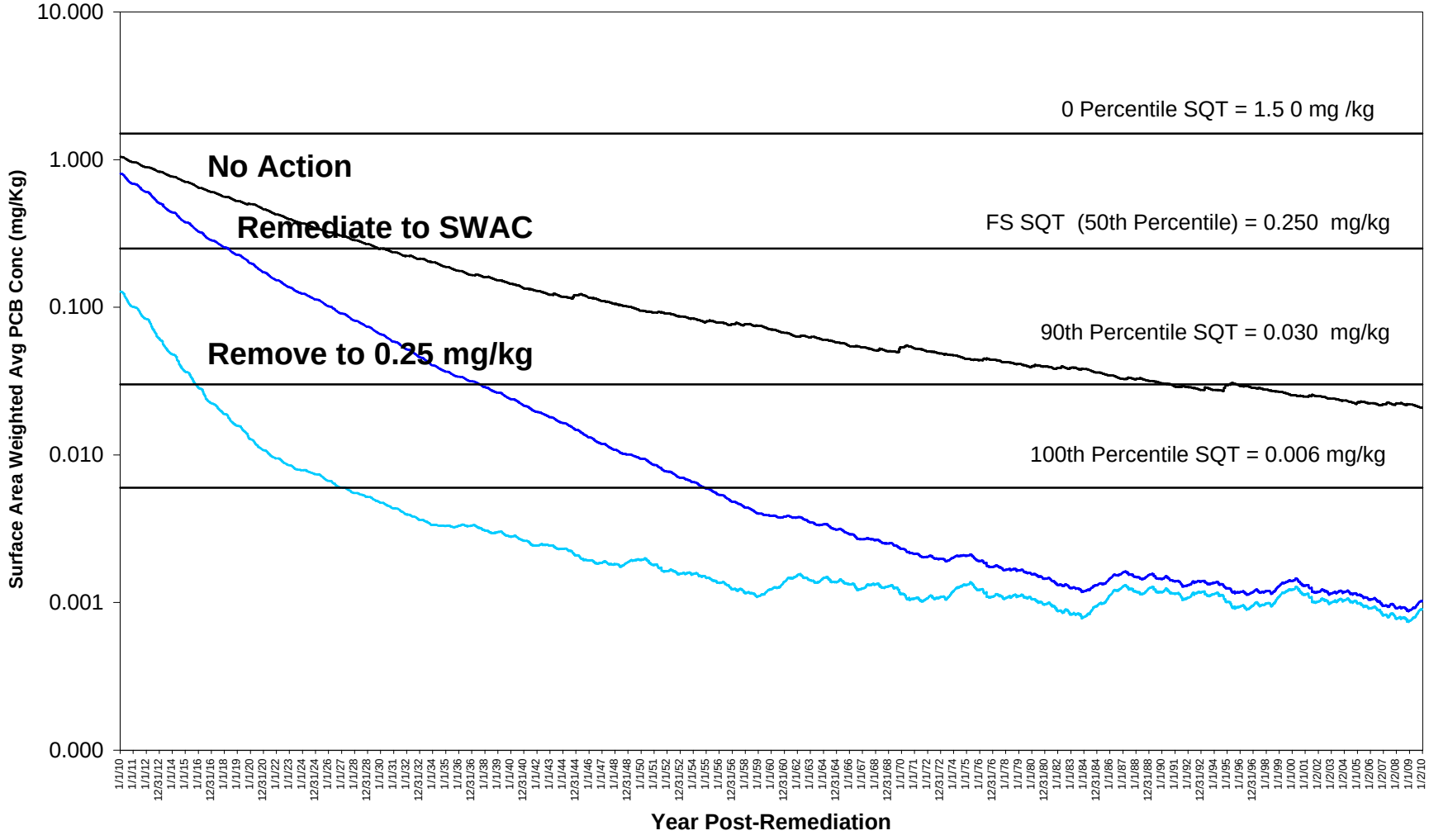
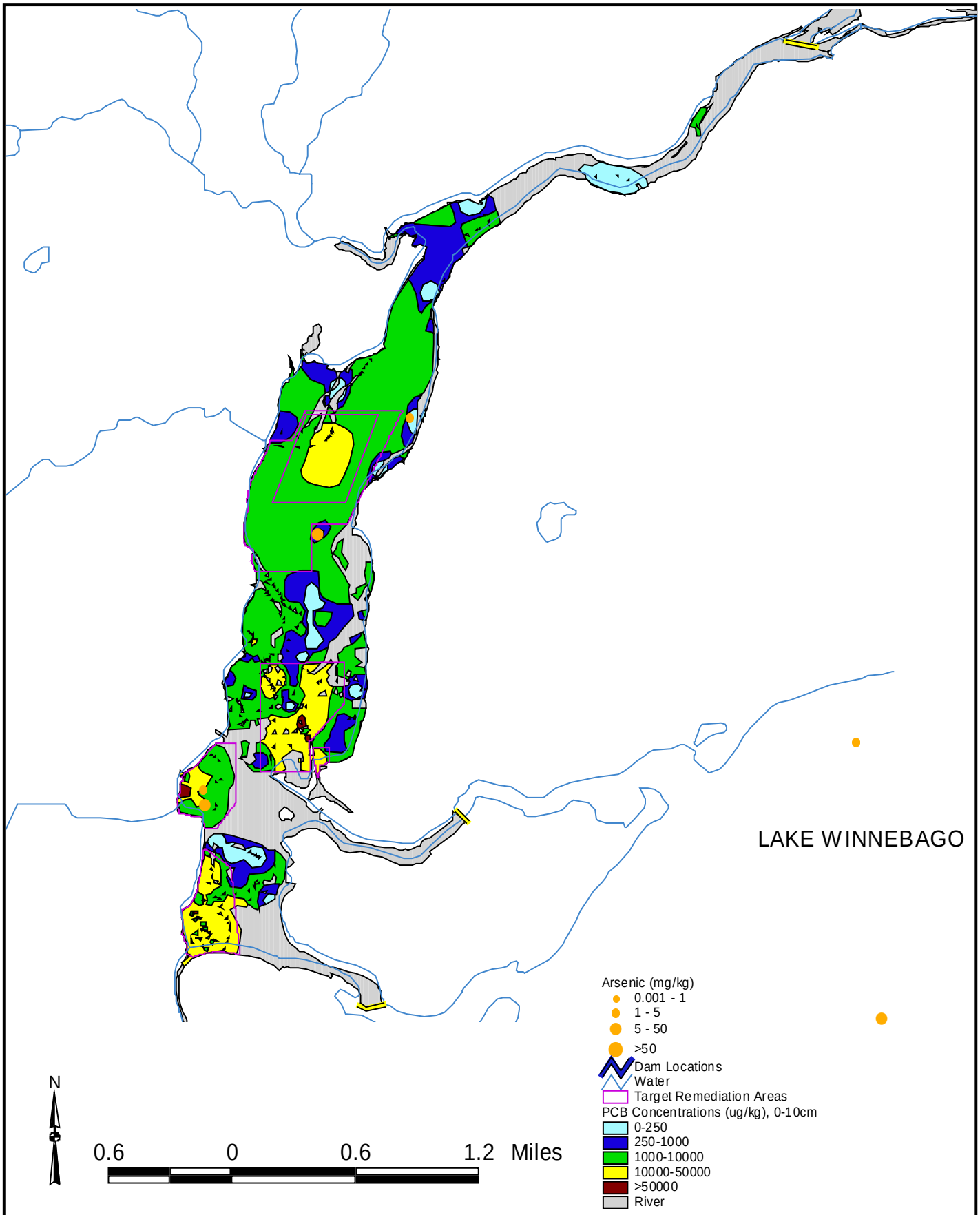


Figure 8-2. Post-Remediation Projected Surface PCB Concentrations
Little Lake Butte des Morts





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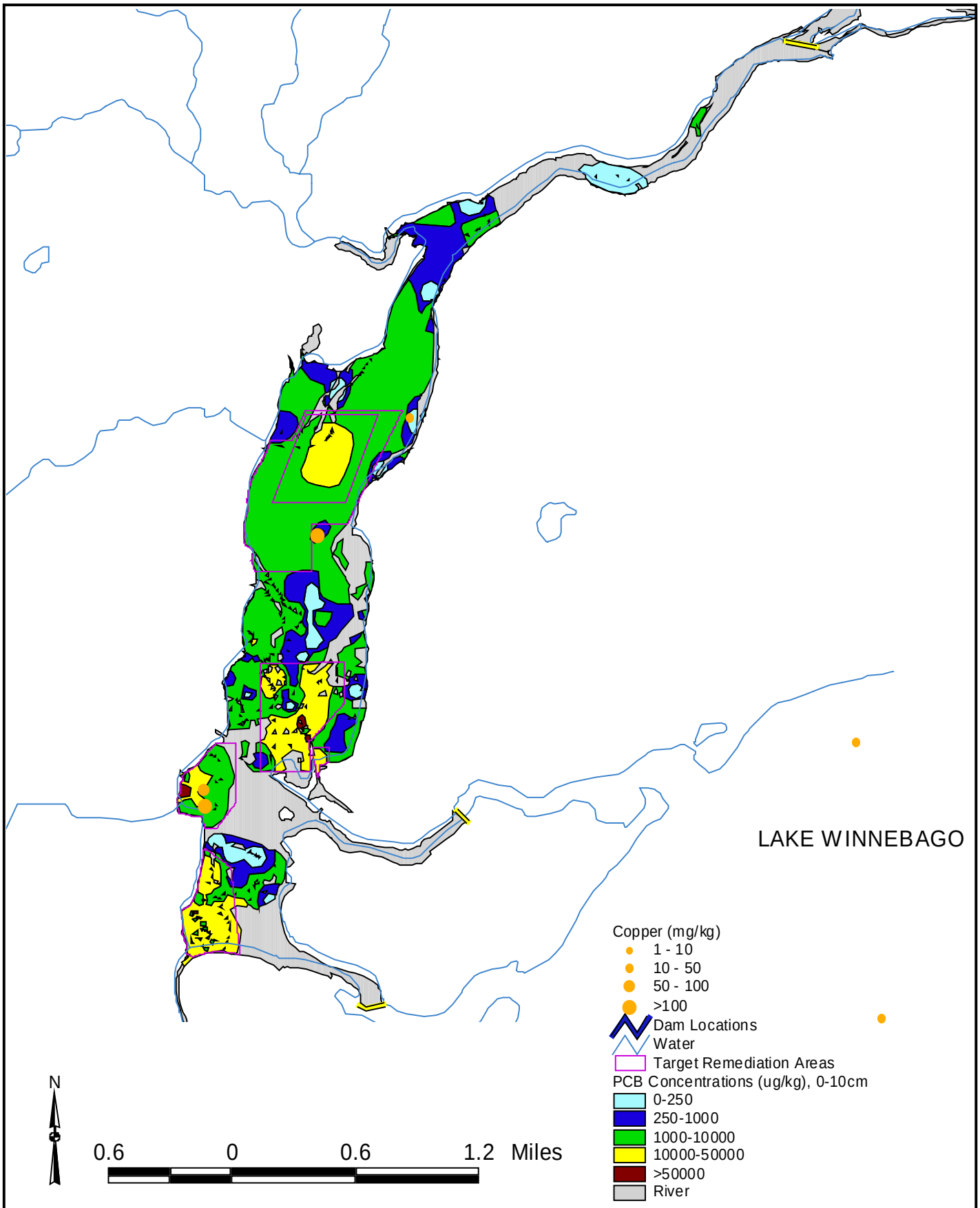
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500		LITTLE LAKE BUTTE DES MORTS SURFACE SEDIMENT TOTAL PCB AND ARSENIC DISTRIBUTION	
DATE: 1/13/1999	FOXRIVER.APR		FIGURE 8-3



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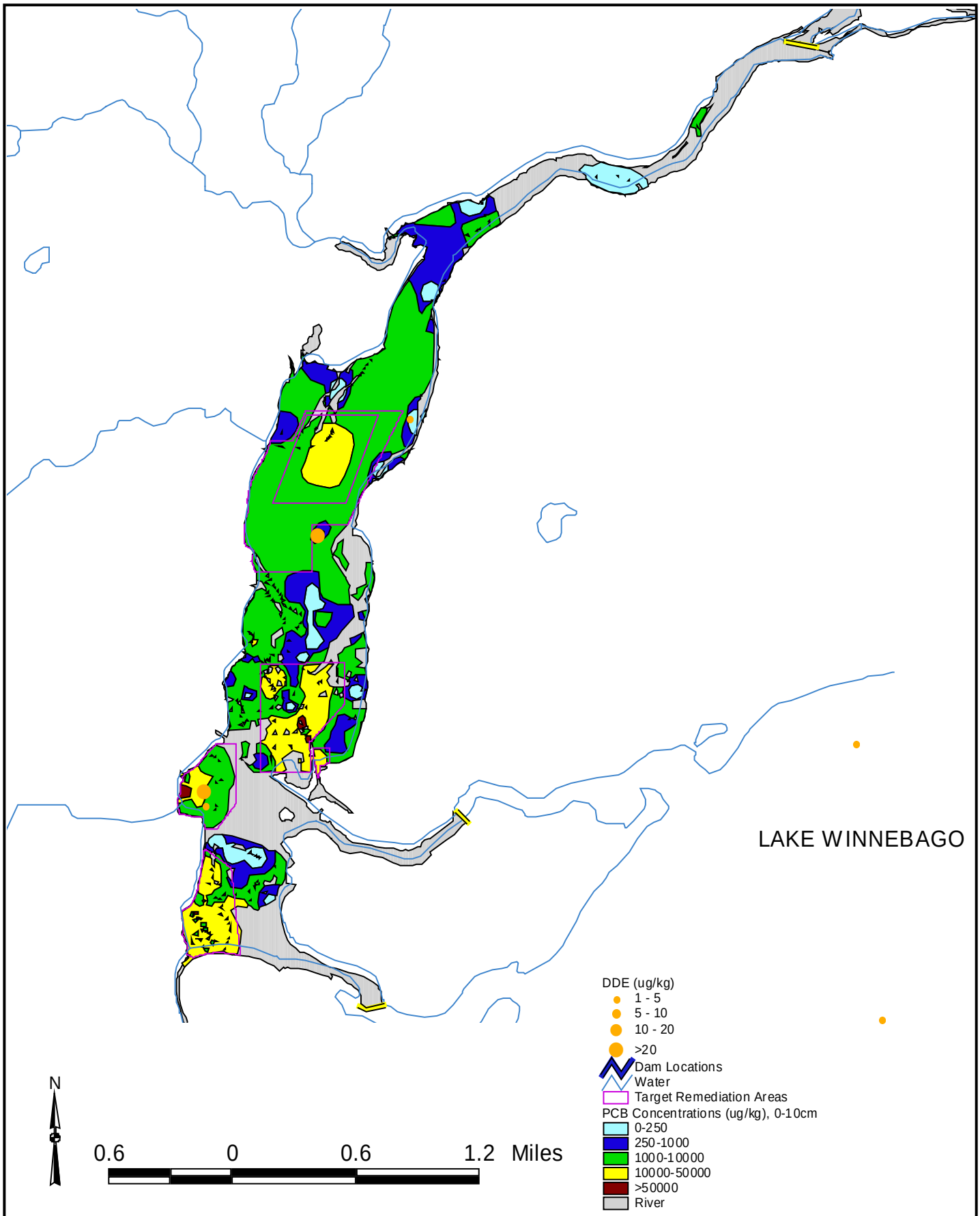
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500		LITTLE LAKE BUTTE DES MORTS SURFACE SEDIMENT TOTAL PCB AND COPPER DISTRIBUTION
DATE: 1/13/1999	FOXRIVER.APR	FIGURE 8-4



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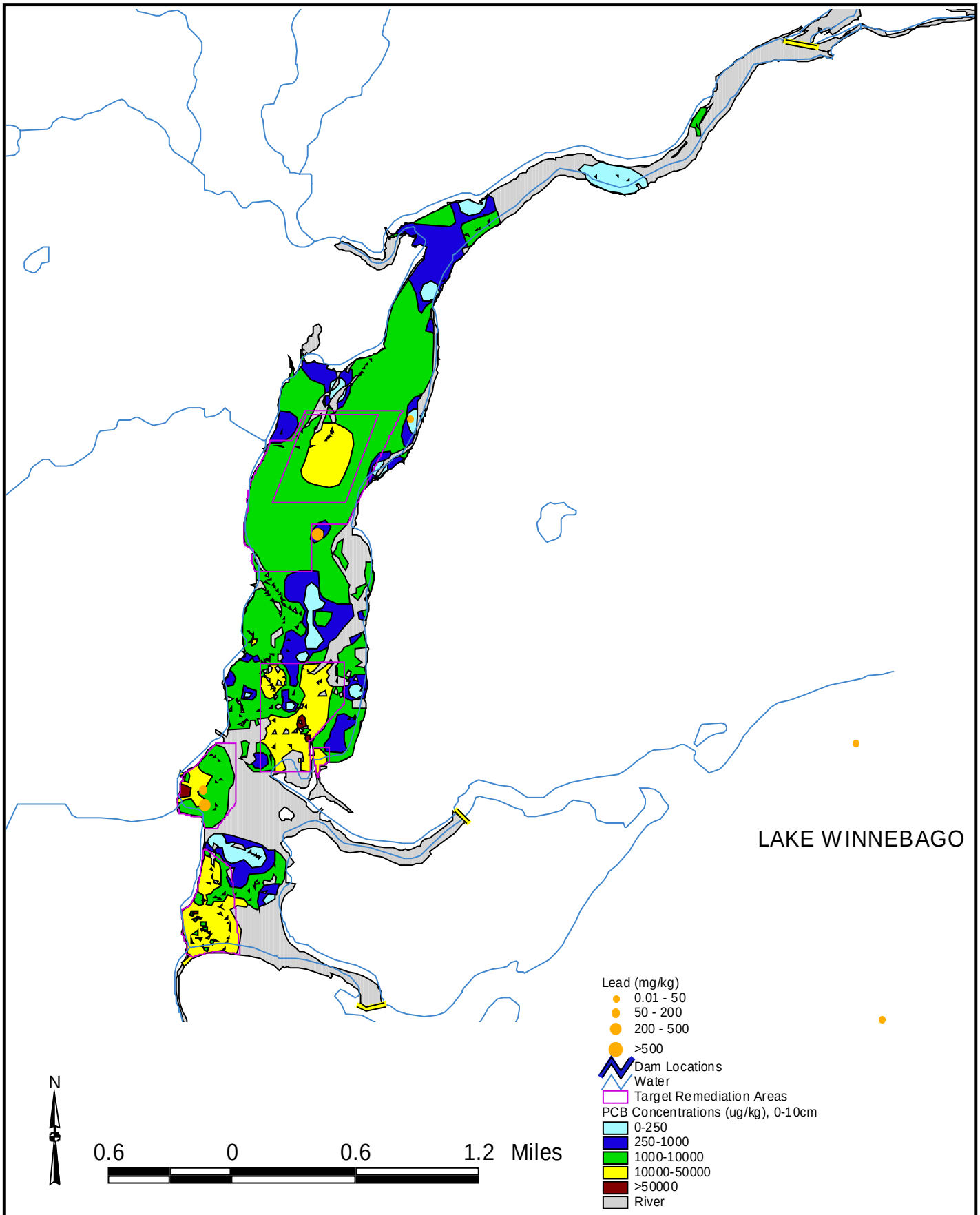
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500	LITTLE LAKE BUTTE DES MORTS SURFACE SEDIMENT TOTAL PCB AND DDE DISTRIBUTION	
DATE: 1/13/1999	FOXRIVER.APR	FIGURE 8-5



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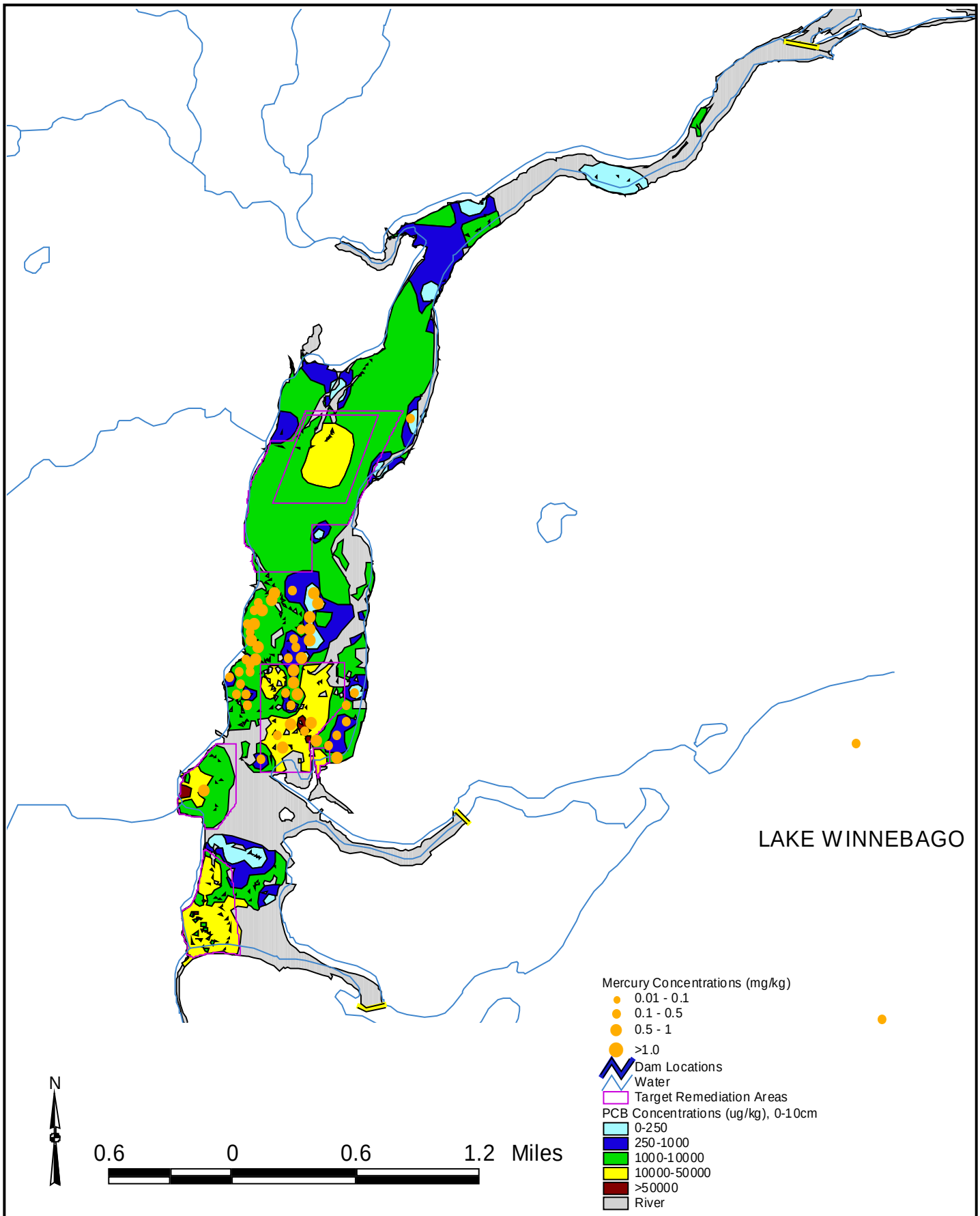
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500	LITTLE LAKE BUTTE DES MORTS SURFACE SEDIMENT TOTAL PCB AND LEAD DISTRIBUTION	
DATE: 1/13/1999	FOXRIVER.APR	FIGURE 8-6



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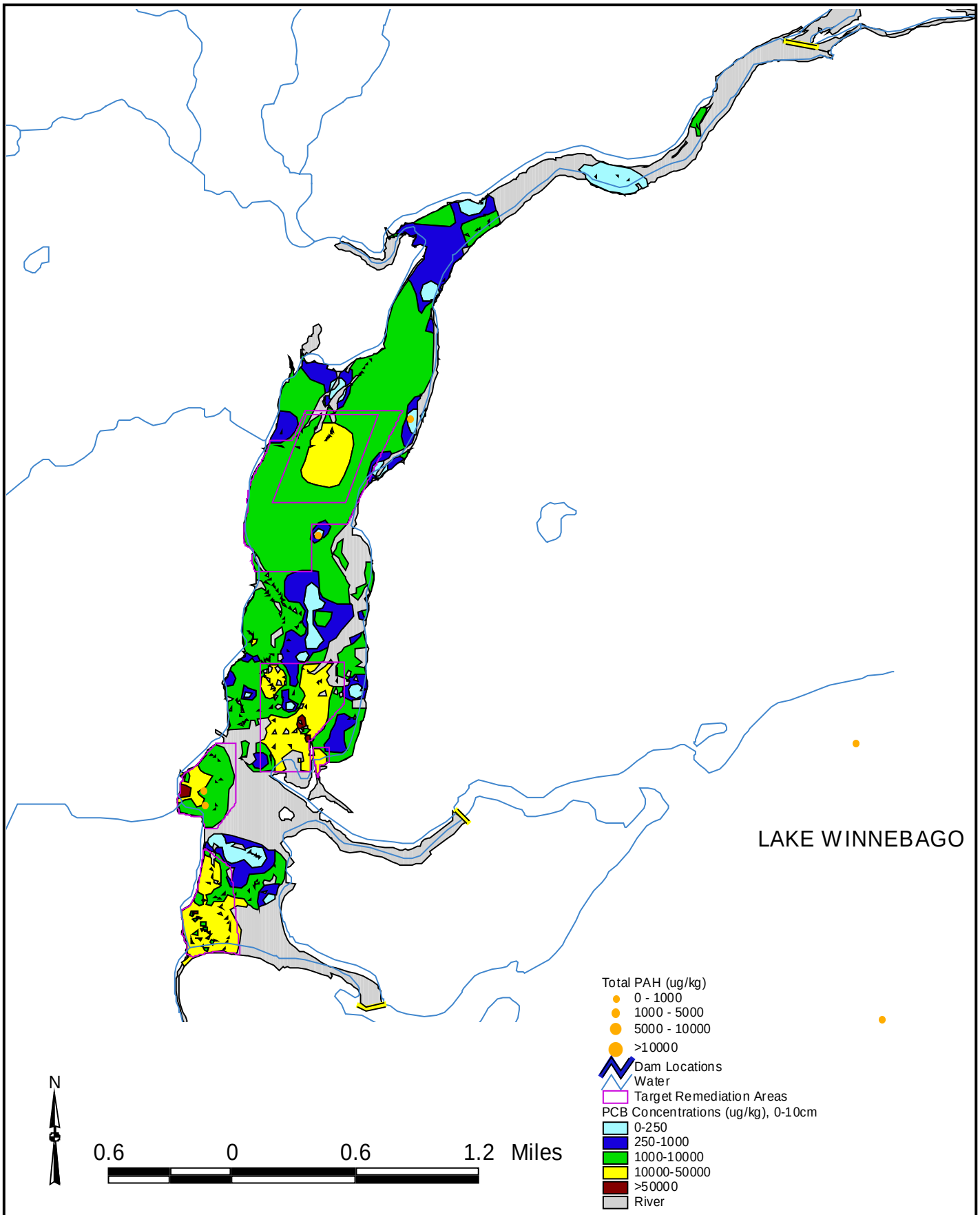
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500	LITTLE LAKE BUTTE DES MORTS SURFACE SEDIMENT TOTAL PCB AND MERCURY DISTRIBUTION	
DATE: 1/13/1999	FOXRIVER.APR	FIGURE 8-7



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LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500	LITTLE LAKE BUTTE DES MORTS SURFACE SEDIMENT TOTAL PCB AND TOTAL PAHs DISTRIBUTION
DATE: 1/13/1999 FOXRIVER.APR	FIGURE 8-8

Figure 8-9. Projected Surface Water PCB Concentrations
Appleton to Little Rapids

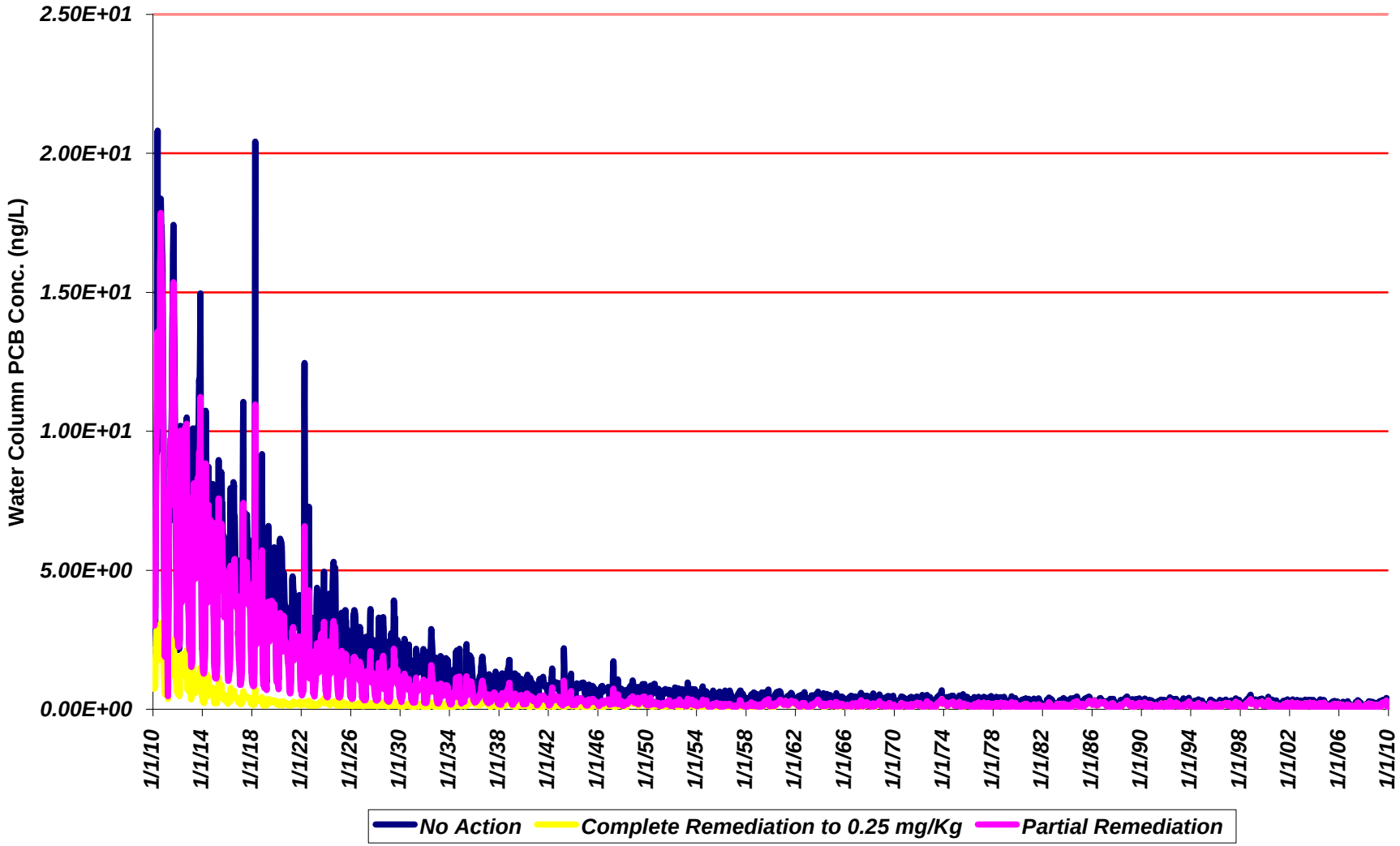
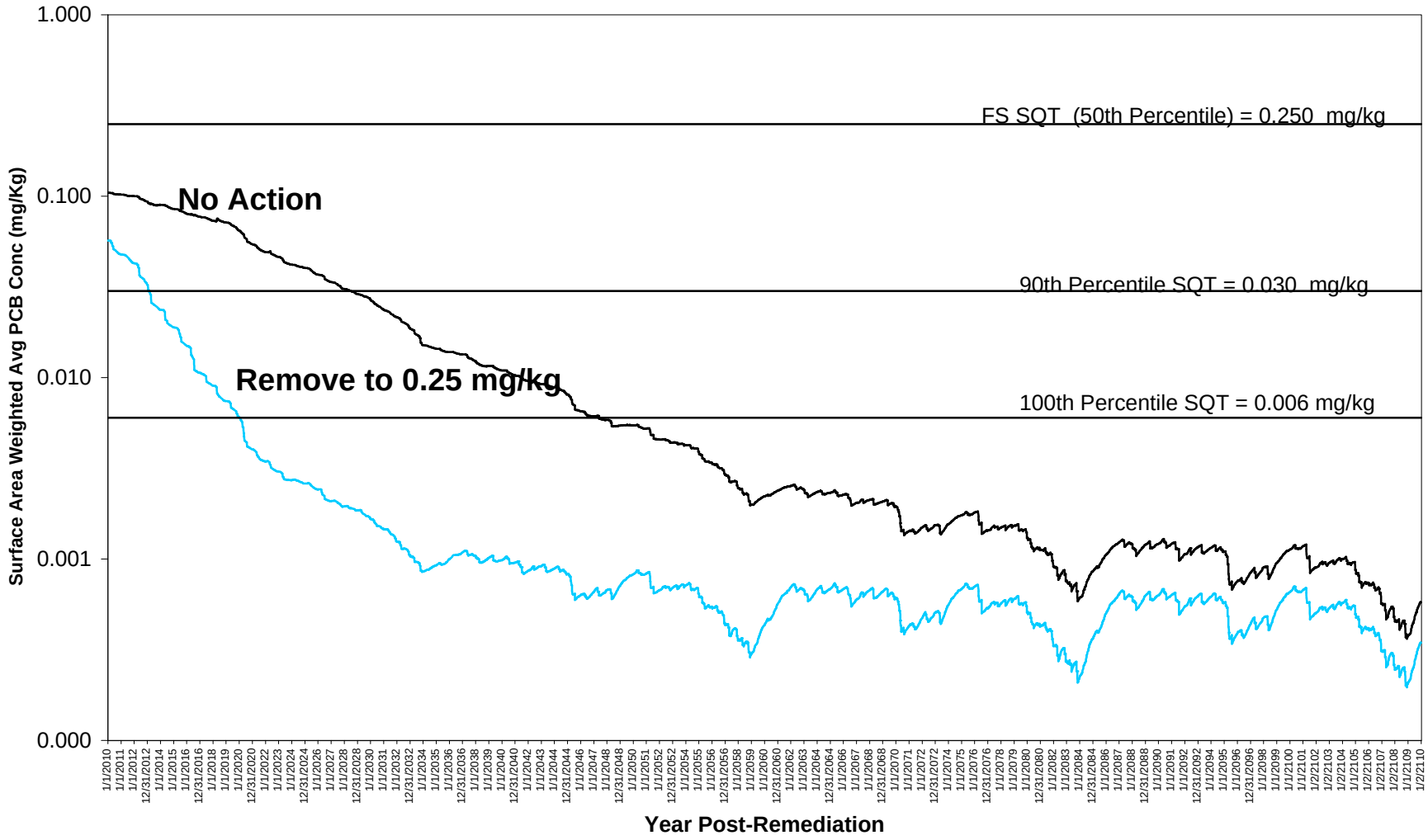
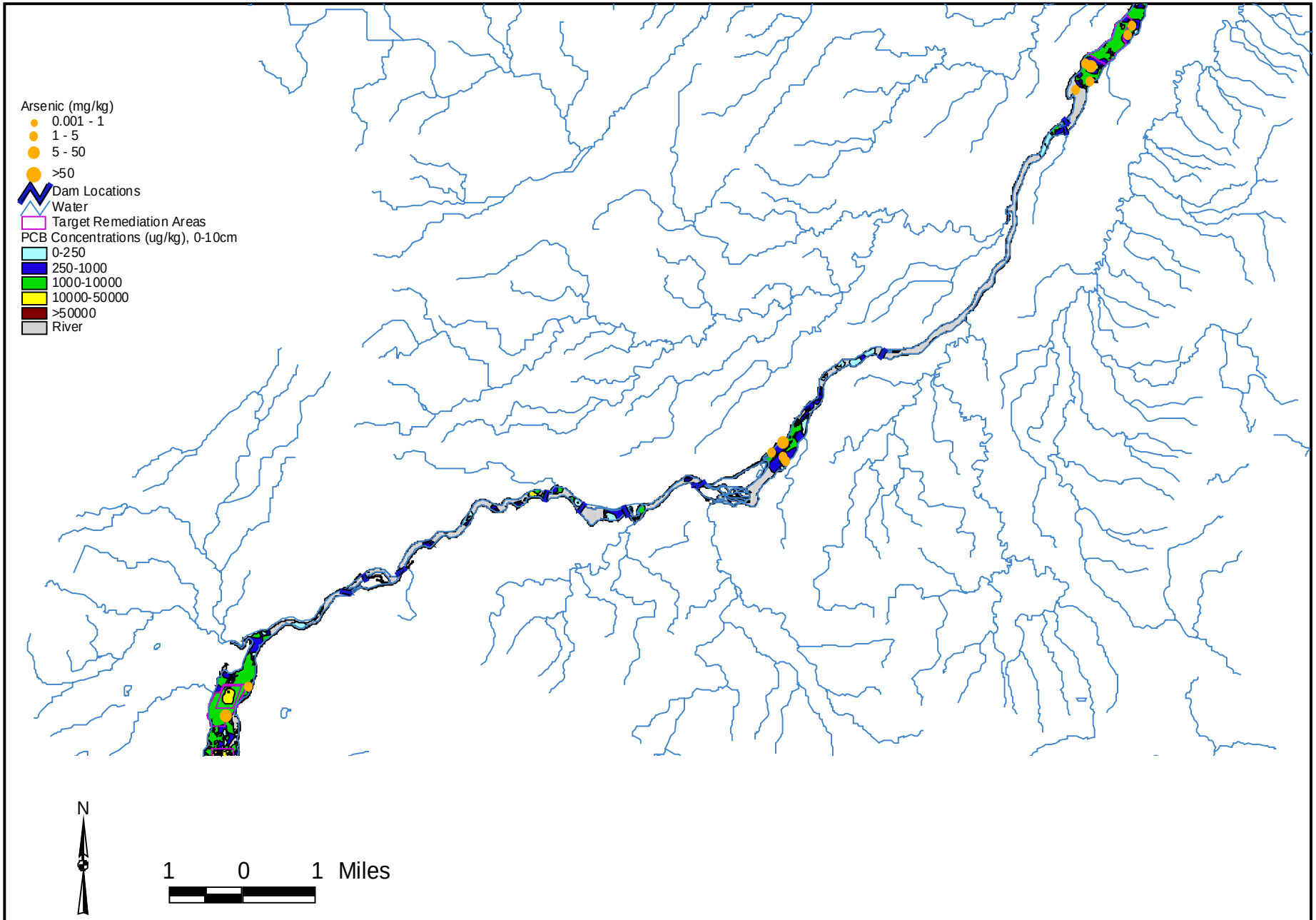


