Final Baseline Human Health and Ecological Risk Assessment

Lower Fox River and Green Bay, Wisconsin Remedial Investigation and Feasibility Study

Prepared for:

Wisconsin Dept. of Natural Resources

Prepared by: The RETEC Group, Inc.

December 2002

Final Baseline Human Health and Ecological Risk Assessment

Lower Fox River and Green Bay, Wisconsin
Remedial Investigation and Feasibility Study

Prepared by:

The RETEC Group, Inc.
1011 S.W. Klickitat Way, Suite #207
Seattle, Washington 98134

and

3040 William Pitt Way
Pittsburgh, Pennsylvania 15238

RETEC Project No.: WISCN-14414-461

Prepared for:

Wisconsin Department of Natural Resources
101 S. Webster Street
Madison, Wisconsin 55703

Prepared by:

Timothy A. Thompson, Senior Environmental Scientist
David Morgan, Senior Technical Consultant
Linda Mortensen, Environmental Scientist
Annette Pearson, Environmental Scientist
Damon Morris, Environmental Scientist
Chris Traynor, Project Scientist

December 2002

EXECUTIVE SUMMARY

A *Baseline Human Health and Ecological Risk Assessment for the Lower Fox River and Green Bay* (BLRA) has been prepared as a companion document to the Remedial Investigation (RI) and Feasibility Study (FS). This section summarizes the baseline risks to human health for the Lower Fox River and Green Bay, and the calculation of sediment quality thresholds (SQTs) that support the selection of a remedy which eliminates, reduces, and/or controls risks identified in the human health and ecological assessments. The SQTs themselves are not cleanup criteria, but are a good approximation of protective sediment values and can be considered to be "working values" from which to select a remedial action level.

This RI/FS report is consistent with the findings of the National Academy of Science's National Research Council Report entitled, *A Risk Management Strategy for PCB Contaminated Sediments* (NRC, 2001).

The overall goals of the BLRA for the Lower Fox River and Green Bay were to:

- Examine how the contaminants of potential concern (COPCs) carried forward from the Screening Level Risk Assessment (SLRA) (RETEC, 1998b) move from the sediment and water into human and ecological receptors within the Lower Fox River and Green Bay.
- Quantify the current (or baseline) human health and ecological risk associated with the COPCs.
- Distinguish those COPCs which pose the greatest potential for risk to human health and the environment and should be carried forward as contaminants of concern (COCs) in the FS.
- Determine which exposure pathways lead to the greatest risks.
- Support the selection of a remedy which eliminates, reduces, and/or controls identified risks by calculating sediment quality thresholds (SQTs).

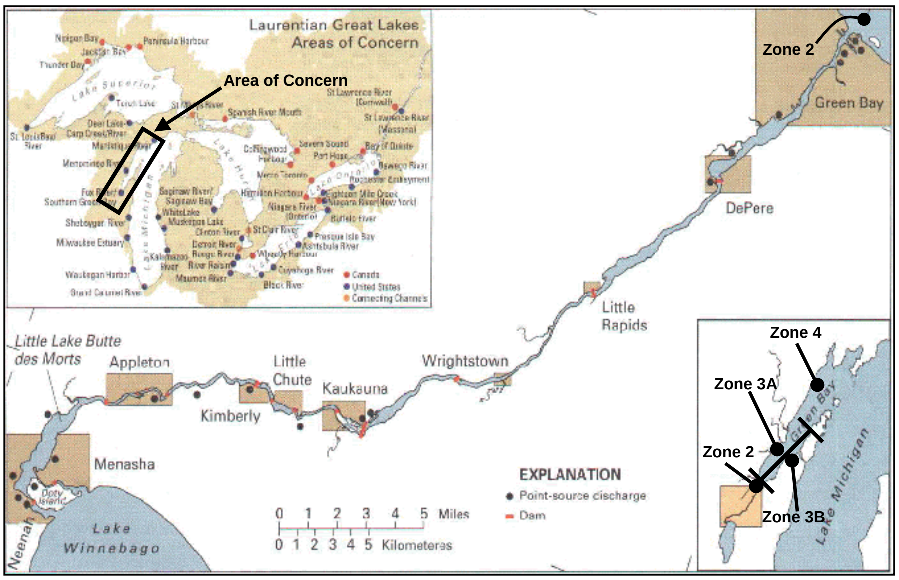


Figure 1 Risk Assessment Study Areas

Site Description

Between 1954 and 1971, paper mills in the Lower Fox River valley manufactured and recycled carbonless copy paper that contained PCBs, resulting in the release of an estimated 313,600 kg (691,370 pounds) of PCBs in the river. It is estimated that 70 percent of the total PCB mass in the river has been transported into Green Bay. Sediment from the Lower Fox River is primarily deposited on the southeastern edge of the bay.

The Fox River valley and Green Bay area is diverse in terms of land use, population density, and habitat types. Overall, the shoreline is much more developed and populated along the Lower Fox River as compared to Green Bay. Both the human health and ecological risk assessments focused on aquatic-dependent receptors and Green Bay has historically supported strong commercial and sport fishing.

For both the human health and ecological assessments, risk was characterized for the four reaches of the Lower Fox River: Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, and De Pere to Green Bay (Green Bay Zone 1); as well as the zones of the bay: Zone 2, Zone 3A, Zone 3B, and Zone 4 (Figure 1). Therefore, risks between each of these reaches and zones could be compared.

Data Evaluated

The COPCs carried forward from the SLRA included polychlorinated biphenyls (PCBs) (total and selected congeners), dioxins and furan congeners, dichlorodiphenyltrichloroethane (DDT) and its metabolites (4,4'-dichlorodiphenyltrichloroethane [DDE] and 4,4'-dichlorodiphenyldichloroethane [DDD]), dieldrin, and three metals (arsenic, lead, and mercury). In the SLRA, hazard quotients (HQs) calculated for PCBs were at least an order of magnitude greater than the HQs for any of the other COPCs. HQs are the ratios of measured COPC concentrations in media (water, sediment, tissue) as compared to safe COPC concentrations in these media.

All available electronic data collected from Lake Winnebago to northern Green Bay were compiled into a single database—the Fox River Database (FRDB). This database contains 474,218 records of sediment, water, and tissue data from the early 1970s through the late 1990s. For the assessment of baseline risk in the Lower Fox River and Green Bay, a subset of the data contained in the FRDB was evaluated. Data were included based on the specific receptors selected, the time during which the data were collected, and the COPCs of interest.

A time trend analysis of fish tissue data indicates that while PCB concentrations in fish tissue initially significantly decreased, since the mid 1980s changes in these concentrations have either slowed, remained constant, or have resulted in increased tissue concentrations. For this reason, only fish tissue concentrations from 1989 and after were considered for the ecological risk evaluation and the focused human health risk evaluation.

Similarly, for risk evaluation purposes, the concentration of total PCBs in the top 10 cm (4 inches) of sediment was interpolated, because this is the depth of sediment that is of primary biological activity. The degree of biological activity influences the potential for bioaccumulative compounds to be taken up in the food chain. PCB concentrations in sediment were interpolated both horizontally and vertically, but for comparative risk purposes non-interpolated sediment PCB concentrations were also evaluated for risk.

General Conclusions

General conclusions of both the human health and ecological assessments were that:

- Fish consumption is the exposure pathway that represents the greatest level of risk for receptors (other than direct risk to benthic invertebrates).

- The primary COC is PCBs, and other COCs carried forward for remedial evaluation and long-term monitoring are mercury and DDE.
- In general, areas evaluated with the greatest risk are Green Bay zones 1 and 2.

Human Health Risk Assessment

For the human health risk assessment, two evaluations were performed, a baseline risk assessment and a focused risk assessment, which are described shortly. For the baseline risk assessment, all data for a specific medium for each COPC were used to evaluate exposures and risks. For the focused risk assessment, which examined only exposure to PCBs in fish, only fish tissue data from 1989 and after were used.

Receptors evaluated in the human health risk assessment were:

- Recreational anglers,
- High-intake fish consumers,
- Hunters,
- Drinking water users,
- Local residents,
- Recreational water users (swimmers and waders), and
- Marine construction workers.

The principle findings of the human health risk assessment are:

- Consumption of fish from the Lower Fox River and Green Bay presented the highest cancer risks and noncancer hazard indices for the pathways evaluated which also included those associated with consumption of waterfowl, drinking water, breathing air near the river or bay, swimming, and construction in the river or bay.
- PCBs contribute more than 70 percent of the cancer risks found from the consumption of fish and waterfowl.
- Using fish data since 1989, lifetime cancer risks as great as one in 1,000 were found for recreational anglers and high-intake fish consumers exposed to PCBs. High-intake fish consumers are individuals in the recreational angler population who may eat significantly more fish than recreational anglers. Groups within the high-intake fish consumer category that were explicitly evaluated in this risk assessment were low-income minority anglers, Hmong/Laotian anglers, and Native American anglers.
- While high-intake fish consumers are individuals who may eat significantly more fish than typical recreational anglers, there were not large differences in risks between recreational anglers and high-intake fish consumers for the high fish consumption or reasonable maximum exposure scenarios.
- Cancer risks from fish consumption are 1,000 times greater than the one-in-a-million cancer risk, which is the point at which risk management decisions may be made under Superfund. The cancer risks are 100 times greater than the one-in-a-hundred-thousand lifetime cancer risk

used by Wisconsin for evaluating hazardous waste sites.

- Noncancer hazard indices from fish consumption were as much as 50 times greater than levels considered acceptable for exposures ranging from 7 years to a lifetime. The noncancer health effects associated with exposure to PCBs include developmental effects (e.g., neurological impairment in infants and children due to maternal exposure), reproductive effects (e.g., conceptive failure), and immune system suppression (e.g., increased incidence of infectious disease in infants).

- Noncancer hazard indices were also calculated for young children eating fish for the Little Lake Butte des Morts and De Pere to Green Bay reaches, the two reaches with the greatest population density. The hazard indices were approximately 2.4 times those found for adults or as much as 125 times greater than acceptable levels.

- Populations potentially exposed to PCBs via fish consumption are large. There are 136,000 fishing licenses issued to individuals living in counties adjacent to the Lower Fox River and Green Bay. About 10 percent of this angler population, or about 14,000 persons, would be considered high-intake anglers. These populations are potentially exposed to PCBs at levels associated with adverse health consequences.

- Cancer risks and noncancer hazard indices are more than 20 times greater than those from the consumption of fish from Lake Winnebago, which does not

Table 1 Summary of Human Health Risks

Location	Recreational Angler		High Intake Fish Consumer		Hunter		Drinking Water User		Local Resident		Swimmer		Wader		Marine Construction Worker	
	Cancer Risk	Noncancer Hazard Index	Cancer Risk	Noncancer Hazard Index	Cancer Risk	Noncancer Hazard Index	Cancer Risk	Noncancer Hazard Index	Cancer Risk	Noncancer Hazard Index	Cancer Risk	Noncancer Hazard Index	Cancer Risk	Noncancer Hazard Index	Cancer Risk	Noncancer Hazard Index
Little Lake Butte des Morts	$>10^{-4}$	>25	$>10^{-4}$	>35	10^{-6}--10^{-4}	~1	$<10^{-6}$	<1	$<10^{-6}$	<1	$<10^{-6}$	<1	$<10^{-6}$	<1	$\sim10^{-6}$	<1
Appleton to Little Rapids	$>10^{-4}$	>20	$>10^{-4}$	>30	10^{-6}--10^{-4}	~1	$<10^{-6}$	<1	$<10^{-6}$	<1	$<10^{-6}$	<1	$<10^{-6}$	<1	$<10^{-6}$	<1
Little Rapids to De Pere	$>10^{-4}$	>15	$>10^{-4}$	>20	10^{-6}--10^{-4}	~1	$<10^{-6}$	<1	$<10^{-6}$	<1	$<10^{-6}$	<1	$<10^{-6}$	<1	$<10^{-6}$	<1
De Pere to GreenBay	$>10^{-4}$	>35	$>10^{-4}$	>50	10^{-6}--10^{-4}	~1	10^{-6}--10^{-4}	<1	$<10^{-6}$	<1	$<10^{-6}$	<1	$<10^{-6}$	<1	$<10^{-6}$	<1
Zone 3A	$>10^{-4}$	>25	$>10^{-4}$	>50												
Zone 3B	$>10^{-4}$	>25	$>10^{-4}$	>35	10^{-6}--10^{-4}	~1	$<10^{-6}$	<1	$<10^{-6}$	<1	$<10^{-6}$	<1	$<10^{-6}$	<1	$<10^{-6}$	<1
Zone 4	$>10^{-4}$	>25	$>10^{-4}$	>35												

Notes:

Risks and hazard indices are based on reasonable maximum exposures.

Interpretation of cancer risks:

$> 10^{-4}$ indicates significant risk

10^{-6}--10^{-4} indicates possibly significant risks

$<10^{-6}$ indicates risks are negligible

Interpretation of hazard indices:

>1 indicates significant noncancer health effects are possible

<1 indicates noncancer health effects are unlikely to be significant

For recreational anglers, high intake fish consumers and hunters, elevated risks and hazard indices are due primarily to PCBs.

For drinking water users in De Pere to Green Bay reach, arsenic is responsible for caculated cancer risk, but arsenic exposure point concentration was based on one detected value in four samples and reporting limits were high, so actual arsenic concentrat have a known source of PCBs and serves as a background location.

- There were not large differences in risks between the Lower Fox River and Green Bay, or among the reaches within the Lower Fox River, or among the zones within Green Bay.

- While evidence exists for slow declines of PCBs in fish, such declines were not consistent among species or locations, and projections of future declines cannot be made with sufficient certainty for use in risk assessment. In addition, in some cases, PCBs were found to be increasing.

Other findings of the human health risk assessment are:

- Cancer risks to hunters consuming waterfowl approach a risk of one in 10,000. Noncancer hazard indices were 3.8 times acceptable levels.

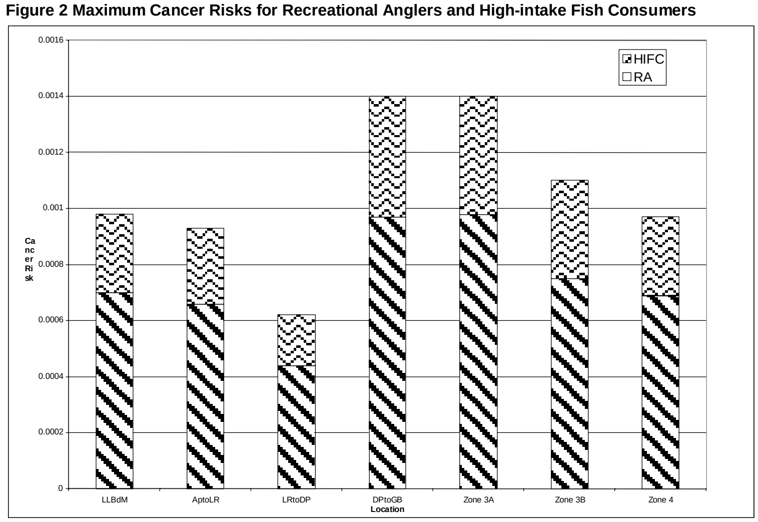
- Cancer risks to local residents exposed to chemicals only through inhalation of air, swimmers, and waders were less than one in a million.

- Cancer risks to drinking water users were less than one in a million in all reaches of the Lower Fox River and all of Green Bay with one exception. The cancer risk in the De Pere to Green Bay Reach was 3.8×10^{-5} due to exposure to arsenic. The arsenic and the exposure to arsenic were based on the detection of this chemical in one of four surface water samples. It is quite likely that this one detected value is anomalous and that the actual risk of exposure to arsenic is much lower. In addition, this reach of the Lower Fox River is not used as a source of drinking water.

- Marine construction workers had cancer risks slightly greater than one in a million. Noncancer hazard indices for drinking water users, local residents, swimmers, waders, and marine construction workers did not exceed acceptable levels.

These results are summarized in Table 1. Figure 2 presents the risks and Figure 3 presents the hazard indices for recreational anglers and high-intake fish consumers due to ingestion of PCBs in fish.

Figure 2 Maximum Cancer Risks for Recreational Anglers and High-intake Fish Consumers



Key:
RA - Recreational Angler
HIFC - High Intake Fish Consumer
LLBdm - Little Lake Butte des Morts
AptoLR - Appleton to Little Rapids
LRtoDP - Little Rapids to De Pere
DPtoGB - De Pere to Green Bay
Zone 3A - Zone 3A of Green Bay
Zone 3B - Zone 3B of Green Bay
Zone 4 - Zone 4 of Green Bay

Ecological Risk Assessment

Types of receptors evaluated for ecological risk included:

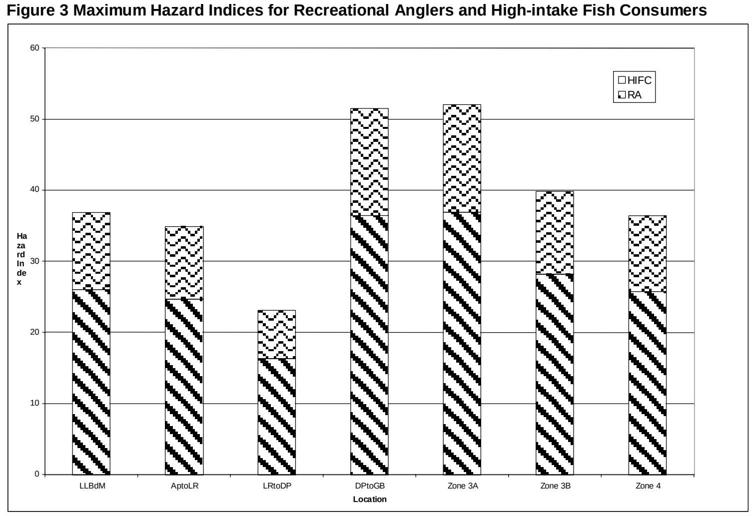
- **Aquatic Invertebrates:** Insects and other invertebrates that live in the water and are important prey items for fish and other insects.

