10 Comparative Analysis of Alternatives

This section presents the final analysis of the alternative screening process incorporating the risks, implementation methods, costs, and action level options screened in the previous sections of the FS. This final section is a comparative analysis among the eight potential remedial alternatives to assess the relative performance of each alternative with respect to four of the CERCLA balancing criteria presented in Section 9 (EPA, 1988 RI/FS Guidance Document). It synthesizes all of the findings presented in the RI, FS, and RA documents for the Lower Fox River and Green Bay RI/FS. The purpose of the comparative analysis is to weigh the relative performance of each alternative against a particular criterion and to determine which alternatives perform consistently well or consistently better in relation to the criterion of interest. A sub-component of this comparison is that for each remedial alternative, a range of action levels is presented resulting in varying levels of effort, protection, and risk reduction (discussed in Section 8). By carrying forward a range of action levels for each alternative, this section creates a three-dimensional comparative analysis between evaluation criteria, remedial alternative, and action level.

Following a description of the comparative process, the comparative analysis for each of the four river reaches are described separately below as they relate to the remedial action objectives. The Green Bay zones are discussed together as Green Bay since most of the outcomes are the same, regardless of the zone. A summary of the comparative measures used in the evaluation process are presented in Table 10-1. A summary of the total cost and anticipated risk reduction associated with each alternative is presented in Tables 10-2 and 10-3 for the Lower Fox River and Green Bay, respectively.

10.1 Description of Comparative Analysis Process

This section compares the predicted performance of: 1) each reach-specific and bay-specific alternative at each action level in relation to specific evaluation criteria; and 2) each action level on a river- and bay-wide basis in relation to specific evaluation criteria. This comparison builds upon the detailed analysis conducted in Section 9 in which each alternative was analyzed independently without consideration of other alternatives and the risk assessment summary in Section 8 in which each action level was evaluated independently. The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative and action level relative to one another, so that the key trade-offs can be identified. This section does not, however, recommend any specific alternative or action level. Final selection will be the responsibility of the resource managers to balance the trade-offs identified in this section and select a final remedy option.

The comparative analysis focuses on synthesizing the evaluation in Section 9 into readily accessible decision-making tools. 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:

- How long after remediation is completed would it take to achieve sediment concentrations resulting in acceptable 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 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?

- How long after remediation is completed would it take to achieve surface water concentrations resulting in acceptable risk to humans and ecological receptors?

- What is the amount of PCBs being transported to Green Bay in the water column as suspended solids following implementation of the alternative?

Each of these issues, and the quantitative measures identified to evaluate the alternatives, are discussed in Table 10-1. In summary, the array of parameters included in the comparative analysis for both the Lower Fox River and Green Bay includes the following components:

- **Remedial Alternatives**
  - A: No Action
  - B: Monitored Natural Recovery and Institutional Controls
  - C: Dredge and Off-site Disposal (C1, C2, and C3 where options are provided[8])
  - D: Dredge to a CDF
  - E: Dredge and Thermal Treatment
  - F: Cap in Place (to the maximum extent possible)
  - G: Dredge to a CAD Facility

- **PCB Action Levels**
  - No Action
  - 125 ppb
  - 250 ppb
  - 500 ppb
  - 1,000 ppb
  - 5,000 ppb

- **Evaluation Parameters (Associated CERCLA Balancing Criterion)**
  - Years to Reach Protective Human Health Levels (long-term effectiveness and permanence)
  - Years to Reach Protective Ecological Health Levels (long-term effectiveness and permanence)
  - Number of Years to Implement Remedy (short-term effectiveness)
  - PCB Mass Removed (reduction of toxicity, mobility and volume)
  - Total Cost (cost)
  - Cost Effectiveness (cost)
  - Years to Reach Ecologically Protective Surface Water Quality (long-term effectiveness and permanence)
  - PCB Sediment Loading to Green Bay (long-term effectiveness and permanence)

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[8] Alternative C or C1 is hydraulic dredging for Little Lake Butte des Morts, Appleton to Little Rapids, and Little Rapids to De Pere.
Alternative C or C1 is mechanical dredging for De Pere to Green Bay and the Green Bay zones.
Alternative C2 is mechanical dewatering for Little Lake Butte des Morts Reach.
Alternative C2A is hydraulic dredging pumped directly to a combined dewatering and disposal facility, and Alternative C2B is passive dewatering and disposal at a dedicated NR 500 monofill for the Little Rapids to De Pere and the De Pere to Green Bay reaches.
Alternative C3 is mechanical dewatering and disposal at an existing NR 500 commercial disposal facility for the Little Rapids to De Pere and De Pere to Green Bay reaches.

As discussed in Section 8, none of the alternatives considered in this FS are projected to meet surface water criteria (RAO 1) that is protective to human health drinking water standards within the modeled time horizon (100 years). As such, the ability to achieve this portion of RAO 1 cannot be used in a comparative analysis to distinguish the various alternatives. However, the ability to achieve wildlife criteria (0.12 ng/L) within 30 years following remediation is discussed under ecological health. In addition, the minimization of contaminant releases during active remediation (RAO 5) was not considered since reliable, comparable, quantitative data are not available for this purpose.

Project expectations for the Lower Fox River and Green Bay project have been summarized as five remedial action objectives previously described in Sections 4 and 8 of the FS. Within each of these remedial action objectives, both WDNR and EPA have quantified their project expectations into numerical values (i.e., number of years to remove fish consumption advisories) in which to evaluate the expected performance of each alternative and each action level. These expectations may change or be revised over the course of the project and through the public review process, but for now, they provide a useful framework to compare and evaluate the alternatives. These quantifiable expectations are described in Section 8.

From the array of risk levels and protective sediment quality thresholds presented in Section 8, several key thresholds were carried forward in the FS for relative comparison between alternatives. These thresholds were selected by both WDNR and EPA as important risk evaluation criteria that relate to the remedial action objectives (RAOs) for the project:

- **Human Health**
  - Achieve protective levels in 10 years following cleanup for recreational anglers - walleye, whole fish, RME, HI is 1.0 (noncancer) (288 μg/kg);

  - Achieve protective levels in 10 years following cleanup for recreational anglers - walleye, whole fish, RME, 10^{-5} cancer risk (106 μg/kg);

  - Achieve protective levels in 30 years following cleanup for high-intake fish consumers - walleye, whole fish, RME, HI is 1.0 (noncancer) (181 μg/kg); and

- Achieve protective levels in 30 years following cleanup for high-intake fish consumers - walleye, whole fish, RME, 10^{-5} cancer risk (71 μg/kg).

Because many of the recreational angler thresholds are met within 30 years following cleanup without implementation of an active remedy, the high-intake fish consumer threshold was added to the comparative analysis.

- **Ecological Health**
  - Achieve protective levels in 30 years following cleanup based on carnivorous bird deformity - NOAEC based on carp, whole fish (121 μg/kg);
  - Achieve protective levels in 30 years following cleanup based on protection of piscivorous mammals (mink) - NOAEC based on carp, whole fish (50 μg/kg); and
  - Achieve surface water quality for the protection of wildlife (0.12 ng/L) in 30 years following cleanup.
- **PCB Transport to Green Bay**
  - Achieve PCB loads from the Lower Fox River (De Pere to Green Bay Reach) into Green Bay that are equivalent to PCB loads from the sum of other tributaries (10 kg/yr).

The projected time required to meet these thresholds based on the action levels selected are discussed in the following sections for each reach and zone.

10.2 Summary of Alternatives

The seven generic remedial alternatives retained for detailed analysis are:

A. No Action,
B. Monitored Natural Recovery and Institutional Controls,
C. Dredge and Off-site Disposal,
D. Dredge to a Confined Disposal Facility (CDF),
E. Dredge and Thermal Treatment,
F. *In-situ* Capping, and
G. Dredge to a Confined Aquatic Disposal (CAD) Facility.

The no action alternative was retained as required under CERCLA and the NCP. This alternative serves as a baseline for comparison with other alternatives and involves taking no action towards a remedy, implying no active management or expectation that the RAOs will be achieved over time.

The monitored natural recovery alternative was also retained as a basis for comparison with other alternatives, but involves an expectation that RAOs will be achieved in 30 years (i.e., ability to consume fish from the Lower Fox River). This alternative assumes that institutional controls will remain in place until acceptable levels of risk have been achieved. Monitored natural recovery is implied in many of these alternatives, because each remedy assumes varying amounts of protectiveness by natural processes by selecting a range of different action levels surrounding the SQT levels identified in the risk assessment (Section 3). Each action level and the amount of risk reduction provided by source removal of contaminated sediment will be compared to the amount of remaining risk and the costs associated with each action level.

Dredge and off-site disposal includes hydraulic and/or mechanical dredging, passive followed by solidification or mechanical dewatering, and truck hauling to an existing or newly-constructed landfill.

Dredge to a CDF includes hydraulic dredging and piping or mechanical dredging and offloading to a newly-constructed nearshore or freestanding CDF. Nearshore CDF construction in the Lower Fox River includes placement of steel sheet piles along the waterside and a clean soil cap once the CDF has been filled to capacity. In-water CDF construction in Green Bay includes placement of contaminated sediment in an elevated cellular cofferdam and capping with clean sand.

Vitrification was retained as the representative thermal treatment process option. It involves hydraulic dredging, passive dewatering followed by thermal treatment by a shore-based unit. Sediment treated by thermal treatment is transformed into glass aggregate that has the potential for a wide variety of beneficial reuse applications.

Thermal treatment was selected as the *ex-situ* thermal treatment process option because the multi-phased study conducted by WDNR has provided data which indicates that this treatment technology is a viable option.

Several sand cap designs were retained in Section 6 for possible application in the Lower Fox River. Design factors that influenced the final selection of an *in-situ* cap included an evaluation of capping materials and cap thickness when applied in the field. In general, sandy sediments are suitable capping material, with the additional option of armoring at locations with the potential for scouring and erosion. Contaminated sediments will be left in place and covered with a 20-inch sand cap overlain by 12 inches of graded armor stone. Sediments located within navigational channels will be dredged, dewatered and taken to an upland disposal site.

Construction of a CAD is only technically feasible in Green Bay. Three possible locations were sited in the FS based on bathymetry, water depth, and currents. Each location was assumed to provide enough capacity for each action level. Construction of the CAD includes placement of contaminated sediment in a mechanically-dredged excavation and covering the sediment with 3 feet of clean sand after placement.

10.3 Comparative Analysis of Alternatives - Little Lake Butte des Morts Reach

The comparative analysis of alternatives for the Little Lake Butte des Morts Reach is presented on Figures 10-1 and 10-2. The following discussion provides a set of observations made as a result of the comparative analysis:

- **Human Health.** Figure 10-1 illustrates the time required following cleanup to reduce human health risk to below acceptable levels such that consumption advisories for recreational anglers can be removed. A general target has been established that these recreational advisories be removed within 10 years following cleanup. Active remedies implemented to the 1,000 ppb action level will satisfy this goal. The largest reductions in time to achieve protective levels is observed between the 5,000 and 1,000 ppb action levels. Figure 10-1 illustrates the time required following cleanup to reduce human health risk to below acceptable levels such that consumption advisories for high-intake fish consumers can be removed. A general target has been established that these advisories be removed within 30 years following cleanup. Active remedies satisfy this goal for action levels 125 through 1,000 ppb with the largest reduction in time to achieve protective levels occurring between the 5,000 and 1,000 ppb action levels.

- **Ecological Health.** Figure 10-1 also illustrates the time required to meet ecologically protective levels. A general target has been established that safe ecological levels should be met within 30 years following cleanup. Active remedies will meet protective levels within the modeled time frame for the 1,000 ppb action level and below, for all alternatives. The largest reduction in time to reach protective levels is observed between the 5,000 and 1,000 ppb action levels.

Figure 10-1 illustrates the time to meet ecologically protective levels based on surface water quality. A general target has been established that safe ecological levels should be met within 30 years following cleanup. Active remedies achieve this target for the 125 and 250 ppb action levels and are marginally above the target for the 500 ppb action level (39 years).

- **Implementation Duration.** Figure 10-2 illustrates the implementation duration for each alternative at each action level. A general target goal has been set to perform the cleanup within a 10-year period. Only the 125 ppb action level does not satisfy this target. All the alternatives have approximately equivalent cleanup durations that vary by action level.

- **PCB Mass Removed.** Figure 10-2 illustrates that alternatives involving dredging remove the same PCB mass at each action level, while the capping alternative (Alternative F) removes slightly less PCB mass. The largest reduction in PCB mass is observed between 5,000 and 1,000 ppb action levels, while any further decrease in the action level does not significantly increase the PCB mass removed (less than 7%).

- **Total Cost.** The total cost to implement an active remedy represents a fivefold cost increase compared to MNR (Alternative B) estimated at $9.9 million (Table 10-2). It can be seen on Figure 10-2 that Alternative E is generally the lowest cost active remedy, while dredging to a CDF and dredge and off-site disposal with mechanical dewatering (Alternatives D and C2) are slightly more expensive, with C1 being the most expensive. Alternative D appears to be least sensitive to changes in action level. At the 1,000 ppb action level, Alternative E is estimated to be the least-cost approach at $64 million with Alternative C2 at 66 million, Alternative D at $68 million, Alternative F at $90 million, and Alternative C1 at $117 million.

- **Cost Effectiveness.** In order to evaluate the cost effectiveness of each alternative at each action level, the incremental cost per year reduction in time to remove fish consumption advisories (for recreational anglers) relative to the Institutional Controls alternative (Alternative B) was calculated using the cancer risk data. Due to the uniformity in the time to remove fish consumption advisories, these data are closely aligned to the total cost data. Thermal Treatment (Alternative E) is the most cost-effective remedy, and 1,000 ppb is the most cost-effective PCB action level that meets protective thresholds.

10.4 Comparative Analysis of Alternatives - Appleton to Little Rapids Reach

The comparative analysis of alternatives for the Appleton to Little Rapids Reach is presented on Figures 10-3 and 10-4. The following discussion provides a set of observations resulting from the comparative analysis:

- **Human Health.** Figure 10-3 illustrates the time required following cleanup to reduce human health risk to below acceptable levels such that consumption advisories for recreational anglers can be removed. A general target has been established that these recreational advisories be removed within 10 years following cleanup. Each active remedy satisfies this goal for action levels 125 through 1,000 ppb, except for the cancer risk time frame which is marginally above the target for the 500 ppb (11 years) and 1,000 ppb (14 years) action levels. The largest reduction in the time to reach protective levels is observed between the 5,000 to 1,000 ppb action levels. Figure 10-3 illustrates the time required following cleanup to reduce human health risk to below acceptable levels such that consumption advisories for high-intake fish consumers can be removed. A general target has been established that these advisories be removed within 30 years following cleanup. Active remedies satisfy this goal for action levels 125 through 1,000 ppb with the largest reduction in time to achieve protective levels occurring between the 5,000 and 1,000 ppb action levels.

- **Ecological Health.** Figure 10-3 also illustrates the time required to meet ecologically protective levels. These data indicate that protective levels will not be reached within 71 to over 100 years with no active remedy (Alternatives A and B). Active remedies will meet protective levels within the 30-year time frame for the 1,000 ppb action level and below, except for the piscivorous mammal that is marginally above 30 years (34 years) at the 1,000 ppb action level. For the 500 ppb action level, the time to reach protective ecological levels varies between 15 and 29 years. For 250 ppb, the time varies between 9 and 18 years and for 125 ppb, the time varies between 7 and 15 years.

Figure 10-3 illustrates the time to meet ecologically protective levels based on surface water quality. A general target has been established that safe ecological levels should be met within 30 years following cleanup. Active remedies achieve this target for the 125 and 250 ppb action levels and are marginally above the target for the 500 ppb action level (40 years).

- **Implementation Duration.** Figure 10-4 illustrates the implementation duration for each alternative at each action level. A general target has been set to perform the cleanup within a 10-year period. All of the alternatives at each action level easily satisfy this target with the maximum implementation duration being 1.3 years.

- **PCB Mass Removed.** Figure 10-4 illustrates that alternatives involving dredging remove the same PCB mass at each action level. The largest reduction in PCB mass is observed between the No Action and 5,000 ppb action levels (63% removed), while further decrease in the action level incrementally increases the PCB mass removed. Only 10 percent of the mass is contained between the 125 and 500 ppb action levels. For Alternatives C and E, the PCB mass removed varies from 67 kg at 5,000 ppb to 105 kg at 250 ppb.

- **Total Cost.** The total cost to implement an active remedy represents a 5- to 20-fold cost increase compared to the MNR alternative (Alternative B) estimated at $9.9 million (Table 10-2). Dredging to an off-site landfill (Alternative C) is a slightly higher cost approach when compared to thermal treatment (Alternative E). Alternative E appears to be the least sensitive to changes in action level. For example, at the 1,000 ppb action level, Alternative E is estimated to be the least-cost approach at $17 million with Alternative C at $20 million.

- **Cost Effectiveness.** In order to evaluate the cost effectiveness of each alternative at each action level, the incremental cost per year reduction in time to remove fish consumption advisories (for recreational anglers) relative to the MNR alternative (Alternative B) was calculated using the cancer risk data. Due to the uniformity in the time to remove fish consumption advisories, these data are closely aligned to the total cost data. Thermal Treatment (Alternative E) is the most cost-effective remedy, and 1,000 ppb is the most cost-effective PCB action level that meets protective thresholds.

10.5 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 on Figures 10-5 and 10-6. The following discussion provides a set of observations made as a result of the comparative analysis:

- **Human Health.** Figure 10-5 illustrates the time required following cleanup to reduce human health risk to below acceptable levels such that consumption advisories for recreational anglers can be removed. A general target has been established that these recreational advisories be removed within 10 years following cleanup. Each active remedy satisfies this goal based on noncancer risk for action levels 125 through 1,000 ppb. The goal is satisfied for only the 125 ppb action level based on cancer risk, while the result is marginally above the goal for the 250 ppb (14 years) and 500 ppb (20 years) action levels. The largest reductions are observed between the 5,000 and 1,000 ppb action levels. Figure 10-9 illustrates the time required following cleanup to reduce human health risk to below acceptable levels such that consumption advisories for high-intake fish consumers can be removed. A general target has been established that these advisories be removed within 30 years following cleanup. Active remedies satisfy this goal for action levels 125 through 1,000 ppb, except for the cancer risk scenario at the 1,000 ppb action level where the goal is not achieved for 42 years. The largest reduction in time to achieve protective levels occurs between the 5,000 and 1,000 ppb action levels.

- **Ecological Health.** Figure 10-5 also illustrates the time required to meet ecologically protective levels. The no action alternatives (Alternatives A and B) do not reach protective levels within the modeled time frame (100 years). Active remedies will meet protective levels within the 30-year target time frame for action levels 125 through 500 ppb, except for the piscivorous mammal scenario at the 500 ppb action level where the goal is not achieved for 31 years.

  Figure 10-5 illustrates the time to meet ecologically protective levels based on surface water quality. A general target has been established that safe ecological levels should be met within 30 years following cleanup. Active remedies achieve this target for the 125 ppb action level and are marginally above the target for the 250 ppb action level (40 years).

- **Implementation Duration.** Figure 10-6 illustrates the implementation duration for each alternative at each action level. A general target has been set to perform the cleanup within a 10-year period. Only the 125 ppb action level does not satisfy this target for all of the active remedies (Alternatives C1, D, and E). For each action level, the Dredge and Pipe to Landfill and Capping alternatives (Alternatives C2 and F) have the lowest implementation durations when compared to other alternatives.

- **PCB Mass Removed.** Figure 10-6 illustrates that all removal alternatives (Alternatives C1 through E) remove the same PCB mass at each action level, while capping (Alternative F) removes significantly less PCB mass. Significant reductions in PCB mass are observed at the 5,000 and 1,000 ppb action levels. Ninety-two percent of the PCB mass is removed at the 1,000 ppb action level while further decreases in the action level do not significantly increase the PCB mass removed. For Alternatives C1 through E, the PCB mass removed varies from 798 kg at 5,000 ppb to 1,192 kg at 250 ppb.

- **Total Cost.** The total cost to implement an active remedy represents a 4- to 25-fold cost increase compared to the MNR alternative (Alternative B) estimated at $9.9 million. Among the active remedies, dredging to a CDF (Alternative D) has the lowest cost at all action levels (except 5,000 ppb) (Table 10-2). Alternative D also appears to be least sensitive to changes in action level. Alternatives D, F, C3, E, C2B, and C1 are incrementally more expensive, with Alternative C1 being the most expensive. For example, at the 1,000 ppb action level, Alternative C2A is estimated to be the least-cost approach at $44 million. Alternative D is estimated to cost $53 million, Alternative F is estimated to cost $63 million, Alternative C3 is estimated at $69 million, Alternative E is estimated at $86 million, Alternative C2B is estimated at $100 million, and Alternative C1 estimated at $95 million.

- **Cost Effectiveness.** In order to evaluate the cost effectiveness of each alternative at each action level, the incremental cost per year reduction in time to remove fish consumption advisories (for recreational anglers) relative to the Institutional Controls alternative (Alternative B) was calculated using the cancer risk data. Due to the uniformity in the time to remove fish consumption advisories, these data are closely aligned to the total cost data. Alternatives C2A and D are the most cost-effective remedies, and 1,000 ppb is the most cost-effective PCB action level that meets protective thresholds.

10.6 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 on Figures 10-7 and 10-8. The following provides a set of observations made as a result of the comparative analysis:

- **Human Health.** Figure 10-7 illustrates the time required following cleanup to reduce human health risk to below acceptable levels such that consumption advisories for recreational anglers can be removed. A general target has been established that these recreational advisories be removed within 10 years following cleanup. Each active remedy will satisfy this goal, based on noncancer risk, for action levels of 125 and 250 ppb. Based on cancer risk, this goal is not achieved with the minimum time of 15 years to reach protective levels at the 125 ppb action level. The largest reduction in time to reach protective levels is observed between 5,000 and 1,000 ppb action levels for cancer risk and noncancer risk. Figure 10-9 illustrates the time required following cleanup to reduce human health risk to below acceptable levels such that consumption advisories for high-intake fish consumers can be removed. A general target has been established that these advisories be removed within 30 years following cleanup. Active remedies achieve the cancer risk target at the 125 and 250 ppb action levels and for the 125 through 1,000 ppb action levels for noncancer risk.

- **Ecological Health.** Figure 10-7 also illustrates the time required to meet ecologically protective levels. Protective levels will not be reached within the modeled time frame (100 years) with no active remedy (Alternatives A and B). Active remedies will meet protective levels within the 30-year target time frame for action levels 125 through 1,000 ppb based on carnivorous bird deformity. Based on the piscivorous mammal, the target will be achieved for the 125 and 250 ppb action levels while marginally above the target for the 500 ppb action level (34 years).

  Figure 10-7 illustrates the time to meet ecologically protective levels based on surface water quality. A general target has been established that safe ecological levels should be met within 30 years following cleanup. Active remedies achieve this target for the 125 ppb action level and are marginally above the target for the 250 ppb action level (40 years).

- **Implementation Duration.** Figure 10-8 illustrates the implementation duration for each alternative at each action level. A general target has been set to perform the cleanup within a 10-year period. All of the alternatives satisfy this target at each action level with Alternative C2 having the shortest duration.

- **PCB Mass Removed.** Figure 10-8 illustrates that removal alternatives (Alternatives C1 through E) remove the same PCB mass at each action level, while capping (Alternative F) removes slightly less PCB mass. The 5,000 ppb action level removes 94 percent of the PCB mass in this reach, while any further decrease in the action level does not significantly increase the PCB mass removed. For Alternatives C1 through E, the mass removed varies from 24,950 kg at 5,000 ppb to 26,581 kg at 250 ppb.

- **Total Cost.** The total cost to implement an active remedy represents a 20- to 85-fold cost increase over the MNR alternative (Alternative B), estimated at $9.9 million. It can be seen on Figure 10-8 that dredging directly to a combined NR 213/NR 500 dewatering and disposal facility (Alternative C2A) is the lowest cost. Alternative C2A is also the least sensitive to changes in action level (Table 10-2). Other dredging and capping alternatives are incrementally more expensive, with Alternative C1 being the most expensive. For example, at the 1,000 ppb action level, Alternative C2A is estimated to be the least-cost approach at $174 million, with Alternative F at $357 million, and Alternative D at $505 million. Alternative E is estimated at $355 million, Alternative C2B is estimated at $492 million, Alternative C3 is estimated at $514 million, and Alternative C1 is estimated to cost $660 million .

- **Cost Effectiveness.** In order to evaluate the cost effectiveness of each alternative at each action level, the incremental cost per year reduction in time to remove fish consumption advisories (for recreational anglers) relative to the MNR alternative (Alternative B) was calculated using the cancer risk data. Due to the uniformity in the time to remove fish consumption advisories, these data are closely aligned to the total cost data. Dredging (Alternative C2A) is the most cost-effective remedy, and 125 and 250 ppb are the most cost-effective PCB action levels that meet protective thresholds.

10.7 Comparative Analysis of Alternatives - Green Bay, All Zones

The comparative analysis of alternatives for Green Bay Zone 2 (Table 8-10 and Figure 10-9), Green Bay Zone 3A (Table 8-11 and Figure 10-10), and Green Bay Zone 3B (Table 8-12 and Figure 10-11) show that regardless of the action taken in the Lower Fox River (excluding no action), there is very little effect (measured as reduced risk) on Green Bay for the human health and ecological scenarios considered. The following discussion provides a set of observations resulting from the comparative analysis:

- **Human Health.** Tables 8-10 through 8-13 illustrate the time required following cleanup in Green Bay to reduce human health risk to below acceptable levels such that consumption advisories for recreational anglers can be removed. A general target has been established that these recreational advisories be removed within 10 years following cleanup. None of the Green Bay active remedies will satisfy this goal. Removal actions conducted in Zone 3B (Alternatives D and G) will reduce the expected time frame to reach protective levels to 99 years for a Fox River action level of 500, 250, or 125 ppb.

- **Ecological Health.** Tables 8-10 through 8-13 also illustrate the time required to meet ecologically protective levels. A general target has been established that these protective ecological levels will be reached within 30 years following cleanup (a total of 40 years). None of the Green Bay active remedies will satisfy this goal for the ecological scenarios considered.

- **Implementation Duration.** Figures 10-9, 10-10, and 10-11 illustrate the implementation duration for each alternative at each action level. A general target has been set to perform the cleanup within a 10-year period. Most of the alternatives satisfy this target. In Green Bay Zone 2, removal to the 1,000 ppb action level will take five times longer than the next highest action level of 5,000 ppb. In Green Bay Zone 3B, the time required to remove sediment to the 500 ppb action level requires slightly more than 10 years, but equipment size and quantity can be modified during the remedial design to complete removal actions within the targeted time frame of 10 years.

- **PCB Mass Removed.** Figures 10-9, 10-10, and 10-11 illustrate that removal alternatives (Alternatives C, D, and G) remove the same PCB mass at each action level. In Green Bay Zone 2, sediment removal to the 1,000 ppb action level removes six times as much PCB mass as the next highest action level of 5,000 ppb (basically there is not much mass above the 5,000 ppb action level). In Green Bay Zone 3A, significantly more PCB mass is removed at the 500 ppb action level as compared with the 1,000 ppb action level. Only one action level is carried forward for Green Bay Zone 3B.

- **Total Cost.** The total cost to implement an active remedy represents a 100-fold to 1,200-fold cost increase over the MNR alternative (Alternative B), estimated at $9.9 million (Table 10-3). It can be seen on Figures 10-9, 10-10, and 10-11 that dredging directly to a CAD site (Alternative G) is the lowest cost active alternative.

- **Cost Effectiveness.** As discussed above, human health and ecologically protective levels are generally not achieved for Green Bay within the modeled time frame. As a result, it was not possible to perform calculations regarding cost-effectiveness.

10.8 Comparative Analysis of Action Levels on a System-wide Basis

The FS and associated modeling efforts have focused on evaluating system-wide action levels; however, as can be seen from the projections, the same action level provides markedly different degrees of RAO achievement. In order to facilitate future decision-making processes and the inherent trade-offs between cleanup cost and achieving RAOs, this section provides the tools that will be necessary during future decision-making efforts for the entire system. Future modeling efforts may be required to fully evaluate the effect of different action levels for each reach or zone, but the following discussion provides a rationale for focusing those modeling efforts.

Figures 10-12 and 10-13 compare the time to achieve protective levels for human health and ecological receptors for all four river reaches. General targets have been established that: 1) recreational fish consumption advisories be removed within 10 years following cleanup; 2) high-intake fish consumption advisories be removed within 30 years following cleanup; and 3) that achievement of safe ecological levels occurs within 30 years. For the MNR alternative, these thresholds are expected to be met in 20 years and 40 years, respectively.

Based on the 100-year modeled projections illustrated on Figures 10-12 and 10-13, it appears that the Appleton to Little Rapids Reach will likely show some reduced risk by natural recovery processes when compared to other river reaches; the Little Lake Butte des Morts Reach will show less improvement without an active remedy. However, neither of these reaches will meet protective levels in the targeted time frame without an active remedy. The other two reaches, Little Rapids to De Pere Reach and De Pere to Green Bay Reach, will not show appreciable improvement (reduced risk) by monitored natural recovery processes alone. Physical site conditions such as: the quantity and volume of PCB mass present in these reaches, the size of the reach, vessel traffic, storm events, and hydraulic exchange of water flow with Green Bay contribute to the long-term fate of contaminants that limit the long-term effectiveness of natural recovery processes. As shown on Figure 10-12, the action levels required to satisfy the targeted time frame of 10 years following remediation include: 1,000 ppb in Little Lake Butte des Morts, 250 ppb in Appleton to Little Rapids, and 125 ppb in Little Rapids to De Pere. The De Pere to Green Bay Reach will not achieve protective levels for 15 years at the 125 ppb action level. The time to reach protective levels would be 7 to 15 years for each of the aforementioned river reaches. At these same action levels, the time to reach ecologically protective levels based on the piscivorous mammal would be approximately 29, 18, 15, and 18 years, respectively. The protectiveness of these action levels would have to be verified by modeling specifically for this selected group of action levels.

The objective of RAO 4 is to reduce PCB sediment loading to Green Bay and ultimately Lake Michigan. Figure 10-14 illustrates the modeled sediment loading to Green Bay for each Fox River action level. These data indicate that the largest decrease occurs between the no action and 5,000 ppb action level. There is also a substantial decrease between the 5,000 and 1,000 ppb actions levels, but only marginal reductions thereafter. A general target has been established to reduce PCB sediment loading to Green Bay from Fox River to below the PCB sediment loading contributed to Green Bay by all other tributaries combined (10 kg/year). This target is achieved immediately following cleanup for the 125, 250, and 500 ppb action levels. For the 1,000 ppb action level, the target level is achieved in 4 years and it is also achieved in 24 years for the 5,000 ppb action level. The target PCB loading to Green Bay is not achieved for the no action approach in Fox River. The PCB loading to Green Bay from the Fox River also drops below the upstream loading contributed by Lake Winnebago (18 kg/year) in less than 24 years for all action levels, except that this level is never achieved using the No Action alternative.

10.9 Comparative Analysis Summary

In summary, this FS does not select the "best" remedial alternative and action level for implementation in the Lower Fox River and Green Bay. Final selection of a remedial alternative and action level will depend on several decision-making factors including long-term land use restrictions, community support, residual risks, and implementation factors discussed in Sections 8 and 9 of the FS. However, the comparative analysis does present the relative performance of each alternative and related action level relative to each criterion. This analysis summarizes key highlights of these comparisons. For example, the largest reductions in time to reach protective levels for a particular PCB action level relative to the next highest action level and the most cost-effective action level relative to the number of years required to remove recreational fish consumption advisories are described below. Key findings for each reach and zone are summarized below.

- **Little Lake Butte des Morts Reach**
  - At a minimum, the 1,000 ppb PCB action level will be required to meet protective human health and ecological thresholds in 10 and 30 years after remedy completion. The 5,000 ppb action level will not meet protective thresholds in this time frame.
  - Ecologically protective surface water concentrations are achieved within the 30-year target for the 125 and 250 ppb action levels.
  - Most of the PCB mass is removed at the 1,000 ppb action level (93%). Only 7 percent of the PCB mass is contained in the combined action levels of 125, 250, and 500 ppb.
  - The Dredge and Off-site Disposal, Thermal Treatment, and Dredge to CDF alternatives (Alternatives C2, E, and D) at the 1,000 ppb action level are the lowest cost alternatives relative to the time required to remove recreational fish consumption advisories.
- **Appleton to Little Rapids Reach**
  - At a minimum, the 500 ppb PCB action level will be required to meet protective human health and ecological thresholds in 30 years after remedy completion. The 250 ppb action level will be required to meet the 10-year time frame. The 1,000 and 5,000

ppb action levels will not meet protective thresholds in this time frame.

- Ecologically protective surface water concentrations are achieved within the 30-year target for the 125 and 250 ppb action levels. The 500 ppb action level is marginally above the target at about 40 years.

- The bulk of PCB mass is removed at the 1,000 ppb action level (87%). The remaining PCB mass (13%) is contained in the combined 125, 250, and 500 ppb action levels.

- The Thermal Treatment alternative (Alternative E) at the 1,000 ppb PCB action level is the lowest cost alternative relative to the time required to remove recreational fish consumption advisories.

- **Little Rapids to De Pere Reach**

  - At a minimum, the 500 ppb PCB action level will be required to meet protective human health and ecological thresholds in 30 years after remedy completion. The 125 ppb action level is required to meet the 10-year time frame. The 5,000 and 1,000 ppb action levels will not meet protective thresholds in this time frame.

  - Ecologically protective surface water concentrations are achieved within the 30-year target for the 125 ppb action level. The 250 ppb action level is marginally above the target at about 40 years.

  - The bulk of PCB mass is removed at the 1,000 ppb action level (92%). Most of the remaining PCB mass (8%) is below the 250 ppb action level (99%).

  - The Dredge and Off-site Disposal at a Combined NR 213/NR 500 Dewatering and Disposal Facility alternative (Alternative C2A), the Dredge to CDF alternative (Alternative D), Thermal Treatment alternative (Alternative E), and Capping alternative (Alternative F) at the three lowest PCB action levels (125, 250, and 500 ppb) are the lowest cost alternatives relative to the time required to remove recreational fish consumption advisories.

- **De Pere to Green Bay Reach**

    - At a minimum, the 250 ppb PCB action level will be required to meet protective human health and ecological thresholds in 30 years after remedy completion. The no action level will meet the 10-year time frame. The 5,000 and 1,000 ppb action levels will not meet protective thresholds in this time frame.

    - Ecologically protective surface water concentrations are achieved within the 30-year target for the 125 ppb action level.

    - The bulk of PCB mass is removed at the 5,000 ppb action level (94%). The remaining PCB mass (6%) is below the 1,000 ppb action level (99%).

    - The Dredge and Off-site Disposal at a Combined NR 213/NR 500 Dewatering and Disposal Facility alternative (Alternative C2A), the Dredge and CDF alternative (Alternative D), the Thermal Treatment alternative (Alternative E), and the Capping alternative (Alternative F) at the three lowest PCB action levels (125, 250, and 500 ppb) are the lowest cost alternatives relative to the time required to remove recreational fish consumption advisories.

    - PCB sediment loading to Green Bay from all the Lower Fox River reaches achieves the target of 10 kg/yr within a reasonable time frame (24 years or less) for all action levels, except the No Action alternative which does not achieve the target within the modeled time frame.

- **Green Bay, All Zones**

    - None of the action levels implemented in the Lower Fox River shows a decrease in long-term fish tissue concentrations in Green Bay. The lower action levels (125, 250, 500, and 1,000 ppb of the Lower Fox River) do not significantly change the outcome of Green Bay fish tissue concentrations. As discussed in Section 8, this is partly because the majority of PCB mass is removed at the 1,000 ppb action level in Green Bay.

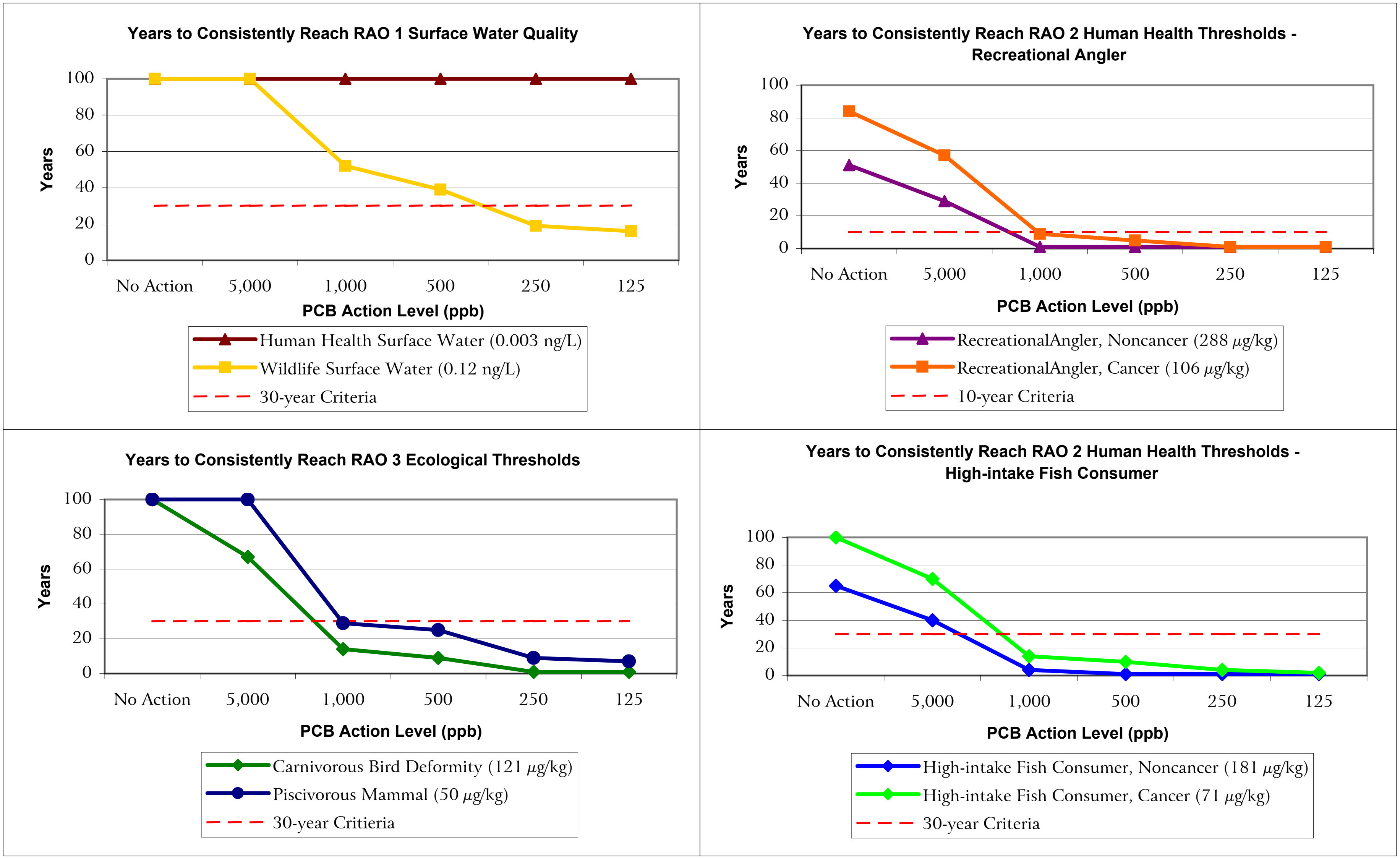
- None of the PCB action levels implemented in Green Bay will meet protective human health and ecological thresholds in 30 years after remedy completion. In Green Bay Zone 3B, removal to the 500 ppb action level will show a reduction in the number of years required to meet protective levels, but not within the targeted time frame.

- The bulk of PCB mass is removed at the 1,000 ppb action level (95%) for Green Bay Zone 2. The remaining PCB mass (5%) is incrementally contained in the lower action levels (125, 250, and 500 ppb). The bulk of PCB mass is removed at the 125 ppb action level (100%) for Green Bay zones 3 and 4. Less than 15 and 30 percent of the PCB mass would be removed at the 500 ppb action level in Green Bay zones 3A and 3B, respectively. The large volume of sediments in Green Bay coupled with the relatively low levels of PCB concentrations indicates that a large quantity of PCB mass resides in Green Bay. However, this PCB mass is widely distributed and dispersed in Green Bay at relatively low concentrations.

10.10 Section 10 Figures and Tables

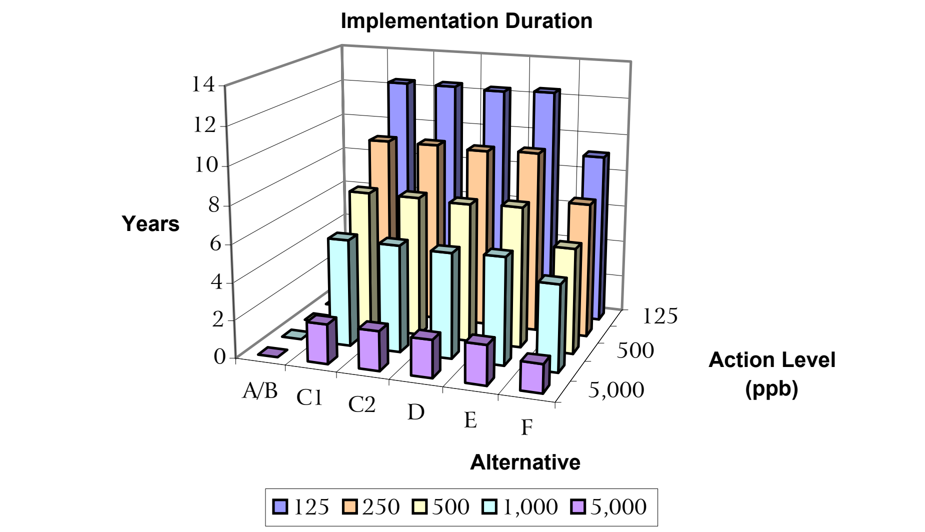
Figures and tables for Section 10 follow page 10-22 and include:

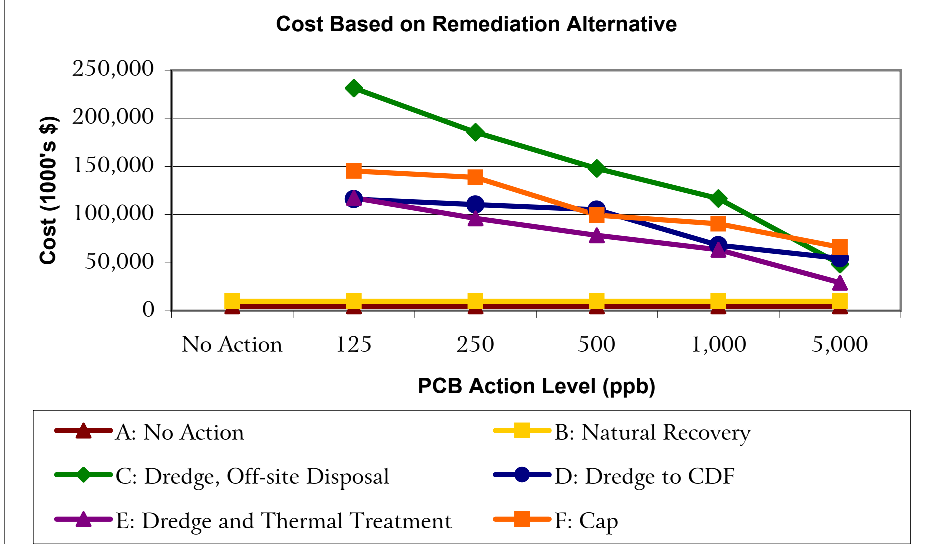
Figure 10-1 Comparison of Human Health and Ecological Protectiveness - Little Lake Butte des Morts to Appleton Reach

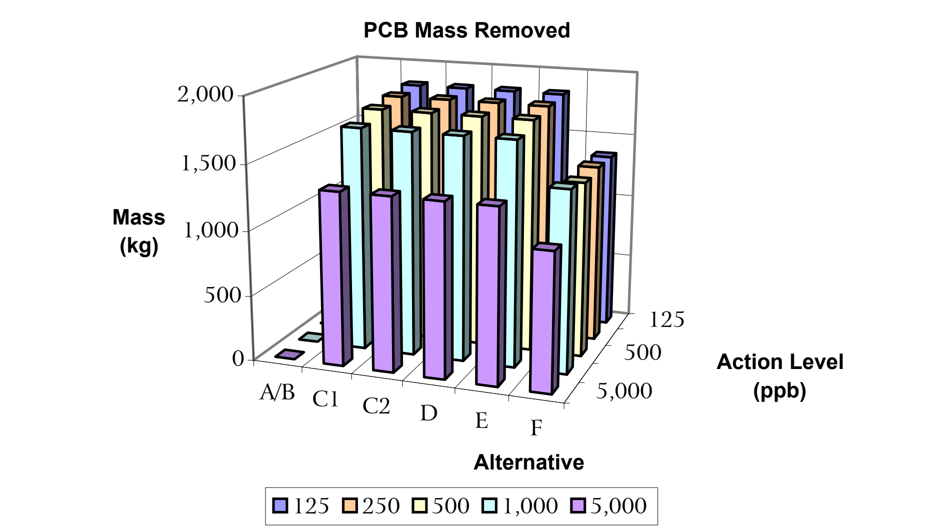


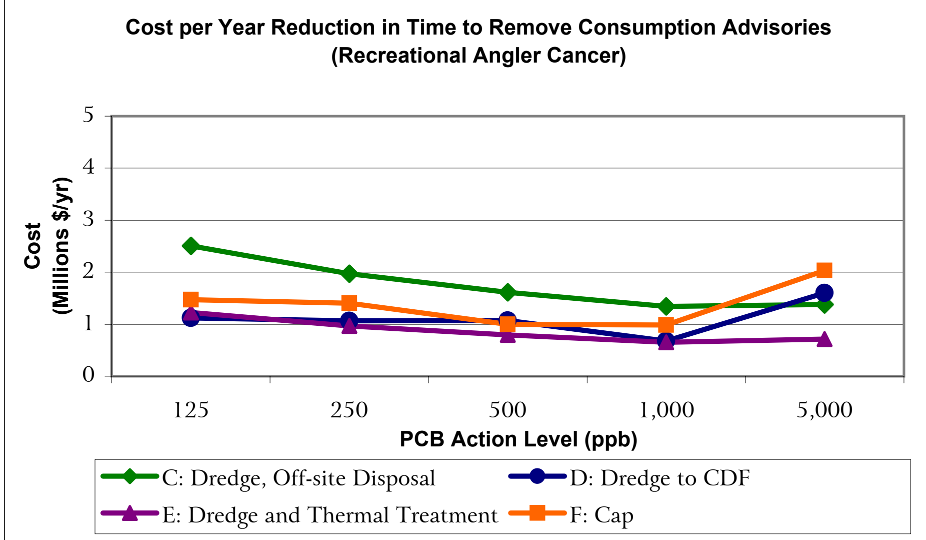
Note: Remedial alternatives C, D, E, and F have the same risk reduction when compared across the same action levels. Therefore, the different remedial alternatives are not displayed separately on the risk reduction graphs (except No Action).