Figure 8-10. Post-Remediation Projected Surface PCB Concentrations
Appleton to Little Rapids





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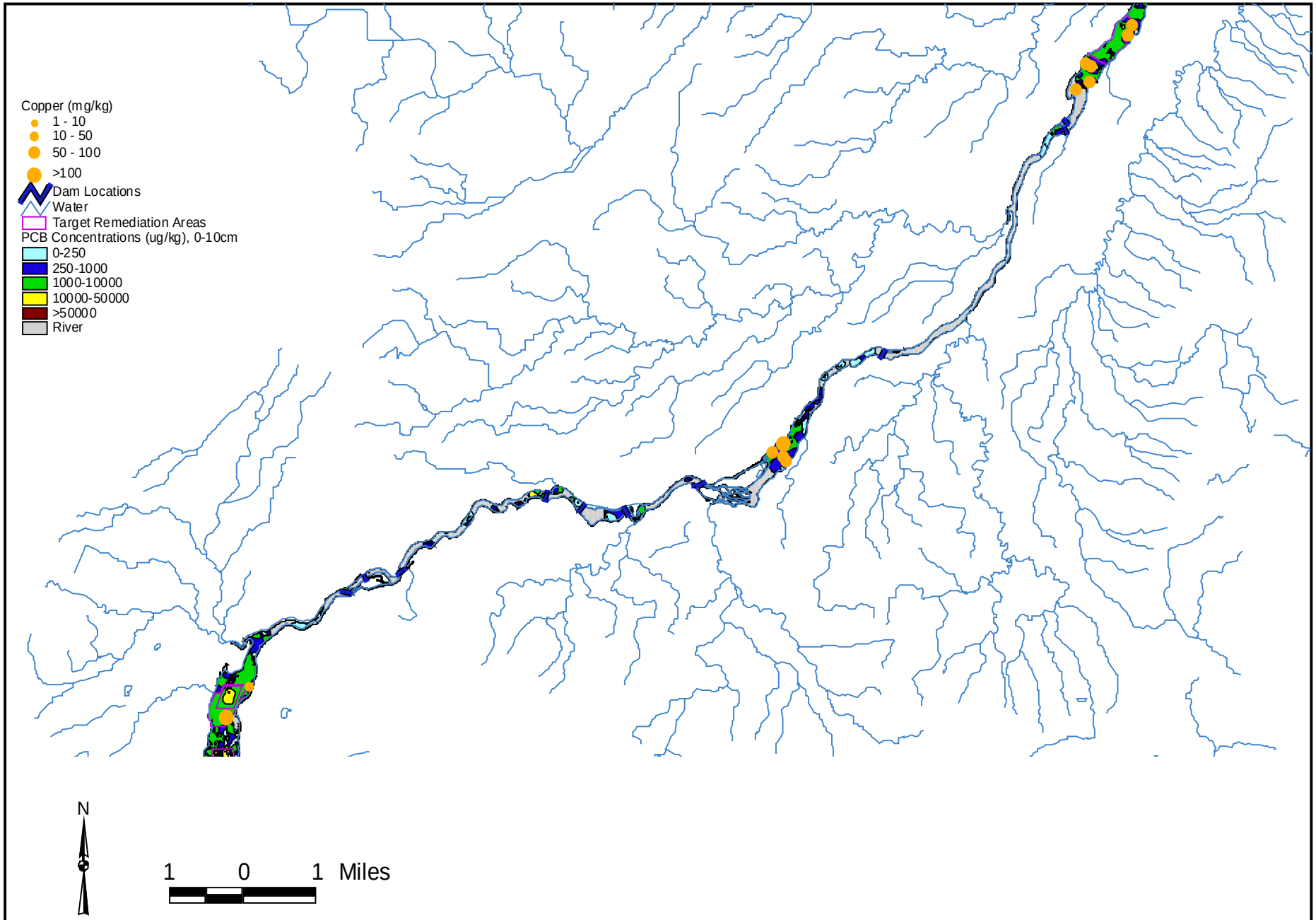
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500		APPLETON TO LITTLE RAPIDS SURFACE SEDIMENT TOTAL PCB AND ARSENIC DISTRIBUTION
DATE: 1/14/1999	FOXRIVER.APR	FIGURE 8-11



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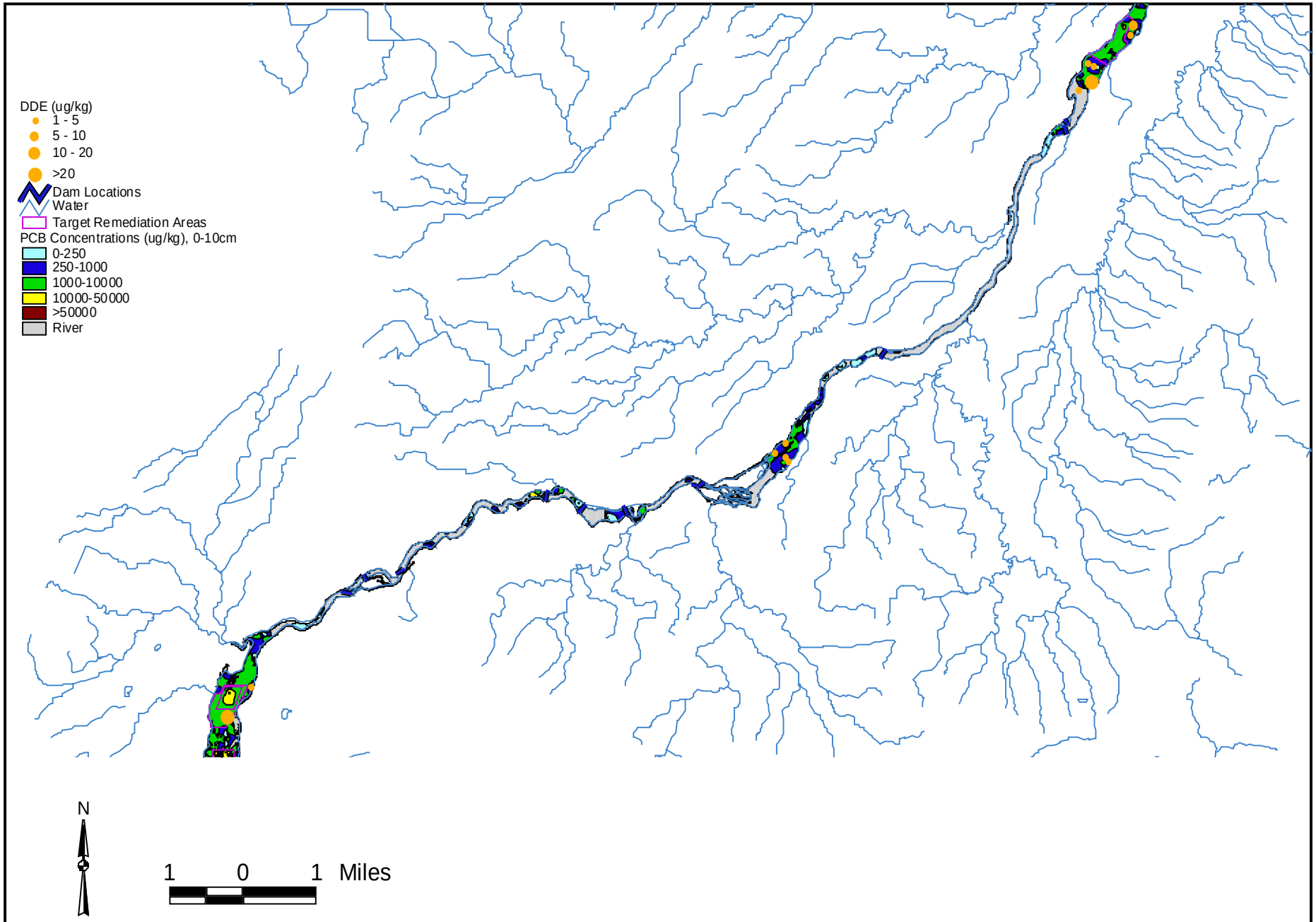
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500		APPLETON TO LITTLE RAPIDS SURFACE SEDIMENT TOTAL PCB AND COPPER DISTRIBUTION
DATE: 1/14/1999	FOXRIVER.APR	FIGURE 8-12



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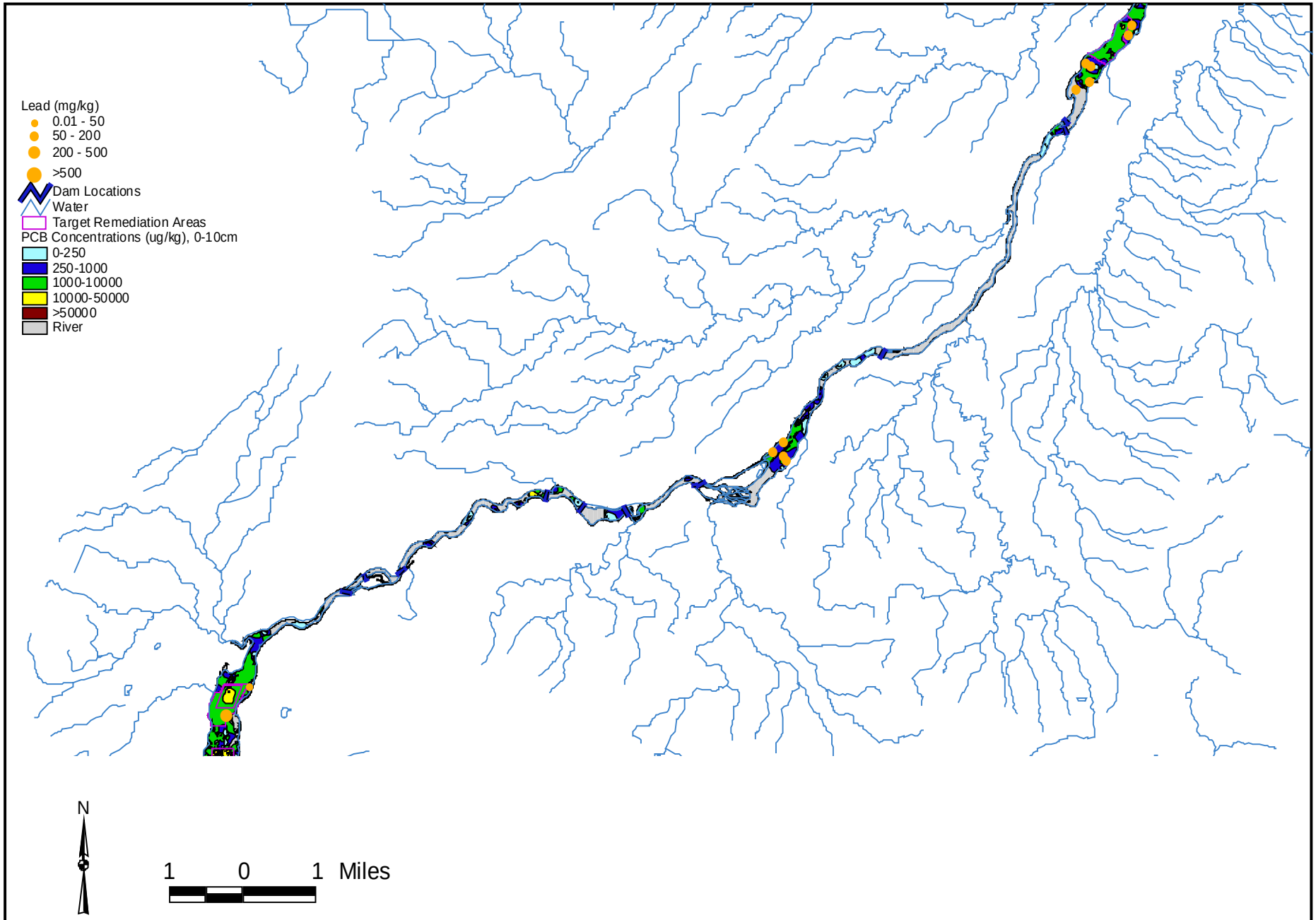
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500		APPLETON TO LITTLE RAPIDS SURFACE SEDIMENT TOTAL PCB AND DDE DISTRIBUTION
DATE: 1/14/1999	FOXRIVER.APR	FIGURE 8-13



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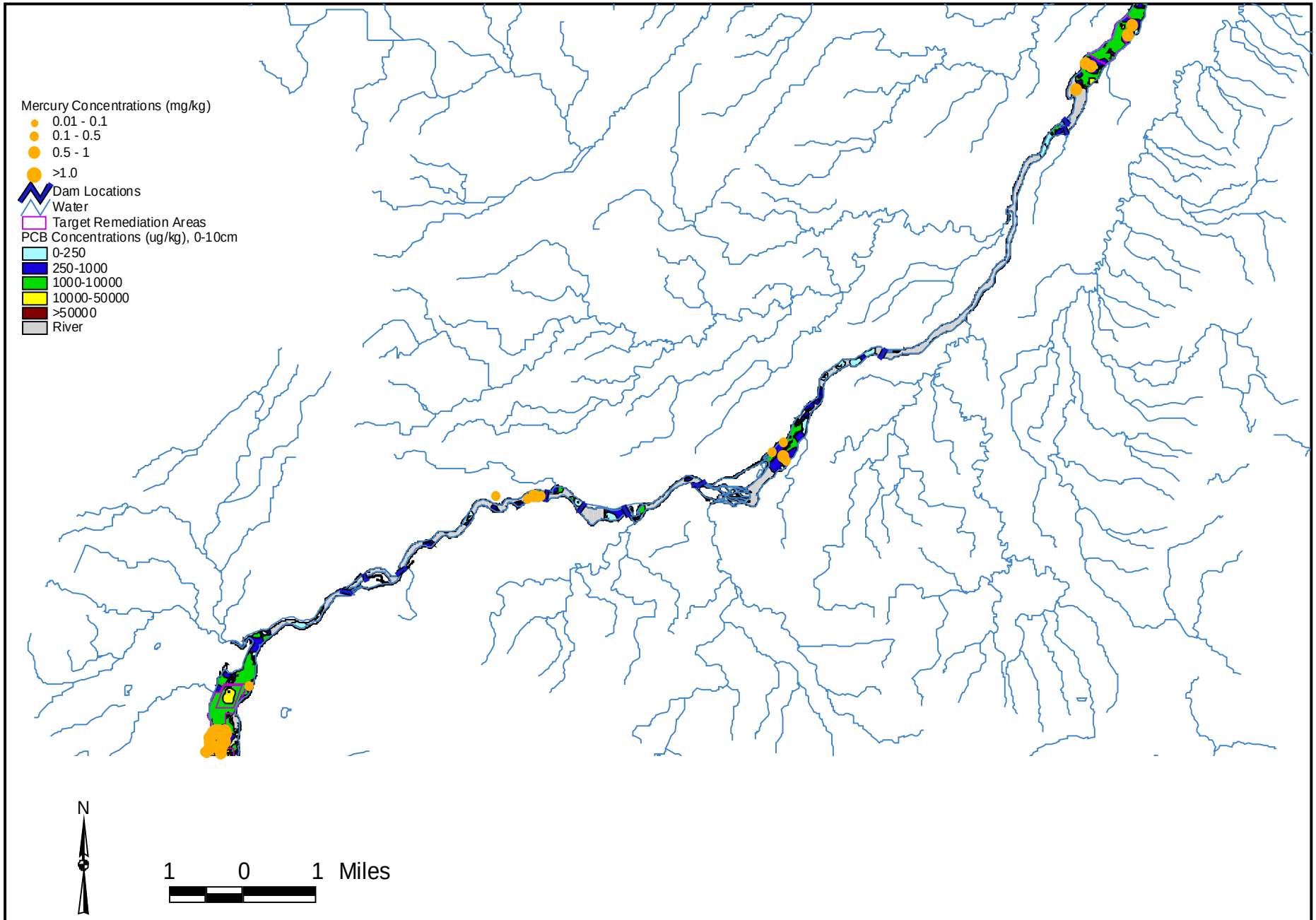
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500		APPLETON TO LITTLE RAPIDS SURFACE SEDIMENT TOTAL PCB AND LEAD DISTRIBUTION
DATE: 1/14/1999	FOXRIVER.APR	FIGURE 8-14



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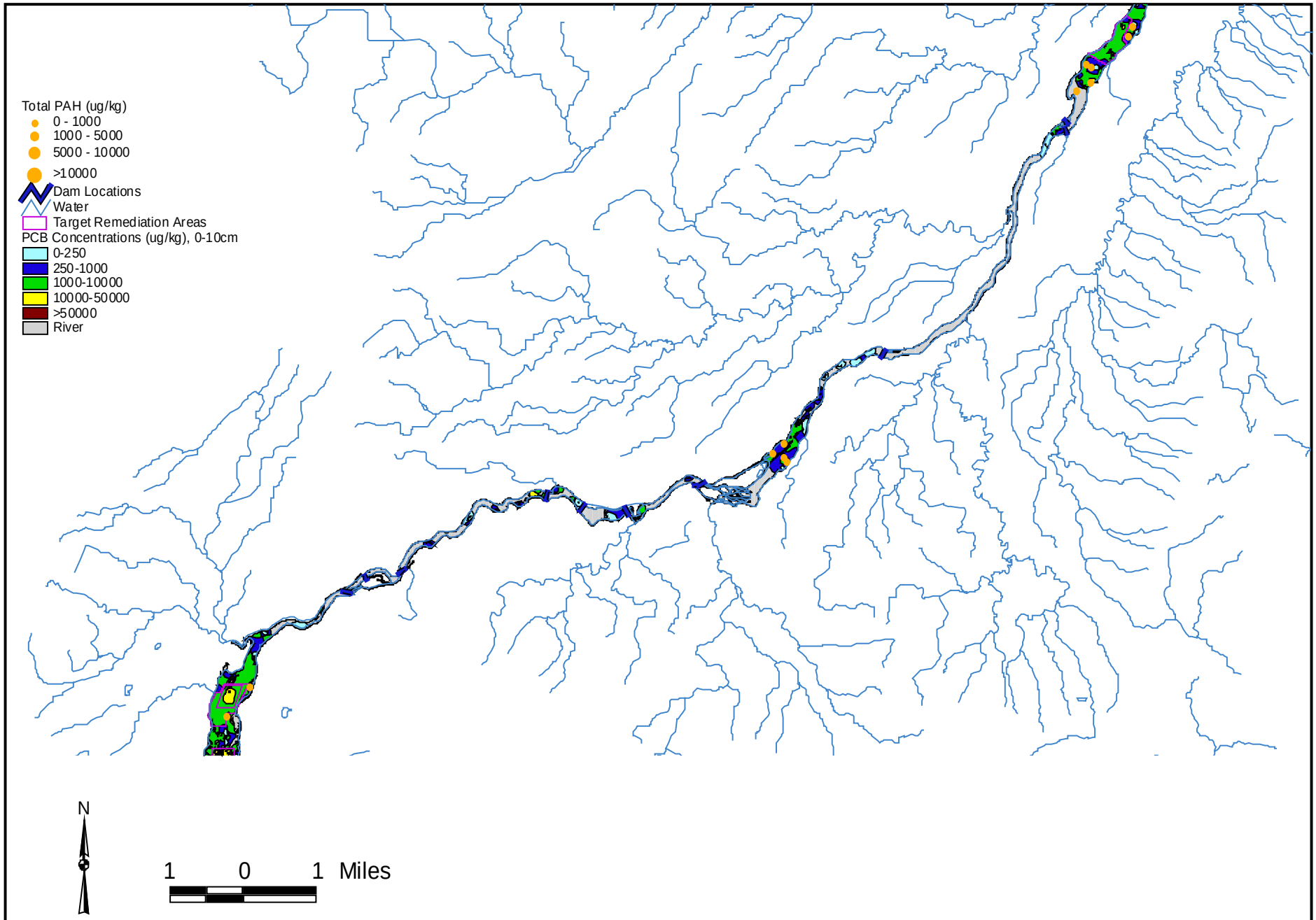
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500	APPLETON TO LITTLE RAPIDS SURFACE SEDIMENT TOTAL PCB AND MERCURY DISTRIBUTION
DATE: 1/14/1999 FOXRIVER.APR	FIGURE 8-15



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LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500	APPLETON TO LITTLE RAPIDS SURFACE SEDIMENT TOTAL PCB AND TOTAL PAHs DISTRIBUTION
DATE: 1/14/1999 FOXRIVER.APR	FIGURE 8-16

Figure 8-17. Projected Surface Water PCB Concentrations
Little Rapids to DePere

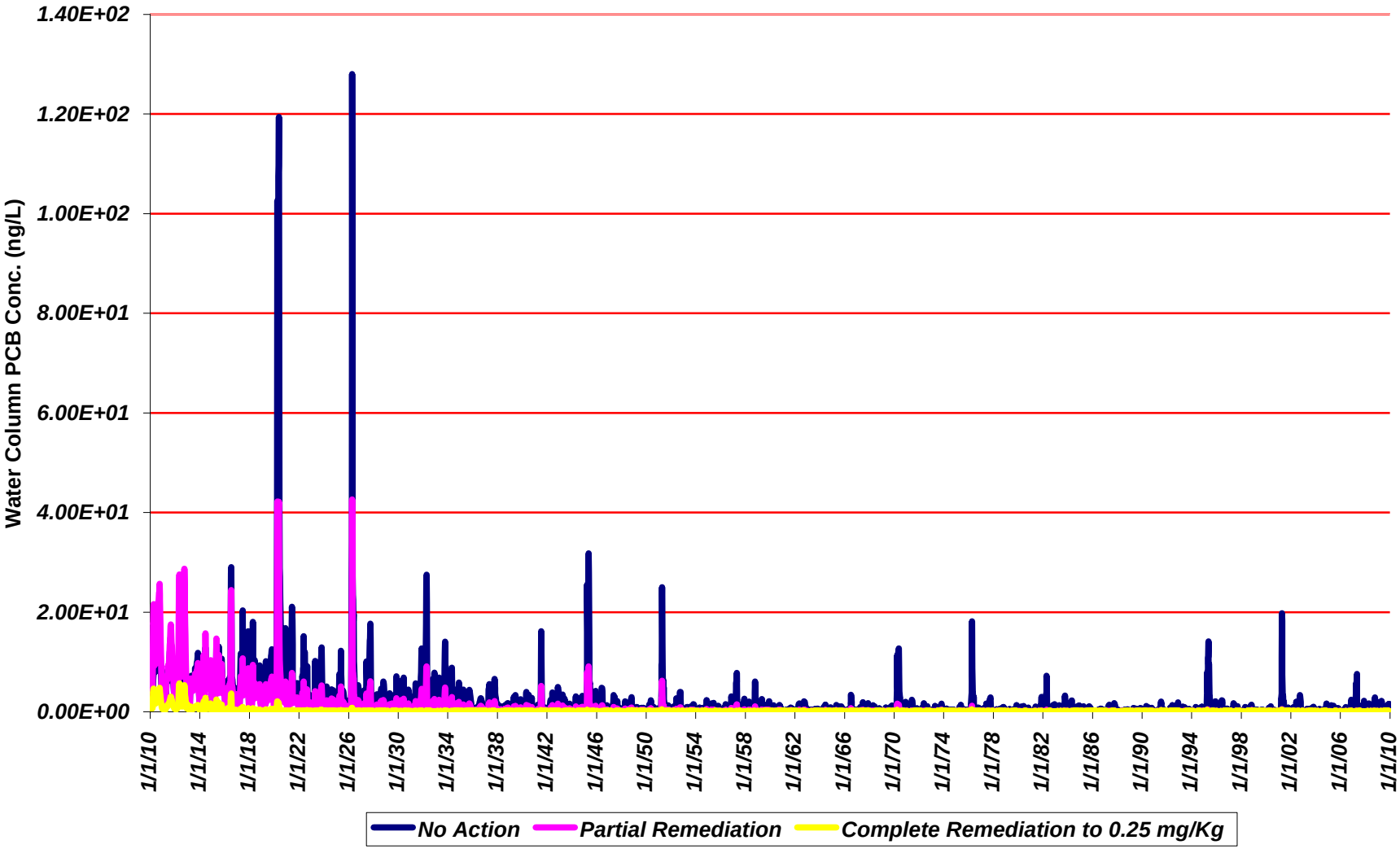
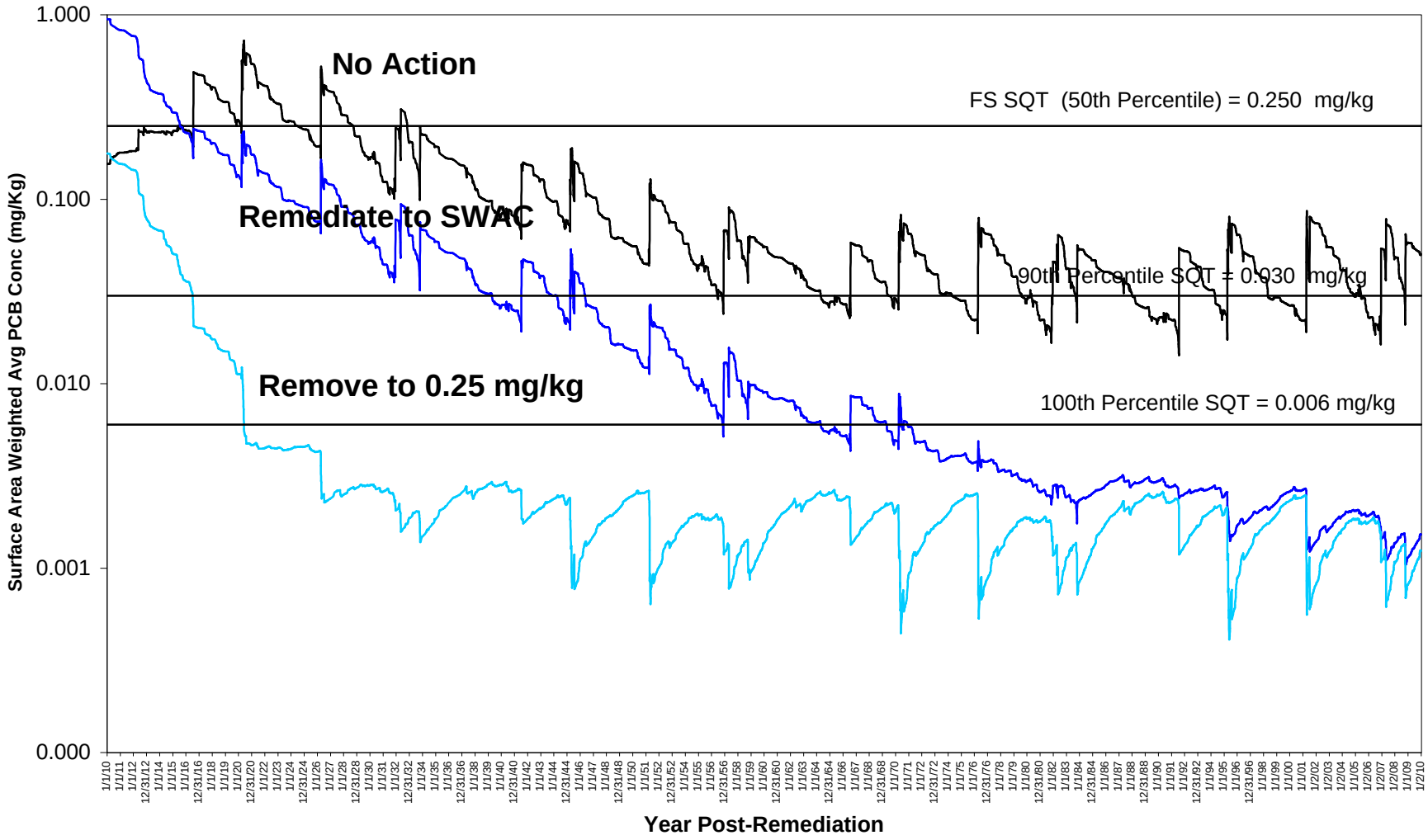
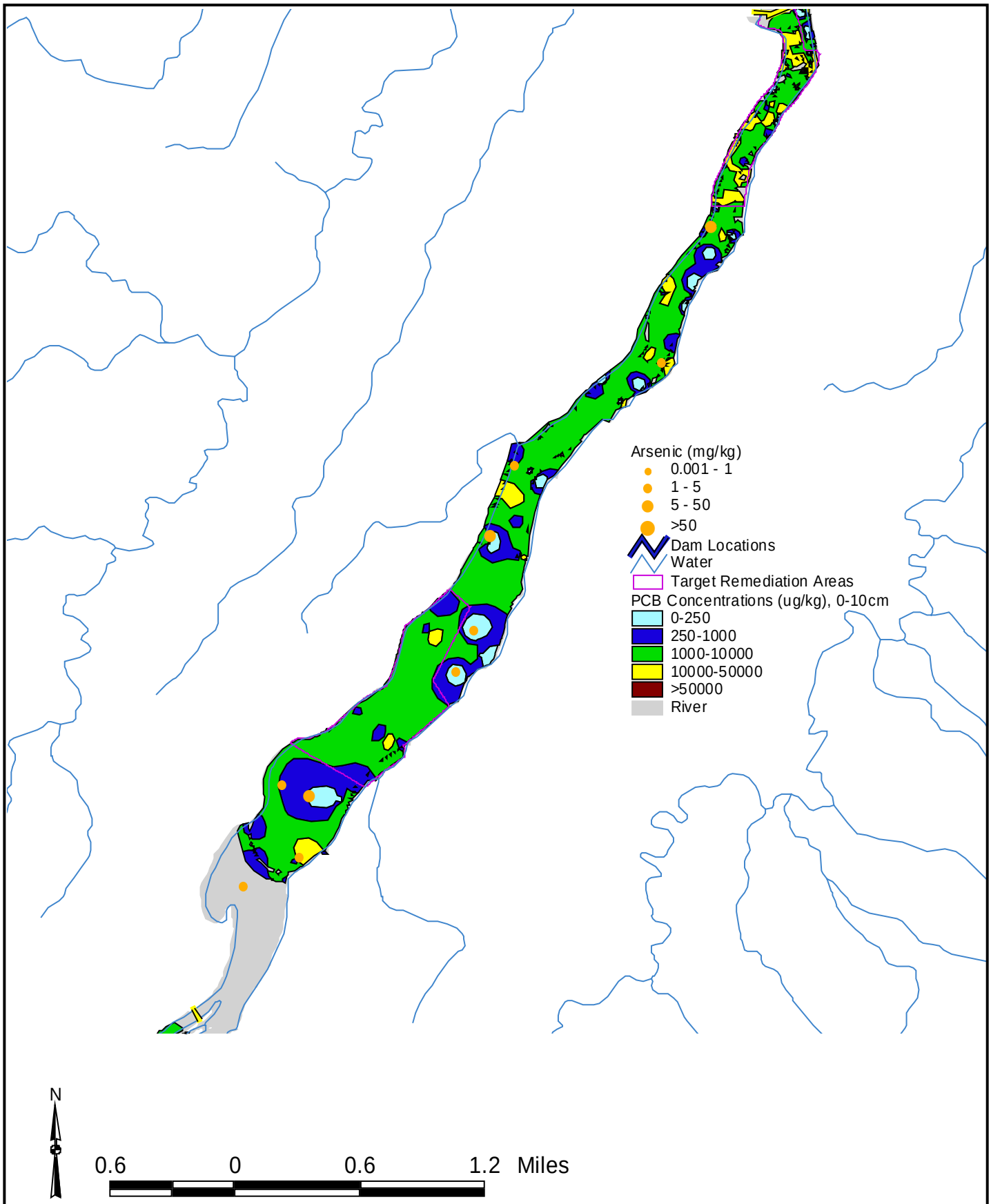