- **Benthic Invertebrates:** Insects and other invertebrates that live in or on the sediment that are important in recycling nutrients and are a principal part of fish diets.

- **Benthic Fish:** Fish, such as carp and catfish, that live on and forage in the sediments and are in turn eaten by other fish, birds, mammals, and people.
- **Pelagic Fish:** Fish, such as walleye and yellow perch, that live in the water column, and eat other fish or insects that live in the water or on the sediments. These fish may be in turn eaten by other fish, birds, mammals, and people.
- **Insectivorous Birds:** Birds, such as swallows, that eat insects that hatch from the sediments.
- **Piscivorous Birds:** Birds, such as cormorants or terns, that principally eat fish from the Lower Fox River or Green Bay.
- **Carnivorous Birds:** Birds, such as eagles, that eat a variety of prey, including fish or small mammals.
- **Piscivorous Mammals:** Mammals, such as mink, that eat fish as an important part of their diet.

Risk was characterized for assessment endpoints based on the calculation of HQs. In the FRDB, data were generally lacking for piscivorous and carnivorous birds, and no data were available for piscivorous mammals, therefore, ecological modeling was used to estimate COPC exposure to these receptors. HQs that are greater than 1.0 imply that risk may be present. Where available, both the No Observed Adverse Effect Concentration (NOAEC) and Lowest Observed Adverse Effect Concentration (LOAEC) HQs were calculated. Effects evaluated were reproductive dysfunction, death at birth, or deformities in the surviving offspring. When NOAEC HQs exceeded 1.0, but LOAEC HQs were less than 1.0, then it was concluded that there was potential risk. When both the NOAEC and LOAEC HQs exceed 1.0, it was assumed that risk is present.

Figure 3 Maximum Hazard Indices for Recreational Anglers and High-intake Fish Consumers



Key:
RA - Recreational Angler
HIFC - High Intake Fish Consumer
LLBdm - Little Lake Butte des
AptoLR - Appleton to Little
LRtoDP - Little Rapids to De
DPtoGB - De Pere to Green
Zone 3A - Zone 3A of Green Bay
Zone 3B - Zone 3B of Green Bay
Zone 4 - Zone 4 of Green Bay

In addition to the HQ, the assessment provides an evaluation of the uncertainties associated with the risk characterization, and evaluates the estimated risk relative to the habitat, field studies, and population data for the receptors species. Together with the HQs, the components of the evaluation provide resource managers with the information necessary to make risk decisions within the context of the Feasibility Study.

The principle findings of the ecological risk assessment are:

- Total PCBs cause, or potentially cause risk to all identified receptors. The exception is insectivorous birds where the weight of evidence suggests that these receptors are not at risk from PCB concentrations. Not all receptors at risk or potentially at risk from PCBs are at risk in all river reaches or bay zones.

- Mercury poses a risk in all river reaches and zones, but not to all receptors. Mercury was not identified as a risk for benthic fish, insectivorous birds, or piscivorous mammals.
- DDT or its metabolites poses a risk to benthic invertebrates (Little Lake Butte des Morts Reach, Little Rapids to De Pere Reach, and Green Bay Zone 1), benthic fish (Green Bay zones 1 and 2), pelagic fish (Green Bay zones 1, 2, 3B, and 4), insectivorous birds (Green Bay Zone 2), piscivorous birds (Green Bay zones 1, 2, and 3B), and carnivorous birds (Green Bay zones 1, 2, 3B, and 4).
- Other COPCs identified as causing or potentially causing risk are arsenic (Zone 1 and Zone 3B benthic invertebrates only) lead (benthic invertebrates only in all areas except Green Bay Zone 2, Zone 3A, and Zone 4), 2,3,7,8-TCDD (benthic invertebrates only in Little Lake Butte des Morts Reach and Little Rapids to De Pere Reach), and dieldrin (piscivorous birds in zones 1, 2, and 3B, carnivorous birds in Green Bay Zone 3A, and piscivorous mammals in Green Bay zones 3A and 3B).

Table 2 summarizes ecological risks based on hazard quotients and other lines of evidence. Figures 4 (total PCBs), 5 (mercury), and 6 (DDT and metabolites) present HQs that were greater than 1.0 for selected receptors.

Table 2 Ecological Risk Summary Table

Location	Water Column Invertebrates	Benthic Invertebrates	Benthic Fish	Pelagic Fish	Insectivorous Bird	Piscivorous Bird	Carnivorous Bird	Piscivorous Mammal
LLBdM	● *mercury* ○ *PCBs*	● *lead; mercury; 2,3,7,8-TCDD; PCBs; DDD; DDT*	○ *PCBs*	○ *PCBs*	○ *PCBs*	○ *mercury; PCBs*	○ *PCBs*	● *PCBs*
Appleton to Little Rapids	○ *PCBs*	● *lead; mercury; PCBs*	○ *PCBs*	○ *PCBs*	NA	○ *mercury; PCBs*	● *PCBs* ○ *mercury*	● *PCBs*
Little Rapids to De Pere	● *mercury*	● *lead; mercury; 2,3,7,8-TCDD; PCBs; DDE; DDT*	○ *mercury; PCBs*	○ *mercury; PCBs*	NA	○ *mercury; PCBs*	○ *mercury; PCBs*	● *PCBs*
Zone 1	○ *PCBs*	● *arsenic; lead; mercury; PCBs; DDD; DDE*	○ *PCBs; DDE*	○ *mercury; PCBs; DDE*	○ *PCBs*	○ *mercury; PCBs; dieldrin; DDE*	○ *mercury; PCBs; DDE*	● *PCBs*
Zone 2	● *mercury*	● *mercury; PCBs*			○ *PCBs; DDE*			
Zone 3A		● *PCBs*	○ *PCBs*	○ *PCBs*	NA	○ *mercury; PCBs*	● *PCBs* ○ *dieldrin*	● *PCBs* ○ *dieldrin*
Zone 3B		● *arsenic; lead; mercury; PCBs*		● *PCBs* ○ *mercury; DDE*	NA	● *PCBs* ○ *mercury; dieldrin; DDE*	○ *mercury; PCBs; DDE*	● *PCBs* ○ *dieldrin*
Zone 4		● *PCBs*	NA	○ *PCBs; DDE*	NA	○ *mercury; PCBs*	○ *mercury; PCBs; DDE*	● *PCBs*

Notes:

NA - No data available.

Risk conclusions based on HQs:

(white box) - No risk

Risk - ●

Potential Risk - ○

Risk conclusions based on weight of evidence:

(yellow box) - Site-specific receptor data suggest that there is no risk.

(cyan box) - Because of the Federal listing of the bald eagle as threatened, it is concluded that potential risk is actual risk.

Sediment Quality Thresholds (SQTs)

SQTs are sediment concentrations that have been linked to a specific magnitude of risk. SQTs were estimated for PCBs with the assumption that a remedy that reduces PCB exposure would also address the other co-occurring COCs. Risk-based concentrations in fish for human and ecological receptors were determined based on:

- Human health cancer risk levels of 10^{-4}, 10^{-5}, and 10^{-6}, and a noncancer hazard index of 1.0 for risk in recreational anglers and high-intake fish consumers

- The NOAECs and LOAECs for species of benthic invertebrates, fish, birds, and riverine mammals found in the river and bay.

SQTs were developed for each pathway and receptor identified as important in the BLRA by the response agencies of the Lower Fox River and Green Bay (e.g., sport fishing consumption, bald eagles). The SQTs themselves are not cleanup criteria, but are used to evaluate levels of PCBs that will be addressed in the Feasibility Study. The final selection of the remedial action levels is a policy decision left to the response agencies. The development and validation of the mathematical model used to define SQTs is described in the BLRA.

To evaluate how PCBs in sediment result in risk to human or ecological receptors, a methodology is needed for translating concentrations of PCBs in sediment to concentrations in fish and higher order organisms. The Fox River Bioaccumulation Model (FRFood Model) was developed for this purpose. FRFood is a series of mathematical equations that describes a food web and the transfer of bioaccumulating contaminants within that food web. The model includes uptake routes from sediment and water to benthic infauna and ultimately fish, and the model was constructed so that it could be used to either predict fish tissue concentrations from a given sediment concentration, or to predict sediment concentrations from a given fish tissue concentration. The model was validated by running the model "forward;" that is, fish tissue concentrations were predicted from existing sediment concentrations and then compared to measured fish tissue concentrations. When the predicted concentrations were compared to the actual measured concentrations of total PCBs in fish collected in the Lower Fox River and Green Bay, the results were highly comparable.

Estimated SQTs for human health and ecological exposures are shown on Figure 7.

Human Health SQTs

To determine SQTs associated with the protection of human health, fish consumption limits were derived using several different assumptions and risk thresholds. Risk-based fish concentrations (RBFCs) were calculated for recreational anglers and high-intake fish consumers. For recreational anglers, RBFCs were calculated using the average fish intake assumptions from two studies on Michigan anglers (West *et al.*, 1989; West *et al.*, 1993). For high-intake fish consumers, RBFCs were calculated using the average fish intake assumptions for low-income minorities (West *et al.*, 1993) and Hmong (Hutchinson and Kraft, 1994). The RBFCs were generated for each of these exposure scenarios for three different target risk levels (10^{-6}, 10^{-5}, and 10^{-4}) and for a target noncancer hazard index of 1.0. The RBFCs were used with the results of the FRFood Model to generate a range of SQTs.

Deriving SQTs for each of the consumption scenarios and each of the risks and hazard indices resulted in a total of 48 human health SQTs, a minimum SQT of 1.1 μg/kg (carp at a risk level of 10^{-6}, RME for a high-intake fish consumer) and a maximum SQT of 6,770 μg/kg (yellow perch at a risk level of 10^{-4}, CTE for a recreational angler).

Figure 4 Selected PCB HQs that Exceed 1.0

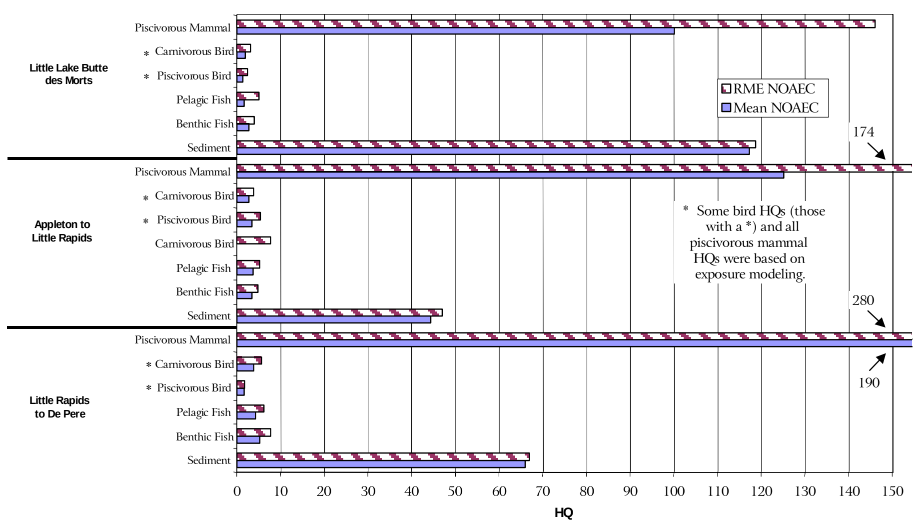
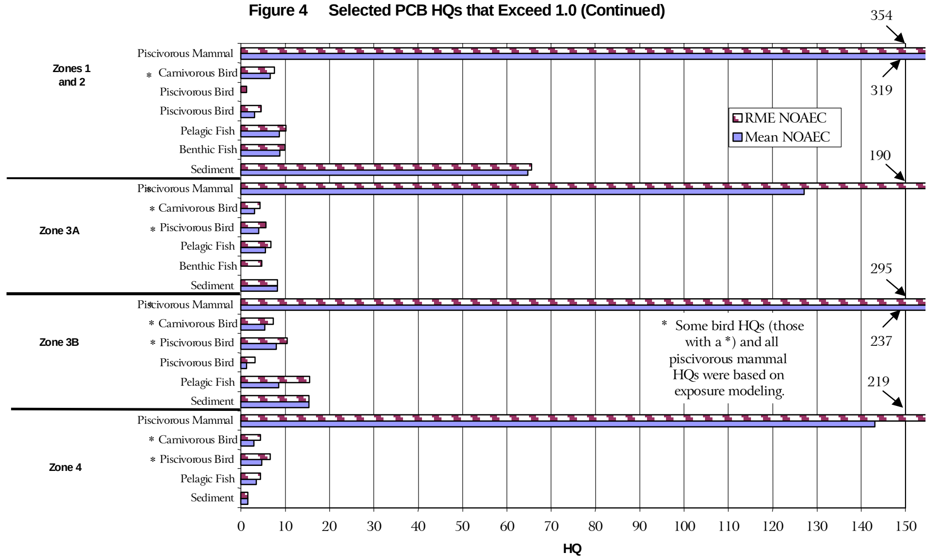


Figure 4 Selected PCB HQs that Exceed 1.0 (Continued)



Ecological SQTs

SQTs protective of ecological receptors were calculated for the Lower Fox River and Green Bay separately. Although the remedial methods may differ between reaches of the river evaluated, the SQTs derived for the De Pere to Green Bay Reach will be applied to the entire river. These SQTs are based upon levels of total PCBs in fish that either cause risk to the fish themselves, or to birds or mammals that are eating the fish. The SQTs for no observed adverse effects (NOAEC) to walleye is 176, and for carp is

363. The only calculated SQTs that were lower than these for any of the other receptors were the SQT for benthic invertebrates and the SQTs for piscivorous mammals (mink). The benthic invertebrates threshold effect level (TEL) is a sediment PCB concentration of 31.6 μg/kg and the NOAEC SQT for mink is 24 μg/kg.