Figure 10-2 Comparison of Cleanup Duration, Mass Removal, and Cost - Little Lake Butte des Morts









Note: 20% contingency costs not included. Alternative C1 costs used.

"Cost per year" is the calculated additional cost per year for implementing any action level other than MNR. $\left[\frac{\textit{Cost Alt x} - \textit{Cost Alt B}}{\textit{Time B} - \textit{Time x}}\right]$

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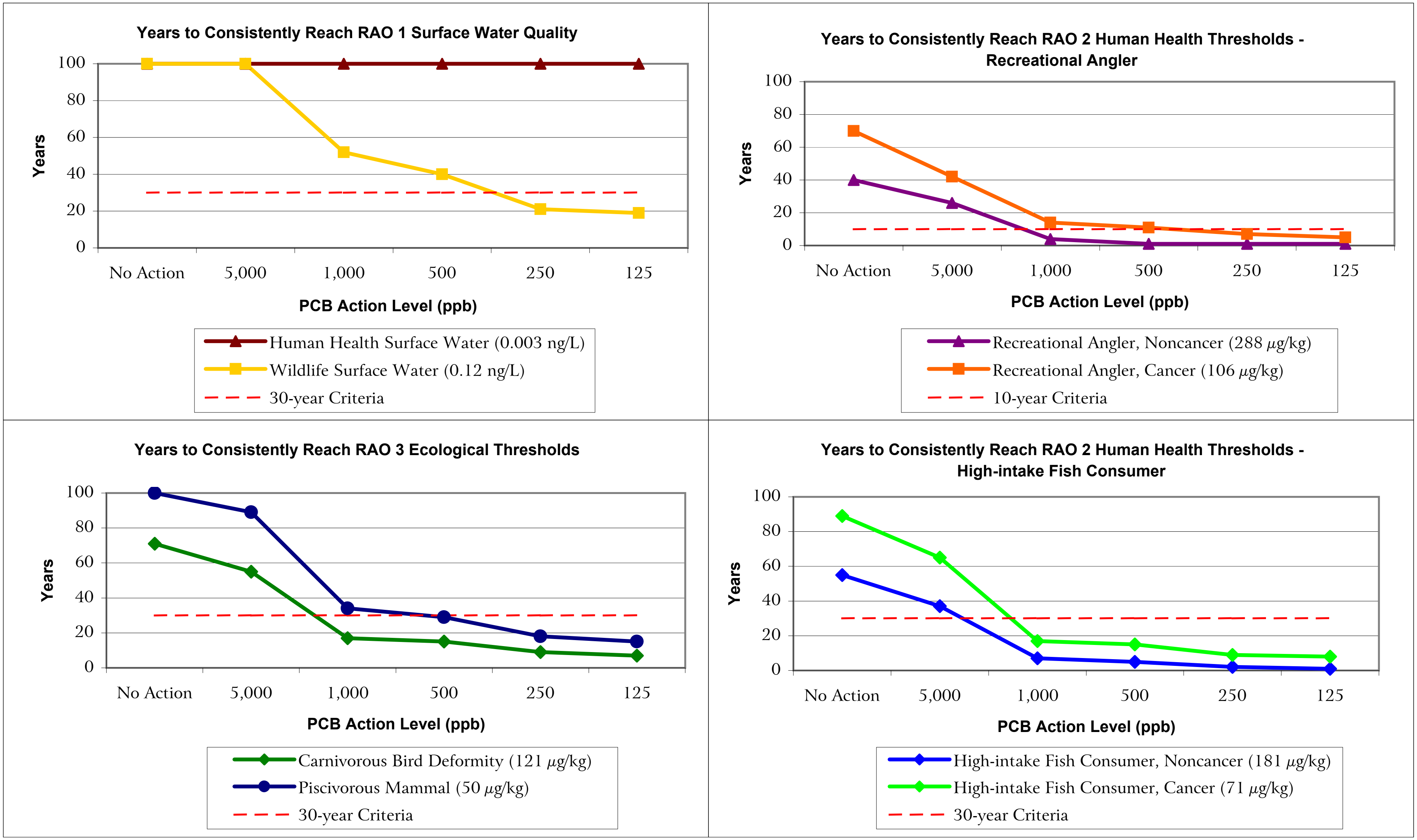
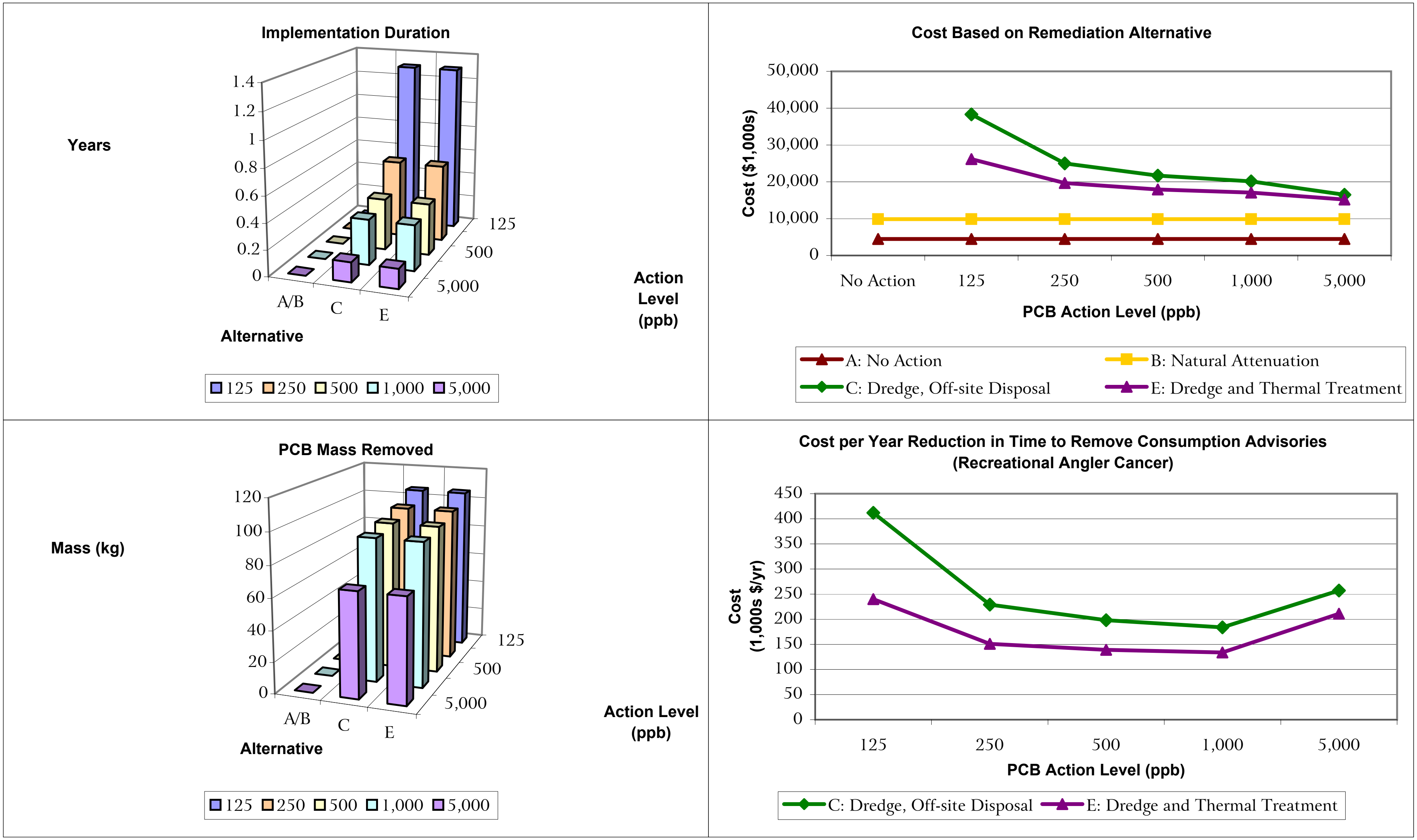
Figure 10-3 Comparison of Human Health and Ecological Protectiveness - Appleton to Little Rapids Reach



Note: Remedial alternatives C, D, E, and F have the same risk reduction when compared across the same action levels. Therefore, the different remedial alternatives are not displayed separately on the risk reduction graphs (except No Action).

Figure 10-4 Comparison of Cleanup Duration, Mass Removal, and Cost - Appleton to Little Rapids Reach



Note: 20% contingency costs not included.

"Cost per year" is the calculated additional cost per year for implementing any action level other than MNR. $\left[\dfrac{\textit{Cost Alt x} - \textit{Cost Alt B}}{\textit{Time B} - \textit{Time x}}\right]$

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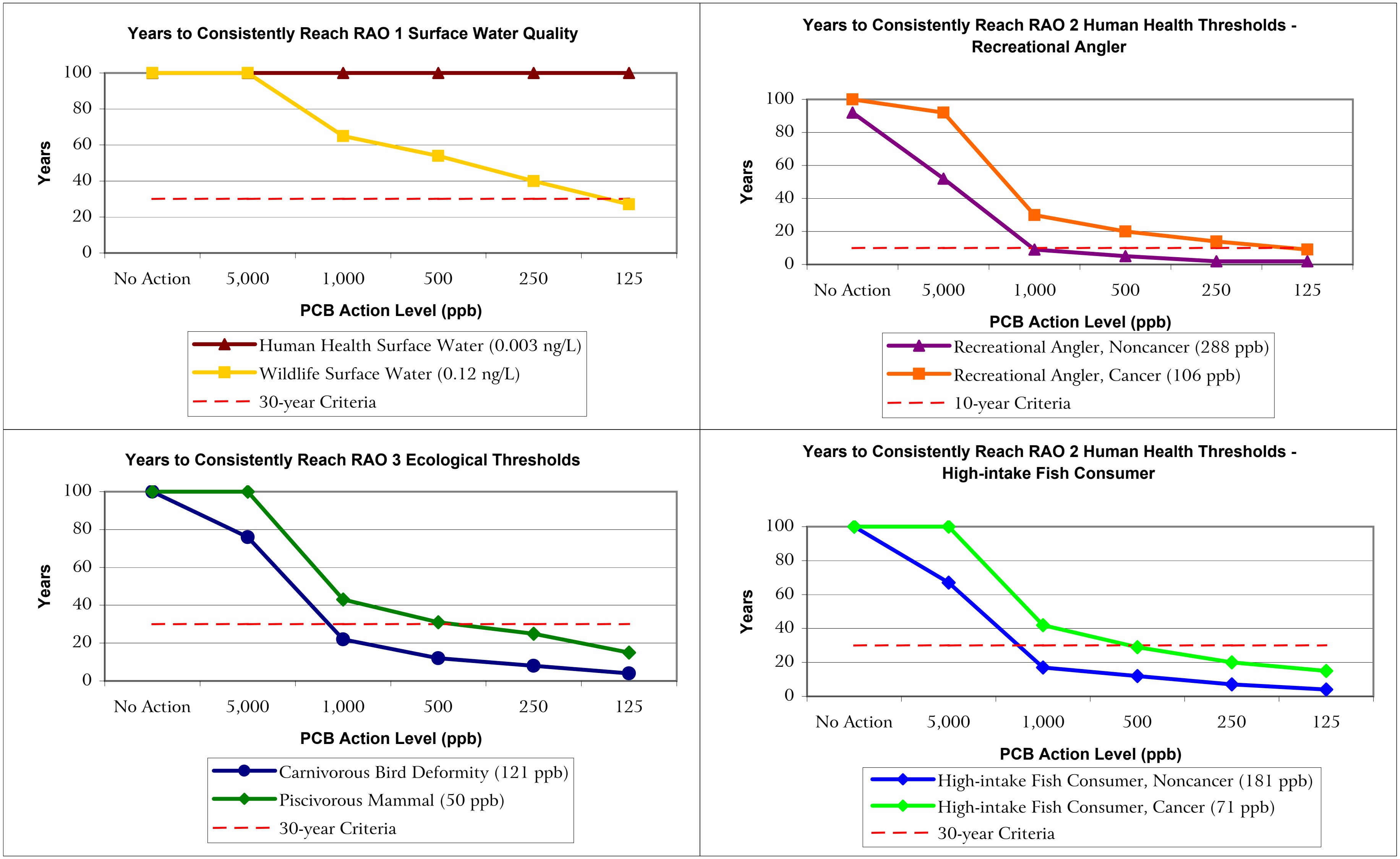
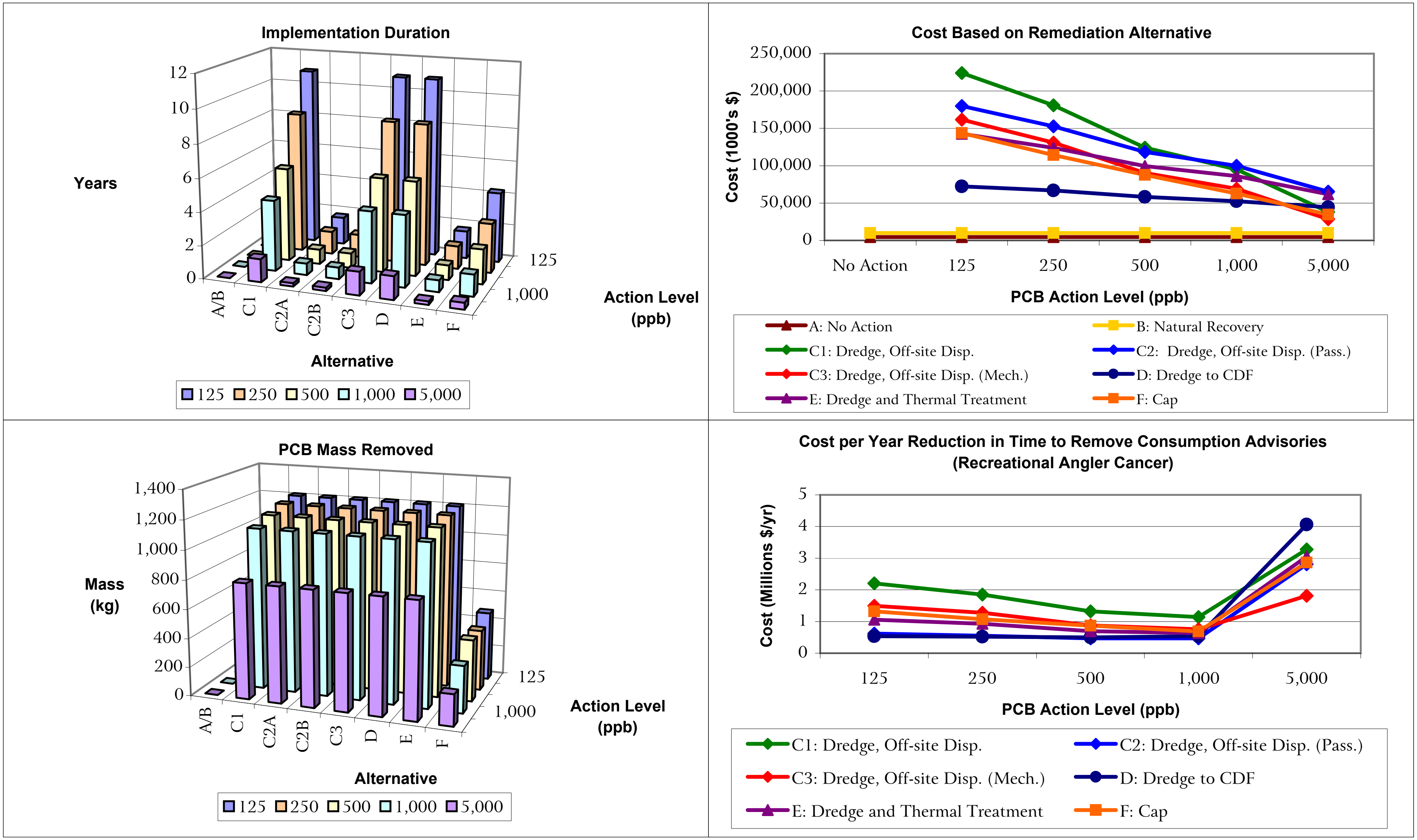
Figure 10-5 Comparison of Human Health and Ecological Protectiveness - Little Rapids to De Pere Reach



Note: Remedial alternatives C, D, E, and F have the same risk reduction when compared across the same action levels. Therefore, the different remedial alternatives are not displayed separately on the risk reduction graphs (except No Action).

Figure 10-6 Comparison of Cleanup Duration, Mass Removal, and Cost - Little Rapids to De Pere Reach



Note: 20% contingency costs not included. Alternative C2B costs used.

"Cost per year" is the calculated additional cost per year for implementing any action level other than MNR. $\left[\frac{Cost\ Alt\ x - Cost\ Alt\ B}{Time\ B - Time\ x}\right]$

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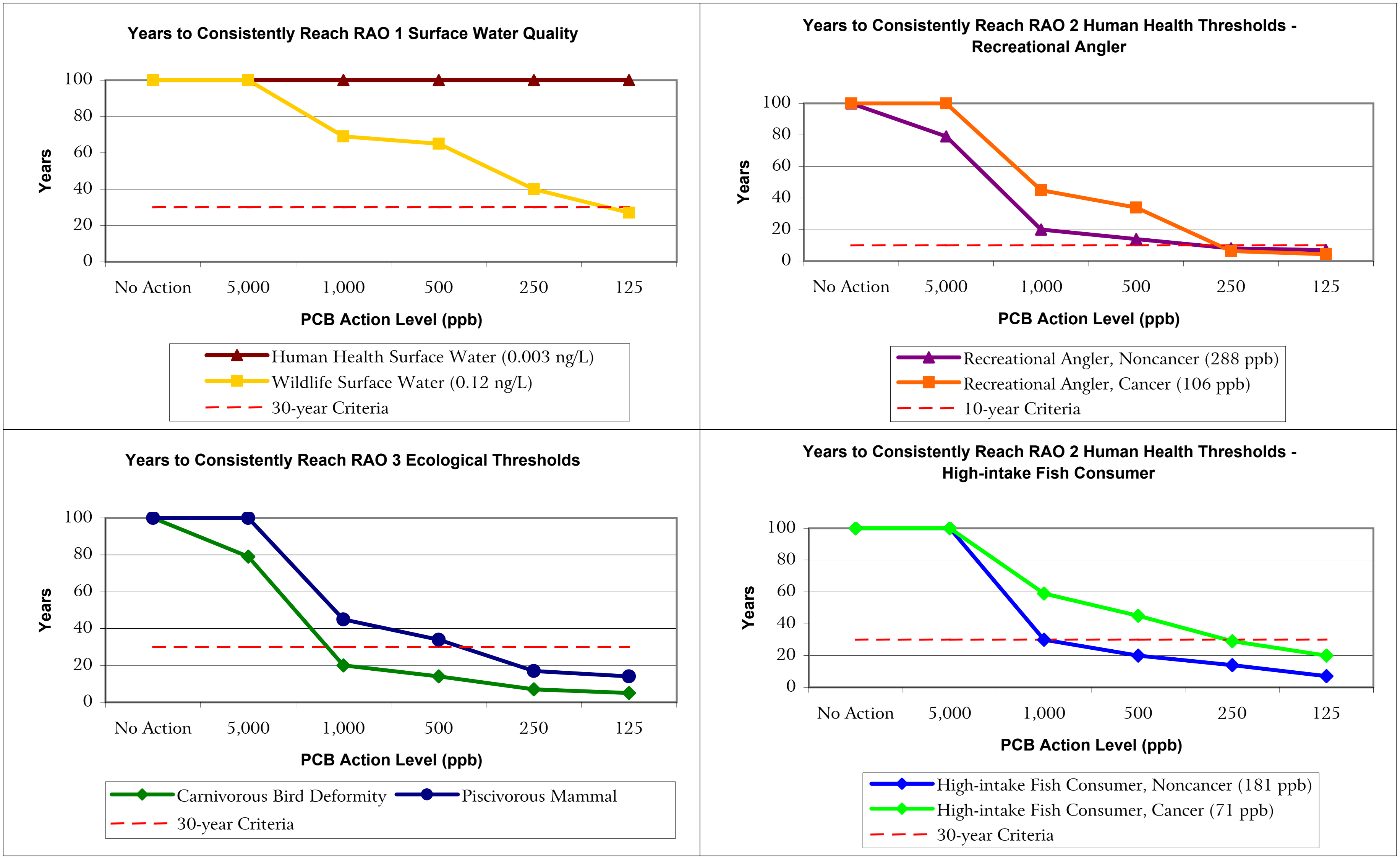
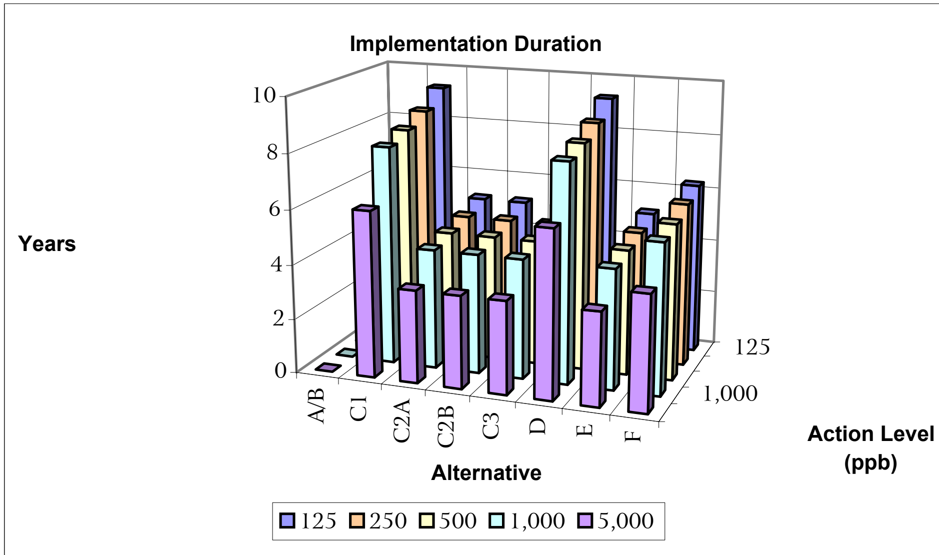
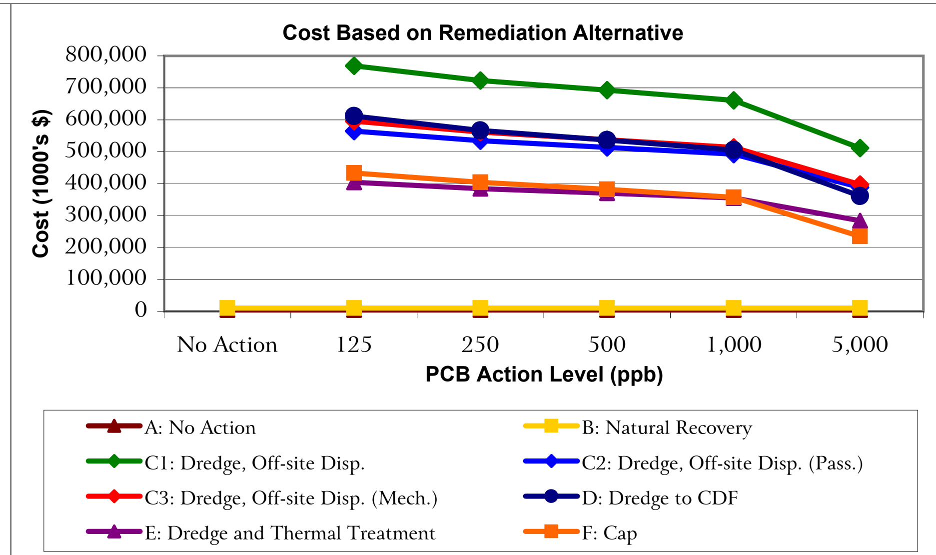
Figure 10-7 Comparison of Human Health and Ecological Protectiveness - De Pere to Green Bay Reach

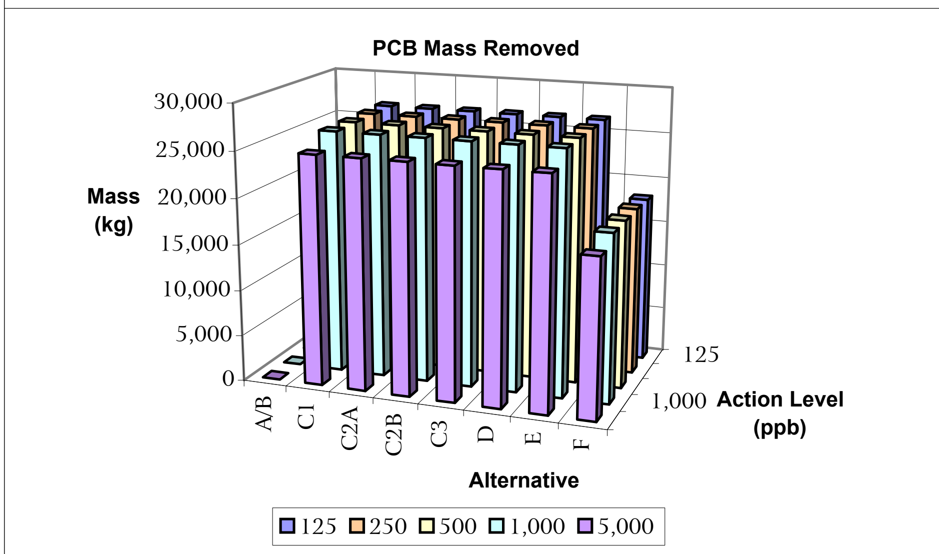


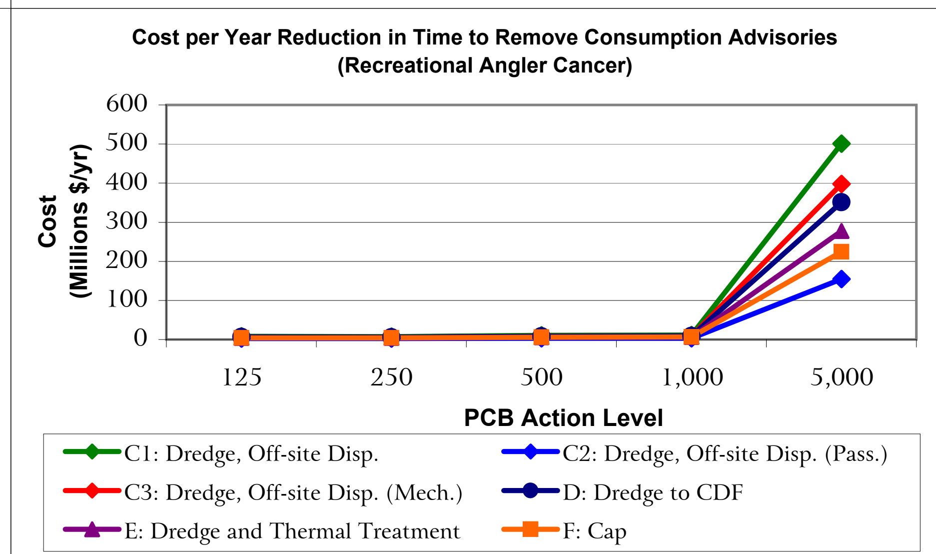
Note: Remedial alternatives C, D, E, and F have the same risk reduction when compared across the same action levels. Therefore, the different remedial alternatives are not displayed separately on the risk reduction graphs (except No Action).

Figure 10-8 Comparison of Cleanup Duration, Mass Removal, and Cost - De Pere to Green Bay Reach (Green Bay Zone 1)









Note: 20% contingency costs not included. Alternative C2B costs used.

"Cost per year" is the calculated additional cost per year for implementing any action level other than MNR. $\left[\frac{Cost\ Alt\ x - Cost\ Alt\ B}{Time\ B - Time\ x}\right]$

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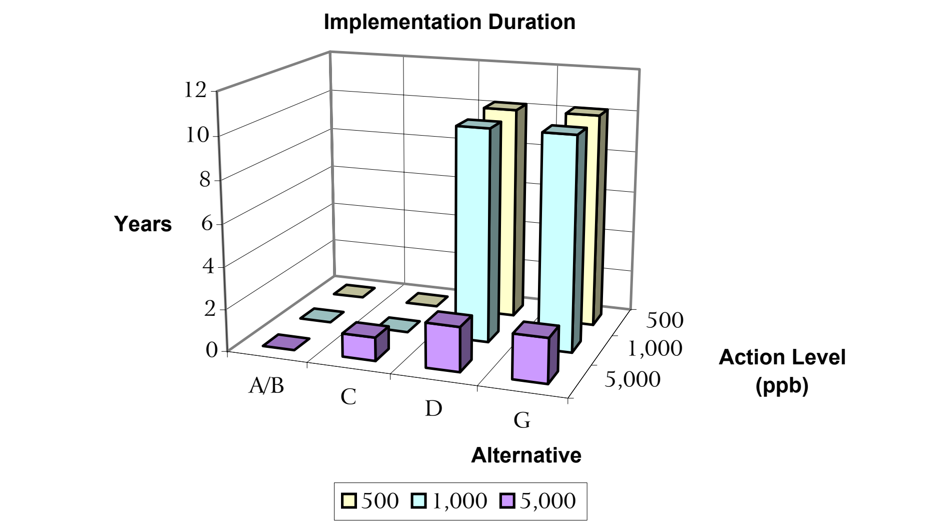
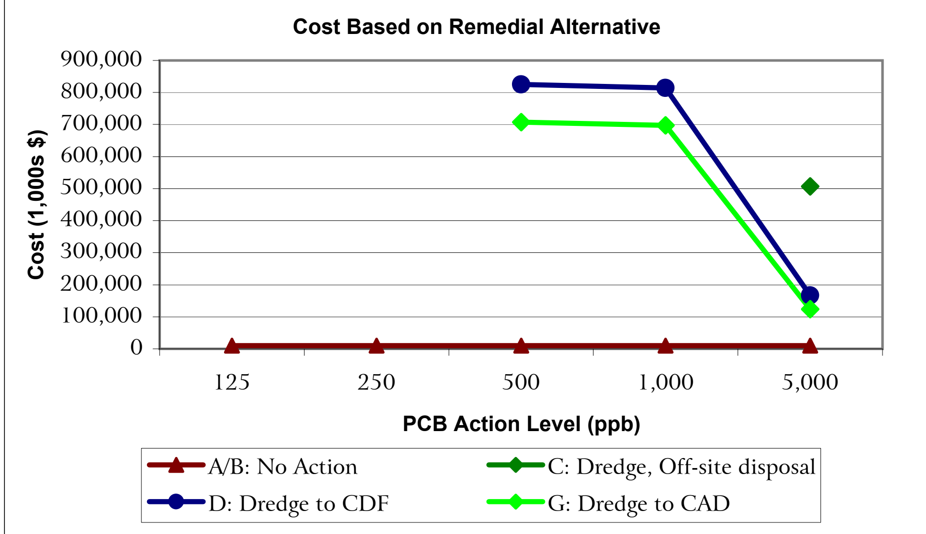
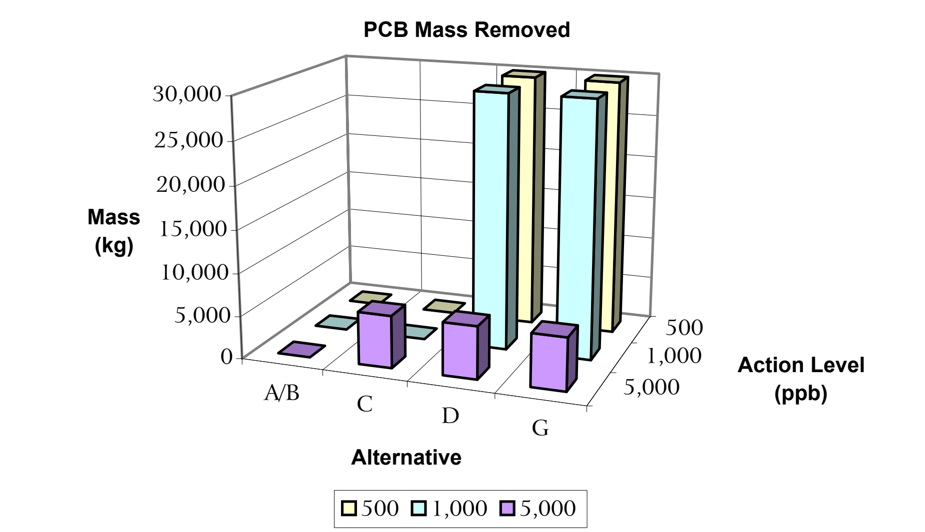
Figure 10-9 Comparison of Cleanup Duration, Mass Removal, and Cost - Green Bay Zone 2



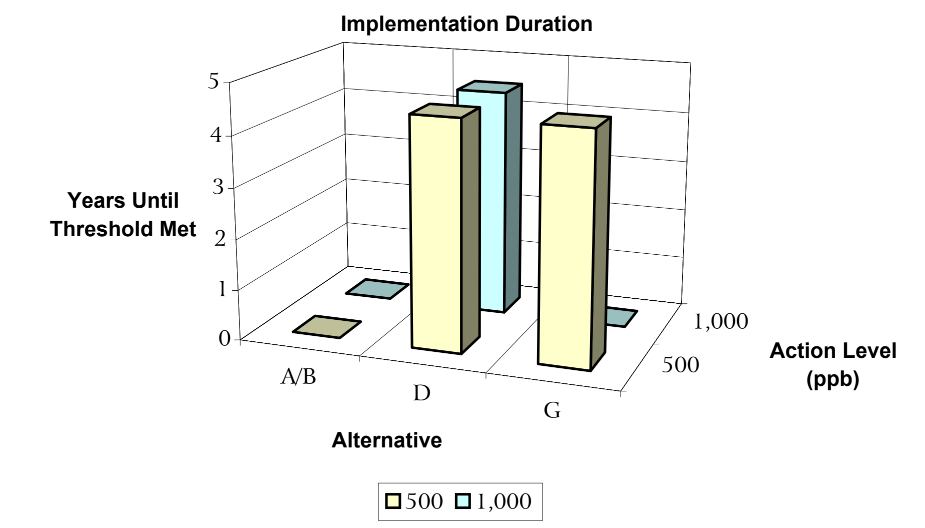


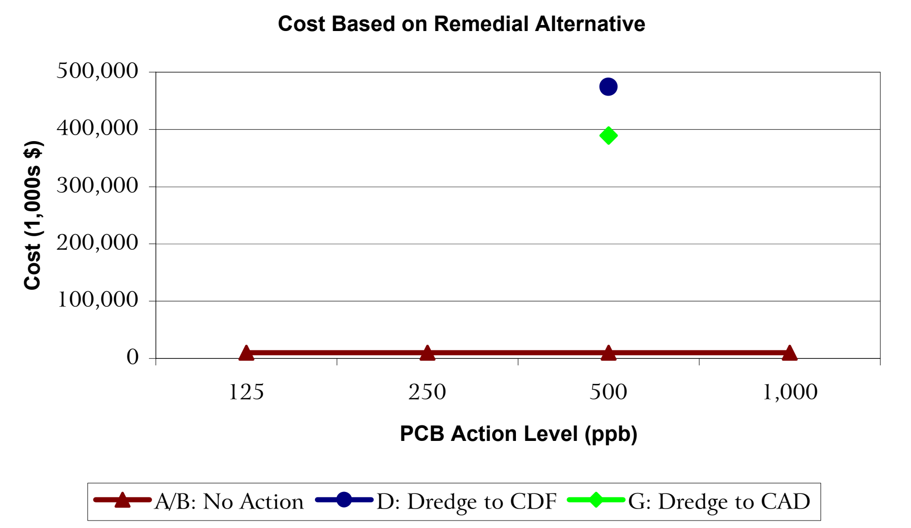


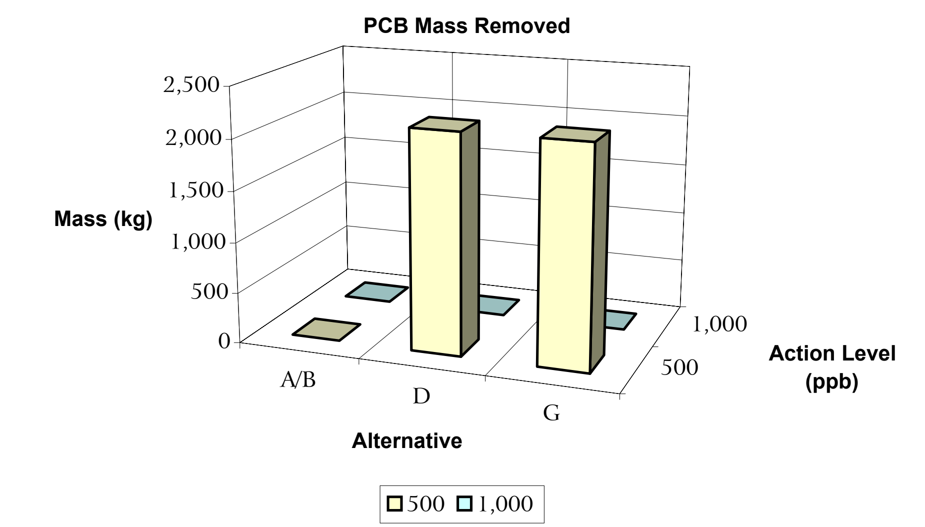
No Cost per year calculated due to thresholds never being met in 100 years.

Note: 20% contingency costs not included.

Figure 10-10 Comparison of Cleanup Duration, Mass Removal, and Cost - Green Bay Zone 3A



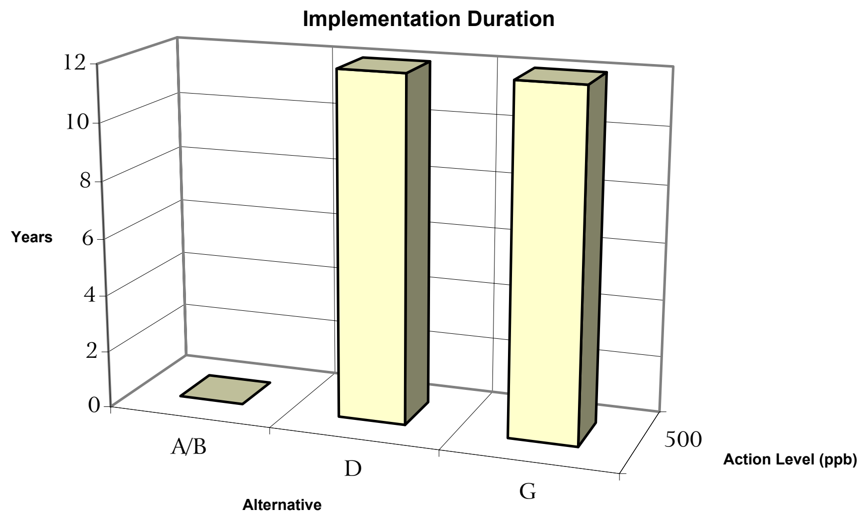


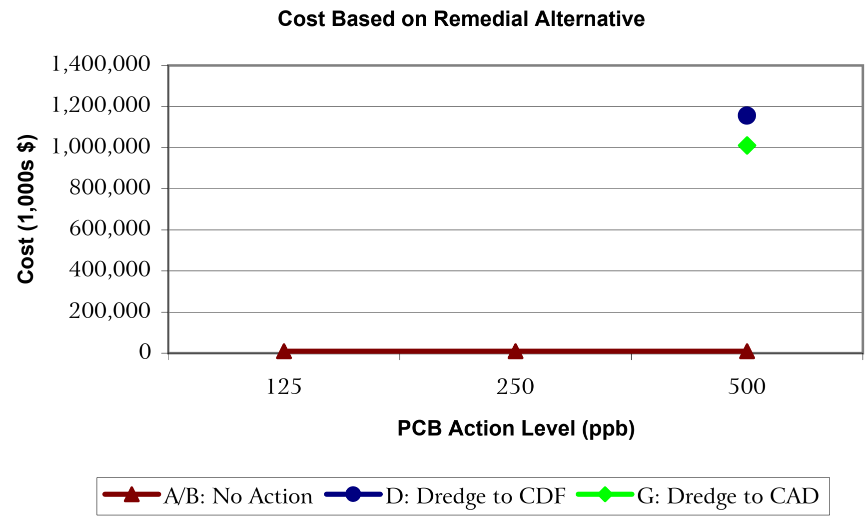


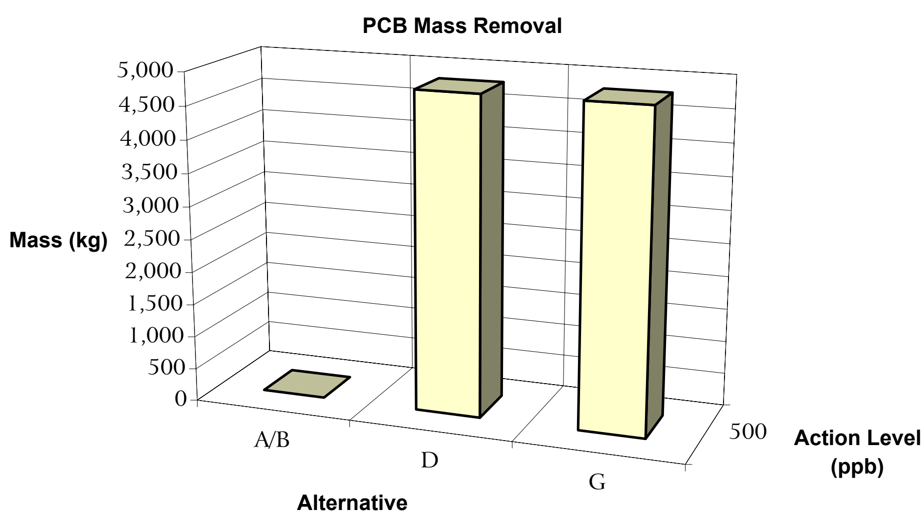
No Cost per year calculated due to thresholds never being met in 100 years.

Note: 20% contingency costs not included.

Figure 10-11 Comparison of Cleanup Duration, Mass Removal, and Cost - Green Bay Zone 3B







No Cost per year calculated due to thresholds never being met in 100 years.

Note: 20% contingency costs not included.