Figure 8-18. Post-Remediation Projected Surface PCB Concentrations
Little Rapids to DePere





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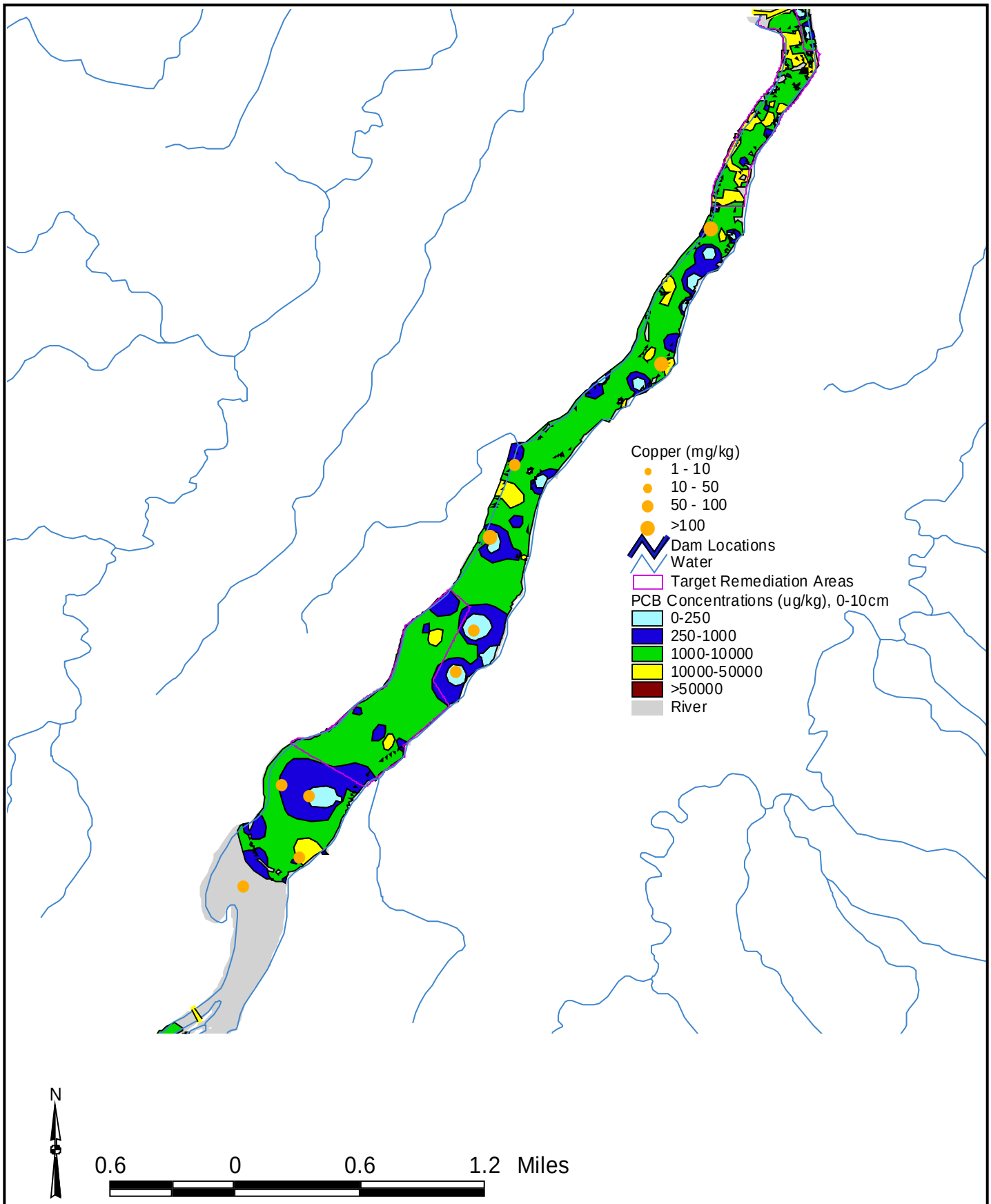
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500		LITTLE RAPIDS TO DePERE SURFACE SEDIMENT TOTAL PCB AND ARSENIC DISTRIBUTION	
DATE: 1/13/1999	FOXRIVER.APR		FIGURE 8-19



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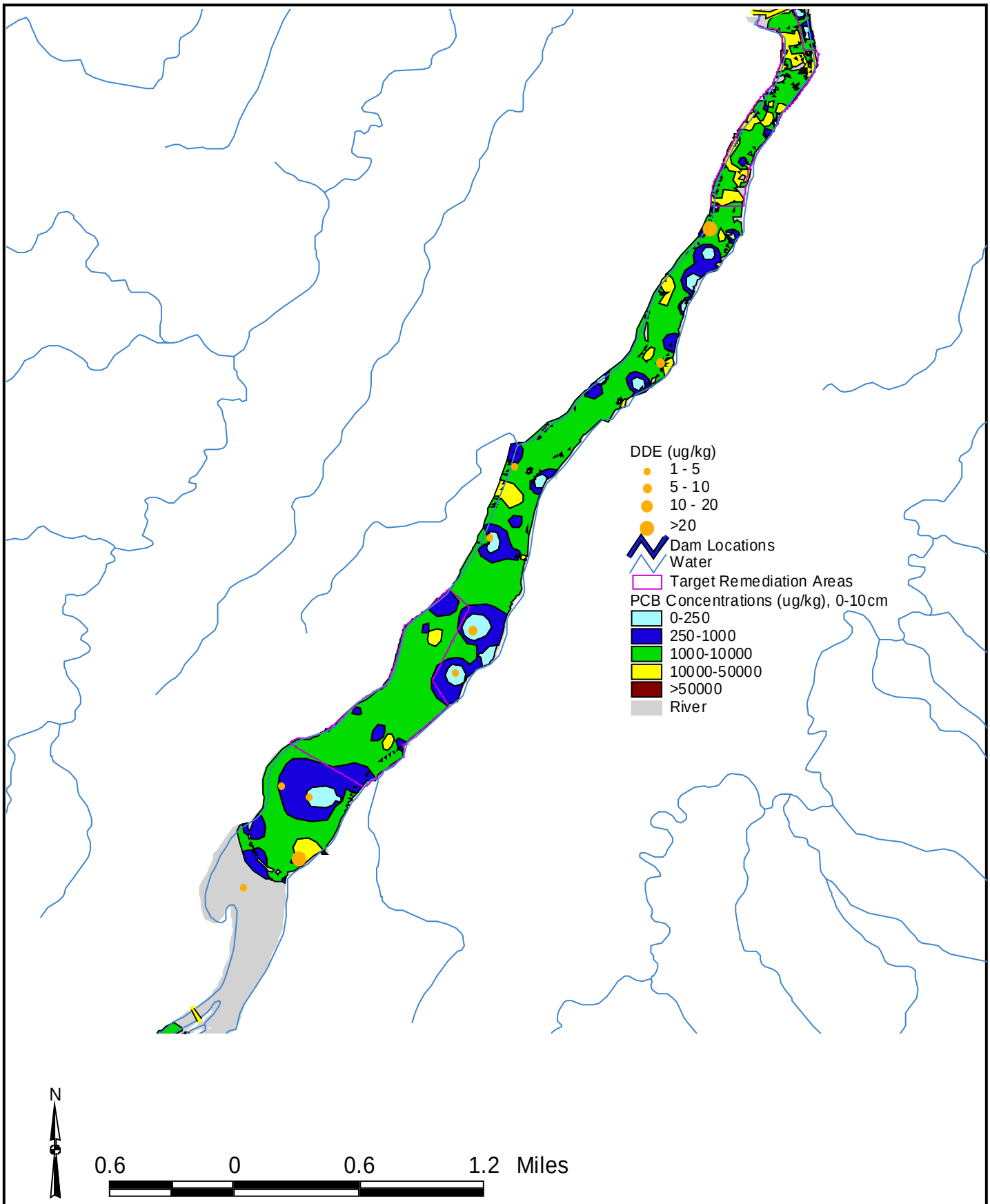
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500		LITTLE RAPIDS TO DePERE SURFACE SEDIMENT TOTAL PCB AND COPPER DISTRIBUTION	
DATE: 1/13/1999	FOXRIVER.APR		FIGURE 8-20



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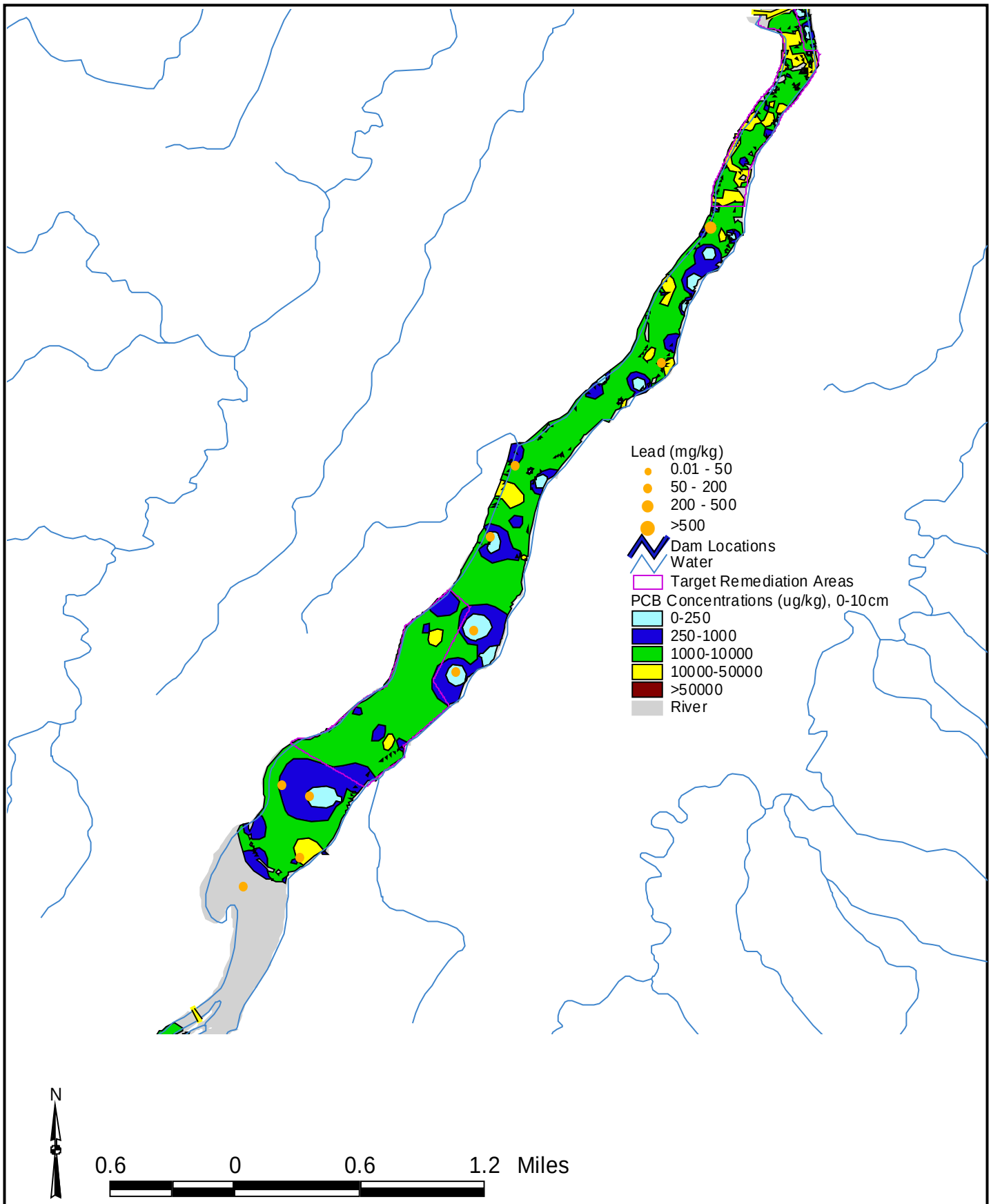
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500		LITTLE RAPIDS TO DePERE SURFACE SEDIMENT TOTAL PCB AND DDE DISTRIBUTION	
DATE: 1/13/1999	FOXRIVER.APR		FIGURE 8-21



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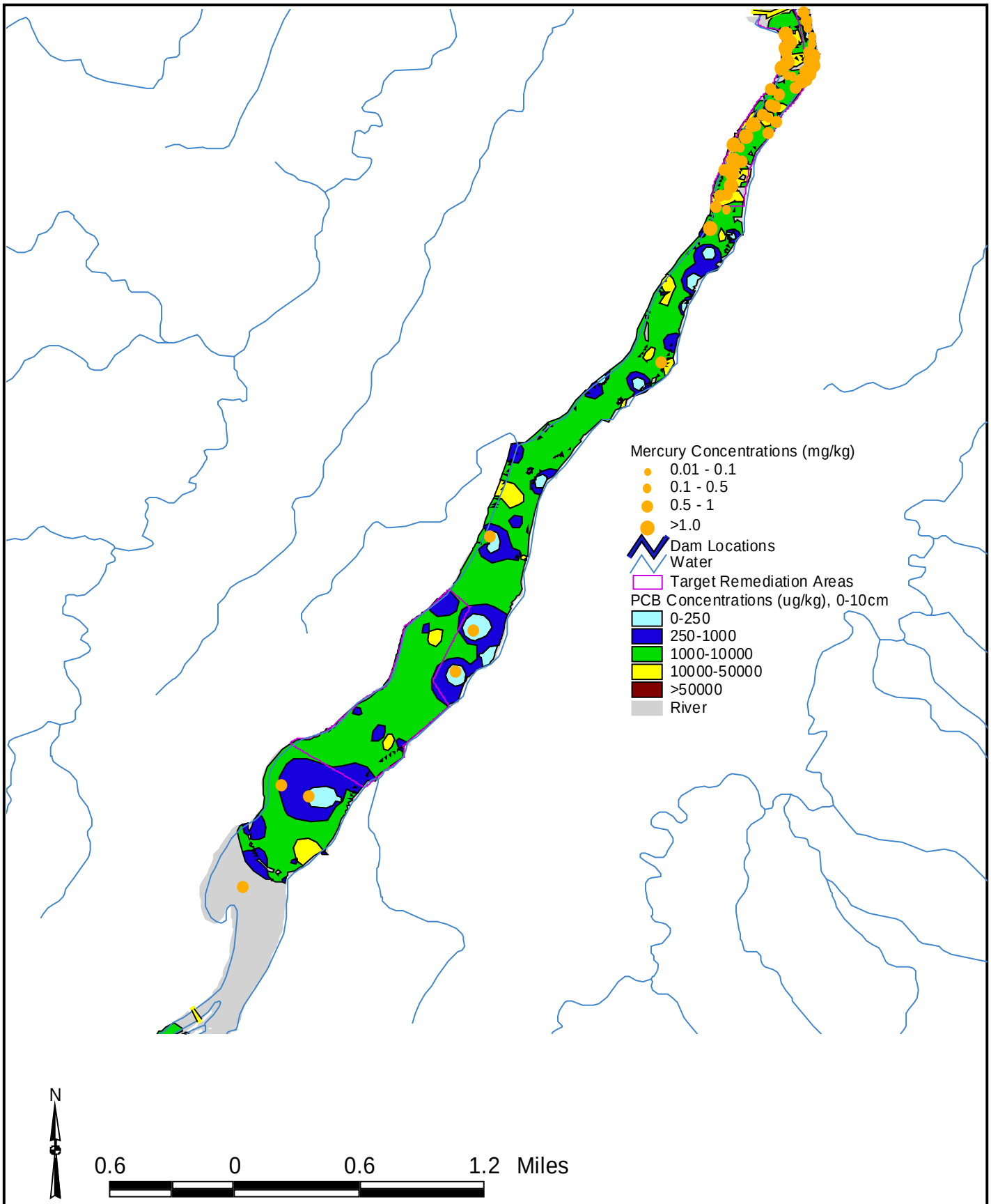
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500		LITTLE RAPIDS TO DePERE SURFACE SEDIMENT TOTAL PCB AND LEAD DISTRIBUTION	
DATE: 1/13/1999	FOXRIVER.APR		FIGURE 8-22



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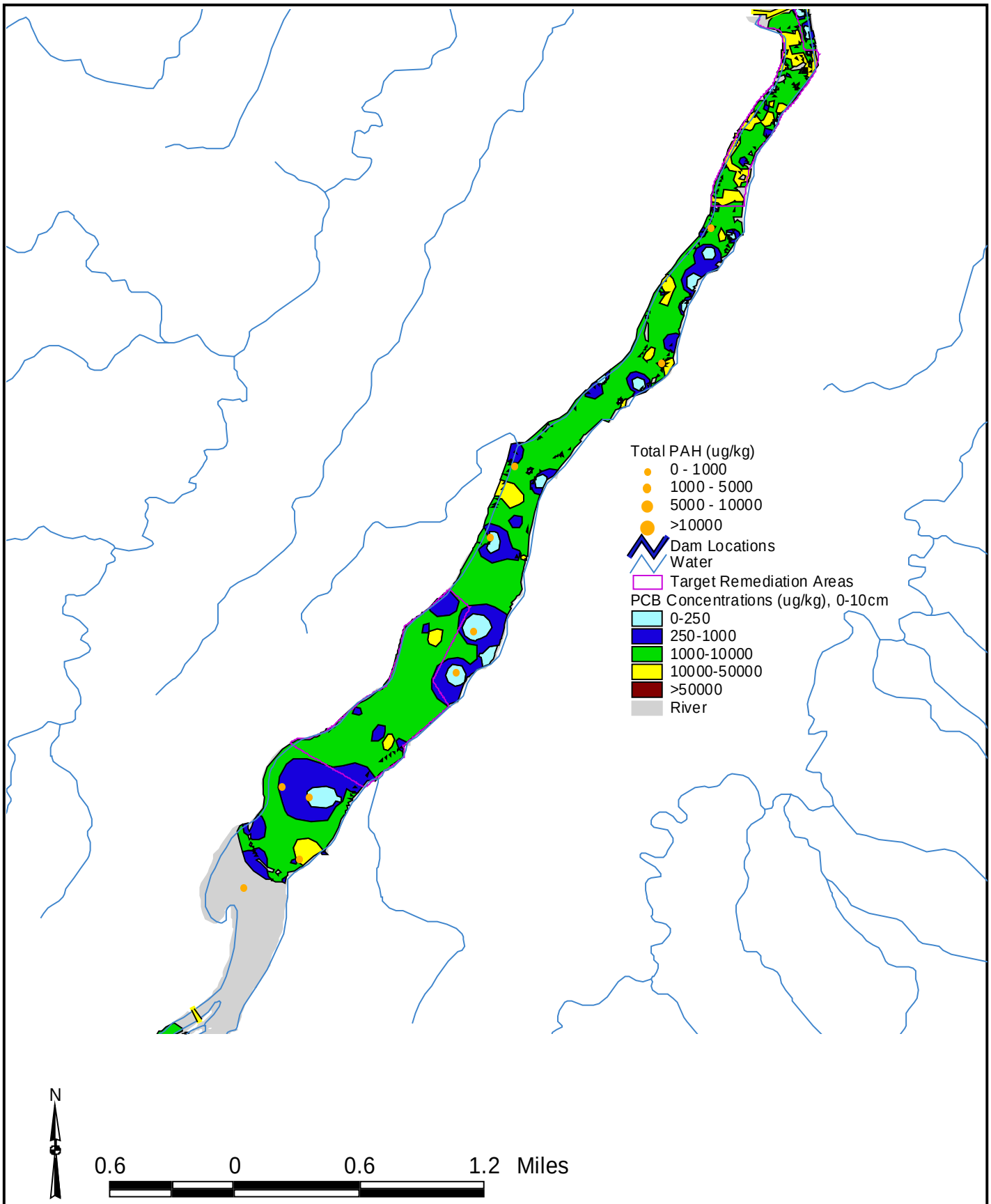
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500		LITTLE RAPIDS TO DePERE SURFACE SEDIMENT TOTAL PCB AND MERCURY DISTRIBUTION	
DATE: 1/13/1999	FOXRIVER.APR		FIGURE 8-23



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LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500		LITTLE RAPIDS TO DePERE SURFACE SEDIMENT TOTAL PCB AND TOTAL PAHs DISTRIBUTION	
DATE: 1/13/1999	FOXRIVER.APR		FIGURE 8-24

Figure 8-25. Projected Surface Water PCB Concentrations
DePere to Green Bay

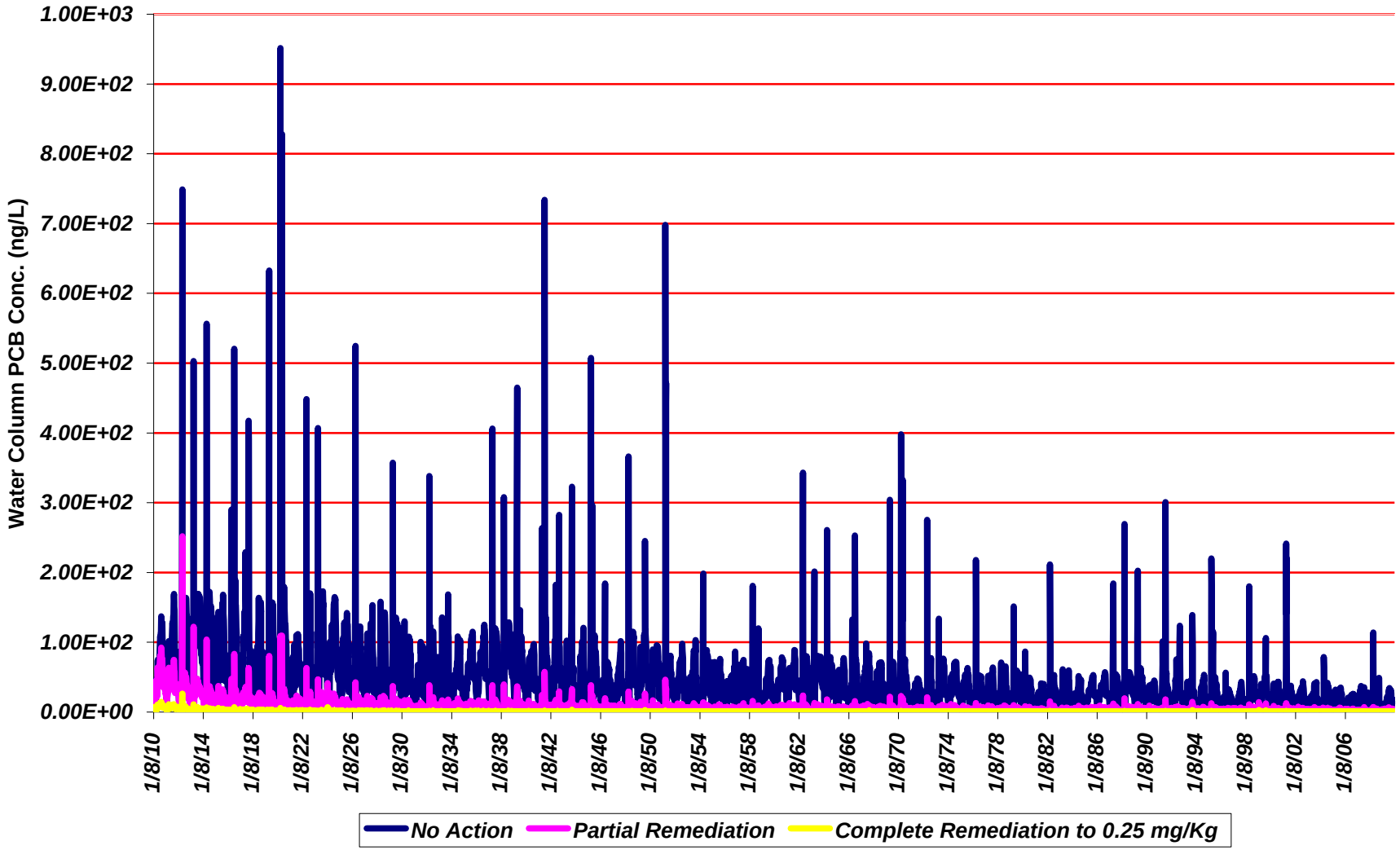
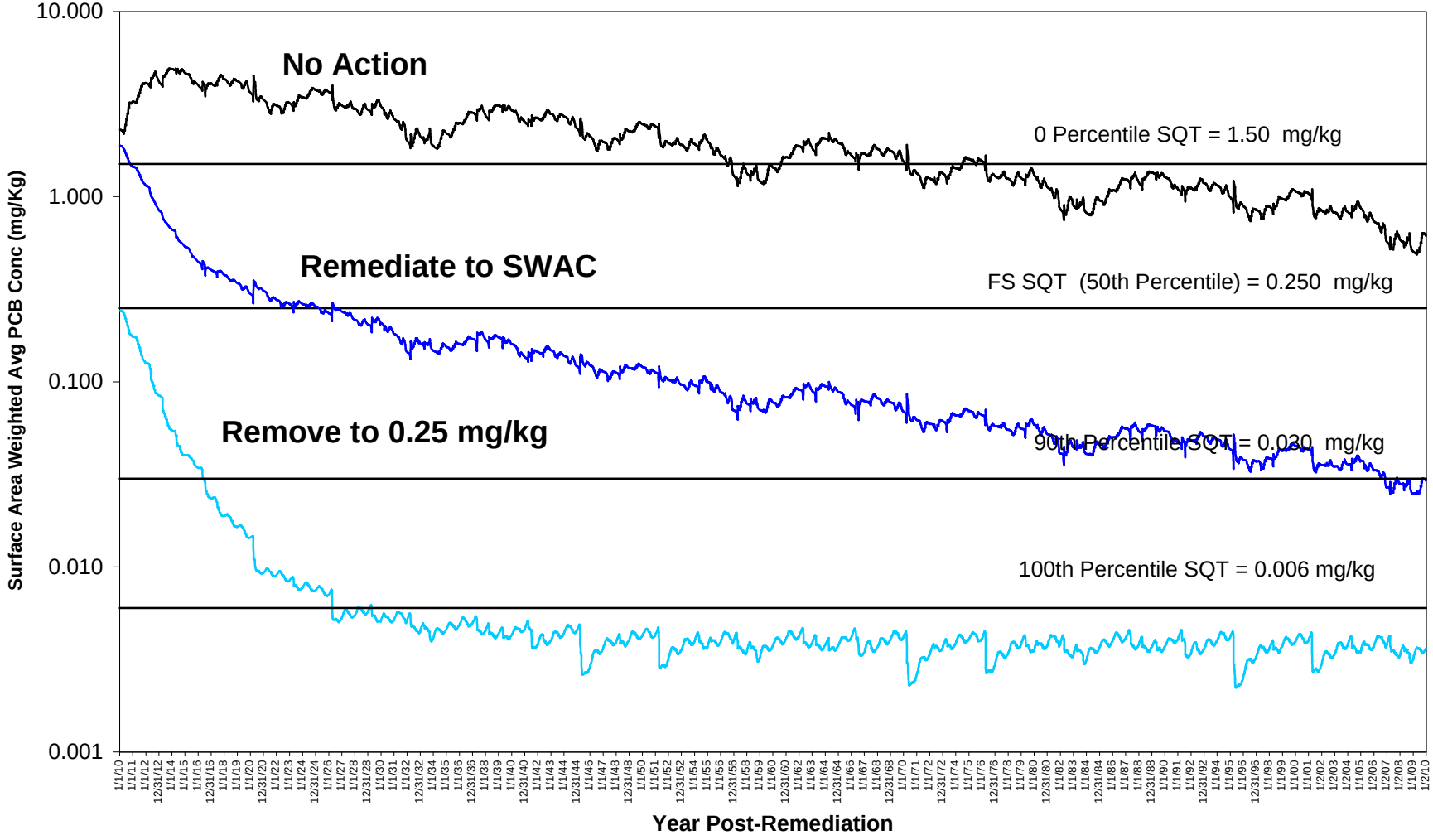
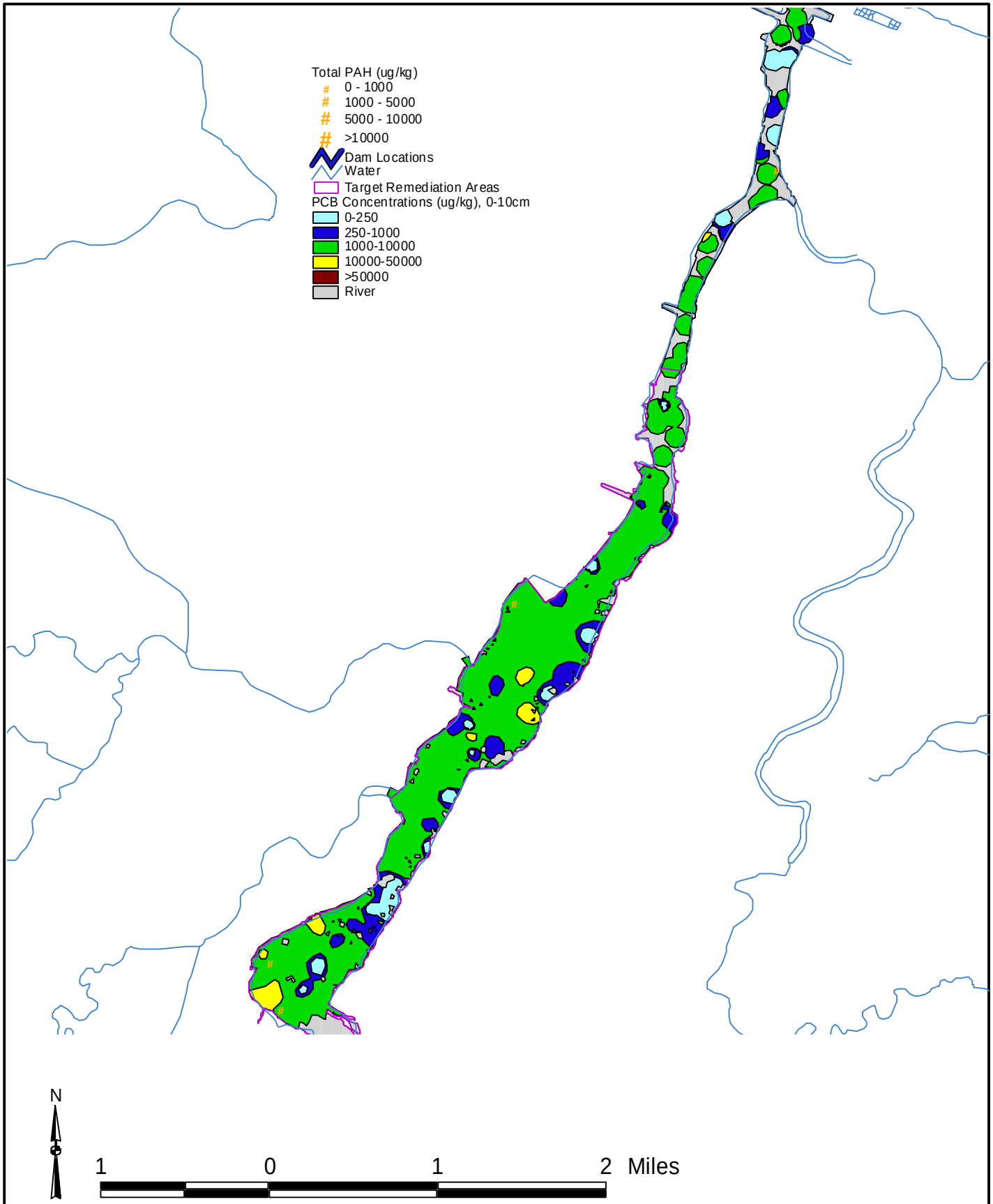