Figure 5 Selected Mercury HQs that Exceed 1.0 *

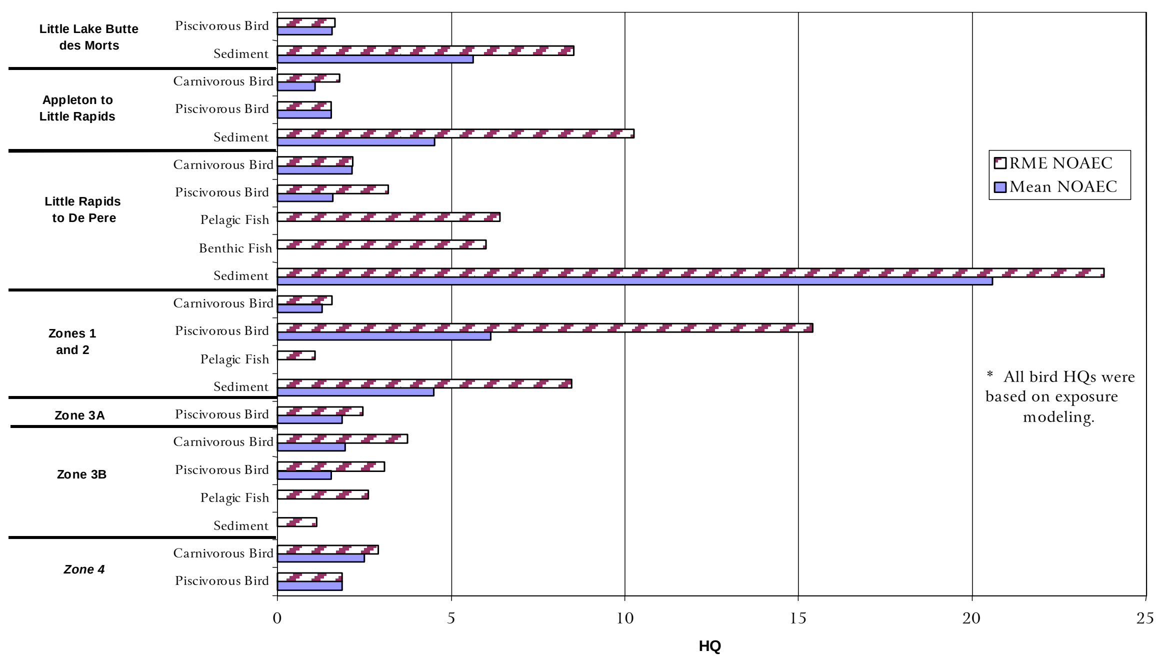


Figure 6 Selected DDT or Metabolite HQs that Exceed 1.0

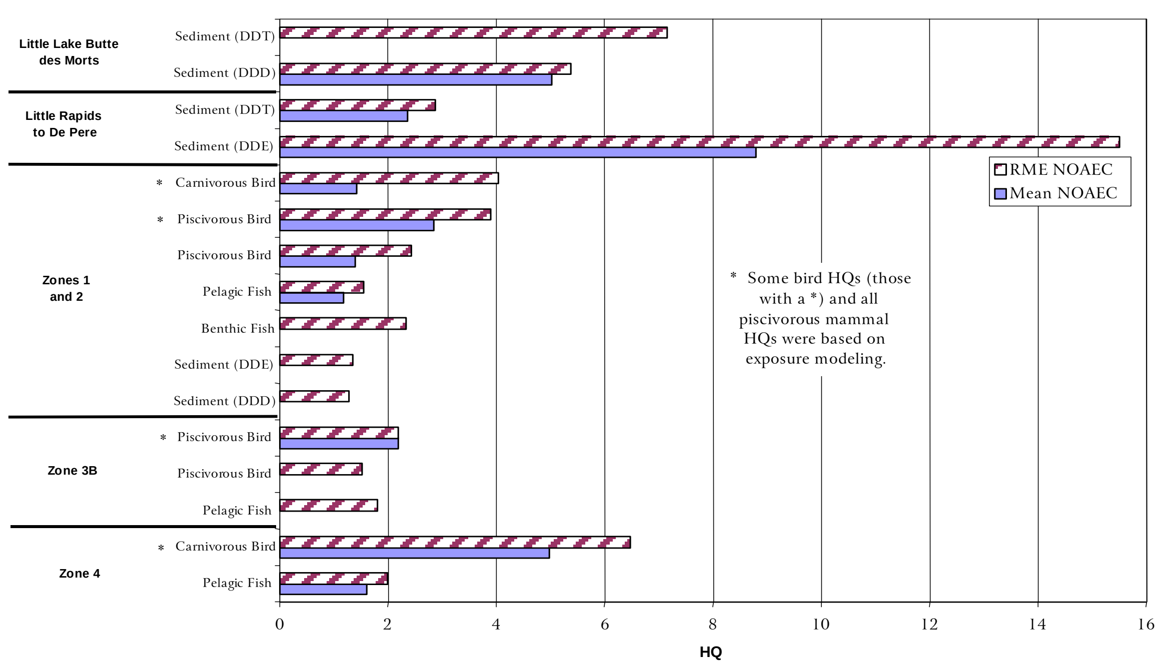
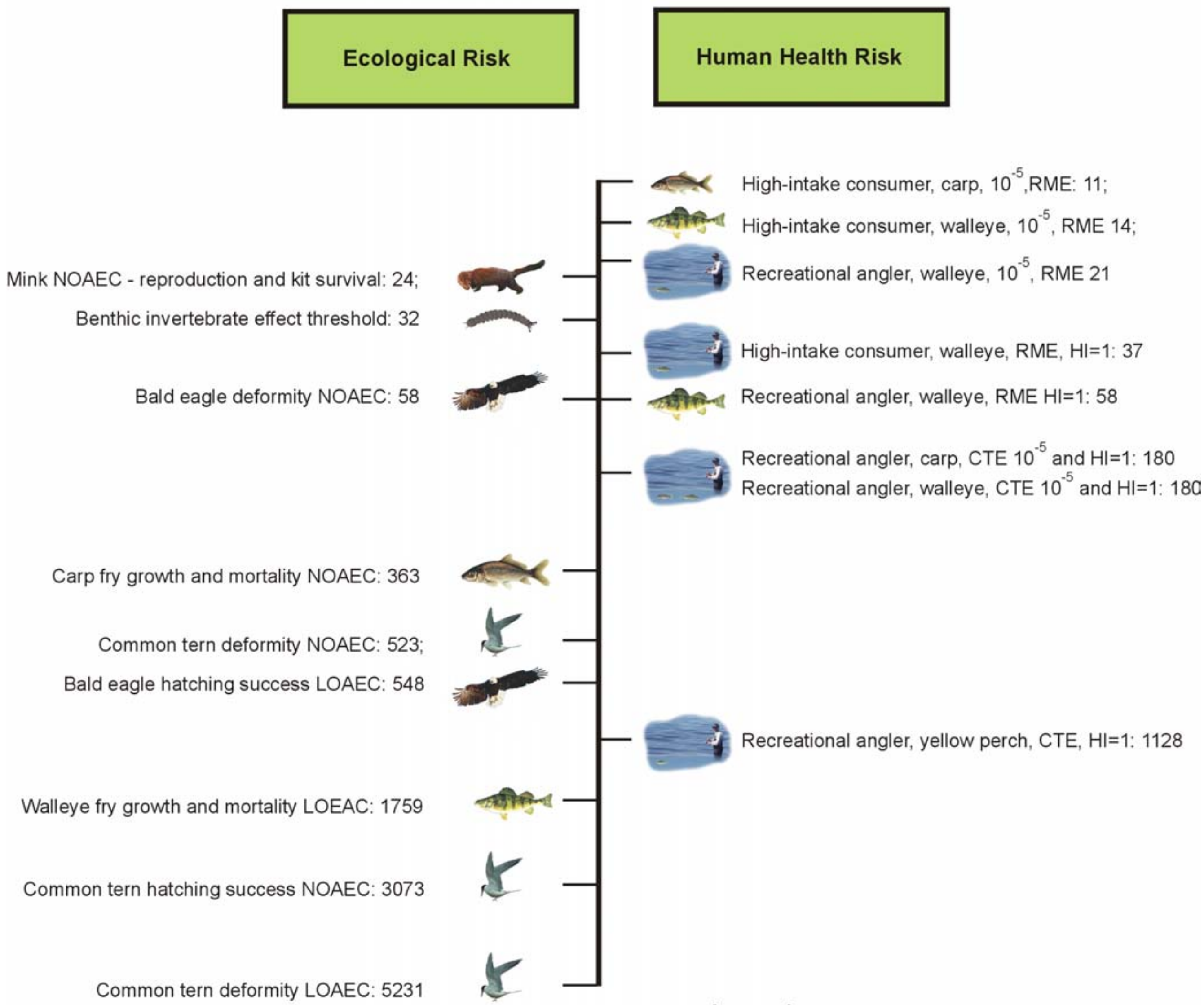


Figure 7. Summary of Sediment Quality Thresholds (SQTs - µg/kg)



Legend

RME	reasonable maximum exposure
CTE	central tendency
HI	hazard index
10^{-5}	risk of 1 additional cancer in 100,000 people
LOAEC	lowest observed adverse effect level
NOAEC	no observed adverse effect level

Note: Remedial long-term monitoring will include the ecological species listed.

[THIS PAGE LEFT INTENTIONALLY BLANK.]

Table of Contents

Table of Contents

Table of Contents

Table of Contents

Table of Contents

[THIS PAGE LEFT INTENTIONALLY BLANK.]

List of Figures

List of Figures

List of Figures

List of Figures

List of Figures

List of Figures

List of Tables

List of Tables

List of Tables

List of Tables

List of Tables

List of Tables

List of Tables

List of Tables

List of Tables

List of Tables

List of Tables

List of Tables

List of Tables

[THIS PAGE LEFT INTENTIONALLY BLANK.]

List of Appendices

[THIS PAGE LEFT INTENTIONALLY BLANK.]

List of Acronyms

2,3,7,8-TCDD	2,3,7,8-tetrachloro-*p*-dibenzodioxin
2,3,7,8-TCDF	2,3,7,8-tetrachloro-*p*-dibenzofuran
95% UCL	95 percent upper confidence limit
˚C	degrees centigrade
˚F	degrees Fahrenheit
μg	microgram
μg/dl	micrograms per deciliter
μg/dl-blood	micrograms per deciliter of blood
μg/kg	micrograms per kilogram
μg/kg-BW/day	micrograms per kilogram of body weight per day
μg/kg-day	micrograms per kilogram per day
μg/kg-fillet	micrograms per kilogram of fish fillet
μg/kg-whole body	micrograms per kilogram of whole-body fish
μg/kg-sediment	micrograms per kilogram of sediment
μg/L	micrograms per liter
$\mu g/m^3$	micrograms per cubic meter
μg-PCB/kg-BW/day	micrograms of polychlorinated biphenyl per kilogram of body weight per day
μg-TCDD/kg-lipid	micrograms of 2,3,7,8-tetrachloro-*p*-dibenzodioxin per kilogram of lipid
μm	micrometer
ABS	ingestion absorption factor (fraction absorbed) or inhalation absorption factor (fraction absorbed)
AChE	acetylcholinesterase
ADD	average daily dose
AE	assimilation efficiency (in %)
AEHS	Association for the Environmental Health of Soils
AF	sediment adherence factor (in mg/cm^2)
$a_{f\text{-}wb}$	ratio of concentrations in fish fillet to concentrations in whole body of fish (in kg-fish/kg-fillets)
AHH	aryl hydrocarbon hydroxylase
Ah-R	aryl hydrocarbon receptor
AQUIRE	Aquatic Information Retrieval Database
ARCS	Assessment and Remediation of Contaminated Sediments
As^{3+}	arsenite (trivalent arsenic compound)
As^{5+}	arsenate
AT	averaging time (in days)
ATc	averaging time (carcinogenic)

List of Acronyms

ATnc	averaging time (non-carcinogenic) or averaging time for chronic, noncancer effects (in days)
$ATnc_C$	non-carcinogenic averaging time for a child
ATSDR	Agency for Toxic Substances and Disease Registry (part of the United States Public Health Service)
BAF	bioaccumulation factor
BLRA	baseline risk assessment
BLRPC	Bay Lake Regional Planning Commission
BMF	biomagnification factor
BSAF	biota-to-sediment accumulation factor
BTAG	Biological Technical Assistance Group
BW or *bw*	body weight (in kg)
BW_C	body weight for a child
C	chemical concentration (in mg/kg-soil or mg/L-water)
CA	concentration of chemical in air (in mg/m^3)
C_{ab}	chemical concentration in indoor air during a bath
C_{as}	chemical concentration in indoor air during a shower
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act of 1980 (the Superfund statute)
CF	conversion factor (in kg/g or kg/mg) or volumetric conversion factor (in L/1,000 cc)
Cfish	chemical concentration in fish (in mg/kg-fish)
$Cfish_{EPC}$	exposure point concentration in fish
$C_{fish\text{-}f}$	concentration of PCBs in fish fillet (in μg/kg-fillet)
$Cfish_{meas}$	measured fish chemical concentration
$Cfish_{measi}$	measured concentration of chemical *i* in fish (in mg/kg)
$C_{fish\text{-}wb}$	concentration of PCBs in whole body of fish (in μg/kg-whole body)
cfs	cubic feet per second
cm	centimeter
cm^2	square centimeter
cm^2/event	square centimeters per event
cm/hr	centimeters per hour
C_{oa}	chemical concentration in outdoor air

List of Acronyms

COC	chemical of concern
COPC	chemical of potential concern
C_{pw}	chemical concentration in sediment pore water
CR	contact rate or the amount of impacted medium contacted per event
CS	chemical concentration in sediment (in mg/kg-sediment)
C_{sed}	measured sediment chemical concentration
CSF	cancer slope factor
CSF_d	cancer slope factor for evaluating absorbed dermal doses (in $[mg/kg\text{-}day]^{-1}$)
CSF_i	inhalation cancer slope factor
CSF_o	cancer slope factor for evaluating administered ingestion doses (in $[mg/kg\text{-}day]^{-1}$)
CSFo	oral cancer slope factor (in $[mg/kg\text{-}day]^{-1}$)
C_{sw}	chemical concentration in surface water
$C_{sw\text{-}di}$	measured dissolved concentration for chemical *i* in water (in mg/L)
$C_{sw\text{-}ti}$	measured total concentration of chemical *i* in water (in mg/L)
CTE	central tendency exposure
CW	chemical concentration in water (in mg/L)
C_{wb}	chemical concentration in bath water
CWF	chemical concentration in waterfowl (in mg/kg-waterfowl)
CWF_{EPC}	exposure point concentration in waterfowl
CWF_{meas}	measured chemical concentration in waterfowl
CWF_{measi}	measured concentration of chemical *i* in waterfowl (in mg/kg)
C_{ws}	chemical concentration in shower water
C_x	concentration of the COPC in medium *x* (in mg/kg ww)
cy	cubic yard
days/yr	days per year
DDD	4,4'-dichlorodiphenyl dichloroethane (includes isomers o,p'-DDD and p,p'-DDD)
DDE	4,4'-dichlorodiphenyl dichloroethylene (includes isomers o,p'-DDE and p,p'-DDE)
DDOH-PA	metabolite of DDT conjugated to a fatty acid

List of Acronyms

DDT	4,4'-dichlorodiphenyl trichloroethane (includes isomers o,p'-DDT and p,p'-DDT)
DNA	deoxyribonucleic acid
D.O.	dissolved oxygen
dwt	dry weight
EC_{20}	20 percent effect concentration
EC_{30}	30 percent effect concentration
EC_{50}	50 percent effect concentration
ED	exposure duration (in years)
ED_C	exposure duration for a child
ED_T	estimated daily dose (in mg/kg-BW/day ww)
EEC	Exposure Effect Concentration or Extreme Effect Concentration
FRFood	Fox River Food Model
FRG	Fox River Group, which is composed of the following seven companies (listed alphabetically): Appleton Papers, Inc.,; Fort James Corporation; NCR Corporation; P. H. Glatfelter Company; Riverside Paper Corporation; U.S. Paper Mills Corporation; and Wisconsin Tissue Mills, Inc.
FS	feasibility study
g	gram
GAS	Graef, Anhalt, Schloemer and Associates, Inc.
GBFood	Green Bay Food Model
GBTOXe	Green Bay Toxics Model
g/day	grams per day
GE	gross energy (in kcal/g)
g-fish/day	grams of fish per day
GLEMEDS	Great Lakes Embryo Mortality, Edema, and Deformities Syndrome
GLWQI	Great Lakes Water Quality Initiative
g/meal	grams per meal
g/mole	grams per mole
g-waterfowl/day	grams of waterfowl per day
g/yr	grams per year
H^+	protons
HEAST	Health Effects Assessment Summary Table
Hg^0	elemental mercury
Hg^{2+}	mercuric ion

List of Acronyms

Hg_2^{2+}	mercurous ion
HgOH	inorganic mercury
HI	hazard index
Hi_i	hazard index for chemical *i*
HQ	hazard quotient
hrs/day	hours per day
I	chemical intake (in mg/kg-BW/day)
I_0	interpolated zeroed grid
I_d	interpolated deleted grid
$I_{der\text{-}s}$	absorbed dose from dermal contact with sediment (in mg/kg-BW/day)
$I_{der\text{-}w}$	absorbed intake from dermal contact with water (in mg/kg-BW/day) = $TBS \cdot FBE$
IEUBK	Integrated Exposure Biokinetic/Uptake Model
$I_{ing\text{-}f}$	intake from ingestion of fish (in mg/kg-BW/day)
$I_{ing\text{-}s}$	intake from incidental ingestion of sediment (in mg/kg-BW/day)
$I_{ing\text{-}w}$	intake from ingestion of water (in mg/kg-BW/day)
$I_{ing\text{-}wf}$	intake from ingestion of waterfowl (in mg/kg-BW/day)
I_{inhal}	intake from inhalation (in mg/kg-BW/day)
Inc	intake from ingestion of fish averaged over the exposure period (in mg/kg-day)
IntFacC	intake factor for cancer risk (in $[mg/kg]^{-1}$)
IntFacNC	intake factor for chronic, noncancer effects (in $[mg/kg]^{-1}$)
IPS	Integrated Paper Services
IR	ingestion rate (in g/day or L/day) or inhalation rate (in m^3/hour) or incidental sediment ingestion rate (in mg-sediment/day)
IR_A	ingestion rate for an adult
IR_C	ingestion rate for a child
IRIS	Integrated Risk Information System
IUPAC	International Union of Pure and Applied Chemistry
I_x	rate of ingestion of medium *x* (in mg/day or kg/day ww)
kcal/day	kilocalories per day
kcal/g	kilocalories per gram

List of Acronyms

kg	kilogram (1 kg is approximately equivalent to 2.2 pounds)
kg-fish/kg-fillets	kilograms of fish-to-kilograms of fillets
kg/g	kilograms per gram
kg/L	kilograms per liter
kg/mg	kilograms per milligram
km	kilometer (1 km is approximately equivalent to 0.6 mile)
km^2	square kilometer
km^3	cubic kilometer
K_{ow}	octanol-water partitioning coefficient
Kp	permeability coefficient
LADD	lifetime average daily dose
LC_{10}	10 percent lowest effect concentration
LC_{12}	12 percent lowest effect concentration
LC_{50}	50 percent lowest effect concentration
LC_{90}	90 percent lowest effect concentration
L/1,000 cc	liters per 1,000 cubic centimeters
LD_{10}	lethal dose to 10 percent of test population
LD_{20}	lethal dose to 20 percent of test population
LD_{30}	lethal dose to 30 percent of test population
LD_{50}	lethal dose to 50 percent of test population
L/day	liters per day
LLBdM	Little Lake Butte des Morts
L/m^3	liters per cubic meter
L/mg	liters per milligram
LOAEC	Lowest Observed Adverse Effect Concentration
LOAEL	Lowest Observed Adverse Effect Level
LOEL	Lowest Observed Effect Level
m^2	square meter
m^3	cubic meter
MDNR	Michigan Department of Natural Resources
ME	metabolizable energy (in kcal/g prey)
meals/yr	meals per year
MEC	Moderate Effect Concentration
MeHg	methylmercury (organic mercury)
MFO	mixed function oxidase
mg	milligram