Figure 10-12 Comparison of Human Health Protectiveness - All Reaches

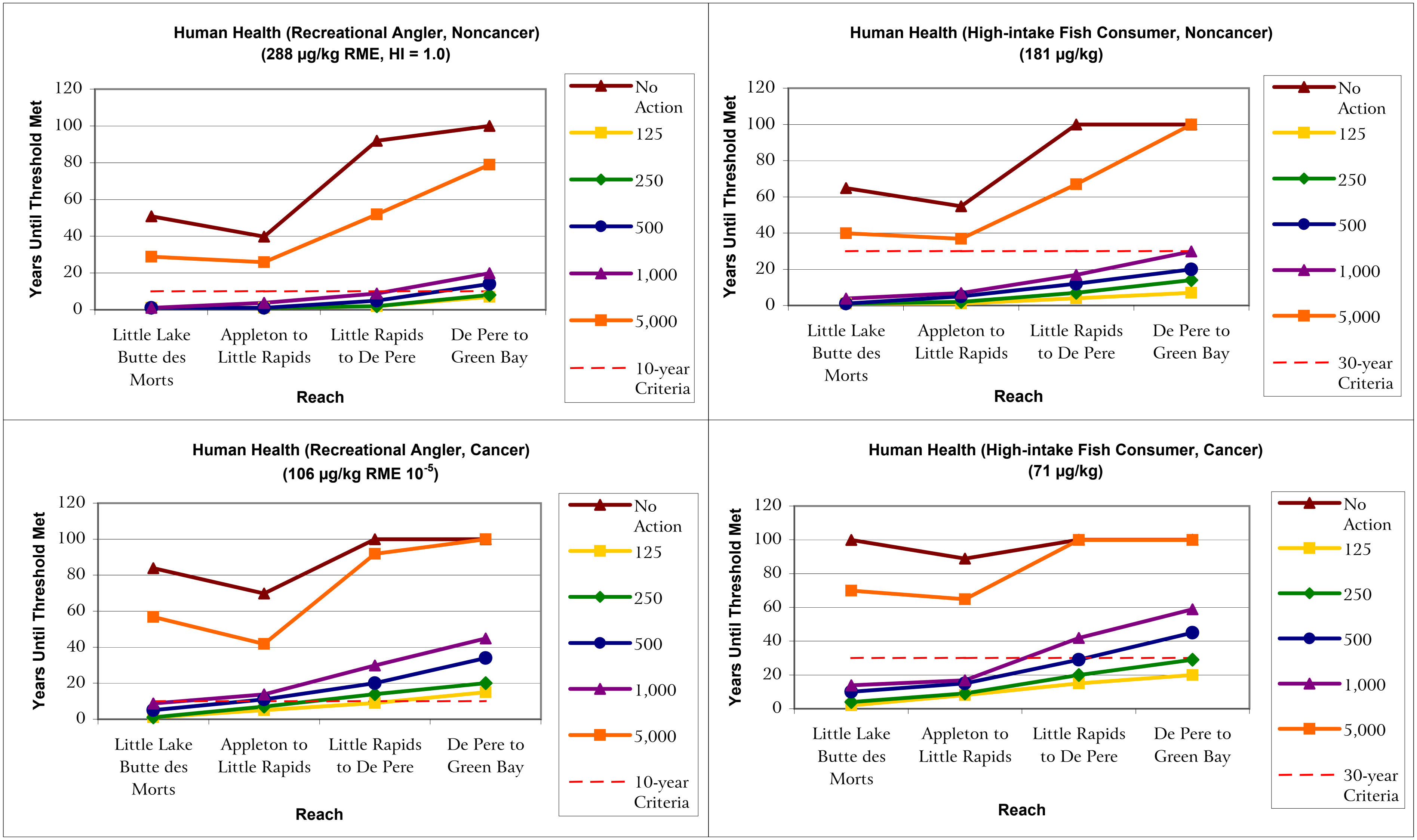
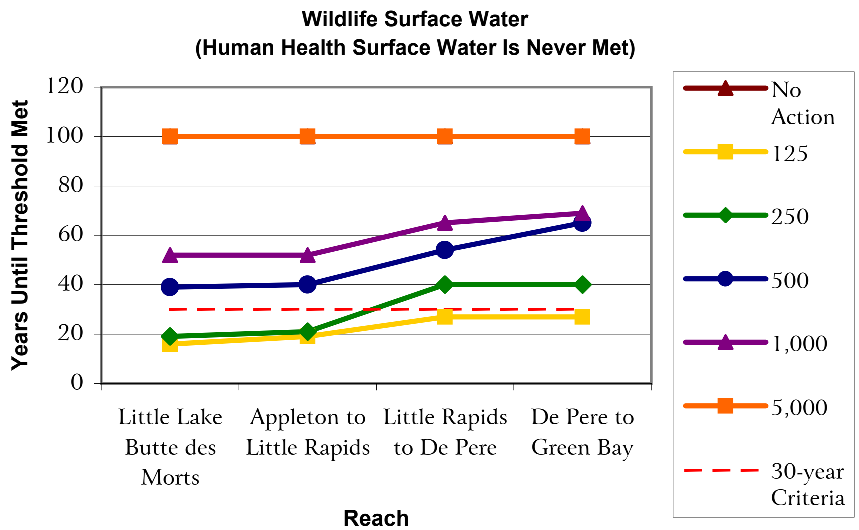
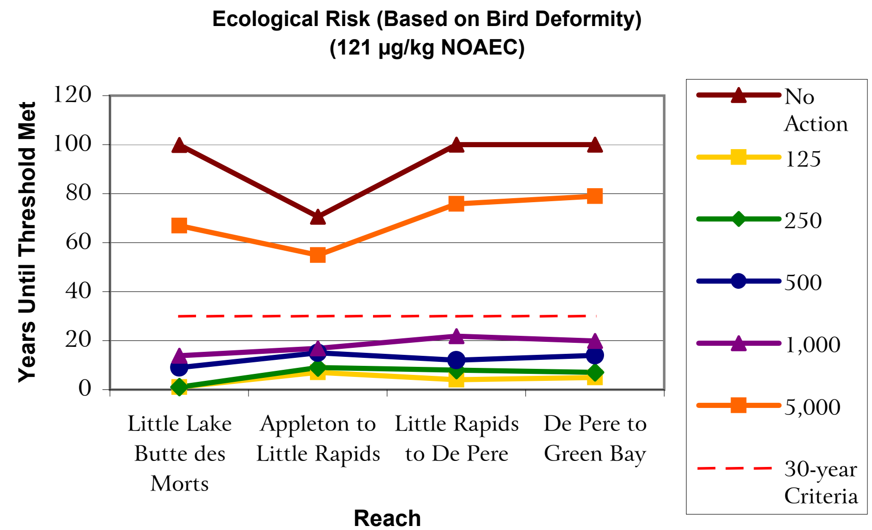
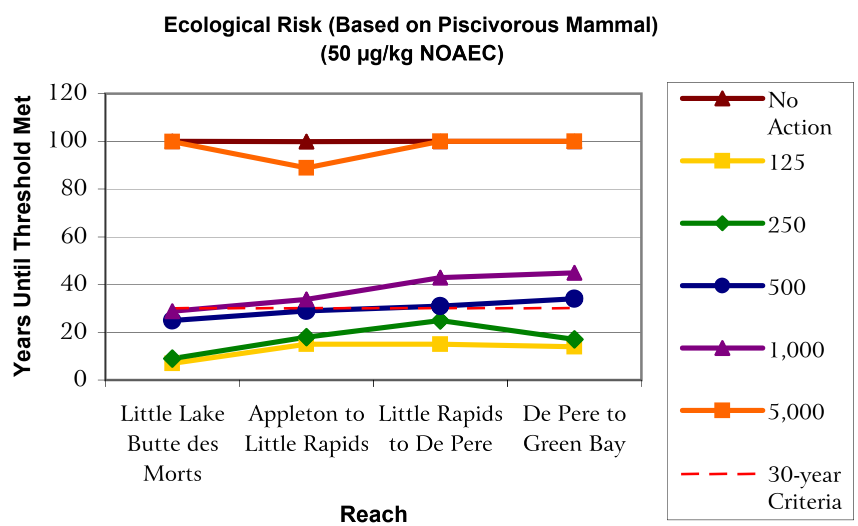


Figure 10-13 Comparison of Protection - All Reaches







RAO 4 not evaluated in Fox River reaches.

Figure 10-14 Total PCB Sediment Loading for All Remedial Action Levels - De Pere to Green Bay Reach

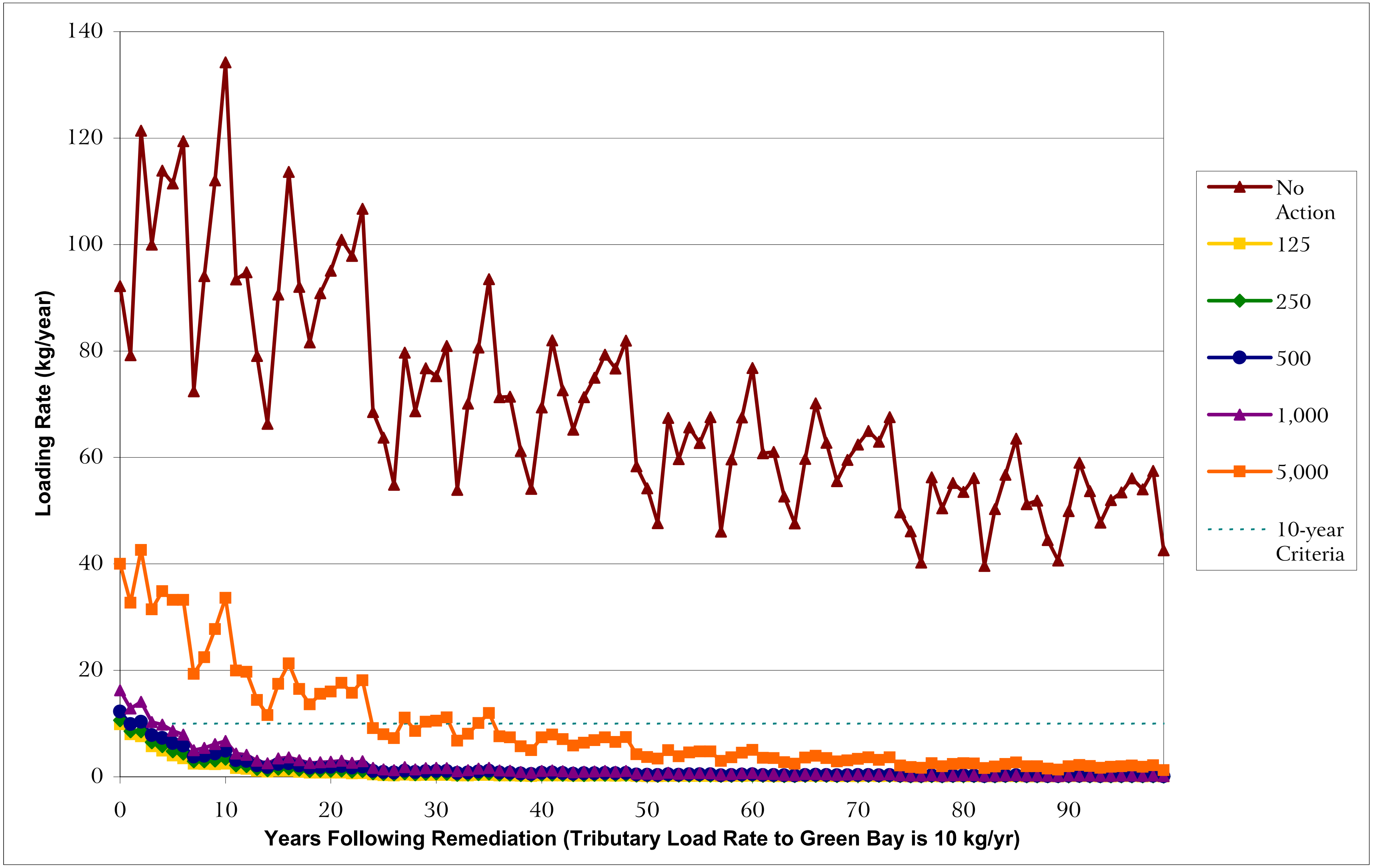


Table 10-1 Comparative Evaluation Measures

Issue	Quantitative Measure	Comment
Time Post-remediation Necessary to Achieve Fish Tissue Concentrations Resulting in Negligible Risk to Human Receptors	Number of years necessary to achieve the "human health - recreational fish consumer RME, HI is 1.0" for noncancer, walleye, whole fish consumption.	As discussed in Section 8, none of the remedial alternatives identified in the FS provide for immediate 100 percent relief for all human and ecological receptors in the river and bay. 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, natural recovery processes would result in restoration of the river and bay 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. Targeted time frame of 10 years following remediation.
	Number of years necessary to achieve the "human health - recreational fish consumer RME" for 10^{-5} cancer risk level, walleye, whole fish consumption.	As discussed in Section 8, the number of years required to reach protective levels were projected for 100 years from a calibration period of 6 years. There is no precision associated with these projections; however, they do provide reasonable expectations of trends between alternatives. Targeted time frame of 10 years following remediation.
	Number of years necessary to achieve the "human health - high-intake fish consumer RME" for 10^{-5} cancer risk level, walleye, whole fish consumption.	The targeted time frame to remove fish consumption advisories for high-intake fish consumers is 30 years following remediation.
	Number of years necessary to achieve the "human health - high-intake fish consumer RME, HI is 1.0" for noncancer walleye whole fish consumption	The targeted time frame to remove fish consumption advisories for high-intake fish consumers is 30 years following remediation.

Table 10-1 Comparative Evaluation Measures (Continued)

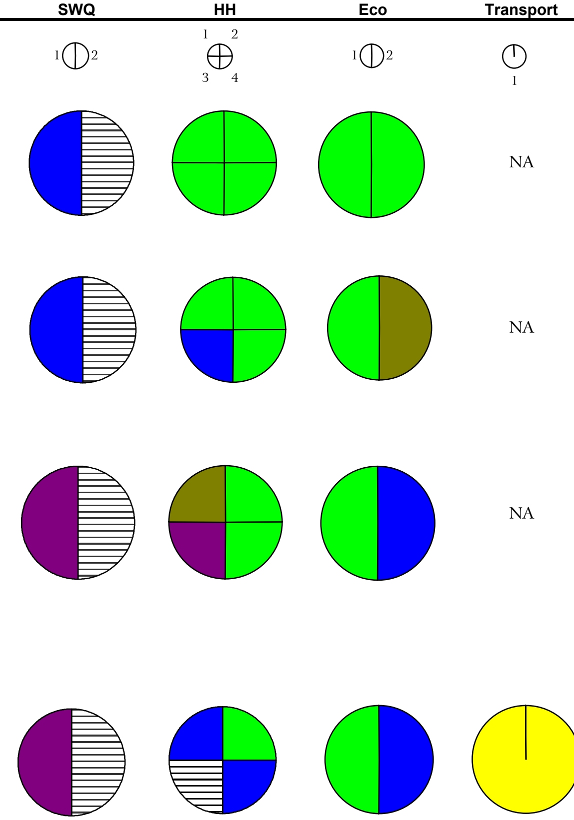
Issue	Quantitative Measure	Comment
Time Post-remediation Necessary to Achieve Fish Tissue Concentrations Resulting in Negligible Risk to Ecological Receptors	Number of years necessary to achieve the "ecological health - carnivorous bird deformity NOAEC" based on carp, whole fish consumption.	For the purposes of this FS, the targeted time frame to achieve ecological protectiveness is 30 years following remediation (or implementation of monitored natural recovery). The ecological thresholds are more stringent than the human health thresholds.
	Number of years necessary to achieve the "ecological health - piscivorous mammal NOAEC" based on carp, whole fish consumption.	For the purposes of this FS, the targeted time frame to achieve ecological protectiveness is 30 years following remediation (or implementation of monitored natural recovery). This ecological threshold is the most stringent threshold carried forward in the FS for comparative purposes.
Time to Meet Surface Water Quality Protective of Human and Ecological Receptors Based on Sediment PCB Concentrations	Number of years necessary to achieve surface water quality criteria - human health drinking water (0.0003 ng/L) and wildlife (0.12 ng/L).	The targeted time frame to achieve, to the extent practicable, is 30 years following remediation (assuming 10 years of remediation for a total of 40 years).
Time Post-remediation Necessary to Achieve PCB Loads from the Lower Fox River to Green Bay that Are Equivalent to the Sum of PCB Loads from Green Bay Tributaries	Number of years necessary to meet Green Bay tributary loads of 10 kg/yr PCBs.	The targeted time frame to reduce PCB loads to Green Bay and achieve source control is 30 years following remediation. For the monitored natural recovery alternative, the expectation is 40 years.

Table 10-1 Comparative Evaluation Measures (Continued)

Issue	Quantitative Measure	Comment
Time to Implement Cleanup Alternative	The estimated number of years for implementation of 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 resuspension), 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.
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. For cost breakdown information, please see Table 10-2. For detailed cost estimates, please see Appendix H.
Incremental Cost to Reduce Years to Reach Protective Levels	Incremental cost (in $M/yr).	This measure represents the incremental cost of reducing the years to achieve protective levels to recreational anglers based on cancer risk by 1 year, and is considered a measure of the cost-to-benefit ratio of the alternatives. It is calculated as: $\left[\frac{Alternative\ Cost - Natural\ Attenuation\ Cost}{Natural\ Attenuation\ Years - Alternative\ Years}\right]$.

Table 10-2 Summary of Remedial Costs and Risk Reduction for Lower Fox River Remedial Alternatives

Lower Fox River Reaches	Remediation Alternative	PCB Action Level (ppb) 125	250	500	1,000	5,000	Maximum Action Level that Meets Risk Reduction Criteria Related to Project RAOs: RAO 1 SWQ	RAO 2 HH	RAO 3 Eco	RAO 4 Transport
Little Lake Butte des Morts	Impacted Volume (cy)	1,689,173	1,322,818	1,023,621	784,192	281,689				NA
	PCB Mass (kg)	1,838	1,814	1,782	1,715	1,329				
	Remedial Cost (in 1,000s $)									
	A/B: No Action	$9,900	$9,900	$9,900	$9,900	$9,900				
	C1: Dredge, Off-site Disp. (Pass. Dewater)	$231,500	$185,600	$147,800	$116,700	$48,500				
	C2: Dredge, Off-site Disp. (Mech. Dewater)	$126,200	$102,500	$82,800	$66,200	$28,300				
	D: Dredge to CDF, Off-site TSCA Disp.	$116,000	$110,300	$105,100	$68,000	$54,500				
	E: Dredge and Thermal Treatment	$117,200	$96,000	$78,500	$63,600	$29,300				
	F: Cap and Dredge to CDF	$145,200	$138,600	$99,300	$90,500	$66,200				
Appleton to Little Rapids	Impacted Volume (cy)	182,450	80,611	56,998	46,178	20,148				NA
	PCB Mass (kg)	106	99	95	92	67				
	Remedial Cost (in 1,000s $)									
	A/B: No Action	$9,900	$9,900	$9,900	$9,900	$9,900				
	C: Dredge, Off-site Disp.	$38,300	$25,000	$21,700	$20,100	$16,500				
	E: Dredge and Thermal Treatment	$26,200	$19,700	$17,900	$17,100	$15,200				
Little Rapids to De Pere	Impacted Volume (cy)	1,483,156	1,171,585	776,791	586,788	186,348				NA
	PCB Mass (kg)	1,210	1,192	1,157	1,111	798				
	Remedial Cost (in 1,000s $)									
	A/B: No Action	$9,900	$9,900	$9,900	$9,900	$9,900				
	C1: Dredge to NR 500 Facility (Pass. Dewater)	$224,200	$180,700	$124,200	$95,100	$38,100				
	C2A: Dredge to Comb. Dewater/Disp. Facility	$72,300	$63,200	$51,400	$43,900	$32,400				
	C2B: Dredge to Sep. Dewater/Disp. Facilities	$179,800	$152,800	$118,300	$99,900	$65,300				
	C3: Dredge to NR 500 Facility (Mech. Dewater)	$161,700	$130,800	$90,300	$69,100	$28,400				
	D: Dredge to CDF, Off-site TSCA Disp.	$72,300	$66,800	$58,400	$52,500	$44,400				
	E: Dredge and Thermal Treatment	$142,700	$123,800	$99,500	$86,200	$61,900				
	F: Cap and Dredge to CDF	$143,700	$114,300	$87,800	$62,900	$34,700				
De Pere to Green Bay	Impacted Volume (cy)	6,868,500	6,449,065	6,169,458	5,879,529	4,517,391				
	TSCA Volume (cy)	240,778	240,778	240,778	240,778	240,778				
	PCB Mass (kg)	26,620	26,581	26,528	26,433	24,950				
	Remedial Cost (in 1,000s $)									
	A/B: No Action	$9,900	$9,900	$9,900	$9,900	$9,900				
	C1: Dredge to NR 500 Facility (Pass. Dewater)	$769,100	$723,100	$692,300	$660,600	$511,100				
	C2A: Dredge to Comb. Dewater/Disp. Facility	$196,000	$186,900	$180,400	$173,500	$138,700				
	C2B: Dredge to Sep. Dewater/Disp. Facilities	$564,500	$534,100	$513,500	$491,800	$388,000				
	C3: Dredge to NR 500 Facility (Mech. Dewater)	$595,200	$561,000	$537,800	$513,500	$397,200				
	D: Dredge to CDF, Off-site TSCA Disp.	$611,800	$566,400	$536,200	$505,100	$360,700				
	E: Dredge and Thermal Treatment	$404,500	$384,000	$370,000	$355,100	$283,300				
	F: Cap and Dredge to CDF	$432,600	$403,900	$381,900	$357,100	$234,400				



Notes:

20% contingency costs not included.

Threshold criteria used to evaluate risk reduction:

RAO 1: 1 = Wildlife Criteria 30-year, 2 = Human Surface Water Drinking Criteria 30-year.

RAO 2: 1 = High-intake Fish Consumer Cancer 30-year, 2 = High-intake Fish Consumer Noncancer 30-year, 3 = Recreational Angler Cancer 10-year, 4 = Recreational Angler Noncancer 10-year.

RAO 3: 1 = Carnivorous Bird Deformity NOAEC 30-year, 2 = Piscivorous Mammal NOAEC 30-year.

RAO 4: 1 = Tributary Load to Reach Green Bay Level 30-year.

NA - Not applicable.

Action Level (ppb) that Consistently Meets Criteria after 10 or 30 Years of Recovery after Remediation Completion

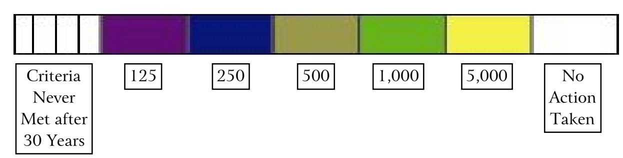
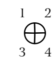
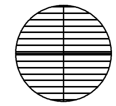
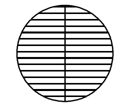
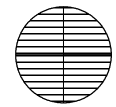
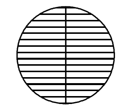
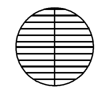
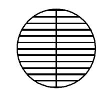
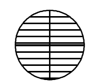
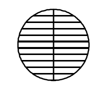


Table 10-3 Summary of Remedial Costs and Risk Reduction for Green Bay Remedial Alternatives

Green Bay Zone	Remediation Alternative	Action Level (ppb) 125	250	500	1,000	5,000	Maximum Action Level that Meets Risk Reduction Criteria Related to Project RAOs: RAO 1 SWQ	RAO 2 HH	RAO 3 Eco	RAO 4 Transport
										
Green Bay	Impacted Volume (cy)	NE	NE	29,748,004	29,322,254	4,070,170				
Zone 2	PCB Mass (kg)	NE	NE	29,896	29,768	6,113				
	Remedial Cost (in 1,000s $)									
	A/B: No Action	NA	NA	$9,900	$9,900	$9,900	NE			NA
	C: Dredge, Off-site Disp.	NA	NA	NA	NA	$507,200				
	D: Dredge to CDF, Off-site TSCA Disp.	NA	NA	$824,700	$814,100	$166,500				
	G: Dredge to CAD	NA	NA	$707,400	$697,800	$124,000				
Green Bay	Impacted Volume (cy)	NE	NE	16,328,102	14,410	NE				
Zone 3A	PCB Mass (kg)	NE	NE	2,156	2	NE				
	Remedial Cost (in 1,000s $)									
	A/B: No Action	NA	NA	$9,900	$9,900	NA	NE			NA
	C: Dredge, Off-site Disp.	NA	NA	NA	$11,000	NA				
	D: Dredge to CDF, Off-site TSCA Disp.	NA	NA	$474,300	NA	NA				
	G: Dredge to CAD	NA	NA	$389,100	NA	NA				
Green Bay	Impacted Volume (cy)	NE	NE	43,625,096	NE	NE				
Zone 3B	PCB Mass (kg)	NE	NE	4,818	NE	NE				
	Remedial Cost (in 1,000s $)						NE			NA
	A/B: No Action	NA	NA	$9,900	NA	NA				
	D: Dredge to CDF, Off-site TSCA Disp.	NA	NA	$1,155,100	NA	NA				
	G: Dredge to CAD	NA	NA	$1,010,900	NA	NA				
Green Bay	Impacted Volume (cy)	NE	NE	0	NE	NE				
Zone 4	PCB Mass (kg)	NE	NE	0	NE	NE	NE			NA
	Remedial Cost (in 1,000s $)									
	A/B: No Action	NA	NA	$9,900	NA	NA				

Notes:

20% contingency costs not included.

Threshold criteria used to evaluate risk reduction:

RAO 1: 1 = Wildlife Criteria 30-year, 2 = Human Surface Water Drinking Criteria 30-year.

RAO 2: 1 = High-intake Fish Consumer Cancer 30-year, 2 = High-intake Fish Consumer Noncancer 30-year, 3 = Recreational Angler Cancer 10-year, 4 = Recreational Angler Noncancer 10-year.

RAO 3: 1 = Carnivorous Bird Deformity NOAEC 30-year, 2 = Piscivorous Mammal NOAEC 30-year.

RAO 4: 1 = Tributary Load to Reach Green Bay Level 30-year.

NA - Not applicable.

NE - Not evaluated.

Action Level (ppb) that Consistently Meets Criteria after 10 or 30 Years of Recovery after Remediation Completion

Criteria Never Met after 30 Years | 125 | 250 | 500 | 1,000 | 5,000 | No Action Taken

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8 Alternative-specific Risk Assessment

This section presents an analysis of the potential for risk reduction associated with the proposed remedial action levels presented in the previous two sections of the FS. Central to the selection of any potential remedy for the river and bay is the ability of the remedy to reduce or eliminate risks to human health and the environment. This evaluation includes both active remedial actions such as capping or removal, but also passive actions such as natural recovery and assumes that all remedial actions would have the same risk reduction at the same action level. For example, at a 250 ppb action level, capping achieves the same level of risk reduction as dredging. This Alternative-specific Risk Assessment (ASRA), therefore, is an action level-specific risk assessment.

The ASRA builds upon the risks, remedial action objectives, and remedial action levels defined in Sections 2, 3, 4, and 5 of the FS. Risks from exposure of humans and environmental receptors within the river and bay for PCBs were presented in the Baseline Risk Assessment for the Lower Fox River and Green Bay (BLRA) (Section 3). Sediment quality thresholds (SQTs) were also presented in the BLRA that, along with estimates of PCB mass and sediment volumes from the Remedial Investigation (Section 2), were used to define remedial action levels in Section 5.

Evaluation of residual risks associated with implementation of a specific remedial action level in sediments requires the ability to estimate the changes over time of total PCBs in water, sediment, and fish as a result of the action. None of the remedial action levels identified provide 100 percent protection immediately after remediation (or initiation of monitored natural recovery) for all of the human or ecological receptors in the Lower Fox River or Green Bay. The key assumption of remediation is that sediment transport and burial over time would achieve further reductions in risk. This is also applicable to the evaluation of passive remedial management; risk reduction under monitored natural recovery.

Mathematical fate, transport, and bioaccumulation models provide a means for estimating the changes in PCB concentrations over time. Using those projections, the level of estimated risk reduction and the time it takes to achieve that risk reduction, can be used as metrics for comparing the efficacy of the remedial action levels in each river reach and bay zone.

The subsections below define:

- What are the metrics for the RAOs used to evaluate risk reduction?
- What are the mathematical models used to project the levels of PCBs in water, sediment, and fish tissue concentrations over time?
- What remedial action levels, or combinations of action levels, are modeled?
- How do the projections for different action levels affect risk in each reach/zone (i.e., comparison against the RAOs)?
- Are there post-remedial risks for other chemicals of concern (COCs) identified in the BLRA (i.e., DDE and mercury)?

These questions provide the foundation for the ASRA. The RAO metrics, models, evaluation process, PCB risk reduction, and risk from other COCs are described below for each river reach and bay zone. It is emphasized here, and will be reiterated throughout this section, that risk reduction predictions are meant to be compared in a relative, and not an absolute sense. The relationship between the predictive models and the estimated PCB concentrations in both sediments and fish tissue are described in Table 8-1.

8.1 Remedial Action Objectives

for the Lower Fox River and Green Bay were defined in Section 4. WDNR and EPA articulated their project expectations into explicit, measurable statements (e.g., number of years to remove fish consumption advisories) in order to evaluate the expected performance of each alternative and each action level. The RAOs and project expectations were defined as follows:

- *RAO 1 - Achieve, to the extent practicable, surface water quality criteria throughout the Lower Fox River and Green Bay.*

  The metric for RAO 1 is that PCBs measured in surface waters are at or below surface water quality criteria. The values used for surface water quality are the human health value defined in NR 105 WAC for drinking water (0.003 ng/L) and wildlife (0.12 ng/L). The drinking water value is actually a surface water value protective of human health at a lifetime cancer risk level of 10^{-5} from the consumption of fish which bioaccumulate PCBs from surface waters. However, it should be noted that these are not ARARs. Additionally, while not a specific criterion, the projected concentrations are also compared to current maximum outflow concentrations from Lake Winnebago.

- *RAO 2 - Protect humans who consume fish from exposure to COCs that exceed protective levels.*

  The metric for RAO 2 is stated as the removal of fish consumption advisories in the Lower Fox River and Green Bay. The metrics below are only one set of goals for risk management decision making, but are used in the FS for relative comparison between alternatives and action levels.

  - Recreational anglers can safely eat fish 10 years after completion of a remedy; and

  - High-intake fish consumers can safely eat fish 30 years after completion of a remedy.

  Within the BLRA, human health risks were estimated for multiple potential exposure scenarios. These included recreational and high-intake fish consumers, risk levels for cancer ranging from 10^{-4} to 10^{-6}, and a noncancer HI of 1.0, for both the Reasonable Maximum Exposure (RME) and the Central Tendency Exposure (CTE). A threshold based on a 10^{-5} cancer risk level indicates that individuals eating fish with this threshold concentration over a lifetime could contract cancer at the rate of one case in 100,000 people. A threshold based on an HI of 1.0 indicates individuals eating fish with this threshold concentration over a lifetime should not experience any adverse noncancer effects. These risks were expressed in Section 7.4.2 of the BLRA in terms of safe total PCB levels in whole walleye, yellow perch, and carp. For the ASRA, the time to achieve these human health fish tissue thresholds by action level was estimated using model projections.

  For the evaluation and comparison of risk under different action levels, four whole fish thresholds were selected by WDNR and EPA for the protection of human health:

  - Recreational angler - walleye, RME, HI is 1.0 (noncancer) (288 μg/kg);

- Recreational angler - walleye, RME, 10^{-5} cancer risk (106 μg/kg);

- High-intake fish consumer - walleye, RME, HI is 1.0 (noncancer) (181 μg/kg); and

- High-intake fish consumer - walleye, RME, 10^{-5} cancer risk (65 μg/kg).

Human health risks in the BLRA were based upon consumption of fillets. As the models (FRFood and GBFood) predict whole fish tissue PCB concentrations, it was necessary to establish fillet-to-whole body ratios from the FRDB and the scientific literature. The relationship between fillets and whole body concentrations is given in Table 8-2.

This does not imply other risk levels could not be used for risk management; these risk levels and time frames are used simply for consideration and comparison between remedial options, along with other evaluation criteria. Additional risk thresholds are used for comparison over time as discussed in later portions of this section.

- *RAO 3 - Protect ecological receptors from exposure to COCs above protective levels.*

  In the BLRA, ecological risks were estimated for specific receptor/receptor groups (e.g., benthic infauna, fish, piscivorous birds). Concentrations of total PCBs in water, sediment, or fish known to affect the selected receptors were used to calculate apparent risks. This included both the "No Observed Apparent Effect Concentration" (NOAEC) and the "Lowest Observed Apparent Effect Concentration" (LOAEC). For the affected fish, bird, and mammal groups, NOAEC and LOAEC risks can be expressed as total PCB threshold concentrations in whole fish (carp, walleye, alewife, shiners, shad). The relationship between the NOAEC/LOAEC, fish tissue concentration, and sediment concentration is defined in Section 7.4.3 of the BLRA.

  For the ASRA, the time to achieve these ecological whole fish thresholds for a specific action level was estimated using model projections (discussed below). For the evaluation and comparison of risk under different action levels, two ecological thresholds were selected by both WDNR and EPA:

- Carnivorous bird deformity - NOAEC based on carp, whole fish (121 μg/kg); and

- Piscivorous mammal - NOAEC based on carp, whole fish (50 μg/kg).

While these are only potential metrics, these values were compared to an equivalent time period to the high-intake fish consumer (30 years post-remediation) with the potential goal that there would be no risk to these receptors within this time frame following remediation. These RAOs are simply used to compare remedial options on the same basis. However, additional thresholds are used for comparison over time in later sections.

- *RAO 4 - Reduce transport of PCBs from the Lower Fox River into Green Bay and Lake Michigan.*

While mass is not specifically related to risk, it is a metric for transport of risk downstream. Mass transport will be presented qualitatively as a comparison between specific action levels, but is only applied to the last reach of the river, De Pere to Green Bay. The last reach accounts for all of the mass transport from materials upstream and downstream of the De Pere dam. Between action levels, projected sediment loading will be compared to 30 years total. In addition, the Lake Winnebago loading rate (18 kg/yr) and the other tributaries to Green Bay loading rate (10 kg/yr) will be used to compare action level results over time. Loading rates from all sources are presented in Section 5.1 of the RI Report (RETEC, 2002a).

- *RAO 5 - Minimize the downstream movement of PCBs during implementation of the remedy.*

This RAO was evaluated in Sections 6 and 7 of the FS, and will not be further discussed here.

In summary, the metrics lists above are used for relative screening of alternatives, but may not necessarily be the same criteria used to select a final remedy by the resource agencies. Expectations may change or be revised over the course of the project and through the public review process, but for now, they initially provide a useful framework to compare and evaluate the action levels. They also provide performance criteria that can be used as measurement tools during development of the *Long-term Monitoring Plan* (Appendix C). RAOs 1 through 3 are applied to all river reaches. For Green Bay, only RAOs 2 and 3 were evaluated. RAO 4 is applied only to the De Pere to Green Bay Reach.

8.2 Lower Fox River/Green Bay Modeling

Computer models have been developed and used in the FS to project changes in total PCBs in water, sediment, and fish over time. These models are mathematical representations of transport and transfer of PCBs between the sediments, water, and uptake into the food webs described in Section 3 of the FS. While the models discussed below are useful for comparing between potential action alternatives, there should be no mistaking that utility for precision. All the models are calibrated over a short time frame (6 years or less), but projected over 100 years. While there is a reasonable assurance that the relative trends are accurate, there are no assurances that the predictions are precise. In other words, comparisons are relatively reliable, but absolute estimates may not be accurate and should not be strictly relied upon.

The relationship between the models, their projected output, and how the output is used in evaluating risks, is shown in Table 8-1. The bed maps produced as part of the Remedial Investigation are the foundation of the modeling inputs. The surface sediment total PCB concentrations for the baseline and action levels discussed in Section 5 are used as the inputs to both hydrodynamic models: the Whole Fox Lower River Model (wLFRM) and the Enhanced Green Bay Toxics Model (GBTOXe). These two models project total PCB concentrations in water and sediment which are used to evaluate risks as defined in RAOs 1 and 4. The output from the two fate models are used by the bioaccumulation models: Fox River Food (FRFood) and Green Bay Food (GBFood). The projected whole fish tissue concentrations of PCBs are used to evaluate risks as defined in RAOs 2 and 3.

The structure of each of these models is briefly described below. A complete description of all the models used in the RI and FS is given in the companion document *Model Documentation Report for the Lower Fox River and Green Bay* (WDNR, 2001). The uncertainties associated with the predictions of long-term residual risks need to be considered. The uncertainties associated with the selection of specific receptors and the thresholds at which those receptors are thought to be placed at risk are discussed in the BLRA. Model uncertainties include the assumptions built into the mass transport models used to predict long-term water and sediment trends, and the associated risks for those river reaches and Green Bay zones. These uncertainties are discussed in Section 8.5.

8.2.1 Whole Lower Fox River Model (wLFRM)

The Whole Lower Fox River Model (wLFRM) was developed by WDNR from two models previously developed for the analysis of flow in the Lower Fox River: the Upper Fox River (UFR) model, which covered the river between Lake Winnebago and the De Pere dam; and the Lower Fox River (LFR) model, which extended from the De Pere dam to the mouth of the river. The wLFRM retains the spatial resolution of the UFR/LFR models, but allows the simulation of the entire Lower Fox River from Lake Winnebago to the mouth of the river using a single model. The wLFRM is calibrated with data collected between 1989 and 1995. Calibration consisted of comparisons between the data and model results for total suspended solids, dissolved/particulate PCBs in water, sediment bed elevation, and net sediment burial rate.

The wLFRM is used to simulate the fate and transport of solids and PCBs in the water and sediments in the Lower Fox River. The model predicts the movement of solids and PCBs among these various model segments. In addition, the model simulates the concentration of organic carbon in the water column. Transport mechanisms in the wLFRM include advection, dispersion, volatilization, deposition, and resuspension. Deposition is a function of particle size or density with different settling rates to represent sand-, silt-, and clay-size particles. The settling rate for clay-size particles can also be used to simulate the settling of low-density organic matter. Resuspension is based on surface water velocity and the effect of sediment bed armoring over time.

The results from the wLFRM are used as input to other the three models. Area-weighted average concentrations of total PCBs and carbon in water and sediments are output for the bioaccumulation models. Results from above the De Pere dam are used as input to the FRFood model. Results from below the De Pere dam to the mouth of the river are used as input to both the FRFood and GBFood models. Finally, the predicted solids and PCB discharges at the mouth of the river are used as inputs to the GBTOXe model. Each of these three models is discussed below.

8.2.2 Enhanced Green Bay Toxics(GBTOXe) Model

The Enhanced Green Bay Toxics Model (GBTOXe) was developed by HydroQual to simulate the fate and transport of PCBs in Green Bay for the RI/FS. GBTOXe is an enhanced version of an existing WASP4-based toxics model developed as part of the Green Bay Mass Balance Study by Bierman *et al.* (1992) and updated by DePinto *et al.* (1993). Enhancements include a higher spatial resolution and linkage to a hydrodynamics model (GBHYDRO) and a sediment transport model (GBSED) of Green Bay. GBTOXe was calibrated against 1989–1990 GLNPO PCB and carbon data.

GBTOXe is used to model total PCBs and three phases of carbon in the water column and sediments. The carbon phases considered are dissolved, biotic, and particulate detritus. Modeled sediment layers represent biologically active sediments, biologically inactive sediments, and a sink to which PCBs are permanently buried through deposition. Sediment segment volumes are assumed to be constant with time. PCB transport mechanisms include advection, dispersion, volatilization, deposition, resuspension of sorbed phase, and pore water exchange. GBTOXe accounts for sediment bed armoring. Output from GBTOXe includes area-weighted (sediments) or volume-weighted (water column) averages of total PCBs and carbon as input to the bioaccumulation models.

8.2.3 Fox River Food (FRFood) Model

The FRFood bioaccumulation model, based on the Gobas model (1993), is a mathematical description of PCB transfer within the food web of the Lower Fox River and the first two zones of Green Bay (zones 1 and 2). The model is designed to take the output of sediment and water concentrations of PCBs from wLFRM and GBTOXe to estimate concentrations in multiple trophic levels in the aquatic food web (i.e., benthic insects, phytoplankton, zooplankton, and fish). This food web model is functionally similar to, and spatially overlaps with, the food web model for Green Bay (GBFood), with the exception that the FRFood model can be run in reverse where the inputs are fish concentrations and the outputs are predicted sediment concentrations.

FRFood is based upon the algorithms originally developed for Lake Ontario PCBs (Gobas, 1993). Since then, the model has been used extensively throughout the Great Lakes, including derivation of bioaccumulation factors, bioconcentration factors, and food chain multipliers in the development of the Great Lakes Water Quality Initiative (GLWQI) criteria (EPA, 1993, 1994a, 1994b). The model was first used for projecting sediment quality thresholds in the 1996 RI/FS for the Upper Fox River (GAS/SAIC, 1996), and has since been used for setting action levels at the Sheboygan River (EVS, 1998), and for predicting long-term effects on biota at the Hudson River, New York (EPA, 2000c).

FRFood is used to estimate PCB concentrations in the food webs leading to forage fish (e.g., shiners, gizzard shad, alewife), benthic fish (e.g., carp), and game fish (perch, walleye) in the river. Water column and sediment PCB concentrations were provided by wLFRM. The model was calibrated using site-specific data from the Fox River Database (FRDB), and from scientific literature-derived values for the various physiological, bioenergetic, and toxicokinetic parameters in the model. FRFood was also used to estimate sediment quality thresholds of Section 7 of the BLRA.

8.2.4 Green Bay Food (GBFood) Model

The GBFood bioaccumulation model is a mathematical description of contaminant transfer within the food web of Green Bay zones 1 through 4. The food web is comprised of the primary energy transfer pathways from the exposure sources (sediment and water) to the fish species of interest, described in Section 4.4. These pathways include: chemical uptake across the gill surface, chemical uptake from food and chemical losses due to excretion, and growth dilution. The mathematical descriptions are generic (common to all aquatic food webs) and were updated as part of this FS.

GBFood is used in the ASRA to estimate PCB concentrations in the food webs leading to brown trout and walleye in zones 2 through 4 of Green Bay. Carp were not evaluated in GBFood as the model was not constructed to include that fish. This was accomplished by specifying values for the various physiological, bioenergetic, and toxicokinetic parameters in the model and the PCB exposure levels in sediments and water. The parameter values were derived from peer-reviewed studies published in the literature and/or site-specific data. The sediment and water column PCB concentrations were provided by wLFRM and GBTOXe model outputs.

8.3 Description of Detailed Analysis Process

8.3.1 Lower Fox River and Green Bay Total PCB Residual Risk Evaluation

Remedial action levels considered for each of the river reaches include no action, 125, 250, 500, 1,000, and 5,000 ppb. Action levels for the FS were discussed in Section 5. The discussion of action levels relative to the process options (i.e., hydraulic dredging, capping, etc.), the quantity of contaminated sediment, and costs will be discussed in Section 10. Only residual risks associated with implementation of a specific action level are discussed in this section. The residual risks associated with no action are discussed in the BLRA, and the non-interpolated total PCB sediment concentrations that were evaluated as part of this assessment are presented in Table 8-3 by river reach and bay zone.

For modeling in the FS, the same action levels were applied to each river reach. For example, under the No Action alternative the models were run assuming that no action had occurred on all four river reaches.

Unlike the river, not all remedial action levels are considered for Green Bay and not all areas of Green Bay are considered for remediation. Remedial action levels carried forward in the transport model for Green Bay zones 2 and 3A included

500 and 1,000 ppb, the only remedial action level considered for Green Bay Zone 3B was 500 ppb, and no remedial action was considered for Green Bay Zone 4.

Finally, remedial action levels evaluated for each bay zone considered the potential for different remedial actions between the river and the bay. Remedial combinations for modeling were selected by WDNR as shown below:

Lower Fox River Cleanup Level (ppb)	Green Bay		
	No Action	500	1000
No Action	✓	—	—
125	✓	✓	✓
250	✓	✓	✓
500	✓	✓	✓
1000	✓	—	✓
5000	✓	—	—

8.3.2 Non-PCB COC Residual Risk Evaluation

In addition to total PCBs, residual post-remediation risk results from the other two chemicals of concern (COCs) identified in the BLRA, mercury and DDD/DDE/DDT, were evaluated for each remedial action level immediately following remediation. The risks to human health and the environment from these other COCs were most often much less than those posed by PCBs. For clarification, in general mercury was measured above risk levels in both sediments and tissues. DDD and DDT were measured above risk levels in sediment, however, only DDE was measured above risk levels in tissues.

As discussed above, the primary tool for evaluating residual PCB exposure assuming different action levels was modeling surface water, sediment, and wildlife tissue concentrations over a 100-year period following remediation. In contrast, the primary tool for evaluating residual mercury and DDD/DDE/DDT exposure was simply the degree of co-location with removed PCBs in the sediment. The degree of this co-location was determined 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 implementation of the alternatives described in Section 7 is assumed to result in the removal or isolation of the non-PCB contaminants along with the PCBs assuming that all of the COCs are co-located. The no action alternatives result in the same residual risks as those identified in the BLRA. No action sediment concentrations of mercury, p,p'-DDD, p,p'-DDE, and p,p'-DDT are presented in Table 8-4. Residual risks to human health and the environment may remain for the action levels that do not remove all areas of contaminated sediment and these are discussed in the reach and zone discussions below. Residual surface sediment concentrations of mercury and DDE as they relate to residual PCB levels by action level are presented on Figures 8-1 through 8-8 for the Lower Fox River and Figures 8-9 and 8-10 for Green Bay.

8.4 Reach- and Zone-specific Risk Assessment

This section discusses the long-term future residual risk associated with each remedial action level, or combination of remedial action levels, in each of the river reaches and bay zones evaluated. Specifically, the associated risks are discussed in terms of the number of years needed before the specific goals of the RAOs outlined above in Section 8.1 are met. RAOs 1 and 4 are not evaluated for any of the Green Bay zones.

Long-term residual risk in the river was determined through using the wLFRM model to derive future water and sediment concentrations and the FRFood model to derive future fish tissue concentrations. Similarly, long-term residual risk in the bay was determined through the GBTOXe model to derive future water and sediment concentrations and the GBFood model to derive future fish tissue concentrations.

RAO 1: Water Quality. For the evaluation of RAO 1, projected surface water total PCB concentrations for each action level were compared to selected thresholds (Table 8-5). The thresholds for surface water, as previously discussed, are the Wisconsin NR 105 water (0.003 ng/L) and wildlife criteria (0.12 ng/L), and the current maximum concentration measured in Lake Winnebago (13 ng/L). These thresholds are compared to the modeled concentrations for each river reach and action level.

The potential risk management goal of meeting human health and ecological thresholds for RAOs 2 and 3 is no risk to any receptors 30 years after remediation has been completed. For consistency, the surface water concentrations 30 years after remediation were noted and compared between action levels. The number of years to reach the surface water thresholds and the surface water concentrations 30 years after remediation are presented in Table 8-5.

RAO 2 and RAO 3: Human Health and Ecological Risk: Human health receptors considered were recreational anglers and high-intake fish consumers. Ecological receptors evaluated included: carp as the surrogate representative for benthic fish, walleye as the surrogate representative of pelagic fish, Forster's terns as the surrogate representative of piscivorous birds, bald eagles as the surrogate representative of carnivorous birds, and mink as the surrogate representative for piscivorous mammals. For the four river reaches and four Green Bay zones, human health and ecological thresholds evaluated by action level are presented in Tables 8-6 through 8-9 and Tables 8-10 through 8-13, respectively.

For the initial evaluation of RAOs 2 and 3, all human health and ecological risk thresholds evaluated in the baseline risk assessment were included: 30 human health thresholds and 15 ecological thresholds. As previously discussed, the risk levels of the human health thresholds were a noncancer HI of 1.0, and cancer risk levels of 10^{-4}, 10^{-5}, and 10^{-6}. The risk levels of the ecological thresholds were NOAECs and LOAECs.

For the final evaluation of RAOs 2 and 3 risks presented in this section, the focus was on just a few select human health and ecological thresholds which were selected by WDNR and EPA: four human health and seven ecological thresholds. For human health, these thresholds were the RME concentration in walleye assuming consumption by recreational anglers and high-intake fish consumers at a noncancer HI of 1.0, and at a cancer risk level of 10^{-5} (i.e., four thresholds total). These human health thresholds (RAO 2) and the years required to meet them assuming different action levels are contained in Table 8-14 (Lower Fox River) and Table 8-15 (Green Bay). The ecological thresholds selected for discussion were the sediment threshold for sediment invertebrates (only evaluated in the river reaches) and the following whole fish tissue thresholds: gizzard shad or alewife concentrations resulting in no or low adverse hatching success or deformity in piscivorous birds, the carp (river) or walleye (bay) concentrations resulting in no adverse deformities in carnivorous birds, and the carp (river) or walleye or alewife (bay) concentrations resulting in no adverse reproductive or survival effects on piscivorous mammals. These ecological thresholds (RAO 3) and the years required to meet them assuming different action levels are contained in Table 8-16 (Lower Fox River) and Table 8-17 (Green Bay). As stated previously, there are potential risk management goals used in the FS. Alternate management goals may be selected by WDNR and EPA.