Figure 8-26. Post-Remediation Projected Surface PCB Concentrations
DePere to Green Bay





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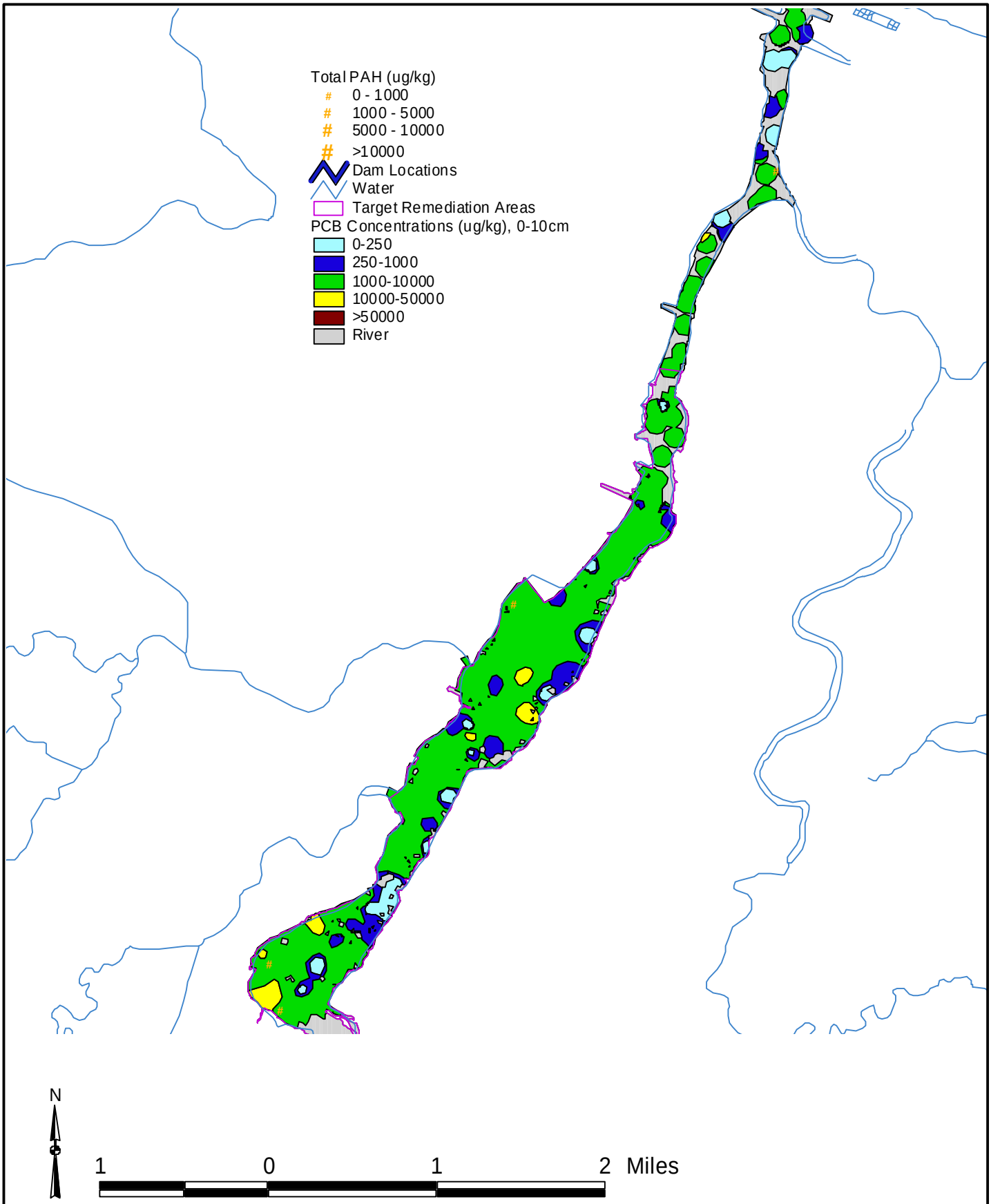
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500	DePERE TO GREEN BAY SURFACE SEDIMENT TOTAL PCB AND ARSENIC DISTRIBUTION
DATE: 1/13/1999 FOXRIVER.APR	FIGURE 8-27



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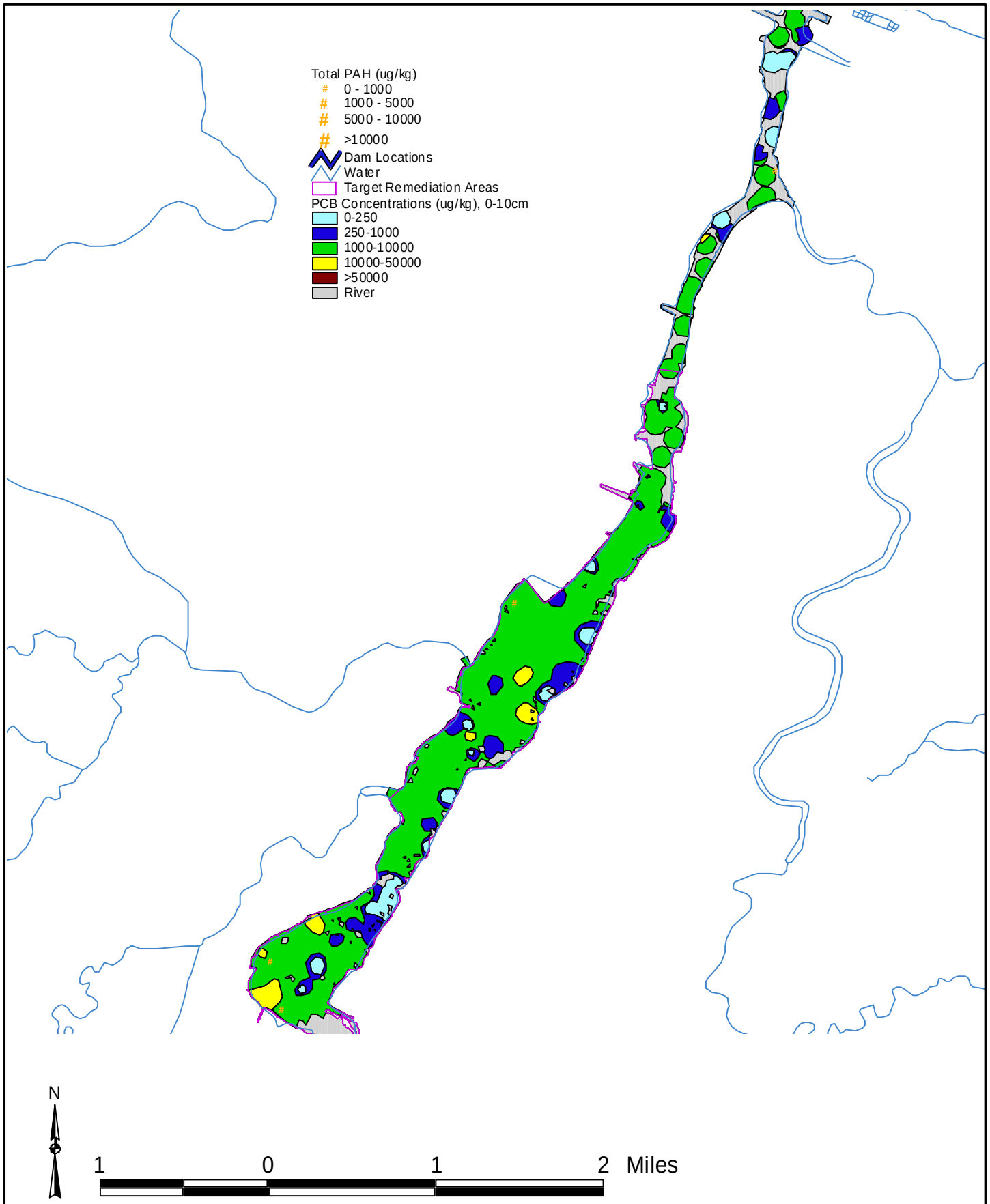
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500		DePERE TO GREEN BAY SURFACE SEDIMENT TOTAL PCB AND COPPER DISTRIBUTION
DATE: 1/13/1999	FOXRIVER.APR	FIGURE 8-28



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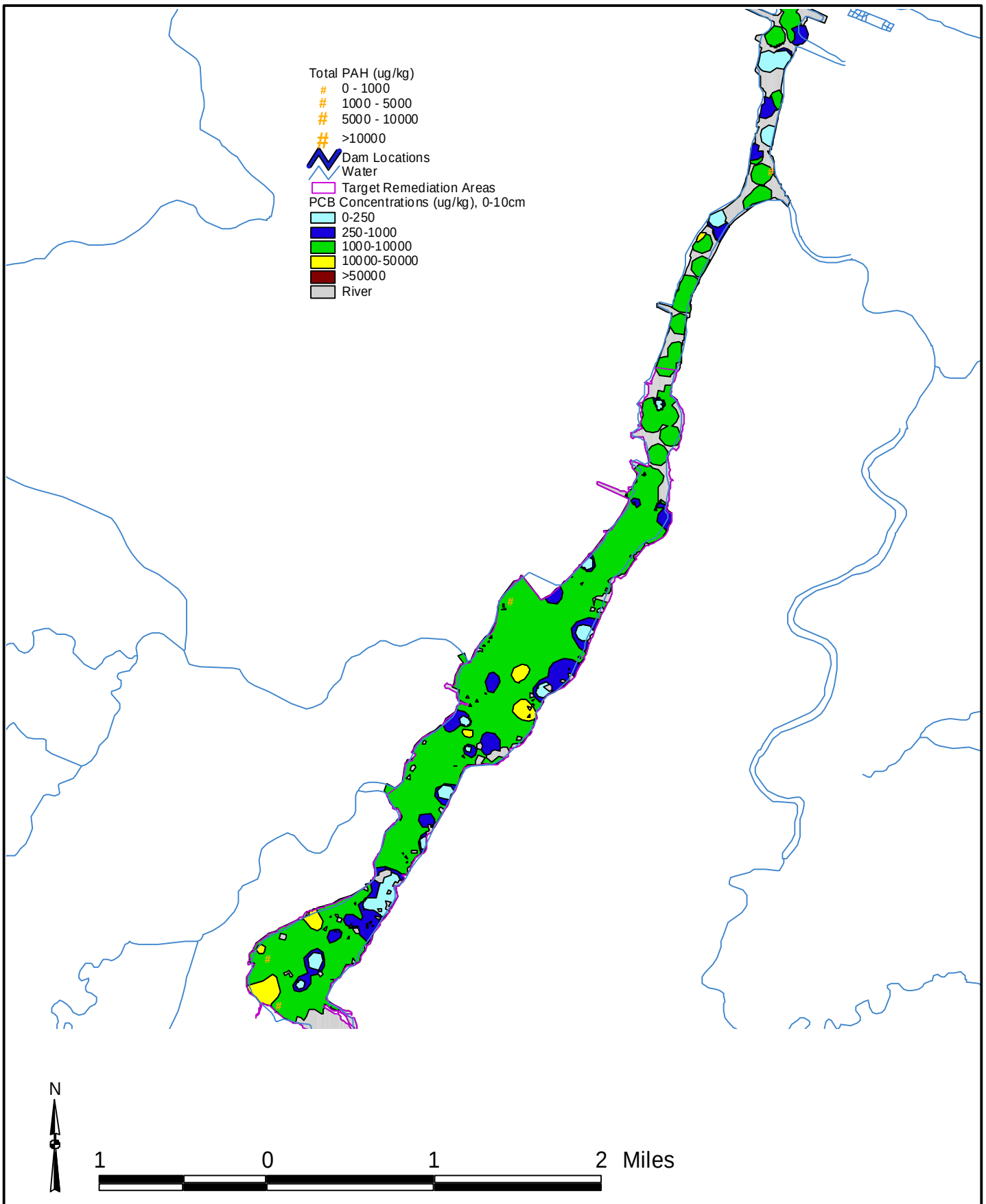
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500		DePERE TO GREEN BAY SURFACE SEDIMENT TOTAL PCB AND DDE DISTRIBUTION	
DATE: 1/13/1999	FOXRIVER.APR		FIGURE 8-29



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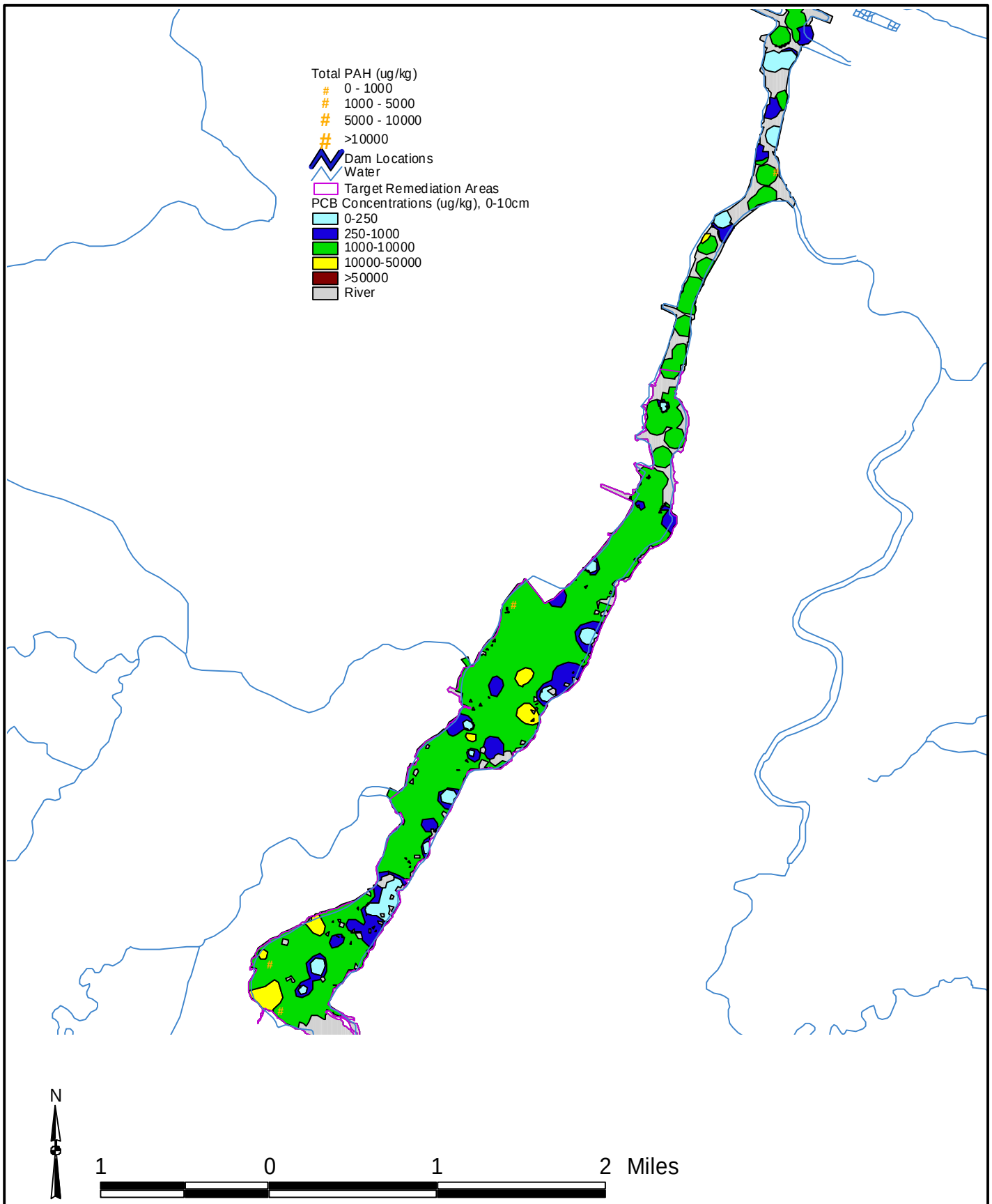
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500	DePERE TO GREEN BAY SURFACE SEDIMENT TOTAL PCB AND LEAD DISTRIBUTION
DATE: 1/13/1999 FOXRIVER.APR	FIGURE 8-30



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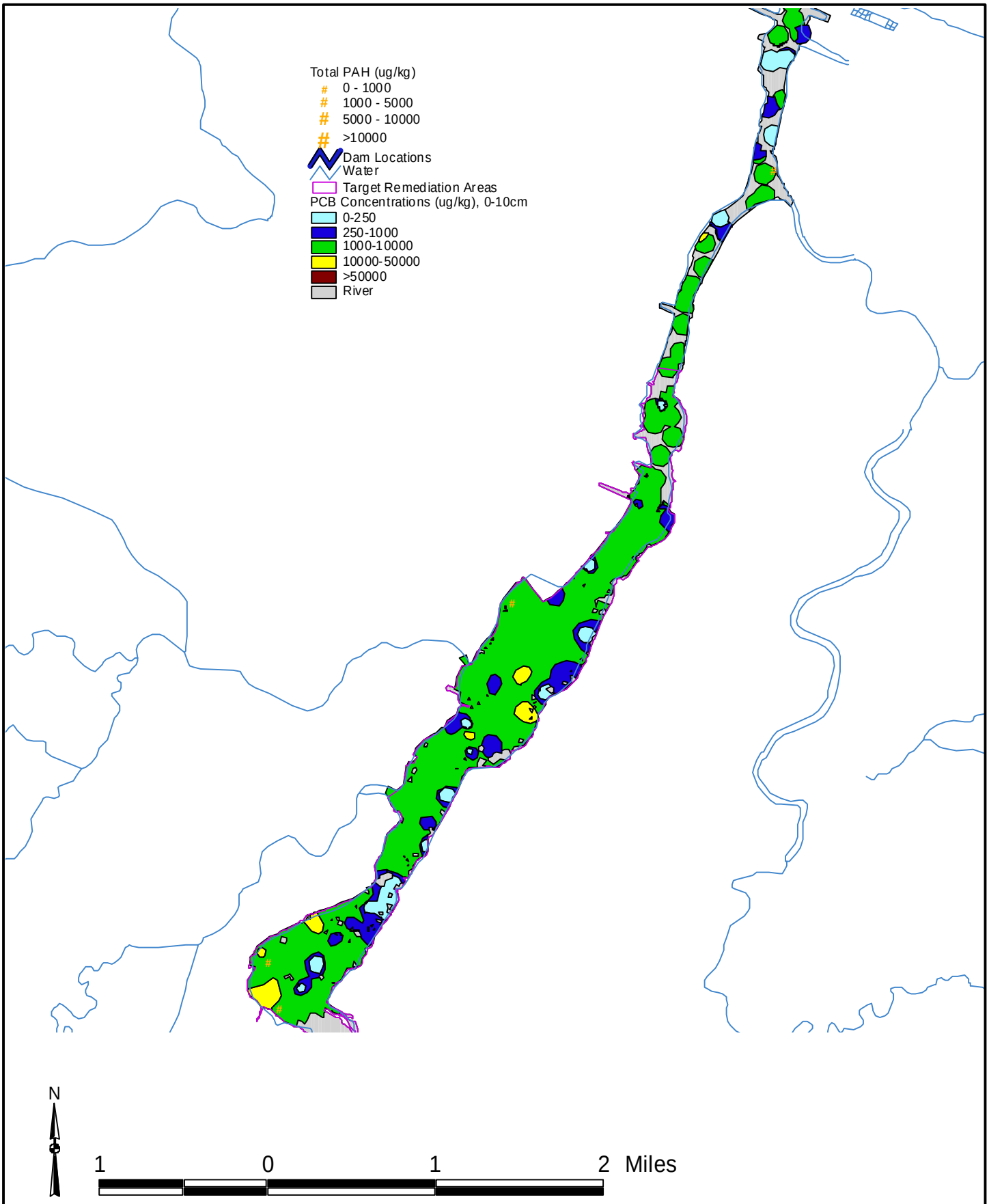
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500		DePERE TO GREEN BAY SURFACE SEDIMENT TOTAL PCB AND MERCURY DISTRIBUTION	
DATE: 1/13/1999	FOXRIVER.APR		FIGURE 8-31



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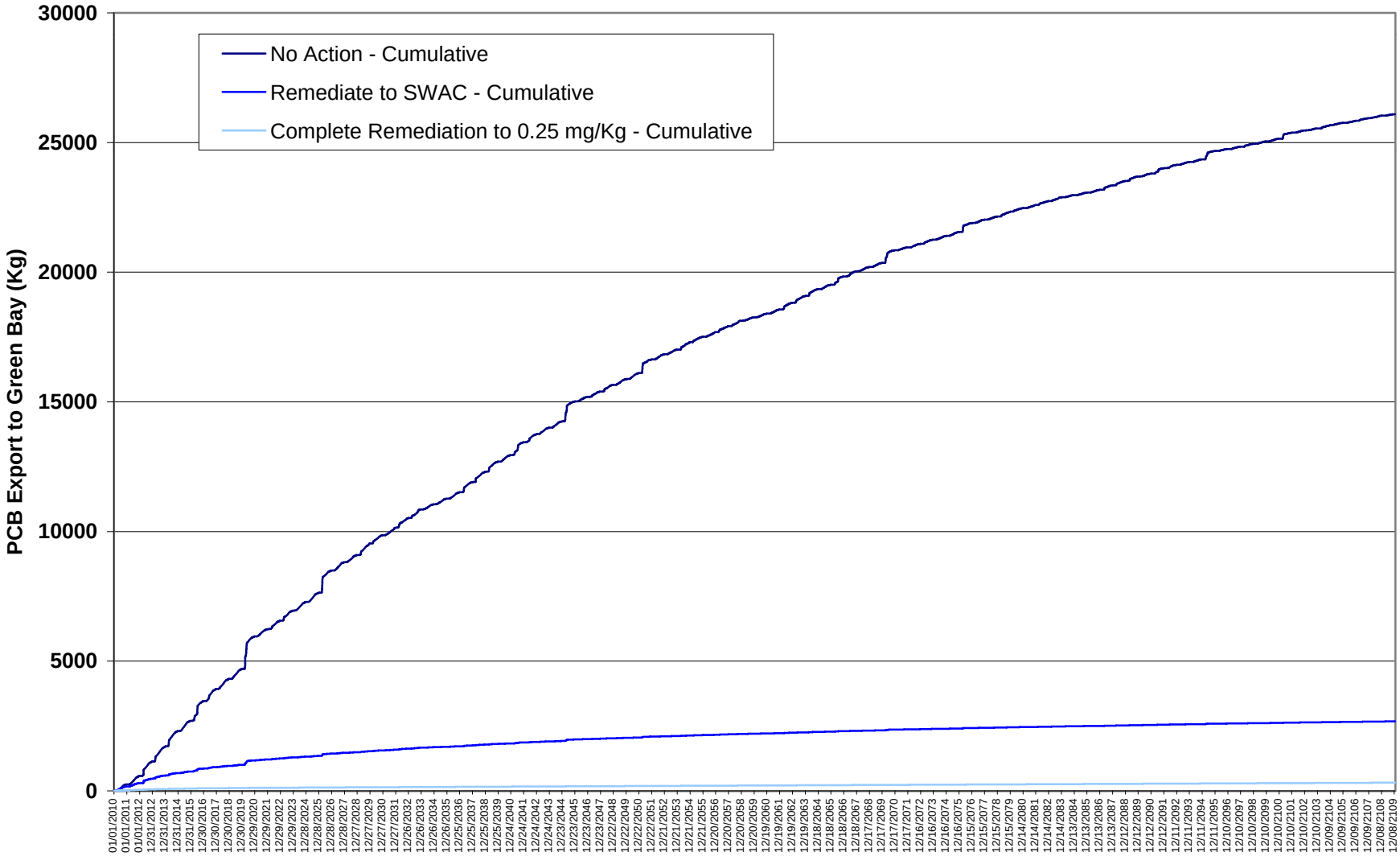
LOWER FOX RIVER FEASIBILITY STUDY 3-3584-500		DePERE TO GREEN BAY SURFACE SEDIMENT TOTAL PCB AND TOTAL PAHs DISTRIBUTION	
DATE: 1/13/1999	FOXRIVER.APR		FIGURE 8-32

Figure 8-33. PCB Export to Green Bay under the Remedial Alternatives



9 Detailed Analysis of Remedial Alternatives

This section presents the detailed analysis of the river reach remedial alternatives developed and presented in Section 7 of this FS Report. Figure 8-1 provides a schematic view of the detailed analysis as described in the EPA RI/FS Guidance. As described in the EPA RI/FS Guidance, and shown in Figure 8-1, the complete detailed analysis consists of the following three sets of analysis:

- Threshold Criteria
  - Overall Protection of Human Health and the Environment
  - Compliance with ARARs
- Balancing Criteria
  - Long-Term Effectiveness and Permanence
  - Reduction of Toxicity, Mobility and Volume Through Treatment
  - Short-Term Effectiveness
  - Implementability
  - Cost
- Regulatory/Community Criteria
  - State Acceptance
  - Community Acceptance

The Regulatory/Community Criteria are not evaluated in this FS Report. As noted on Figure 9-1, these criteria are assessed through substantial public involvement at work shops, public meetings and working groups, some of which have been completed, and through the upcoming public comment period. The public comment period will involve public meetings where comments will be solicited by the WDNR on the contents of the RI and FS Reports. The following sections describe how the Threshold Criteria and the Balancing Criteria are addressed in the detailed analysis.

9.1 Description of the Detailed Analysis Process

This section describes the detailed analysis process. Sections 9.2 and 9.3 are organized according to the primary criteria introduced at the start of this section

(with the exception of the Regulatory/ Community Criteria). The evaluation is accomplished by considering each remedial alternative in terms of the criteria. With respect to the Balancing Criteria, the evaluation is conducted by proposing a number of questions directly related to each criteria, as a means of considering and thoroughly evaluating the river reach alternatives.

Sections 9.2 and 9.3 describe the Threshold Criteria and the Balancing Criteria, respectively.

9.2 Threshold Criteria

The Threshold Criteria are addressed through the development of the remedial alternatives, and within the context of the screening conducted for the Balancing Criteria.

9.2.1 Overall Protection of Human Health and the Environment

The criterion, Overall Protection of Human Health and the Environment, is first addressed in Section 7 of this FS Report through the identification of the methods used to reduce the potential for adverse exposures to contaminated sediments. Section 8 of this FS Report continues the discussion of Overall Protection of Human Health and the Environment by providing a detailed analysis of this criteria for each of the remedial alternatives.

As discussed in Section 8, the primary risk to human health associated with the contaminated sediments is consumption of fish. Protection of human health is achieved to varying degrees for each of the remedial alternatives through the application of the response actions. The specific residual risk associated with each remedial alternative is provided in the screening of the Balancing Criteria under Magnitude and Type of Residual Risk (see Tables 9-1, 9-6, 9-11 and 9-16). The residual risk values provided in these tables are for subsistence anglers and recreational anglers.

9.2.2 Compliance with ARARs and TBCs

Section 4 of this FS Report introduces the ARARs. Table 4-1 and Table 4-2 identify the ARARs as well as the TBCs. Some of the listed ARARs and TBCs identify guidance documents and reference documents that apply to the management of the impacted sediments and the construction of containment structures in water environments. The screening conducted in this section is for those ARARs and TBCs that relate to actions taken to implement the remedial alternatives.

Approval for, and performance of, the remedial alternatives will require that the actions taken comply with the ARARs and TBCs, to the extent practicable. The following subsections provide a summary of these issues with respect to: Chemical-Specific ARARs/TBCs, Action-Specific ARARs/TBCs, and Location-Specific ARARs/TBCs.

Chemical-Specific ARARs/TBCs

Chemical-Specific ARARs/TBCs apply to elements of the remedial alternatives which relate to the management of PCBs. The following provides a summary of the issues related to compliance with Chemical-Specific ARARs/TBCs and the measures to be employed to attain compliance.

PCB Contaminated Media. ARARs/TBCs for this area relate to management of the PCB contaminated sediments including handling and disposal. The following identifies specific approaches to be taken to address these ARARs/TBCs:

- NR 157 W.A.C. - Management of PCBs and Products Containing PCBs
  - WDNR approval is required prior to the acceptance of PCB waste by a landfill as per NR 630, 660 and 680 W.A.C.

- Remedial activities involving sediments with concentrations greater than 50 mg/kg PCBs (TSCA level sediments) will employ protective features to provide containment so as to prevent releases to the environment.

  - PCB containing substances shall be handled to prevent losses to the environment.

  - A spill containment program is required to prevent spillage of PCB containing materials.

- TBCs for handling of PCB Contaminated Material:
  - Disposal of TSCA level sediments in an NR 500 W.A.C. landfill will require a modified landfill facility plan prior to the acceptance of sediments. WDNR approval along with EPA concurrence is required in addition to the landfill facility plan modification prior to the acceptance of sediments with PCB concentrations greater than 500 mg/kg (Adamkus, 1995).

  - Sediments that are placed within a facility are subject to the regulatory authority of the WDNR waste management program. (Lynch, 1998)

- Proposed capping of sediments with concentrations of 50 mg/kg or greater has not been perceived by the EPA as providing adequate protection to human health and the environment.

Air Emissions. ARARs for this area relate to air emissions from remedial activities. The following identifies specific approaches to be taken to address these ARARs:

- NR 157 W.A.C. - Management of PCBs and Products Containing PCBs
  - Facilities used for the incineration of PCBs require written approval from the WDNR prior to being established.
  - Complete plans of the facility must be submitted to the WDNR.
  - Facility must meet the minimum requirements of the following operational parameters:
    - Dwell time (2 seconds)
    - temperature (2,000°F)
    - turbulence
    - Excess oxygen (3%)
  - Facility must have scrubber to remove hydrochloric acid from exhaust gas.
- NR 400-499 W.A.C. - Air Pollution Control
  - An annual emission fee is required if total annual emissions of all air contaminants are less than 5 tons.
  - Depending on location and size of the thermal treatment unit, specific maximum particulate concentrations are regulated.
- 40 CFR Part 761 - PCB Storage and Disposal
  - PCB air emissions from incineration (i.e., thermal treatment) cannot exceed 0.001 g PCB per kg of PCB treated.

Surface Water. ARARs/TBCs for this area relate to discharges to surface water from dredging operations, in-water construction or wastewater resulting from sediment dewatering. The following identifies specific approaches to be taken to address these ARARs/TBCs:

- NR 347 W.A.C. - Monitoring Protocol
  - Project characteristics to be monitored may include:

- Total suspended solids
- Dissolved oxygen concentrations
- Flow rates
- Thermal properties of effluent and receiving waters
- pH

- NR 322 W.A.C. - Sediment control during construction activities
  - Erosion control measures must be implemented

- NR 200 W.A.C., NR 220-297 W.A.C. - Wisconsin Pollution Discharge Elimination System
  Application to discharge pollutants must be on file with the WDNR at minimum 180 days prior to discharge commencement date.

  - Water discharged to the river would need to comply with the WPDES requirements.

  - Discharge limitations for TSS and PCBs for the Lower Fox River Deposit N WPDES permit are as follows:
    - TSS not to exceed concentration of 10 mg/L

    - PCBs daily total discharge concentrations not to exceed 0.0036 pounds

- NR 207 W.A.C. - Water Quality Antidegradation
  - Discharge of effluent water cannot contain COC concentrations which exceed concentrations found in the Lower Fox River.

Action-Specific ARARs/TBCs

Action-Specific ARARs/TBCs apply to elements of the remedial alternatives. The following provides a summary of the issues related to compliance with Action-Specific ARARs/TBCs and the measures to be employed to attain compliance.

Surface Water. ARARs for this area relate to discharges to surface water from dredging operations, in-water construction or wastewater resulting from sediment dewatering. The following identifies specific approaches to be taken to address these ARARs:

- NR 108 W.A.C. - Plans and Specifications Review of Projects and Operations
  - Construction of an industrial wastewater facility or an industrial pretreatment facility requires approval of final plans and specifications for the facility by the WDNR.

- Submission of final plans and specifications required a minimum of 90 days prior to commencement of construction.

- Industrial wastewater facility must employ a certified operator

- 30 day supply of chemicals are required on-site to insure against ineffective treatment, shortages, and delays.

- NR 200 W.A.C., NR 220-297 W.A.C. - Wisconsin Pollution Discharge Elimination System (WPDES)
  - Requires a Construction Site Stormwater Discharge Permit when construction activities disturb greater than 5 acres of land.
    - Permit requires a site-specific erosion control plan be developed for the construction site.