List of Acronyms

mg-Aroclor 1254/kg-BW/day	milligrams of Aroclor 1254 per kilogram of body weight per day
mg/cm^2	milligrams per square centimeter
mg/day	milligrams per day
mg-Hg/kg-BW/day	milligrams of mercury per kilogram of body weight per day
mg/kg	milligrams per kilogram
mg/kg-BW	milligrams per kilogram of body weight
mg/kg-BW/day	milligrams per kilogram of body weight per day
mg/kg-day	milligrams per kilogram per day
mg/kg-DDE	milligrams per kilogram of 4,4'-dichlorodiphenyl dichloroethylene
mg/kg-DDT	milligrams per kilogram of 4,4'-dichlorodiphenyl trichloroethane
mg/kg-egg	milligrams per kilogram of egg
mg/kg-fish	milligrams per kilogram of fish
mg/kg-sediment	milligrams per kilogram of sediment
mg/kg-soil	milligrams per kilogram of soil
mg/kg-waterfowl	milligrams per kilogram of waterfowl
mg/L	milligrams per liter
mg/L-water	milligrams per liter of water
mg/m^3	milligrams per cubic meter
mg/mg	milligrams per milligram
mg-sediment/day	milligrams of sediment per day
mg/yr	milligrams per year
m^3/hr	cubic meters per hour
mi^2	square mile
mi^3	cubic mile
ml/day	milliliters per day
mm	millimeter
m^3/mg	cubic meters per milligram
MNFI	Michigan Natural Features Inventory
MRL	Minimal Risk Level
m/s	meters per second
m^3/s	cubic meters per second
MSA	Metropolitan Statistical Area
MT	metric ton
MW	molecular weight (in g/mole)
N	non-interpolated grid

List of Acronyms

NASS	National Agricultural Statistics Service
NAWQC	National Ambient Water Quality Criteria
NCP	National Contingency Plan
NCR	National Cash Register
"ND"	no data
NEC	No Effect Concentration
ng/kg	nanograms per kilogram
ng/kg-egg	nanograms per kilogram of egg
ng/kg-TCDD/egg	nanograms per kilogram of 2,3,7,8-tetrachloro-*p*-dibenzodioxin per egg
ng/kg-TEQ/egg	nanograms per kilogram of toxic equivalency per egg
ng/kg-ww/eagle	nanograms per kilogram of wet weight per eagle
ng/kg-ww/egg	nanograms per kilogram of wet weight per egg
ng/L	nanograms per liter
ng-TEQ/kg-ww/egg	nanograms of toxic equivalency per kilogram of wet weight per egg
NOAA	National Oceanic and Atmospheric Administration
NOAEC	No Observed Adverse Effect Concentration
NOAEL	No Observed Adverse Effect Level
NOEL	No Observed Effect Level
NRDA	Natural Resource Damage Assessment
N.W.R.	National Wildlife Refuge
OMOE	Ontario Ministry of the Environment
PAH	polynuclear aromatic hydrocarbon
PC	permeability constant (in cm/hr)
PCB	polychlorinated biphenyl
PCDD	polychlorinated dibenzodioxin
PCDF	polychlorinated dibenzofuran
PCH	planar chlorinated hydrocarbon
PCP	pentachlorophenol
pg	picogram
pg/g	picograms per gram
pg/kg-day	picograms per kilogram per day
PHH	planar halogenated hydrocarbons
ppb	parts per billion
ppm	parts per million
ppt	parts per trillion
PRP	potentially responsible party
QA	quality assurance

List of Acronyms

QA/QC	quality assurance/quality control
R	cancer risk
RA	risk assessment
$Ratio_{CAFI}$	child-to-adult fish ingestion ratio
RBFC	risk-based fish concentration
RBSC	risk-based screening concentration
$RBSC_{SA\text{-}fish}$	high-intake fish consumer risk-based screening concentration for carcinogenic or non-carcinogenic chemicals
RETEC	Remediation Technologies, Inc.
RF	reduction factor
RfC	EPA Reference Concentration
RfD	chronic oral reference dose (chemical-specific) or EPA Reference Dose
RfD_d	reference dose for evaluating absorbed dermal doses (in mg/kg-day)
RfD_o	reference dose for evaluating administered ingestion doses (in mg/kg-day)
RfDo	oral reference dose for chronic, noncancer effects (in mg/kg-day)
RF_{fish}	reduction factor for fish
RF_{fishi}	reduction factor for chemical *i* for fish (in mg/mg)
RF_{WF}	reduction factor for waterfowl
RF_{WFi}	reduction factor for chemical *i* for waterfowl (in mg/mg)
R_i	cancer risk for chemical *i*
RI	remedial investigation
RI/FS	remedial investigation and feasibility study
RME	reasonable maximum exposure
ROD	Record of Decision
SA	exposed skin surface area (in cm^2 or cm^2/event) = $TBS \cdot FBE$
SAIC	Science Applications International Corporation
SAV	submerged aquatic vegetation and/or floating vegetation
SCS	Soil Conservation Service
SEC	Sediment Effect Concentration
SF	oral cancer slope factor (chemical-specific)
SLRA	screening level risk assessment

List of Acronyms

SMDP	Scientific Management Decision Point
SMU	sediment management unit
SQC	Sediment Quality Criteria
SQT	sediment quality threshold
SVOC	semivolatile organic compound
SWAC	sediment-weighted average concentration
TBS	total body surface area (in cm^2)
TCDD	2,3,7,8-tetrachloro-*p*-dibenzodioxin
TCDD-Eq	2,3,7,8-tetrachloro-*p*-dibenzodioxin equivalent
TCDF	2,3,7,8-tetrachloro-*p*-dibenzofuran
TEC	Threshold Effect Concentration
TEF	toxic equivalency factor
TEL	Environmental Canada Threshold Effect Level
TEQ	toxic equivalency
TF_{bwa}	bath water-to-air transfer factor
Tf_{bwai}	transfer factor for chemical *i* for volatilization from bath water to air (in L/m^3)
TF_{sdpw}	sediment-to-pore water transfer factor
Tf_{sdpwi}	transfer factor for chemical *i* for sediment to pore water (in kg/L)
TF_{sh}	shower water-to-air transfer factor
Tf_{shi}	transfer factor for chemical *i* for volatilization from shower water to air (in L/m^3)
TF_{swoa}	surface water-to-air transfer factor
Tf_{swoai}	transfer factor for volatilization from surface water to outdoor air (in L/m^3)
THI	target hazard index
THQ	target hazard quotient
TIE	Toxicity Evaluation Identification
TOC	total organic carbon
TR	target risk
TRV	Toxicity Reference Value
TSS	total suspended solids
$UHIa1\text{-}inh\text{-}c_i$	unit hazard index for chemical *i* for inhalation of outdoor air by a young child (in m^3/mg)
$UHIa2\text{-}inh\text{-}c_i$	unit hazard index for chemical *i* for inhalation of outdoor air (in m^3/mg)
$UHIfd1\text{-}ing\text{-}c_i$	unit hazard index for chemical *i* for ingestion of waterfowl (in kg/mg)

List of Acronyms

$UHIfsh1\text{-}ing\text{-}c_i$	unit hazard index for chemical *i* for ingestion of fish (in kg/mg)
$UHIsd1\text{-}d\text{-}c_i$	unit hazard index for chemical *i* for dermal contact with sediment (in kg/mg)
$UHIsd1\text{-}ing\text{-}c_i$	unit hazard index factor for chemical *i* for ingestion of sediment (in kg/mg)
$UHIw1av\text{-}inh\text{-}c_i$	unit hazard index for chemical *i* for inhalation of indoor air by a young child (in m^3/mg)
$UHIw1\text{-}d\text{-}c_i$	unit hazard index for chemical *i* for dermal contact with surface water by a young child (in L/mg)
$UHIw1\text{-}ing\text{-}c_i$	unit hazard index for chemical *i* for incidental ingestion of surface water by a young child (in L/mg)
$UHIw2av\text{-}inh\text{-}c_i$	unit hazard index for chemical i for inhalation of indoor air by an adult (in m^3/mg)
$UHIw2\text{-}d\text{-}c_i$	unit hazard index for chemical *i* for dermal contact with surface water (in L/mg)
$UHIw2\text{-}ing\text{-}c_i$	unit hazard index for chemical *i* for incidental ingestion of surface water (in L/mg)
$UHIw3\text{-}d\text{-}c_i$	unit hazard index for chemical *i* for dermal contact with sediment pore water (in L/mg)
UP	Michigan's Upper Peninsula
URF	unit risk factor
$URFa1\text{-}inh\text{-}c_i$	unit risk factor for chemical *i* for inhalation of outdoor air by a young child (in m^3/mg)
$URFa2\text{-}inh\text{-}c_i$	unit risk factor for chemical *i* for inhalation of outdoor air (in m^3/mg)
$URFfd1\text{-}ing\text{-}c_i$	unit risk factor for chemical *i* for ingestion of waterfowl (in kg/mg)
$URFfsh1\text{-}ing\text{-}c_i$	unit risk factor for chemical *i* for ingestion of fish (in kg/mg)
URF_i	inhalation unit risk factor
$URFsd1\text{-}d\text{-}c_i$	unit risk factor for chemical *i* for dermal contact with sediment (in kg/mg)
$URFsd1\text{-}ing\text{-}c_i$	unit risk factor for chemical *i* for ingestion of sediment (in kg/mg)
$URFw1av\text{-}inh\text{-}c_i$	unit risk factor for chemical *i* for inhalation of indoor air by a young child (in m^3/mg)
$URFw1\text{-}d\text{-}c_i$	unit risk factor for chemical *i* for dermal contact with surface water by a young child (in L/mg)

List of Acronyms

URFw1-ing-c_i	unit risk factor for chemical *i* for incidental ingestion of surface water by a young child (in L/mg)
URFw2av-inh-c_i	unit risk factor for chemical *i* for inhalation of indoor air by an adult (in m^3/mg)
URFw2-d-c_i	unit risk factor for chemical *i* for dermal contact with surface water (in L/mg)
URFw2-ing-c_i	unit risk factor for chemical *i* for incidental ingestion of surface water (in L/mg)
URFw3-d-c_i	unit risk factor for chemical *i* for dermal contact with sediment pore water (in L/mg)
USACE	United States Army Corps of Engineers
USDA	United States Department of Agriculture
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UWSGI	University of Wisconsin Sea Grant Institute
W.A.	Wildlife Area
WDH	Wisconsin Department of Health and Social Services
WDNR	Wisconsin Department of Natural Resources
WHO	World Health Organization
wLFRM	Whole Lower Fox River Model
WSEV	Window Subsampling Empirical Variance
ww	wet weight
YOY	young-of-the-year

1 Introduction

This document presents the results of the baseline risk assessment (BLRA) for human health and ecological risk in the Lower Fox River and Green Bay, Wisconsin. The BLRA is being undertaken as part of the Fox River Remedial Investigation and Feasibility Study (RI/FS), and is intended to provide an assessment of risks to human health and the environment that will support selection of a remedy to eliminate, reduce, or control those risks. The overall programmatic goal is to develop an RI/FS report that is sufficient to support the selection of an approach for site remediation, and then to use this data in a well-supported Record of Decision (ROD). The ROD defines the cleanup alternative selected for the site.

This RI/FS report is consistent with the findings of the National Academy of Science's National Research Council Report entitled *A Risk Management Strategy for PCB Contaminated Sediments* (NRC, 2001). Based on national and growing concern regarding the long-term management of PCB-contaminated sediments, the National Academy of Sciences (NAS) was mandated by the United States Congress, via the National Research Council (NRC), to address the complexities and risks associated with managing PCB-contaminated sediments. The NRC was tasked with reviewing the availability, effectiveness, cost, and effects of technologies used for the remediation of sediments containing PCBs. The results of their findings were published in a document titled *A Risk Management Strategy for PCB-contaminated Sediments* (NRC, 2001). Based on their review of PCB effects at several sites nationally, the NRC also concluded that PCBs in sediment do pose a chronic risk to human health and the environment, and that these risks must be managed. The NRC recommended that remedies should be site-specific and risk-based, and that no one remedy (dredging, capping, or monitored natural recovery) is applicable or preferred for all sites.

The recommendations of the NRC were adapted by the United States Environmental Protection Agency (EPA) in a document titled *Principles for Managing Contaminated Sediment Risks at Hazardous Waste Sites* (EPA, 2002). EPA used the guiding principals defined by the NRC to develop a set of 11 risk management principles for application at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or Resource Conservation and Recovery Act (RCRA) sediment sites. The EPA guidance principles specify use of scientific, risk-based, site-specific remedy decisions using an iterative decision process, as appropriate, which evaluates the short-term and long-term risks of all potential cleanup alternatives. These principles are also consistent with the nine remedy selection criteria defined in the National Contingency Plan

(NCP) (40 CFR Part 300.430) and application of these principles does not affect existing statutory and regulatory requirements. A comparison of the NRC-developed and the EPA sediment management principals is given in the white paper titled *Applicability of the NRC Recommendations and EPA's 11 Management Principles* in the Responsiveness Summary.

The Lower Fox River and Green Bay RI/FS followed the guidance set forth by both the EPA and the NRC. These included:

- Using EPA risk assessment frameworks (EPA, 1989 for human health risk; EPA, 1997 and 1998 for ecological risk) that were based on the framework developed by NRC in 1983 which recommended a tiered and iterative approach;

- Using an extensive body of site-specific scientific information and data to bound the problem, and by calibrating and defining the uncertainty of models that were used in the risk assessment and feasibility study;

- Defining the problem in a site-specific manner through review of all existing scientific information in a preliminary assessment;

- Calibrating and defining the uncertainty of models that were used in the assessment; and by

- Structuring the documents so that a range of site-specific risks to human health and the environment were delineated, and articulating Remedial Action Objectives (RAOs) around which to structure potential remedial alternatives.

EPA's 11 risk management principles also are covered by the above bullet, as well as through public involvement; development of sophisticated fate, transport, and bioaccumulation models; early involvement of trustee groups; and implementation of three demonstration projects to test potential remedial technologies. These are discussed throughout the FS.

The RI/FS is being conducted under contract to the Wisconsin Department of Natural Resources (WDNR). While this is a state-lead effort, the overall assessment follows the procedures and paradigms developed as part of CERCLA and National Contingency Plan (NCP) (i.e., "The Superfund Program"). Specific procedures are addressed in relevant sections below.

In addition to the WDNR, this BLRA received review and comment from the EPA, United States Fish and Wildlife Service (USFWS), the National Oceanic and Atmospheric Administration (NOAA), and the Menominee and Oneida Nations.

1.1 Statement of the Problem

The area investigated for this BLRA includes the Lower Fox River and all of Green Bay. The Lower Fox River is 39 miles long and extends from the outlet of Lake Winnebago, flowing north, to Green Bay (Figure 1-1). Green Bay begins at the mouth of the Lower Fox River, extends north for approximately 193 kilometers (km) (120 miles), and has an average width of 37 km (23 miles) (Figure 1-2).

The Lower Fox River is the most industrialized river in Wisconsin, and has had reported water quality problems since the early 1900s. Beginning in the mid-1800s, forests were cleared for lumber and the cleared land was converted to agriculture. The runoff from farmlands increased the sediment and nutrient loads to the river and bay. The expanding paper industries and communities discharged increasing amounts of untreated sewage and industrial wastes into the river and, ultimately, the bay. The Lower Fox River received discharges from 15 pulp and/or paper mills, one electrical generating facility, and eight municipal wastewater treatment plants. Green Bay's ability to trap nutrients hastened its degradation under the increasing loads of biological oxygen-demanding wastes and suspended solids (Smith *et al.*, 1988). Until the early 1970s, the extreme southern portion of Green Bay (including the 11 km [7 miles] of the Fox River downstream of the De Pere dam) was a shallow (1- to 5-meter [3- to 16-foot] depth), eutrophic water body which received virtually all of its nutrient loadings from the Fox River and the city of Green Bay.

In the early 1970s, polychlorinated biphenyls (PCBs) were discovered in sediments and water in the Lower Fox River. PCBs were also detected in many fish species and birds in the Lower Fox River and Green Bay. Between 190,000 and 375,000 kg (418,878 and 826,734 pounds) of PCBs have been released into the Lower Fox River over the period from 1957 to 1992 (WDNR, 1998a).

In 1977, the WDNR issued the first warnings regarding human consumption of trout, salmon, and carp principally due to elevated levels of PCBs. Since 1977, WDNR has annually issued fish consumption advisories for most common species in the Lower Fox River and Green Bay. Additionally, a waterfowl consumption advisory exists for mallard ducks taken between Lake Winnebago and the northeast limits of Kaukauna.

Extensive evaluations of PCB contamination in sediment, fish, and wildlife have been conducted on the Lower Fox River and Green Bay by the WDNR, the EPA, and the USFWS. These studies included measurement of concentrations in sediments, surface water, fish, and avian species; fate and transport modeling of PCBs; and evaluations of environmental impacts.

While, historically, the concerns on the Lower Fox River have largely centered on PCBs, other studies have identified additional chemicals that could pose risks to human health and ecological receptors on the Fox River (Sullivan and Delfino, 1982). For example, Sullivan and Delfino (1982) found more than 100 chemicals in Lower Fox River sediments, water, and fish tissues. More recent estimates list up to 362 potentially toxic substances in the river and southern Green Bay (WDNR, 1993), including mercury, total polynuclear aromatic hydrocarbons (PAHs) and ammonia. Other contaminants found in specific locations of the river and Green Bay include arsenic, chromium, copper, lead, zinc, 4,4'-dichlorodiphenyl trichloroethane (DDT), 4,4'-dichlorodiphenyl dichloroethylene (DDE), dieldrin, and pentachlorophenol (PCP). Presently, of the potentially toxic substances found, PCBs are considered to be the primary chemical of potential concern (RETEC, 1998b). Adverse effects associated with these substances can include altered benthic community structure and reproductive impairments in fish-eating birds.