For each river reach and bay zone, the number of years to reach these human health and ecological remedial action objective thresholds are discussed below. With each decrease in remedial action level, there is a corresponding decrease in the number of years that it takes to meet a threshold. Overall goals of the remedial action level(s) are that recreational anglers will be able to eat walleye within 10 years following remediation with no cancer or noncancer risks, that high-intake consumers will be able to eat walleye within 30 years following remediation with no cancer or noncancer risks, and that there will be no adverse risks to ecological receptors within 30 years following remediation. Based on these potential remedial goals, action levels that achieve these goals are summarized in the conclusion of each reach/bay discussion below.

Although this risk analysis is useful for comparing relative residual risk resulting from each action level and for comparing the relative risk between areas, there are inherent uncertainties associated with the magnitude of residual risk projected 100 years into the future and, therefore, the number of years required to meet the stated remedial action objectives. For example, while the baseline human health and ecological risk assessment concluded that there are potential risks to piscivorous birds, the forward projection of these risks suggests that in the Little Lake Butte des Morts and Appleton to Little Rapids reaches and for all remedial action levels, risks to piscivorous birds do not persist for more than 1 year, even for the No Action alternative. In the Little Rapids to De Pere and De Pere to Green Bay reaches, the only piscivorous bird threshold that is not met within 1 year is the no deformity threshold. A full discussion of this and other uncertainties associated with the forward projection of sediment and fish tissue concentrations and assessment of residual risk is presented in Section 8.5. In part, to address these uncertainties a monitoring program following remediation will be implemented as described in Appendix C.

RAO 4: Mass Transport to Green Bay. For RAO 4, projected mass loads by action levels at the mouth of the Fox River were compared to the background total PCB loadings identified in the Remedial Investigation. The PCB loading rate to the Lower Fox River from Lake Winnebago is 18 kg/yr. The combined loading rate for all tributaries to Green Bay is estimated at 102 kg/yr (see RI Section 5.1.2.1). Overall, the sediment PCB loading discussion focused on comparing relative reductions in sediment loading with each increase in the action level applied. The sediment PCB loading rates 30 years after remediation are presented in Table 8-18.

8.4.1 Little Lake Butte des Morts

Residual PCB Levels

RAO 1 - Surface Water Quality. As presented in Table 8-5, the surface water criteria of 0.003 ng/L are projected to never be met no matter what action level is selected. The wildlife criteria of 0.12 ng/L is not met within 100 years for either the no action or 5,000 ppb action level, yet it is projected to be met within 100 years for the other action levels: 52 years (1,000 ppb), 39 years (500 ppb), 19 years (250 ppb), and 16 years (125 ppb). As compared to the Lake Winnebago current maximum concentration of PCBs in surface water (13 ng/L), under the No Action alternative this concentration is met within 4 years, under an action level of 5,000 ppb this concentration is projected to be met within 1 year,[4] and for all of the other action levels, this concentration is met immediately following remediation. Thirty years after remediation, it is estimated that surface water total PCB concentrations range from 0.04 ng/L (125 ppb) to 2.99 ng/L (no action).

RAO 2 - Human Health. As indicated in Table 8-14, remedial action levels as high as 1,000 ppb are projected to result in the attainment of fish threshold concentrations within 1 year following remediation. For noncancer risks, fish thresholds are estimated to be met within a year up to a remedial action level of 1,000 ppb. Noncancer risks at the 5,000 ppb action level represent a risk reduction of approximately 40 percent as compared to no action. For cancer risks, the only remedial action levels that result in fish thresholds being met within a year are the 250 and 125 ppb action levels. As compared to the No Action alternative, the projected 5,000, 1,000, and 500 ppb action levels result in a cancer risk reduction of approximately 31, 87, and 92 percent, respectively.

For the 125 and 250 ppb action levels, all fish thresholds except the high-intake fish consumer cancer risk threshold (71 μg/kg) are projected to be met in less than a year. For the 500 ppb action level, within 1 year there are no noncancer risks to recreational anglers and high-intake fish consumers; however, cancer risks persist for 5 years (recreational intake) to 10 years (high intake). For the 1,000 ppb action level, noncancer risks are estimated to persist for less than 1 year (recreational angler) to 4 years (high-intake fish consumer); cancer risks persist for 9 years (recreational angler) to 14 years (high-intake fish consumer). For the 5,000 ppb action level projections, noncancer risk of fish consumption persists for 29 years (recreational intake) to 40 years (high intake) and cancer risk of fish consumption persists for 57 years (recreational intake) to 70 years (high intake). For the No Action alternative, noncancer risks of fish consumption are estimated to persist for 51 years (recreational intake) to 65 years (high intake) and cancer risk of fish consumption persists for 84 years (recreational intake) to 100 years (high intake).

With the goals in mind of 10 years for safe fish consumption by recreational anglers and 30 years for safe fish consumption by high-intake consumers, only projections for remedial action levels of 1,000 ppb or less result in meeting these goals. The 1,000 and 500 ppb action levels differ by approximately 37 percent

[4] A projection of "1 year following remediation" is a model output, and should not necessarily be literally interpreted. PCBs will remain at a steady level in the current age population of fish for 3 to 6 years. The next generation of fish would show the projected PCB reduction. Thus, while the model projects risk reduction in 1 year, in the real world this would be up to 6 years.

and the 125 and 250 ppb action levels do not differ, in terms of the level of risk reduction achieved.

RAO 3 - Ecological Health. As indicated in Table 8-16, the range of remedial action levels are projected to result in either thresholds being met within a year following remediation (i.e., carnivorous bird deformity assuming the 250 or 125 ppb action level and all piscivorous bird thresholds at all action levels), or thresholds not being met within 100 years (i.e., sediment concentrations protective of sediment invertebrates assuming no action or a remedial action level of 5,000 ppb and the piscivorous mammal NOAEC assuming no action). As compared to the 5,000 ppb action level, other action level projections result in a risk reduction to carnivorous birds of 79 percent (1,000 ppb action level) and 87 percent (500 ppb action level), and a risk reduction to piscivorous mammals of 71 percent (1,000 ppb), 75 percent (500 ppb), 91 percent (250 ppb), and 93 percent (125 ppb). As compared to the 1,000 ppb action level, the projections for other action levels result in a risk reduction to sediment invertebrates of 13 percent (500 ppb), 57 percent (250 ppb), and 65 percent (125 ppb).

Estimates for the attainment of the carnivorous bird threshold under action levels which result in risk for more than 1 year ranges from 9 years (500 ppb action level) to 100 years (no action). Attainment of the piscivorous mammal threshold ranges from 7 years (125 ppb action level) to more than 100 years (no action). The sediment invertebrate threshold is only met within 100 years for remedial action levels of 1,000 ppb or less, where achieving this threshold ranges from 21 years (125 ppb action level) to 60 years (1,000 ppb action level).

With the goal in mind of 30 years for no adverse ecological risks, only remedial action levels of 250 or 125 ppb result in meeting this goal. The 250 and 125 ppb action levels only differ by approximately 3 percent in terms of the level of risk reduction achieved. The action levels of 5,000, 1,000, and 500 ppb do not result in achievement of the stated goal, and the 125 ppb action level is not appreciably more protective than the 250 ppb action level.

RAO 4 - Sediment Transport. As presented in Table 8-18, 30 years following remediation, the sediment PCB loading rates for the action levels as compared to the No Action alternative represent sediment PCB loading reductions of 44 percent (5,000 ppb), 94 percent (1,000 ppb), 96 percent (500 ppb), 98 percent (250 ppb), and 99 percent (125 ppb). Compared to the Lake Winnebago sediment PCB loading rate of 18 kg/yr, the No Action alternative results in meeting this rate in 17 years, the 5,000 ppb action level results in meeting this rate in 7 years, and for all of the other action levels this rate is met immediately following remediation.

Residual Mercury and DDE Levels

The distribution and concentrations of mercury and DDE in sediments and degree of co-location with PCBs within the Little Lake Butte des Morts Reach are shown on Figure 8-1 (mercury and PCBs) and Figure 8-2 (DDE and PCBs). These figures clearly indicate that mercury and DDE are both extensively co-located with PCBs.

The only area which contains mercury, but not PCBs, is the eastern side of this reach near the connection with Lake Winnebago. Regardless of the remedial action level selected, mercury concentrations here remain in the range of 1 to 5 mg/kg. Even with no remedial action in this reach, mercury concentrations do not exceed 5 mg/kg. These residual concentrations of mercury may pose a risk to water column and benthic invertebrates as well as piscivorous birds.

Under the No Action alternative, DDE concentrations may be more than 1,000 μg/kg. Under the 5,000 ppb action level, DDE concentrations drop to 25 to 100 μg/kg and these DDE concentrations in sediment are still present, although smaller in area, under the 1,000 and 500 ppb action alternatives. At the 250 and 125 ppb action levels, no DDE is present in the sediment. Because all areas of DDE contamination are co-located with PCBs, residual risk from DDE will not exceed residual risks from PCBs.

Conclusion

Based upon the evaluations presented above, the remedial action levels of 1,000 and 250 ppb will meet the stated goals of the RAOs.

8.4.2 Appleton to Little Rapids

Residual PCB Levels

RAO 1 - Surface Water Quality. As presented in Table 8-5, the drinking water criteria of 0.003 ng/L is never met no matter what action level is selected. The wildlife criteria of 0.12 ng/L is not met within 100 years for either the no action or 5,000 ppb action level, yet it is met within 100 years for the other action levels: 52 years (1,000 ppb), 40 years (500 ppb), 21 years (250 ppb), and 19 years (125 ppb). As compared to the Lake Winnebago current maximum concentration of PCBs in surface water (13 ng/L), under the No Action alternative this concentration is met within 4 years, and for all of the other action levels this concentration is met immediately following remediation. Thirty years after remediation, surface water total PCB concentrations range from 0.04 ng/L (125 ppb) to 2.76 ng/L (No Action).

RAO 2 - Human Health. As indicated in Table 8-14, projections for remedial action levels as high as 1,000 ppb can result in the attainment of fish threshold concentrations within 1 year[5] following remediation. For noncancer risks, fish thresholds are met within 1 year following remediation up to a remedial action level of 250 ppb for recreational anglers. As compared to the No Action alternative, the 5,000, 1,000, and 500 ppb action level projections result in a noncancer risk reduction of approximately 34, 89, and 91 percent, respectively. Cancer thresholds are not met within 1 year. As compared to the No Action alternative, the 5,000, 1,000, 500, 250, and 125 ppb action levels result in a cancer risk reduction of approximately 37, 80, 83, 90, and 92 percent, respectively.

For the 125 ppb action level, there are no noncancer risks within 1 year, and cancer risks are estimated to persist for 5 years (recreational intake) to 8 years (high intake). For the 250 ppb action level, noncancer risks persist for less than 1 year (recreational intake) to 2 years (high intake) and cancer risks persist for 7 years (recreational intake) to 9 years (high intake). For the 500 ppb action level, within 1 year there are no estimated noncancer risks to recreational anglers, but high-intake fish consumer noncancer risks persist for 5 years. For the 1,000 ppb action level, noncancer risks persist for 4 years (recreational intake) to 7 years (high intake) and cancer risks persist for 14 years (recreational intake) to 17 years (high intake). For the 5,000 ppb action level, noncancer risks persist for 26 years (recreational intake) to 37 years (high intake), and cancer risks persist for 42 years (recreational intake) to 65 years (high intake). For the No Action alternative, noncancer risks persist for 40 years (recreational intake) to 55 years (high intake), and cancer risks persist for 70 years (recreational intake) to 89 years (high intake).

With the goals in mind of 10 years for safe fish consumption by recreational anglers and 30 years for safe fish consumption by high-intake consumers after completion of an active remedy, only a remedial action level of 500 ppb or less result in meeting these goals. The 500, 250, and 125 ppb action levels only differ by approximately 6 percent in terms of the level of risk reduction achieved. Effectively, therefore, an action level of 500 ppb may be appropriate for this reach and this RAO. The action levels of 5,000 and 1,000 ppb never meet the stated goals, and the 250 and 125 ppb action levels are not appreciably more protective than the 500 ppb action level.

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[5] A projection of "1 year following remediation" is a model output, and should not necessarily be literally interpreted. See footnote 1 in Section 8.4.1, RAO 3 for a discussion.

RAO 3 - Ecological Health. As indicated in Table 8-16, the range of remedial action level projections results in thresholds being met within 7 to 100 years following remediation, with the exception of piscivorous mammal thresholds which are met in less than 1 year for all action levels. As compared to no action, the 5,000, 1,000, 500, 250, and 125 ppb action levels, respectively, result in an estimated risk reduction of 23, 76, 79, 87, and 90 percent for carnivorous birds, respectively; a risk reduction of 11, 66, 71, 82, and 85 percent for piscivorous mammals, respectively; and a risk reduction of 22, 65, 71, 80, and 84 percent for sediment invertebrates, respectively. Attainment of the carnivorous bird threshold ranges from 7 years (125 ppb action level) to 71 years (No Action). Attainment of the piscivorous mammal and sediment thresholds range from 15 years (125 ppb action level) to 100 years (No Action).

With the goal in mind of 30 years for no adverse ecological risks, only a remedial action level of 500 ppb or less is projected to meet this goal. The 1,000 and 500 ppb, and 250 and 125 ppb action levels only differ by approximately 7 and 5 percent, respectively, in terms of the level of risk reduction achieved. The 500 and 250 ppb action levels differ by approximately 50 percent in terms of the level of risk reduction achieved. The 250 and 125 ppb action levels differ by approximately 8 percent in terms of the level of risk reduction achieved. Therefore, an action level of either 500 or 250 ppb may be appropriate for this reach and this RAO. The action levels of 5,000 and 1,000 ppb never result in the achievement of the stated goal, and the 125 ppb action level is not appreciably more protective than the 250 ppb action level.

RAO 4 - Sediment Transport. As presented in Table 8-18, 30 years following remediation the sediment PCB loading rates for the action levels as compared to the No Action alternative represent sediment PCB loading reductions of 42 percent (5,000 ppb), 93 percent (1,000 ppb), 95 percent (500 ppb), 98 percent (250 ppb), and 99 percent (125 ppb).

Residual Mercury and DDE Levels

The distribution and concentrations of mercury and DDE and degree of co-location with PCBs within the Appleton to Little Rapids Reach are shown on Figure 8-3 (mercury and PCBs) and Figure 8-4 (DDE and PCBs). These figures indicate that mercury and DDE are predominantly co-located with PCBs, but that there is one area at which mercury and DDE are both located, but not PCBs. Additionally, much of the PCB sediment contamination in this reach has already been remediated.

The only area which contains mercury and DDE is a small area in the middle of the reach located on the eastern side of the river. Regardless of the remedial action level, mercury concentrations in this area are approximately 1 to 5 mg/kg and DDE concentrations are approximately 25 to 100 μg/kg. These concentrations suggest no risk from DDE, but the potential risk of mercury to sediment invertebrates, as well as piscivorous and carnivorous birds.

Conclusion

Based upon the evaluations presented above, the remedial action levels of 500 and 250 ppb will meet the stated goals of the RAOs for this reach.

8.4.3 Little Rapids to De Pere

Residual PCB Levels

RAO 1 - Surface Water Quality. As presented in Table 8-5, the drinking water criteria of 0.003 ng/L is never met no matter what action level is selected. The wildlife criteria of 0.12 ng/L is not met within 100 years for either the no action or 5,000 ppb action level, yet it is met within 100 years for the other action levels: 65 years (1,000 ppb), 54 years (500 ppb), 40 years (250 ppb), and 27 years (125 ppb). As compared to the Lake Winnebago current maximum concentration of PCBs in surface water (13 ng/L), under the No Action alternative this concentration is met within 9 years, under an action level of 5,000 ppb this concentration is met within 2 years, and for all of the other action levels this concentration is met immediately following remediation. Thirty years after remediation, surface water total PCB concentrations range from 0.08 ng/L (125 ppb) to 5.37 ng/L (no action).

RAO 2 - Human Health. As indicated in Table 8-14, no remedial action level estimates result in the attainment of fish threshold concentrations within 1 year following remediation and assuming no action, the only threshold that is met in less than 100 years is the recreational angler noncancer risk threshold (288 μg/kg). For noncancer risks, fish thresholds are met within 1 year[6] following remediation up to a remedial action level of 125 ppb for high-intake fish consumers, and up to a remedial action level of 500 ppb for recreational anglers. As compared to the 5,000 ppb action level, the 1,000, 500, 250, and 125 ppb action levels result in a noncancer risk reduction of approximately 79, 86, 93, and 95 percent, respectively. As compared to the 5,000 ppb action level, the 1,000, 500, 250, and 125 ppb action levels result in a cancer risk reduction of approximately 62, 74, 83, and 88 percent, respectively.

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[6] A projection of "1 year following remediation" is a model output, and should not necessarily be literally interpreted. See footnote 1 in Section 8.4.1, RAO 3 for a discussion.

For the 125 ppb action level, noncancer risks are estimated to persist for 2 years (recreational intake) to 4 years (high intake), and cancer risks persist for 9 years (recreational intake) to 15 years (high intake). For the 250 ppb action level, noncancer risks are estimated to persist for 2 years (recreational intake) to 7 years (high intake) and cancer risks are estimated to persist for 14 years (recreational intake) to 20 years (high intake). For the 500 ppb action level, the noncancer risks are estimated to persist for 5 years (recreational intake) to 12 years (high intake) and cancer risks are estimated to persist for 20 years (recreational intake) to 29 years (high intake). For the 1,000 ppb action level, noncancer risks are estimated to persist for 9 years (recreational intake) to 17 years (high intake) and the cancer risks are estimated to persist for 30 years (recreational intake) to 42 years (high intake). For the 5,000 ppb action level, noncancer risks are projected to persist for 52 years (recreational intake) to 67 years (high intake), and cancer risks are projected persist for 92 years (recreational intake) to 100 years (high intake). For the No Action alternative, the only threshold that is met in less than 100 years is the threshold for the recreational consumption of walleye which is achieved in 92 years.

With the goals in mind of 10 years for safe fish consumption by recreational anglers and 30 years for safe fish consumption by high-intake consumers, only a remedial action level of 125 ppb results in meeting these goals in this reach.

RAO 3 - Ecological Health. As indicated in Table 8-16, the range of remedial action level projections results in thresholds being met within 1 year following remediation (e.g., piscivorous bird deformity and hatching success for all action levels, except for deformity NOAEC under no action) or thresholds not being met within 100 years (e.g., carnivorous bird, piscivorous mammal, and sediment invertebrate thresholds under the No Action alternative, and the sediment and piscivorous mammal thresholds under the 5,000 ppb action level). As compared to the 5,000 ppb action level, the 1,000, 500, 250, and 125 ppb action levels estimate a risk reduction to carnivorous birds of 71, 84, 89, and 95 percent, respectively. As compared to the 1,000 ppb action level, the 500, 250, and 125 ppb action levels result in a risk reduction to piscivorous mammals of 28, 42, and 65 percent, respectively, and a risk reduction to sediment invertebrates of 29, 39, and 65 percent, respectively. Attainment of the carnivorous bird threshold for the 125 ppb action level to the 5,000 ppb action level ranges from 4 to 76 years, respectively. Attainment of the piscivorous mammal threshold for the 125 ppb action level to the 1,000 ppb action level ranges from 15 to 43 years, respectively. Attainment of the sediment threshold for the 125 ppb action level to the 1,000 ppb action level ranges from 16 to 46 years, respectively.

With the goal in mind of 30 years for no adverse ecological risks, only a remedial action level of 250 ppb or less meets this goal. The 250 and 125 ppb action levels differ by approximately 45 percent in terms of the level of risk reduction achieved. Therefore, the action levels recommended that may be appropriate for this reach and this RAO are 250 and 125 ppb. The action levels of 5,000, 1,000, and 500 ppb should be dropped because they never result in the achievement of the stated goal.

RAO 4 - Sediment Transport. As presented in Table 8-18, 30 years following remediation the sediment PCB loading rates for the action levels as compared to the No Action alternative represent sediment PCB loading reductions of 55 percent (5,000 ppb), 93 percent (1,000 ppb), 96 percent (500 ppb), 97 percent (250 ppb), and 99 percent (125 ppb).

Residual Mercury and DDE Levels

The distribution and concentrations of mercury and DDE and degree of co-location with PCBs within the Little Rapids to De Pere Reach are shown on Figure 8-5 (mercury and PCBs) and Figure 8-6 (DDE and PCBs). These figures indicate that mercury and DDE are predominantly co-located with PCBs.

The residual risk from mercury is about the same for the No Action alternative and the 5,000 ppb action level, although while concentrations of mercury may be as high as 10 mg/kg under both scenarios, the area of contamination is dramatically reduced with remedial action. Under either of these scenarios, mercury may be a risk to all ecological assessment endpoints evaluated except for piscivorous mammals and insectivorous birds (for which there were no data). Under the 1,000, 500, and 250 ppb remedial action levels, mercury levels are consistently between 1 and 5 mg/kg, which like the concentrations found in the Little Lake Butte des Morts Reach, may pose risk to invertebrates and piscivorous birds. At the 125 ppb action level, mercury concentrations of 0 to 1 mg/kg are found in the sediment, but these concentrations are not expected to result in any adverse risk.

Beginning with the 5,000 ppb remedial action level and remaining through the 125 ppb action level, DDE concentrations are between 1 and 25 μg/kg in the sediment and suggest no residual risk to ecological receptors.

Conclusion

Based upon the evaluations presented above, the remedial action level of 125 ppb will meet the stated goals of the RAOs for this reach.

8.4.4 De Pere to Green Bay

Residual PCB Levels

RAO 1 - Surface Water Quality. As presented in Table 8-5, the drinking water criteria of 0.003 ng/L is never met no matter what action level is selected. The wildlife criteria of 0.12 ng/L is not met within 100 years for either the no action or 5,000 ppb action level, yet it is met within 100 years for the other action levels: 69 years (1,000 ppb), 65 years (500 ppb), 40 years (250 ppb), and 27 years (125 ppb). As compared to the Lake Winnebago current maximum concentration of PCBs in surface water (13 ng/L), under the No Action alternative this concentration is not met within 100 years, under an action level of 5,000 ppb this concentration is met within 2 years, and for all of the other action levels this concentration is met immediately following remediation. Thirty years after remediation, surface water total PCB concentrations range from 0.09 ng/L (125 ppb) to 21.08 ng/L (no action).

RAO 2 - Human Health. As indicated in Table 8-14, the No Action alternative model output results in none of the thresholds being met within 100 years. As compared to the 5,000 ppb action level, the 1,000, 500, 250, and 125 ppb action level estimates result in a noncancer risk reduction of approximately 73, 81, 88, and 92 percent, respectively. As compared to the 5,000 ppb action level, the 1,000, 500, 250, and 125 ppb action levels result in a cancer risk reduction of approximately 48, 60, 76, and 83 percent, respectively.

For the 125 ppb remedial action level, noncancer risks are projected to persist for 7 years (recreational and high intake), and cancer risks are projected to persist for 15 years (recreational intake) to 20 years (high intake). For the 250 ppb action level, noncancer risks are projected to persist for 8 years (recreational intake) to 14 years (high intake), and cancer risks are projected to persist for 20 years (recreational intake) to 29 years (high intake). For the 500 ppb action level, noncancer risks are estimated to persist for 14 years (recreational intake) to 20 years (high intake), and cancer risks are estimated to persist for 34 years (recreational intake) to 45 years (high intake). For the 1,000 ppb action level, noncancer risks are projected to persist for 20 years (recreational intake) to 30 years (high intake) and cancer risks are projected to persist for 45 years (recreational intake) to 59 years (high intake). For the 5,000 ppb action level, modeled noncancer risks persist for 79 years (recreational intake) to 100 years (high intake), and modeled cancer risks persist for 100 years (recreational and high intake).

With the goals in mind of 10 years for safe fish consumption by recreational anglers, and 30 years for safe fish consumption by high-intake consumers following completion of an active remedy, none of the remedial action levels results in meeting these goals. The 250 and 125 ppb action levels come closest to achieving this goal, and differ by less than 10 percent in terms of the level of risk reduction achieved. Therefore, an action level of 250 ppb may be appropriate for this reach and this RAO.

RAO 3 - Ecological Health. As indicated in Table 8-16, the range of remedial action level projections results in thresholds being met within 1 year following remediation i.e., all piscivorous bird thresholds with the exception of the piscivorous bird NOAEC under the no action and 5,000 ppb action levels), or thresholds not being met within 100 years i.e., the carnivorous bird, piscivorous mammal, and sediment invertebrate thresholds under the No Action alternative). As compared to the 5,000 ppb action level, the 1,000, 500, 250, and 125 ppb action levels result in a risk reduction to carnivorous birds of 75, 82, 91, and 94 percent, respectively; a risk reduction to piscivorous mammals of 55, 66, 83, and 86 percent, respectively; and a risk reduction to sediment invertebrates of 60, 75, 86, and 94 percent, respectively. Excluding the No Action alternative, attainment of the carnivorous bird threshold ranges from 5 to 79 years, attainment of the piscivorous mammal threshold ranges from 14 to 100 years, and attainment of the sediment threshold ranges from 6 to 93 years for the 125 and 5,000 ppb action levels, respectively.

With the goal in mind of 30 years for no adverse ecological risks, only a remedial action level of 250 or 125 ppb results in meeting this goal. The 250 and 125 ppb action levels differ by approximately 33 percent in terms of the level of risk reduction achieved. Therefore, either action level may be appropriate for this reach and this RAO. The 5,000, 1,000, and 500 ppb action levels never result in the achievement of the stated goal.

RAO 4 - Sediment Transport. As presented in Table 8-18, 30 years following remediation the sediment PCB loading rates for the action levels as compared to the No Action alternative represent sediment PCB loading reductions of 86 percent (5,000 ppb), 98 percent (1,000 ppb), 99 percent (500 ppb), 99 percent (250 ppb), and 100 percent (125 ppb). Compared to the combined sediment PCB loading rate of the other tributaries to Green Bay (10 kg/yr), the No Action alternative results in not meeting this rate within 100 years, the 5,000 ppb action levels results in meeting this rate in 24 years, the 1,000 ppb action level results in meeting this rate in 4 years, the 500 and 250 ppb action levels result in meeting this rate in 1 year, and the 125 ppb action level meets this rate immediately following remediation.

Residual Mercury and DDE Levels

The distribution and concentrations of mercury and DDE and degree of co-location with PCBs within the De Pere to Green Bay Reach are shown on Figure 8-7 (mercury and PCBs) and Figure 8-8 (DDE and PCBs). These figures clearly indicate that mercury and DDE are highly co-located with PCBs.

Under the 5,000, 1,000, and 500 ppb remedial action levels, mercury concentrations are consistently between 1 and 5 mg/kg, which like the concentrations found in the Little Lake Butte des Morts Reach, may pose risk to invertebrates and piscivorous birds. At the 250 and 125 ppb action levels, mercury concentrations of 0 to 1 mg/kg are found in the sediment, but these concentrations are not expected to result in any adverse risk.

DDE concentrations in sediment are found to be reduced with each level of remedial action. At the 5,000 ppb remedial action level, DDE concentrations of 25 to 100 μg/kg in the sediment may be present. At the 1,000 and 500 ppb action levels, these DDE concentrations are reduced to 1 to 25 μg/kg. At the 250 and 125 ppb action levels, DDE concentrations are less than 1 μg/kg. No action DDE concentrations in the sediment are 25 to 100 μg/kg and based on the risk assessment evaluation, these concentrations were found to pose risk to benthic invertebrates, benthic and pelagic fish, and piscivorous and carnivorous birds. Presumably, these risks decrease as the concentrations in the sediment decrease.

Conclusion

Based upon the evaluations presented above, none of the remedial action levels meets all goals, but remedial action levels of 250 and 125 ppb will meet the stated goals of the ecological RAOs.

8.4.5 Green Bay Zone 2

Residual PCB Levels

The remedial action levels considered for this zone included no action, 500, and 1,000 ppb.

RAO 2 - Human Health. As indicated in Table 8-15, none of the human health thresholds are met within 100 years no matter what remedial action level is used in the river or the bay.

RAO 3 - Ecological Health. As indicated in Table 8-17, the piscivorous bird LOAEC ecological thresholds are met in less than 1 year,[7] and the piscivorous bird deformity NOAEC and the carnivorous bird and piscivorous mammal thresholds are not met within 100 years no matter what remedial action level is used in the river or the bay. The only thresholds that are met within 100 years are the piscivorous bird NOAECs. Lower Fox River remedial action levels of 125 and 250 ppb did not affect the length of time required to meet the no observed deformity or hatching success thresholds for piscivorous birds in Green Bay; rather, the length of time was dependent only on the Green Bay action level. The deformity NOAEC threshold is met in the following number of years: 25 years (assuming a Green Bay action level of 500 ppb) and 28 years (assuming a Green Bay action level of 1,000 ppb). For the Lower Fox River remedial action level of 500 ppb, it takes 26 years (Green Bay action level of 500 ppb) and 29 years (Green Bay action level of 1,000 ppb), respectively. For the Lower Fox River remedial action level of 1,000 ppb, it takes 30 years (Green Bay action level of 1,000 ppb) to meet the deformity threshold. Assuming no action in Green Bay, the deformity NOAEC threshold is not met in less than 100 years. The piscivorous bird hatching success NOAEC was met in less than 1 year, except where the Green Bay action level was 1,000 ppb (1,000 ppb action level on the Lower Fox River) or where there was no action in Green Bay (for all Lower Fox River action levels).

Residual Mercury and DDE Levels

The distribution and concentrations of mercury and DDE and degree of co-location with PCBs within the De Pere to Green Bay Reach are shown on Figure 8-9 (mercury and PCBs) and Figure 8-10 (DDE and PCBs). These figures indicate that mercury and DDE are highly co-located with PCBs, and that these compounds are widely dispersed in terms of area, but not in terms of frequency of occurrence. In the 11 samples that were analyzed, mercury was detected in 9 samples, and p,p'-DDD, p,p'-DDE, and p,p'-DDT were never detected (Table 8-4).

Under the no action remedial action level, mercury concentrations are consistently between non-detect and 5 mg/kg, which may pose risk to invertebrates and piscivorous birds. At the 1,000 and 500 ppb action levels, mercury concentrations of up to 1 mg/kg are found in the sediment, but these concentrations are not expected to result in any adverse risk.

[7] A projection of “1 year following remediation” is a model output, and should not necessarily be literally interpreted. See footnote 1 in Section 8.4.1, RAO 3 for a discussion.

8.4.6 Green Bay Zone 3A

Residual PCB Levels

The remedial action levels considered for this zone included no action, 500, and 1,000 ppb.

RAO 2 - Human Health. As indicated in Table 8-15, none of the human health thresholds are met within 100 years no matter what remedial action level is used in the river or the bay.

RAO 3 - Ecological Health. As indicated in Table 8-17, all of the piscivorous bird ecological thresholds, except no observed piscivorous bird deformities, are met in less than 1 year, and the carnivorous bird and piscivorous mammal thresholds are not met within 100 years no matter what remedial action level is used in the river or the bay. Lower Fox River remedial action levels of 125, 250, 500, and 1,000 ppb did not affect the length of time required to meet the no observed piscivorous bird deformity threshold in Green Bay assuming Green Bay action levels of 500 and 1,000 ppb. Rather, the length of time was dependent only on the Green Bay action level. This threshold is met in the following number of years: 8 years (assuming a Green Bay action level of 500 ppb) and 11 years (assuming a Green Bay action level of 1,000 ppb). The number of years to reach this threshold assuming no action in Green Bay ranges from 43 years (with Lower Fox River action levels of 125, 250, 500, and 1,000 ppb), 44 years (with a Lower Fox River action level of 5,000 ppb), to 51 years (assuming no action on the river).

Residual Mercury and DDE Levels

Assuming action levels of 500 and 1,000 ppb or no action in Green Bay Zone 3A, mercury is of potential risk to piscivorous birds and DDE is of no potential risk. These BLRA conclusions are based limited data: 2 sediment samples, 1 benthic fish, 12 pelagial fish, 3 carnivorous birds, and modeled concentrations in piscivorous and carnivorous birds, and piscivorous mammals. No data were available for insectivorous birds. As indicated on Figures 8-9 and 8-10 and in Table 8-4, of the two sediment samples analyzed, mercury and DDD/DDE/DDT were not detected.

8.4.7 Green Bay Zone 3B

Residual PCB Levels

The remedial action levels considered for this zone included no action and 500 ppb.

RAO 2 - Human Health. As indicated in Table 8-15, the only human health threshold that is met in less than 100 years is the noncancer threshold for recreational anglers. This threshold is only met when Green Bay Zone 3B is remediated to an action level of 500 ppb and the Lower Fox River is remediated to either 125, 250, or 500 ppb. Under these different Lower Fox River action levels, it takes 99 years to reach the threshold.

RAO 3 - Ecological Health. As indicated in Table 8-17, all of the piscivorous bird ecological thresholds, except no observed piscivorous bird deformities, are met in less than 1 year, and the carnivorous bird and piscivorous mammal thresholds are not met within 100 years no matter what remedial action level is used in the river or the bay. Lower Fox River remedial action levels of 125, 250, 500, and 1,000 ppb did not affect the length of time required to meet the no observed piscivorous bird deformity threshold in Green Bay assuming a Green Bay action level of 500 ppb. Rather, the length of time was dependent only on the Green Bay action level. This threshold is met in 7 years assuming a Green Bay action level of 500 ppb (Lower Fox River action levels of 125, 250, and 500 ppb). The number of years to reach this threshold assuming no action in Green Bay ranges from 32 years (with as Lower Fox River action levels of 125, 250, 500, and 1,000 ppb), to 33 years (with a Lower Fox River action level of 5,000 ppb), to 38 years assuming no action on the river.

Residual Mercury and DDE Levels

Assuming an action level of 500 ppb or no action in Green Bay Zone 3B, mercury is of risk to benthic invertebrates and potential risk to pelagial fish, and piscivorous and carnivorous birds. DDE is a potential risk for pelagic fish, and piscivorous and carnivorous birds. These BLRA conclusions are based on limited data: 4 sediment samples, 1 benthic fish, 4 pelagial fish, 20 piscivorous birds, and modeled concentrations in piscivorous and carnivorous birds, and piscivorous mammals. No data were available for insectivorous birds. As indicated on Figures 8-9 and 8-10 and in Table 8-4, of the four sediment samples analyzed, DDD/DDE/DDT were not detected, mercury was only detected in one of the samples, and the samples were not collected in areas of known PCB contamination.

8.4.8 Green Bay Zone 4

Residual PCB Levels

No remedial action levels were considered for this zone. Only the No Action alternative was carried forward in the FS.

RAO 2 - Human Health. As indicated in Table 8-15, none of the human health thresholds are met within 100 years no matter what remedial action level is used in the river.

RAO 3 - Ecological Health. As indicated in Table 8-17, all of the piscivorous bird ecological thresholds are met in less than 1 year except for the deformity NOAEC, and the carnivorous bird and piscivorous mammal thresholds are not met within 100 years no matter what remedial action level is used in the river. The deformity NOAEC for piscivorous birds is met within 5 years at all Lower Fox River action levels.

Residual Mercury and DDE Levels

Assuming no action in Green Bay Zone 4, mercury is of potential risk to piscivorous and carnivorous birds, and DDE is a potential risk for pelagic fish and carnivorous birds. These BLRA conclusions are based on limited data: 4 sediment samples, 20 pelagial fish, and modeled concentrations in piscivorous and carnivorous birds, and piscivorous mammals. No data were available for benthic fish or insectivorous birds. As indicated on Figures 8-9 and 8-10 and in Tables 8-3 and 8-4, of the four sediment samples analyzed, DDD/DDE/DDT were not detected, mercury was only detected in one of the samples, and PCB concentrations were less than 500 μg/kg.

Conclusion

For all of Green Bay (zones 2, 3A, 3B, and 4), based upon the evaluations presented above, none of the action levels meet the state goals of the human health RAO. The only ecological RAO goals that are met within 100 years are the piscivorous bird hatching success NOAEC and LOAEC, and the piscivorous bird deformity LOAEC. Additionally, the piscivorous bird deformity NOAEC is met within 100 years in all zones except Zone 2.

8.5 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 wLFRM 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, 1997), there remains uncertainty in the actual magnitude of the changes predicted by the model. These same uncertainties also apply to the GBTOXe model. These uncertainties reside in the models themselves, the assumptions used for each of the functional action levels, and the application of the actual data to the models. An assumption of the models that are used to project sediment loading rates and water, sediment, and tissue concentrations is that no matter what remedial action level is selected, the remediation will take 10 years. A result of this assumption is that all of the model runs start and occur within the same hydrograph time frame. Therefore, water flow rates are consistent for each action level—high and low flow events occur at the same week for each action level. While this simplifies the comparison of residual PCB concentrations and load rates, it is understood that not all remedial action levels will take 10 years to implement. 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 action levels, and not necessarily to provide 100 percent accurate predictions. Within this context, the models employed and the accompanying assumptions are adequate for the purposes of this FS.

Additional uncertainty results from the time between achieving an RAO human health or ecological threshold, and the time until risk reduction is actually observed. While total PCB concentrations in sediments may be at the selected action level concentration, it may take 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 monitoring program (Appendix C).

Use of the wLFRM 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 COCs 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.

8.6 Section 8 Figures and Tables

Figures and tables for Section 8 follow page 8-32 and include:

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Lower Fox River & Green Bay Feasibility Study

Surface Sediment Total PCB and Mercury Distribution: Little Lake Butte des Morts Reach

FIGURE 8-1

FIGURE NO:	FS8-1
CREATED BY:	SCJ
PRINT DATE:	1/18/01
APPROVED:	AGF

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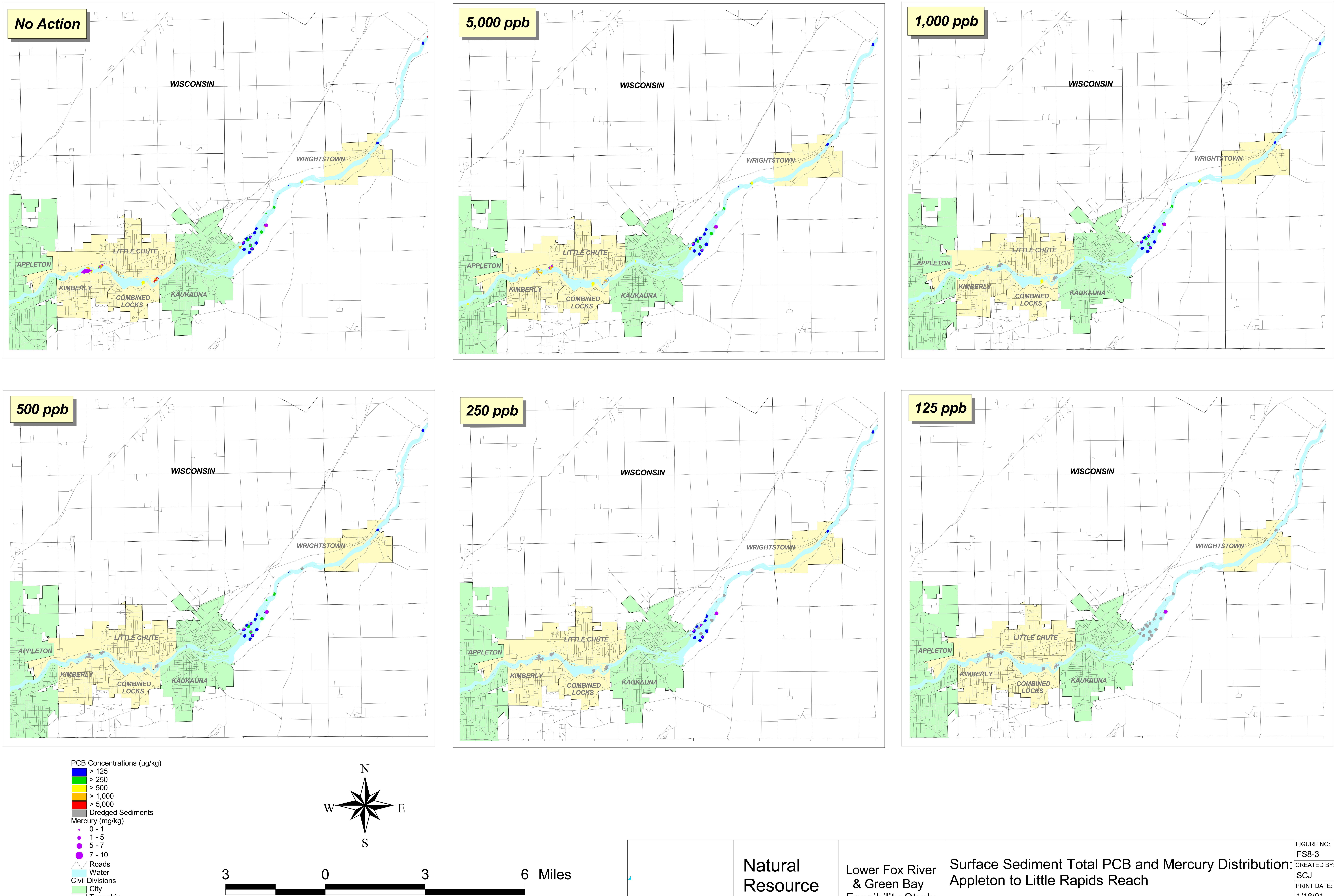
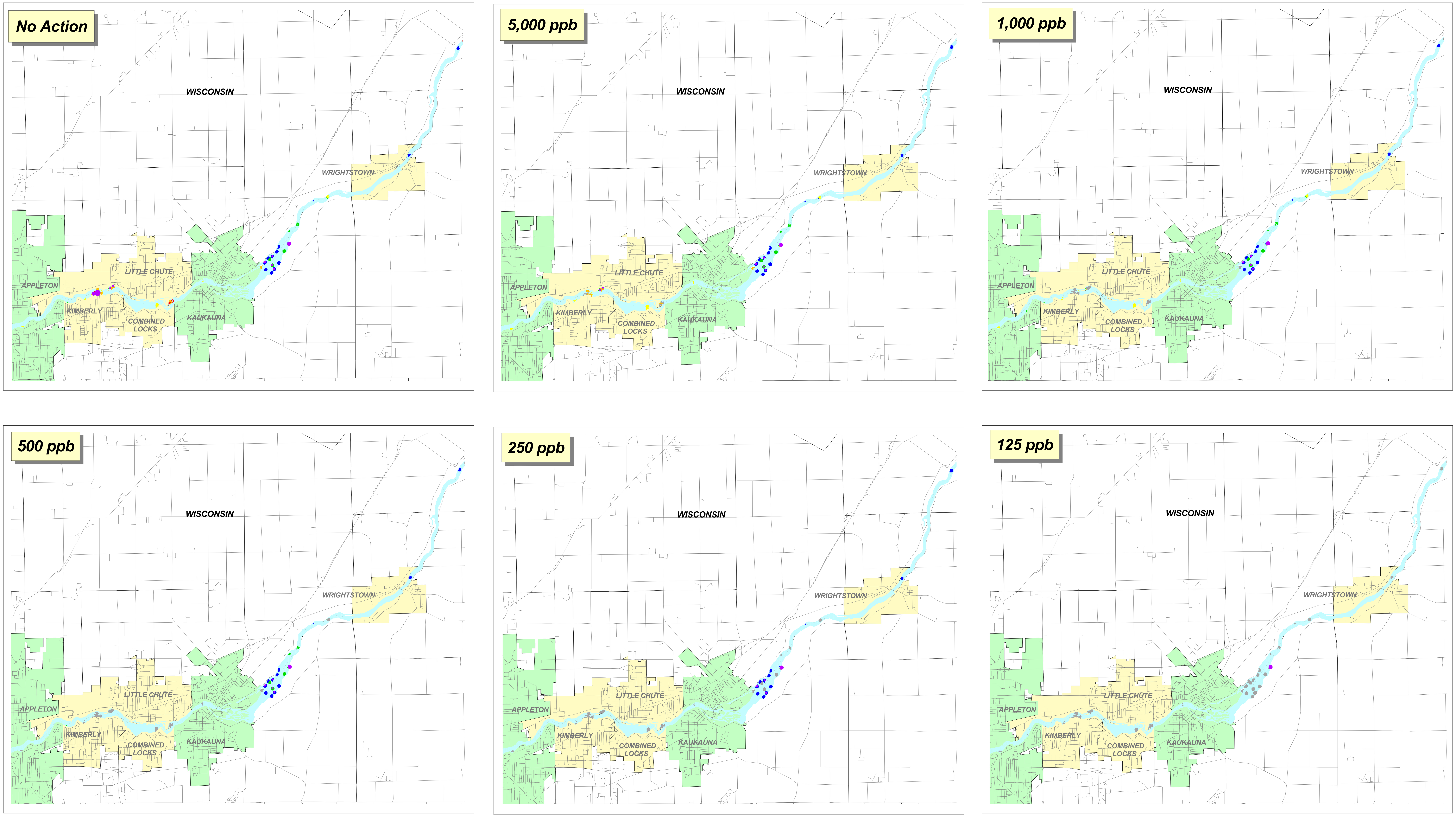
Surface Sediment Total PCB and DDE Distribution: Little Lake Butte des Morts Reach

FIGURE 8-2

FIGURE NO: FS8-2
CREATED BY: SCJ
PRINT DATE: 1/18/01
APPROVED: AGF



Natural Resource Technology	Lower Fox River & Green Bay Feasibility Study	Surface Sediment Total PCB and Mercury Distribution: Appleton to Little Rapids Reach	FIGURE NO: FS8-3
			CREATED BY: SCJ
			PRINT DATE: 1/18/01
		FIGURE 8-3	APPROVED: AGF



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Surface Sediment Total PCB and DDE Distribution: Appleton to Little Rapids Reach

FIGURE 8-4

FIGURE NO: FS8-4
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Surface Sediment Total PCB and Mercury Distribution: Little Rapids to De Pere Reach

FIGURE 8-5

FIGURE NO:	FS8-5
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Lower Fox River & Green Bay Feasibility Study

Surface Sediment Total PCB and DDE Distribution: Little Rapids to De Pere Reach

FIGURE 8-6

FIGURE NO:	FS8-6
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Lower Fox River & Green Bay Feasibility Study

Surface Sediment Total PCB and Mercury Distribution: De Pere to Green Bay Reach

FIGURE 8-7

FIGURE NO: FS8-7
CREATED BY: SCJ
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Lower Fox River & Green Bay Feasibility Study