- Effluent water resulting from the dewatering of the dredged sediments will be treated by filtration and flocculation for solids removal.

- NR 322 W.A.C. - Sediment Control During Construction Activities
  - Silt fences and rip-rap will be utilized to minimize upland soil losses.

  - Silt curtains will be utilized around the perimeter of the work zone to minimize the downstream migration of suspended particles.

Dredge and Fill. ARARs/TBCs for this area relate to removal of sediments and the placement of a cap or CDF materials and specifically the requirements to protect water quality, aquatic and wildlife habitat and wetland areas. The following identifies specific approaches to be taken to address these ARARs/TBCs:

- NR 157 W.A.C. - Management of PCBs and Products Containing PCBs
  - PCB containing substances shall be handled to prevent losses to the environment.

  - Presence of a spill containment program to prevent spillage of PCB containing materials.

- NR 322 W.A.C. - General Design Standards
  - Specific design plans will be developed that show the size and construction specifications for the in-water construction. These plans will incorporate protective features to attain the requirements for

protection of water quality, aquatic and wildlife habitat and wetland areas.

- NR 346 W.A.C. - Dredging Contract Fees
  - A contract fee of $1 is charged for the removal of material from natural lakes.
  - Contractor removing sediments must have a performance bond which would be used to correct any undesirable environmental conditions caused by improper removal of material.
- NR 347 W.A.C. - Sediment Sampling and Analysis, Monitoring Protocol and Disposal Criteria for Dredging Projects
  - A permit is required prior to the removal of sediments
  - The following preliminary information is required by the WDNR prior to the submission of a formal application:
    - Location of project
    - Volume of sediment to be dredged
    - Description of removal method and equipment
    - Description of disposal location and method
    - Previous analytical results from areas being dredged
    - Map illustrating location and cut of dredged amounts
    - Anticipated starting and completion dates
- Wis. Statutes Chapter 30 - Permit in Navigable Waters
  - A permit is required from the WDNR or authorization from the legislature prior to removing material from navigable waters.
- TBCs for Dredging and Filling of Water Bodies:
  - WDNR 1990 Report of the Technical Sub-Committee on Determination of Dredge Material Suitability of In-Water Disposal
    - Specific habitat and wetland area will be identified for each of the cap or CDF locations to allow for the development of protective measures and other compensatory actions.
    - Construction will require applicable permits for the containment within the river.
  - Proposed capping of sediments with concentrations of 50 mg/kg or greater has not been perceived by the EPA as providing adequate protection to human health and the environment.

PCB Contaminated Media. ARARs/TBCs for this area relate to proper management of the PCB contaminated sediments including handling and disposal. The following identifies specific approaches to be taken to address these ARARs/TBCs:

- NR 157 W.A.C. - management of PCBs and Products Containing PCBs
  - Remedial activities involving sediments with concentrations greater than 50 ppm PCBs (i.e., TSCA level sediments) will employ protective features to provide containment so as to prevent releases to the environment.
  - Handling areas will be lined and covered.
  - NR 347 W.A.C. - Sediment Sampling and Analysis, Monitoring Protocol and Disposal Criteria for Dredging Projects
  - Disposal of PCBs in facilities require WDNR review and approval
- TBCs for Handling of PCB Contaminated Media:
  - Land Disposal of PCB Sediments (Adamkus, 1995)
    - EPA concurrence is required to dispose of sediments containing PCBs at concentrations greater than 500 mg/kg in Wisconsin landfills.
    - WDNR has authority to regulate disposal of sediments containing concentrations less than 500 mg/Kg.
    - Disposal facility operations plan must be modified prior to the acceptance of PCB sediments with concentrations greater than 50 mg/kg.

Air Emissions. ARARs for this area relate to air emissions from remedial activities. The following identifies specific approaches to be taken to address these ARARs:

- NR 400-499 W.A.C. - Air Pollution Control
  - A construction permit is required for the construction/relocation of a thermal treatment unit.
  - A general operation permit is required prior to the operation of a thermal treatment unit.
  - An annual emission fee is required if total annual emissions of all air contaminants are less than 5 tons.

- Depending on location and size of the thermal treatment unit, specific maximum particulate concentrations are regulated.

Transportation and Handling. ARARs/TBCs for this area relate to the transportation and handling of PCB containing sediments during remedial activities. The following identifies specific approaches to be taken to address these ARARs/TBCs:

- NR 157 W.A.C. - Management of PCBs and Products Containing PCBs and Products Containing PCBs
  - Transporters of PCB wastes must be licensed for transport of hazardous wastes.
  - PCB wastes must by contained to prevent leakage/spillage.
  - Transporter is responsible for cleanup of all spillage of PCB wastes.
- NR 140 W.A.C.- Groundwater Quality
  - Impacts to groundwater resulting from spillage must be controlled
- 40 CFR Part 761 - Disposal for PCB Remediation Waste
  - PCB wastes must be managed and transported under a Uniform Hazardous Waste Manifest
- 49 CFR Part 172, 173 - General Requirements and Provisional Shipping Requirements for PCB Containing Material
  - Transport vehicle transporting greater than 1001 pounds of PCB waste must display Class 9 placards
- TBCs for Transportation of PCB Contaminated Media:
  - City, County and State Highway Weight Restrictions

Worker Safety. ARARs for this area relate to protection of workers that are exposed, or potentially exposed to, hazardous materials. The following identifies specific approaches to be taken to address these ARARs:

- 29 CFR Part 1910 - Occupational Safety and Health Administration
  - 1910.120 (e)(3), 1910.120 (f) - Workers with such actual or potential contacts will be required to conform to the standards for hazardous material workers including participation in a medical monitoring program and current certifications for training in hazardous materials exposures.

- 1910.132, 1910.134, 1920.138 - Personal Protective Equipment (PPE) will be employed to assure that workers are not exposed to adverse conditions during the work.

- 1910.120(h) - Real time monitoring will be conducted to assure that work zones are properly delineated and that workers are wearing the proper PPE.

- 1910.95 - Noise levels that exceed an 8 hr time weighted average (TWA) of 85 decibels requires hearing protection.

- 1910.120(m) - Work areas will have adequate lighting to allow workers to identify hazards.

- 1910 subpart S - All electrical power must have a ground fault circuit interrupter and be approved for the class of hazard.

- 1910.147 - Operations where the unexpected energization or start-up of equipment or released of stored energy could cause injury to personnel will be protected by the implementation of a lockout/tagout program.

- 1910.21-1910.32, 1910.104-1910.107 - Requirements to help prevent falls will be implemented.

- 1910.151(c) - Operations involving the potential for eye injury, splash, etc., must have approved eye wash units locally available.

Location-Specific ARARs/TBCs

Location-Specific ARARs/TBCs apply to certain types of remedial alternatives. The following provides a summary of the issues related to compliance with Location-Specific ARARs/TBCs and the measures to be employed to attain compliance:

CDF Construction. ARARs/TBCs for this area relate to construction requirements, siting and control measures to minimize impacts to the environment. The following identifies specific approaches to be taken to address these ARARs/TBCs:

- NR 322 W.A.C. - General Design Standards
  - Specific design plans will be developed that show the size and construction specifications for the in-water construction. These plans

will incorporate protective features to attain the requirements for protection of water quality, aquatic and wildlife habitat and wetland areas.

- Wis. Statutes Chapter 30 - Permit in Navigable Waters
  - A bulkhead line is required prior to placing deposits in navigable waters
  - A permit must be issued by the WDNR or Legislature prior to placing deposits in navigable waters
- TBCs for Placement of PCB Sediments in CDFs:
  - n-Water Disposal (Lynch, 1998)
    - Sediments that are placed within CDF are subject to the WDNR Watershed Management Requirements.
    - New facility construction will be located outside of navigable waters and flood plains as permitted by the WDNR waste management program.
    - CDFs in LLBdM require a legislative lake bed grant prior to construction.
    - CDFs elsewhere in the Lower Fox River require one of the following prior to construction:
      CDF bulkhead line
      River lease from the riparian owner
      Legislative authority
  - Precedents for in-water design requirements can be found in USACE's proposed expansion of the Kidney Island CDF in Green Bay.

Capping Construction. ARARs/TBCs for this area relate to the construction requirements, siting and control measures to minimize impacts to the environment. The following identifies specific approaches to be taken to address these ARARs/TBCs:

- Wis. Statutes Chapter 30 - Permit in Navigable Waters
  - A bulkhead line is required prior to placing deposits in navigable waters.
  - A permit must be issued by the WDNR or Legislature prior to placing deposits in navigable waters.

- 40 CFR Part 761 - Disposal for PCB Remediation Waste
  - Standards for cap performance and perpetual care requirements for capping.

- TBCs for Previously Proposed Capping Projects in Wisconsin:
  - River velocity
  - River depth
  - Cap thickness
  - Location of a sediment cap in relation to commercially navigable waters

Off-site Disposal Facility Construction. ARARs/TBCs for this area relate to construction and disposal requirements, siting and control measures to minimize impacts to the environment. The following identifies specific approaches to be taken to address these ARARs/TBCs:

Wis. Statutes, Chapter 289 - Landfill Siting and Approval Process

- Local approval may be required prior to siting of new facility (If petitioned, WDNR may waive requirements)
- New facilities will require an approval process including:
  - Feasibility Report
  - Environmental Review
  - Informational Hearings
  - Plan of Operation

- Landfill facilities are prohibited from areas under jurisdiction of shoreland floodplain zoning regulation except permits issued by the WDNR

- TBCs for Construction of Landfill for PCB Contaminated Sediments:
  - New facility construction will be located outside of navigable waters and flood plains as permitted by the WDNR waste management program. (Lynch, 1998)

Effects of EPA Initiated Cleanup on ARARs

An EPA initiated cleanup of the Lower Fox River under CERCLA would have the following effects (Lynch, 1998):

- Any permit required to remove, handle, treat, and dispose of sediment while remaining on or immediately adjacent to the river would not be required. The requirements of each regulatory program would need to be attained.

- WDNR permit requirements for off-site disposal and related transportation would require the applicable Wisconsin permit.

9.2.3 ARARs Applicable to Process Options Included in the River Reach Remedial Alternatives

The river reach specific remedial alternatives presented in Section 7 are developed from the retained process options technologies identified in Section 6. The ARARs and TBCs presented above in Section 9.2.2 are applicable to at least one process option used in the remedial alternatives. The No Action and Institutional Control alternatives are also evaluated here since these alternatives do not rely on other process options. The following subsections present a summary of significant ARARs and TBCs that must be addressed prior to and during the remedial work.

No Action

The No Action alternative has a primary ARAR that relates to this alternative. The Water Quality Standards for Wisconsin Surface Waters defines water use for protection of public health and propagation of fish, shellfish, and wildlife. These standards will be used over time to monitor the changing (diminishing) concentrations of PCBs in the Lower Fox River.

Institutional Controls

Institutional Controls is similar to the No Action alternative. The Water Quality Standards for Wisconsin Surface Waters will be used to monitor water for the changing concentration of PCBs in the Lower Fox River. Other important ARARs/TBCs include fish consumption advisories which limit the consumption of fish containing PCBs by sensitive populations and institutional controls in which limitations or restrictions are placed on recreational and irrigation usage.

Containment

The containment technology involves the *in situ* capping of the river sediments with a synthetic liner, or a layer of sand, clay, or rock. Most of the ARARs/TBCs for the river reach alternatives that include capping are similar to disposal of the sediments in a CDF or landfill. However, permits are required prior to filling any navigable water (Wis. Statute Chapter 30). Other important TBCs include the permanence of the cap when factoring in the cap thickness, river velocity, and the scouring effects of ships and boats passing over the cap. The containment process option is in compliance with ARARs when the applicable ARARs in Section 9.2.2 are attained through proper implementation of a remedial alternative.

Removal

There are two removal technologies utilized in the Section 7 river reach alternatives: hydraulic dredging and mechanical dredging. The ARARs/TBCs that are directly related to the removal of sediment from the Lower Fox River are identical for either of these removal technologies and can be placed into two groups: protection of surface water(NR 322, 200, 220-297 W.A.C.) and permits and fees to remove sediment (NR 346, 347 W.A.C.). The surface water ARARs/TBCs limit the discharge of PCBs and TSS into the Lower Fox River so that the water quality is not adversely affected. The removal process options are in compliance with ARARs when the applicable ARARs in Section 9.2.2 are attained through proper implementation of a remedial alternative.

Ex Situ Treatment

HTTD is a process option for only a select few of the Section 7 river reach alternatives. HTTD is used only for the treatment of sediments that contain PCB concentrations above the TSCA level of 50 mg/kg. ARARs specific to this technology relate to the air emission and permitting requirements of thermal treatment units (40 CFR 701, NR 400-499 W.A.C.). In addition, there are performance requirements of the thermal unit from NR 157 W.A.C. that the thermal unit must meet in order to efficiently treat PCB sediments. The *ex situ* treatment process option is in compliance with ARARs when the applicable ARARs in Section 9.2.2 are attained through proper implementation of a remedial alternative.

Dewatering and Water Treatment

There are three types of dewatering technologies utilized in the Section 7 river reach alternative. These include mechanical dewatering, passive dewatering, and solidification. There is also effluent water from the mechanical and passive dewatering technologies that must be managed. The WPDES permit requirements (NR 200, 220-297 W.A.C.) sets forth requirements for the discharge of water to POTWs and to navigable waters (i.e., Lower Fox River). Permits for previous remedial activities on the Lower Fox River provide an indication of the treatment requirements to discharge effluent water to the Lower Fox River or a POTW. Another requirement of the WPDES permit is the Construction Site Stormwater Discharge Permit which will be required for the construction of dewatering ponds. Another potential important ARAR (NR 108 W.A.C.) involves the construction of a wastewater treatment facility specifically to treat water from remedial activities. This ARAR requires a WDNR review of wastewater treatment facility designs and specifications. There are no ARARs at this time that pertain to the solidification of sediments other than general construction ARARs, such as OSHA requirements, which are applicable for each

process option. The dewatering and water treatment process options are in compliance with ARARs when the applicable ARARs in Section 9.2.2 are attained through proper implementation of a remedial alternative.

Disposal

There are two primary disposal options of PCB sediments removed from the Fox River as presented in the Section 7 river reach alternatives. These include in-water disposal (i.e., the construction of a CDF) and disposal in a landfill or newly constructed landfill. ARARs/TBCs specific to this process option include the siting requirements for a landfill (Wis. Statutes Chapter 289) and obtaining lakebeds and riverbeds for CDF constructions from the Legislature and riparian land owners. There are also general design requirements for in-water construction (NR 322 W.A.C.) that must also be met. General disposal requirements of PCB containing sediments are simplified with the agreement between the EPA and WDNR on the placement for PCB containing material in a landfill. The agreement allows the placement of PCB containing material up to 500 mg/kg in a NR 500 W.A.C. regulated landfill as long as the landfill operations permit is modified. This agreement does not explicitly allow the disposal of PCB material greater than 50 mg/Kg in a CDF. The disposal process options are in compliance with ARARs when the applicable ARARs in Section 9.2.2 are attained through proper implementation of a remedial alternative.

Transportation

There are three primary transportation methods of PCB sediment as presented in the Section 7 river reach alternatives. These include trucking the sediments to a disposal facility, the pumping of sediments to a dewatering and disposal facility, and the barging of dredged sediments to a dewatering/treatment location. ARARs and TBCs that are important to this process option include the requirements to prevent spills and releases of PCB materials (NR 140,157 W.A.C.). The following two ARARs are applicable only to the trucking of dredged sediments to a disposal facility. The Department of Transportation (DOT) has detailed requirements on the shipping of PCB materials. NR 157 W.A.C. also has shipping requirements that include licensing of transporters of PCBs as transporters of hazardous wastes. The transportation process options are in compliance with ARARs when the applicable ARARs in Section 9.2.2 are attained through proper implementation of a remedial alternative.

9.3 Balancing Criteria

The detailed analysis of the Balancing Criteria is completed in a set of tables provided in Section 8.4 through Section 8.7. These tables provide screening comments for each of the criteria in relation to each of the river reach remedial

alternatives. The following subsections provide a description of the criteria evaluated in this portion of the detailed analysis.

9.3.1 Long Term Effectiveness and Permanence

Long-term effectiveness and permanence provides a means of evaluating the final risk at the site where remedial work has been completed. By evaluating each remedial alternative with respect to this criteria, it is possible to determine the effectiveness of each remedial alternative and the risks associated with the untreated residuals. The following questions were used to evaluate the long-term effectiveness of each alternative:

- What residuals remain after completion of the remedy? Examples of residuals include solid residues after thermal treatment, sediments that spill from trucks and machinery, suspended solids during removal, and unremoved sediments with concentrations of COC above the cleanup goals.
- What is the magnitude of the residual risk?
- What institutional and/or engineering controls are needed?
- Are the controls reliable?
- What are the operations and maintenance requirements?

Long-term effectiveness and permanence is evaluated in tables 9-1. 9-6, 9-11, and 9-16 for each of the remedial alternatives. Detailed information pertaining to the residual risk for each remedial alternative is presented in Section 8.

9.3.2 Reduction of Toxicity, Mobility or Volume Through Treatment

Reduction of toxicity, mobility or volume through treatment provides a means of evaluating the permanence of each remedial alternative in reducing the toxicity, mobility or volume of PCBs within the river sediments. By evaluating each remedial alternative with respect to this criteria, it is possible to determine the effectiveness of the alternative in destroying, reducing the mass, immobilizing, or reducing the volume of PCBs. The following questions were used to evaluate the long-term effectiveness of each alternative:

- Is the treatment portion of the remedy reversible?
- How does the remedy address toxicity, mobility, and volume?

- To what extent are COC destroyed?
- Does the remedy rely on treatment or containment?

Reduction of toxicity, mobility or volume through treatment is evaluated in tables 9-2. 9-7, 9-12, and 9-17 for each of the remedial alternatives.

9.3.3 Short-Term Effectiveness

Short-term effectiveness provides a means of evaluating the risk at the site while remedial work is being completed. By evaluating each remedial alternative with respect to this criteria, it is possible to determine the effectiveness of each remedial alternative and the risks to on-site workers, nearby residences, associated with the untreated residuals. The following questions were used to evaluate the short-term effectiveness of each alternative:

- What are the major risks to community, and what are the applicable control procedures?

- What are the major risks to remediation workers, and what are the applicable control procedures?

- What are the environmental impacts during construction and implementation of the remedy?

- What is the estimated duration of the remedial action?

Short-term effectiveness is evaluated on tables 9-3, 9-8, 9-13, and 9-18 for each of the remedial alternatives. The short-term effectiveness factor until remedial objectives are achieved for each remedial alternative, is presented in Section 8.

9.3.4 Implementability

Implementability provides a means of evaluating the technical and administrative feasibility of implementing the remedial alternative. By evaluating each remedial alternative with respect to this criteria, it is possible to determine the necessary services, supplies, permits, and physical requirements that must be met to execute the alternative. The following questions were used to evaluate the long-term effectiveness of each alternative:

- Can the technology reliably meet cleanup goals? This criteria is also addressed in Section 7 of this FS Report.

- Are there site-specific technology limitations? The site-specific limitations are addressed for each alternative as described in Section 7 of this FS Report.

- What are the major uncertainties with implementation of the remedy?
- Can effectiveness of a remedy be monitored?
- Is a backup remedy necessary and implementable?
- Can required approvals be obtained from other agencies?
- Is the technology available?

Implementability s evaluated on tables 9-4, 9-9, 9-14, and 9-19 for each of the remedial alternatives.

9.3.5 Total Cost

Total costs include the capital costs, indirect costs, and annual operation and monitoring costs. Capital costs involve the actual cost to conduct the remedial work including land rights, material costs, and equipment costs. Indirect costs include engineer design costs, permit costs and costs to cover unforseen contingencies. Annual operation and maintenance costs are the costs to annually monitor a site until closure, the costs associated with operating a long-term remediation system (i.e., electricity), and the labor costs involved in the above activities. The following questions were used to provide a total cost for each alternative:

- What are the total costs involved with this alternative?

The total cost for each of the remedial alternatives is summarized in tables 9-5, 9-10, 9-15, and 9-20. Appendix D contains the detail cost spreadsheets for each of the remedial alternatives.

9.4 Detailed Analysis of Remedial Alternatives for the LLBdM River Reach

Tables 9-1 through 9-5 provide the detailed screening of the remedial alternatives for the LLBdM river reach. Each table includes the evaluation of each alternative identified in Section 7 by the five primary criteria identified for the Balancing Criteria in Section 9.3. The screening is performed by contrasting each alternative, based on the questions identified for each primary criteria.

9.5 Detailed Analysis of the Remedial Alternatives for the Appleton to Little Rapids River Reach

Tables 9-6 through 9-10 provide the detailed screening of the remedial alternatives for the Appleton to Little Rapids river reach. Each table includes the screening of each alternative identified in Section 7 by the five primary criteria identified for the Balancing Criteria in Section 9.3. The screening is performed by contrasting each alternative, based on the questions identified for each primary criteria.

9.6 Detailed Analysis of the Remedial Alternatives for the Little Rapids to De Pere Dam River Reach

Tables 9-11 through 9-15 provide the detailed screening of the remedial alternatives for the Little Rapids to De Pere Dam river reach. Each table includes the screening of each alternative identified in Section 7 by the five primary criteria identified for the Balancing Criteria in Section 9.3. The screening is performed by contrasting each alternative, based on the questions identified for each primary criteria.

9.7 Detailed Analysis of the Remedial Alternatives for the De Pere Dam to Green Bay River Reach

Tables 9-16 through 9-20 provide the detailed screening of the remedial alternatives for the De Pere Dam to Green Bay river reach. Each table includes the screening of each alternative identified in Section 7 of the five primary criteria identified for the Balancing Criteria in Section 9.3. The screening is performed by contrasting each alternative, based on the questions identified for each primary criteria

9.8 Summary of Detailed Analysis

The detailed analysis provided in this section provides the basis for the decision-making tools presented in the comparative analysis in Section 10. Each alternative was evaluated against the two threshold and five balancing criteria in detail. Included in this evaluation was the identification and compliance measures for ARARs and TBCs that were chemical, action, and location specific for process options that make up each remedial alternative. Each detailed evaluation was conducted independently and emphasized differences, rather than similarities, that exist between the remedial alternatives within a river reach. These differences will be used in the comparative analysis in Section 10 to provide

alternative-specific advantages and disadvantages when comparing alternatives within a river reach.

9.9 Section 9 Tables and Figure

Tables and Figures for Section 9 follow this page, and include:

Tables

Table 9-1 Evaluation of Long Term Effectiveness and Permanence - LLBdM Reach
Table 9-2 Evaluation of Reduction of Toxicity, Mobility or Volume Through Treatment - LLBdM Reach
Table 9-3 Evaluation of Short-term Effectiveness - LLBdM Reach
Table 9-4 Evaluation of Implementability - LLBdM Reach
Table 9-5 Evaluation of Estimated Total Costs - LLBdM Reach
Table 9-6 Evaluation of Long Term Effectiveness and Permanence - Appleton to Little Rapids Reach
Table 9-7 Evaluation of Reduction of Toxicity, Mobility or Volume Through Treatment - Appleton to Little Rapids Reach
Table 9-8 Evaluation of Short-term Effectiveness - Appleton to Little Rapids Reach
Table 9-9 Evaluation of Implementability - Appleton to Little Rapids Reach
Table 9-10 Evaluation of Estimated Total Costs - Appleton to Little Rapids Reach
Table 9-11 Evaluation of Long Term Effectiveness and Permanence - Little Rapids to De Pere Dam Reach
Table 9-12 Evaluation of Reduction of Toxicity, Mobility or Volume Through Treatment - Little Rapids to De Pere Dam Reach
Table 9-13 Evaluation of Short-term Effectiveness - Little Rapids to De Pere Dam Reach
Table 9-14 Evaluation of Implementability - Little Rapids to De Pere Dam Reach
Table 9-15 Evaluation of Estimated Total Costs - Little Rapids to De Pere Dam Reach
Table 9-16 Evaluation of Long Term Effectiveness and Permanence - De Pere Dam to Green Bay Reach
Table 9-17 Evaluation of Reduction of Toxicity, Mobility or Volume Through Treatment - De Pere Dam to Green Bay Reach
Table 9-18 Evaluation of Short-term Effectiveness - De Pere Dam to Green Bay Reach
Table 9-19 Evaluation of Implementability - De Pere Dam to Green Bay Reach

Table 9-20 Evaluation of Estimated Total Costs - De Pere Dam to Green Bay Reach

Figure

Figure 9-1 Criteria for Detailed Analyses of Alternatives

Table 9-1 Evaluation of Long Term Effectiveness And Permanence - LLBDM Reach

Alternative	Magnitude and Type of Residual Risk	Adequacy and Reliability of Controls
Alternative A - Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	Residual risk is reduced to **$9.0x10^{-6}$** for subsistence anglers, and to **$6.4x10^{-6}$** for recreational anglers. This alternative will also reduce risks to ecological receptors.	The alternative relies on institutional and engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills includes the possible, but unlikely, failure of the containment liners, leachate collection, or leak detection system. Properly designed and managed NR 500 landfills provide reliable controls for long term disposal. Long term monitoring and maintenance is included in operation of off-site NR 500 landfill.
Alternative B - Dredge with Off-Site Disposal of Sediments to a SWAC of 250 µg/kg PCB	Residual risk is reduced to **$1.8x10^{-4}$** for subsistence anglers, and to $1.28x10^{-4}$ for recreational anglers. This alternative will also reduce risks to ecological receptors.	The alternative relies on institutional and engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills includes the possible, but unlikely, failure of the containment liners, leachate collection, or leak detection system. Properly designed and managed NR 500 landfills provide reliable controls for long term disposal. Long term monitoring and maintenance is included in operation of off-site NR 500 landfill.
Alternative C - Dredge to the SWAC, with On-Site Thermal Treatment (HTTD) of TSCA Sediments, and Disposal in On-Site CDFs	Residual risk is reduced to **$1.8x10^{-4}$** for subsistence anglers, and to $1.28x10^{-4}$ for recreational anglers. This alternative will also reduce risks to ecological receptors.	Sediments placed within a CDF will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CDFs include lack of liner or leachate collection system, minor water seepages through sheet pilings, and potential difficulties in maintaining a hydraulic gradient to ensure containment of leachate. Offgas and particulate emissions from HTTD units are effectively controlled by scrubbers and other pollution control devices. Uncertainty involving the adequacy and reliability of HTTD units include difficulties in maintaining a consistent treatment temperatures which determines the desorption rate when treating high moisture material. Institutional controls are reliable if properly enforced. Long term monitoring and maintenance will be required for the CDF to document and maintain the effectiveness of the containment.
Alternative D - Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments, and Disposal of Remaining Sediments in On-Site CDFs	Residual risk is reduced to **$1.8x10^{-4}$** for subsistence anglers, and to $1.28x10^{-4}$ for recreational anglers. This alternative will also reduce risks to ecological receptors.	The alternative relies on institutional and engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills includes the possible, but unlikely, failure of the containment liners, leachate collection, or leak detection system. Properly designed and managed NR 500 landfills provide reliable controls for long term disposal. Sediments placed within a CDF will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CDFs include lack of liner or leachate collection system, minor water seepages through sheet pilings, and potential difficulties in maintaining a hydraulic gradient to ensure containment of leachate. Institutional controls are reliable if properly enforced. Long term monitoring and maintenance will be required for the CDF to document and maintain the effectiveness of the containment.
Alternative E - Cap to the Maximum Extent Practicable; Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments	Residual risk is reduced to **$1.8x10^{-4}$** for subsistence anglers, and to $1.28x10^{-4}$ for recreational anglers. This alternative will also reduce risks to ecological receptors.	The alternative relies on institutional and engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills includes the possible, but unlikely, failure of the containment liners, leachate collection, or leak detection system. Properly designed and managed NR 500 landfills provide reliable controls for long term disposal. Capped sediments will require institutional controls which may limit recreational activities and permit only low wake boat passage through the capped area. Uncertainty involving the adequacy and reliability of caps include prone to failure under natural (uncontrolled) riverine environments, and winter weather may delay necessary repair or maintenance of cap. Long term monitoring and maintenance will be required for the cap to document and maintain the effectiveness of the containment

Table 9-1 Evaluation of Long Term Effectiveness And Permanence - LLBDM Reach (Continued)

Alternative	Magnitude and Type of Residual Risk	Adequacy and Reliability of Controls
Alternative F - Institutional Controls	Residual risk is reduced for subsistence and recreational anglers recreational anglers through effective implementation of institutional controls. Residual risk is not reduced for anglers not complying with institutional controls. Residual risk for non-complying anglers is $9.0x10^{-4}$ for subsistence anglers, and **$6.4x10^{-4}$** for recreational anglers. No reduction of risks for ecological receptors.	Enforcement of institutional controls may be difficult along the entire length of the river. Fish advisories in particular are difficult to enforce. Restrictions on dredging and in-water construction activities and recreational uses are more readily enforced. Long term sediment and river water quality monitoring will be required to evaluate locations and concentrations of contaminated sediments.
Alternative G - No Action	Risks are not reduced and are **$9.0x10^{-4}$** for subsistence anglers, and **$6.4x10^{-4}$** for recreational anglers. No reduction of risks for ecological receptors.	The no action alternative does not include engineering or institutional controls. Long term sediment and river water quality monitoring will be required to evaluate locations and concentrations of contaminated sediments.

Note:
COC - Chemical-of-Concern
TSCA sediments are sediments with concentrations of PCBs greater than 50 mg/kg

Table 9-2 Evaluation of Reduction of Toxicity, Mobility or Volume Through Treatment - LLBDM Reach

Alternative	Irreversibility of The Treatment	Type And Quantity of Treatment Residual	Reduction of Toxicity, Mobility, or Volume
Alternative A - Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Treatment residuals consist of flocculation sludges and sand filter sands used in the water treatment process. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are solidified and placed within a lined disposal facility.
Alternative B - Dredge with Off-Site Disposal of Sediments to a SWAC of 250 µg/kg PCB	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Treatment residuals consist of flocculation sludges and sand filter sands used in the water treatment process. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are solidified and placed within a lined disposal facility.
Alternative C - Dredge to the SWAC, with On-Site Thermal Treatment (HTTD) of TSCA Sediments, and Disposal in On-Site CDFs	Thermal treatment destroys the COC, therefore TSCA sediments are irreversibly treated. No treatment of sediments below TSCA levels are included in this alternative.	Treatment residuals consist of flocculation sludges, and sand filter sands used in the water treatment process. Thermal ash/inorganics and large rocks and boulders unable to pass through the thermal treatment unit are also residuals. Actual quantities are dependent upon sediment volumes removed.	Toxicity, mobility, and volume of COCs present in TSCA sediments are reduced by irreversible thermal treatment. Mobility of COCs below TSCA levels are reduced when sediments are solidified and placed within the CDF.
Alternative D- Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments, and Disposal of Remaining Sediments in On-Site CDFs	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Treatment residuals consist of flocculation sludges and sand filter sands used in the water treatment process. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs above TSCA levels are reduced when sediments are solidified and placed within a lined disposal facility. Mobility of COCs below TSCA levels are reduced when sediments are solidified and placed within the CDF.
Alternative E - Cap to the Maximum Extent Practicable; Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Treatment residuals consist of flocculation sludges and sand filter sands used in the water treatment process. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions beyond natural degradation do not occur as a result of capping. Mobility of COCs are reduced when sediments are capped and when sediments are solidified and placed within a lined disposal facility.
Alternative F - Institutional Controls	Institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.
Alternative G- No Action	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.