In order to focus the RI/FS process, a Screening Level Risk Assessment (SLRA) was conducted to evaluate which chemicals in the Lower Fox River system posed the greatest degree of risk to human and ecological receptors. The SLRA for the Lower Fox River and Green Bay evaluated the potential for human health and ecological risks associated with contaminants in sediments, surface waters, and biota. Based upon those results (see Section 2, below), eight chemicals of potential concern (COPCs) were identified by WDNR (letter from Bruce Baker, August 3, 1998; Appendix A) for carrying forward into the BLRA. These are:

- PCBs (expressed as total, PCBs and PCB coplanar congeners);
- 2,3,7,8-Tetrachloro-*p*-dibenzodioxin (TCDD);[1]
- 2,3,7,8-Tetrachloro-*p*-dibenzofuran (TCDF);[1]

[1] Although 2,3,7,8-TCDD is the most toxic dioxin congener, all structurally related dioxin and furan congeners will be evaluated for toxicity based on the toxicity equivalency method. The dioxin and furan congeners that will be evaluated are those that have been measured in site media and those that have toxic equivalency factors (TEFs).

- 4,4'-Dichlorodiphenyl trichloroethylene (DDT) and its metabolites (DDE, DDD);
- Dieldrin;
- Arsenic;
- Lead; and
- Mercury.

1.2 Objectives of the Baseline Risk Assessment

The BLRA for the Lower Fox River and Green Bay focuses on defining the current (or baseline) human health and ecological risks associated with the COPCs identified in the SLRA. The specific media of interest are the sediments, surface waters, and biota in the Lower Fox River from Lake Winnebago into the Green Bay estuary. The BLRA will quantify the levels of risk and identify potentially significant risks by distinguishing chemicals that pose the greatest potential for risk from those that pose negligible risks.

The primary objectives of the BLRA are to:

- Define the sources, receptors, and pathways at risk
  - Define the sources of contaminants in the river
  - Identify the critical fate and transport processes
  - Define the human health and critical receptors potentially at risk
  - Describe exposure pathways
  - Select assessment endpoints
  - Develop a defensible conceptual model
- Identify the extent of exposure
  - Critically evaluate all data and determine which points in sediment, water, and tissues may be defensibly used for the BLRA
  - Using site-specific data, determine area-wide average concentrations of COPCs
  - Develop site-specific exposure scenarios to be used in the risk estimations

- Determine the extent and likelihood of actual or potential impacts

  - Select how risks to human health and the environment will be measured
  - Evaluate toxicity values from literature and database sources
  - Derive and defend levels of COPCs in environmental media that place receptors at risk
  - Quantify the current level (baseline risk) to human health and the environment

- Describe the uncertainty associated with the characterized risk

  - Identify those assumptions and data gaps which may contribute to the over/underestimation of risk

- Evaluate risk-based sediment quality thresholds (SQTs) for PCBs

  - Determine PCB sediment concentrations that would not result in accumulations to fish tissues at levels that exceed acceptable human health cancer risk levels ($>10^{-4}$, $>10^{-5}$, $>10^{-6}$) or noncancer risk hazard indices (HQ > 1)
  - Identify PCB sediment concentrations that would not result in unacceptable risks to ecological receptors (e.g., no observed effect level [NOEL], lowest observed effect level [LOEL], 20 percent effect concentration [EC_{20}], and 30 percent effect concentration [EC_{30}])

1.3 Geographic Boundaries of the Baseline Risk Assessment

The Lower Fox River and Green Bay, Lake Michigan are located in northeastern Wisconsin within the eastern ridges and lowlands of the state. The Lower Fox River is defined as the 63-km (39-mile) segment of the river beginning at the mouth of Lake Winnebago and terminating at the mouth of Green Bay (Figure 1-1). Flowing north, the Fox River is the primary tributary that leads into lower (southern) Green Bay. The BLRA also includes Green Bay.

For the BLRA, the reaches of the Fox River discussed in this report are as follows:

- **Little Lake Butte des Morts Reach:** the river reach from the outlet of Lake Winnebago to the city of Appleton, including Little Lake Butte des Morts (LLBdM);

- **Appleton to Little Rapids Reach:** the river reach from approximately Appleton to Wrightstown;

- **Little Rapids to De Pere Reach:** the section of the river from Little Rapids to the De Pere dam;

- **De Pere to Green Bay Reach (Green Bay Zone 1):** the approximately 11 km (7 miles) of river downstream from De Pere to the mouth of Green Bay; and

- **Green Bay:** the entirety of Green Bay that begins at the mouth of the Lower Fox River and extends north for 193 km (120 miles) (Figure 1-2). Green Bay is narrow compared to its length; on average, Green Bay is 37 km (23 miles) wide. Within the comprehensive Green Bay Mass Balance Study (WDNR, 1995), the bay was further evaluated in four zones.

  - **Zone 1:** corresponds to the De Pere to Green Bay reach in this study (approximately 11 km or 7 miles),
  - **Zone 2:** defined as the lower bay area to a line transversing the bay at Little Tail Point (approximately 13 km or 8 miles),
  - **Zone 3:** runs north until just south of Chambers Island (approximately 76 km or 47 miles), and
  - **Zone 4:** includes all of the northern bay, including the islands marking the entrance to Lake Michigan (approximately 93 km or 58 miles).

All zones can be considered as "east" and "west" reaches based upon a line drawn from Chambers Island to the mouth of the Fox River, where zones on the west side of the bay are denoted as "A" and those on the east side of the bay are denoted as "B." For the purposes of evaluating risk in zones 1 through 4, only Zone 3 will be independently evaluated as Zone 3A (the west side) and Zone 3B (the east side). This distinction is noted for Zone 3 because much of the area in Zone 3B is part of the Lower Fox River depositional zone (Manchester-Neesvig *et al.*, 1996) and, therefore, potentially quite different in terms of risk than Zone 3A. Further detail regarding descriptions of the river reaches and Green Bay zones is provided in the Remedial Investigation.

1.4 Organization of the Baseline Risk Assessment

The remainder of this BLRA is organized as follows:

- **Section 2, Review of the Remedial Investigation,** presents a summary of the *Remedial Investigation for the Lower Fox River* (RETEC, 2002a) that includes the overall environmental setting, site description, previous studies, contaminants known to exist at the site, and fate and transport processes, as it relates to the BLRA.

- **Section 3, Summary of the Screening Level Risk Assessment,** discusses the relevant pathways, receptors, and chemicals of potential concern identified in the SLRA.

- **Section 4, Sediment, Water, and Tissue Chemistry Data,** presents the sources of analytical data, the compilation into a single database, and an evaluation of the data quality for use in the BLRA.

- **Section 5, Human Health Risk Assessment,** includes the conceptual site model identifying potential sources of contaminants, migration and exposure pathways for human receptors, and the relevant exposure assumptions and risk calculations.

- **Section 6, Ecological Risk Assessment,** includes the problem formulation, description of the affected ecosystem, a conceptual site model for the receptors on the Lower Fox River, selection of assessment and measurement endpoints, characterization of exposure and of risk, and a description of the uncertainties in the ecological BLRA.

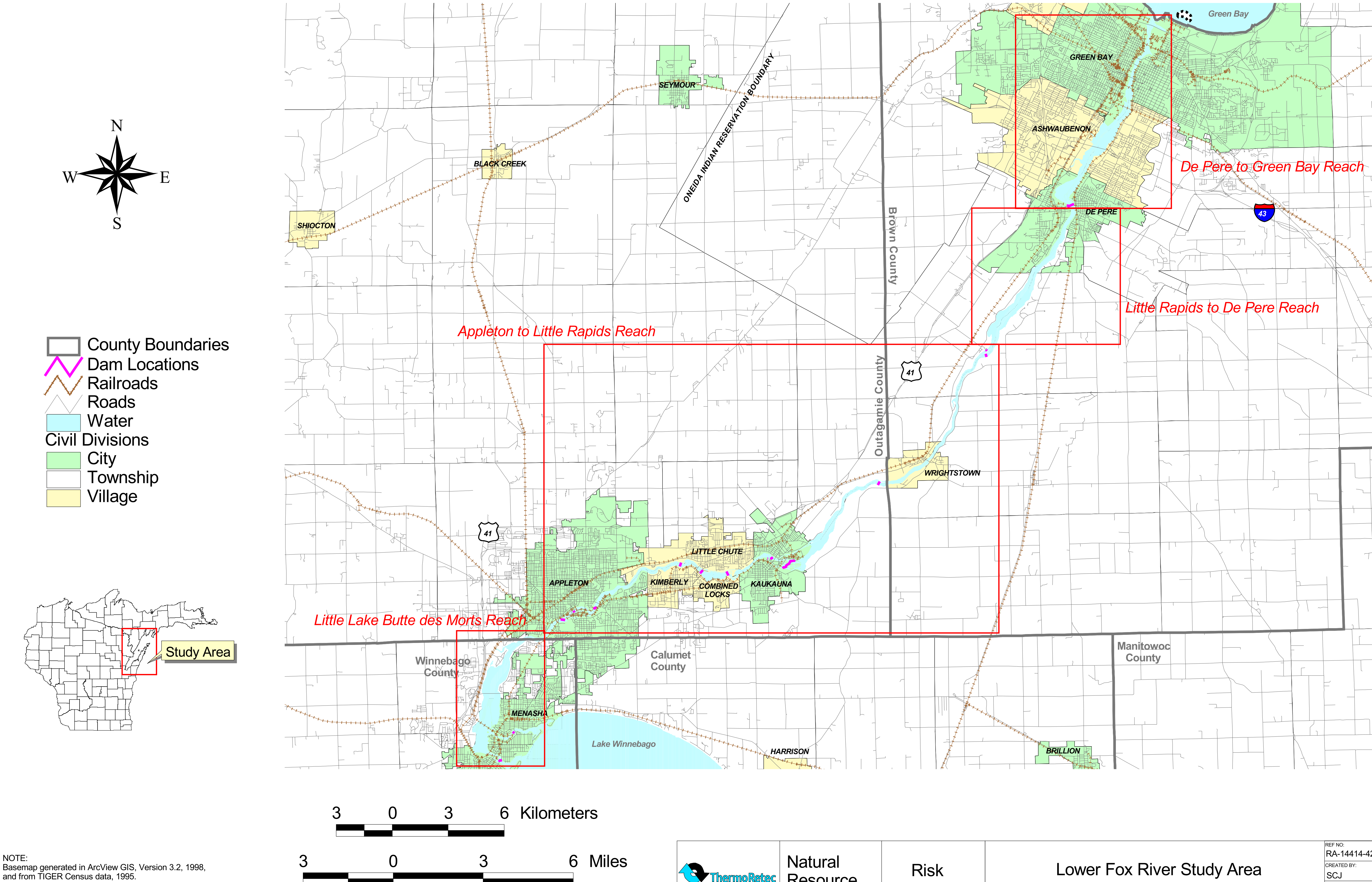
- **Section 7, Sediment Quality Thresholds,** uses the risk levels identified to human health and the environment to develop concentrations in sediments that should not result in exceedances of these risk thresholds.

- **Section 8, References,** includes the literature, studies, internet websites, and personal communications used to build the BLRA.

1.5 Section 1 Figures

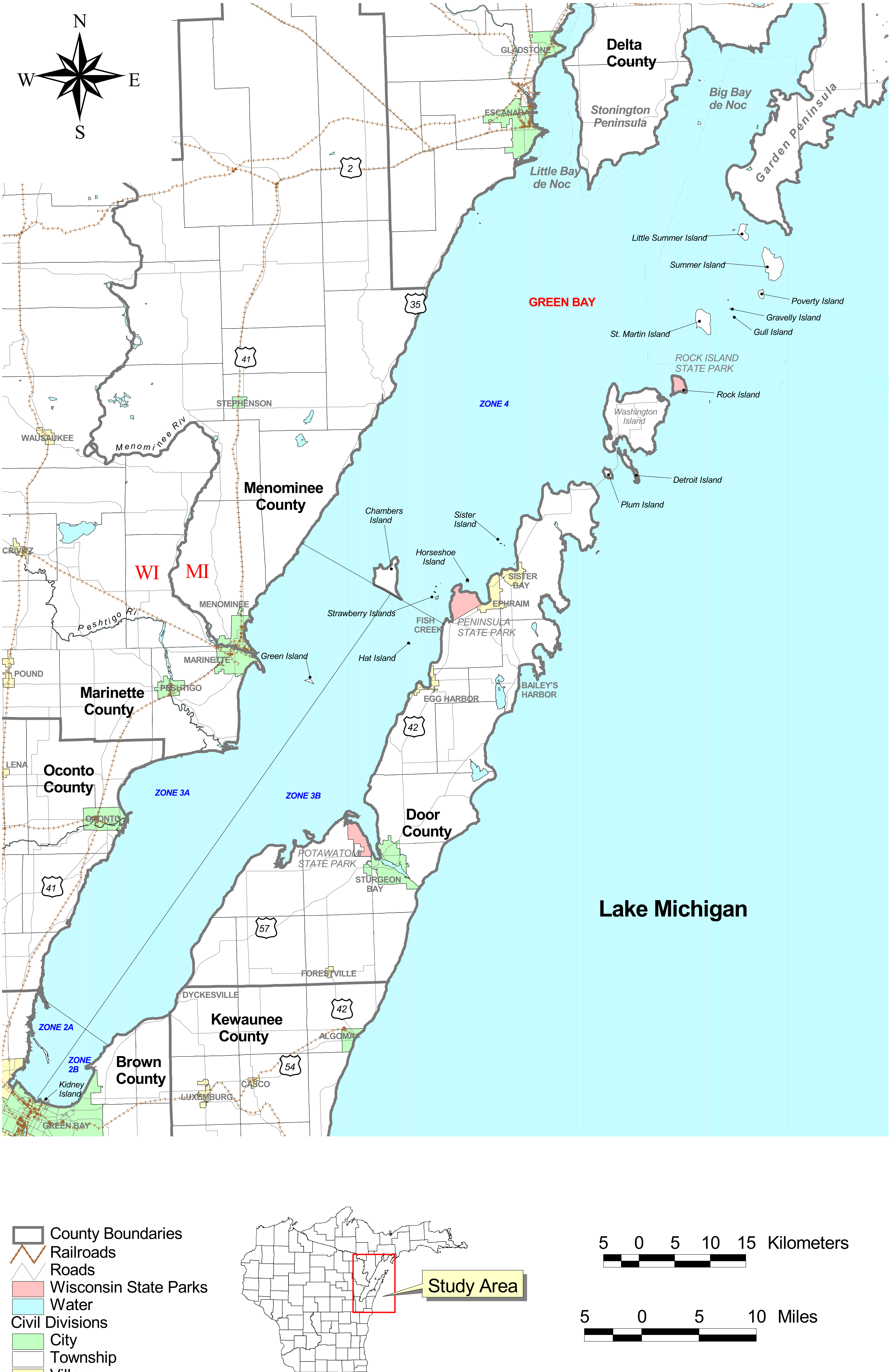
Figures for Section 1 follow this page and include:

Figure 1-1 Lower Fox River Study Area
Figure 1-2 Green Bay Study Area



NOTE:
Basemap generated in ArcView GIS, Version 3.2, 1998, and from TIGER Census data, 1995.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Lower Fox River Study Area	REF NO: RA-14414-425-1-1
				CREATED BY: SCJ
				PRINT DATE: 3/14/01
			FIGURE 1-1	APPROVED: AGF



NOTE:
Basemap generated in ArcView GIS, Version 3.2, 1998, and from TIGER Census data, 1995.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Green Bay Study Area	REF NO: RA-14414-425-1-2 CREATED BY: SCJ PRINT DATE: 3/14/01 APPROVED: AGF
			FIGURE 1-2	

2 Remedial Investigation Summary

This section provides a summary of information from the Remedial Investigation (RI) report for the Lower Fox River and Green Bay that is relevant to the human health and ecological risk assessment. This includes the hydrologic, physical, chemical, fate and transport and important habitat and ecological characteristics of the system and biological characteristics of the river and bay. Specifically, this summary of the RI report will:

- Define the historical setting, including sources of chemicals of concern in the Lower Fox River;
- Describe the physical characteristics of the Lower Fox River and Green Bay along areas of impacted sediment deposits;
- Estimate the occurrence, volume, and mass of sediments containing identified chemical compounds, particularly polychlorinated biphenyls (PCBs);
- Discuss the fate and transport of contaminants within the Lower Fox River and Green Bay;
- Describe the biological distribution of observed species, the shoreline habitat types, and habitat quality of the Lower Fox River and Green Bay; and
- Present the results of an analysis of time trends within the Lower Fox River for changing sediment and fish tissue concentrations.

2.1 Environmental Setting and Background

2.1.1 Site History

The Lower Fox River and Green Bay regions have long been important transportation corridors within the state of Wisconsin. Abundant and reliable food, as well as other natural resources in the area, have fostered development since prior to arrival of Europeans to the region. By the early 1800s, timber, agriculture, fishing and fur trading, and other commercial activities were either well established or beginning to be developed, based on the availability of the local resources. During the 1820s and 1830s, Green Bay was a key entrance into the American west and large-scale migration to the area and development occurred (Burridge, 1997). In 1839–40, representatives of the U.S. federal government (the Topographical Engineers office) recommended the construction of a series of dams, locks, canals, and other improvements in order to make the Lower Fox River navigable between Green Bay and Lake Winnebago (Burridge, 1997). Channelization of the Lower Fox River began as part of this effort, as did construction of the locks and dams at each of the river's rapids. Along with development came utilization, exploitation, and degradation of the local resources, including the water quality of the river and bay.