Surface Sediment Total PCB and DDE Distribution: De Pere to Green Bay Reach

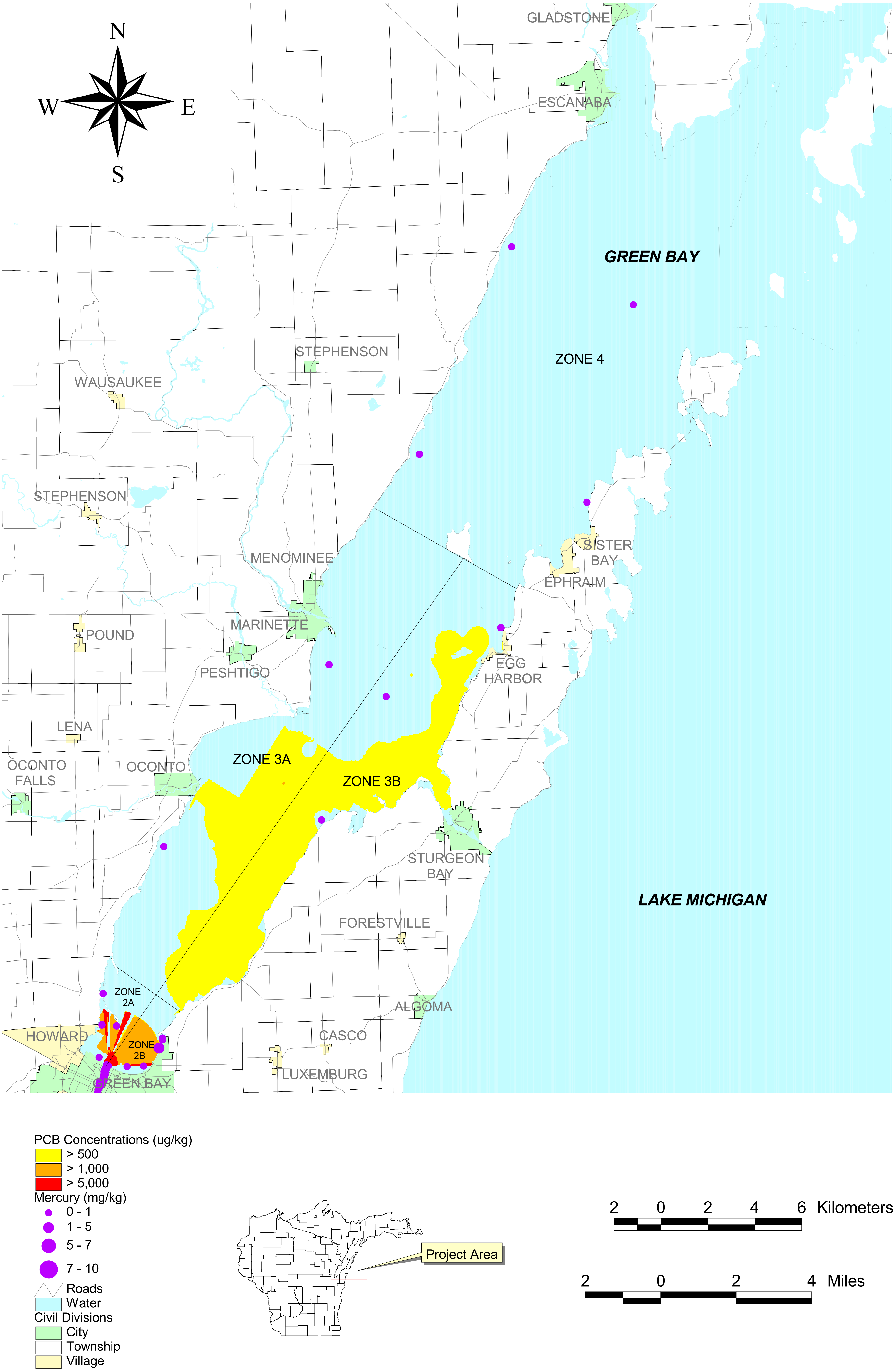
FIGURE 8-8

FIGURE NO: FS8-8

CREATED BY: SCJ

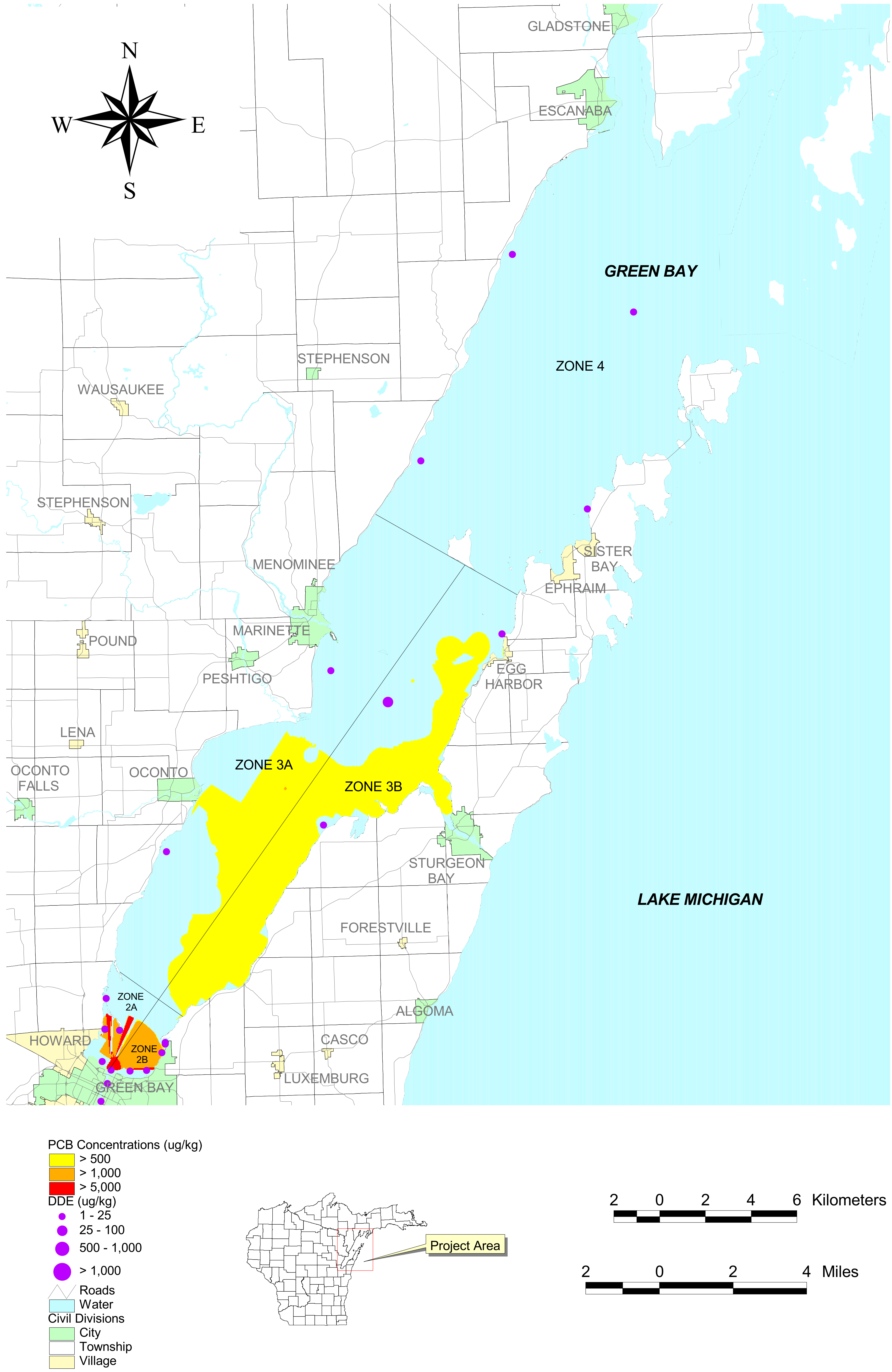
PRINT DATE: 1/18/01

APPROVED: AGF



ThermoRetec

Lower Fox River & Green Bay Feasibility Study			SURFACE SEDIMENT PCB AND MERCURY DISTRIBUTION IN GREEN BAY
DATE: 05/03/01		FILE: FS8GB	FIGURE 8-9



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Lower Fox River & Green Bay Feasibility Study

SURFACE SEDIMENT PCB AND DDE DISTRIBUTION IN GREEN BAY

DATE: 05/03/01 | FILE: FS8GB | FIGURE 8-10

Table 8-1 Relationship of Models Used for Risk Projections in the Lower Fox River or Green Bay

	BASELINE AND REMEDIAL CONDITIONS	FATE AND TRANSPORT MODELS	BIOACCUMULATION MODELS
MODEL	SEDIMENT BED MAPS	WHOLE LOWER FOX RIVER MODEL Little Lake Butte des Morts to River Mouth ENHANCED GREEN BAY TOXICS MODEL Zone 2 through Zone 4	FOX RIVER FOOD Little Lake Butte des Morts to River Mouth GREEN BAY FOOD Zone 2 through Zone 4
OUTPUT	• Baseline and Remedial Action Level Surface Sediment Concentrations • Surface-weighted Average Concentrations • Residual DDE and Mercury Risks (RAO 2 & 3)	• Total PCBs in Water (RAO 1) • Total PCBs in Sediments (RAO 3) • Downstream PCB Transport (RAO 4)	• Total PCBs in Forage Fish (RAO 3) Alewife, shiners, shad • Total PCBs in Benthic Fish (RAO 2 & 3) Carp • Total PCBs in Piscivorous Fish (RAO 2 & 3) Walleye, perch
DOCUMENTATION	*Remedial Investigation* *Technical Memorandum 2e* *Technical Memorandum 2e Addendum* *Technical Memorandum 2f*	*Model Documentation Technical Memo* *wLFRM Model Documentation Report (Appendix B)* *GBTOXe Model Documentation Report (Appendix C)*	*Baseline Risk Assessment* *FRFood Model Documentation Report (Appendix D)* *GBFood Model Documentation Report (Appendix E)*
APPLICATION	*Remedial Investigation* *Baseline Risk Assessment* *Feasibility Study*	*Baseline Risk Assessment* *Feasibility Study*	*Baseline Risk Assessment* *Feasibility Study*

Table 8-2 Whole Body Fish Tissue Concentrations Estimated for Human Health Effects at a 10^{-5} Cancer Risk and a Hazard Index of 1.0

	Fish Parameters	Whole Fish Tissue Concentrations			
	Fillet-to-whole Fish Ratio	Recreational Anglers: Avgerage of Michigan Studies (West *et al.* , 1989; West *et al.* , 1993)		High-intake Fish Consumers: Average of Low-income Minority Anglers and Hmong Anglers (West *et al.* , 1993; Hutchison and Kraft, 1994)	
		RME µg/kg	CTE µg/kg	RME µg/kg	CTE µg/kg
Risk-based Fillet Fish Concentrations (µg/kg) for Risk of 10^{-5} *		18	120	12	63
Whole Fish Thresholds for Risk of 10^{-5}					
Carp	0.53	***34***	***226***	***23***	***119***
Walleye	0.17	***106***	***706***	***71***	***371***
Yellow Perch	0.17	***106***	***706***	***71***	***371***
Risk-based Fillet Fish Concentrations (µg/kg) for HI of 1.0		49	200	31	101
Whole Fish Thresholds for HI of 1.0					
Carp	0.53	***92***	***377***	***58***	***191***
Walleye	0.17	***288***	***1,176***	***181***	***594***
Yellow Perch	0.17	***288***	***1,176***	***181***	***594***

Notes:

* ***Whole fish thresholds for cancer risks of 10^{-4} and 10^{-6} are an order of magnitude higher, and lower, respectively.***

RME indicates reasonable maximum exposure and CTE indicates central tendency exposure.

Whole fish thresholds are **bolded** and in *italics* .

Table 8-3 No Action Non-interpolated Sediment Concentrations of Total PCBs (µg/kg)

Reach or Zone	Number of Samples	Number of Detects	Mean	95% UCL
Little Lake Butte des Morts	302	294	10,724	22,848
Appleton to Little Rapids	131	122	6,751	15,267
Little Rapids to De Pere	209	203	4,782	10,543
De Pere to Green Bay (Green Bay Zone 1)	290	285	4,184	5,510
Green Bay Zone 2	15	14	251	720
Green Bay Zone 3A	15	13	376	518
Green Bay Zone 3B	40	35	542	809
Green Bay Zone 4	31	27	83	117

Table 8-4 No Action Sediment Concentrations of Mercury and DDT/DDD/DDE

Reach or Zone	Analyte	Units	Number of Samples	Number of Detects	Mean	95% UCL	
Little Lake Butte des Morts	Mercury	mg/kg	86	71	1.0	1.4	
	p,p'-DDD	µg/kg	23	4	17.8	19	*
	p,p'-DDE	µg/kg	20	0			
	p,p'-DDT	µg/kg	20	2	13.0	50.0	**
Appleton to Little Rapids	Mercury	mg/kg	10	10	0.8	1.7	
	p,p'-DDD	µg/kg	10	2	1.0	1.7	**
	p,p'-DDE	µg/kg	10	0			
	p,p'-DDT	µg/kg	10	1		3.4	***
Little Rapids to De Pere	Mercury	mg/kg	74	74	3.5	4.0	
	p,p'-DDD	µg/kg	20	5	1.5	2.8	**
	p,p'-DDE	µg/kg	19	4	12.5	22.0	*
	p,p'-DDT	µg/kg	14	3	16.5	20.0	*
De Pere to Green Bay (Green Bay Zone 1)	Mercury	mg/kg	92	89	1.0	1.4	
	p,p'-DDD	µg/kg	22	3	1.2	4.5	**
	p,p'-DDE	µg/kg	22	1		1.9	***
	p,p'-DDT	µg/kg	22	0			
Green Bay Zone 2	Mercury	mg/kg	11	9	0.5	1.5	*
	p,p'-DDD	µg/kg	11	0			
	p,p'-DDE	µg/kg	11	0			
	p,p'-DDT	µg/kg	11	0			
Green Bay Zone 3A	Mercury	mg/kg	2	0			
	p,p'-DDD	µg/kg	2	0			
	p,p'-DDE	µg/kg	2	0			
	p,p'-DDT	µg/kg	2	0			
Green Bay Zone 3B	Mercury	mg/kg	4	1		0.2	***
	p,p'-DDD	µg/kg	4	0			
	p,p'-DDE	µg/kg	4	0			
	p,p'-DDT	µg/kg	4	0			
Green Bay Zone 4	Mercury	mg/kg	4	1		0.11	***
	p,p'-DDD	µg/kg	4	0			
	p,p'-DDE	µg/kg	4	0			
	p,p'-DDT	µg/kg	4	0			

Notes:

* Maximum concentration not the 95% UCL.

** Minimum and maximum concentration.

*** Only concentration.

Table 8-5 Projected Surface Water Concentrations - RAO 1

A. RAO 1: Years to Reach Comparative Surface Water Concentrations

River Reach	Comparative Surface Water Total PCB Concentrations (ng/L)[1]	Action Level (ppb) No Action	5,000	1,000	500	250	125
Little Lake Butte des Morts	drinking water criteria (0.003 ng/L)	>100	>100	>100	>100	>100	>100
	wildlife criteria (0.12 ng/L)	>100	>100	52	39	19	16
	Lake Winnebago maximum concentration (13 ng/L)	4	1	<1	<1	<1	<1
Appleton to Little Rapids	drinking water criteria (0.003 ng/L)	>100	>100	>100	>100	>100	>100
	wildlife criteria (0.12 ng/L)	>100	>100	52	40	21	19
	Lake Winnebago maximum concentration (13 ng/L)	4	<1	<1	<1	<1	<1
Little Rapids to De Pere	drinking water criteria (0.003 ng/L)	>100	>100	>100	>100	>100	>100
	wildlife criteria (0.12 ng/L)	>100	>100	65	54	40	27
	Lake Winnebago maximum concentration (13 ng/L)	9	2	<1	<1	<1	<1
De Pere to Green Bay	drinking water criteria (0.003 ng/L)	>100	>100	>100	>100	>100	>100
	wildlife criteria (0.12 ng/L)	>100	>100	69	65	40	27
	Lake Winnebago maximum concentration (13 ng/L)	>100	2	<1	<1	<1	<1

Note:

[1] Wildlife criteria comes from NR 105 WAC and the Lake Winnebago concentration is the current concentration.

B. RAO 1: Surface Water Total PCB Concentrations - 30 Years Post-remediation (ng/L)[1]

River Reach	Action Level (ppb) No Action	5,000	1,000	500	250	125
Little Lake Butte des Morts	2.99	1.67	0.18	0.13	0.05	0.04
Appleton to Little Rapids	2.76	1.59	0.19	0.14	0.06	0.04
Little Rapids to De Pere	5.37	2.36	0.37	0.24	0.14	0.08
De Pere to Green Bay	21.08	2.60	0.42	0.28	0.15	0.09

Note:

[1] 30 years post-remediation for all action levels.

Table 8-6 Remedial Action Levels and Attainment of Human Health and Ecological Thresholds (Years until Thresholds Are Met): Little Lake Butte des Morts Reach

Media Threshold Concentration (µg/kg) [1]	Media [2]	Threshold Type	Risk Level	Receptor	Remedial Action Level (ppb)					
					No Action	5,000	1,000	500	250	125
7,060	walleye	human health	CTE 10^{-4} cancer risk level	recreational angler	<1	<1	<1	<1	<1	<1
3,710	walleye	human health	CTE 10^{-4} cancer risk level	high-intake fish consumer	<1	<1	<1	<1	<1	<1
2,260	carp	human health	CTE 10^{-4} cancer risk level	recreational angler	8	<1	<1	<1	<1	<1
1,190	carp	human health	CTE 10^{-4} cancer risk level	high-intake fish consumer	20	8	<1	<1	<1	<1
1,176	walleye	human health	CTE hazard index of 1.0	recreational angler	14	2	<1	<1	<1	<1
1,060	walleye	human health	RME 10^{-4} cancer risk level	recreational angler	14	4	<1	<1	<1	<1
710	walleye	human health	RME 10^{-4} cancer risk level	high-intake fish consumer	20	9	<1	<1	<1	<1
706	walleye	human health	CTE 10^{-5} cancer risk level	recreational angler	20	9	<1	<1	<1	<1
588	walleye	human health	CTE hazard index of 1.0	high-intake fish consumer	29	11	<1	<1	<1	<1
377	carp	human health	CTE hazard index of 1.0	recreational angler	55	34	<1	<1	<1	<1
371	walleye	human health	CTE 10^{-5} cancer risk level	high-intake fish consumer	40	17	<1	<1	<1	<1
340	carp	human health	RME 10^{-4} cancer risk level	recreational angler	58	35	2	<1	<1	<1
288	walleye	human health	RME hazard index of 1.0	recreational angler	51	29	<1	<1	<1	<1
230	carp	human health	RME 10^{-4} cancer risk level	high-intake fish consumer	70	46	5	2	<1	<1
226	carp	human health	CTE 10^{-5} cancer risk level	recreational angler	71	46	5	2	<1	<1
189	carp	human health	CTE hazard index of 1.0	high-intake fish consumer	77	54	8	4	<1	<1
181	walleye	human health	RME hazard index of 1.0	high-intake fish consumer	65	40	4	<1	<1	<1
119	carp	human health	CTE 10^{-5} cancer risk level	high-intake fish consumer	100	67	14	10	2	<1
106	walleye	human health	RME 10^{-5} cancer risk level	recreational angler	84	57	9	5	<1	<1
92	carp	human health	CTE hazard index of 1.0	recreational angler	>100	77	17	14	4	2
71	walleye	human health	RME 10^{-5} cancer risk level; CTE 10^{-6} cancer risk level	high-intake fish consumer; recreational angler	100	70	14	10	4	2
58	carp	human health	RME hazard index of 1.0	high-intake fish consumer	>100	95	25	21	8	5
37	walleye	human health	CTE 10^{-6} cancer risk level	high-intake fish consumer	>100	95	25	20	9	7
34	carp	human health	RME 10^{-5} cancer risk level	recreational angler	>100	>100	37	33	15	11
23	carp	human health	RME 10^{-5} cancer risk level; CTE 10^{-6} cancer risk level	high-intake fish consumer; recreational angler	>100	>100	51	42	20	17
12	carp	human health	CTE 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	70	61	34	30
11	walleye	human health	RME 10^{-6} cancer risk level	recreational angler	>100	>100	58	50	25	20
7	walleye	human health	RME 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	70	64	34	30
3	carp	human health	RME 10^{-6} cancer risk level	recreational angler	>100	>100	>100	>100	>100	>100
2	carp	human health	RME 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	>100	>100	>100	>100
7,600	walleye	ecological	LOAEC	fish	<1	<1	<1	<1	<1	<1
7,600	carp	ecological	LOAEC	fish	<1	<1	<1	<1	<1	<1
4,083	gizzard shad	ecological	LOAEC	piscivorous bird deformity	<1	<1	<1	<1	<1	<1
3,879	gizzard shad	ecological	LOAEC	piscivorous bird hatching success	<1	<1	<1	<1	<1	<1
2,399	gizzard shad	ecological	NOAEC	piscivorous bird hatching success	<1	<1	<1	<1	<1	<1
1,207	carp	ecological	LOAEC	carnivorous bird deformity	18	8	<1	<1	<1	<1
1,147	carp	ecological	LOAEC	carnivorous bird hatching success	17	8	<1	<1	<1	<1
760	walleye	ecological	NOAEC	fish	20	8	<1	<1	<1	<1
760	carp	ecological	NOAEC	fish	32	14	<1	<1	<1	<1
709	carp	ecological	NOAEC	carnivorous bird hatching success	34	15	<1	<1	<1	<1
500	carp	ecological	LOAEC	piscivorous mammal	42	22	<1	<1	<1	<1
408	gizzard shad	ecological	NOAEC	piscivorous bird deformity	<1	<1	<1	<1	<1	<1
121	carp	ecological	NOAEC	carnivorous bird deformity	100	67	14	9	< 1	< 1
50	carp	ecological	NOAEC	piscivorous mammal	>100	100	29	25	9	7
223	sediment	ecological	TEL	sediment invertebrate	>100	>100	60	52	26	21

Notes:

[1] Sediment concentration is presented in units of mg/kg OC.
[2] Fish concentrations are whole body.
CTE - Central Tendency Exposure
LOAEC - Lowest Observed Adverse Effect Concentration
NOAEC - No Observed Adverse Effect Concentration
RME - Reasonable Maximum Exposure
TEL - Threshold Effect Level

Table 8-7 Remedial Action Levels and Attainment of Human Health and Ecological Thresholds (Years until Thresholds Are Met): Appleton to Little Rapids Reach

Media Threshold Concentration (µg/kg) [1]	Media [2]	Threshold Type	Risk Level	Receptor	Remedial Action Level (ppb)					
					No Action	5,000	1,000	500	250	125
7,060	walleye	human health	CTE 10^{-4} cancer risk level	recreational angler	<1	<1	<1	<1	<1	<1
3,710	walleye	human health	CTE 10^{-4} cancer risk level	high-intake fish consumer	<1	<1	<1	<1	<1	<1
2,260	carp	human health	CTE 10^{-4} cancer risk level	recreational angler	2	<1	<1	<1	<1	<1
1,190	carp	human health	CTE 10^{-4} cancer risk level	high-intake fish consumer	12	5	<1	<1	<1	<1
1,176	walleye	human health	CTE hazard index of 1.0	recreational angler	9	2	<1	<1	<1	<1
1,060	walleye	human health	RME 10^{-4} cancer risk level	recreational angler	9	2	<1	<1	<1	<1
710	walleye	human health	RME 10^{-4} cancer risk level	high-intake fish consumer	17	9	<1	<1	<1	<1
706	walleye	human health	CTE 10^{-5} cancer risk level	recreational angler	17	9	<1	<1	<1	<1
588	walleye	human health	CTE hazard index of 1.0	high-intake fish consumer	20	9	<1	<1	<1	<1
377	carp	human health	CTE hazard index of 1.0	recreational angler	39	26	4	2	<1	<1
371	walleye	human health	CTE 10^{-5} cancer risk level	high-intake fish consumer	34	17	2	<1	<1	<1
340	carp	human health	RME 10^{-4} cancer risk level	recreational angler	42	30	5	3	<1	<1
288	walleye	human health	RME hazard index of 1.0	recreational angler	40	26	4	<1	<1	<1
230	carp	human health	RME 10^{-4} cancer risk level	high-intake fish consumer	55	37	9	7	2	<1
226	carp	human health	CTE 10^{-5} cancer risk level	recreational angler	55	39	9	7	2	<1
189	carp	human health	CTE hazard index of 1.0	high-intake fish consumer	62	42	12	9	4	2
181	walleye	human health	RME hazard index of 1.0	high-intake fish consumer	55	37	7	5	2	<1
119	carp	human health	CTE 10^{-5} cancer risk level	high-intake fish consumer	76	55	17	15	9	7
106	walleye	human health	RME 10^{-5} cancer risk level	recreational angler	70	42	14	11	7	5
92	carp	human health	RME hazard index of 1.0	recreational angler	87	65	21	17	12	6
71	walleye	human health	RME 10^{-5} cancer risk level; CTE 10^{-6} cancer risk level	high-intake fish consumer; recreational angler	89	65	17	15	9	8
58	carp	human health	RME hazard index of 1.0	high-intake fish consumer	78	84	30	25	17	14
37	walleye	human health	CTE 10^{-6} cancer risk level	high-intake fish consumer	100	92	33	26	17	14
34	carp	human health	RME 10^{-5} cancer risk level	recreational angler	>100	100	43	37	23	14
23	carp	human health	RME 10^{-5} cancer risk level; CTE 10^{-6} cancer risk level	high-intake fish consumer; recreational angler	>100	100	57	45	29	23
12	carp	human health	CTE 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	80	65	42	35
11	walleye	human health	RME 10^{-6} cancer risk level	recreational angler	>100	100	70	55	34	27
7	walleye	human health	RME 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	89	80	50	42
3	carp	human health	RME 10^{-6} cancer risk level	recreational angler	>100	>100	>100	>100	>100	60
2	carp	human health	RME 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	>100	>100	>100	81
7,600	walleye	ecological	LOAEC	fish	<1	<1	<1	<1	<1	<1
7,600	carp	ecological	LOAEC	fish	<1	<1	<1	<1	<1	<1
4,083	gizzard shad	ecological	LOAEC	piscivorous bird deformity	<1	<1	<1	<1	<1	<1
3,879	gizzard shad	ecological	LOAEC	piscivorous bird hatching success	<1	<1	<1	<1	<1	<1
2,399	gizzard shad	ecological	NOAEC	piscivorous bird hatching success	<1	<1	<1	<1	<1	<1
1,207	carp	ecological	LOAEC	carnivorous bird deformity	12	4	<1	<1	<1	<1
1,147	carp	ecological	LOAEC	carnivorous bird hatching success	12	5	<1	<1	<1	<1
760	walleye	ecological	NOAEC	fish	15	8	<1	<1	<1	<1
760	carp	ecological	NOAEC	fish	20	11	<1	<1	<1	<1
709	carp	ecological	NOAEC	carnivorous bird hatching success	21	12	<1	<1	<1	<1
500	carp	ecological	LOAEC	piscivorous mammal	33	17	2	<1	<1	<1
408	gizzard shad	ecological	NOAEC	piscivorous bird deformity	<1	<1	<1	<1	<1	<1
121	carp	ecological	NOAEC	carnivorous bird deformity	71	55	17	15	9	7
50	carp	ecological	NOAEC	piscivorous mammal	100	89	34	29	18	15
771	sediment	ecological	TEL	sediment invertebrate	81	63	28	24	16	13

Notes:

[1] Sediment concentration is presented in units of mg/kg OC.

[2] Fish concentrations are whole body.

CTE - Central Tendency Exposure
LOAEC - Lowest Observed Adverse Effect Concentration
NOAEC - No Observed Adverse Effect Concentration
RME - Reasonable Maximum Exposure
TEL - Threshold Effect Level

Table 8-8 Remedial Action Levels and Attainment of Human Health and Ecological Thresholds (Years until Thresholds Are Met): Little Rapids to De Pere Reach

Media Threshold Concentration (µg/kg) [1]	Media [2]	Threshold Type	Risk Level	Receptor	Remedial Action Level (ppb)					
					No Action	5,000	1,000	500	250	125
7,060	walleye	human health	CTE 10^{-4} cancer risk level	recreational angler	<1	<1	<1	<1	<1	<1
3,710	walleye	human health	CTE 10^{-4} cancer risk level	high-intake fish consumer	2	<1	<1	<1	<1	<1
2,260	carp	human health	CTE 10^{-4} cancer risk level	recreational angler	4	<1	<1	<1	<1	<1
1,190	carp	human health	CTE 10^{-4} cancer risk level	high-intake fish consumer	30	4	<1	<1	<1	<1
1,176	walleye	human health	CTE hazard index of 1.0	recreational angler	30	10	<1	<1	<1	<1
1,060	walleye	human health	RME 10^{-4} cancer risk level	recreational angler	34	14	<1	<1	<1	<1
710	walleye	human health	RME 10^{-4} cancer risk level	high-intake fish consumer	51	20	2	<1	<1	<1
706	walleye	human health	CTE 10^{-5} cancer risk level	recreational angler	51	20	2	<1	<1	<1
588	walleye	human health	CTE hazard index of 1.0	high-intake fish consumer	59	29	2	<1	<1	<1
377	carp	human health	CTE hazard index of 1.0	recreational angler	70	34	4	<1	<1	<1
371	walleye	human health	CTE 10^{-5} cancer risk level	high-intake fish consumer	80	42	8	2	<1	<1
340	carp	human health	RME 10^{-4} cancer risk level	recreational angler	77	38	5	<1	<1	<1
288	walleye	human health	RME hazard index of 1.0	recreational angler	92	52	9	5	2	2
230	carp	human health	RME 10^{-4} cancer risk level	high-intake fish consumer	100	52	9	2	<1	<1
226	carp	human health	CTE 10^{-5} cancer risk level	recreational angler	100	52	9	4	<1	<1
189	carp	human health	CTE hazard index of 1.0	high-intake fish consumer	>100	58	14	5	2	<1
181	walleye	human health	RME hazard index of 1.0	high-intake fish consumer	>100	67	17	12	7	4
119	carp	human health	CTE 10^{-5} cancer risk level	high-intake fish consumer	>100	77	22	14	9	4
106	walleye	human health	RME 10^{-5} cancer risk level	recreational angler	>100	92	30	20	14	9
92	carp	human health	RME hazard index of 1.0	recreational angler	>100	90	30	17	12	7
71	walleye	human health	RME 10^{-5} cancer risk level; CTE 10^{-6} cancer risk level	high-intake fish consumer; recreational angler	>100	100	42	29	20	15
58	carp	human health	RME hazard index of 1.0	high-intake fish consumer	>100	>100	40	27	20	14
37	walleye	human health	CTE 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	62	45	36	15
34	carp	human health	RME 10^{-5} cancer risk level	recreational angler	>100	>100	55	42	34	20
23	carp	human health	RME 10^{-5} cancer risk level; CTE 10^{-6} cancer risk level	high-intake fish consumer; recreational angler	>100	>100	67	54	43	25
12	carp	human health	CTE 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	90	80	65	45
11	walleye	human health	RME 10^{-6} cancer risk level	recreational angler	>100	>100	100	92	79	55
7	walleye	human health	RME 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	>100	>100	>100	70
3	carp	human health	RME 10^{-6} cancer risk level	recreational angler	>100	>100	>100	>100	>100	95
2	carp	human health	RME 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	>100	>100	>100	>100
7,600	walleye	ecological	LOAEC	fish	<1	<1	<1	<1	<1	<1
7,600	carp	ecological	LOAEC	fish	<1	<1	<1	<1	<1	<1
4,083	gizzard shad	ecological	LOAEC	piscivorous bird deformity	<1	<1	<1	<1	<1	<1
3,879	gizzard shad	ecological	LOAEC	piscivorous bird hatching success	<1	<1	<1	<1	<1	<1
2,399	gizzard shad	ecological	NOAEC	piscivorous bird hatching success	<1	<1	<1	<1	<1	<1
1,207	carp	ecological	LOAEC	carnivorous bird deformity	20	4	<1	<1	<1	<1
1,147	carp	ecological	LOAEC	carnivorous bird hatching success	22	5	<1	<1	<1	<1
760	walleye	ecological	NOAEC	fish	45	20	<1	<1	<1	<1
760	carp	ecological	NOAEC	fish	39	14	<1	<1	<1	<1
709	carp	ecological	NOAEC	carnivorous bird hatching success	42	15	<1	<1	<1	<1
500	carp	ecological	LOAEC	piscivorous mammal	61	25	2	<1	<1	<1
408	gizzard shad	ecological	NOAEC	piscivorous bird deformity	2	<1	<1	<1	<1	<1
121	carp	ecological	NOAEC	carnivorous bird deformity	>100	76	22	12	8	4
50	carp	ecological	NOAEC	piscivorous mammal	>100	>100	43	31	25	15
596	sediment	ecological	TEL	sediment invertebrate	>100	>100	46	33	28	16

Notes:

1 Sediment concentration is presented in units of mg/kg OC.
2 Fish concentrations are whole body.
CTE - Central Tendency Exposure
LOAEC - Lowest Observed Adverse Effect Concentration
NOAEC - No Observed Adverse Effect Concentration
RME - Reasonable Maximum Exposure
TEL - Threshold Effect Level

Table 8-9 Remedial Action Levels and Attainment of Human Health and Ecological Thresholds (Years until Thresholds Are Met): De Pere to Green Bay Reach

Media Threshold Concentration (µg/kg) [1]	Media [2]	Threshold Type	Risk Level	Receptor	Remedial Action Level (ppb)					
					No Action	5,000	1,000	500	250	125
7,060	walleye	human health	CTE 10^{-4} cancer risk level	recreational angler	<1	<1	<1	<1	<1	<1
3,710	walleye	human health	CTE 10^{-4} cancer risk level	high-intake fish consumer	100	4	<1	<1	<1	<1
2,260	carp	human health	CTE 10^{-4} cancer risk level	recreational angler	>100	<1	<1	<1	<1	<1
1,190	carp	human health	CTE 10^{-4} cancer risk level	high-intake fish consumer	>100	8	<1	<1	<1	<1
1,176	walleye	human health	CTE hazard index of 1.0	recreational angler	>100	27	2	<1	<1	<1
1,060	walleye	human health	RME 10^{-4} cancer risk level	recreational angler	>100	36	4	<1	<1	<1
710	walleye	human health	RME 10^{-4} cancer risk level	high-intake fish consumer	>100	42	7	4	2	2
706	walleye	human health	CTE 10^{-5} cancer risk level	recreational angler	>100	42	7	4	2	2
588	walleye	human health	CTE hazard index of 1.0	high-intake fish consumer	>100	51	9	5	4	2
377	carp	human health	CTE hazard index of 1.0	recreational angler	>100	22	5	<1	<1	<1
371	walleye	human health	CTE 10^{-5} cancer risk level	high-intake fish consumer	>100	65	15	9	7	4
340	carp	human health	RME 10^{-4} cancer risk level	recreational angler	>100	38	5	2	<1	<1
288	walleye	human health	RME hazard index of 1.0	recreational angler	>100	79	20	14	8	7
230	carp	human health	RME 10^{-4} cancer risk level	high-intake fish consumer	>100	52	10	5	2	2
226	carp	human health	CTE 10^{-5} cancer risk level	recreational angler	>100	52	11	5	2	2
189	carp	human health	CTE hazard index of 1.0	high-intake fish consumer	>100	100	14	7	4	2
181	walleye	human health	RME hazard index of 1.0	high-intake fish consumer	>100	100	30	20	14	7
119	carp	human health	CTE 10^{-5} cancer risk level	high-intake fish consumer	>100	79	20	14	8	5
106	walleye	human health	RME 10^{-5} cancer risk level	recreational angler	>100	100	45	34	20	15
92	carp	human health	RME hazard index of 1.0	recreational angler	>100	92	29	17	9	7
71	walleye	human health	RME 10^{-5} cancer risk level; CTE 10^{-6} cancer risk level	high-intake fish consumer; recreational angler	>100	100	59	45	29	20
58	carp	human health	RME hazard index of 1.0	high-intake fish consumer	>100	100	54	29	17	11
37	walleye	human health	CTE 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	80	70	51	31
34	carp	human health	RME 10^{-5} cancer risk level	recreational angler	>100	>100	58	45	27	17
23	carp	human health	RME 10^{-5} cancer risk level; CTE 10^{-6} cancer risk level	high-intake fish consumer; recreational angler	>100	>100	70	59	38	22
12	carp	human health	CTE 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	92	87	61	42
11	walleye	human health	RME 10^{-6} cancer risk level	recreational angler	>100	>100	100	100	100	77
7	walleye	human health	RME 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	>100	>100	>100	>100
3	carp	human health	RME 10^{-6} cancer risk level	recreational angler	>100	>100	>100	>100	>100	>100
2	carp	human health	RME 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	>100	>100	>100	>100
7,600	walleye	ecological	LOAEC	fish	91	<1	<1	<1	<1	<1
7,600	carp	ecological	LOAEC	fish	8	<1	<1	<1	<1	<1
4,083	alewife	ecological	LOAEC	piscivorous bird deformity	<1	<1	<1	<1	<1	<1
3,879	alewife	ecological	LOAEC	piscivorous bird hatching success	<1	<1	<1	<1	<1	<1
2,399	alewife	ecological	NOAEC	piscivorous bird hatching success	<1	<1	<1	<1	<1	<1
1,207	carp	ecological	LOAEC	carnivorous bird deformity	>100	7	<1	<1	<1	<1
1,147	carp	ecological	LOAEC	carnivorous bird hatching success	>100	8	<1	<1	<1	<1
760	walleye	ecological	NOAEC	fish	>100	42	7	4	2	<1
760	carp	ecological	NOAEC	fish	>100	15	<1	<1	<1	<1
709	carp	ecological	NOAEC	carnivorous bird hatching success	>100	17	<1	<1	<1	<1
500	carp	ecological	LOAEC	piscivorous mammal	>100	27	2	<1	<1	<1
408	alewife	ecological	NOAEC	piscivorous bird deformity	100	9	<1	<1	<1	<1
121	carp	ecological	NOAEC	carnivorous bird deformity	>100	79	20	14	7	5
50	carp	ecological	NOAEC	piscivorous mammal	>100	100	45	34	17	14
632	sediment	ecological	TEL	sediment invertebrate	>100	93	37	23	13	6

Notes:

[1] Sediment concentration is presented in units of mg/kg OC.
[2] Fish concentrations are whole body.
CTE - Central Tendency Exposure
LOAEC - Lowest Observed Adverse Effect Concentration
NOAEC - No Observed Adverse Effect Concentration
RME - Reasonable Maximum Exposure
TEL - Threshold Effect Level

Table 8-10 Remedial Action Levels and Attainment of Human Health and Ecological Thresholds (Years until Thresholds Are Met): Green Bay Zone 2

A. Organized by Fox River Remedial Action Level

Media Threshold Concentration (μg/kg) [1]	Media [2]	Threshold Type	Risk Level	Receptor	Fox River No Action	Fox River 5,000 ppb	Fox River 1,000 ppb		Fox River 500 ppb			Fox River 250 ppb			Fox River 125 ppb		
					Green Bay	Green Bay	Green Bay (ppb)		Green Bay (ppb)			Green Bay (ppb)			Green Bay (ppb)		
					No Action	No Action	No Action	1,000	No Action	1,000	500	No Action	1,000	500	No Action	1,000	500
7,060	walleye	human health	CTE 10^{-4} cancer risk level	recreational angler	45	34	32	< 1	32	< 1	< 1	32	< 1	< 1	32	< 1	< 1
3,710	walleye	human health	CTE 10^{-4} cancer risk level	high-intake fish consumer	83	62	60	3	60	2	2	60	2	2	60	2	< 1
1,176	walleye	human health	CTE hazard index of 1.0	recreational angler	>100	>100	>100	61	>100	59	55	>100	58	54	>100	58	53
1,060	walleye	human health	RME 10^{-4} cancer risk level	recreational angler	>100	>100	>100	75	>100	75	71	>100	74	70	>100	74	69
710	walleye	human health	RME 10^{-4} cancer risk level	high-intake fish consumer	>100	>100	>100	99	>100	99	99	>100	99	99	>100	99	99
706	walleye	human health	CTE 10^{-5} cancer risk level	recreational angler	>100	>100	>100	99	>100	99	99	>100	99	99	>100	99	99
588	walleye	human health	CTE hazard index of 1.0	high-intake fish consumer	>100	>100	>100	>100	>100	>100	99	>100	99	99	>100	99	99
371	walleye	human health	CTE 10^{-5} cancer risk level	high-intake fish consumer	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
288	walleye	human health	RME hazard index of 1.0	recreational angler	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
181	walleye	human health	RME hazard index of 1.0	high-intake fish consumer	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
106	walleye	human health	RME 10^{-5} cancer risk level	recreational angler	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
71	walleye	human health	RME 10^{-5} cancer risk level; RME 10^{-6} cancer risk level	high-intake fish consumer; recreational angler	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
37	walleye	human health	CTE 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
11	walleye	human health	RME 10^{-6} cancer risk level	recreational angler	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
7	walleye	human health	RME 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
7,600	walleye	ecological	LOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
7,600	alewife	ecological	LOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
4,083	alewife	ecological	LOAEC	piscivorous bird deformity	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
3,879	alewife	ecological	LOAEC	piscivorous bird hatching success	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2,399	alewife	ecological	NOAEC	piscivorous bird hatching success	30	24	23	3	23	< 1	< 1	23	< 1	< 1	23	< 1	< 1
1,207	walleye	ecological	LOAEC	carnivorous bird deformity	>100	>100	>100	57	>100	55	51	>100	54	50	>100	54	50
1,147	walleye	ecological	LOAEC	carnivorous bird hatching success	>100	>100	>100	64	>100	63	59	>100	62	58	>100	62	57
760	walleye	ecological	NOAEC	fish	>100	>100	>100	40	>100	39	34	>100	38	33	>100	37	33
760	alewife	ecological	NOAEC	fish	>100	75	74	7	73	6	5	73	6	5	73	6	5
709	walleye	ecological	NOAEC	carnivorous bird hatching success	>100	>100	>100	99	>100	99	99	>100	99	99	>100	99	99
500	walleye	ecological	LOAEC	mink	>100	>100	>100	94	>100	94	91	>100	93	90	>100	93	90
500	alewife	ecological	LOAEC	mink	>100	80	83	10	80	10	9	80	10	8	80	9	8
408	alewife	ecological	NOAEC	piscivorous bird deformity	>100	>100	>100	30	>100	29	26	>100	28	25	>100	28	25
121	walleye	ecological	NOAEC	carnivorous bird deformity	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
50	walleye	ecological	NOAEC	mink	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
50	alewife	ecological	NOAEC	mink	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100

Table 8-10 Remedial Action Levels and Attainment of Human Health and Ecological Thresholds (Years until Thresholds Are Met): Green Bay Zone 2 (Continued)

B. Organized by Green Bay Remedial Action Level

Media Threshold Concentration (µg/kg) [1]	Media [2]	Threshold Type	Risk Level	Receptor	Green Bay No Action						Green Bay 1,000 ppb				Green Bay 500 ppb		
					Fox River (ppb)						Fox River (ppb)				Fox River (ppb)		
					No Action	5,000	1,000	500	250	125	1,000	500	250	125	500	250	125
7,060	walleye	human health	CTE 10^{-4} cancer risk level	recreational angler	45	34	32	32	32	32	< 1	< 1	< 1	< 1	< 1	< 1	< 1
3,710	walleye	human health	CTE 10^{-4} cancer risk level	high-intake fish consumer	83	62	60	60	60	60	3	2	2	2	< 1	2	< 1
1,176	walleye	human health	CTE hazard index of 1.0	recreational angler	>100	>100	>100	>100	>100	>100	61	59	58	58	55	54	53
1,060	walleye	human health	RME 10^{-4} cancer risk level	recreational angler	>100	>100	>100	>100	>100	>100	75	75	74	74	71	70	69
710	walleye	human health	RME 10^{-4} cancer risk level	high-intake fish consumer	>100	>100	> 100	>100	>100	>100	99	99	99	99	99	99	99
706	walleye	human health	CTE 10^{-5} cancer risk level	recreational angler	>100	>100	> 100	>100	>100	>100	99	99	99	99	99	99	99
588	walleye	human health	CTE hazard index of 1.0	high-intake fish consumer	>100	>100	> 100	>100	>100	>100	>100	>100	99	99	99	99	99
371	walleye	human health	CTE 10^{-5} cancer risk level	high-intake fish consumer	>100	>100	> 100	>100	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
288	walleye	human health	RME hazard index of 1.0	recreational angler	>100	>100	> 100	>100	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
181	walleye	human health	RME hazard index of 1.0	high-intake fish consumer	>100	>100	> 100	>100	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
106	walleye	human health	RME 10^{-5} cancer risk level	recreational angler	>100	>100	> 100	>100	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
71	walleye	human health	RME 10^{-5} cancer risk level; RME 10^{-6} cancer risk level	high-intake fish consumer; recreational angler	>100	>100	> 100	>100	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
37	walleye	human health	CTE 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	> 100	>100	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
11	walleye	human health	RME 10^{-6} cancer risk level	recreational angler	>100	>100	> 100	>100	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
7	walleye	human health	RME 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	> 100	>100	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
7,600	walleye	ecological	LOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
7,600	alewife	ecological	LOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
4,083	alewife	ecological	LOAEC	piscivorous bird deformity	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
3,879	alewife	ecological	LOAEC	piscivorous bird hatching success	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2,399	alewife	ecological	NOAEC	piscivorous bird hatching success	30	24	23	23	23	23	3	< 1	< 1	< 1	< 1	< 1	< 1
1,207	walleye	ecological	LOAEC	carnivorous bird deformity	>100	>100	>100	>100	>100	89	57	55	54	54	51	50	50
1,147	walleye	ecological	LOAEC	carnivorous bird hatching success	>100	>100	>100	>100	>100	>100	64	63	62	62	59	58	57
760	walleye	ecological	NOAEC	fish	>100	>100	> 100	>100	>100	>100	40	39	38	37	34	33	33
760	alewife	ecological	NOAEC	fish	>100	75	74	73	73	73	7	6	6	6	5	5	5
709	walleye	ecological	NOAEC	carnivorous bird hatching success	>100	>100	> 100	>100	>100	>100	99	99	99	99	99	99	99
500	walleye	ecological	LOAEC	mink	>100	>100	> 100	>100	>100	>100	94	94	93	93	91	90	90
500	alewife	ecological	LOAEC	mink	>100	83	80	80	80	80	10	10	10	9	9	8	8
408	alewife	ecological	NOAEC	piscivorous bird deformity	>100	>100	>100	>100	>100	>100	30	29	28	28	26	25	25
121	walleye	ecological	NOAEC	carnivorous bird deformity	>100	>100	> 100	>100	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
50	walleye	ecological	NOAEC	mink	>100	>100	> 100	>100	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
50	alewife	ecological	NOAEC	mink	>100	>100	> 100	>100	>100	>100	> 100	>100	>100	>100	> 100	>100	>100