Notes:
COC - Chemical-of-Concern
TSCA sediments are sediments with concentrations of PCBs greater than 50 mg/kg

Table 9-3 Evaluation of Short-term Effectiveness - LLBDM Reach

Alternative	Risk to Community And Workers And Controls	Environmental Impacts of Remedy And Controls	Duration of Short-term Risks
Alternative A - Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	Risks to community and workers are potentially caused by air emissions from construction equipment and dust, discharges to water from sediment removal and management, and by transportation from site to disposal facility. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Ambient air monitoring will be conducted. Risks during transport will be minimized by the solid nature of the material, use of truck routes, and spill prevention control and countermeasures plans. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by (a) treating water to be discharged off-site; (b) controlling stormwater run-on and run-off; (c) utilizing removal techniques that minimize TSS; (d) and by removing material in an upstream to downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. Noise will be mitigated with a buffer zone and by limiting work hours.	4.9 years are estimated to complete sediment removal and disposal. (Assuming six working months per year)
Alternative B - Dredge with Off-Site Disposal of Sediments to a SWAC of 250 µg/kg PCB	Risks to community and workers are potentially caused by air emissions from construction equipment and dust, discharges to water from sediment removal and management, and by transportation from site to disposal facility. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Ambient air monitoring will be conducted. Risks during transport will be minimized by the solid nature of the material, use of truck routes, and spill prevention control and countermeasures plans. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by (a) treating water to be discharged off-site; (b) controlling stormwater run-on and run-off; (c) utilizing removal techniques that minimize TSS; (d) and by removing material in an upstream to downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. Noise will be mitigated with a buffer zone and by limiting work hours.	3.4 years are estimated to complete sediment removal, and disposal. (Assuming six working months per year)
Alternative C - Dredge to the SWAC, with On-Site Thermal Treatment (HTTD) of TSCA Sediments, and Disposal in On-Site CDFs	Risks to community and workers are potentially caused by air emissions from construction equipment and dust, discharges to water from sediment removal and management, and by transportation from site to disposal facility. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Ambient air monitoring will be conducted. Air emission controls form thermal treatment facility will be provided. Risks from fuel spills, fire, and explosions related to thermal treatment will be controlled through implementation of contingency plans. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by (a) controlling air emissions from the thermal treatment unit; (b) treating water to be discharged off-site; (c) controlling stormwater run-on and run-off; (d) utilizing removal techniques that minimize TSS; (e) and by removing material in an upstream to downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. The construction of a CDF will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. The constructed CDF, when completed, will provide additional habitat for near shore wildlife. Noise will be mitigated with a buffer zone and by limiting work hours. CDFs may alter river use availability and aesthetics for riparian owners.	2.4 years are estimated to complete sediment removal, HTTD treatment, and CDF construction. (Assuming six working months per year)

Table 9-3 Evaluation of Short-term Effectiveness - LLBDM Reach (Continued)

Alternative	Risk to Community and Workers and Controls	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks
Alternative D - Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments, and Disposal of Remaining Sediments in On-Site CDFs	Risks to community and workers are potentially caused by air emissions from construction equipment and dust, discharges to water from sediment removal and management, and by transportation from site to disposal facility. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Risks during transport will be minimized by the solid nature of the material, use of truck routes, and spill prevention control and countermeasures plans. Ambient air monitoring will be conducted. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by (a) treating water to be discharged off-site; (b) controlling stormwater run-on and run-off; (c) utilizing removal techniques that minimize TSS; (d) and by removing material in an upstream to downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. The construction of a CDF will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. The constructed CDF, when completed, will provide additional habitat for near shore wildlife. Noise will be mitigated with a buffer zone and by limiting work hours. CDFs may alter river use availability and aesthetics for riparian owners.	2.4 years are estimated to complete sediment removal and disposal (Assuming six working months per year)
Alternative E - Cap to the Maximum Extent Practicable; Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments	Risks to community and workers are potentially caused by air emissions from construction equipment and dust, discharges to water from sediment removal and management, and by transportation from site to disposal facility. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Ambient air monitoring will be conducted. Risks during transport will be minimized by the solid nature of the material, use of truck routes, and spill prevention control and countermeasures plans. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by (a) treating water to be discharged off-site; (b) controlling stormwater run-on and run-off; (c) utilizing removal techniques that minimize TSS; (d) and by removing material in an upstream to downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. The construction of a river bottom cap will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. Noise will be mitigated with a buffer zone and by limiting work hours. Capping may alter river use availability.	2.2 years are estimated to complete sediment capping, removal and disposal (Assuming six working months per year)
Alternative F - Institutional Controls	There are no short-term risks associated with this remedy.	Since a remedy is not part of the institutional controls alternative, there are no environmental impacts associated with the remedy.	Institutional controls alternative does not include a remedy.
Alternative G - No Action	There are no short-term risks associated with this remedy.	Since a remedy is not part of the no action alternative, there are no environmental impacts associated with the remedy.	No action alternative does not include a remedy.

Notes:

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COC - Chemical-of-Concern

TSCA sediments are sediments with concentrations of PCBs greater than 50 mg/kg

Table 9-4 Evaluation of Implementability - LLBDM Reach

Alternative	Technical Feasibility	Administrative Feasibility	Availability
Alternative A - Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-1 Evaluation of Long Term Effectiveness. Effectiveness is measured by sampling limit-of- excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. Local permits such as building permits, curb cut permits, etc. may also be required.	Off-site disposal facilities are commercially available.
Alternative B - Dredge with Off-Site Disposal of Sediments to a SWAC of 250 µg/kg PCB	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-1 Evaluation of Long Term Effectiveness. Effectivenes is measured by sampling limit-of- excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. Local permits such as building permits, curb cut permits, etc. may also be required.	Off-site disposal facilities are commercially available.
Alternative C - Dredge to the SWAC, with On-Site Thermal Treatment (HTTD) of TSCA Sediments, and Disposal in On-Site CDFs	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-1 Evaluation of Long Term Effectiveness. Effectiveness is measured by sampling limit-of- excavation, ambient air quality, wastewater effluent, and river water. Air emission restrictions are unknown at this time and could greatly affect feasibility. Backup remedy is not required for thermal treatment. CDFs can be (a) removed and contained in off-site disposal facility, or (b) removed and treated ex-situ.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Air emissions permits will be required for the thermal treatment of sediments. A lake bed permit may be required from the Wisconsin Legislature to construct a CDF Local permits such as building permits, curb cut permits, etc. may also be required.	The technology and associated goods and services are commercially available to thermally treat the COC. Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.

Table 9-4 Evaluation of Implementability - LLBDM Reach (Cont.)

Alternative	Technical Feasibility	Administrative Feasibility	Availability
Alternative D - Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments, and Disposal of Remaining Sediments in On-Site CDFs	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-1 Evaluation of Long Term Effectiveness. Effectiveness is measured by sampling limit-of- excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal. CDFs can be (a) removed and contained in off-site disposal facility, or (b) removed and treated ex-situ.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Landfill construction/operation permits will be required for any disposal facility A lake bed permit may be required from the Wisconsin Legislature to construct a CDF Local permits such as building permits, curb cut permits, etc. may also be required.	Off-site disposal facilities are commercially available. Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.
Alternative E - Cap to the Maximum Extent Practicable; Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-1 Evaluation of Long Term Effectiveness. Effectiveness is measured by sampling limit-of- excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal. Capped sediment deposits can be (a) recapped; (b) removed and contained in off-ste disposal facility; or (c) removed and treated ex-situ.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Landfill construction/operation permits will be required for any disposal facility A lake bed permit may be required from the Wisconsin Legislature to construct a river cap. Local permits such as building permits, curb cut permits, etc. may also be required	Off-site disposal facilities are commercially available. Technology and associated goods and services are available to cap sediment deposits.
Alternative F - Institutional Controls	Although no action is technically feasible, it will not meet the cleanup goals.	Institutional controls is likely not administratively feasible.	Technologies, goods, and services are available to monitor river water and sediments.
Alternative G - No Action	Although no action is technically feasible, it will not meet the cleanup goals.	No action is likely not administratively feasible.	Technologies, goods, and services are available to monitor river water and sediments.

Notes:
COC - Chemical-of-Concern
TSCA sediments are sediments with concentrations of PCBs greater than 50 mg/Kg.

Table 9-5 Evaluation of Estimated Total Costs - LLBDM Reach

Alternative		Total Costs
Alternative A -	Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	$93,500,000
Alternative B -	Dredge with Off-Site Disposal of Sediments to a SWAC of 250 µg/kg PCB	$67,000,000
Alternative C -	Dredge to the SWAC, with On-Site Thermal Treatment (HTTD) of TSCA Sediments, and Disposal in On-Site CDFs	$58,200,000
Alternative D -	Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments, and Disposal of Remaining Sediments in On-Site CDFs	$51,500,000
Alternative E -	Cap to the Maximum Extent Practicable; Dredge to the SWAC, with Off- Site Disposal of TSCA Sediments	$56,600,000
Alternative F -	Institutional Controls	$1,200,000
Alternative G -	No Action	$0

Note:
TSCA sediments are sediments with concentrations of PCBs greater than 50 mg/kg

Table 9-6 Evaluation of Long Term Effectiveness and Permanence - Appleton to Little Rapids Reach

Alternative	Magnitude and Type of Residual Risk	Adequacy And Reliability of Controls
Alternative A - Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	Residual risk is reduced to **$4.2x10^{-5}$** for subsistence anglers, and to **$3.0x10^{-5}$** for recreational anglers. This alternative will also reduce risks to ecological receptors.	The alternative relies on institutional and engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills includes the possible, but unlikely, failure of the containment liners, leachate collection, or leak detection system. Properly designed and managed NR 500 landfills provide reliable controls for long term disposal. Long term monitoring and maintenance is included in operation of off-site NR 500 landfill.
Alternative B - Institutional Controls	Residual risk is reduced for subsistence and recreational anglers recreational anglers through effective implementation of institutional controls. Residual risk is not reduced for anglers not complying with institutional controls. Residual risk for non-complying anglers is $7.0x10^{-4}$ for subsistence anglers, and **$5.0x10^{-4}$** for recreational anglers. No reduction of risks for ecological receptors.	Enforcement of institutional controls may be difficult along the entire length of the river. Fish advisories in particular are difficult to enforce. Restrictions on dredging and in-water construction activities and recreational uses are more readily enforced. Long term sediment and river water quality monitoring will be required to evaluate locations and concentrations of contaminated sediments.
Alternative C - No Action	Risks are not reduced and are $7.0x10^{-4}$ for subsistence anglers, and **$5.0x10^{-4}$** for recreational anglers. No reduction of risks for ecological receptors.	The no action alternative does not include engineering or institutional controls. Long term sediment and river water quality monitoring will be required to evaluate locations and concentrations of contaminated sediments.

Notes:

COC - Chemical-of-Concern

Table 9-7 Evaluation of Reduction of Toxicity, Mobility or Volume Through Treatment - Appleton to Little Rapids Reach

Alternative	Irreversibility of the Treatment	Type and Quantity of Treatment Residual	Reductions in Toxicity, Mobility, or Volume
Alternative A - Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Treatment residuals consist of flocculation sludges and sand filter sands used in the water treatment process. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are solidified and placed within a lined disposal facility.
Alternative B - Institutional Controls	Institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.
Alternative C - No Action	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.

Notes:
COC - Chemical-of-Concern

Table 9-8 Evaluation of Short-term Effectiveness - Appleton to Little Rapids Reach

Alternative	Risk to Community and Workers and Controls	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks[1]
Alternative A - Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	Risks to community and workers are potentially caused by air emissions from construction equipment and dust, discharges to water from sediment removal and management, and by transportation from site to disposal facility. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Ambient air monitoring will be conducted. Risks during transport will be minimized by the solid nature of the material, use of truck routes, and spill prevention control and countermeasures plans. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by (a) treating water to be discharged off- site; (b) controlling stormwater run-on and run-off; (c) utilizing removal techniques that minimize TSS; (d) and by removing material in an upstream to downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. Noise will be mitigated with a buffer zone and by limiting work hours.	4.4 years are estimated to complete sediment removal and disposal. (Assuming six working months per year)
Alternative B - Institutional Controls	There are no short-term risks associated with this remedy.	Since a remedy is not part of the institutional controls alternative, there are no environmental impacts associated with the remedy.	Institutional controls alternative does not include a remedy.
Alternative C - No Action	There are no short-term risks associated with this remedy.	Since a remedy is not part of the no action alternative, there are no environmental impacts associated with the remedy.	No action alternative does not include a remedy.

Notes:
1 = Duration is based upon time for sediment removal plus one month for mobilization and 1 month for demobilization
COC - Chemical-of-Concern

Table 9-9 Evaluation of Implementability - Appleton to Little Rapids Reach

Alternative	Technical Feasibility	Administrative Feasibility	Availability
Alternative A - Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-6 Evaluation of Long Term Effectiveness. Effectiveness is measured by sampling limit-of-excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. Local permits such as building permits, curb cut permits, etc. may also be required.	Off-site disposal facilities are commercially available.
Alternative B - Institutional Controls	Although no action is technically feasible, it will not meet the cleanup goals.	Institutional controls is likely not administratively feasible.	Technologies, goods, and services are available to monitor river water and sediments.
Alternative C - No Action	Although no action is technically feasible, it will not meet the cleanup goals.	No action is likely not administratively feasible.	Technologies, goods, and services are available to monitor river water and sediments.

Notes:
COC - Chemical-of-Concern

Table 9-10 Evaluation of Estimated Total Costs - Appleton to Little Rapids Reach

Alternative	Total Costs
Alternative A - Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	$23,660,000
Alternative B - Institutional Controls	$1,200,000
Alternative C - No Action	$0

Table 9-11 Evaluation of Long Term Effectiveness and Permanence - Little Rapids to DePere Dam Reach

Alternative	Magnitude and Type of Residual Risk	Adequacy and Reliability of Controls
Alternative A - Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	Residual risk is reduced to **$3.9x10^{-5}$** for subsistence anglers, and to **$2.8x10^{-5}$** for recreational anglers. This alternative will also reduce risks to ecological receptors.	The alternative relies on institutional and engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills includes the possible, but unlikely, failure of the containment liners, leachate collection, or leak detection system. Properly designed and managed NR 500 landfills provide reliable controls for long term disposal. Long term monitoring and maintenance is included in operation of off-site NR 500 landfill.
Alternative B - Dredge and Pump to Offsite Disposal of all Sediments Greater than 250 µg/kg PCB	Residual risk is reduced to **$3.9x10^{-5}$** for subsistence anglers, and to **$2.8x10^{-5}$** for recreational anglers. This alternative will also reduce risks to ecological receptors.	The alternative relies on institutional and engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills includes the possible, but unlikely, failure of the containment liners, leachate collection, or leak detection system. Properly designed and managed NR 500 landfills provide reliable controls for long term disposal. Long term monitoring and maintenance is included in operation of off-site NR 500 landfill.
Alternative C - Dredge with Off-Site Disposal of Sediments to a SWAC of 250 µg/kg PCB	Residual risk is reduced to **$5.5x10^{-4}$** for subsistence anglers, and to **$3.9x10^{-4}$** for recreational anglers. This alternative will also reduce risks to ecological receptors.	The alternative relies on institutional and engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills includes the possible, but unlikely, failure of the containment liners, leachate collection, or leak detection system. Properly designed and managed NR 500 landfills provide reliable controls for long term disposal. Long term monitoring and maintenance is included in operation of off-site NR 500 landfill.
Alternative D - Dredge to the SWAC and Placement of Sediment in CDFs	Residual risk is reduced to **$5.5x10^{-4}$** for subsistence anglers, and to **$3.9x10^{-4}$** for recreational anglers. This alternative will also reduce risks to ecological receptors.	Sediments placed within a CDF will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CDFs include lack of liner or leachate collection system, minor water seepages through sheet pilings, and potential difficulties in maintaining a hydraulic gradient to ensure containment of leachate. Long term monitoring and maintenance will be required for the CDF to document and maintain the effectiveness of the containment. Institutional controls are reliable if properly enforced.

Table 9-11 Evaluation of Long Term Effectiveness and Permanence - Little Rapids to DePere Dam Reach (Continued)

Alternative	Magnitude and Type of Residual Risk	Adequacy and Reliability of Controls
Alternative E - Cap and Dredge to the SWAC, with Placement of Sediments in CDFs	Residual risk is reduced to **$5.5x10^{-4}$** for subsistence anglers, and to **$3.9x10^{-4}$** for recreational anglers. This alternative will also reduce risks to ecological receptors.	Sediments placed within a CDF will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CDFs include lack of liner or leachate collection system, minor water seepages through sheet pilings, and potential difficulties in maintaining a hydraulic gradient to ensure containment of leachate. Long term monitoring and maintenance will be required for the CDF to document and maintain the effectiveness of the containment. Capped sediments will require institutional controls which may limit recreational activities and permit only low wake boat passage through the capped area. Uncertainty involving the adequacy and reliability of caps include prone to failure under natural (uncontrolled) riverine environments, and winter weather may delay necessary repair or maintenance of cap. Long term monitoring and maintenance will be required for the cap to document and maintain the effectiveness of the containment Institutional controls are reliable if properly enforced.
Alternative F - Cap All Deposits	Residual risk is reduced to **$3.9x10^{-5}$** for subsistence anglers, and to **$2.8x10^{-5}$** for recreational anglers. This alternative will also reduce risks to ecological receptors.	Capped sediments will require institutional controls which may limit recreational activities and permit only low wake boat passage through the capped area. Uncertainty involving the adequacy and reliability of caps include prone to failure under natural (uncontrolled) riverine environments, and winter weather may delay necessary repair or maintenance of cap. Long term monitoring and maintenance will be required for the cap to document and maintain the effectiveness of the containment Institutional controls are reliable if properly enforced.
Alternative G - Institutional Controls	Residual risk is reduced for subsistence and recreational anglers recreational anglers through effective implementation of institutional controls. Residual risk is not reduced for anglers not complying with institutional controls. Residual risk for non-complying anglers is $5.9x10^{-4}$ for subsistence anglers, and **$4.2x10^{-4}$** for recreational anglers. No reduction of risks for ecological receptors.	Enforcement of institutional controls may be difficult along the entire length of the river. Fish advisories in particular are difficult to enforce. Restrictions on dredging and in-water construction activities and recreational uses are more readily enforced. Long term sediment and river water quality monitoring will be required to evaluate locations and concentrations of contaminated sediments.

Table 9-11 Evaluation of Long Term Effectiveness and Permanence - Little Rapids to DePere Dam Reach (Continued)

Alternative	Magnitude and Type of Residual Risk	Adequacy and Reliability of Controls
Alternative H - No Action	Risks are not reduced and are **$5.9x10^{-4}$** for subsistence anglers, and **$4.2x10^{-4}$** for recreational anglers. No reduction of risks for ecological receptors.	The no action alternative does not include engineering or institutional controls. Long term sediment and river water quality monitoring will be required to evaluate locations and concentrations of contaminated sediments.

Notes:
COC - Chemical-of-Concern
TSCA sediments are sediments with concentrations of PCBs greater than 50 mg/kg

Table 9-12 Evaluation of Reduction of Toxicity, Mobility or Volume Through Treatment - Little Rapids to DePere Dam Reach

Alternative	Irreversibility of The Treatment	Type And Quantity of Treatment Residual	Reductions in Toxicity, Mobility, or Volume
Alternative A - Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Treatment residuals consist of flocculation sludges and sand filter sands used in the water treatment process. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are solidified and placed within a lined disposal facility.
Alternative B - Dredge and Pump to Offsite Disposal of Sediments Greater than 250 µg/kg PCB	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Treatment residuals consist of flocculation sludges and sand filter sands used in the water treatment process. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are solidified and placed within a lined disposal facility.
Alternative C - Dredge with Off-Site Disposal of Sediments to a SWAC of 250 µg/kg PCB	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Treatment residuals consist of flocculation sludges and sand filter sands used in the water treatment process. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are solidified and placed within a lined disposal facility.
Alternative D - Dredge to the SWAC and Placement of Sediment in CDFs	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Treatment residues consist of flocculation sludges and sand filter sands used in the water treatment process. Actual quantities are dependent upon soil volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are solidified and placed within a CDF.
Alternative E - Cap and Dredge to the SWAC, with Placement of Sediments in CDFs	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Treatment residues consist of flocculation sludges and sand filter sands used in the water treatment process. Actual quantities are dependent upon soil volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs above TSCA levels are reduced when sediments are solidified and placed within a CDF. Mobility of COCs below TSCA levels are reduced when sediments are capped.
Alternative F - Cap All Deposits	No treatment of sediments is included in this alternative.	Residuals do not exist under this alternative	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes. Mobility of COCs are reduced when sediments are capped.
Alternative G - Institutional Controls	Institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.
Alternative H - No Action	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.

Notes:
COC - Chemical-of-Concern
TSCA sediments are sediments with concentrations of PCBs greater than 50 mg/kg

Table 9-13 Evaluation of Short-term Effectiveness - Little Rapids to DePere Dam Reach

Alternative	Risk to Community and Workers and Controls	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks
Alternative A - Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	Risks to community and workers are potentially caused by air emissions from construction equipment and dust, discharges to water from sediment removal and management, and by transportation from site to disposal facility. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Ambient air monitoring will be conducted. Risks during transport will be minimized by the solid nature of the material, use of truck routes, and spill prevention control and countermeasures plans. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by (a) treating water to be discharged off-site; (b) controlling stormwater run-on and run-off; (c) utilizing removal techniques that minimize TSS; (d) and by removing material in an upstream to downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. Noise will be mitigated with a buffer zone and by limiting work hours.	3.6 years are estimated to complete sediment removal and disposal. (Assuming six working months per year)
Alternative B - Dredge and Pump to Offsite Disposal of Sediments Greater than 250 µg/kg PCB	Risks to community and workers are potentially caused by air emissions from construction equipment and dust, discharges to water from sediment removal and management, and by transportation from site to disposal facility. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Ambient air monitoring will be conducted. Risks during transport will be minimized by the solid nature of the material, use of truck routes, and spill prevention control and countermeasures plans. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by (a) treating water to be discharged off-site; (b) controlling stormwater run-on and run-off; (c) utilizing removal techniques that minimize TSS; (d) and by removing material in an upstream to downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. Noise will be mitigated with a buffer zone and by limiting work hours.	3.6 years are estimated to complete sediment removal, and disposal. (Assuming six working months per year)
Alternative C - Dredge with Off-Site Disposal of Sediments to a SWAC of 250 µg/kg PCB	Risks to community and workers are potentially caused by air pollution, water pollution, and by transportation from site to disposal facility for communities along transportation route. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Ambient air monitoring will be conducted. Risks during transport will be minimized by the solid nature of the material, and spill prevention control and countermeasures plans. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by (a) treating water to be discharged off-site; (b) controlling stormwater run-on and run-off; (c) utilizing removal techniques that minimize TSS; (d) and by removing material in an upstream to downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. Noise will be mitigated with a buffer zone and by limiting work hours. techniques.	3.2 years are estimated to complete sediment removal, and disposal. (Assuming six working months per year)

Table 9-13 Evaluation of Short-term Effectiveness - Little Rapids to DePere Dam Reach (Continued)

Alternative D - Dredge to the SWAC and Placement of Sediment in CDFs	Risks to community and workers are potentially caused by air pollution, and water pollution. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Ambient air monitoring will be conducted. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise, and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by (a) treating water to be discharged off-site; (b) controlling stormwater run-on and run-off; (c) utilizing removal techniques that minimize TSS; (d) and by removing material in an upstream to downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. The construction of a CDF will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. The constructed CDF, when completed, will provide additional habitat for near shore wildlife. Noise will be mitigated with a buffer zone and by limiting work hours. CDFs may alter river use availability and aesthetics for riparian owners.	3.2 years are estimated to complete sediment removal and disposal (Assuming six working months per year)
Alternative E - Cap and Dredge to the SWAC, with Placement of Sediments in CDFs	Risks to community and workers are potentially caused by air pollution, water pollution, and by transportation of construction materials. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Ambient air monitoring will be conducted. Risks during construction material transport will be minimized by the use of truck routes. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise, and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by (a) treating water to be discharged off-site; (b) controlling stormwater run-on and run-off; (c) utilizing removal techniques that minimize TSS; (d) and by removing material in an upstream to downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. The construction of a CDF will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. The constructed CDF, when completed, will provide additional habitat for near shore wildlife. The construction of a river bottom cap will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. Noise will be mitigated with a buffer zone and by limiting work hours. Capping may alter river use availability. CDFs may alter river use availability and aesthetics for riparian owners.	1.8 years are estimated to complete sediment capping, removal and disposal (Assuming six working months per year)

Table 9-13 Evaluation of Short-term Effectiveness - Little Rapids to DePere Dam Reach (Continued)

Alternative F - Cap All Deposits	Risks to community and workers are potentially caused by air pollution, water pollution, and by transportation of construction materials. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Ambient air monitoring will be conducted. Risks during construction material transport will be minimized by the use of truck routes. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise. Environmental releases will be minimized during remediation by (a) controlling stormwater run-on and run-off. The construction of a river bottom cap will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. Noise will be mitigated with a buffer zone and by limiting work hours. Capping may alter river use availability.	5.0 years are estimated to complete sediment capping (Assuming six working months per year)
Alternative G - Institutional Controls	There are no short-term risks associated with this remedy.	Since a remedy is not part of the institutional controls alternative, there are no environmental impacts associated with the remedy.	Institutional controls alternative does not include a remedy.
Alternative H - No Action	There are no short-term risks associated with this remedy.	Since a remedy is not part of the no action alternative, there are no environmental impacts associated with the remedy.	No action alternative does not include a remedy.

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COC - Chemical-of-Concern

TSCA sediments are sediments with concentrations of PCBs greater than 50 mg/kg

Table 9-14 Evaluation of Implementability - Little Rapids to DePere Dam Reach

Alternative	Technical Feasibility	Administrative Feasibility	Availability
Alternative A - Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-11 Evaluation of Long Term Effectiveness. Effectiveness is measured by sampling limit-of- excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. Local permits such as building permits, curb cut permits, etc. may also be required.	Off-site disposal facilities are commercially available.
Alternative B - Dredge and Pump to Offsite Disposal of Sediments Greater than 250 µg/kg PCB	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-11 Evaluation of Long Term Effectiveness. Effectiveness is measured by sampling limit-of- excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. Local permits such as building permits, curb cut permits, etc. may also be required.	Off-site disposal facilities are commercially available.
Alternative C - Dredge with Off-Site Disposal of Sediments to a SWAC of 250 µg/kg PCB	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-11 Evaluation of Long Term Effectiveness. Effectiveness is measured by sampling limit-of- excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. Local permits such as building permits, curb cut permits, etc. may also be required.	Possible construction locations of offsite disposal facilities are available.

Table 9-14 Evaluation of Implementability - Little Rapids to DePere Dam Reach (Continued)

Alternative	Technical Feasibility	Administrative Feasibility	Availability
Alternative D - Dredge to the SWAC and Placement of Sediment in CDFs	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-11 Evaluation of Long Term Effectiveness. Effectiveness is measured by sampling limit-of- excavation, ambient air quality, wastewater effluent, and river water. Backup remedies for CDFs include: (a) removal and containment in off-ste disposal facility; or (c) removal and treated ex-situ.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. A CDF bulkhead line, river lease from riparian owner, or legislative authority may be required prior to constructing a CDF. Local permits such as building permits, curb cut permits, etc. may also be required.	Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.
Alternative E - Cap and Dredge to the SWAC, with Placement of Sediments in CDFs	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-11 Evaluation of Long Term Effectiveness. Effectiveness is measured by sampling limit-of- excavation, ambient air quality, wastewater effluent, and river water. Backup remedies for capped sediment deposits and CDFs include: (a) recapping; (b) removal and containment in off-ste disposal facility; or (c) removal and treated ex-situ.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. A CDF bulkhead line, river lease from riparian owner, or legislative authority may be required prior to constructing a CDF. A bulkhead line and a permit issued by the WDNR or Wisconsin Legislature may be required to construct a river cap. Local permits such as building permits, curb cut permits, etc. may also be required	Technology and associated goods and services are available to cap sediment deposits. Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.

Table 9-14 Evaluation of Implementability - Little Rapids to DePere Dam Reach (Continued)

Alternative F - Cap All Deposits	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-11 Evaluation of Long Term Effectiveness. Effectiveness is measured by sampling sediment cap, ambient air quality, and river water. Backup remedies for capped sediment deposits include: (a) recapping; (b) removal and containment in off-site disposal facility; or (c) removed and treated ex-situ.	Alternative is administratively feasible. A bulkhead line and a permit issued by the WDNR or Wisconsin Legislature may be required to construct a river cap. Local permits such as building permits, curb cut permits, etc. may also be required	Technology and associated goods and services are available to cap sediment deposits.
Alternative G - Institutional Controls	Although no action is technically feasible, it will not meet the cleanup goals.	Institutional controls is likely not administratively feasible.	Technologies, goods, and services are available to monitor river water and sediments.
Alternative H - No Action	Although no action is technically feasible, it will not meet the cleanup goals.	No action is likely not administratively feasible.	Technologies, goods, and services are available to monitor river water and sediments.

Notes:
COC - Chemical-of-Concern
TSCA sediments are sediments with concentrations of PCBs greater than 50 mg/kg

Table 9-15 Evaluation of Estimated Total Costs - Little Rapids to DePere Dam Reach

Alternative	Total Costs
Alternative A - Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	$113,800,000
Alternative B - Dredge and Pump to Offsite Disposal of Sediments Greater than 250 µg/kg PCB	$22,200,000
Alternative C - Dredge with Off-Site Disposal of Sediments to a SWAC of 250 µg/kg PCB	$103,200,000
Alternative D - Dredge to the SWAC and Placement of Sediment in CDFs	$29,300,000
Alternative E - Cap and Dredge to the SWAC, with Placement of Sediments in CDFs	$42,100,000
Alternative F - Cap All Deposits	$22,000,000
Alternative G - Institutional Controls	$1,200,000
Alternative H - No Action	$0

Notes:
TSCA sediments are sediments with concentrations of PCBs greater than 50 mg/kg

Table 9-16 Evaluation of Long Term Effectiveness and Permanence - DePere Dam to Green Bay Reach

Alternative	Magnitude and Type of Residual Risk	Adequacy and Reliability of Controls
Alternative A - Mechanical Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	Residual risk is reduced to **$6.5x10^{-6}$** for subsistence anglers, and to **$4.8x10^{-6}$** for recreational anglers. This alternative will also reduce risks to ecological receptors.	The alternative relies on institutional and engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills includes the possible, but unlikely, failure of the containment liners, leachate collection, or leak detection system. Properly designed and managed NR 500 landfills provide reliable controls for long term disposal. Long term monitoring and maintenance is included in operation of off-site NR 500 landfill.
Alternative B - Hydraulic Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	Residual risk is reduced to **$6.5x10^{-6}$** for subsistence anglers, and to **$4.8x10^{-6}$** for recreational anglers. This alternative will also reduce risks to ecological receptors.	The alternative relies on institutional and engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills includes the possible, but unlikely, failure of the containment liners, leachate collection, or leak detection system. Properly designed and managed NR 500 landfills provide reliable controls for long term disposal. Long term monitoring and maintenance is included in operation of off-site NR 500 landfill.
Alternative C - Dredge with Off-Site Disposal of Sediments to a SWAC of 250 µg/kg PCB	Residual risk is reduced to **$1.9x10^{-4}$** for subsistence anglers, and to **$1.4x10^{-4}$** for recreational anglers. This alternative will also reduce risks to ecological receptors.	The alternative relies on institutional and engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills includes the possible, but unlikely, failure of the containment liners, leachate collection, or leak detection system. Properly designed and managed NR 500 landfills provide reliable controls for long term disposal. Long term monitoring and maintenance is included in operation of off-site NR 500 landfill.
Alternative D - Dredge to the SWAC, with On-Site Thermal Treatment (HTTD) of TSCA Sediments, and Disposal in On-Site CDFs	Residual risk is reduced to **$1.9x10^{-4}$** for subsistence anglers, and to **$1.4x10^{-4}$** for recreational anglers. This alternative will also reduce risks to ecological receptors.	Sediments placed within a CDF will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CDFs include lack of liner or leachate collection system, minor water seepages through sheet pilings, and potential difficulties in maintaining a hydraulic gradient to ensure containment of leachate. Offgas and particulate emissions from HTTD units are effectively controlled by scrubbers and other pollution control devices. Uncertainty involving the adequacy and reliability of HTTD units include difficulties in maintaining a consistent treatment temperatures which determines the desorption rate when treating high moisture material. Institutional controls are reliable if properly enforced. Long term monitoring and maintenance will be required for the CDF to document and maintain the effectiveness of the containment.
Alternative E- Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments, and Disposal of Remaining Sediments in On-Site CDFs	Residual risk is reduced to **$1.9x10^{-4}$** for subsistence anglers, and to **$1.4x10^{-4}$** for recreational anglers. This alternative will also reduce risks to ecological receptors.	The alternative relies on institutional and engineering controls at the off-site disposal facility. Uncertainty involving the adequacy and reliability of NR 500 landfills include the possible catastrophic failure of the containment liners, leachate collection system, or leak detection system. Sediments placed within a CDF will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CDFs include lack of liner or leachate collection system, minor water seepages through sheet pilings, and potential difficulties in maintaining a hydraulic gradient to ensure containment of leachate. Institutional controls are reliable if properly enforced. Long term monitoring and maintenance will be required for the CDF to document and maintain the effectiveness of the containment.

Table 9-16 Evaluation of Long Term Effectiveness and Permanence - DePere Dam to Green Bay Reach (Continued)

Alternative	Magnitude and Type of Residual Risk	Adequacy and Reliability of Controls
Alternative F - Cap to the Maximum Extent Practicable; Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments	Residual risk is reduced to **$1.9x10^{-4}$** for subsistence anglers, and to **$1.4x10^{-4}$** for recreational anglers. This alternative will also reduce risks to ecological receptors.	Sediments placed within a CDF will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CDFs include lack of liner or leachate collection system, minor water seepages through sheet pilings, and potential difficulties in maintaining a hydraulic gradient to ensure containment of leachate. Long term monitoring and maintenance will be required for the CDF to document and maintain the effectiveness of the containment. Capped sediments will require institutional controls which may limit recreational activities and permit only low wake boat passage through the capped area. Uncertainty involving the adequacy and reliability of caps include prone to failure under natural (uncontrolled) riverine environments, and winter weather may delay necessary repair or maintenance of cap. Long term monitoring and maintenance will be required for the cap to document and maintain the effectiveness of the containment Institutional controls are reliable if properly enforced.
Alternative G - Institutional Controls	Residual risk is reduced for subsistence and recreational anglers recreational anglers through effective implementation of institutional controls. Residual risk is not reduced for anglers not complying with institutional controls. Residual risk for non-complying anglers is $1.5x10^{-3}$ for subsistence anglers, and **$1.1x10^{-3}$** for recreational anglers. No reduction of risks for ecological receptors.	Enforcement of institutional controls may be difficult along the entire length of the river. Fish advisories in particular are difficult to enforce. Restrictions on dredging and in-water construction activities and recreational uses are more readily enforced. Long term sediment and river water quality monitoring will be required to evaluate locations and concentrations of contaminated sediments.
Alternative H - No Action	Risks are not reduced and are **$1.5x10^{-3}$** for subsistence anglers, and **$1.1x10^{-3}$** for recreational anglers. No reduction of risks for ecological receptors.	The no action alternative does not include engineering or institutional controls. Long term sediment and river water quality monitoring will be required to evaluate locations and concentrations of contaminated sediments.