Currently, the Lower Fox River and Green Bay areas support a population of approximately 595,000, about 10 percent of the state's population. The Lower Fox River valley, especially in the Appleton and Neenah-Menasha area, may still contain the largest concentration of pulp and paper industries in the world (20 mills in approximately 60 kilometers (km) [37 miles]). The paper industry remains active within the valley and plays a vital role in the local and state economy. Other industries important to the region include metal working, printing, food and beverages, textiles, leather goods, wood products, and chemicals. In addition to heavy industrial land use, the region also supports a mixture of agricultural, residential, light industrial, conservancy, and wetland areas.

2.1.2 Chemicals of Potential Concern in the Lower Fox River

COPCs, representing potential risks to human and ecological health, were identified in the Screening Level Risk Assessment (SLRA) (RETEC, 1998b). These compounds include the chlorinated organic compounds PCBs and dioxins/furans, the chlorinated pesticides dichlorodiphenyltrichloroethane (DDT), DDD, and DDE, and dieldrin, and the inorganic compounds mercury, lead, and arsenic. The SLRA determined that risks were primarily associated with PCBs, mercury, and DDE.

Polychlorinated Biphenyls (PCBs)

From the early 1950s through the early 1970s, the manufacture of carbonless copy paper used a PCB emulsion. In 1954, Fox River valley paper mills began manufacturing, de-inking, and recycling of carbonless copy paper. Aroclor 1242 was the PCB mixture used in the manufacture of carbonless copy paper and approximately 20.4 million kilograms (kg) (45 million pounds) of this emulsion were reportedly used in the Lower Fox River valley between about 1954 and 1971. The use of PCBs was unregulated and the potential health effects were unknown during this time period.

The use of PCBs in carbonless paper manufacturing ceased in 1971. The Wisconsin Department of Natural Resources (WDNR) estimated that approximately 313,600 kg (691,370 pounds) of PCBs were released to the environment during this time (1954 to 1971), although the discharge estimates range from 126,450 to 399,450 kg (278,775 to 880,640 pounds) based on the percentages of PCBs lost during production or recycling of carbonless copy paper (WDNR, 1999a). Further, WDNR (1999a) estimated that 98 percent of the total PCBs released into the Lower Fox River had occurred by the end of 1971. In addition, WDNR (1999a) indicated that five facilities, including the Appleton Papers-Coating Mill, P. H. Glatfelter Company and associated Arrowhead Landfill, Fort James-Green Bay West Mill (formerly Fort Howard), Wisconsin Tissue, and Appleton Papers-Locks Mill contributed over 99 percent of the total PCBs discharged to the river. A portion of these PCBs settled into river sediments.

The companies discussed above have been named as potentially responsible parties (PRPs) under the CERCLA statute. Fort James Corporation, P. H. Glatfelter, Riverside Paper Company, U.S. Paper Mills Corporation, and Wisconsin Paper Mills, Inc. were identified as PRPs by the U.S. Fish and Wildlife Service in 1994, and NCR Corporation and Appleton Papers, Inc. in 1996. These parties refer to themselves as the Fox River Group (FRG).

Point source discharges of the COPCs have decreased significantly since implementation of the Clean Water Act and other environmental regulations in the early 1970s. As a result, input of PCBs into the Lower Fox River from regulated discharges is essentially eliminated. However, residual sources for PCBs and other detected compounds remain in the river sediments, continuing to affect water quality, fish, wildlife, and potentially humans. PCBs have also been detected in many fish and bird species in the Lower Fox River and Green Bay. Due to the continued elevated levels of PCBs present within the Lower Fox River and Green Bay, WDNR issued consumption advisories in 1977 and 1987 for fish and waterfowl, respectively; Michigan issued fish consumption advisories for Green Bay in 1977. Most of these advisories are still in place.

Sediments are the most significant source of PCBs entering the water column (Fitzgerald and Steuer, 1996) and over 95 percent of the PCB load into Green Bay is derived from the Lower Fox River (WDNR, 1998c). PCBs from sediment deposits are discharged into Green Bay at the mouth of the Lower Fox River through sediment transport and PCB dissolution in the water column. Up to 280 kg (620 pounds) of PCBs were transported from the Lower Fox River into Green Bay during a 1-year period in 1989–1990 (Velleux and Endicott, 1994). Approximately 122 kg (270 pounds) of PCBs are transported from Green Bay to Lake Michigan annually (EPA, 1998a). Based on the data included in the Fox

River database, the estimated mass of PCBs in sediments of the Lower Fox River and Green Bay is approximately 100,000 kg (220,000 pounds).

Mercury and DDE

Sediments from upstream of the Kaukauna dam to Green Bay contain elevated mercury concentrations. Elevated mercury levels in Lower Fox River sediments are attributed to mercuric slimicides (phenyl mercuric acetate) used in paper manufacturing. This practice was discontinued in 1971. Studies completed in the 1990s indicate that mercury concentrations remain elevated more than 20 years after mercury use was discontinued (WDNR, 1996b).

Few identifiable point sources exist for the other compounds of potential concern in the Lower Fox River. Dioxin is not a manufactured compound; rather it is a byproduct of various chlorinated organic compounds, such as PCBs. The pesticides DDT and dieldrin once had widespread use in agriculture, but there is no point source associated with these compounds. However, DDE in sediments below the De Pere dam and Green Bay are of risk to fish and birds. Similarly, the metals lead and arsenic, even now, have widespread uses and are not associated with any specific point sources.

2.2 Physical Characteristics

2.2.1 Total Organic Carbon

Total organic carbon (TOC) affects the bioavailability and toxicity of some substances and influences the composition and abundance of benthic communities. Some chemicals (particularly low-solubility organic compounds) strongly adsorb onto organic coatings over the surfaces of inorganic particles. As a result, sediment with high TOC content tends to accumulate higher concentrations of organic compounds than sediment with lower TOC content. TOC was analyzed in over 1,600 sediment samples from the Lower Fox River, Green Bay, and select tributaries to assist in the interpretation of the sediment organics data. TOC concentrations in sediments are extremely variable.

Average TOC value in Lake Winnebago is 7.8 percent (78,000 milligrams per kilogram [mg/kg]), suggesting that significant background TOC levels are present within the system. Moving downstream, the TOC average in each reach shows a general decline. The river-wide TOC average is 4.91 percent. The average TOC concentrations in Green Bay range from 0.14 to 2.33 percent. In comparison, the Lake Michigan TOC average is 0.35 percent.

2.2.2 Lower Fox River

The Lower Fox River flows northeast approximately 63 km (39 miles) from Lake Winnebago to Green Bay. The Lower Fox River is the primary tributary to lower Green Bay, draining approximately 16,395 square kilometers (km^2) (6,330 square miles [mi^2]) with a mean discharge of 122 cubic meters [m^3] (4,300 cubic feet per second [cfs]) (USGS, 1998a, 1998b, 1998c, 1998d, 1998e, 1998f). The change in river elevation between Lake Winnebago and Green Bay is approximately 51 meters (168 feet).

Bathymetry and Currents

The Lower Fox River is relatively narrow, generally less than 305 meters (1,000 feet) wide over much of its length, and ranges up to approximately 6.1 meters (20 feet) deep in some areas. Where the river widens significantly, water depths generally decrease to less than 3 meters (10 feet) deep. In Little Lake Butte des Morts, water depths range between 0.61 and 1.53 meters (2 and 5 feet) except in the main channel. In general, however, the main channel of the river ranges from approximately 1.8 to 6.1 meters (6 to 20 feet) deep. Figure 2-1 presents the elevation profile of the Lower Fox River.

Navigation

There are 17 locks and 12 dams located on the Lower Fox River between Lake Winnebago and the De Pere dam. The river is still navigable to recreational boats, but the Rapide Croche lock is permanently closed to restrict sea lamprey migration. Navigation for ocean-bound vessels extends from Green Bay, upriver approximately 4.8 km (3 miles) to the Fort James Paper Company (formerly Fort Howard) turning basin via a shipping channel maintained to a water depth of approximately 7.3 meters (24 feet). Flow in this section of the river is sometimes reversed by wind-driven increases in Green Bay water levels, commonly known as seiche events.

Sediment Composition and Deposition

Soils and river sediments in the region are predominantly silt and clay units with varying amounts of sand and gravel due to past glacial events. The glacial deposits also affect the surficial soils in the vicinity of the Lower Fox River, many of which are described as silty clay loam, silty clay, and clay. Sediment is typically deposited on the inside portion of a meander bend, while the outer part of the meander bend (the cut bank) usually is erosional due to increased stream flow velocities. Between the Little Rapids and De Pere dams, the river is again relatively straight, although not as wide or as shallow as Little Lake Butte des Morts.

Reach Designations

To facilitate modeling activities and identification of specific points along the river, the Lower Fox River was divided into the following four separate reaches in sequential order going downstream:

- Little Lake Butte des Morts (LLBdM),
- Appleton to Little Rapids,
- Little Rapids to De Pere, and
- De Pere to Green Bay (also Green Bay Zone 1).

These four reaches were based on similar water depths, current velocities, contaminant concentrations and distribution, and dam/lock structures (Table 2-1 and Figure 1-1). These reach designations were used during the RI to streamline the evaluation and reporting of sediment, water, and biological tissue data. Specific sediment deposits were identified in the first three reaches (Little Lake Butte des Morts, Appleton to Little Rapids, and Little Rapids to De Pere). These deposits were labeled A through HH and POG. Deposits were originally designated based on physical attributes, then later the chemical nature and extent of each deposit was determined. The De Pere to Green Bay Reach was divided into 96 Sediment Management Units (SMUs) to support the modeling efforts of the 1989 Green Bay Mass Balance Study. Table 2-1 summarizes the 35 sediment deposits (labeled A through HH) upstream of the De Pere dam and 96 Sediment Management Units (SMUs 20 through 115) downstream of the De Pere dam.

2.2.3 Green Bay

Green Bay is a narrow, elongated bay, approximately 190 km (119 miles) in length and an average of 37 km (23 miles) in width. The bay is bounded by the City of Green Bay at the south end and by both Big and Little Bays de Noc, in Michigan's Upper Peninsula (UP), on the north end. Wisconsin's Door Peninsula separates the majority of Green Bay from Lake Michigan. Urban areas located along the west shore of Green Bay include the cities of Marinette, Peshtigo, and Oconto, Wisconsin; and Escanaba and Menominee, Michigan. The city of Sturgeon Bay, Wisconsin, is the only urban area located on the east shore of Green Bay.

The Green Bay watershed drains approximately 40,000 km^2 (15,625 mi^2) or about one-third of the Lake Michigan drainage basin. Two-thirds of the Green Bay drainage is in Wisconsin and one-third in Michigan. The Lower Fox River is the largest tributary to Green Bay, contributing approximately 42 percent of the total drainage, over 95 percent of the PCB load, and 70 percent of the suspended sediments (WDNR, 1999a; Smith *et al.*, 1988). Other significant tributaries, located along the west and north sides of the bay, include Duck Creek and the following rivers: Suamico, Pensaukee, Oconto, Peshtigo, Menominee, Cedar, Ford, Escanaba, Tacoosh, Rapid, Whitefish, Sturgeon, and Fishdam.

Bathymetry and Currents

The bathymetry in Green Bay is controlled by its geologic history. Based on the eastern dip of the bedrock units along its lengthwise axis and the glacial scouring of the basin, the bay gently slopes to mid-bay moving from west to east. Eastward of this mid-bay, the bottom is a relatively flat sediment plain that rises abruptly near the east shore. Within this framework, the bathymetry for each Green Bay zone has unique characteristics. The bathymetry for the De Pere to Green Bay Reach (Zone 1) has been described above. The bathymetry of Zone 2 is more complicated than the bathymetry of either Zone 3 or Zone 4, due to the numerous shallow areas located within Zone 2. Zones 3 and 4 comprise a large, relatively deep body of water which only have areas with depths less than 9 meters (30 feet) located along the shoreline.

At the south end, the bay is a freshwater estuary due to the shallow water depths, while the northern end is a deep-water lake. The mean depth of the bay is approximately 20 meters (65 feet), with much shallower water depths near the shoreline. Few areas of the bay have depths exceeding 40 meters (131 feet). Green Bay covers an area of approximately 4,150 km^2 (1,600 mi^2) and has a volume of about 83 cubic kilometers (km^3) (20 cubic miles [mi^3]). The long-term average Lake Michigan and Green Bay elevation is 176.49 meters (579.02 feet), according to the International Great Lakes Data (USACE, 1996).

The dominant currents in Green Bay flow counterclockwise. In addition, the bay waters are subject to seiches, which may temporarily change water levels from several centimeters up to 1 foot or more, and reverse the flow of the Lower Fox River up to the De Pere dam. The combination of these factors results in relatively rapid mixing of sediment-rich tributary waters, and therefore contaminant loads, with those of Green Bay.

Sediment Composition and Deposition

In the northern portion of Green Bay, especially along the west side of the bay, outwash and glacial lake plains (typically dominated by sands) developed and ultimately affected soil formation, while on the Door and Garden peninsulas, clay till deposits are predominant. Superimposed on the glacial deposits are modern fluvial and alluvial sediments associated with slopewash, river, and floodplain deposits. Discharge at the mouth of the Lower Fox River is directed easterly by the counterclockwise currents. This can result in plumes of sediment-rich water up to 20 to 40 km (12 to 24 miles) along the east shore of the bay. Sediment initially deposited in the southern end of the bay can become resuspended due to seiche action and redeposited further to the north along the eastern shore. Consequently, the majority of river-related sediment in Green Bay is present along the southern and eastern portions.

Zone Designations

The Green Bay Mass Balance Study (EPA, 1989d, 1989e) divided the bay into four morphometric zones based on physical/chemical/biological characteristics observed in the bay (Table 2-2 and Figure 1-2). Observations included eutrophication, chemical contaminants, foraging areas, habitat gradients, and distribution of fish populations. Green Bay Zone 1 is the same as the De Pere to Green Bay Reach of the Lower Fox River. Zones 2 and 3 are further divided into A and B segments by a center line extending out from the mouth of the Lower Fox River to Chambers Island. Zones 2A and 3A are located on the west side of this line, while zones 2B and 3B are located on the east side of this line.

2.3 Nature and Extent of Contaminants of Potential Concern

2.3.1 Estimation of PCB Distributions

This section discusses: 1) data interpolation methods for determining PCB spatial distributions, 2) occurrence of sediment, 3) PCB sediment volume and mass distribution, and 4) riverbed maps showing the occurrence of PCBs in the sediments of the Lower Fox River and Green Bay. These bed maps were prepared from surface and subsurface sediment profile data contained within the Fox River database (FRDB), and originating at specific points along the river and in the bay. Specific details of the bed mapping procedure may be found in the Remedial Investigation Report (RETEC, 2002a). A summary specific to the BLRA is presented below.

In order to view the spatial distribution of PCBs across the study area, a methodology was developed to predict, or interpolate, sediment concentrations between known data collection points. An interpolation grid was necessary to resolve discrepancies between samples with different detection limits, depth intervals, and sample collection and compositing methods from numerous studies conducted over a 10-year period. From the interpolated PCB concentration points, a map of the overall concentrations as sediment isopleths could be produced. The methodology for mapping property distributions was developed jointly by WDNR and the Fox River Group, and is further described in the RI Report.

Data Interpolation for the Lower Fox River

The interpolations for the Lower Fox River are based on the results included in the FRDB as of March 1, 2000, consisting of about 900 sample results and locations in the Lower Fox River from nine studies conducted between 1989 and 1999.[2] The 1999 data set included post-dredge sampling data from the Deposit N sediment removal demonstration project. Data for the Lower Fox River were first screened to remove older data that were geographically too close to locations with newer data. Sediment data for the Lower Fox River has been collected in various studies since 1989. In order to use the most recent data available, the data were assigned to three different time periods: 1989 through 1992, 1993 through 1995, and 1996 through 1998. All of the data from the period 1996 through 1998 were used in the interpolation. A relationship was developed between similar ranges of PCB concentrations and the distances between data points in each range. From this analysis, a distance of less than 133 meters (436 feet) was determined to indicate that an older sample location was too close to a newer sample location. In this case, the older data were not used in the interpolations. This analysis was conducted first on the 1993 through 1996 data set to create a new data set for the 1993 through 1998 period. The analysis was then repeated using the 1989 through 1992 data set. In this way, the entire data set from 1989 through 1998 was used, but older data were superseded by newer data.

The interpolation used the revised 1989 through 1998 data set. The entire area of the Lower Fox River was superimposed with a square grid containing cells 10 meters by 10 meters (33 feet by 33 feet). The screened data were used to interpolate the parameter value at each grid point.

Interpolations used the inverse distance method, whereby grid point values were more strongly affected by the sampling location(s) closest to the grid point. The inverse distance method gives more weight to closer points by using an inverse distance to the fifth power, meaning that points farther away have significantly less effect on the interpolated value at a point. For instance, for two data points, where the first point is half as far from the grid point as the second point, the first point contributes 32 times more to the interpolation than does the second point.

In addition to inverse weighting, a maximum set distance was selected for which data points may influence grid point results. Erroneous interpolations can occur if data are extrapolated over excessive distances. To prevent this condition, grid point values were computed using data within a certain distance or radius of the grid point location. Data points located further from the grid point than the

---

2 The specific sediment studies used in the BLRA are discussed in Section 4.

established radius were not used in the interpolation. If there were no data points within the interpolation radius of a grid point, then no value was interpolated for that grid point.