Table 8-11 Remedial Action Levels and Attainment of Human Health and Ecological Thresholds (Years until Thresholds Are Met): Green Bay Zone 3A

A. Organized by Fox River Remedial Action Level

Media Threshold Concentration (µg/kg)[1]	Media[2]	Threshold Type	Risk Level	Receptor	Fox River No Action	Fox River 5,000 ppb	Fox River 1,000 ppb		Fox River 500 ppb			Fox River 250 ppb			Fox River 125 ppb		
					Green Bay No Action	Green Bay No Action	Green Bay (ppb)		Green Bay (ppb)			Green Bay (ppb)			Green Bay (ppb)		
							No Action	1,000	No Action	1,000	500	No Action	1,000	500	No Action	1,000	500
7,060	walleye	human health	CTE 10^{-4} cancer risk level	recreational angler	2	2	2	< 1	2	< 1	< 1	2	< 1	>100	2	< 1	< 1
3,710	walleye	human health	CTE 10^{-4} cancer risk level	high-intake fish consumer	25	19	18	5	18	5	4	18	5	4	18	5	4
1,176	walleye	human health	CTE hazard index of 1.0	recreational angler	99	99	99	60	99	60	55	99	60	55	99	60	55
1,060	walleye	human health	RME 10^{-4} cancer risk level	recreational angler	99	99	99	75	99	74	70	99	74	69	99	74	69
710	walleye	human health	RME 10^{-4} cancer risk level	high-intake fish consumer	>100	90	89	>100	88	>100	>100	88	>100	>100	88	>100	>100
706	walleye	human health	CTE 10^{-5} cancer risk level	recreational angler	>100	91	89	>100	89	>100	>100	89	36	>100	89	>100	>100
588	walleye	human health	CTE hazard index of 1.0	high-intake fish consumer	>100	>100	> 100	>100	>100	>100	>100	>100	57	>100	>100	57	>100
371	walleye	human health	CTE 10^{-5} cancer risk level	high-intake fish consumer	>100	>100	> 100	> 100	>100	>100	> 100	>100	>100	>100	>100	>100	>100
288	walleye	human health	RME hazard index of 1.0	recreational angler	>100	>100	> 100	> 100	>100	>100	> 100	>100	>100	>100	>100	>100	>100
181	walleye	human health	RME hazard index of 1.0	high-intake fish consumer	>100	>100	> 100	> 100	>100	>100	> 100	>100	>100	>100	>100	>100	>100
106	walleye	human health	RME 10^{-5} cancer risk level	recreational angler	>100	>100	> 100	> 100	>100	>100	> 100	>100	>100	>100	>100	>100	>100
71	walleye	human health	RME 10^{-5} cancer risk level; RME 10^{-6} cancer risk level	high-intake fish consumer; recreational angler	>100	>100	> 100	> 100	>100	>100	> 100	>100	>100	>100	>100	>100	>100
37	walleye	human health	CTE 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	> 100	> 100	>100	>100	> 100	>100	>100	>100	>100	>100	>100
11	walleye	human health	RME 10^{-6} cancer risk level	recreational angler	>100	>100	> 100	> 100	>100	>100	> 100	>100	>100	>100	>100	>100	>100
7	walleye	human health	RME 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	> 100	> 100	>100	>100	> 100	>100	>100	>100	>100	>100	>100
7,600	walleye	ecological	LOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
7,600	alewife	ecological	LOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
4,083	alewife	ecological	LOAEC	piscivorous bird deformity	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
3,879	alewife	ecological	LOAEC	piscivorous bird hatching success	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2,399	alewife	ecological	NOAEC	piscivorous bird hatching success	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,207	walleye	ecological	LOAEC	carnivorous bird deformity	99	99	99	57	99	57	51	99	56	51	99	56	50
1,147	walleye	ecological	LOAEC	carnivorous bird hatching success	99	99	99	64	99	63	59	99	63	58	99	63	58
760	walleye	ecological	NOAEC	fish	>100	84	82	31	82	>100	>100	82	>100	>100	82	>100	>100
760	alewife	ecological	NOAEC	fish	6	5	5	< 1	5	< 1	< 1	5	2	< 1	5	2	< 1
709	walleye	ecological	NOAEC	carnivorous bird hatching success	>100	90	89	>100	89	>100	>100	89	>100	>100	88	>100	>100
500	walleye	ecological	LOAEC	mink	>100	>100	> 100	80	>100	79	75	>100	79	75	>100	79	75
500	alewife	ecological	LOAEC	mink	35	30	29	7	29	< 1	5	29	7	5	29	7	5
408	alewife	ecological	NOAEC	piscivorous bird deformity	51	44	43	11	43	11	8	43	11	8	43	11	8
121	walleye	ecological	NOAEC	carnivorous bird deformity	>100	>100	> 100	> 100	>100	>100	> 100	>100	>100	>100	>100	>100	>100
50	walleye	ecological	NOAEC	mink	>100	>100	> 100	> 100	>100	>100	> 100	>100	>100	>100	>100	>100	>100
50	alewife	ecological	NOAEC	mink	>100	>100	> 100	> 100	>100	>100	> 100	>100	>100	>100	>100	>100	>100

Table 8-11 Remedial Action Levels and Attainment of Human Health and Ecological Thresholds (Years until Thresholds Are Met): Green Bay Zone 3A (Continued)

B. Organized by Green Bay Remedial Action Level

Media Threshold Concentration (µg/kg)[1]	Media[2]	Threshold Type	Risk Level	Receptor	Green Bay No Action						Green Bay 1,000 ppb				Green Bay 500 ppb		
					Fox River (ppb)						Fox River (ppb)				Fox River (ppb)		
					No Action	5,000	1,000	500	250	125	1,000	500	250	125	500	250	125
7,060	walleye	human health	CTE 10^{-4} cancer risk level	recreational angler	2	2	2	2	2	2	< 1	< 1	< 1	< 1	< 1	99	< 1
3,710	walleye	human health	CTE 10^{-4} cancer risk level	high-intake fish consumer	25	19	18	18	18	18	5	5	5	5	4	4	4
1,176	walleye	human health	CTE hazard index of 1.0	recreational angler	99	99	99	99	99	99	60	60	60	60	55	55	55
1,060	walleye	human health	RME 10^{-4} cancer risk level	recreational angler	99	99	99	99	99	99	75	74	74	74	70	69	69
710	walleye	human health	RME 10^{-4} cancer risk level	high-intake fish consumer	>100	90	89	88	88	88	99	99	99	99	99	99	99
706	walleye	human health	CTE 10^{-5} cancer risk level	recreational angler	>100	91	89	89	89	89	99	99	99	99	99	99	99
588	walleye	human health	CTE hazard index of 1.0	high-intake fish consumer	>100	>100	>100	>100	>100	>100	99	99	57	57	99	99	99
371	walleye	human health	CTE 10^{-5} cancer risk level	high-intake fish consumer	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
288	walleye	human health	RME hazard index of 1.0	recreational angler	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
181	walleye	human health	RME hazard index of 1.0	high-intake fish consumer	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
106	walleye	human health	RME 10^{-5} cancer risk level	recreational angler	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
71	walleye	human health	RME 10^{-5} cancer risk level; RME 10^{-6} cancer risk level	high-intake fish consumer; recreational angler	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
37	walleye	human health	CTE 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
11	walleye	human health	RME 10^{-6} cancer risk level	recreational angler	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
7	walleye	human health	RME 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
7,600	walleye	ecological	LOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
7,600	alewife	ecological	LOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
4,083	alewife	ecological	LOAEC	piscivorous bird deformity	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
3,879	alewife	ecological	LOAEC	piscivorous bird hatching success	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2,399	alewife	ecological	NOAEC	piscivorous bird hatching success	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,207	walleye	ecological	LOAEC	carnivorous bird deformity	99	99	99	99	99	99	57	57	56	56	51	51	50
1,147	walleye	ecological	LOAEC	carnivorous bird hatching success	99	99	99	99	99	99	64	63	63	63	59	58	58
760	walleye	ecological	NOAEC	fish	>100	84	82	82	82	82	99	99	99	99	99	99	99
760	alewife	ecological	NOAEC	fish	6	5	5	5	5	5	< 1	< 1	2	2	< 1	< 1	< 1
709	walleye	ecological	NOAEC	carnivorous bird hatching success	>100	90	89	89	89	88	99	99	99	99	99	99	99
500	walleye	ecological	LOAEC	mink	>100	>100	>100	>100	>100	>100	80	79	79	79	75	75	75
500	alewife	ecological	LOAEC	mink	35	30	29	29	29	29	7	< 1	7	7	5	5	5
408	alewife	ecological	NOAEC	piscivorous bird deformity	51	44	43	43	43	43	11	11	11	11	8	8	8
121	walleye	ecological	NOAEC	carnivorous bird deformity	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
50	walleye	ecological	NOAEC	mink	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
50	alewife	ecological	NOAEC	mink	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100

Table 8-12 Remedial Action Levels and Attainment of Human Health and Ecological Thresholds (Years until Thresholds Are Met): Green Bay Zone 3B

A. Organized by Fox River Remedial Action Level

Media Threshold Concentration (µg/kg)[1]	Media[2]	Threshold Type	Risk Level	Receptor	Fox River No Action	Fox River 5,000 ppb	Fox River 1,000 ppb	Fox River 500 ppb		Fox River 250 ppb		Fox River 125 ppb	
					Green Bay No Action	Green Bay No Action	Green Bay No Action	Green Bay (ppb) No Action	Green Bay (ppb) 500	Green Bay (ppb) No Action	Green Bay (ppb) 500	Green Bay (ppb) No Action	Green Bay (ppb) 500
7,060	walleye	human health	CTE 10^{-4} cancer risk level	recreational angler	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
3,710	walleye	human health	CTE 10^{-4} cancer risk level	high-intake fish consumer	< 1	< 1	< 1	< 1	< 1	< 1	< 1	3	< 1
1,176	walleye	human health	CTE hazard index of 1.0	recreational angler	59	51	51	50	13	50	13	50	13
1,060	walleye	human health	RME 10^{-4} cancer risk level	recreational angler	67	57	56	56	16	56	16	56	16
710	walleye	human health	RME 10^{-4} cancer risk level	high-intake fish consumer	99	84	83	83	31	82	31	82	31
706	walleye	human health	CTE 10^{-5} cancer risk level	recreational angler	99	84	83	83	31	83	31	83	31
588	walleye	human health	CTE hazard index of 1.0	high-intake fish consumer	99	99	98	98	47	98	47	99	46
371	walleye	human health	CTE 10^{-5} cancer risk level	high-intake fish consumer	>100	97	95	95	98	95	99	95	98
288	walleye	human health	RME hazard index of 1.0	recreational angler	>100	>100	> 100	>100	99	>100	99	>100	99
181	walleye	human health	RME hazard index of 1.0	high-intake fish consumer	>100	>100	> 100	>100	> 100	>100	>100	>100	>100
106	walleye	human health	RME 10^{-5} cancer risk level	recreational angler	>100	>100	> 100	>100	> 100	>100	>100	>100	>100
71	walleye	human health	RME 10^{-5} cancer risk level; RME 10^{-6} cancer risk level	high-intake fish consumer; recreational angler	>100	>100	> 100	>100	> 100	>100	>100	>100	>100
37	walleye	human health	CTE 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	> 100	>100	> 100	>100	>100	>100	>100
11	walleye	human health	RME 10^{-6} cancer risk level	recreational angler	>100	>100	> 100	>100	> 100	>100	>100	>100	>100
7	walleye	human health	RME 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	> 100	>100	> 100	>100	>100	>100	>100
7,600	walleye	ecological	LOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
7,600	alewife	ecological	LOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
4,083	alewife	ecological	LOAEC	piscivorous bird deformity	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
3,879	alewife	ecological	LOAEC	piscivorous bird hatching success	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2,399	alewife	ecological	NOAEC	piscivorous bird hatching success	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,207	walleye	ecological	LOAEC	carnivorous bird deformity	58	50	49	49	13	49	13	49	13
1,147	walleye	ecological	LOAEC	carnivorous bird hatching success	62	53	52	52	14	52	14	52	14
760	walleye	ecological	NOAEC	fish	97	79	78	77	27	77	26	77	26
760	alewife	ecological	NOAEC	fish	5	5	4	4	< 1	4	< 1	4	1
709	walleye	ecological	NOAEC	carnivorous bird hatching success	99	84	83	83	31	83	31	83	31
500	walleye	ecological	LOAEC	mink	90	99	99	99	65	99	65	99	65
500	alewife	ecological	LOAEC	mink	25	22	21	21	4	21	4	21	4
408	alewife	ecological	NOAEC	piscivorous bird deformity	38	33	32	32	7	32	7	32	7
121	walleye	ecological	NOAEC	carnivorous bird deformity	>100	>100	> 100	>100	> 100	>100	>100	>100	>100
50	walleye	ecological	NOAEC	mink	>100	>100	> 100	>100	> 100	>100	>100	>100	>100
50	alewife	ecological	NOAEC	mink	>100	>100	> 100	>100	> 100	>100	>100	>100	>100

Table 8-12 Remedial Action Levels and Attainment of Human Health and Ecological Thresholds (Years until Thresholds Are Met): Green Bay Zone 3B (Continued)

B. Organized by Green Bay Remedial Action Level

Media Threshold Concentration (µg/kg)[1]	Media[2]	Threshold Type	Risk Level	Receptor	Green Bay No Action						Green Bay 500 ppb		
					Fox River (ppb) No Action	5,000	1,000	500	250	125	Fox River (ppb) 500	250	125
7,060	walleye	human health	CTE 10^{-4} cancer risk level	recreational angler	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
3,710	walleye	human health	CTE 10^{-4} cancer risk level	high-intake fish consumer	3	3	3	3	3	3	< 1	< 1	< 1
1,176	walleye	human health	CTE hazard index of 1.0	recreational angler	59	51	51	50	50	50	13	13	13
1,060	walleye	human health	RME 10^{-4} cancer risk level	recreational angler	67	57	56	56	56	56	16	16	16
710	walleye	human health	RME 10^{-4} cancer risk level	high-intake fish consumer	99	84	83	83	82	82	31	31	31
706	walleye	human health	CTE 10^{-5} cancer risk level	recreational angler	99	84	83	83	83	83	31	31	31
588	walleye	human health	CTE hazard index of 1.0	high-intake fish consumer	99	99	98	98	98	98	47	47	46
371	walleye	human health	CTE 10^{-5} cancer risk level	high-intake fish consumer	>100	97	95	95	95	95	98	98	98
288	walleye	human health	RME hazard index of 1.0	recreational angler	>100	>100	> 100	>100	>100	>100	99	99	99
181	walleye	human health	RME hazard index of 1.0	high-intake fish consumer	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
106	walleye	human health	RME 10^{-5} cancer risk level	recreational angler	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
71	walleye	human health	RME 10^{-5} cancer risk level; RME 10^{-6} cancer risk level	high-intake fish consumer; recreational angler	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
37	walleye	human health	CTE 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
11	walleye	human health	RME 10^{-6} cancer risk level	recreational angler	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
7	walleye	human health	RME 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
7,600	walleye	ecological	LOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
7,600	alewife	ecological	LOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
4,083	alewife	ecological	LOAEC	piscivorous bird deformity	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
3,879	alewife	ecological	LOAEC	piscivorous bird hatching success	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
2,399	alewife	ecological	NOAEC	piscivorous bird hatching success	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
1,207	walleye	ecological	LOAEC	carnivorous bird deformity	58	50	49	49	49	49	13	13	13
1,147	walleye	ecological	LOAEC	carnivorous bird hatching success	62	53	52	52	52	52	14	14	14
760	walleye	ecological	NOAEC	fish	97	79	78	77	77	77	27	26	26
760	alewife	ecological	NOAEC	fish	5	5	4	4	4	4	1	< 1	< 1
709	walleye	ecological	NOAEC	carnivorous bird hatching success	99	52	83	83	83	83	31	31	31
500	walleye	ecological	LOAEC	mink	90	99	99	99	99	99	65	65	65
500	alewife	ecological	LOAEC	mink	21	22	21	21	21	21	4	4	4
408	alewife	ecological	NOAEC	piscivorous bird deformity	38	33	32	32	32	32	7	7	7
121	walleye	ecological	NOAEC	carnivorous bird deformity	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
50	walleye	ecological	NOAEC	mink	>100	>100	> 100	>100	>100	>100	> 100	>100	>100
50	alewife	ecological	NOAEC	mink	>100	>100	> 100	>100	>100	>100	> 100	>100	>100

Table 8-13 Remedial Action Levels and Attainment of Human Health and Ecological Thresholds (Years until Thresholds Are Met): Green Bay Zone 4

A. Organized by Fox River Remedial Action Level

Media Threshold Concentration (µg/kg) [1]	Media [2]	Threshold Type	Risk Level	Receptor	Fox River No Action / Green Bay No Action	Fox River 5,000 ppb / Green Bay No Action	Fox River 1,000 ppb / Green Bay No Action	Fox River 500 ppb / Green Bay No Action	Fox River 250 ppb / Green Bay No Action	Fox River 125 ppb / Green Bay No Action
7,060	walleye	human health	CTE 10^{-4} cancer risk level	recreational angler	< 1	< 1	< 1	< 1	< 1	< 1
3,710	walleye	human health	CTE 10^{-4} cancer risk level	high-intake fish consumer	< 1	< 1	< 1	< 1	< 1	< 1
1,176	walleye	human health	CTE hazard index of 1.0	recreational angler	91	81	86	86	86	86
1,060	walleye	human health	RME 10^{-4} cancer risk level	recreational angler	99	99	99	99	99	99
710	walleye	human health	RME 10^{-4} cancer risk level	high-intake fish consumer	>100	>100	> 100	>100	>100	>100
706	walleye	human health	CTE 10^{-5} cancer risk level	recreational angler	>100	>100	> 100	>100	>100	>100
588	walleye	human health	CTE hazard index of 1.0	high-intake fish consumer	>100	>100	> 100	>100	>100	>100
371	walleye	human health	CTE 10^{-5} cancer risk level	high-intake fish consumer	>100	>100	> 100	>100	>100	>100
288	walleye	human health	RME hazard index of 1.0	recreational angler	>100	>100	> 100	>100	>100	>100
181	walleye	human health	RME hazard index of 1.0	high-intake fish consumer	>100	>100	> 100	>100	>100	>100
106	walleye	human health	RME 10^{-5} cancer risk level	recreational angler	>100	>100	> 100	>100	>100	>100
71	walleye	human health	RME 10^{-5} cancer risk level; RME 10^{-6} cancer risk level	high-intake fish consumer; recreational angler	>100	>100	> 100	>100	>100	>100
37	walleye	human health	CTE 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	> 100	>100	>100	>100
11	walleye	human health	RME 10^{-6} cancer risk level	recreational angler	>100	>100	> 100	>100	>100	>100
7	walleye	human health	RME 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	> 100	>100	>100	>100
7,600	walleye	ecological	LOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1
7,600	alewife	ecological	LOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1
4,083	alewife	ecological	LOAEC	piscivorous bird deformity	< 1	< 1	< 1	< 1	< 1	< 1
3,879	alewife	ecological	LOAEC	piscivorous bird hatching success	< 1	< 1	< 1	< 1	< 1	< 1
2,399	alewife	ecological	NOAEC	piscivorous bird hatching success	< 1	< 1	< 1	< 1	< 1	< 1
1,207	walleye	ecological	LOAEC	carnivorous bird deformity	91	81	80	80	80	80
1,147	walleye	ecological	LOAEC	carnivorous bird hatching success	99	95	94	94	94	94
760	walleye	ecological	NOAEC	fish	99	99	99	99	99	99
760	alewife	ecological	NOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1
709	walleye	ecological	NOAEC	carnivorous bird hatching success	>100	>100	> 100	>100	>100	>100
500	walleye	ecological	LOAEC	mink	>100	>100	> 100	>100	>100	>100
500	alewife	ecological	LOAEC	mink	< 1	< 1	< 1	< 1	< 1	< 1
408	alewife	ecological	NOAEC	piscivorous bird deformity	5	5	5	5	5	5
121	walleye	ecological	NOAEC	carnivorous bird deformity	>100	>100	> 100	>100	>100	>100
50	walleye	ecological	NOAEC	mink	>100	>100	> 100	>100	>100	>100
50	alewife	ecological	NOAEC	mink	>100	>100	> 100	>100	>100	>100

Table 8-13 Remedial Action Levels and Attainment of Human Health and Ecological Thresholds (Years until Thresholds are Met): Green Bay Zone 4 (Continued)

B. Organized by Green Bay Remedial Action Level

Media Threshold Concentration (µg/kg) [1]	Media [2]	Threshold Type	Risk Level	Receptor	Green Bay No Action					
					Fox River (ppb)					
					No Action	5,000	1,000	500	250	125
7,060	walleye	human health	CTE 10^{-4} cancer risk level	recreational angler	< 1	< 1	< 1	< 1	< 1	< 1
3,710	walleye	human health	CTE 10^{-4} cancer risk level	high-intake fish consumer	< 1	< 1	< 1	< 1	< 1	< 1
1,176	walleye	human health	CTE hazard index of 1.0	recreational angler	91	81	86	86	86	86
1,060	walleye	human health	RME 10^{-4} cancer risk level	recreational angler	99	99	99	99	99	99
710	walleye	human health	RME 10^{-4} cancer risk level	high-intake fish consumer	>100	>100	> 100	>100	>100	>100
706	walleye	human health	CTE 10^{-5} cancer risk level	recreational angler	>100	>100	> 100	>100	>100	>100
588	walleye	human health	CTE hazard index of 1.0	high-intake fish consumer	>100	>100	> 100	>100	>100	>100
371	walleye	human health	CTE 10^{-5} cancer risk level	high-intake fish consumer	>100	>100	> 100	>100	>100	>100
288	walleye	human health	RME hazard index of 1.0	recreational angler	>100	>100	> 100	>100	>100	>100
181	walleye	human health	RME hazard index of 1.0	high-intake fish consumer	>100	>100	> 100	>100	>100	>100
106	walleye	human health	RME 10^{-5} cancer risk level	recreational angler	>100	>100	> 100	>100	>100	>100
71	walleye	human health	RME 10^{-5} cancer risk level; RME 10^{-6} cancer risk level	high-intake fish consumer; recreational angler	>100	>100	> 100	>100	>100	>100
37	walleye	human health	CTE 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	> 100	>100	>100	>100
11	walleye	human health	RME 10^{-6} cancer risk level	recreational angler	>100	>100	> 100	>100	>100	>100
7	walleye	human health	RME 10^{-6} cancer risk level	high-intake fish consumer	>100	>100	> 100	>100	>100	>100
7,600	walleye	ecological	LOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1
7,600	alewife	ecological	LOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1
4,083	alewife	ecological	LOAEC	piscivorous bird deformity	< 1	< 1	< 1	< 1	< 1	< 1
3,879	alewife	ecological	LOAEC	piscivorous bird hatching success	< 1	< 1	< 1	< 1	< 1	< 1
2,399	alewife	ecological	NOAEC	piscivorous bird hatching success	< 1	< 1	< 1	< 1	< 1	< 1
1,207	walleye	ecological	LOAEC	carnivorous bird deformity	91	81	80	80	80	80
1,147	walleye	ecological	LOAEC	carnivorous bird hatching success	99	95	94	94	94	94
760	walleye	ecological	NOAEC	fish	99	99	99	99	99	99
760	alewife	ecological	NOAEC	fish	< 1	< 1	< 1	< 1	< 1	< 1
709	walleye	ecological	NOAEC	carnivorous bird hatching success	>100	>100	> 100	>100	>100	>100
500	walleye	ecological	LOAEC	mink	>100	>100	> 100	>100	>100	>100
500	alewife	ecological	LOAEC	mink	< 1	< 1	< 1	< 1	< 1	< 1
408	alewife	ecological	NOAEC	piscivorous bird deformity	5	5	5	5	5	5
121	walleye	ecological	NOAEC	carnivorous bird deformity	>100	>100	> 100	>100	>100	>100
50	walleye	ecological	NOAEC	mink	>100	>100	> 100	>100	>100	>100
50	alewife	ecological	NOAEC	mink	>100	>100	> 100	>100	>100	>100

Table 8-14 RAO 2: Years to Reach Human Health Thresholds for Lower Fox River Remedial Action Levels

River Reach	Whole Fish Threshold Concentration (µg/kg)	Fish	Risk Level	Receptor	Remedial Action Level (ppb)					
					No Action	5,000	1,000	500	250	125
Little Lake Butte des Morts	288	walleye	RME hazard index of 1.0	recreational angler	51	29	<1	<1	<1	<1
	181	walleye	RME hazard index of 1.0	high-intake fish consumer	65	40	4	<1	<1	<1
	106	walleye	RME 10^{-5} cancer risk level	recreational angler	84	57	9	5	<1	<1
	71	walleye	RME 10^{-5} cancer risk level	high-intake fish consumer	100	70	14	10	4	2
Appleton to Little Rapids	288	walleye	RME hazard index of 1.0	recreational angler	40	26	4	<1	<1	<1
	181	walleye	RME hazard index of 1.0	high-intake fish consumer	55	37	7	5	2	<1
	106	walleye	RME 10^{-5} cancer risk level	recreational angler	70	42	14	11	7	5
	71	walleye	RME 10^{-5} cancer risk level	high-intake fish consumer	89	65	17	15	9	8
Little Rapids to De Pere	288	walleye	RME hazard index of 1.0	recreational angler	92	52	9	5	2	2
	181	walleye	RME hazard index of 1.0	high-intake fish consumer	>100	67	17	12	7	4
	106	walleye	RME 10^{-5} cancer risk level	recreational angler	>100	92	30	20	14	9
	71	walleye	RME 10^{-5} cancer risk level	high-intake fish consumer	>100	100	42	29	20	15
De Pere to Green Bay	288	walleye	RME hazard index of 1.0	recreational angler	>100	79	20	14	8	7
	181	walleye	RME hazard index of 1.0	high-intake fish consumer	>100	100	30	20	14	9
	106	walleye	RME 10^{-5} cancer risk level	recreational angler	>100	100	45	34	20	15
	71	walleye	RME 10^{-5} cancer risk level	high-intake fish consumer	>100	100	59	45	29	20

Table 8-15 RAO 2: Years to Reach Human Health Thresholds for Green Bay Remedial Action Levels

Green Bay Zone	Whole Fish Threshold Concentration (µg/kg)	Fish Species	Risk Level	Receptor	Fox River No Action	Fox River 5,000 ppb	Fox River 1,000 ppb		Fox River 500 ppb			Fox River 250 ppb			Fox River 125 ppb		
					Green Bay No Action	Green Bay No Action	Green Bay (ppb)		Green Bay (ppb)			Green Bay (ppb)			Green Bay (ppb)		
							No Action	1,000	No Action	1,000	500	No Action	1,000	500	No Action	1,000	500
2	288	walleye	RME hazard index of 1.0	recreational angler	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
	181	walleye	RME hazard index of 1.0	high-intake fish consumer	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
	106	walleye	RME 10^{-5} cancer risk level	recreational angler	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
	71	walleye	RME 10^{-5} cancer risk level	high-intake fish consumer	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
3A	288	walleye	RME hazard index of 1.0	recreational angler	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
	181	walleye	RME hazard index of 1.0	high-intake fish consumer	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
	106	walleye	RME 10^{-5} cancer risk level	recreational angler	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
	71	walleye	RME 10^{-5} cancer risk level	high-intake fish consumer	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
3B	288	walleye	RME hazard index of 1.0	recreational angler	>100	>100	>100	NC	>100	NC	99	>100	NC	99	>100	NC	99
	181	walleye	RME hazard index of 1.0	high-intake fish consumer	>100	>100	>100	NC	>100	NC	>100	>100	NC	>100	>100	NC	>100
	106	walleye	RME 10^{-5} cancer risk level	recreational angler	>100	>100	>100	NC	>100	NC	>100	>100	NC	>100	>100	NC	>100
	71	walleye	RME 10^{-5} cancer risk level	high-intake fish consumer	>100	>100	>100	NC	>100	NC	>100	>100	NC	>100	>100	NC	>100
4	288	walleye	RME hazard index of 1.0	recreational angler	>100	>100	>100	NC	>100	NC	NC	>100	NC	NC	>100	NC	NC
	181	walleye	RME hazard index of 1.0	high-intake fish consumer	>100	>100	>100	NC	>100	NC	NC	>100	NC	NC	>100	NC	NC
	106	walleye	RME 10^{-5} cancer risk level	recreational angler	>100	>100	>100	NC	>100	NC	NC	>100	NC	NC	>100	NC	NC
	71	walleye	RME 10^{-5} cancer risk level	high-intake fish consumer	>100	>100	>100	NC	>100	NC	NC	>100	NC	NC	>100	NC	NC

Note:

NC - Not Considered.

Table 8-16 RAO 3: Years to Reach Ecological Thresholds for Lower Fox River Remedial Action Levels

River Reach	Media Threshold Concentration (µg/kg) [1]	Media [2]	Risk Level	Receptor	Remedial Action Level (ppb)					
					No Action	5,000	1,000	500	250	125
Little Lake Butte des Morts	4,083	gizzard shad	LOAEC	piscivorous bird deformity	<1	<1	<1	<1	<1	<1
	3,879	gizzard shad	LOAEC	piscivorous bird hatching success	<1	<1	<1	<1	<1	<1
	2,399	gizzard shad	NOAEC	piscivorous bird hatching success	<1	<1	<1	<1	<1	<1
	408	gizzard shad	NOAEC	piscivorous bird deformity	<1	<1	<1	<1	<1	<1
	121	carp	NOAEC	carnivorous bird deformity	100	67	14	9	<1	<1
	50	carp	NOAEC	piscivorous mammal	>100	100	29	25	9	7
	223	sediment	TEL	sediment invertebrate	>100	>100	60	52	26	21
Appleton to Little Rapids	4,083	gizzard shad	LOAEC	piscivorous bird deformity	<1	<1	<1	<1	<1	<1
	3,879	gizzard shad	LOAEC	piscivorous bird hatching success	<1	<1	<1	<1	<1	<1
	2,399	gizzard shad	NOAEC	piscivorous bird hatching success	<1	<1	<1	<1	<1	<1
	408	gizzard shad	NOAEC	piscivorous bird deformity	<1	<1	<1	<1	<1	<1
	121	carp	NOAEC	carnivorous bird deformity	71	55	17	15	9	7
	50	carp	NOAEC	piscivorous mammal	100	89	34	29	18	15
	771	sediment	TEL	sediment invertebrate	81	63	28	24	16	13
Little Rapids to De Pere	4,083	gizzard shad	LOAEC	piscivorous bird deformity	<1	<1	<1	<1	<1	<1
	3,879	gizzard shad	LOAEC	piscivorous bird hatching success	<1	<1	<1	<1	<1	<1
	2,399	gizzard shad	NOAEC	piscivorous bird hatching success	<1	<1	<1	<1	<1	<1
	408	gizzard shad	NOAEC	piscivorous bird deformity	2	<1	<1	<1	<1	<1
	121	carp	NOAEC	carnivorous bird deformity	>100	76	22	12	8	4
	50	carp	NOAEC	piscivorous mammal	>100	>100	43	31	25	15
	596	sediment	TEL	sediment invertebrate	>100	>100	46	33	28	16
De Pere to Green Bay	4,083	alewife	LOAEC	piscivorous bird deformity	<1	<1	<1	<1	<1	<1
	3,879	alewife	LOAEC	piscivorous bird hatching success	<1	<1	<1	<1	<1	<1
	2,399	alewife	NOAEC	piscivorous bird hatching success	<1	<1	<1	<1	<1	<1
	408	alewife	NOAEC	piscivorous bird deformity	100	9	<1	<1	<1	<1
	121	carp	NOAEC	carnivorous bird deformity	>100	79	20	14	7	5
	50	carp	NOAEC	piscivorous mammal	>100	100	45	34	17	14
	632	sediment	TEL	sediment invertebrate	>100	93	37	23	13	6

Notes:

[1] Sediment concentration is presented in units of mg/kg OC.

[2] Fish concentrations are whole body.

Table 8-17 RAO 3: Years to Reach Ecological Thresholds for Green Bay Remedial Action Levels

Green Bay Zone	Threshold Type	Fish Species	Thresholds Name	Whole Fish Threshold Concentration (µg/kg)	Fox River No Action	Fox River 5,000 ppb	Fox River 1,000 ppb		Fox River 500 ppb			Fox River 250 ppb			Fox River 125 ppb		
					Green Bay No Action	Green Bay No Action	Green Bay (ppb)		Green Bay (ppb)			Green Bay (ppb)			Green Bay (ppb)		
							No Action	1,000	No Action	1,000	500	No Action	1,000	500	No Action	1,000	500
2	Ecological	alewife	Forster's tern deform. LOAEC	4,083	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
		alewife	Forster's tern hatch suc. LOAEC	3,879	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
		alewife	Forster's tern hatch suc. NOAEC	2,399	30	24	23	3	23	< 1	< 1	23	< 1	< 1	23	< 1	< 1
		alewife	Forster's tern deform. NOAEC	408	>100	>100	>100	30	>100	29	26	>100	28	25	>100	28	25
		walleye	bald eagle deform. NOAEC	121	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
		walleye	mink NOAEC	50	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
		alewife	mink NOAEC	50	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
3A	Ecological	alewife	Forster's tern deform. LOAEC	4,083	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
		alewife	Forster's tern hatch suc. LOAEC	3,879	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
		alewife	Forster's tern hatch suc. NOAEC	2,399	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1	< 1
		alewife	Forster's tern deform. NOAEC	408	51	44	43	11	43	11	8	43	11	8	43	11	8
		walleye	bald eagle deform. NOAEC	121	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
		walleye	mink NOAEC	50	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
		alewife	mink NOAEC	50	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100	>100
3B	Ecological	alewife	Forster's tern deform. LOAEC	4,083	< 1	< 1	< 1	NC	< 1	NC	< 1	< 1	NC	< 1	< 1	NC	< 1
		alewife	Forster's tern hatch suc. LOAEC	3,879	< 1	< 1	< 1	NC	< 1	NC	< 1	< 1	NC	< 1	< 1	NC	< 1
		alewife	Forster's tern hatch suc. NOAEC	2,399	< 1	< 1	< 1	NC	< 1	NC	< 1	< 1	NC	< 1	< 1	NC	< 1
		alewife	Forster's tern deform. NOAEC	408	38	33	32	NC	32	NC	7	32	NC	7	32	NC	7
		walleye	bald eagle deform. NOAEC	121	>100	>100	>100	NC	>100	NC	>100	>100	NC	>100	>100	NC	>100
		walleye	mink NOAEC	50	>100	>100	>100	NC	>100	NC	>100	>100	NC	>100	>100	NC	>100
		alewife	mink NOAEC	50	>100	>100	>100	NC	>100	NC	>100	>100	NC	>100	>100	NC	>100
4	Ecological	alewife	Forster's tern deform. LOAEC	4,083	< 1	< 1	< 1	NC	< 1	NC	NC	< 1	NC	NC	< 1	NC	NC
		alewife	Forster's tern hatch suc. LOAEC	3,879	< 1	< 1	< 1	NC	< 1	NC	NC	< 1	NC	NC	< 1	NC	NC
		alewife	Forster's tern hatch suc. NOAEC	2,399	< 1	< 1	< 1	NC	< 1	NC	NC	< 1	NC	NC	< 1	NC	NC
		alewife	Forster's tern deform. NOAEC	408	5	5	5	NC	5	NC	NC	5	NC	NC	5	NC	NC
		walleye	Bald eagle deform. NOAEC	121	>100	>100	>100	NC	>100	NC	NC	>100	NC	NC	>100	NC	NC
		walleye	mink NOAEC	50	>100	>100	>100	NC	>100	NC	NC	>100	NC	NC	>100	NC	NC
		alewife	mink NOAEC	50	>100	>100	>100	NC	>100	NC	NC	>100	NC	NC	>100	NC	NC

Note:

NC - Not Considered

Table 8-18 RAO 4: Sediment Loading Rates - 30 Years Post-remediation (kg/yr)

River Reach	Action Level (ppb)					
	No Action	5,000	1,000	500	250	125
Little Lake Butte des Morts	11.33	6.35	0.66	0.49	0.18	0.15
Appleton to Little Rapids	11.33	6.55	0.78	0.57	0.23	0.17
Little Rapids to De Pere	21.25	9.54	1.46	0.94	0.54	0.32
De Pere to Green Bay	75.27	10.51	1.67	1.10	0.61	0.34

9 Detailed Analysis of Remedial Alternatives

This section presents the detailed analysis of individual remedial alternatives for the river reaches and Green Bay zones that were developed in Section 7 of this FS Report. A total of seven possible remedial alternatives (Alternatives A through G) are compared to nine evaluation criteria designed to address CERCLA remediation requirements. Figure 9-1 provides a schematic view of the detailed analysis as described in the EPA RI/FS Guidance (EPA, 1988). As described in the EPA RI/FS Guidance, the detailed analysis for individual alternatives consists of the following three sets of analysis involving nine evaluation criteria:

- **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 (technical and administrative feasibility)
  - Cost

- **Regulatory/Community Criteria**
  - State acceptance
  - Community acceptance

These nine evaluation criteria are intended to provide a framework for assessing the risks, costs and benefits for each remedial alternative, individually. The next step, conducted in Section 10, is a comparative analysis among the alternatives to assess the relative performance of each alternative with respect to each evaluation criterion and action level, and to identify the key tradeoffs between them.

9.1 Description of the Detailed Analysis Process

This section describes the detailed analysis process. Subsections are organized according to the primary criteria introduced at the start of this section. 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 and Green Bay zone alternatives. In summary, the seven generic remedial alternatives developed for the Lower Fox River and Green Bay include:

A. No Action,
B. Monitored Natural Recovery and Institutional Controls,
C. Dredge and Off-site Disposal,
D. Dredge to On-site CDF,
E. Dredge and Thermal Treatment,
F. *In-situ* Cap to Maximum Extent Possible, and
G. Dredge to CAD site.

Sections 9.2, 9.3, and 9.4 describe the Threshold Criteria, the Balancing Criteria, and the Regulatory/Community Acceptance Criteria, respectively. However, the regulatory/community acceptance criteria will be addressed during the public comment period as described in Section 9.4.

9.2 Threshold Criteria

Threshold criteria serve as essential determinations that should be met by any remedial alternative in order to be eligible for selection. They serve as primary project goals for a remediation project. The threshold criteria are primarily addressed through the development of the remedial alternatives in Sections 6 and 7, and within the context of the detailed risk assessment in Section 8.

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 protecting human health and the environment in a detailed risk analysis 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. The primary risk to the environment is bioaccumulation of PCBs from the consumption of fish, or direct ingestion/consumption of sediments for invertebrates. Protection of human health and the environment is achieved to varying degrees for each remedial alternative by selecting protective SQT risk levels, remedial action levels, and response actions. In this section, protection of human health and the environment is evaluated by residual risk in surface sediments using three lines of evidence:

- The projected number of years required to reduce PCB sediment loads and improve surface water quality based on residual PCB concentrations in surface sediments (surface-weighted averaging after completion of a remedy);

- The projected number of years required to consistently reach safe consumption of fish; and

- The projected number of years required to consistently reach surface sediment concentrations protective of fish or other biota.

The residual concentrations and duration of residual risk will be dependent upon the sediment action level selected for a particular alternative (detailed in Section 10). For this evaluation, the residual risk associated with each remedial alternative is provided in the screening tables under "Magnitude and Type of Residual Risk," and the values presented in these tables are for recreational anglers and carp-eating carnivorous birds and mammals. A summary of estimated "overall protection of human health and the environment" for each alternative is presented in Section 8.

The alternative-specific risk assessment (presented in Section 8 of the FS) estimated the number of years to consistently reach protective human health and environment thresholds after completion of a remedy. The term "consistently met" refers to the last time the predicted model results exceed the protective threshold in the modeled 100-year time frame. Several different receptors, risk levels, and media were presented, each with a different sediment threshold concentration. In order to continue forward with evaluations of risk in Sections 9 and 10 of the FS, a total of four human health and two environmental thresholds (based on fish tissue levels) were carried forward in the FS to facilitate risk comparison between alternatives and action levels. These key remedial thresholds include:

- **Human Health:** recreational angler, RME, HI is 1.0 (noncancer) for walleye (288 μg/kg PCBs);

- **Human Health:** recreational angler, RME, 10^{-5} cancer risk level for walleye (106 μg/kg PCBs);

- **Human Health:** high-intake fish consumer, RME, HI is 1.0 (noncancer) for walleye (181 μg/kg PCBs);

- **Human Health:** high-intake fish consumer, RME, 10^{-5} cancer risk level for walleye (71 μg/kg PCBs);

- **Environmental Health:** NOAEC carnivorous bird deformity from carp (121 μg/kg PCBs); and

- **Environmental Health:** NOAEC piscivorous mammal from carp (50 μg/kg PCBs).

These remedial thresholds represent fish tissue concentrations that are protective of human health and biotic receptors. Residual surface sediment concentrations required to meet these thresholds were predictive elements included in the PCB transport and bioaccumulation models used in the Lower Fox River and Green Bay. Outputs of the model were expressed as the number of years required to meet the protective fish tissue levels (based on residual sediment concentrations of an action level).

9.2.2 Compliance with ARARs and TBCs

Section 4 of this FS Report introduces the federal and state Applicable or Relevant Appropriate Requirements (ARARs) (Tables 4-2 and 4-3). Some of the listed ARARs and TBCs identify guidance and reference documents that apply to the management of the impacted sediments and the construction of containment structures in aquatic 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 subsections provide a summary of the issues related to compliance with chemical-specific ARARs/TBCs applicable to sediment remediation and the measures to be employed to attain compliance. For the purposes of this FS, there are no chemical-specific ARARs related to the removal and/or management of Lower Fox River sediments. Only chemical-specific TBCs exist.

Surface Water Quality. ARARs/TBCs for this area relate to maintaining surface water during remedial actions and long-term goals of achieving surface water quality after remedy completion. Specific approaches identified to address these ARARs/TBCs include:

- **Wisconsin State Water Quality Criteria.** Wisconsin's surface water quality criteria (NR 100) are TBCs for a sediment remediation project. Water quality criteria are intended to be protective of both human health (through fish tissue) and the environment (wildlife).

- **Federal Clean Water Act.** Since the project area includes "water of the United States," surface water quality criteria apply. However, EPA has approved Wisconsin's water quality criteria as compliance standards.

Sediment Quality. The state of Wisconsin has the authority to calculate sediment quality criteria on a site-specific basis. However, for the purposes of this RI/FS, state surface water quality criteria were the valued endpoints of concern for long-term protection of human health and the environment instead of sediment quality. Water quality criteria are considered TBCs for the project. Sediment concentrations that are protective of human and biological endpoints were predicted through transport and bioaccumulation models for surface water and residual fish tissue levels.

Location-specific ARARs/TBCs

Location-specific ARARs/TBCs apply to certain types of remedial alternatives, many related to site-specific development and disposal restrictions (i.e., navigational constraints). The following subsections provide a summary of the issues related to compliance with location-specific ARARs/TBCs and the measures to be employed to attain compliance.

CDF Construction (Floodplain or In-water). ARARs/TBCs for this area relate to construction requirements, siting, and control measures to minimize impacts to the environment. Specific approaches identified to address these ARARs/TBCs include:

- **Wisconsin Statutes Chapter 30 - Permit in Navigable Waters.** A bulkhead line is required prior to placing deposits in navigable waters. If a legislative bulkhead line or lakebed grant is issued, then these areas cease to be waters of the state and the title is transferred to a local municipality.

- **TBCs for Placement of PCB Sediments in CDFs.** CDF construction within bulkhead lines or lakebed grant areas could not be approved under the waste management program siting process of licensed landfills, but could be approved under a low-hazard waste exemption in the waste management program statutes (but likely limited to non-TSCA dredged material).

Upland Disposal Facility Construction. ARARs/TBCs for this area relate to construction and disposal requirements for sensitive areas. Specific approaches include:

- New facility construction will be located outside of navigable waters and floodplains as permitted by the WDNR waste management program (Lynch, 1998).

- Any off-site licensed landfill disposal site would have to comply with codified locational restrictions, including setback requirements from surface waters and floodplains.

Action-specific ARARs/TBCs

Action-specific ARARs/TBCs apply to implementation of the remedial alternatives. The following subsections provide a summary of the issues related to compliance with action-specific ARARs/TBCs and the measures to be employed to attain compliance.

Dredge and On-site Fill. ARARs/TBCs for this area relate to removal of sediments and the placement of sediments in a CDF or CAD site, or placement of a cap. The requirements specifically relate to protection of water quality, aquatic and wildlife habitat, and wetland areas. Specific approaches identified to address these ARARs/TBCs include:

- **Federal 33 USC 403, 33 CFR 320 through 330, and 40 CFR 230 - Excavation or Dredging of Contaminated Sediments.** Dredge and fill activities must comply with Section 10 of the Rivers and Harbors Act, Sections 301 and 404 of the Clean Water Act, and USACE regulations.

- **TBCs for Dredging and Filling of Water Bodies:**

  - WDNR 1990 Report of the Technical Subcommittee on Determination of Dredge Material Suitability of In-Water Disposal: specific habitat and wetland areas will be identified for each of the cap or CDF locations to allow for the development of protective measures and other compensatory actions.

  - 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.

  - The EPA Wetlands Action Plan requires no net loss of remaining wetlands.