Notes:
COC - Chemical-of-Concern
TSCA sediments are sediments with concentrations of PCBs greater than 50 mg/kg

Table 9-17 Evaluation of Reduction of Toxicity, Mobility or Volume Through Treatment - DePere Dam to Green Bay Reach

Alternative	Irreversibility of the Treatment	Type and Quantity of Treatment Residual	Reductions in Toxicity, Mobility, or Volume
Alternative A - Mechanical Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Treatment residuals consist of flocculation sludges and sand filter sands used in the water treatment process. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are solidified and placed within a lined disposal facility.
Alternative B - Hydraulic Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Treatment residuals consist of flocculation sludges and sand filter sands used in the water treatment process. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are solidified and placed within a lined disposal facility.
Alternative C - Dredge with Off-Site Disposal of Sediments to a SWAC of 250 µg/kg PCB	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Treatment residuals consist of flocculation sludges and sand filter sands used in the water treatment process. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when sediments are solidified and placed within a lined disposal facility.
Alternative D - Dredge to the SWAC, with On-Site Thermal Treatment (HTTD) of TSCA Sediments, and Disposal in On-Site CDFs	Thermal treatment destroys the COC, therefore TSCA sediments are irreversibly treated. No treatment of sediments at TSCA levels are included in this alternative.	Treatment residuals consist of flocculation sludges, and sand filter sands used in the water treatment process. Thermal ash/inorganics and large rocks and boulders unable to pass through the thermal treatment unit are also residuals. Actual quantities are dependent upon sediment volumes removed.	Toxicity, mobility, and volume of COCs present in TSCA sediments are reduced by irreversible thermal treatment. Mobility of COCs below TSCA levels are reduced when sediments are solidified and placed within the CDF.
Alternative E - Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments, and Disposal of Remaining Sediments in On-Site CDFs	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Treatment residuals consist of flocculation sludges and sand filter sands used in the water treatment process. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs above TSCA levels are reduced when sediments are solidified and placed within a lined disposal facility. Mobility of COCs below TSCA levels are reduced when sediments are solidified and placed within the CDF.
Alternative F - Cap to the Maximum Extent Practicable; Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Treatment residues consist of flocculation sludges and sand filter sands used in the water treatment process. Actual quantities are dependent upon soil volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs above TSCA levels are reduced when sediments are solidified and placed within a CDF. Mobility of COCs below TSCA levels are reduced when sediments are capped.
Alternative G - Institutional Controls	Institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.
Alternative H - No Action	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.

Notes:
COC - Chemical-of-Concern
TSCA sediments are sediments with concentrations of PCBs greater than 50 mg/kg

Table 9-18 Evaluation of Short-term Effectiveness - DePere Dam to Green Bay Reach

Alternative	Risk to Community And Workers And Controls	Environmental Impacts of Remedy And Controls	Duration of Short-term Risks[1]
Alternative A - Mechanical Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	Risks to community and workers are potentially caused by air emissions from construction equipment and dust, discharges to water from sediment removal and management, and by transportation from site to disposal facility. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Ambient air monitoring will be conducted. Risks during transport will be minimized by the solid nature of the material, use of truck routes, and spill prevention control and countermeasures plans. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by (a) treating water to be discharged off- site; (b) controlling stormwater run-on and run-off; (c) utilizing removal techniques that minimize TSS; (d) and by removing material in an upstream to downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. Noise will be mitigated with a buffer zone and by limiting work hours.	6.1 years are estimated to complete sediment removal and disposal. (Assuming six working months per year)
Alternative B - Hydraulic Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	Risks to community and workers are potentially caused by air emissions from construction equipment and dust, discharges to water from sediment removal and management, and by transportation from site to disposal facility. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Ambient air monitoring will be conducted. Risks during transport will be minimized by the solid nature of the material, use of truck routes, and spill prevention control and countermeasures plans. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by (a) treating water to be discharged off- site; (b) controlling stormwater run-on and run-off; (c) utilizing removal techniques that minimize TSS; (d) and by removing material in an upstream to downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. Noise will be mitigated with a buffer zone and by limiting work hours.	8.5 years are estimated to complete sediment removal and disposal. (Assuming six working months per year)
Alternative C - Dredge with Off-Site Disposal of Sediments to a SWAC of 250 µg/kg PCB	Risks to community and workers are potentially caused by air emissions from construction equipment and dust, discharges to water from sediment removal and management, and by transportation from site to disposal facility. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Ambient air monitoring will be conducted. Risks during transport will be minimized by the solid nature of the material, use of truck routes, and spill prevention control and countermeasures plans. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by (a) treating water to be discharged off- site; (b) controlling stormwater run-on and run-off; (c) utilizing removal techniques that minimize TSS; (d) and by removing material in an upstream to downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. Noise will be mitigated with a buffer zone and by limiting work hours.	7.3 years are estimated to complete sediment removal, and disposal. (Assuming six working months per year)

Table 9-18 Evaluation of Short-term Effectiveness - DePere Dam to Green Bay Reach (Continued)

Alternative D - Dredge to the SWAC, with On-Site Thermal Treatment (HTTD) of TSCA Sediments, and Disposal in On-Site CDFs	Risks to community and workers are potentially caused by air emissions from construction equipment and dust, discharges to water from sediment removal and management, and by transportation from site to disposal facility. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Ambient air monitoring will be conducted. Air emission controls form thermal treatment facility will be provided. Risks from fuel spills, fire, and explosions related to thermal treatment will be controlled through implementation of contingency plans. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by (a) controlling air emissions from the thermal treatment unit; (b) treating water to be discharged off- site; (c) controlling stormwater run-on and run-off; (d) utilizing removal techniques that minimize TSS; (e) and by removing material in an upstream to downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. The construction of a CDF will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. The constructed CDF, when completed, will provide additional habitat for near shore wildlife. Noise will be mitigated with a buffer zone and by limiting work hours. CDFs may alter river use availability and aesthetics for riparian owners.	6.4 years are estimated to complete sediment removal, HTTD treatment, and CDF construction. (Assuming six working months per year)

Table 9-18 Evaluation of Short-term Effectiveness - DePere Dam to Green Bay Reach (Continued)

Alternative	Risk to Community And Workers And Controls	Environmental Impacts of Remedy And Controls	Duration of Short-term Risks[1]
Alternative E - Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments, and Disposal of Remaining Sediments in On-Site CDFs	Risks to community and workers are potentially caused by air emissions from construction equipment and dust, discharges to water from sediment removal and management, and by transportation from site to disposal facility. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Risks during transport will be minimized by the solid nature of the material, use of truck routes, and spill prevention control and countermeasures plans. Ambient air monitoring will be conducted. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by (a) treating water to be discharged off- site; (b) controlling stormwater run-on and run-off; (c) utilizing removal techniques that minimize TSS; (d) and by removing material in an upstream to downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. The construction of a CDF will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. The constructed CDF, when completed, will provide additional habitat for near shore wildlife. Noise will be mitigated with a buffer zone and by limiting work hours. CDFs may alter river use availability and aesthetics for riparian owners.	6.4 years are estimated to complete sediment removal and disposal (Assuming six working months per year)
Alternative F - Cap to the Maximum Extent Practicable; Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments	Risks to community and workers are potentially caused by air pollution, water pollution. Risks to community will be minimized by utilizing silt curtains and not working during residence high occupancy times such as evening and weekends. Ambient air monitoring will be conducted. Risks during construction material transport will be minimized by the use of truck routes. Risk to workers will be minimized with a site-specific health and safety program.	Environmental impacts consist of noise, and release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by (a) treating water to be discharged off- site; (b) controlling stormwater run-on and run-off; (c) utilizing removal techniques that minimize TSS; (d) and by removing material in an upstream to downstream fashion to prevent recontamination of remediated areas. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms. The construction of a river bottom cap will also initially create a loss of habitat for aquatic organisms along with changes in river flow patterns. Noise will be mitigated with a buffer zone and by limiting work hours. Capping may alter river use availability.	5.8 years are estimated to complete sediment capping, removal and disposal (Assuming six working months per year)

Table 9-18 Evaluation of Short-term Effectiveness - DePere Dam to Green Bay Reach (Continued)

Alternative	Risk to Community and Workers and Controls	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks[1]
Alternative G - Institutional Controls	There are no short-term risks associated with this remedy.	Since a remedy is not part of the institutional controls alternative, there are no environmental impacts associated with the remedy.	Institutional controls alternative does not include a remedy.
Alternative H - No Action	There are no short-term risks associated with this remedy.	Since a remedy is not part of the no action alternative, there are no environmental impacts associated with the remedy.	No action alternative does not include a remedy.

Notes:

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COC - Chemical-of-Concern

TSCA sediments are sediments with concentrations of PCBs greater than 50 mg/kg

Table 9-19 Evaluation of Implementability - DePere Dam to Green Bay Reach

Alternative	Technical Feasibility	Administrative Feasibility	Availability
Alternati e A - echanical redge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-16 Evaluation of Long Term Effectiveness. Effectiveness is measured by sampling limit-of-excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. Local permits such as building permits, curb cut permits, etc. may also be required.	Off-site disposal facilities are commercially available.
Alternative B - Hydraulic Dredge with Off-Site Disposal of all Sediments Greater than 250 µg/kg PCBs	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-16 Evaluation of Long Term Effectiveness. Effectiveness is measured by sampling limit-of-excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. Local permits such as building permits, curb cut permits, etc. may also be required.	Off-site disposal facilities are commercially available.
Alternative C - Dredge with Off-Site Disposal of Sediments to a SWAC of 250 µg/kg PCB	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-16 Evaluation of Long Term Effectiveness. Effectiveness is measured by sampling limit-of-excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Landfill construction/operation permits will be required for any disposal facility. Local permits such as building permits, curb cut permits, etc. may also be required.	Off-site disposal facilities are commercially available.

Table 9-19 Evaluation of Implementability - DePere Dam to Green Bay Reach (Continued)

Alternative	Technical Feasibility	Administrative Feasibility	Availability
Alternative D - Dredge to the SWAC, with On-Site Thermal Treatment (HTTD) of TSCA Sediments, and Disposal in On-Site CDFs	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-16 Evaluation of Long Term Effectiveness. Effectiveness is measured by sampling limit-of-excavation, ambient air quality, wastewater effluent, and river water. Air emission restrictions are unknown at this time and could greatly affect feasibility. Backup remedy is not required for thermal treatment. CDFs can be (a) removed and contained in off-site disposal facility, or (b) removed and treated ex-situ.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Air emissions permits will be required for the thermal treatment of sediments. A CDF bulkhead line, river lease from riparian owner, or legislative authority may be required prior to constructing a CDF. Local permits such as building permits, curb cut permits, etc. may also be required.	The technology and associated goods and services are commercially available to thermal treat the COC. Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.
Alternative E - Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments, and Disposal of Remaining Sediments in On-Site CDFs	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-16 Evaluation of Long Term Effectiveness. Effectiveness is measured by sampling limit-of-excavation, ambient air quality, wastewater effluent, and river water. Backup remedy is not required for off-site land disposal. CDFs can be (a) removed and contained in off-site disposal facility, or (b) removed and treated ex-situ.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. Landfill construction/operation permits will be required for any disposal facility A CDF bulkhead line, river lease from riparian owner, or legislative authority may be required prior to constructing a CDF. Local permits such as building permits, curb cut permits, etc. may also be required.	Offsite disposal facilities are commercially available. Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.

Table 9-19 Evaluation of Implementability - DePere Dam to Green Bay Reach (Continued)

Alternative F - Cap to the Maximum Extent Practicable; Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk based number derived from the ecological risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Table 9-16 Evaluation of Long Term Effectiveness. Effectiveness is measured by sampling limit-of-excavation, ambient air quality, wastewater effluent, and river water. Backup remedies for capped sediment deposits and CDFs include: (a) recapping; (b) removal and containment in off-site disposal facility; or (c) removal and treated ex-situ.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required to remove the sediment. Discharge permits (i.e., NPDES/WPDES) will likely be required for the discharge of dewatering effluent. A bulkhead line and a permit issued by the WDNR or Wisconsin Legislature may be required to construct a river cap. Local permits such as building permits, curb cut permits, etc. may also be required	Technology and associated goods and services are available to cap sediment deposits. Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.
Alternative G - Institutional Controls	Although no action is technically feasible, it will not meet the cleanup goals.	Institutional controls is likely not administratively feasible.	Technologies, goods, and services are available to monitor river water and sediments.
Alternative H - No Action	Although no action is technically feasible, it will not meet the cleanup goals.	No action is likely not administratively feasible.	Technologies, goods, and services are available to monitor river water and sediments.

Notes:
COC - Chemical-of-Concern
TSCA sediments are sediments with concentrations of PCBs greater than 50 mg/kg

Table 9-20 Evaluation of Estimated Total Costs - DePere Dam to Green Bay Reach

Alternative		Total Costs
Alternative A -	Mechanical Dredge with Off-Site Disposal all Sediments Greater than 250 µg/kg PCBs	$490,000,000
Alternative B -	Hydraulic Dredge with Off-Site Disposal all Sediments Greater than 250 µg/kg PCBs	$45,900,000
Alternative C -	Dredge with Off-Site Disposal of Sediments to a SWAC of 250 µg/kg PCB	$437,600,000
Alternative D -	Dredge to the SWAC, with On-Site Thermal Treatment (HTTD) of TSCA Sediments, and Disposal in On-Site CDFs	$131,000,000
Alternative E -	Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments, and Disposal of Remaining Sediments in On-Site CDFs	$122,700,000
Alternative F -	Cap to the Maximum Extent Practicable; Dredge to the SWAC, with Off-Site Disposal of TSCA Sediments	$130,500,000
Alternative G -	Institutional Controls	$1,200,000
Alternative H -	No Action	$0

Notes:

TSCA sediments are sediments with concentrations of PCBs greater than 50 mg/kg

FIGURE 9-1 Criteria For Detailed Analyses Of Alternatives

Overall Protection of Human Health and the Environment

- How Alternative Provides Human Health and Environmental Protection

Compliance With ARARs

- Compliance with Chemical-Specific ARARs
- Compliance with Action-Specific ARARs
- Compliance with Location-Specific ARARs
- Compliance with Other Criteria, Advisories, and Guidelines

Long-Term Effectiveness and Performance

- Magnitude of Residual Risk
- Adequacy and Reliability of Controls

Reduction of Toxicity Mobility, and Volume Through Treatment

- Treatment Process Used and Materials Treated
- Amount of Hazardous Materials Destroyed or Treated
- Degree of Expected Reductions in Toxicity, Mobility, and Volume
- Degree to Which Treatment is Irreversible
- Type and Quantity of Residuals Remaining after Treatment

Short-Term Effectiveness

- Protection of Community During Remedial Actions
- Protection of Workers During Remedial Actions
- Environmental Impacts
- Time Until Remedial Action Objectives are Achieved

Implementability

- Ability to Construct and Operate the Technology
- Reliability of the Technology
- Ease of Undertaking Additional Remedial Actions, if Necessary
- Ability to Monitor Effectiveness of Remedy
- Ability to Obtain Approvals From Other Agencies
- Coordination with Other Agencies
- Availability of Offsite Treatment, Storage, and Disposal Services and Capacity
- Availability of Necessary Equipment and Specialists
- Availability of Prospective Technologies

Cost

- Capital Costs
- Operating and Maintenance Costs
- Present Worth Cost

State[1] Acceptence

Community[1] Acceptence

3-3584-540

[1]These Criteria are Assessed Following Comment on the RI/FS Report and the Proposed Plan.

10 Comparative Analysis of Alternatives

10.1 Description of Comparative Analysis Process

This section consists of a synoptic comparison of the predicted performance of each of the reach-specific alternatives in relation to specific decision-making evaluation criteria. This comparison is in contrast with the detailed analysis conducted in Section 9 in which each alternative was analyzed independently without a consideration of other alternatives. The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative relative to one another, so that the key tradeoffs the decision-maker must balance can be identified.

The comparative analysis presented in this section focuses on synthesizing the evaluation in Section 9 into readily accessible decision-making tools. To accomplish this, numerical measures are used to evaluate how each alternative compares relative to all others with respect to addressing each of the following questions:

- What is the residual human health risk after the implementation of the alternative?
- How long after remediation is completed would it take to achieve sediment concentrations resulting in negligible risk to humans and ecological receptors?
- What is the level of disruption to local communities associated with the construction of each alternative?
- What is the administrative effort necessary to implement each alternative?
- What is the mass of PCBs removed from the Lower Fox River?
- What is the cost of implementing each alternative?
- What is the incremental cost of reducing risk for each alternative?

Each of these issues, and the quantitative measures identified to score the alternatives, are discussed in Table 10-1. The results of the comparative

evaluation of alternatives are presented in Tables 10-2 through 10-5, and Figures 10-1 through 10-4.

It should be noted that the effect of the various reach-specific remedial alternatives on surface water PCB concentrations is not considered in the comparative analysis. As discussed in Section 8, none of the alternatives considered in this FS is able to meet the remedial action objective of achieving surface water ARARs (RAO 1) within the modeled time horizon (100 years). As such, the ability to achieve such ARARs cannot be used in a comparative analysis to distinguish the various alternatives.

10.2 Comparative Analysis of Alternatives - LLBdM Reach

The comparative analysis of alternatives for the LLBdM reach is presented in Table 10-2 and Figure 10-1. The following provides a set of observations made as a result of the comparative analysis:

- Only Alternative A results in a reduction of risk to subsistence anglers in the acceptable range of 10^{-6} to 10^{-4}. This reduction is due to the greatest amount of sediments addressed by Alternative A, and consequent greatest decrease in the average overall sediment PCB concentrations with respect to all other alternatives. The residual risk for Alternatives B through E is equal and is just above the 10^{-4} threshold. No residual risk was calculated for Alternative F (Institutional Controls). Alternative G (No Action) results in no risk reduction, and in a residual risk close to 10^{-3}.

- Due to its greatest decrease in post-remediation sediment concentrations, Alternative A is also superior to the other ones with respect to the time necessary to reach a no-risk PCB level in sediment. The predicted time to reach this level (17 years) is about 2.6 times less for Alternative A than for Alternatives B through E (44 years), and greater than 6 times less than for Alternatives F and G (> 100 years).

- Alternative A also results in the greatest impacts to the local communities, as measured by the amount of time necessary for its implementation (close to five years). The level of disruption due to Alternative A is approximately 40% greater than for Alternative B (which has an implementation duration of approximately 3.4 years). The duration of Alternative A is approximately a factor of two greater than for Alternatives C, D and E, which have implementation durations slightly over 2 years. Alternative F (Institutional

Controls) and Alternative G (No Action) would result in no disruption to local communities.

- Alternatives F and G, which do not involve any active remediation, are considered the least administratively feasible and are therefore assigned the highest administrative effort score (8 and 10, respectively). The implementation of remaining alternatives is contingent on the procurement of a series of permits from local, state and federal agencies, and on obtaining the concurrence of the local communities. Alternatives C, D an E are considered less administratively feasible (i.e., have a higher score) than Alternatives A and B, due to the long-term changes in use of some areas of the river related to capping and the construction of CDFs.

- Alternatives A and B are considered the most permanent long-term remedial options for the LLBdM reach because they result in the greatest mass of PCBs permanently removed from the Lower Fox River (approximately 1800 Kg). Alternatives C through E result in the removal of a PCB mass ranging between approximately 1/3 and ½ that of Alternatives A and B. It should be noted that although Alternatives A and B result in essentially the same PCB mass removal, the overall value of sediments removed in Alternative A is considerably less than in Alternative B (1.1 million cy vs. 1.6 million cy). Alternatives F and G result in no removal of PCB mass.

- Alternatives B through E have costs within the same general range (between approximately $50 million and $70 million). The cost for the implementation of Alternative A is approximately 50% greater (greater than $90 million). The cost for Alternative F is approximately two orders of magnitude less than the cost for all other alternatives (approximately $1.2 million). Finally, no cost is associated with the No Action alternative (Alternative G). A review of the LLBdM costs indicates that the costs for the remedial alternatives are closely related to the volume of sediments addressed (either by dredging the sediments, or by capping the sediments). The three process options considered for Alternatives B through D for management of dredged sediments, (i.e., off-site disposal of all dredged sediments; on-site thermal treatment of TSCA sediments and disposal in on-site CDFs; and off-site disposal of TSCA sediments and disposal of remaining sediments in on-site CDFs) only differ slightly in cost (the on-site CDF option - Alternative D being the lowest cost one). The cost of Alternative E, which involves the in-situ capping of the non-TSCA portion of the addressed sediments is similar to that of Alternatives B through D.

- Alternative A has the highest incremental cost associated with reducing the human health risk within the LLBdM reach, due to the fact that compared to the other alternatives, the incremental cost for this alternative does not result in a proportionally equivalent risk reduction (i.e., with respect to the No Action alternative). Alternatives B through E have incremental costs that are relatively close and range between 70% and 90% of the value for Alternative A, indicating that they provide proportionally a more cost effective approach to reduce risk. In this group of Alternatives, Alternative D offers the lowest incremental risk reduction cost. The incremental cost for Alternative F (Institutional Controls) is not calculated because the risk reduction associated with this alternative cannot be reliably calculated. Alternative G (No Action) results in no cost and no risk reduction.

10.3 Comparative Analysis of Alternatives - Appleton to Little Rapids Reach

The comparative analysis of alternatives for the Appleton to Little Rapids reach is presented in Table 10-3 and Figure 10-2. The following provides a set of observations resulting from the comparative analysis:

- Only Alternative A results in a reduction of risk to subsistence anglers in the acceptable range of 10^{-6} to 10^{-4}. No residual risk was calculated for Alternative B (Institutional Controls). Alternative G (No Action) results in no risk reduction, and in a residual risk of 7×10^{-4}.

- Based on the analysis presented in Section 8, it would take approximately 10 years post-remediation to achieve a no-risk PCB level in sediments if Alternative A were implemented. Under the no active remediation scenarios (Alternatives B and C), this time would be approximately 37 years, or close to 4 times longer.

- Alternative A is the only alternative involving active remediation of the river, and is the only one resulting in impacts to local communities during construction (i.e., as measured by the amount of time necessary for its implementation). These activities would last for approximately 4.4 years.

- The construction of Alternative A is contingent on the procurement of a series of permits from local, state and federal agencies, and on obtaining the concurrence of the local communities. The feasibility of this alternative is considered considerably greater (as reflected in a score approximately twice as low) than that of Alternatives B and C. Alternatives B and C, which do not involve any active remediation, are considered the most unfeasible from an

administrative point of view, and are assigned the highest administrative effort score (8 and 10, respectively).

- Alternative A results in close to 300 Kg of PCB mass being removed from the Lower Fox River. The permanence of this alternative, as it relates to the presence of PCBs in the Appleton to Little Rapids reach, is considered significantly greater than that of Alternatives B and C, which result in no removal of PCB mass.

- Alternative A has a cost of approximately $24 million. This is approximately 20 times greater than the cost for Alternative B. No cost is associated with the No Action alternative (Alternative C).

- Alternative A is the only one for which an incremental cost associated with reducing the human health risk within the Appleton to Little Rapids reach was calculated. The incremental cost for Alternative B (Institutional Controls) was not calculated because the risk reduction associated with this alternative cannot be reliably calculated. This measure is not defined for the No Action alternative, as this alternative results in no cost and no risk reduction.

10.4 Comparative Analysis of Alternatives - Little Rapids to De Pere Reach

The comparative analysis of alternatives for the Little Rapids to De Pere reach is presented in Table 10-4 and Figure 10-3. The following provides a set of observations made as a result of the comparative analysis:

- Only Alternatives A, B and F result in a reduction of risk to subsistence anglers in the acceptable range of 10^{-6} to 10^{-4}. This reduction is due to the greatest amount of sediments addressed by these alternatives (either by removal or by capping) and consequent decrease in the average overall sediment PCB concentrations with respect to all other alternatives. The residual risk for Alternatives C through E is equal, and is very close to that of the No Action Alternative. No risk reduction was calculated for Alternative G (Institutional Controls). Alternative H (No Action) results in no risk reduction, and in a residual risk of 5.9×10^{-4}.

- The time necessary to achieve a no-risk PCB level in sediments is approximately 10 years for Alternatives A, B and F. For Alternatives C, D and E, this time is approximately six times longer. For Alternatives G and H, the time is greater than ten times longer.

- The greatest impacts to the local communities would be produced by Alternative F, with an implementation time of about 5 years. Alternative E would result in the least impacts (2 years). Alternatives A through D are comparable as far as this measure is considered.

- Alternatives G and H, which do not involve any active remediation, are considered the least administratively feasible and are therefore assigned the highest administrative effort score (8 and 10, respectively). The implementation of remaining alternatives is contingent on the procurement of a series of permits from local, state and federal agencies, and on obtaining the concurrence of the local communities. Alternatives D and E are considered less administratively feasible (i.e., have a higher score) than Alternative A and Alternative B, due to long-term changes in use of some areas of the river. The alternative with the lowest level of administrative effort score (i.e., the one considered the most feasible from an administrative standpoint) is Alternative F (Cap All Sediments). No discharge, disposal, or treatment permits are required for implementation of Alternative F.

- Alternatives A and B are considered the most permanent long-term remedial option for the Little Rapids to DePere reach because they result in the greatest amount of PCB mass being removed from the Lower Fox River environment (approximately 1400 Kg). Alternative E results in a PCB mass removal which is approximately one-half that of Alternatives A and B. Alternatives C and D result in a PCB mass removal which is approximately 30% less than that for Alternatives A and B. Alternatives F, G and H result in no removal of sediments and are therefore assigned the lowest score for this measure.

- Alternative A and Alternative C have the highest costs. These alternatives have similar costs (greater than $100 million). The costs are similar because they address similar volumes of sediments using similar dredging and disposal process options. Even though Alternatives B and D remove the same volume of sediments as Alternatives A and C, they cost approximately 4 to 5 times less. The cost differential is mainly due to the different off-site disposal options proposed for these alternatives: loading and transportation to an off-site landfill for Alternatives A and C, versus pumping to a new NR 500 landfill for Alternative B or disposal to an on-site CDF for Alternative D. Alternative F addresses (by capping) the same volume of sediments as Alternative A through D. Its cost is comparable to that of Alternatives B and D and approximately one-fifth that of Alternatives A and C. Alternative E includes both sediment removal and capping. The cost for this alternative (approximately $40 million) is higher than for Alternatives A, D and F due to a loss of economy of scale involved with the CDF construction. The cost for

the Institutional Controls alternative (Alternative G) is considerably lower than that of all the other alternatives.

- From the standpoint of the incremental cost associated with reducing the human health risk within the reach, the alternatives can be divided into three groups. Alternatives B and F, have by far the lowest incremental cost. Alternatives A, D and E have an intermediate incremental cost, and Alternative C, has by far the highest incremental cost. The incremental cost for Alternative G (Institutional Controls) was not calculated because the risk reduction associated with this alternative cannot be reliably calculated. This measure is not defined for the No Action alternative (Alternative H), as this alternative results in no cost and no risk reduction.

10.5 Comparative Analysis of Alternatives - De Pere to Green Bay Reach

The comparative analysis of alternatives for the De Pere to Green Bay reach is presented in Table 10-5 and Figure 10-4. The following provides a set of observations made as a result of the comparative analysis:

- Only Alternatives A and B result in a reduction of risk to subsistence anglers in the acceptable range of 10^{-6} to 10^{-4}. This reduction is due to the greatest amount of sediments addressed by these alternatives, and consequent greatest decrease in the average overall sediment PCB concentrations with respect to all other alternatives. The residual risk for Alternatives B through F is equal, and is barely above the 10^{-4} threshold. No risk reduction was calculated in Alternative G. Alternative H (No Action) results in no risk reduction, and in a residual risk in the 10^{-3} range.

- Only Alternatives A and B, which include the removal of greater than 5.5 million cubic yards of sediments, result in no-risk PCB levels in sediments in less than 100 years. For all other alternatives, the no-risk level is not achieved within the modeled time horizon (100 years).

- All alternatives considered involving sediment remediation would result in protracted impacts to local communities (ranging from approximately six to greater than eight years). Given the length of this reach, however, different local communities might be impacted at different times. Alternatives F (Institutional Controls) and Alternative G (No Action) would result in no disruption to local communities.

- Alternatives F and G, which do not involve any active remediation, are considered the least administratively feasible and are therefore assigned the highest administrative effort score (8 and 10, respectively). Implementation of the remaining alternatives is contingent on the procurement of a series of permits from local, state and federal agencies, and on obtaining the concurrence of the local communities. Alternatives A through C are considered to be the most administratively implementable ones. In fact, the permit requirements for these alternatives are similar to those for all the others. However, Alternatives A through C do not involve any modifications to the physical river setting, or restrictions to the current river use. Alternatives D and E are considered slightly less administratively feasible (i.e., have a higher score) than Alternatives A through C, due to the long-term changes in the use of some areas of the river associated with the construction of a CDF. Alternative F, which involves capping is considered slightly more administratively implementable than Alternatives D and E, but slightly less administratively implementable than Alternatives A through C.

- Alternatives A and B are considered the most permanent long-term remedial options for the De Pere to Green Bay reach because they result in the greatest amount of PCB mass being removed from the Lower Fox River. Alternatives C through E result in PCB mass removal roughly between 10% and 20% that for Alternative A. Alternatives G and H result in no removal of sediments, and are thus assigned the lowest score for this measure.

- Alternative B, which involves hydraulic dredging and disposal of sediment via pumping to a new NR 500 landfill is by far the most cost-effective alternative involving active sediment remediation. The greatest cost advantage is realized by the use of the NR 500 landfill for disposal, and associated savings achieved by pumping versus loading and transporting sediment. Alternatives A and C, which involve the removal and off-site disposal of comparable sediment volumes using the same approach, also have similar costs (in the $400 million to $500 million range). These are the highest costs among all alternatives for the reach. The costs for Alternatives D, E, and F are similar, all close to $100 million. These alternatives cannot readily be distinguished based on cost.

- From the standpoint of the incremental cost associated with reducing the human health risk within the reach, the alternatives can be divided into three groups. Alternatives A and B, have the highest incremental cost. Alternatives D, E and F, have an intermediate incremental cost, and Alternative B has the lowest incremental cost. The incremental cost for Alternatives D through F is approximately one-third less than for Alternatives A and C. The incremental cost for Alternative B is lower by approximately 1 order of

magnitude with respect to Alternatives A and C. The incremental cost for Alternative G was not calculated because the risk reduction associated with this alternative cannot be reliably calculated. This measure is not defined for the No Action alternative, as this alternative results in no cost and no risk reduction.

10.6 Conclusions

In this subsection, a set of conclusions are provided that generally apply to all four reaches. These conclusions are based on the comparative analysis presented in the preceding subsections.

The alternatives addressing the greatest volumes of contaminated sediments result in the greatest reduction of human health risk due to fish ingestion. However, as clearly indicated by the last set of bar graphs in Figures 10-1 through 10-4, the risk reduction achievable by the implementation of the most extensive remedial alternatives does not typically result in a proportional risk decrease. As such, except for the De Pere to Green Bay reach, the alternatives with the highest cost are the ones for which the incremental risk benefit of remediation also has the highest cost. Since the sediment volumes addressed to achieve a meaningful risk reduction are generally large, the associated remediation costs are also large. Conversely, the Institutional Controls alternatives, which are estimated to cost just over $1 million, may be able to achieve measurable risk reductions. As discussed in Table 10-1, though, such risk reduction is contingent on effectively preventing fish consumption, and cannot be reliably quantified at this stage.

The number of years to reach a no-risk PCB level is a function of the extent of remediation associated with each alternative. For all reaches, this time is less than 20 years for the alternatives addressing the largest sediment volumes. Except for the Appleton to Little Rapids reach, where it is predicted that natural processes would restore the river to a no-risk PCB level within less than 40 years, for all other reaches, the No Action and Institutional Controls alternative would not achieve such levels within the 100 years time horizon of the model. It should also be noted that for the De Pere to Green Bay reach, Alternatives A and B, which involve the removal of all sediments exceeding 250 mg/kg PCBs concentrations, are the only ones able to achieve a no-risk level within the 100 years modeled time horizon.

The implementation duration is also a function of the volume of sediments addressed. Since the volumes of impacted sediments are different in the various reaches, the amounts of time local communities along each reach would be affected also varies. For the sediment remediation alternatives developed in this

FS (excluding the Institutional Controls alternatives), the construction duration ranges between approximately 2 years to greater than 8 years. During the remediation periods, a considerable amount of disruption to local communities is expected.

The implementation of the No Action and Institutional Controls alternatives is not administratively feasible, due to regulatory constraints, and goals for the river. The administrative implementability of the various alternatives is somewhat variable, and is dependent on obtaining a considerable number of permits and on the approval of local stakeholders. However, based on the objective measure used, the administrative feasibility does not vary significantly among the various alternatives. As such, this measure cannot readily be used to distinguish among alternatives.

The various remedial alternatives developed for the Lower Fox River vary greatly in terms of PCB mass removed across reaches, and within the same reach. Within each reach the removed PCB mass generally varies between a maximum corresponding to removal of all sediments exceeding 250 ppb PCBs, to a minimum of zero, for the capping, Institutional Controls and No Action alternatives. Across reaches, the maximum removed PCB mass vary from approximately 300 Kg for the Appleton to Little Rapids reach to volumes greater than 20,000 Kg for the De Pere to Green Bay reach.

Finally, the cost analysis developed in the FS provides the following general guidelines.

- *In-situ* management of the sediments via capping is in general more cost effective than dredging and disposal. The cost advantage generally increases with increasing sediment volumes to be addressed.

- In general, disposal of non-TSCA dredged sediments in an on-site CDF is advantageous with respect to disposal in an off-site landfill.