The interpolation radius for computing sediment thickness was set at 100 meters (328 feet). For all other parameters, the interpolation radius varied among the river reaches. In the Little Lake Butte des Morts Reach, complete coverage of the river required a radius of 400 meters (1,312 feet). For the Appleton to Little Rapids Reach, the river is more narrow and linear. For this reach, the interpolation radius was computed as one-third of the average river width, or 79 meters (259 feet), to minimize the influence of separate deposits on the interpolation. The Little Rapids to De Pere and De Pere to Green Bay reaches used an interpolation radius of 1,000 meters (3,280 feet), as specified in Technical Memorandum 2e and in the Technical Memorandum 2e Addendum (WDNR, 1999c, 2000c).

Data interpolations for the Lower Fox River were conducted for nine different layers of sediment depth: 0 to 10 centimeters (cm) (0 to 4 inches), 10 to 30 cm (0.33 to 1 foot), 30 to 50 cm (1 to 1.6 feet), 50 to 100 cm (1.6 to 3.3 feet), 100 to 150 cm (3.3 to 4.9 feet), 150 to 200 cm (4.9 to 6.6 feet), 200 to 250 cm (6.6 to 8.2 feet), 250 to 300 cm (8.2 to 9.8 feet), and greater than 300 cm (9.8 feet). These sediment depths were selected based on previous and current modeling efforts as well as being defined by WDNR (1998b).

Data Interpolation for Green Bay

Interpolation of sediment data from Green Bay followed the same methods as used in the Lower Fox River. The data set for the Green Bay interpolations included approximately 240 sample results and locations from three studies conducted between 1989 and 1998.

For the interpolation, Green Bay was divided into a square grid with 100 meters (328 feet) between points. The same inverse distance approach was used on both the Lower Fox River and Green Bay, but the analysis on Green Bay used the distance squared rather than distance raised to the fifth power. Therefore, interpolated results in Green Bay were more affected by data points farther way from the grid point than in the Lower Fox River interpolation. For instance, for two data points, where the first point is half as far from the grid point as the second point, the first point contributes four times more to the interpolation than does the second point.

The maximum interpolation radius for Green Bay was set at 8,000 meters (26,250 feet). This means that data points more than 8,000 meters (26,250 feet) from a grid point were not used in the interpolation for that grid point. Conversely, grid points more than 8,000 meters (26,250 feet) from any data point have no interpolated value, and this is evidenced by the lack of data in some areas of the bay, particularly along the west shore of Zone 3A and in Zone 4.

Green Bay data were integrated for four different layers of sediment depth: 0 to 2 cm (0 to 0.8 inches), 2 to 10 cm (0.8 to 4 inches), 10 to 30 cm (0.33 to 1 foot), and greater than 30 cm (1 foot). In addition to these four sediment layers, a composite sediment layer was developed for a thickness of 0 to 10 cm (0 to 4 inches). This layer was computed as a thickness-weighted average of the 0- to 2- and 2- to 10-cm layers (0- to 0.8- and 0.8- to 4-inch). The 0- to 10-cm (0- to 4-inch) layer was developed for use in the RA and food web modeling because the top 10 cm (4 inches) is considered to be the biologically active zone (Ecology, 1995). The other two layers were selected to coincide with layering developed for the river.

PCB Bed Maps

Maps showing the distribution of PCBs in sediment were constructed directly from the interpolated grids using ArcView and Spatial Analyst. The interpolated grid was displayed and color contoured into different ranges based on PCB concentration. Areas where sediment is absent were not included in the color contouring. Similarly, areas outside the interpolation radius are not included in the color contouring. The concentration intervals selected for the bed maps were based upon a combination of observed concentration ranges, cleanup level evaluations, the 50 ppb PCB detection limit, variability of the data collection, and criteria for bed mapping. The total PCB concentration ranges and mapping intervals used for the Lower Fox River and Green Bay (in micrograms per kilogram [μg/kg]) are:

- 0 to 50;
- 50 to 125;
- 125 to 250;
- 250 to 500;
- 500 to 1,000;
- 1,000 to 5,000;
- 5,000 to 10,000;
- 10,000 to 50,000;
- Greater than 50,000 (Lower Fox River); and
- Greater than 5,000 (Green Bay).

Sediment bed maps for total PCBs are shown on Figures 2-2 through 2-6, and are discussed further below.

2.3.2 Extent of PCB Chemical Impacts

Approximately 96,800 kg (213,400 pounds) of PCBs in the Lower Fox River and Green Bay system are distributed in about 474 million m^3 (620 million cy). Review of the PCB mass and contaminated sediment volume herein considers sediments which contain more than 50 μg/kg PCBs. The results are summarized below and indicate that the De Pere to Green Bay Reach and Green Bay Zone 2, combined, contain almost 60 percent of the total PCB mass in the system in less than 10 percent of the total contaminated sediment volume. The PCB mass and volume of contaminated sediment for each river reach and bay zone are listed below.

Location	PCB Mass and Percent in System*	Contaminated Sediment Volume and Percent in System*
Little Lake Butte des Morts Reach	1,540 kg (1.6%)	1.35 million m^3 (0.29%)
Appleton to Little Rapids Reach	94 kg (0.1%)	0.18 million m^3 (0.04%)
Little Rapids to De Pere Reach	980 kg (1.0%)	1.71 million m^3 (0.36%)
De Pere to Green Bay Reach	25,984 kg (26.8%)	5.52 million m^3 (1.16%)
Green Bay Zone 2	32,013 kg (33.1%)	39.5 million m^3 (8.33%)
Green Bay Zone 3	35,243 kg (36.4%)	397 million m^3 (83.72%)
Green Bay Zone 4	925 kg (1.0%)	28.9 million m^3 (6.10%)
Total	**96,784 kg**	**474.16 million m^3**

Note:
* Includes sediments containing PCB concentrations greater than 50 μg/kg.

As shown above, over 96 percent of the total PCB mass within the Lower Fox River and Green Bay is located between the De Pere dam and the northern boundary of Zone 3, which is bounded by Chambers Island. The magnitude and extent of PCB-impacted sediments for each river reach and zone of Green Bay are summarized below.

Little Lake Butte des Morts Reach

PCB distribution in the surface sediments of Little Lake Butte des Morts is shown on Figure 2-2. The nine sediment deposits in this reach (deposits A through H and POG) contain about 1,540 kg (3,395 pounds) of PCBs in about 1.35 million m^3 (1.77 million cy) of sediment with concentrations greater than 50 μg/kg PCBs. These deposits cover about 314 hectares (775 acres) and thicknesses range up to approximately 1.9 meters (6.2 feet) thick. The highest detected total PCB concentration in sediment was 222,722 μg/kg (average 15,043 μg/kg). Upstream deposits A, B, and POG have the highest PCB mass-to-sediment volume ratios in this reach. These three deposits contain 952 kg (2,100 pounds) of the PCBs in about 252,000 m^3 (329,600 cy) of sediment. About 910 kg (2,000 pounds) of the PCBs in these three deposits are present in the upper 100 cm (3.3 feet) of sediment. Deposits A/B, E, and POG contain over 1,400 kg (3,086 pounds) of PCBs, or about 91 percent of the PCBs present in this reach. About 53 percent of the mass in the deposits listed above are present in the upper 30 cm (1 foot) of sediment.

Appleton to Little Rapids Reach

Sediment accumulation in the Appleton to Little Rapids Reach is more localized compared with the other three reaches. The 22 sediment deposits in this reach (deposits I through DD) contain about 94 kg (207 pounds) of PCBs in about 184,790 m^3 (241,700 cy) of sediment with concentrations greater than 50 μg/kg PCBs (Figure 2-3). These deposits cover approximately 153 hectares (378 acres) and generally occur in areas of slower stream flow velocities (e.g., where the river widens, in the vicinity of dams/locks, eddy pools along the banks, etc.). Sediment thicknesses range up to approximately 100 cm (3.3 feet) thick. The highest detected total PCB concentration in sediment was 77,444 μg/kg (average 6,406 μg/kg). Only deposits W, X, and DD have a volume exceeding 30,000 m^3 (39,240 cy) of sediment and these are located where the river widens and/or upstream of a dam. The average sediment volume in each of the remaining 19 deposits in this reach is about 3,780 m^3 (4,944 cy). Approximately 32 kg (71 pounds) of PCBs remain in deposits N and O following completion of the 1999 sediment remediation demonstration project and no future attempt to remove this mass is currently under consideration. The total surface area of this reach is approximately 7,000,000 square meters (m^2) (2.7 mi^2), while deposits with measurable PCBs are only 870,000 m^2 (0.3 mi^2) (12.6 percent). In general, surface sediment PCB concentrations are less than 1,000 μg/kg in this section.

Little Rapids to De Pere Reach

Sediment accumulation in this reach extends over a long distance and large area. The four sediment deposits in this reach (deposits EE through HH) contain 980 kg (2,160 pounds) of PCBs in approximately 1.71 million m^3 (2.24 million cy) of sediment with concentrations greater than 50 μg/kg PCBs (Figure 2-4). The four deposits in this reach are essentially a single sediment unit covering about 266 hectares (657 acres). Sediment thicknesses range up to 2.3 meters (7.5 feet) thick in select areas, especially near the De Pere dam. The highest detected total PCB concentration in sediment was 54,000 μg/kg (average 6,292 μg/kg). Concentrations exceeding 5,000 μg/kg exist at the southernmost limit to Deposit EE, and at the northernmost part of the reach behind the De Pere dam. Almost all of the PCBs are contained in the upper 100 cm (3.3 feet) of sediments, with 535 kg (1,180 pounds) contained in the upper 0 to 30 cm (0 to 1 foot).

De Pere to Green Bay Reach

This reach contains the largest volume and areal extent of impacted sediments in the Lower Fox River (Figure 2-5). Ninety-one (91) percent of the PCB mass for the entire river is present in this reach. The 96 SMUs in this reach contain 25,984 kg (57,285 pounds) of PCBs in over 5.5 million m^3 (7.2 million cy) of sediments with concentrations greater than 50 μg/kg PCBs. Almost the entire sediment bottom contains soft sediment covering about 524 hectares (1,295 acres) and ranging in thickness up to 4 meters (13 feet). The highest detected total PCB concentration in sediment was 710,000 μg/kg (average 21,722 μg/kg) before completion of the SMU 56/57 demonstration project.

Approximately 636 kg (1,400 pounds) of PCBs and 31,000 m^3 (40,550 cy) of sediment were removed from SMUs 56–61 during the SMU 56/57 sediment remediation demonstration project. Further, removal of additional sediment and PCBs from SMU 56/57 started in August 2000, but the final mass and volume estimates are not expected to be known until early 2001. Excluding SMUs 56–61, six SMU groups (SMUs 20–25, 32–37, 38–43, 62–67, 78–73, and 80–85) contain almost 11,000 kg (24,250 pounds) of PCBs, or about 37 percent of the total mass in the Lower Fox River. These SMU groups also exhibit the highest PCB concentrations or greatest PCB mass-to-sediment volume ratios in the river.

The mass of PCBs increases significantly with depth. Approximately 16,150 kg (35,530 pounds) of PCBs, or about 55 percent of the total PCB mass in the Lower Fox River, occurs in the upper 100 cm (3.3 feet) of sediment. Approximately 10,600 kg (23,370 pounds) of PCBs (36 percent of the PCBs in the river) are buried below 100 cm (3.3 feet).

PCBs are fairly evenly distributed in the surface sediments within this reach. Of the 5.2 million m^2 (2 mi^2) of sediment surface within this reach, 4.5 million m^2 (1.7 mi^2) (87 percent) have PCB concentrations greater than 1,000 μg/kg.

Green Bay Zone 2

This zone contains approximately 32,000 kg (70,550 pounds) of PCBs in 39.5 million m^3 (51.6 million cy) of sediment with concentrations greater than 50 μg/kg (Figure 2-6). Sediments with the highest PCB concentrations have accumulated adjacent to the navigation channel and between the mouth of the river and Point Au Sable. The PCB distribution reflects the influence of Green Bay current patterns, as higher concentrations are located along the east side of the bay. Sediments in Zone 2A cover about 5,930 hectares (14,650 acres) and have an average thickness of about 0.34 meter (1.1 feet). In Zone 2B, the sediments cover about 5,150 hectares (12,725 acres) and have an average thickness of about 0.38 meter (1.25 feet). The highest total PCB concentration in sediment was 17,000 μg/kg (average 324 μg/kg).

Considering only sediments with more than 1,000 μg/kg PCBs reduces the mass and volume estimates to 27,470 kg (60,430 pounds) and 17.8 million m^3 (23.3 million cy). This represents slightly more than 45 percent of the PCBs, but less than 3 percent of the estimated volume of impacted sediment in the bay.

Approximately 14,500 kg (31,900 pounds) of PCBs are contained in about 29.8 million m^3 (39 million cy) of sediment in the upper 30 cm (1 foot). Sediments with the highest PCB concentrations have accumulated adjacent to the navigation channel and between the mouth of the river and Point Au Sable. The distribution shows the influence of Green Bay current patterns, as higher PCB concentrations are located along the east side of the bay.

Green Bay Zone 3

This zone contains approximately 35,240 kg (77,700 pounds) of PCBs in 397 million m^3 (519 million cy) of sediment with concentrations greater than 50 μg/kg (Figure 2-6). PCB distribution results show that sediments with the highest concentrations have accumulated along the east shore of Green Bay, extending from Dyckesville to Egg Harbor, reflecting the influence of Green Bay current patterns. Sediments in Zone 3A cover about 85,890 hectares (212,240 acres) and have an average thickness of just 21 cm (0.7 foot). In Zone 3B, the sediments cover about 69,340 hectares (171,340 acres) and have an average thickness of about 31 cm (1 foot). The highest detected total PCB concentration in sediment was 1,320 μg/kg (average 448 μg/kg).

Considering sediments with more than 1,000 μg/kg PCBs reduces the mass and volume estimates to 1.65 kg (3.64 pounds) and 8,800 m^3 (11,510 cy), respectively. This represents less than 0.003 percent of both the PCB mass and sediment volumes in the bay.

Considering the upper 30 cm (1 foot) of sediments, approximately 30,000 kg (66,000 pounds) of PCBs are contained within about 355.9 million m^3 (465.5 million cy). However, as indicated above, a large majority of this mass is located in sediments with concentrations below 1,000 μg/kg PCBs. Surface sediment PCB concentrations are generally higher in the southern part of the zone (greater than 500 μg/kg), and lower (less than 125 μg/kg) just below Chambers Island.

Green Bay Zone 4

The estimated PCB mass and sediment volume results indicate that Zone 4 is relatively unaffected by PCBs compared to zones 2 and 3. However, fewer soft sediment locations were noted and sampled in this zone than in either zones 2 or 3 during 1989 and 1990 sampling activities. Zone 4 contains less than 925 kg (2,040 pounds) of PCBs, or only about 1 percent of the total mass in the system (Figure 2-6). Total PCB concentrations detected in sediment within Zone 4 are all less than 500 μg/kg with an average of 54 μg/kg.

Findings regarding the presence and distribution of other COPCs identified in the Screening Level Risk Assessment are fully described in the Lower Fox River and Green Bay RI Report (RETEC, 2002a).

2.3.3 Extent of Other COC Impacts

Major findings regarding the distribution of other chemical parameters in sediments include the following:

- Mercury was used in a number of pulp and paper production activities to reduce slime. The SLRA identified mercury concentrations exceeding 0.15 mg/kg as a potential concern. Mercury concentrations in Lake Winnebago sediments averaged 0.14 mg/kg, while average concentrations in each reach of the Lower Fox River ranged from 1.26 to 2.42 mg/kg. The elevated mercury concentrations are widespread in the Lower Fox River sediments and are not associated with any specific deposit or point source discharge.

- Mercury concentrations in Green Bay are much lower than levels in the river. The average concentration in Zone 2 was 0.593 mg/kg, but averages in zones 3 and 4 range only up to 0.19 mg/kg, which is just above the Lake Winnebago background concentration.

- The spatial distribution of dioxin/furan compounds cannot be evaluated because only 22 samples were collected from deposits D/E/POG, deposits EE/HH, and SMUs 56/57. Concentrations of 2,3,7,8-TCDD/TCDF detected in sediments ranged from 0.23 to 170 nanograms/kilogram (ng/kg) (parts per trillion [ppt]).

- Sixteen (16) chlorinated pesticides, generally associated with agricultural non-point source activities, were detected in river sediments at concentrations up to 67 μg/kg. Additional non-point pesticide sources may include atmospheric deposition and stormwater runoff from pesticides used at parks, golf courses, and other institutional facilities; however, these sources are likely to be small compared with agricultural activities. Only seven compounds, DDT, DDD, DDE, endrin aldehyde, endrin ketone, gamma-BHC (lindane), and heptachlor, were detected in more than four sediment samples. Distribution of these compounds was generally sporadic. Only DDT and dieldrin were identified by the SLRA as being chemicals of potential concern. The SLRA identified DDT (total) concentrations above 1.6 μg/kg as a potential concern. DDT was detected at 10 widely-distributed locations within the Lower Fox River above this concentration. There is no established concentration of concern for dieldrin, which was detected in only one sample from Little Lake Butte des Morts, suggesting that dieldrin distribution is very limited. Neither DDT nor dieldrin were detected within Green Bay.