PCB-contaminated Media. ARARs/TBCs for this area relate to proper management of the PCB-contaminated sediments including handling and disposal. Specific approaches identified to address these ARARs/TBCs include:

- **Federal TSCA (40 CFR 761).** Remedial activities involving TSCA-level sediments (less than 50 ppm PCBs and defined as PCB waste) will employ protective features to provide containment so as to prevent releases. Any ARARs specific to TSCA would be limited to PCB wastes with greater than 50 ppm concentrations. For dredged material with PCB concentrations less than 50 ppm, state rules apply, but TSCA does not.

- **TBCs for Handling of PCB-contaminated Media.** EPA concurrence is required to dispose of dredged materials containing PCBs at concentrations greater than 50 mg/kg in Wisconsin landfills (Adamkus, 1995):

  - With EPA approval, WDNR has authority to regulate disposal of dredged materials containing concentrations less than 500 mg/kg; and

  - Disposal facility operations plan must be modified prior to upland acceptance of PCB dredged materials with concentrations greater than 50 mg/kg.

Dredged materials 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.

Surface Water Quality. ARARs and TBCs for this area relate to discharges to surface water from dredging operations, in-water construction, or wastewater resulting from sediment dewatering. Specific approaches identified to address these ARARs/TBCs include:

- **NR 200 WAC, NR 212 through 220 WAC - Wisconsin Pollution Discharge Elimination System (WPDES).** A Construction Site Stormwater Discharge Permit is required when construction activities disturb greater than 5 acres of land.

  Discharge limitations for the Lower Fox River Deposit N WPDES Permit included, but were not limited to:

  - TSS not to exceed daily maximum concentration of 10 mg/L (monthly average of 5 mg/L);
  - PCBs daily total discharge mass limits not to exceed 0.0036 pounds;
  - PCBs daily total discharge concentration limit not to exceed 1.2 μg/L per day; and
  - Other parameters included: heavy metals, select PAHs, pesticides, dioxins, pH, ammonia, BOD, and oil/grease.

- **NR 207 WAC - Water Quality Antidegradation.** Discharge of effluent water cannot contain COC concentrations which exceed concentrations found in the Lower Fox River.

- **Federal TSCA (40 CFR 761).** Remedial activities involving TSCA-level sediments (less than 50 ppm total suspended solids) must monitor:

- Dissolved oxygen concentrations,
- Flow rates,
- Thermal properties of effluent and receiving waters, and
- pH.

In Section 761.50(a)(3), no discharger may discharge effluent containing PCBs to a treatment works or to navigable waterways unless the PCB concentration is less than 3 μg/L in accordance with an NPDES permit.

Air Emissions. ARARs for this area relate to air emissions from remedial activities. Specific approaches identified to address these ARARs include:

- **NR 157 WAC - Management of PCBs and Products Containing PCBs.** Facilities used for the incineration of PCBs require written approval from the WDNR prior to being established.

  Facility must meet the minimum requirements of the following operational parameters:

  - Dwell time (2 seconds),
  - Temperature (2,000 °F),
  - Turbulence, and
  - Excess oxygen (3%).

  Facility must have scrubber to remove hydrochloric acid from exhaust gas.

- **NR 400 through 499 WAC - Air Pollution Control.** Depending on location and size of the thermal treatment unit, specific maximum particulate concentrations are regulated.

- **Clean Air Act, 40 CFR Part 761 - PCB Storage and Disposal.** PCB air emissions from incineration (i.e., thermal treatment) cannot exceed 0.01 gram PCB per kg of PCB treated.

- **Clean Air Act, 40 CFR Part 50.** Establishes ambient air quality standards for the protection of public health.

Upland Disposal Facility Construction. ARARs/TBCs for this area relate to construction and disposal requirements, siting, and control measures to minimize impacts to the environment. Disposal in a solid waste landfill is applicable to both non-TSCA level and TSCA-level PCB-contaminated dredged material. Specific approaches identified to address these ARARs/TBCs include:

- **Wisconsin Statutes, Chapter 289 - Landfill Siting and Approval Process.** Disposal of dredged material in a licensed solid waste landfill is subject to the landfill approval process (Chapter 289 Statutes and Chapters NR 500 to 520 WAC).

  Specific design and construction requirements for a new solid waste landfill (or a "monofill" dedicated specifically to PCB sediments) are found in NR 504. WDNR has indicated that these requirements may also apply to the construction of an upland confined disposal facility (also described as a "wet" landfill).

  If temporary passive dewatering ponds are used, the performance requirements of Chapter NR 213 ("Lining of Industrial Lagoons and Design of Storage Structures") may apply. Alternatively, if WDNR decides to regulate passive dewatering ponds as a "solid waste processing facility," the requirements of the NR 500 series of rules may apply.

  No licensed hazardous waste landfills (Chapter 291 Statutes and NR 600 to 690 WAC) currently exist in the state of Wisconsin. However, permit requirements and the siting process would be similar to the solid waste landfill process.

  Solid wastes may be exempt from landfill siting requirements of WAC NR 500 through 520 if a "new" (i.e., treated material) is produced and meets the low-hazard exemption standards.

- **Wisconsin Statutes, Chapter 289 - Low-hazard Waste Grant of Exemption Disposal Site Process.** Low-hazard waste grant of exemption must meet authority (Section 289.43(8), Statutes) and public meeting requirements (Section 289.54, Statutes) set forth in state regulations.

  Placement in a low-hazard exemption disposal site applies to non-TSCA level dredged material only.

Transportation and Handling. ARARs/TBCs for this area relate to the transportation and handling of PCB-containing sediments during remedial activities. Specific approaches identified to address these ARARs/TBCs include:

- **49 CFR Parts 172 and 173 - General Requirements and Provisional Shipping Requirements for PCB-containing Material.** Transport vehicle transporting greater than 1,001 pounds of PCB waste must display Class 9 placards.

- **TBCs for Transportation of PCB-contaminated Media.** Establishes 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. Specific approaches identified to address these ARARs include:

- **29 CFR Part 1910 - Occupational Safety and Health Administration:**

  - 1910.120(e)(3) and 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, and 1920.138 - Personal protective equipment (PPE) will be employed to ensure that workers are not exposed to adverse conditions during the work.

  - 1910.120(h) - Real-time monitoring will be conducted to ensure that work zones are properly delineated and that workers are wearing the proper PPE.

  - 1910.95 - Noise levels that exceed an 8-hour time-weighted average (TWA) of 85 decibels require 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 startup of equipment or release of stored energy could cause injury to personnel will be protected by the implementation of a lockout/tagout program.

- 1910.21 through 1910.32 and 1910.104 through 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 eyewash units locally available.

Effects of EPA-initiated Cleanups on ARARs

An EPA-led cleanup under CERCLA authority would not have to formally comply with Wisconsin procedural regulatory requirements for any dredging, storage, dewatering, or disposal activities that occurred within the limits of the project area. The limits of the project area would be defined in the proposed cleanup plan, but would closely conform to the limits of contamination. EPA's cleanup plans would have to consider and include the substantive requirements of state regulatory codes.

Any costs associated with a cleanup, such as dewatering, storage, handling, or disposal that took place outside of the defined limits of the project area would have to comply with all state regulatory requirements.

9.2.3 ARARs Applicable to Process Options Included in the Remedial Alternatives for the River and Bay

The specific remedial alternatives presented in Section 7 for each river reach and Green Bay zone are developed from the retained process options and 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 one primary TBC that relates to this alternative. The Water Quality Standards for Wisconsin Surface Waters define 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 and Green Bay.

Monitored Natural Recovery/Institutional Controls

Concerning compliance with ARARs and TBCs, the MNR and Institutional Controls alternative is similar to the No Action alternative. The Water Quality Standards for Wisconsin Surface Waters will be used as TBCs to monitor surface water for the changing concentration of PCBs in the Lower Fox River and Green Bay. 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 *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 CDF disposal alternatives. In addition, permits are required prior to filling any navigable water (Wisconsin 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 dredging alternatives: hydraulic dredging and mechanical dredging. The ARARs/TBCs that are directly related to the removal of sediment from the Lower Fox River and Green Bay are the same for both removal technologies and can be placed into two groups: protection of surface water (NR 322, 200, and 220 through 297 WAC) and permits and fees to remove sediment (NR 346 and 347 WAC). The surface water ARARs/TBCs limit the discharge of PCBs and TSS into the receiving water bodies 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

Thermal treatment is a process option retained for most of the river reaches and bay zones. ARARs specific to this technology relate to the air emission and permitting requirements of thermal treatment units (40 CFR 701 and NR 400 through 499 WAC). In addition, there are performance requirements of the thermal unit from NR 157 WAC 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 for the dredging alternatives. 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 and 220 through 297 WAC) 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 WAC) involves the construction of a wastewater treatment facility specifically to treat water from remedial activities. This ARAR requires WDNR review of wastewater treatment facility designs and specifications. The passive dewatering ponds are also managed under the wastewater treatment ARAR (NR 213 WAC) which sets effluent permit limitations associated with wastewater treatment facilities. There are no ARARs at this time that pertain to the solidification of dredged materials 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 and Green Bay. These include in-water disposal (i.e., the construction of a CDF or CAD site) and disposal in an upland landfill or newly constructed landfill for TSCA and non-TSCA level sediments. A low-hazard waste grant of exemption landfill can also be considered for non-TSCA level dredged material. ARARs/TBCs specific to this process option include the siting requirements for a landfill (Wisconsin Statutes Chapter 289) and obtaining lakebed and riverbed grants for CDF constructions from the Legislature and riparian landowners. There are also general design requirements for in-water construction (NR 322 WAC) that must also be met. General disposal requirements of PCB-containing dredged material are simplified with the agreement between the EPA and WDNR for placement of TSCA-level PCB-containing material (greater than 50 ppm PCBs) in a state-licensed landfill. The agreement allows the placement of PCB-containing material up to 500 mg/kg in an NR 500 WAC-regulated landfill as long as the landfill operations permit is modified. However, only public municipal landfills receive long-term liability protection for accepting PCB-impacted dredged material. This TSCA waiver agreement is not applicable to CDF or CAD sites. Placement of dredged material into CDFs could be approved under the low-hazard waste grant of exemption process. 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 for PCB sediment upland disposal alternatives. These include trucking of dredged material to a disposal facility, pumping of sediments to a dewatering and disposal facility, and 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 and 157 WAC). The following two ARARs are applicable only to the trucking of dredged material to a disposal facility. The Department of Transportation (DOT) has detailed requirements on the shipping of PCB materials. NR 157 WAC 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. ARARs and TBCs related to in-water transportation activities (i.e., piping and barging) include the protection of surface water (NR 322, 200, and 220 through 297 WAC). The surface water ARARs/TBCs limit the potential discharge of PCBs into receiving water bodies from potential barge overflows or pipeline breaks.

9.3 Balancing Criteria

Balancing criteria are included in the detailed analysis of alternatives because these five variables (long-term effectiveness, reduction, short-term effectiveness, implementability, and cost) are important components that often define the major trade-offs between alternatives. They serve as important elements of project goals that require careful consideration for successful implementation and long-term success of a remediation project. The five balancing criteria are evaluated for each remedial alternative in Tables 9-1 through 9-8 for each river reach and Green Bay zone, respectively. Detailed information pertaining to the residual risk for each remedial alternative is presented in Section 8. 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?

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 and bay 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 COCs destroyed?
- Does the remedy rely on treatment or containment?

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 as they relate to risks posed to on-site workers, nearby residences, and downstream resources 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?

9.3.4 Implementability

Implementability refers to 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, approvals, fees, and physical requirements that must be met to execute the alternative. The following questions were used to evaluate the feasibility and effectiveness of each alternative during implementation:

- 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?
- Is a remedy administratively feasible (approvals, permits, fees)?

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. Cost effectiveness refers to the relative cost to implement a remedy that will meet the risk reduction goals of the project. The following questions were used to provide a cost comparison for each alternative:

- What are the total costs involved with this alternative?
- Does the alternative meet the risk reduction goals for the project and how cost effectively does it meet these goals?

The total cost for each of the remedial alternatives is summarized in Tables 9-1 through 9-8. Appendix H contains the detailed cost spreadsheets for each of the remedial alternatives.

9.4 Community and Regulatory Acceptance

The regulatory/community acceptance criteria are not detailed in this FS Report. However, this RI/FS project for the Lower Fox River and Green Bay is being conducted under direct supervision by Wisconsin Department of Natural Resources and U.S. EPA Region 5. Both agencies have been involved with the data collection and analysis efforts, and development of the remedial alternatives and expectations presented in this FS report. Both the state and federal agencies support the evaluation of alternatives and action levels presented in this FS report. As noted on Figure 9-1, community acceptance of these criteria are assessed through substantial public involvement at work shops, public meetings, and working groups, some of which have been completed, and will be completed 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, RA, and FS reports. Several trustee groups including NOAA, USFWS, and local tribe communities have also been involved in the review and development of the RI/FS reports prior to public release.

The recently completed pilot projects on the Fox River at Deposit N and SMU 56/57 provide examples of communication with the local communities and residents in the selection and implementation of sediment remediation projects. The experience showed that a strong commitment to ongoing communication and outreach efforts greatly facilitated the public input, coordination, and the design of the projects. The agencies received positive feedback on the use of public meetings, media interviews, fact sheets, brochures, the internet, and other methods of disseminating information. Based on the experience of the pilot projects and with previous RI/FS outreach, local concerns are expected to parallel many of the issues explored in the analysis of the CERCLA evaluation criteria such as protectiveness, effectiveness, implementability, and cost. In addition, the community can be expected to have interest in issues such as disturbance and potential risk to local residents, traffic, and noise.

The PCB mass balance study conducted during Deposit N dredging activities (Water Resources Institute, 2000) demonstrated that short-term risks of downstream PCB transport during dredging could be controlled and minimized to less than 1 percent of the PCB mass removed. This study estimated that 96 percent of the PCB mass removed 17 kg (37 pounds) from the deposit was contained in press cake material (ready for off-site disposal) and that less than 0.01 percent (0.2 grams) of the PCB mass removed was discharged back to the river. The downstream concentrations observed during the dredging activity were comparable to background concentrations observed at other times of the year (summer peaks, high-flow peaks) and from other river activities such as passing ship traffic.

A similar community involvement effort was not conducted for the SMU 56/57 demonstration project (in the community of Aswaubenon) in part because this project was in a predominantly industrial area, not near residential properties. Nevertheless, there were extensive informational efforts for the SMU 56/57 project. Upon project completion, most citizens were supportive of the project. During the 2000 dredging activities, there were numerous tours and informational meetings for the media and local communities. Additionally, it was ensured that transportation of dredge spoils from the dredge location to the local disposal facility did not go through residential areas. Similar to Deposit N, there were no significant disruptions to the local community or activities on the river. These projects were well received by the communities.

9.5 Detailed Analysis of Remedial Alternatives for the Lower Fox River and Green Bay

Tables 9-1 through 9-8 provide the detailed screening of the remedial alternatives for each river reach and bay zone respectively. Each table includes the screening of each alternative retained in Section 7 by the nine primary criteria introduced in this section. The evaluation is performed by contrasting each alternative with the questions identified for each primary criteria, regardless of action level. A comparison of action levels within each alternative and between different alternatives is presented in Section 10. Implementation costs associated with each action level are detailed in Section 7. The important evaluation points projected in the tables are summarized below for each remedial alternative. Since the primary concepts evaluated for each alternative are the same regardless of the reach or zone, the four river reaches and four Green Bay zones are summarized together below.

9.5.1 Alternative A - No Action

This alternative involves no active remedy and long-term monitoring to evaluate potential system recovery over time. A detailed evaluation of this alternative is described in Tables 9-1 through 9-8 for each river reach and bay zone using the nine evaluation criteria described above.

Threshold Criteria (Protection and Compliance)

Since no active remediation would be undertaken, the site would remain in its current state, with any changes occurring only through natural processes. The Lower Fox River and Green Bay fate/transport and bioaccumulation models predicted that this alternative will not protect human health or the environment over time (in 30 years). Routine monitoring would be performed to maintain the fish consumption advisories already in place.

Balancing Criteria (Effectiveness, Reduction, Implementability, Cost)

Since this alternative includes no remedial actions, the magnitude of residual risks remains the same, with any future changes occurring only through natural processes. This alternative is the least-cost alternative, but provides limited adequacy and reliability in terms of long-term risk controls, source control and reduction of exposure pathways. Costs include institutional controls such as fish consumption advisories that would likely remain in place for over 40 years.

9.5.2 Alternative B - Monitored Natural Recovery and Institutional Controls

This alternative involves no active remedy but does incur the expectation that natural processes will contribute to the recovery of the system. Under this alternative, institutional controls will remain in place until the project objectives are eventually obtained. A long-term monitoring plan will be developed to verify natural recovery of the system. A detailed evaluation of this alternative is described in Tables 9-1 through 9-8 for each river reach and bay zone using the nine evaluation criteria described above.

Threshold Criteria (Protection and Compliance)

According to EPA, natural recovery as a remedy is appropriate at sites where the levels of contamination are relatively low, the area of contamination is large, and natural recovery is proceeding at a high rate. The time trends analysis (RI report, RETEC, 2002a) conducted for the Lower Fox River and Green Bay suggests that PCB levels are declining in surface sediments, but no change is occurring at depth. Mass balance work conducted on the Lower Fox River and Green Bay determined, quantitatively, that PCB transport (including Lake Michigan), settling, resuspension, burial, and volatilization mechanisms were all involved (Raghunathan, De Pinto *et al.*, 1994). Empirical data, recently supplied for the fate and transport models, suggest that PCB-contaminated sediments are being transported within the Lower Fox River and into low-level deposits that are widely distributed in Green Bay. Among other lines of evidence, analysis of bathymetry data generated by the USACE show significant movement of sediments in the navigational channels.

Although empirical data may show a slow decline of PCBs in sediment, water, and fish tissues, this alternative may not provide long-term protection of human health and the environment. The transport and bioaccumulation models for the Lower Fox River and Green Bay predict that No Action will require greater than 30 years to consistently reach protective fish tissue thresholds.

Balancing Criteria (Effectiveness, Reduction, Implementability, Cost)

Implementation of an active remedy would likely involve a natural recovery component. If a large PCB mass is removed (i.e., source control of sediments) then natural recovery processes may continue after completion of an active remedy thereby continuing the decline of PCB levels in sediment, surface water, and biota. This recovery would be monitored through implementation of a long-term monitoring plan. Some natural processes may accelerate after removal of sediments (i.e., dredging) such as low areas in the river bottom that would likely fill more rapidly. Thus, residual contaminated sediments would be rapidly buried.

The MNR alternative has the lowest total cost among alternatives, but is not cost effective as a standalone remedy because MNR does not meet most of the RAOs in 30 years. Some of the RAOs (i.e., surface water quality criteria) are not met in 100 years. In addition, MNR does not significantly reduce the volume, toxicity, or mobility of COCs throughout the deposit profile over time.

9.5.3 Alternative C - Dredge and Off-site Disposal

This alternative involves physical removal of sediments from the river or bay and off-site disposal of dewatered sediments to a landfill willing to accept dredged sediments. Sediments will be hydraulically or mechanically dredged, then dewatered and solidified, as necessary, prior to off-site disposal. A detailed evaluation of this alternative is described in Tables 9-1 through 9-7 for each river reach and bay zone using the nine evaluation criteria described above.

Threshold Criteria (Protection and Compliance)

Based on evidence from other sites, dredging is capable of reducing overall sediment contaminant concentrations, reducing exposure pathways, and reducing long-term risks to human health and the environment, as shown in several case studies (Appendix B). By definition, dredging can serve as an effective source control measure by removing a significant portion of sediment mass and volume from a system. The Lower Fox River and Green Bay modeling results predicts that protective fish tissue levels can be met in 30 years following remedy completion.

Short-term compliance with ARARs and TBCs is expected. The two pilot demonstration projects conducted at Deposit N and SMU 56/57 in the Lower Fox River successfully met monitoring requirements during dredging including: downstream turbidity and PCB levels, effluent water quality, and air quality at compliance boundaries. No ARARs or TBCs were exceeded in the pilot projects.

Balancing Criteria (Effectiveness, Reduction, Implementability, Cost)

Depending upon the action level selected for this alternative, residual risk can be two to twenty times lower than the No Action alternative. Dredging with off-site disposal does not destroy or treat material containing PCBs, therefore, PCB volume and toxicity are not reduced. However, effective containment and isolation in a permitted landfill would effectively reduce the mobility of COCs. Reduced mobility and elimination of an exposure pathway would effectively eliminate aquatic exposure and thus reduce the human and ecological risks associated with the consumption of fish.

Short-term Effectiveness. Potential short-term risks associated with dredging do exist. Some of these risks observed on many sediment remediation projects include: the removal, physical disturbance, and/or alteration of aquatic habitats, possible suspension and escape of sediments containing PCBs, and temporary disturbance of silt curtains. Monitoring activities undertaken at other sediment remediation sites (see Appendix B) indicate that potential short-term risks associated with dredging are possible due to the suspension and escape of sediments containing PCBs during dredging (surface water, sediment trap, and caged fish results). For air monitoring, although increases in ambient air PCB concentrations were observed near the sediment dewatering area, estimated PCB emissions were found to be relatively small and insignificant relative to human exposure and risk. The maximum PCB air levels detected at the sediment processing site did not exceed 80 percent of the protective 70-year cancer risk level.

Measurements of water quality downstream of dredging operations during both the Deposit N and SMU 56/57 demonstration projects reported turbidity measurements consistently below or equal to background values during dredging operations (however the cutterhead dredge at Deposit N only operated for 10 minutes every hour). Based on monitoring of Deposit N, PCB mass loss via downstream transport during dredging operations was estimated to be less than 1 percent of the total PCB mass removed from the deposits. These measurements were comparable to the daily contribution of PCB mass from upstream sources to the project area. In summary, in-water control measures can effectively prevent adverse downstream transport of COCs during dredging operations.

The PCB mass balance study conducted during Deposit N dredging activities (Water Resources Institute, 2000) demonstrated that short-term risks of downstream PCB transport during dredging could be controlled and minimized to less than 1 percent of the PCB mass removed. This study estimated that 96 percent of the PCB mass removed 17 kg (37 pounds) from the deposit was contained in press cake material (ready for off-site disposal) and that less than 0.01 percent (0.2 grams) of the PCB mass removed was discharged back to the river. The downstream concentrations observed during the dredging activity were comparable to background concentrations observed at other times of the year (summer peaks, high-flow peaks) and from other river activities such as passing ship traffic.

Long-term Effectiveness. Removal of impacted sediments provides the most long-term effectiveness compared to other alternatives. Long-term operation and maintenance would not be required after removal.

Technical Implementability. This would be a relatively large dredging project (up to 8 million cy in the river and 25 million cy in Green Bay), without precedent in Wisconsin, although other similar sized projects are currently planned or proposed throughout the United States. Dredging projects of similar size have been implemented internationally (1 million cy in Minamata Bay, Japan) verifying the feasibility of conducting, managing and coordinating a large remedial action. Dry excavation of sediment could provide a suitable and cost-effective alternative to proposed wet excavation methods (using hydraulic and mechanical techniques) but would likely be limited to shallow areas that are easily accessible by land-based equipment. Site-specific use of dry excavation techniques will be evaluated during the remedial design. Construction of a containment structure for dewatering of the dredge prism may adversely affect nearshore habitats and wetlands when compared to wet excavation techniques.

Unexpected site conditions (i.e., wood debris, hard underlying material, debris, cobbles) may have contributed to the inability to meet design goals during the 1999 SMU 56/57 horizontal auger dredging activities. Equipment difficulties and the presence of large debris significantly slowed the pilot test progress. The auger cutterhead dredge produced a sediment slurry with 4.5 percent solids; much lower than the design specifications, however, in 2000, the dredge slurry averaged 8 percent solids. Debris was encountered during dredging, which hindered progress and production rates.

The two pilot projects on the Lower Fox River successfully demonstrated the implementability of environmental dredging, water treatment, and disposal of PCB-contaminated sediment. Both projects extended past the original time schedule due to late season startups. The work was postponed over the intervening winter months and completed the following year. The projects demonstrated the availability of necessary equipment and contractors to perform and oversee this type of work.

Administrative Implementability. As expressed in some of the public comments (April 1999), local siting of landfills for the disposal of PCB sediments is an extremely important factor that has tremendous impact of the cost and implementability of this alternative. Local governments generally support the use of existing local landfills and siting of new landfills, to the extent practicable, but recognize that siting of new landfills is a lengthy process involving multiple layers of cities, towns, villages, and counties. This FS fully anticipates that an in-state landfill will be identified for this alternative, but recognizes that inherent uncertainties exist with this assumption. Additional disposal sites, such as out-of-state landfills and newly constructed CDFs may be necessary to match capacity and volume needs.

With EPA approval, the State of Wisconsin has created a viable in-state alternative for the disposal of PCB-contaminated sediments from the Lower Fox River and Green Bay. In-state licensed landfills can accept TSCA-level sediments (greater than 50 mg/kg PCBs) with long-term protection from liability. Long-term liability protection is also extended to in-state municipal (i.e., county) landfills that accept PCB-impacted sediments with less than 50 ppm PCBs.

Some of the required permits, fees, and approvals required to administratively implement a sediment removal and dewatering operation include: dredging contract fees and bonds (NR 346 WAC), a WDNR permit or authorization from the Legislature to remove material from navigable waters, submittal of a Remedial Action Plan and design document for acquisition of a state permit, and proper manifests and placards for transporting PCB wastes. Construction of an industrial wastewater facility may also be necessary.

Under NR 346 WAC (Dredging Contract Fees), a contract fee of $1 is charged for the removal of material from natural lakes. The contractor removing sediments must have a performance bond which would be used to correct any undesirable environmental conditions caused by improper removal of material.

Under NR 108 WAC (Plans and Specifications), construction of an industrial wastewater facility or an industrial pretreatment facility requires approval of final plans and specifications for the facility by the WDNR. Final plans and specifications must be submitted a minimum of 90 days prior to commencement of construction. A 30-day supply of chemicals is required on site to insure against ineffective treatment, shortages, and delays. Design requirements are established on a case-by-case basis, with incorporation of containment and isolation features necessary to protect water resources. The site could be placed in a floodplain, but still designed to protect resources. Design requirements (Chapters NR 500 to 520 WAC) often include a multi-foot clay liner, leachate collection system, intermediate cover and drainage systems, and a final cover system. Handling areas will be lined and covered.

Under NR 157 WAC criteria (Management of PCBs), transporters of PCB wastes must be licensed for transport of hazardous wastes. PCB wastes must be contained to prevent leakage/spillage, and the transporter is responsible for cleanup of all spillage of PCB wastes. Presence of a spill containment program is required for handling of PCB-containing materials. Under 40 CFR Part 761 (Disposal of PCB Remediation Waste), PCB wastes may require management and transport under a Uniform Hazardous Waste Manifest. Development of a new disposal facility, or expansion of an existing one, is subject to the Wisconsin landfill siting process (Chapter 289 Statutes and Chapters 500 to 520 WAC). Wisconsin's landfill siting process includes the following elements: initial site inspection and report, feasibility report, plan of operation, construction inspections, construction documentation and initial licensure, site closure documentation, and demonstration of financial responsibility and long-term care. Under the Wisconsin State Statutes Chapter 289 (Landfill Siting and Approval Process), local approval may be required prior to siting of a new facility (if petitioned, WDNR may waive requirements).

Under NR 200 WAC criteria (WPDES), effluent water resulting from the dewatering of the dredged sediments will be treated by filtration and flocculation for solids removal. Carbon adsorption may be required in addition to solids removal in order to meet WPDES effluent criteria. Application to discharge pollutants must be on file with the WDNR a minimum 180 days prior to discharge commencement date.

Under Wisconsin 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.

Under NR 322 WAC criteria (Sediment Control During Construction Activities), erosion control measures must be implemented. Silt curtains must be utilized around the perimeter of the work zone to minimize the downstream migration of suspended particles.

For two of the river reaches, Little Rapids to De Pere and the De Pere to Green Bay, one of the proposed alternatives is to hydraulically dredge up to 5,700,000 cy and pump the material through a dedicated pipeline that is approximately 18 miles in length, to a newly constructed receiving landfill. The concept of directly pumping PCB-containing sediments through an urban, residential area for several years to an upland landfill may have several hurdles to overcome including land use, traffic constrictions, community acceptance, and spill controls. However, this alternative is feasible but would be difficult to implement without community support. Construction of another long pipeline has been successfully implemented in Dallas, Texas. This 25-mile pipeline pumped dredge slurry over a year from White Rock Lake through city neighborhoods to a former gravel pit disposal site with two booster pumps (Sosnin, 1998).

The total cost to implement the Dredge and Off-site Disposal alternative is generally more expensive than either the Capping or On-site Disposal alternatives. It is also less cost-effective at meeting risk reduction goals than Capping or On-site

Disposal alternatives for action levels at and below 1,000 ppb (which meet most of the goals in 30 years).

As summarized in the *Sediment Technologies Memorandum* (Appendix B), dredging costs ranged from $280 to $525 per cubic yard for planning, dredging, dewatering, monitoring, and disposal costs for the two demonstration projects.

9.5.4 Alternative D - Dredge and CDF Disposal

This alternative involves physical removal of sediments and long-term disposal of sediments to a newly constructed confined disposal facility (CDF). Sediments will be hydraulically dredged and pumped directly to the CDF or mechanically dredged and placed in the CDF for passive dewatering, then capped. The CDF would be constructed on site as a nearshore or in-water facility dedicated to long-term confinement of sediments. A detailed evaluation of this alternative is described in Tables 9-1 through 9-7 for each of the reaches and zones using the nine evaluation criteria described above.

Threshold Criteria (Protection and Compliance)

Dredging with direct placement to a CDF would effectively isolate the contaminant mass and therefore provide long-term protection of human health and the environment. Previous USACE and regional studies have shown that CDFs can eliminate the exposure pathways involving ingestion or direct contact with sediment, and subsequent bioaccumulation up the food chain, as long as the CDF containment structure remains intact. Based on monitoring results of other CDFs constructed around the country (see Appendix B), a well-designed CDF structure can effectively isolate COCs and comply with project ARARs. The Lower Fox River and Green Bay modeling results predict that protective fish tissue levels can be met in 30 years following remedy completion.

Short-term compliance with ARARs and TBCs is expected. The two pilot demonstration projects conducted at Deposit N and SMU 56/57 in the Lower Fox River successfully met monitoring requirements during dredging including: downstream turbidity and PCB levels, effluent water quality, and air quality at compliance boundaries. Long-term compliance with ARARs and TBCs related to siting a new CDF is expected prior to construction of new CDF. Monitoring conducted around existing CDFs in Arrowhead Park, Bayport, and Kidney Island show that chemical-specific ARARs and TBCs can be met with effective containment structures.

Balancing Criteria (Effectiveness, Reduction, Implementability, Cost)

Residual risks are generally two to twenty times lower than the No Action alternative. However, the removal of sediments during dredging and construction of a CDF may result in relatively long-term changes to the substrate characteristics, and thus the habitat value of the site. In-water placement of a CDF will result in acreage loss of shallow subtidal habitat areas.

Dredging to a CDF does not destroy or treat material containing PCBs, therefore, PCB volume or toxicity is not reduced. However, containment of dredged sediment can effectively isolate the material and eliminate the mobility of COCs. Effective containment could likely reduce the toxicity of the COCs by eliminating the exposure pathway. Short-term environmental risks and controls are similar to those identified for Alternative C.

Construction operations occurring within the river would have a temporary effect on commercial and recreational boating. However, as noted during construction at Deposit N and at SMU 56/57, the physical construction sites themselves drew tourists to the sites. Thus, a net benefit can also be achieved.

Technologies utilized for dredging and on-site disposal are not expected to be different than those identified in Alternative C. In-water CDFs have been successfully constructed through the United States (see Appendix B) and the ability to construct a containment berm and surface cap is well established. No operational difficulties or limited availability is expected that would affect the technical feasibility of this alternative. Segregation of TSCA level sediment would be necessary prior to disposal in a CDF. Administrative implementability would depend on community acceptance of nearshore or in-water disposal of the dredged materials and habitat loss.

9.5.5 Alternative E - Dredge and *Ex-situ* Thermal Treatment

This alternative involves physical removal of sediments and irreversible thermal treatment of sediment coupled with destruction of resulting air emissions. A detailed evaluation of this alternative is described in Tables 9-1 through 9-7 for each reach and zone using the nine evaluation criteria described above.

Threshold Criteria (Protection and Compliance)

Dredging with treatment should reduce the bioavailability of PCBs in sediments by removing and eliminating the source of toxicity. Protection of human health and the environment is dependent on the project design and successful implementation of the dredging project (discussed above). Regarding compliance with ARARs, thermal treatment is capable of meeting the air quality ARARs for

PCB air emissions, according to unit specifications and implementation on other projects (see Waukegan Harbor in Appendix B).

Balancing Criteria (Effectiveness, Reduction, Implementability, Cost)

Thermally-treated sediments will achieve long-term effectiveness and permanence. This alternative is the only remedial option that destroys material containing PCBs, therefore, it is the only alternative that reduces the toxicity, volume, and mobility of COCs. This alternative may be costly, but permanently eliminates the risks posed by contaminated sediments. However, thermal treatment by vitrification is not widely used in the United States. This technology also requires significant capital investment.

Under NR 400 through 499 WAC criteria(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, and an annual emission fee is required if total annual emissions of all air contaminants are less than 5 tons.

The total cost to implement the Dredge and Treat alternative is more expensive than other alternatives with active remedies. This alternative is also less cost effective at meeting risk reduction goals at most action levels. As the action level becomes lower, this alternative becomes less cost effective.

9.5.6 Alternative F - Cap to the Maximum Extent Possible

This alternative involves physical isolation and immobilization of sediments from the water column and biota. This isolation is achieved by placement of an armored sand cap over surface sediments creating *in-situ* containment. This alternative is defined as *in-situ* capping to the maximum extent possible because capping is not practical or implementable in some areas (i.e., navigational channels with frequent dredging needs or minimum water depths to prevent disturbance). A capping alternative was not developed for the Green Bay zones because of the large areal extent of impacted sediments requiring capping and the lack of sufficient local capping material. A detailed evaluation of this alternative is described in Tables 9-1 through 9-4 for each reach and zones using the nine evaluation criteria described above.

Threshold Criteria (Protection and Compliance)

Previous USACE and other site-specific studies have shown that sand cap containment and armoring can effectively reduce the bioavailability and bioaccumulation of PCBs to aquatic organisms by blocking the transport of PCBs from surface sediments into the overlying water column (see Appendix D).

Containment can provide long-term protection of human health and the environment as long as the system remains intact. This requirement includes preservation and maintenance of the 17 locks and 12 dams located along the Lower Fox River. Monitoring of the cap structure will be required (e.g., sediment cores, caged biota) to ensure containment and structural integrity. The Lower Fox River and Green Bay modeling results predict that protective fish tissue levels can be achieved in 30 years following remedy completion.

Balancing Criteria (Effectiveness, Reduction, Implementability, Cost)

Capping is moderately cost-effective when compared to dredging alternatives, but requires long-term deed restrictions, site access restrictions, and long-term monitoring to ensure cap integrity. There is a long-term liability associated with *in-situ* containment of impacted sediments, however, if a conventional cap is placed with the intent of enhanced natural recovery instead of containment, then long-term reduction of contaminant volume and toxicity may be enhanced. Although capping does not reduce or actively treat PCB-contaminated material, it can effectively reduce the mobility of PCBs in a sediment deposit.

In-situ capping does not destroy or treat material containing PCBs, therefore, PCB volume or toxicity is not reduced. However, containment of dredged sediment can effectively isolate the material and eliminate the mobility of COCs. Effective containment could likely reduce the toxicity of the COCs by eliminating the exposure pathway.

Use of proper engineering controls, project planning and design, and contingency plans should mitigate the potential short-term risks associated with resuspended sediment. It is expected that all ARARs and TBCs associated with the implementation of the remedy would be achievable. Environmental impacts and risk to workers during construction and implementation are expected to be low due to the limited disturbance of the impacted material. Potential downstream transport of suspended solids or COCs during placement will be lower for this alternative compared to dredging options. Placement of a cap is technically and administratively implementable, however, physical limitations of the site will limit the practical extent of cap placement. Cap placement in a federally-authorized navigational channel would require special approval by an act of Congress and would be administratively difficult. For the purposes of this FS, navigational channels will be dredged and not capped. The Capping alternative is presented in combination with other dredging and MNR alternatives for all reaches because physical site restrictions prevent cap placement everywhere. Although this alternative is administratively feasible, the large quantity of material required for cap placement will require coordination and acceptance by the community and local industries for land acquisition needed for staging areas.

Cap placement will result in long-term site access and deed restrictions to ensure no disturbances of the cap by passing vessels, ice scour, or other aquatic activities. Long-term maintenance of a sand cap may also potentially impact future commerce or recreational use of the river.

Long-term effectiveness of a cap could be compromised by large-scale flood events, ice scour, vessel draft, or dam removal or failure. These issues can be mitigated by periodic addition of new capping material, armoring the cap with coarser material to minimize future scour potential, or removing the cap entirely and dredging the area. Long-term effectiveness could also be compromised by PCB migration through the cap via groundwater advective processes, but potential groundwater migration would be considered during the design phase. In summary, capping would be less protective as a long-term solution when compared to sediment removal.

The total cost to implement the Capping alternative is generally similar to other remedies for relatively small volumes and considerably less expensive than other remedies for large removal volumes. Capping is generally more cost effective than dredging and similar to on-site disposal alternatives for meeting risk reduction goals. However, as stated above, long-term maintenance and monitoring of a cap will be required.

9.5.7 Alternative G - Dredge to CAD Site

This alternative involves removal of contaminated sediment and placement of material in a confined aquatic disposal site (considered for Green Bay only). This remedy includes mechanical or slurry placement of dredged material in an excavation and covering the material with a sand cap to create a containment cell in an underwater environment. A detailed evaluation of this alternative is described in Tables 9-5 through 9-7 for Green Bay zones 2, 3A and 3B.

Threshold Criteria (Protection and Compliance)

Previous USACE studies and dredge disposal monitoring programs (see Appendix B) have shown that sand cap containment in a CAD site, with natural confinement on the sides and bottom of the excavation, can effectively reduce the bioavailability and bioaccumulation of PCBs to aquatic organisms by blocking the transport of PCBs from surface sediments into the overlying water column. Containment can provide long-term protection of human health and the environment as long as the system remains intact. Monitoring of the CAD structure will be required (e.g., sediment cores) to ensure containment and structural integrity. The Lower Fox River and Green Bay modeling results predict that protective fish tissue thresholds can be achieved in 30 years following remedy completion.

Balancing Criteria (Effectiveness, Reduction, Implementability, Cost)

Construction of a CAD site is moderately cost effective when compared to dredging alternatives but requires long-term deed restrictions, site access restrictions, and long-term monitoring to ensure cap integrity. There is a long-term liability associated with in-water containment of contaminated sediments.

Dredging to a CAD site does not destroy or treat material containing PCBs; therefore, PCB volume or toxicity is not reduced. However, containment of dredged sediment can effectively isolate the material and eliminate the mobility of COCs. Effective containment could likely reduce the toxicity of the COCs by eliminating the exposure pathway. Construction of a CAD site and placement of impacted sediments in the disposal site is implementable and has been constructed at numerous sites around the country, many in the New York-Boston area. The same equipment used for dredging can be used to construct the CAD site. Under Wisconsin Statutes Chapter 30 (Permit in Navigable Waters), a permit must be issued by the WDNR or Legislature prior to placing deposits in navigable waters. Implementability is dependent on the Wisconsin Legislature passing a lakebed grant for the use of a CAD site as a disposal site for dredged material.

The total cost to implement the Dredge to CAD Site alternative in Green Bay is generally similar to other active remedies with similar volumes. The total cost to construct a CAD site and transport dredged material to the CAD site is approximately 17 percent less than the cost to construct a freestanding confined disposal facility.

9.6 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.

9.7 Section 9 Figure and Tables

The figure and tables for Section 9 follow page 9-34 and include:

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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 and 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 Off-site 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] Acceptance

Community[1] Acceptance

Note:

[1] These criteria are assessed in the RI/FS Report and the proposed plan.

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Table 9-1 Detailed Analysis of Alternatives Summary - Little Lake Butte des Morts Reach

Alternative [1]	Long-term Effectiveness and Permanence		Reduction of Toxicity, Mobility, and Volume			Short-term Effectiveness
	Magnitude and Type of Residual Risk [2]	Adequacy and Reliability of Controls	Irreversibility of the Treatment	Type and Quantity of Treatment Residual	Reduction of Toxicity, Mobility, or Volume	Risk to Community and Workers and Controls
Alternative A: No Action	No action will require 51 to 84 years to continually meet safe fish consumption levels for recreational anglers. No action will require >100 years to consistently meet safe ecological levels for carp. Surface water quality will not be met in 100 years. PCB loading rates will equal Lake Winnebago inputs in 17 years.	The no action alternative does not include engineering or institutional controls. Long-term fish tissue monitoring will be required to evaluate status of consumption advisories already in place.	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy.
Alternative B: Monitored Natural Recovery and Institutional Controls	Similar to no action.	Enforcement of institutional controls may be difficult along the entire length of the reach. 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, river water quality, and tissue monitoring will be required to evaluate system recovery over time and achievement of project RAOs.	MNR and institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy. Monitored natural recovery will likely require many years, therefore institutional controls will remain in-place until the project RAOs are met.
Alternative C: Dredge and Off-site Disposal	Remedy will require <1 to 57 years to consistently meet safe fish consumption levels after completion of remedy. Remedy will require <1 to 100 years to consistently meet safe ecological levels for carp. Surface water quality for wildlife will be met in 16 to >100 years, other criteria will not be met in 100 years. Off-site landfill will require long-term monitoring and liability.	The alternative relies on 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 liner, 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.	No treatment of sediments is included in this alternative, except for dewatering.	Water treatment residuals consist of flocculation sludges and filter sands. 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.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment, dewatering operations, and transport to disposal facility. Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Risks from spillage during transport will be minimized by the solidification of sediments, 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.
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Same as Alternative C, except on-site CDF will require long-term monitoring to ensure source control and containment.	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 seepage, 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.	No treatment of sediments is included in this alternative.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when confined within the CDF.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment and dewatering operations. Risks to community will be minimized by establishing buffer zones around work areas and limiting work hours. PCB air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program. The constructed CDF, when completed, may provide recreational park space for the community.
Alternative E: Dredge and Thermal Treatment	Same as Alternative C, except treated residuals are available for beneficial reuse.	Off-gas and particulate emissions from thermal treatment units are effectively controlled by scrubbers and other pollution control devices. Uncertainty involving the adequacy and reliability of thermal treatment units include difficulties in maintaining optimum moisture content of feed material and treatment temperature during the treatment process.	Thermal treatment destroys the COCs, therefore sediments are irreversibly treated.	Water treatment residuals consist of flocculation sludges and filter sands. Thermal treatment residuals include metals/inorganics and rocks unable to pass through the treatment unit. Thermal treatment residuals also include condensate water. Actual quantities are dependent upon sediment volumes removed.	Toxicity, mobility, and volume of COCs present in sediments are reduced by irreversible thermal treatment.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment, dewatering operations, and transportation to designated reuse area. Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Air emission controls for thermal treatment 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.
Alternative F: *In-situ* Capping	Same as Alternative C, except *in-situ* sand cap will require long-term monitoring to ensure containment.	Capped sediments will require long-term institutional controls which may limit recreational activities and boat access through the capped area. Uncertainty involving the adequacy and reliability of caps include disturbance from river currents, boat passage and draft, and ice scour. 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.	No treatment of sediments is included in this alternative.	No treatment residuals are included in this alternative, unless dredging occurs in uncapped areas. Treatment residuals from dredged material will be the same as Alternative C.	Toxicity and volume reductions beyond natural degradation do not occur as a result of capping. Mobility of COCs are reduced for capped sediments.	Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program.

Table 9-1 Detailed Analysis of Alternatives Summary - Little Lake Butte des Morts Reach (Continued)

Alternative [1]	Short-term Effectiveness		Implementability			Cost
	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks [3]	Technical Feasibility	Administrative Feasibility	Availability	Estimated Costs [4]
Alternative A: No Action	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.	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 tissue quality.	$4,500,000
Alternative B: Monitored Natural Recovery and Institutional Controls	Since an active remedy is not part of the MNR and Institutional Controls alternative, there are no environmental impacts associated with implementation of the remedy.	MNR and Institutional Controls alternative does not include an active remedy.	Although MNR is technically feasible, it will likely not meet the cleanup goals of unrestricted fish consumption in 40 years or less. MNR will likely not significantly reduce the mass transport of PCBs to Green Bay.	Institutional controls are likely not administratively feasible.	Technologies, goods, and services are available to monitor sediments, water, and tissue.	$9,900,000
Alternative C: Dredging and Off-site Disposal	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by: 1) treating water prior to discharge; 2) controlling stormwater runon and runoff; 3) utilizing removal techniques that minimize TSS; and 4) utilizing silt curtains to reduce downstream transport of COCs. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	2.1 to 12.4 years estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering and water treatment.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments,. Magnitude and risk of residual sediments are discussed in Section 8. 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 for sediment removal. Discharge permits (i.e., WPDES) will likely be required for 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.	Dredging equipment and off-site disposal facilities are commercially available.	$116,700,000 for Alternative C1 or $66,200,000 for Alternative C2
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. 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, may provide additional habitat for near shore wildlife. CDFs may alter river use availability and aesthetics for riparian owners.	2.2 to 12.5 years estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering, water treatment, and CDF capping, and up to 6 months for CDF construction.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. 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: 1) removed and contained in off-site disposal facility, or 2) removed and treated *ex situ*.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., WPDES) will likely be required for 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.	Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.	$68,000,000
Alternative E: Dredge and Thermal Treatment	Environmental impacts consist of release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	2.1 to 12.4 years estimated to complete sediment removal and thermal treatment (assuming 6 working months per year).	Alternative is technically implementable and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Air emission restrictions could affect feasibility. Backup remedy is not required for thermal treatment.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., WPDES) will likely be required for dewatering effluent. Air emissions permits will be required for the thermal treatment of sediments. 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 COCs. However, thermal treatment units are not available but need to be built to treat all dredged sediment.	$63,600,000
Alternative F: *In-situ* Capping	Environmental releases will be minimized during capping by: 1) utilizing placement techniques that minimize TSS; and 2) utilizing silt curtains to reduced downstream transport of COCs. 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.	1.7 to 12.5 years are estimated to complete sediment removal. 0.7 to 3.7 years estimated to complete cap placement and 0.7 to 3.3 years for armoring (assuming 6 working months per year).	Alternative is technically feasible and can reliably meet the cleanup goals. However, the cap can only be placed in areas with adequate water depth; sediments outside of the capping footprint must be dredged. Effectiveness is measured by sampling capped sediments, ambient air quality, and river water. Capped sediment deposits can be: 1) recapped; 2) removed and contained in off-site disposal facility; or 3) 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. 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.	$90,500,000

Notes:

1 Alternative G was not retained for this reach.

2 Human health risk threshold concentrations include: RME hazard index of 1.0 and RME 10^{5} cancer risk level for walleye (recreational angler). Ecological risk threshold concentrations include: the NOAEC bird deformity and NOAEC piscivorous mammal for carp.