- For TSCA sediment, pre-treatment followed by CDF disposal, and off-site disposal in a landfill are essentially equivalent from a cost stand point.

- For the two reaches where it was considered, disposal of dredged sediment (both TSCA and non-TSCA) is a new, dedicated off-site NR 500 landfill presents significant cost advantages with respect to an existing, off-site disposal at a landfill.

- Disposal of dredged sediment at a NR 500 landfill is also cost advantageous with respect to disposal at an on-site CDF. The cost advantage is slight for the Little Rapids to De Pere reach, but it is much greater for the De Pere to Green Bay reach.

10.7 Section 10 Tables and Figures

Tables and Figures for Section 10 follow this page and include:

Tables

Table 10-1 Comparative Evaluation Measures
Table 10-2 Comparative Analysis of Alternatives - LLBdM Reach
Table 10-3 Comparative Analysis of Alternatives - Appleton to Little Rapids Reach
Table 10-4 Comparative Analysis of Alternatives - Little Rapids to De Pere Dam Reach
Table 10-5 Comparative Analysis of Alternatives - De Pere Dam to Green Bay Reach

Figures

Figure 10-1 Comparative Analysis of Alternatives - Little Lake Butte des Morts Reach
Figure 10-2 Comparative Analysis of Alternatives - Appleton to Little Rapids Reach
Figure 10-3 Comparative Analysis of Alternatives - Little Rapids to De Pere Dam Reach
Figure 10-4 Comparative Analysis of Alternatives - De Pere to Green Bay Reach

Table 10-1 Comparative Evaluation Measures

Issue	Quantitative Measure	Comment
Residual human health risk	Risk to subsistence anglers after implementation of the alternative.	The baseline and ecological human health risk assessment has identified a number of potential human receptor groups. The subsistence anglers are chosen as the reference receptor group as they have the highest estimated lifetime cancer risk. This risk is mostly due to fish ingestion. A quantitative measure of the effect of alternatives on ecological risk is not included in the quantitative measure. The risk after the implementation of the remedial alternative is calculated by using the reduction in reach-averaged surface area weighted sediment PCB concentrations, as predicted by the concatenated FRM model, and as presented in Section 8. The predicted reduction achieved 10 yrs post-remediation is used. It should be noted that the risk to subsistence anglers after the implementation of the Institutional Controls alternatives is not presented in the analysis, because the effectiveness of these measures to prevent ingestion of fish cannot be reliably quantified at the FS level.
Time post-remediation necessary to achieve sediment PCB concentrations resulting in negligible risk to human and ecological receptors.	Number of years necessary to achieve the Mink reproduction and Survival NOEL, as presented in Table 8-1.	As discussed in Section 8, none of the remedial alternatives identified in the FS provide for immediate 100% relief for all human and ecological receptors in the river. A key assumption in this alternative analysis is that sediment transport and burial over time would achieve further reductions in PCB mass and thus concomitant reductions in risk. At some time in the future, this self-cleaning function would result in restoration of the river to be fully protective for all uses and all receptors. Thus, the time to achieve such risk reduction is considered an objective measure of the efficacy of an alternative.
Disruption of local communities	A numerical score equal to the estimated number of years for implementation is assigned to each alternative.	Significant disruptions to the community are expected to occur during implementation of the alternatives. The disruption may be caused by a number of factors, including: noise, environmental releases (air emissions and sediment re-suspension), diminution of recreational use of the river, presence of heavy equipment, truck traffic, etc. The expected disruption of local communities is expected to be similar for all alternatives during the construction period. The alternatives do however, vary considerably with respect to the expected time for completion of construction activities. For these reasons, the expected time of construction is considered an objective measure of the level of disruption to local communities.

Table 10-1 Comparative Evaluation Measures (Cont'd)

Issue	Quantitative Measure	Comment
Administrative Effort for Implementation	A score ranging from 1 (can be easily implemented from an administrative standpoint) to 10 (likely to be administratively unfeasible) is assigned to each alternative.	The administrative feasibility of implementing the remedial alternatives, can be evaluated with respect to the ease of obtaining the concurrence of federal, state and local agencies and the public on the issuance of permits for construction of an alternative. A number of permits may be required to proceed with remedial activities, including: water quality permits, discharge permits, landfill permits, local permits, air emission permits, and lake bed permits. The number of types of permits required is considered as an objective measure of the administrative feasibility of each alternative. This number can range up to 6. In addition, some of the alternatives involve capping, which might result in disruption to the navigability and restrict recreational use of some sections of the river, and/or the construction of CDFs, which would affect the physical configuration of the river. In addition, capping and the construction of CDFs could effect flood flow and riparian and fish/wildlife habitats. These alternatives involve actions that may affect the long-term use of the river, and might be of additional concern to local communities. For these alternatives, an additional score of 1 is added to the previously described score. The No Action alternatives (which are carried forth in the alternative analysis as a reference point) are considered administratively unfeasible, as they do not address the health and environmental issues associated with the presence of contaminants in the Lower Fox River. A score of 10 is assigned to them. The Institutional Controls alternatives are also considered relatively unfeasible from an administrative standpoint. However, this approach to addressing environmental issues in the Lower Fox River is considered less unfeasible than no action, since it results in actively addressing the human health issues associated with the presence of contaminants in the river. As such, the Institutional Controls alternatives are assigned a score of 8.
Mass of PCBs removed	Mass of PCBs removed from the river (Kg)	The mass of PCBs removed from the river as a result of remediation is considered an objective measure of the permanence of the remedial option as it relates to environmental conditions within the river.
Cost	Estimated total alternative cost ($M)	The total cost provides a direct measure of the estimated funds to implement a remedial alternative. Total costs include capital costs, indirect costs and annual operation and maintenance costs.
Incremental cost of risk reduction	Incremental cost (in $M/unit risk)	This measure represents the incremental cost of reducing the risk to subsistence anglers by one unit, and is considered a measure of the cost/benefit ratio of the alternatives. It is calculated as: [(Alternative Cost)/(NoActionRisk-AlternativeRisk)]

Table 10-2 Comparative Analysis of Alternatives - LLBdM Reach

	ALTERNATIVE						
	A	B	C	D	E	F	G
Residual Risk	9.0E-06	1.8E-04	1.8E-04	1.8E-04	1.8E-04	NA	9.0E-04
Time to Reach No Risk Level (yrs)	17	44	44	44	44	100	100
Implementation Duration (yrs)	4.9	3.4	2.4	2.4	2.2	0	0
Level of administrative Effort	4	4	6	6	6	8	10
Mass of PCB removed (kg)	1808	1798	969	969	697	0	0
Incremental Cost of Risk Reduction ($M/unit risk)	104,938	93,056	80,833	71,528	78,611	NA	NA
Cost (M$)	93.5	67	58.2	51.5	56.6	1.2	0

Table 10-3 Comparative Analysis of Alternatives - Appleton to Little Rapids Reach

	ALTERNATIVE		
	A	B	C
Residual Risk	4.2E-05	NA	7.0E-04
Time to Reach No Risk Level (yrs)	10	37	37
Implementation Duration (yrs)	4.4	0	0
Level of administrative Effort	4	8	10
Mass of PCB removed (kg)	289	0	0
Incremental Cost of Risk Reduction ($M/unit risk)	36,018	NA	NA
Cost (M$)	23.7	1.2	0

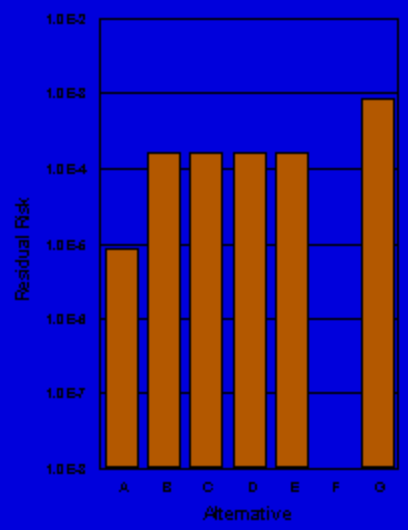
Table 10-4 Comparative Analysis of Alternatives - Little Rapids to de Pere Dam Reach

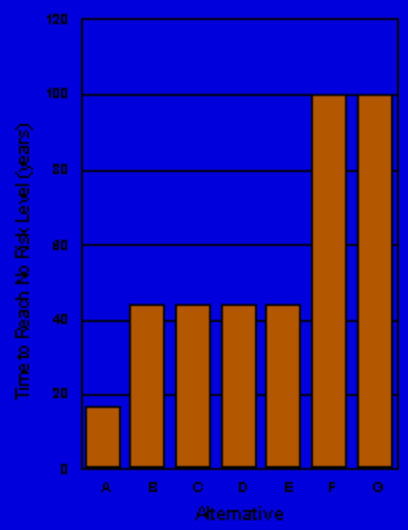
	ALTERNATIVE							
	A	B	C	D	E	F	G	H
Residual Risk	3.9E-05	3.9E-05	5.5E-04	5.5E-04	5.5E-04	3.9E-05	NA	5.9E-04
Time to Reach No Risk Level (yrs)	10	10	61	61	61	10	100	100
Implementation Duration (yrs)	3.6	3.6	3.2	3.2	1.8	5	0	0
Level of administrative Effort	4	4	4	5	5	3	8	10
Mass of PCb removed (kg)	1,429	1,429	1,073	1,073	700	0	0	0
Incremental Cost of Risk Reduction ($M/unit risk)	206,646	40,312	2,646,154	751,282	1,079,487	39,949	NA	NA
Cost (M$)	113.8	22.2	103.2	29.3	42.1	22	1.2	0

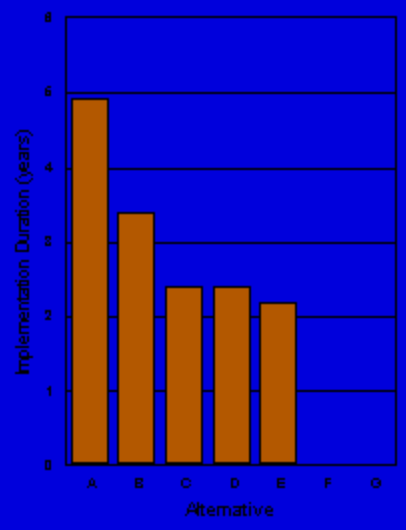
Table 10-5 Comparative Analysis of Alternatives - De Pere Dam to Green Bay Reach

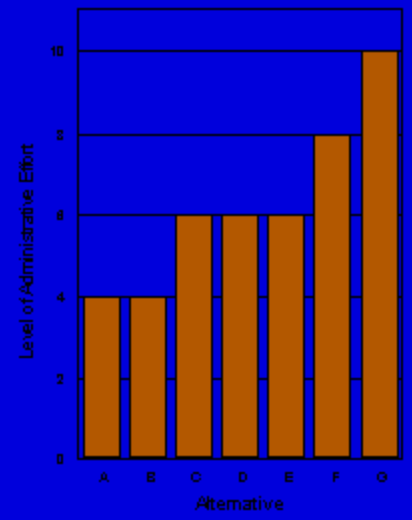
	ALTERNATIVE							
	A	B	C	D	E	F	G	H
Residual Risk	6.5E-06	6.5E-06	2.0E-04	2.0E-04	2.0E-04	2.0E-04	NA	1.5E-03
Time to Reach No Risk Level (yrs)	19	19	100	100	100	100	100	100
Implementation Duration (yrs)	6.1	8.5	7.3	6.4	6.4	5.8	0	0
Level of administrative Effort	4	4	4	6	6	5	8	10
Mass of PCb removed (kg)	23,417	23,417	21,142	19,753	19,753	19,074	0	0
Incremental Cost of Risk Reduction ($M/unit risk)	328,093	30,734	335,583	100,460	94,095	100,077	NA	NA
Cost (M$)	490	45.9	437.6	131	122.7	130.5	1.2	0

Figure 10-1 Comparative Analysis of Alternatives - Little Lake Butte des Morts Reach

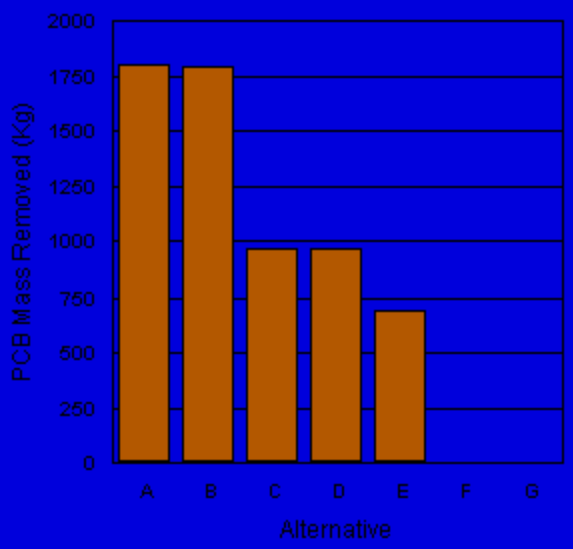


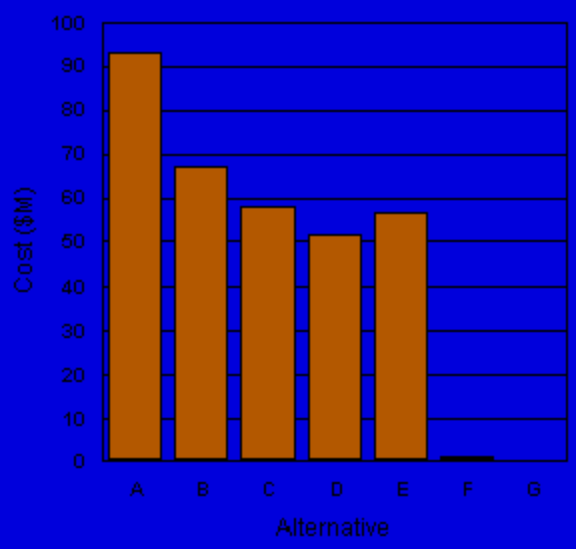


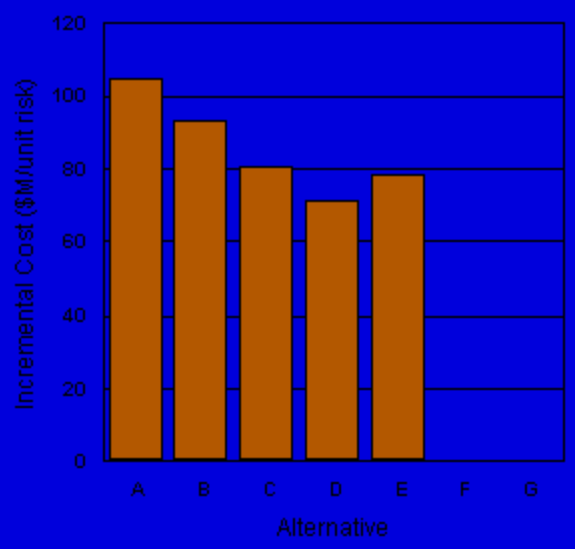




This measure is not calculated for the Institutional Controls Alternative.

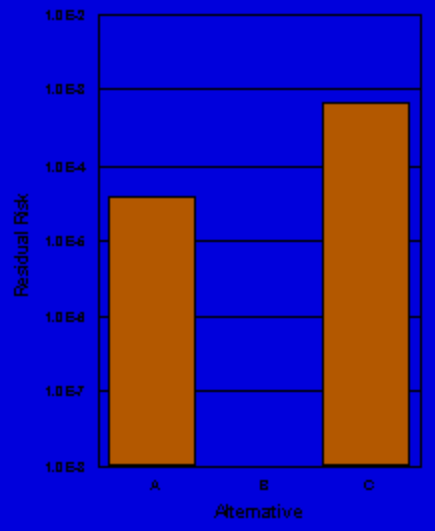


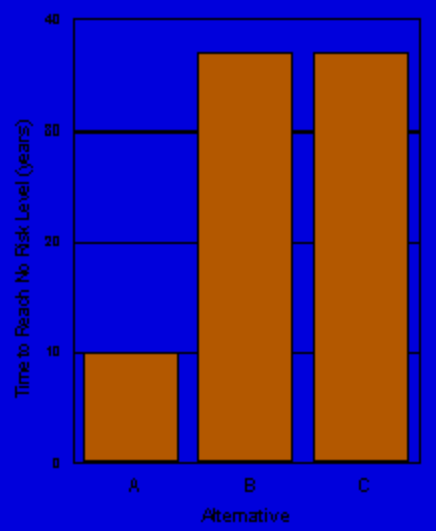


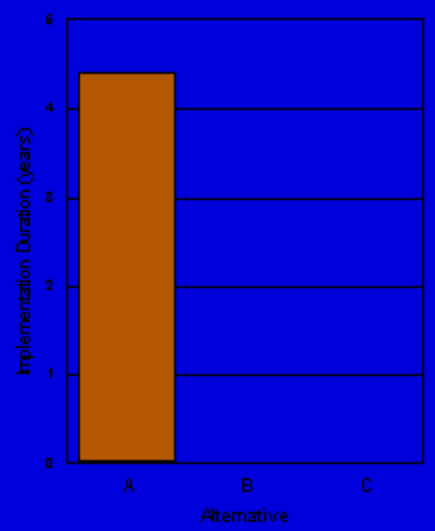


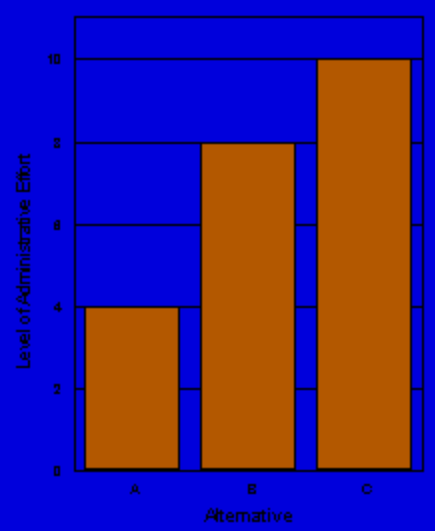
This measure is not calculated for the Institutional Controls Alternative and, is not defined for the No Action Alternative.

Figure 10-2 Comparative Analysis of Alternatives - Appleton to Little Rapids Reach









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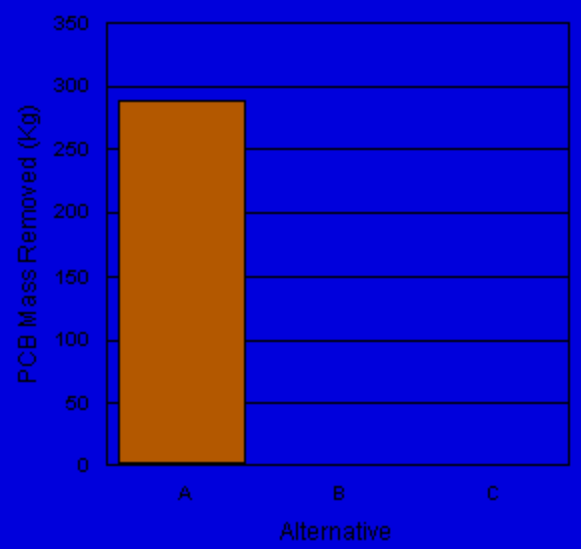
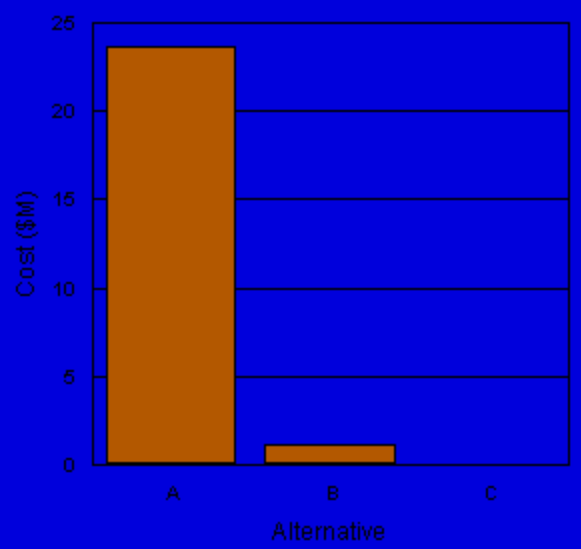
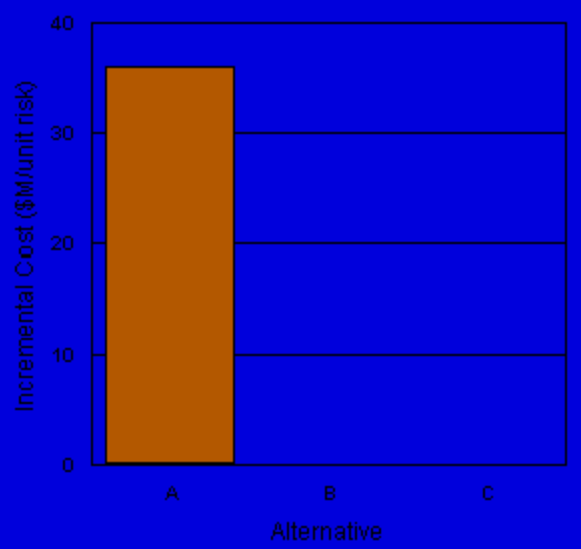
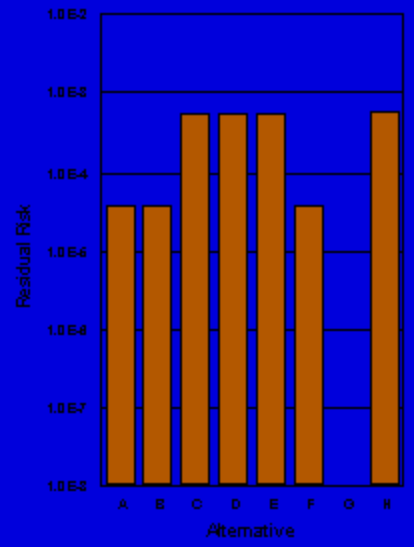






This measure is not calculated for the Institutional Controls Alternative and, is not defined for the No Action Alternative.

Figure 10-3 Comparative Analysis of Alternatives - Little Rapids to de Pere Dam Reach



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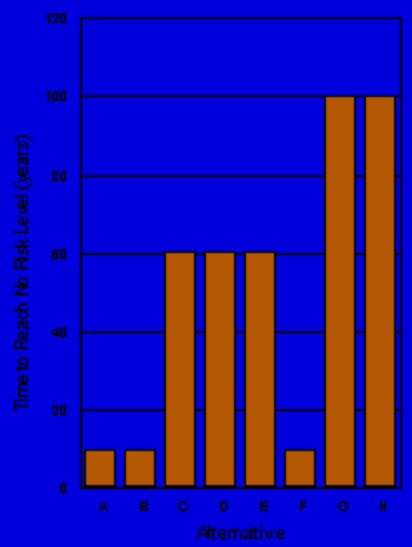
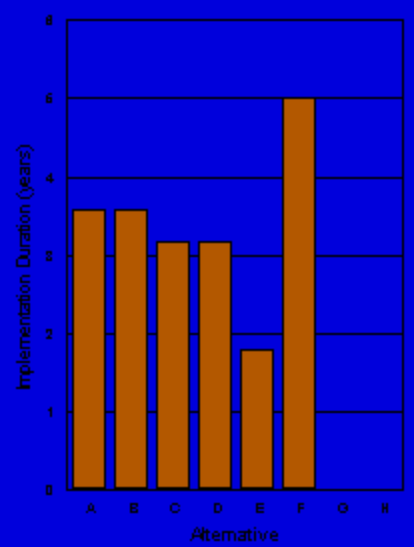
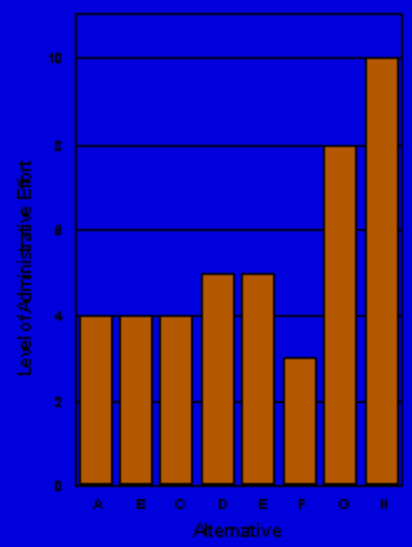
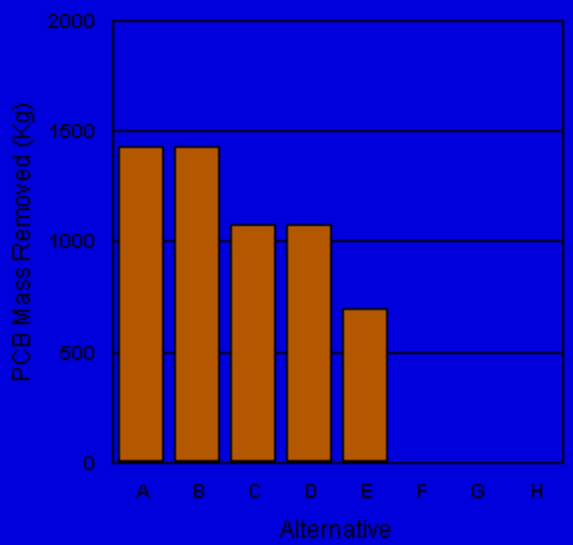
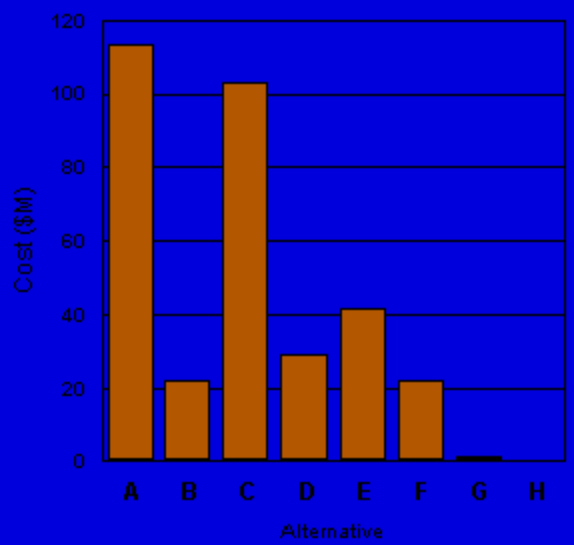
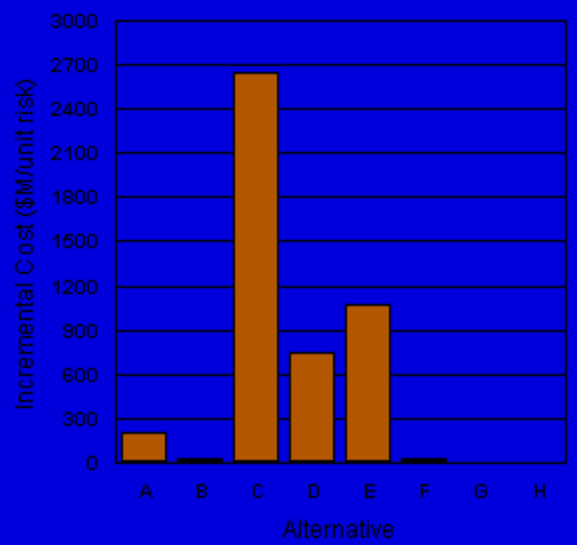






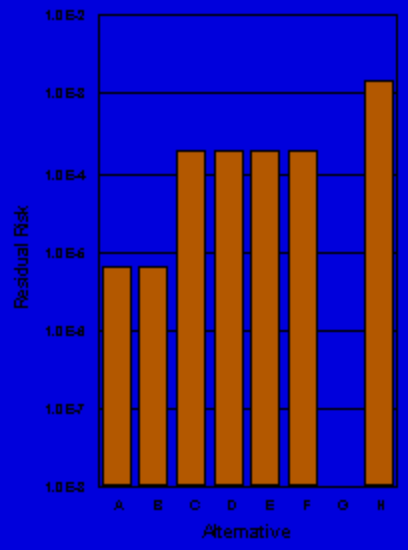






This measure is not calculated for the Institutional Controls Alternative and, is not defined for the No Action Alternative.

Figure 10-4 Comparative Analysis of Alternatives - De Pere Dam to Green Bay Reach



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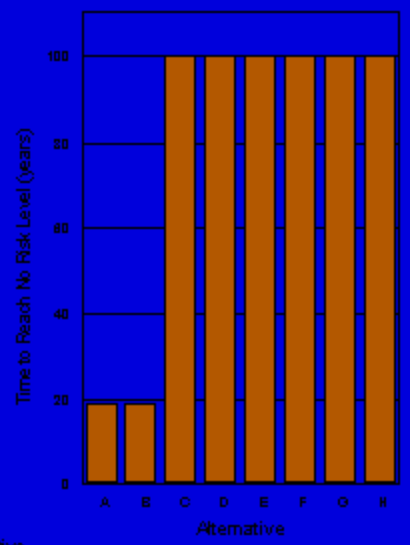

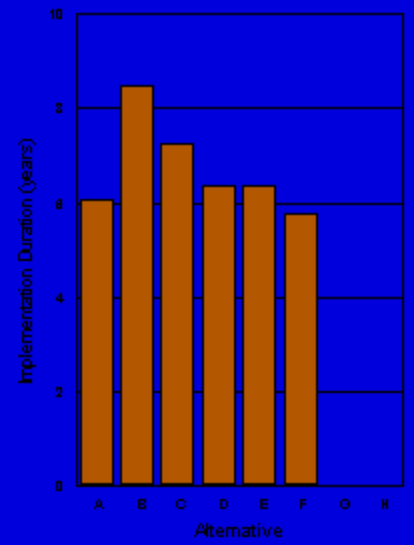

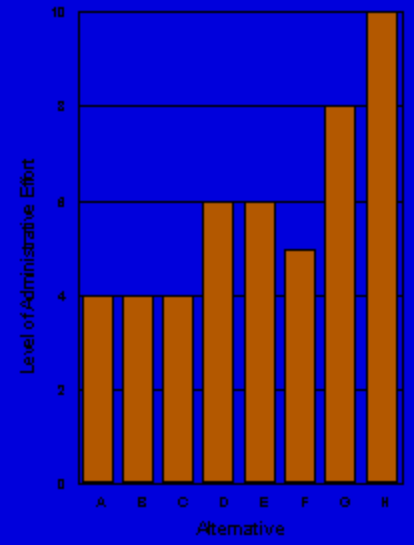

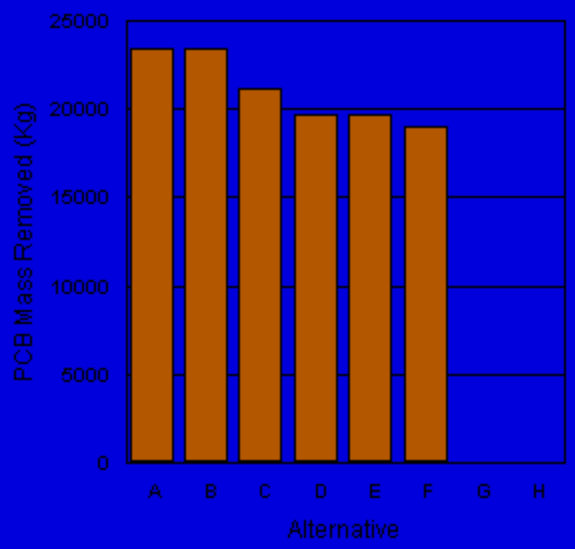

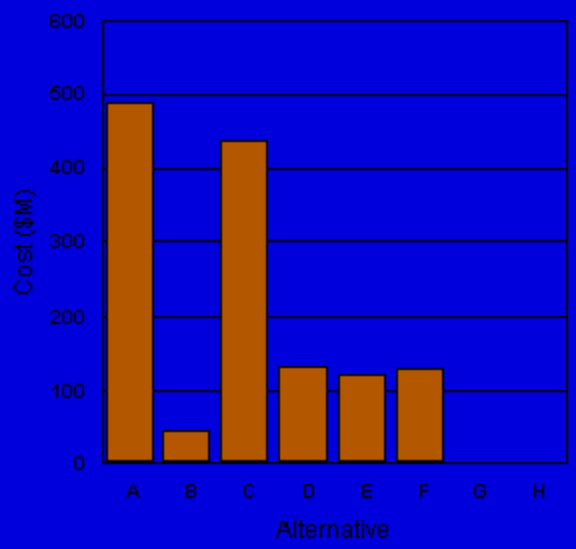

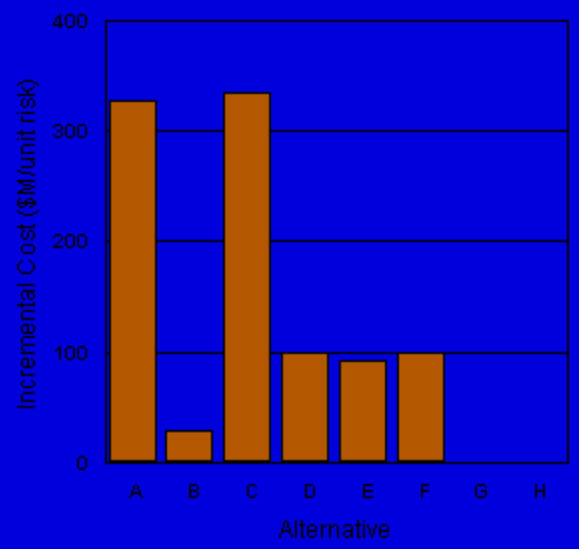

This measure is not calculated for the Institutional Controls Alternative and, is not defined for the No Action Alternative.

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