3 Duration of short-term risks are included for the range of applicable action levels. Expect 2 months each for mobilization and demobilization for each alternative based on Deposit N project (Foth and Van Dyke, 2001).

4 For relative comparison between alternatives, costs for only one action level are presented (1,000 ppb) action level. Refer to Section 7 of the FS for costs associated with other action levels. Remedy costs do not include 20 percent contingency costs.

Table 9-2 Detailed Analysis of Alternatives Summary - Appleton to Little Rapids Reach

Alternative [1]	Long-term Effectiveness and Permanence		Reduction of Toxicity, Mobility, and Volume			Short-term Effectiveness
	Magnitude and Type of Residual Risk [2]	Adequacy and Reliability of Controls	Irreversibility of the Treatment	Type of Quantity of Treatment Residual	Reductions in Toxicity, Mobility, or Volume	Risk to Community and Workers and Controls
Alternative A: No Action	No action will require 51 to 84 years to consistently reach safe fish consumption levels for recreational anglers. No action will require >71 years to consistently meet safe ecological levels for carp. Surface water quality will not be met in 100 years.	The no action alternative does not include engineering or institutional controls. Long-term fish tissue monitoring will be required to evaluate status of consumption advisories already in place.	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy.
Alternative B: Monitored Natural Recovery and Institutional Controls	Similar to No Action alternative.	Enforcement of institutional controls may be difficult along the entire length of the reach. 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, river water quality, and tissue monitoring will be required to evaluate system recovery over time and achievement of project Remedial Action Objectives (RAOs).	MNR and institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy. Monitored natural recovery will likely require many years, therefore institutional controls will remain in-place until the project RAOs are met.
Alternative C: Dredging and Off-site Disposal	Remedy will require <1 to 42 years to consistently meet safe fish consumption levels for recreational anglers after completion of remedy. Remedy will require 7 to 89 years to consistently reach safe ecological levels. Surface water quality for wildlife will be met in 19 to >100 years, other criteria will not be met in 100 years. Duration of residual risk is dependent upon the selected action level. Off-site landfill will require long-term monitoring and liability.	The alternative relies on 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 liner, 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.	No treatment of sediments is included in this alternative, except for dewatering.	Water treatment residuals consist of flocculation sludges and filter sands. 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.	As successfully demonstrated during the 1999 Lower Fox River demonstration dredging project at Deposit N, inhalation and disturbance risks to the community can be minimized by: 1) coordination with and involvement of the community; 2) limiting work hours; 3) establishing buffer zones around the work areas; and 4) ambient air monitoring. Risk to workers will be minimized with a site-specific health and safety program.
Alternative E: Dredge and Thermal Treatment	Same as Alternative C, except treated residuals are available for beneficial reuse.	Off-gas and particulate emissions from thermal treatment units are effectively controlled by scrubbers and other pollution control devices. Uncertainty involving the adequacy and reliability of thermal treatment units include difficulties in maintaining optimum moisture content of feed material and treatment temperature during the treatment process.	Thermal treatment destroys the COCs, therefore sediments are irreversibly treated.	Water treatment residuals consist of flocculation sludges and filter sands. thermal treatment treatment residuals include metals/inorganics and ocks unable to pass through the treatment unit. Thermal treatment residuals also include condensate water. Actual quantities are dependent upon sediment volumes removed.	Toxicity, mobility, and volume of COCs present in sediments are reduced by irreversible thermal treatment.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment, dewatering operations, and transportation to designated reuse area. Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Air emission controls for thermal treatment 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.

Table 9-2 Detailed Analysis of Alternatives Summary - Appleton to Little Rapids Reach (Continued)

Alternative [1]	Short-term Effectiveness		Implementability			Cost
	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks [3]	Technical Feasibility	Administrative Feasibility	Availability	Estimated Costs [4]
Alternative A: No Action	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.	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 tissue quality.	$4,500,000
Alternative B: Monitored Natural Recovery and Institutional Controls	Since a remedy is not part of the MNR and Institutional Controls alternative, there are no environmental impacts associated with implementation of the remedy.	MNR and Institutional Controls alternative does not include a remedy.	Although MNR is technically feasible, it will likely not meet the cleanup goals of unrestricted fish consumption in 40 years or less. MNR will likely not significantly reduce the mass transport of PCBs to Green Bay.	Institutional controls are likely not administratively feasible.	Technologies, goods, and services are available to monitor sediments, water, and tissue.	$9,900,000
Alternative C: Dredging and Off-site Disposal	Environmental impacts consist of COC releases from removed sediments into the air and water. As successfully demonstrated during the 1999 Lower Fox River demonstration dredging project at Deposit N, environmental releases can be minimized during remediation by: 1) treating water prior to discharge; 2) controlling stormwater runoff; 3) utilizing removal techniques that minimize TSS; and 4) ambient air monitoring. Silt curtains were installed around the dredge areas to minimize downstream transport of COCs in the river, but were deemed unnecessary based on water quality monitoring results. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	0.2 to 1.3 years are estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering and water treatment.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments,. Magnitude and risk of residual sediments are discussed in Section 8. 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., WPDES) will likely be required for 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.	Dredging equipment and off-site disposal facilities are commercially available.	$20,100,000
Alternative E: Dredge and Thermal Treatment	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. 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, may provide additional habitat for near shore wildlife. CDFs may alter river use availability and aesthetics for riparian owners.	0.2 to 1.3 years are estimated to complete sediment removal and thermal treatment (assuming 6 working months per year).	Alternative is technically implementable and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Air emission restrictions could affect feasibility. Backup remedy is not required for thermal treatment.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., WPDES) will likely be required for dewatering effluent. Air emissions permits will be required for the thermal treatment of sediments. 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 COCs. However, thermal treatment units are not available but need to be built to treat all dredged sediment.	$17,100,000

Notes:

1 Alternatives D, F, and G were not retained for this reach.

2 Human health risk threshold concentrations include: RME hazard index of 1.0 and RME 10^{5} cancer risk level for walleye (recreational angler). Ecological risk threshold concentrations include: the NOAEC bird deformity and NOAEC piscivorous mammal for carp.

3 Duration of short-term risks are included for the range of applicable action levels. Expect 2 months each for mobilization and demobilization for each alternative based on Deposit N project (Foth and Van Dyke, 2001).

4 For relative comparison between alternatives, costs for only one action level are presented (1,000 ppb) action level. Refer to Section 7 of the FS for costs associated with other action levels. Remedy costs do not include 20 percent contingency costs.

Table 9-3 Detailed Analysis of Alternatives Summary - Little Rapids to De Pere Reach

Alternative [1]	Long-term Effectiveness and Permanence		Reduction of Toxicity, Mobility, and Volume			Short-term Effectiveness
	Magnitude and Type of Residual Risk [2]	Adequacy and Reliability of Controls	Irreversibility of the Treatment	Type and Quantity of Treatment Residual	Reduction of Toxicity, Mobility, or Volume	Risk to Community and Workers and Controls
Alternative A: No Action	No action will require 92 to >100 years to consistently meet safe fish consumption levels for recreational anglers. No action will require >100 years to reach safe ecological levels for carp. Surface water quality will not be met in 100 years.	The no action alternative does not include engineering or institutional controls. Long-term fish tissue monitoring will be required to evaluate status of consumption advisories already in place.	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy.
Alternative B: Monitored Natural Recovery and Institutional Controls	Similar to No Action alternative.	Enforcement of institutional controls may be difficult along the entire length of the reach. 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, river water quality, and tissue monitoring will be required to evaluate system recovery over time and achievement of project RAOs.	MNR and institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy. Monitored natural recovery will likely require many years, therefore institutional controls will remain in-place until the project RAOs are met.
Alternative C: Dredging and Off-site Disposal	Remedy will require 2 to 92 years to consistently meet safe fish consumption levels for recreational anglers after completion of a corrective remedy. Remedy will require <1 to >100 years to consistently reach safe ecological levels for carp. Surface water quality for wildlife will be met in 27 to >100 years, other criteria will not be met in 100 years. Duration of residual risk is dependent upon the selected action level. Off-site landfill will require long-term monitoring and liability.	The alternative relies on 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 liner, 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.	No treatment of sediments is included in this alternative, except for dewatering.	Water treatment residuals consist of flocculation sludges and filter sands. 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.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment, dewatering operations, and transport to disposal facility. Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Risks from spillage during transport will be minimized by the solidification of sediments, 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.
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Same as Alternative C, except on-site CDF will require long-term monitoring to ensure source control and containment.	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 seepage, 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.	No treatment of sediments is included in this alternative.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when confined within the CDF.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment and dewatering operations. Risks to community will be minimized by establishing buffer zones around work areas and limiting work hours. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program. The constructed CDF, when completed, may provide recreational park space for the community.
Alternative E: Dredge and Thermal Treatment	Same as Alternative C, except treated residuals are available for beneficial reuse.	Off-gas and particulate emissions from thermal treatment units are effectively controlled by scrubbers and other pollution control devices. Uncertainty involving the adequacy and reliability of thermal treatment units include difficulties in maintaining optimum moisture content of feed material and treatment temperature during the treatment process.	Thermal treatment destroys the COCs, therefore sediments are irreversibly treated.	Water treatment residuals consist of flocculation sludges and filter sands. Thermal treatment residuals include metals/inorganics and rocks unable to pass through the treatment unit. Thermal treatment residuals also include condensate water. Actual quantities are dependent upon sediment volumes removed.	Toxicity, mobility, and volume of COCs present in sediments are reduced by irreversible thermal treatment.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment, dewatering operations, and transportation to designated reuse area. Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Air emission controls for thermal treatment 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.
Alternative F: *In-situ* Capping	Same as Alternative C, except *in-situ* sand cap will require long-term monitoring to ensure containment.	Capped sediments will require long-term institutional controls which may limit recreational activities and boat access through the capped area. Uncertainty involving the adequacy and reliability of caps include disturbance from river currents, boat passage and draft, and ice scour. 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.	No treatment of sediments is included in this alternative.	No treatment residuals are included in this alternative, unless dredging occurs in uncapped areas. Treatment residuals from dredged material will be the same as Alternative C.	Toxicity and volume reductions beyond natural degradation do not occur as a result of capping. Mobility of COCs are reduced for capped sediments.	Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program.

Table 9-3 Detailed Analysis of Alternatives Summary - Little Rapids to De Pere Reach (Continued)

Alternative [1]	Short-term Effectiveness		Implementability			Cost
	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks [3]	Technical Feasibility	Administrative Feasibility	Availability	Estimated Costs [4]
Alternative A: No Action	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.	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 tissue quality.	$4,500,000
Alternative B: Monitored Natural Recovery and Institutional Controls	Since a remedy is not part of the MNR and Institutional Controls alternative, there are no environmental impacts associated with implementation of the remedy.	MNR and Institutional Controls alternative does not include an active remedy.	Although MNR is technically feasible, it will likely not meet the cleanup goals of unrestricted fish consumption in 40 years or less. MNR will likely not significantly reduce the mass transport of PCBs to Green Bay.	Institutional controls are likely not administratively feasible.	Technologies, goods, and services are available to monitor sediments, water, and tissue.	$9,900,000
Alternative C: Dredging and Off-site Disposal	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by: 1) treating water prior to discharge; 2) controlling stormwater runon and runoff; 3) utilizing removal techniques that minimize TSS; and 4) utilizing silt curtains to reduce downstream transport of COCs. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	1.4 to 10.9 years are estimated for Alternatives C1 and C3, and 0.2 to 1.7 years for Alternative C2 to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering and water treatment.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments,. Magnitude and risk of residual sediments are discussed in Section 8. 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., WPDES) will likely be required for 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.	Dredging equipment and off-site disposal facilities are commercially available.	$95,100,000 for Alternative C1, $43,900,000 for Alternative C2A, $99,900,000 for Alternative C2B, or $69,100,000 for Alternative C3
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. 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, may provide additional habitat for near shore wildlife. CDFs may alter river use availability and aesthetics for riparian owners.	1.4 to 10.9 years are estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering, water treatment, and CDF capping, and up to 6 months for CDF construction.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. 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: 1) removed and contained in off-site disposal facility, or 2) removed and treated *ex situ*.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., WPDES) will likely be required for 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.	Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.	$52,500,000
Alternative E: Dredge and Thermal Treatment	Environmental impacts consist of release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	1.4 to 10.9 years are estimated to complete sediment removal and thermal treatment (assuming 6 working months per year).	Alternative is technically implementable and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Air emission restrictions could affect feasibility. Backup remedy is not required for thermal treatment.	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. 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 COCs. However, thermal treatment units are not available but need to be built to treat all dredged sediments.	$86,200,000
Alternative F: *In-situ* Capping	Environmental releases will be minimized during capping by: 1) utilizing placement techniques that minimize TSS; and 2) utilizing silt curtains to reduced downstream transport of COCs. 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.	0.4 to 4.3 years are estimated to complete sediment removal. 1.2 to 4.6 years are estimated to complete cap placement and 1.1 to 4.2 years for armoring (assuming 6 working months per year).	Alternative is technically feasible and can reliably meet the cleanup goals. However, the cap can only be placed in areas with adequate water depth; sediments outside of the capping footprint must be dredged. Effectiveness is measured by sampling capped sediments, ambient air quality, and river water. Capped sediment deposits can be: 1) recapped; 2) removed and contained in off-site disposal facility; or 3) 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. 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.	$62,900,000

Notes:

1 Alternative G was not retained for this reach.

2 Human health risk threshold concentrations include: RME hazard index of 1.0 and RME 10^{5} cancer risk level for walleye (recreational angler). Ecological risk threshold concentrations include: the NOAEC bird deformity and NOAEC piscivorous mammal for carp.

3 Duration of short-term risks are included for the range of applicable action levels. Expect 2 months each for mobilization and demobilization for each alternative based on Deposit N project (Foth and Van Dyke, 2001).

4 For relative comparison between alternatives, costs for only one action level are presented (1,000 ppb) action level. Refer to Section 7 of the FS for costs associated with other action levels. Remedy costs do not include 20 percent contingency costs.

Table 9-4 Detailed Analysis of Alternatives Summary - De Pere to Green Bay Reach (Green Bay Zone 1)

Alternative [1]	Long-term Effectiveness and Permanence		Reduction of Toxicity, Mobility, and Volume			Short-term Effectiveness
	Magnitude and Type of Residual Risk [2]	Adequacy and Reliability of Controls	Irreversibility of the Treatment	Type and Quantity of Treatment Residual	Reduction of Toxicity, Mobility, or Volume	Risk to Community and Workers and Controls
Alternative A: No Action	No action will require >100 years to consistently meet safe fish consumption levels for recreational anglers. No action will require >100 years to consistently reach safe ecological levels for carp. Surface water quality will not be met in 100 years. PCB loading rates into Green Bay will not equal tributary loading rates in 100 years.	The no action alternative does not include engineering or institutional controls. Long-term fish tissue monitoring will be required to evaluate status of consumption advisories already in place.	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy.
Alternative B: Monitored Natural Recovery and Institutional Controls	Similar to No Action alternative.	Enforcement of institutional controls may be difficult along the entire length of the reach. 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, river water quality, and tissue monitoring will be required to evaluate system recovery over time and achievement of project RAOs.	MNR and institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy. Monitored natural recovery will likely require many years, therefore institutional controls will remain in-place until the project RAOs are met.
Alternative C: Dredging and Off-site Disposal	Remedy will require 7 to >100 years to consistently meet safe fish consumption levels after completion of remedy. Remedy will require 5 to >100 years to consistently reach safe ecological levels for carp. Surface water quality for wildlife will be consistently met in 27 to >100 years. PCB loading rates into Green Bay will consistently equal tributary loading rates in <1 to 36 years following remedy completion. Duration of residual risk is dependent upon the selected action level. Off-site landfill will require long-term monitoring and liability.	The alternative relies on 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 liner, 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.	No treatment of sediments is included in this alternative, except for dewatering.	Water treatment residuals consist of flocculation sludges and filter sands. 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.	As successfully demonstrated during the 2000 Lower Fox River demonstration dredging project at SMU 56/57, inhalation and disturbance risks to the community can be minimized by: 1) coordination with and involvement of the community; 2) limiting work hours; 3) establishing buffer zones around the work areas; and 4) ambient air monitoring. Risk to workers will be minimized with a site-specific health and safety program.
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Same as Alternative C, except on-site CDF will require long-term monitoring to ensure source control and containment.	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 seepage, 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.	No treatment of sediments is included in this alternative.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when within the CDF.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment and dewatering operations. Risks to community will be minimized by establishing buffer zones around work areas and limiting work hours. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program. The constructed CDF, when completed, may provide recreational park space for the community.
Alternative E: Dredge and Thermal Treatment	Same as Alternative C, except treated residuals are available for beneficial reuse.	Off-gas and particulate emissions from thermal treatment units are effectively controlled by scrubbers and other pollution control devices. Uncertainty involving the adequacy and reliability of thermal treatment units include difficulties in maintaining optimum moisture content of feed material and treatment temperature during the treatment process.	Thermal treatment destroys the COCs, therefore sediments are irreversibly treated.	Water treatment residuals consist of flocculation sludges and filter sands. Thermal treatment residuals include metals/inorganics and large rocks and boulders unable to pass through the treatment unit. Thermal treatment residuals also include condensate water. Actual quantities are dependent upon sediment volumes removed.	Toxicity, mobility, and volume of COCs present in sediments are reduced by irreversible thermal treatment.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment, dewatering operations, and transportation to designated reuse area. Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Air emission controls for thermal treatment 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.
Alternative F: *In-situ* Capping	Same as Alternative C, except *in-situ* sand cap will require long-term monitoring to ensure containment.	Capped sediments will require long-term institutional controls which may limit recreational activities and boat access through the capped area. Uncertainty involving the adequacy and reliability of caps include disturbance from river currents, boat passage and draft, and ice scour. 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.	No treatment of sediments is included in this alternative.	No treatment residuals are included in this alternative, unless dredging occurs in uncapped areas. Treatment residuals from dredged material will be the same as Alternative C.	Toxicity and volume reductions beyond natural degradation do not occur as a result of capping. Mobility of COCs are reduced for capped sediments.	Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program.

Table 9-4 Detailed Analysis of Alternatives Summary - De Pere to Green Bay Reach (Green Bay Zone 1) (Continued)

Alternative [1]	Short-term Effectiveness		Implementability			Cost
	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks [3]	Technical Feasibility	Administrative Feasibility	Availability	Estimated Costs [4]
Alternative A: No Action	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.	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 tissue quality.	$4,500,000
Alternative B: Monitored Natural Recovery and Institutional Controls	Since a remedy is not part of the MNR and Institutional Controls alternative, there are no environmental impacts associated with implementation of the remedy.	MNR and Institutional Controls alternative does not include an active remedy.	Although MNR is technically feasible, it will likely not meet the cleanup goals of unrestricted fish consumption in 40 years or less. MNR will likely not significantly reduce the mass transport of PCBs to Green Bay.	Institutional controls are likely not administratively feasible.	Technologies, goods, and services are available to monitor sediments, water, and tissue.	$9,900,000
Alternative C: Dredging and Off-site Disposal	Environmental impacts consist of COC releases from removed sediments into the air and water. As successfully demonstrated during the 2000 SMU 56/57 demonstration dredging project, environmental releases can be minimized during remediation by: 1) treating water prior to discharge; 2) controlling stormwater runoff; 3) utilizing removal techniques that minimize TSS; and 4) ambient air monitoring. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	6.1 to 9.3 years are estimated for Alternative C1 and 5.2 to 8.0 years for Alternatives C2 and C3 to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering and water treatment.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. 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., WPDES) will likely be required for 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.	Dredging equipment and off-site disposal facilities are commercially available.	$660,600,000 for Alternative C1, $173,500,000 for Alternative C2A, $491,800,000 for Alternative C2B, or $513,500,000 for Alternative C3
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. 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, may provide additional habitat for near shore wildlife. CDFs may alter river use availability and aesthetics for riparian owners.	6.1 to 9.3 years are estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering, water treatment, and CDF capping, and up to 6 months for CDF construction.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. 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: 1) removed and contained in off-site disposal facility, or 2) removed and treated *ex situ*.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., WPDES) will likely be required for 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.	Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.	$505,100,000
Alternative E: Dredge and Thermal Treatment	Environmental impacts consist of release of COCs from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	5.2 to 8.0 years are estimated to complete sediment removal and thermal treatment (assuming 6 working months per year).	Alternative is technically implementable and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, and river water. Air emission restrictions could affect feasibility. Backup remedy is not required for thermal treatment.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., WPDES) will likely be required for dewatering effluent. Air emissions permits will be required for the thermal treatment of sediments. 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 COCs. However, thermal treatment units are not available but need to be built to treat all dredged sediment.	$355,100,000
Alternative F: *In-situ* Capping	Environmental releases will be minimized during capping by: 1) utilizing placement techniques that minimize TSS; and 2) utilizing silt curtains to reduced downstream transport of COCs. 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.	4.2 to 6.3 years are estimated to complete sediment removal. 4.9 to 8.3 years are estimated to complete cap placement and 4.5 to 7.5 years for armoring (assuming 6 working months per year).	Alternative is technically feasible and can reliably meet the cleanup goals. However, the cap can only be placed in areas with adequate water depth; sediments outside of the capping footprint must be dredged. Effectiveness is measured by sampling capped sediments, ambient air quality, and river water. Capped sediment deposits can be: 1) recapped; 2) removed and contained in off-site disposal facility; or 3) 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. 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.	$357,100,000

Notes:

1 Alternative G was not retained for this reach.
2 Human health risk threshold concentrations include: RME hazard index of 1.0 and RME 10^{5} cancer risk level for walleye (recreational angler). Ecological risk threshold concentrations include: the NOAEC bird deformity and NOAEC piscivorous mammal for carp.
3 Duration of short-term risks are included for the range of applicable action levels. Expect 2 months each for mobilization and demobilization for each alternative based on Deposit N project (Foth and Van Dyke, 2001).
4 For relative comparison between alternatives, costs for only one action level are presented (1,000 ppb) action level. Refer to Section 7 of the FS for costs associated with other action levels. Remedy costs do not include 20 percent contingency costs.

Table 9-5 Detailed Analysis of Alternatives Summary - Green Bay Zone 2

Alternative [1]	Long-term Effectiveness and Permanence		Reduction of Toxicity, Mobility, and Volume			Short-term Effectiveness
	Magnitude and Type of Residual Risk [2]	Adequacy and Reliability of Controls	Irreversibility of the Treatment	Type and Quantity of Treatment Residual	Reduction of Toxicity, Mobility, or Volume	Risk to Community and Workers and Controls
Alternative A: No Action	No action will not meet safe fish consumption levels for recreational anglers in 100 years (first meet nor consistently meet), regardless of the action taken in the Lower Fox River. No action will not meet safe ecological levels for walleye in 100 years, regardless of the action taken in the Lower Fox River. Surface water quality was not evaluated.	The no action alternative does not include engineering or institutional controls. Long-term fish tissue monitoring will be required to evaluate status of consumption advisories already in place.	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy.
Alternative B: Monitored Natural Recovery and Institutional Controls	Similar to No Action alternative.	Enforcement of institutional controls may be difficult along the entire length of the reach. 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, river water quality, and tissue monitoring will be required to evaluate system recovery over time and achievement of project Remedial Action Objectives (RAOs).	MNR and institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy. Monitored natural recovery will likely require many years, therefore institutional controls will remain in-place until the project RAOs are met.
Alternative C: Dredging and Off-site Disposal	Remedy will not consistently meet safe fish consumption levels in 100 years after completion of remedy. Remedy will require >100 years to consistently reach safe ecological levels for walleye, regardless of the action taken in the Lower Fox River. Risk reduction is projected for alewife levels (see Section 8). Duration of residual risk is dependent upon the selected action level. Off-site landfill will require long-term monitoring and liability.	The alternative relies on 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 liner, 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.	No treatment of sediments is included in this alternative, except for dewatering.	Water treatment residuals consist of flocculation sludges and filter sands. 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.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment, dewatering operations, and transport to disposal facility. Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Risks from spillage during transport will be minimized by the solidification of sediments, 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.
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Same as Alternative C, except on-site CDF will require long-term monitoring to ensure source control and containment.	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 seepage, 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.	No treatment of sediments is included in this alternative.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when confined within the CDF.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment and dewatering operations. Risks to community will be minimized by establishing buffer zones around work areas and limiting work hours. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program. The constructed CDF, when completed, may provide recreational park space for the community.
Alternative G: Dredge to a Contained Aquatic Disposal (CAD) Facility	Same as Alternative C, except on-site CAD site will require long-term monitoring to ensure source control and containment.	Sediments placed within a CAD will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CADs include lack of liner and potential difficulties in maintaining a hydraulic gradient to ensure containment of pore water. Institutional controls are reliable if properly enforced. Long-term monitoring and maintenance will be required for the CAD to document and maintain the effectiveness of the containment. Permanent deed and access restrictions will be required.	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Water treatment residuals consist of flocculation sludges and 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 placed within confined disposal facility.	Risks to community and workers are potentially caused by air emissions from construction equipment and discharges to water from sediment removal and management. Risks to community will be minimized by utilizing silt curtains and not working during residence high-occupancy times such as evenings and weekends. Risks during transport will be minimized by the solid nature of the material and spill prevention control and countermeasures plans. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program.

Table 9-5 Detailed Analysis of Alternatives Summary - Green Bay Zone 2 (Continued)

Alternative [1]	Short-term Effectiveness		Implementability			Cost
	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks [3]	Technical Feasibility	Administrative Feasibility	Availability	Estimated Costs [4]
Alternative A: No Action	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.	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 tissue quality.	$4,500,000
Alternative B: Monitored Natural Recovery and Institutional Controls	Since a remedy is not part of the MNR and Institutional Controls alternative, there are no environmental impacts associated with implementation of the remedy.	MNR and Institutional Controls alternative does not include an active remedy.	Although MNR is technically feasible, it will likely not meet the cleanup goals of unrestricted fish consumption in 40 years or less. MNR will likely not significantly reduce the mass transport of PCBs to Lake Michigan.	Institutional controls are likely not administratively feasible.	Technologies, goods, and services are available to monitor sediments, water, and tissue.	$9,900,000
Alternative C: Dredging and Off-site Disposal	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by: 1) treating water prior to discharge; 2) controlling stormwater runon and runoff; 3) utilizing removal techniques that minimize TSS; and 4) utilizing silt curtains to reduce downstream transport of COCs. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	1.1 years are estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering and water treatment.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments,. Magnitude and risk of residual sediments are discussed in Section 8. 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 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.	Dredging equipment and off-site disposal facilities are commercially available.	$507,200,000 (for 5,000 ppb action level)
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. 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, may provide additional habitat for near shore wildlife. CDFs may alter river use availability and aesthetics for riparian owners.	1.1 to 8.2 years are estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering, water treatment, and CDF capping.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. 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: 1) removed and contained in off-site disposal facility, or 2) removed and treated *ex situ*.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., WPDES) will likely be required for 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.	Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.	$814,100,000
Alternative G: Dredge to a Contained Aquatic Disposal (CAD) Facility	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: 1) treating water to be discharged off site; 2) controlling stormwater runon and runoff; 3) utilizing removal techniques that minimize TSS; and 4) 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 CAD will also initially create a loss of habitat for aquatic organisms along with changes in water flow patterns. Noise will be mitigated with a buffer zone and by limiting work hours. CADs may alter river use availability and aesthetics for riparian owners.	1.1 to 8.2 years are estimated to complete sediment removal (assuming 6 working months per year). 1 to 2 additional years estimated for CAD cap placement.	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk-based number derived from the risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, surface water, and sand cap after placement.	Alternative is administratively feasible, however, legislative authority may be required prior to constructing a CAD (Wisconsin Statute 30 Lakebed Grant). 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. Local permits such as building permits, zoning permits, etc. may also be required.	Potential CAD construction areas exist and technology and associated goods and services are available to construct CADs. Sufficient upland areas can be secured to operate staging and water treatment activities.	$697,800,000

Notes:

1 Alternatives E and F were not retained for this reach.

2 Human health risk threshold concentrations include: RME hazard index of 1.0 and RME 10^{5} cancer risk level for walleye (recreational angler). Ecological risk threshold concentrations include: the NOAEC bird deformity and NOAEC piscivorous mammal for carp.

3 Duration of short-term risks are included for the range of applicable action levels. Expect 2 months each for mobilization and demobilization for each alternative based on Deposit N project (Foth and Van Dyke, 2001).

4 For relative comparison between alternatives, costs for only one action level are presented (1,000 ppb) action level. Refer to Section 7 of the FS for costs associated with other action levels. Remedy costs do not include 20 percent contingency costs.

Table 9-6 Detailed Analysis of Alternatives Summary - Green Bay Zone 3A

Alternative [1]	Long-term Effectiveness and Permanence		Reduction of Toxicity, Mobility, and Volume			Short-term Effectiveness
	Magnitude and Type of Residual Risk [2]	Adequacy and Reliability of Controls	Irreversibility of the Treatment	Type and Quantity of Treatment Residual	Reduction of Toxicity, Mobility, or Volume	Risk to Community and Workers and Controls
Alternative A: No Action	No action will not meet (first meet nor consistently meet) safe fish consumption levels for recreational anglers in 100 years, regardless of the action taken in the Lower Fox River. No action will not meet safe ecological levels for walleye in 100 years, regardless of the action taken in the Lower Fox River. Surface water quality was not evaluated.	The no action alternative does not include engineering or institutional controls. Long-term fish tissue monitoring will be required to evaluate status of consumption advisories already in place.	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy.
Alternative B: Monitored Natural Recovery and Institutional Controls	Similar to No Action alternative.	Enforcement of institutional controls may be difficult along the entire length of the reach. 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, river water quality, and tissue monitoring will be required to evaluate system recovery over time and achievement of project RAOs.	MNR and institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy. Monitored natural recovery will likely require many years, therefore institutional controls will remain in-place until the project RAOs are met.
Alternative C: Dredging and Off-site Disposal	Remedy will not consistently meet safe fish consumption levels in 100 years after completion of remedy. Remedy will require >100 years to reach safe ecological levels for walleye. Some ecological levels for bird deformities associated with alewife consumption (discussed in Section 8) will be met in <30 years following remedy completion. Duration of residual risk is dependent upon the selected action level. Off-site landfill will require long-term monitoring and liability.	The alternative relies on 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 liner, 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.	No treatment of sediments is included in this alternative, except for dewatering.	Water treatment residuals consist of flocculation sludges and filter sands. 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.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment, dewatering operations, and transport to disposal facility. Risks to community will be minimized by establishing buffer zones around the work areas and limiting work hours. Ambient air monitoring may be required. Risks from spillage during transport will be minimized by the solidification of sediments, 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.
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Same as Alternative C, except on-site CDF will require long-term monitoring to ensure source control and containment.	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 seepage, 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.	No treatment of sediments is included in this alternative.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when confined within the CDF.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment and dewatering operations. Risks to community will be minimized by establishing buffer zones around work areas and limiting work hours. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program. The constructed CDF, when completed, may provide recreational park space for the community.
Alternative G: Dredge to a Contained Aquatic Disposal (CAD) Facility	Same as Alternative C, except on-site CAD site will require long-term monitoring to ensure source control and containment.	Sediments placed within a CAD will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CADs include lack of liner and potential difficulties in maintaining a hydraulic gradient to ensure containment of pore water. Institutional controls are reliable if properly enforced. Long-term monitoring and maintenance will be required for the CAD to document and maintain the effectiveness of the containment. Permanent deed and access restrictions will be required.	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Water treatment residuals consist of flocculation sludges and 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 placed within confined disposal facility.	Risks to community and workers are potentially caused by air emissions from construction equipment and discharges to water from sediment removal and management. Risks to community will be minimized by utilizing silt curtains and not working during residence high-occupancy times such as evenings and weekends. Risks during transport will be minimized by the solid nature of the material and spill prevention control and countermeasures plans. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program.

Table 9-6 Detailed Analysis of Alternatives Summary - Green Bay Zone 3A (Continued)

Alternative [1]	Short-term Effectiveness		Implementability			Cost
	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks [3]	Technical Feasibility	Administrative Feasibility	Availability	Estimated Costs [4]
Alternative A: No Action	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.	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 tissue quality.	$4,500,000
Alternative B: Monitored Natural Recovery and Institutional Controls	Since a remedy is not part of the MNR and Institutional Controls alternative, there are no environmental impacts associated with implementation of the remedy.	MNR and Institutional Controls alternative does not include an active remedy.	Although MNR is technically feasible, it will likely not meet the cleanup goals of unrestricted fish consumption in 40 years or less. MNR will likely not significantly reduce the mass transport of PCBs to Lake Michigan.	Institutional controls are likely not administratively feasible.	Technologies, goods, and services are available to monitor sediments, water, and tissue.	$9,900,000
Alternative C: Dredging and Off-site Disposal	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by: 1) treating water prior to discharge; 2) controlling stormwater runon and runoff; 3) utilizing removal techniques that minimize TSS; and 4) utilizing silt curtains to reduce downstream transport of COCs. Environmental impacts of sediment removal will likely include a temporary loss of habitat for aquatic organisms.	0.6 day is estimated to complete sediment removal.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments,. Magnitude and risk of residual sediments are discussed in Section 8. 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 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.	Dredging equipment and off-site disposal facilities are commercially available.	$11,000,000 (for 1,000 ppb action level)
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. 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, may provide additional habitat for near shore wildlife. CDFs may alter river use availability and aesthetics for riparian owners.	4.5 years are estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for final dewatering, water treatment, and CDF capping.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. 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: 1) removed and contained in off-site disposal facility, or 2) removed and treated *ex situ*.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., WPDES) will likely be required for 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.	Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.	$474,300,000 (for 500 ppb action level)
Alternative G: Dredge to a Contained Aquatic Disposal (CAD) Facility	Same as Alternative C, except on-site CAD site will require long-term monitoring to ensure source control and containment. The construction of a CAD will also initially create a loss of habitat for aquatic organisms along with changes in water flow patterns.	4.5 years are estimated to complete sediment removal (assuming 6 working months per year). 2 additional years estimated for CAD cap placement.	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk-based number derived from the risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, surface water, and sand cap after placement.	Alternative is administratively feasible, however, legislative authority may be required prior to constructing a CAD (Wisconsin Statute 30 Lakebed Grant). 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. Local permits such as building permits, zoning permits, etc. may also be required.	Potential CAD construction areas exist and technology and associated goods and services are available to construct CADs. Sufficient upland areas can be secured to operate staging and water treatment activities.	$389,100,000 (for 500 ppb action level)

Notes:

1 Alternatives E and F were not retained for this reach.

2 Human health risk threshold concentrations include: RME hazard index of 1.0 and RME 10^{5} cancer risk level for walleye (recreational angler). Ecological risk threshold concentrations include: the NOAEC bird deformity and NOAEC piscivorous mammal for carp.

3 Duration of short-term risks are included for the range of applicable action levels. Expect 2 months each for mobilization and demobilization for each alternative based on Deposit N project (Foth and Van Dyke, 2001).

4 For relative comparison between alternatives, costs for only one action level are presented (500 ppb) action level when applicable. Refer to Section 7 of the FS for costs associated with other action levels. Remedy costs do not include 20 percent conting

Table 9-7 Detailed Analysis of Alternatives Summary - Green Bay Zone 3B

Alternative [1]	Long-term Effectiveness and Permanence		Reduction of Toxicity, Mobility and Volume			Short-term Effectiveness
	Magnitude and Type of Residual Risk [2]	Adequacy and Reliability of Controls	Irreversibility of the Treatment	Type and Quantity of Treatment Residual	Reduction of Toxicity, Mobility, or Volume	Risk to Community and Workers and Controls
Alternative A: No Action	No action will not meet (first meet nor consistently meet) safe fish consumption levels for recreational anglers in 100 years, regardless of the action taken in the Lower Fox River. No action will not meet safe ecological levels in 100 years, regardless of the action taken in the Lower Fox River. Surface water quality was not evaluated.	The no action alternative does not include engineering or institutional controls. Long-term fish tissue monitoring will be required to evaluate status of consumption advisories already in place.	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy.
Alternative B: Monitored Natural Recovery and Institutional Controls	Similar to No Action alternative.	Enforcement of institutional controls may be difficult along the entire length of the reach. 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, river water quality, and tissue monitoring will be required to evaluate system recovery over time and achievement of project Remedial Action Objectives (RAOs).	MNR and institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy. Monitored natural recovery will likely require many years, therefore institutional controls will remain in-place until the project RAOs are met.
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Remedy will require >100 years to consistently meet safe fish consumption levels after completion of remedy, regardless of the action taken on the Lower Fox River. Remedy will require >100 years to reach safe ecological levels for walleye. Some alewife protective levels related to bird deformities will be met in <30 years following completion of a remedy (discussed in Section 8). Surface water quality was not evaluated. Duration of residual risk is dependent upon the selected action level.	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 seepage, 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.	No treatment of sediments is included in this alternative.	Water treatment residuals consist of flocculation sludges and filter sands. Actual quantities are dependent upon sediment volumes removed.	Toxicity and volume reductions are minimal due to disposal. Mobility of COCs are reduced when confined within the CDF.	Risks to community and workers are potentially caused by air emissions and excessive noise from construction equipment and dewatering operations. Risks to community will be minimized by establishing buffer zones around work areas and limiting work hours. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program. The constructed CDF, when completed, may provide recreational park space for the community.
Alternative G: Dredge to a Contained Aquatic Disposal (CAD) Facility	Same as Alternative D, except on-site CAD site will require long-term monitoring to ensure source control and containment.	Sediments placed within a CAD will require long-term institutional controls such as land use restrictions to prevent disturbance of the sediments. Uncertainty involving the adequacy and reliability of CADs include lack of liner and potential difficulties in maintaining a hydraulic gradient to ensure containment of pore water. Institutional controls are reliable if properly enforced. Long-term monitoring and maintenance will be required for the CAD to document and maintain the effectiveness of the containment. Permanent deed and access restrictions will be required.	No treatment of sediments is included in this alternative.	No treatment of sediments is included in this alternative. Water treatment residuals consist of flocculation sludges and 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 placed within confined disposal facility.	Risks to community and workers are potentially caused by air emissions from construction equipment and discharges to water from sediment removal and management. Risks to community will be minimized by utilizing silt curtains and not working during residence high-occupancy times such as evenings and weekends. Risks during transport will be minimized by the solid nature of the material and spill prevention control and countermeasures plans. Ambient air monitoring may be required. Risk to workers will be minimized with a site-specific health and safety program.

Table 9-7 Detailed Analysis of Alternatives Summary - Green Bay Zone 3B (Continued)

Alternative [1]	Short-term Effectiveness		Implementability			Cost
	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks [3]	Technical Feasibility	Administrative Feasibility	Availability	Estimated Costs [4]
Alternative A: No Action	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.	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 tissue quality.	$4,500,000
Alternative B: Monitored Natural Recovery and Institutional Controls	Since a remedy is not part of the MNR and Institutional Controls alternative, there are no environmental impacts associated with implementation of the remedy.	MNR and Institutional Controls alternative does not include an active remedy.	Although MNR is technically feasible, it will likely not meet the cleanup goals of unrestricted fish consumption in 40 years or less. MNR will likely not significantly reduce the mass transport of PCBs to Lake Michigan.	Institutional controls are likely not administratively feasible.	Technologies, goods, and services are available to monitor sediments, water, and tissue.	$9,900,000
Alternative D: Dredge to a Confined Disposal Facility (CDF)	Environmental impacts consist of COC releases from removed sediments into the air and water. Environmental releases will be minimized during remediation by following the same control measures outlined in Alternative C. 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, may provide additional habitat for near shore wildlife. CDFs may alter river use availability and aesthetics for riparian owners.	12 years are estimated to complete sediment removal (assuming 6 working months per year). 1 additional year estimated for dewatering, water treatment, and CDF capping.	Alternative is technically feasible and can reliably meet the cleanup goals. The cleanup goal is a risk-based number derived from residual sediments. Magnitude and risk of residual sediments are discussed in Section 8. 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: 1) removed and contained in off-site disposal facility, or 2) removed and treated *ex situ*.	Alternative is administratively feasible. Water quality permits from the WDNR and the USACE are likely to be required for sediment removal. Discharge permits (i.e., NPDES/WPDES) will likely be required for 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.	Potential CDF construction areas exist and technology and associated goods and services are available to construct CDFs.	$1,155,100,000
Alternative G: Dredge to a Contained Aquatic Disposal (CAD) Facility	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: 1) treating water to be discharged off site; 2) controlling stormwater runon and runoff; 3) utilizing removal techniques that minimize TSS; and 4) 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 CAD will also initially create a loss of habitat for aquatic organisms along with changes in water flow patterns. Noise will be mitigated with a buffer zone and by limiting work hours. CADs may alter river use availability and aesthetics for riparian owners.	12 years are estimated to complete sediment removal (assuming 6 working months per year). 4 additional years estimated for CAD cap placement.	Alternative can reliably meet the cleanup goal. The cleanup goal for this alternative is a risk-based number derived from the risk of residual sediments. The magnitude and risk of the residual sediments is outlined in Section 8. Effectiveness is measured by sampling limit of excavation, ambient air quality, wastewater effluent, surface water, and sand cap after placement.	Alternative is administratively feasible, however, legislative authority may be required prior to constructing a CAD (Wisconsin Statute 30 Lakebed Grant). 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. Local permits such as building permits, zoning permits, etc. may also be required.	Potential CAD construction areas exist and technology and associated goods and services are available to construct CADs. Sufficient upland areas can be secured to operate staging and water treatment activities.	$1,010,900,000

Notes:

1 Alternatives C, E, and F were not retained for this reach.

2 Human health risk threshold concentrations include: RME hazard index of 1.0 and RME 10^{5} cancer risk level for walleye (recreational angler). Ecological risk threshold concentrations include: the NOAEC bird deformity and NOAEC piscivorous mammal for carp.

3 Duration of short-term risks are included for the range of applicable action levels. Expect 2 months each for mobilization and demobilization for each alternative based on Deposit N project (Foth and Van Dyke, 2001).

4 For relative comparison between alternatives, costs for only one action level are presented (500 ppb) action level. Refer to Section 7 of the FS for costs associated with other action levels. Remedy costs do not include 20 percent contingency costs.

Table 9-8 Detailed Analysis of Alternatives Summary - Green Bay Zone 4

Alternative [1]	Long-term Effectiveness and Permanence		Reduction of Toxicity, Mobility, and Volume			Short-term Effectiveness
	Magnitude and Type of Residual Risk [2]	Adequacy and Reliability of Controls	Irreversibility of the Treatment	Type and Quantity of Treatment Residual	Reduction of Toxicity, Mobility, or Volume	Risk to Community and Workers and Controls
Alternative A: No Action	No action will not meet (first meet nor consistently meet) safe fish consumption levels for recreational anglers in 100 years, regardless of the action taken on the Lower Fox River. No action will not meet safe ecological levels in 100 years, regardless of the action taken in the Lower Fox River. Surface water quality was not evaluated.	The no action alternative does not include engineering or institutional controls. Long-term fish tissue monitoring will be required to evaluate status of consumption advisories already in place.	No action is reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy.
Alternative B: Monitored Natural Recovery and Institutional Controls	Similar to No Action alternative.	Enforcement of institutional controls may be difficult along the entire length of the reach. 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, river water quality, and tissue monitoring will be required to evaluate system recovery over time and achievement of project Remedial Action Objectives (RAOs).	MNR and institutional controls are reversible.	Residuals do not exist under this alternative.	Minimal reductions of toxicity, mobility, and volume of COCs through naturally-occurring processes.	There are no short-term risks associated with this remedy. Monitored natural recovery will likely require many years, therefore institutional controls will remain in-place until the project RAOs are met.

Table 9-8 Detailed Analysis of Alternatives Summary - Green Bay Zone 4 (Continued)

Alternative [1]	Short-term Effectiveness		Implementability			Cost
	Environmental Impacts of Remedy and Controls	Duration of Short-term Risks [3]	Technical Feasibility	Administrative Feasibility	Availability	Estimated Costs [4]
Alternative A: No Action	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.	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 tissue quality.	$4,500,000
Alternative B: Monitored Natural Recovery and Institutional Controls	Since a remedy is not part of the MNR and Institutional Controls alternative, there are no environmental impacts associated with implementation of the remedy.	MNR and Institutional Controls alternative does not include an active remedy.	Although MNR is technically feasible, it will likely not meet the cleanup goals of unrestricted fish consumption in 40 years or less. MNR will likely not significantly reduce the mass transport of PCBs to Lake Michigan.	Institutional controls are likely not administratively feasible.	Technologies, goods, and services are available to monitor sediments, water, and tissue.	$9,900,000

Notes:

1 Alternatives C, D, E, F, and G were not retained for this reach.

2 Human health risk threshold concentrations include: RME hazard index of 1.0 and RME 10^{5} cancer risk level for walleye (recreational angler). Ecological risk threshold concentrations include: the NOAEC bird deformity and NOAEC piscivorous mammal for carp.

3 Duration of short-term risks are included for the range of applicable action levels. Expect 2 months each for mobilization and demobilization for each alternative based on Deposit N project (Foth and Van Dyke, 2001).

4 For relative comparison between alternatives, costs for only one action level are presented (500 ppb) action level. Refer to Section 7 of the FS for costs associated with other action levels. Remedy costs do not include 20 percent contingency costs.