- Lead is a naturally-occurring element in soil and sediment. Background lead concentrations in Lake Winnebago sediments averaged 35 mg/kg while average concentrations in each reach of the Lower Fox River ranged from 75.6 to 167.8 mg/kg. The SLRA identified lead concentrations above 47 mg/kg as a potential concern. While some deposits detected lead concentrations as high as 1,400 mg/kg, lead occurrence is widespread in the Lower Fox River sediments and cannot be related to any specific point source discharge. In Green Bay, the average lead concentration ranged from 1.5 to 29.9 mg/kg, which is lower than the Lake Winnebago background concentration.

- Arsenic is also naturally occurring in soil and sediment. Background arsenic concentrations in Lake Winnebago sediments averaged 5.33 mg/kg. The SLRA identified arsenic concentrations above 8.2 mg/kg as a potential concern. An elevated arsenic concentration was detected in only one location (SMU 38) at 385 mg/kg. Excluding this arsenic detection, average concentrations in both the river and the bay were below the Lake Winnebago background concentration of 8.2 mg/kg.

- SVOCs, which result from both point and non-point sources in urban and rural areas, were detected throughout the Lower Fox River at concentrations exceeding the background levels observed in Lake Winnebago. The SVOCs detected at higher concentrations included PAHs and also occurred in widespread areas of the river. Total PAH concentrations below 4,000 μg/kg typically do not warrant further assessment. Total PAH concentrations along the Lower Fox River ranged non-detectable to 60,000 μg/kg. A number of locations from Little Lake Butte des Morts to the mouth of the river exceeded 4,000 μg/kg with the highest values frequently observed downstream of more urbanized areas. None of the sediment samples collected within Green

Bay Zone 2 exceeded 4,000 μg/kg, and PAHs were not detected in zones 3 or 4.

2.4 Contaminant Fate and Transport

Contaminant fate and transport in the Lower Fox River and Green Bay is largely a function of suspension, deposition, and redeposition of the chemicals of concern that are bound to sediment particles. The organic compounds of concern, including PCBs and pesticides, exhibit strong affinities for organic material in the sediments. The suspension and fate and transport of these organic compounds absorbed onto the sediments is largely controlled by moving water in the Lower Fox River and Green Bay. Greater volumes of sediments become suspended and are transported during high-flow events (such as storms and spring snowmelt). The Lower Fox River has an average discharge of 122 m^3/s (9,605 cfs) 10 percent of the time. Previous investigators have estimated that these high-flow events transport more than 50 to 60 percent of the PCB mass that moves over the De Pere dam and into Green Bay.

Other modes of contaminant transport such as volatilization, atmospheric deposition, and point-source discharges are negligible when compared to the river transport. Figures 2-7 and 2-8 each present a conceptual model of PCB fate and transport in the Lower Fox River and Green Bay system by volume and mass, respectively.

2.4.1 Lower Fox River Sediment Deposition

Sediment deposition and resuspension processes are primarily a function of particle size and water velocity. Transport of sediments occurs as particles are suspended in the water or moved along the base of the river as bed load. The system is dynamic and areas of sediment accumulation may become erosional areas, or vice versa, based on changes in water velocity (e.g., storm events), river bathymetry (e.g., shoreline erosion), and other factors.

TSS data have been evaluated to estimate the movement of sediment through the system. Distinct deposits of accumulated sediment occur throughout the Lower Fox River in areas of low stream flow velocity. These areas are generally in the vicinity of the locks, dams, shoreline coves, and back eddies, or in areas where the river widens. However, estimates of net deposition or net erosion only reflect an average accumulation or loss over time for an entire reach and do not explain finer-scale deposition/erosion events occurring within a reach. Net deposition does not imply a purely depositional environment and vice versa.

Over 75,000 metric tons (MT) (82,700 tons) of TSS enters Little Lake Butte des Morts from Lake Winnebago annually. However, the TSS load at the Appleton gauging station is lower than this figure by approximately 8,000 MT (8,800 tons). Based on the net loss of TSS load, the slow water velocity, shallow bathymetry, and extensive sediment deposits, the Little Lake Butte des Morts Reach is subject to sediment accumulation.

The Appleton to Little Rapids Reach experiences a net loss of sediment. Between Appleton and Kaukauna, the river shows a marginal increase of approximately 2,500 MT (2,750 tons) in the TSS load. However, between Kaukauna and Little Rapids, the river experiences a net erosion as the TSS load doubles from approximately 67,000 MT (77,000 tons) to approximately 142,000 MT (154,000 tons) (Figure 2-7). The lack of soft sediment between Rapide Croche dam and Little Rapids suggest that resuspended sediments are likely transported to Little Rapids (Deposit DD) or further downstream. Based on the net increase of TSS load, the fast stream velocities (as high as 0.3 m/s), narrow river sections, and the lack of many sediment deposits, the Appleton to Little Rapids Reach is subject to a net loss of sediment.

The TSS load within the Little Rapids to De Pere Reach declines by about 61,500 MT (68,000 tons), a 43 percent decrease from upstream inputs. Deposit EE, the largest sediment deposit upstream of the De Pere dam, extends approximately 8.5 km (5.3 miles) upstream of the dam. Based on the significant net decrease of TSS load, the large number of sediment deposits, and the slow stream flow velocities (average of 0.12 m/s), the Little Rapids to De Pere Reach experiences net sediment deposition and accumulation.

In the De Pere to Green Bay Reach, TSS loads coming over the De Pere dam range between approximately 80,000 and about 100,000 MT (90,000 and 110,000 tons) annually. At the river mouth, the TSS load was only 20,000 MT (22,000 tons), indicating that the TSS load declined by approximately 75 to 80 percent. The average stream flow velocity in this reach was less than 0.08 m/s, which is the lowest value for any of the four river reaches. Results of the Green Bay Mass Balance Study show that at a typical discharge rate of 105 m^3/s (3,700 cfs), approximately 272 MT (300 tons) per day of TSS flows over the De Pere dam; however, only approximately 54 MT (60 tons) per day are discharged at the mouth. Based on the significant net decrease of TSS load, the large number of thick sediment deposits, and the slow stream flow velocities, the De Pere to Green Bay Reach experiences net sediment deposition.

For storm events with flows around 280 m^3/s (9,900 cfs), the TSS load over the De Pere dam increases to 1,800 MT (2,000 tons) per day, while storm events with flows of 430 m^3/s (15,250 cfs) have a TSS load of about 7,100 MT (7,850 tons) per day. Quadrupling the stream flow rate in the river results in an approximately 26 times greater TSS load.

2.4.2 Green Bay Sediment Deposition

Estimated annual sediment accumulation in Green Bay varies from about 20,000 MT to about 150,000 MT (22,050 to 165,350 tons). The USGS estimated the average annual sediment load from the Fox River into Green Bay is approximately 82,500 MT (90,940 tons) to 136,000 MT (150,000 tons). Recent 1998 data suggests that about 153,000 MT (168,800 tons) of sediment were discharged into the bay during 1998.

Sediment is not deposited uniformly across the bottom of the bay. Water current patterns determine the distribution of sediments, and ultimately, that of PCBs and other chemical compounds in Green Bay. The primary depositional zone in Green Bay extends along the east shore for a distance of approximately 25 km (15.5 miles) north of the Lower Fox River mouth.

Approximately 17,500 MT (19,290 tons) of sediment is transported from the inner bay to the outer bay along the east side of Chambers Island. However, about 19,000 MT (20,943 tons) of sediment is transported from the outer bay to the inner bay along the west side of the island, following dominant circulation patterns (Figure 2-7). Therefore, there is a net sediment gain in the inner bay of approximately 2,400 MT (2,645 tons). Approximately 10 to 33 percent of the inner bay tributary sediment load (the majority of which is from the Lower Fox River) is transported to the outer bay.

Sediments that have been deposited can be re-entrained and transported. A number of different studies and models have evaluated sediment resuspension, and it has been shown that most sediment transport within the bay occurs during large storms. A large volume of sediment was transported from the inner bay to the outer bay as a result of a September 1989 storm. Erosion of shore and nearshore sediments was found to be directly related to the magnitude, direction, and duration of winds within the bay, which effected currents and wave action. Within the bay, sediment deposits are located in areas where the stress ratios were less than about five to nine, in comparison with the Lower Fox River ratios of three to five. Sediments within the bay settle in a far less turbulent environment than those of the Lower Fox River; therefore, the uppermost layer of sediment was found to have consolidated in 7 to 14 days, rather than less than 3 hours. Moderate to strong winds, which are the single most important factor for bay sediment resuspension, occur on average every 7 days on the Great Lakes.

2.4.3 PCB Transport

Review of sediment transport through the river reaches and bay zones was evaluated to assess where PCB transport is occurring with all movement. The conceptual models show the PCB mass/volume contained with each reach/zone (greater than 50 μg/kg PCB) and how much PCBs are transported from one reach/zone into the next annually (Figures 2-7 and 2-8).

Fox River

Approximately 1,540 kg (3,395 pounds) of PCBs are present within the Little Lake Butte des Morts Reach. The sediments of the lake have long acted as a continuing source of PCBs to the river/bay system. WDNR (1995) estimates are that less than 1 kg per year are annually transported from Lake Winnebago into Little Lake Butte des Morts (Figure 2-8). Approximately 40 kg (88 pounds) of PCBs are resuspended and transported from Little Lake Butte des Morts to the Appleton to Little Rapids Reach, even though Little Lake Butte des Morts is a net depositional area.

The Appleton to Little Rapids Reach exhibits increased stream flow velocities compared with the rest of the river. Only about 94 kg (207 pounds) of PCBs are located within sediments in this reach. These data show that little of the sediment or PCBs are deposited permanently within this reach.

Within the Little Rapids to De Pere Reach, the De Pere dam acts as a sediment trap. Approximately 64 kg (141 pounds) per year of PCBs enter the reach and 77 kg (169 pounds) per year are transported over the De Pere dam. Although net sediment deposition occurs in this reach (Figure 2-8), dissolution of PCBs from sediment into the water column becomes more important than does actual transport of sediment to which PCBs are sorbed.

The De Pere to Green Bay Reach experiences net sediment deposition and over 25,900 kg (57,100 pounds) of PCBs are present in this reach. On a mass and volume basis, this reach has the most significant sediment load in the river. Sediments in this reach act as the major continuing source of PCBs into Green Bay.

Green Bay and Lake Michigan

Based on river water sample results, approximately 220 to 280 kg (485 to 617 pounds) of PCBs were transported from the Lower Fox River into Green Bay annually in 1989 through 1990 and 1994 through 1995. These results suggested that roughly 1 percent of the PCB mass within the river is discharged into the bay annually. However, recent 1998 data suggest that the PCB load into Green Bay may be decreasing and only about 125 kg (275 pounds) of PCBs were discharged from the river into the bay based on the 1998 data, which is just over 0.4 percent of the river mass. The average estimates of the PCB mass entering Green Bay from the Lower Fox River annually range between 125 and 220 kg (275 and 485 pounds) per year. Based on peak flow conditions within the river, the highest estimated PCB load into Green Bay is about 550 kg (1,212 pounds) per year. Approximately 120 kg (264 pounds) of PCBs are transported from Green Bay into Lake Michigan annually (Figure 2-8). However, the results of these studies suggest that the PCB mass located between the De Pere dam (in the Lower Fox River) and Chambers Island (in Green Bay) is so large that, at these low rates of loss, a large mass of PCBs will remain in these sediments far into the future.

Other PCB Pathways

In addition to PCB input to the river and bay from contaminated sediments, other PCB sources and sinks exist. Approximately 3 to 5 kg (6 to 11 pounds) of PCBs are introduced into the river from other discharge locations where PCBs remain in effluent lines or from continued carbonless paper recycling. Due to the ubiquitous and resilient nature of PCBs, low concentrations of PCBs have been detected at discharge locations that continue to contribute PCBs to the system. Estimates of atmospheric deposition of PCBs into Green Bay range from 2 to 35 kg (4 to 77 pounds) annually. Based on a 1987 and 1988 USGS PCB mass-loading study of major tributaries into Green Bay, more than 90 percent of the PCB load into Green Bay was attributable to the Lower Fox River. The other Green Bay tributaries contributed only about 10 kg (22 pounds) annually to the bay (Figure 2-8).

In addition to accumulation of PCBs in river and bay sediments, PCBs do exit the system through volatilization (Figure 2-8). A number of studies have indicated that PCB volatilization from the water exceeds atmospheric deposition. PCB losses through volatilization to the atmosphere range between 0 and 5 kg (0 and 11 pounds) per year for the Lower Fox River, whereas volatilization losses in Green Bay range between 130 and 500 kg (286 to 1,102 pounds) annually. The surface area for Green Bay is a significant volatilization pathway (Figure 2-8).

2.5 Ecological Characteristics (Habitats and Species)

The Lower Fox River basin and Green Bay varies considerably in its potential to provide and support different kinds of wildlife habitat and this variability affects the wildlife diversity and populations. While the BLRA focuses primarily on aquatic, or aquatic-dependent species, the RI discusses the two major types of habitat; terrestrial (on land) and aquatic (within or near the water). The two main terrestrial habitats within the Lower Fox River and Green Bay area are open land and woodland. Aquatic habitats within the area are wetland, riverine, and lacustrine. Aquatic habitats are generally much more complex than terrestrial habitats. All five of these habitats are described below. Cities and villages represent an urban environment that most wildlife typically avoid, except certain passerines that nest almost anywhere (i.e., select species of wrens, swallows, sparrows, robins, blackbirds, etc.) and scavengers (i.e., racoons, squirrels, vermin, etc.).

The significant groups of wildlife found within these habitats include the following:

- Both pelagic and benthic aquatic invertebrate species form the primary prey in the food webs of the river and bay. Species of oligochaetes and chironomids (worms and midges) are typically most abundant and are found throughout the Lower Fox River and Green Bay. Amphipods, crayfish, snails, and mussels are also present in the river and bay. Zebra mussels, an exotic species, are present throughout Green Bay and in parts of the river.

- Fish of the region include salmon/trout; game fish, including walleye, yellow perch, and northern pike; and pelagic and benthic non-game fish. A discussion of the significant fish species within the study area is presented later in this section.

- Birds of the region include raptors, gulls/terns, diving birds, migratory waterfowl, passerines, shorebirds, and wading birds. A listing of the significant bird species within the study area is presented later in this section. These animals are found nesting, feeding, and living in both terrestrial and aquatic habitat environments.

- Mammals of the region include large and small game animals that generally live in open or wooded habitat, as well as fur-bearing animals that may forage or live within or near aquatic environments. The small and large game animals include rabbits, squirrels, bear, and deer. The fur-bearing animals include beaver, red fox, mink, raccoon, muskrat, and otter. Additionally, bats feed on insects in the vicinity of Lake Winnebago and along the Lower Fox River near the Fox Cities. Few of the mammals will be discussed in detail within this document. Mink are the principal species discussed in the BLRA.

- Reptiles and amphibians, including snakes, turtles, frogs, and toads are present in the region (Exponent, 1998). Typically, the frogs and turtles confine themselves to the wetland and nearshore areas while several snake species and toads are found in association with both terrestrial and aquatic habitats. Frogs and toads that dwell in wetlands or nearshore areas are fed upon by wading birds of the region.

A series of habitat and species area use maps were compiled and presented in the Remedial Investigation. Only the results of those compilations are presented below.

Within the Lower Fox River valley, the terrestrial habitats are generally located adjacent to the river from a point downstream of Kaukauna to just upstream of De Pere. In the vicinity of the Fox Cities Metropolitan Statistical Area (MSA) and Green Bay MSA, much of the river shoreline and associated wildlife habitat has been developed (Figures 2-9 through 2-12). Natural habitats have retreated from the river and exist only in less developed areas, usually as cultivated lands for agriculture, open meadows, or small localized woodlands. The aquatic habitat is wetland and riverine, and is comprised of and confined to the Lower Fox River and its tributaries.

Green Bay represents a lacustrine habitat, one of several habitats found in the area surrounding the bay. The land surrounding Green Bay is much less developed than the Lower Fox River valley. Open, agricultural land and forests/woodlands comprise between 65 and 94 percent of the land use outside of Brown County, while residential and commercial/industrial land use is less than 5 percent. Wetlands also account for up to 20 percent of county land use in these areas (Table 2-3). The communities located along the shores of Green Bay are much smaller and less populated than the cities of the Lower Fox River valley. Excluding the city of Green Bay, approximately 255,000 people inhabit the Green Bay tributary watersheds (Table 2-4). While individual residences or structures may be located along the shores of Green Bay, shoreline development is much less concentrated than in the Lower Fox River valley and extensive open land or forested tracts may be present along or in close proximity to the shore.

2.5.1 Open Lands

Open land habitat in the Lower Fox River and Green Bay area is largely agricultural and characterized as cropland, orchards, pastures, and meadows with grasses, herbaceous shrubs, and vines. The Fox Cities and Brown County land use maps (East Central Wisconsin Regional Planning Commission, 1996 and Brown County Planning Commission, 1990, respectively) indicate this is the largest habitat present within 0.8 km (0.5 mile) of the Lower Fox River.

Along the east side of Green Bay, from the Lower Fox River mouth to Little Sturgeon Bay, open land is the predominant habitat (Exponent, 1998). Use of the land for agricultural purposes along the east shore of Green Bay is responsible for the presence of this habitat in this area. Review of Door County SCS soil survey maps (1978) and land use information (see RI Section 3.1.2) indicates that open land habitat is prevalent north of Little Sturgeon Bay and throughout the Door Peninsula. Approximately 50 percent of the land in Door County is classified as agricultural, in part due the large number of orchards and other agricultural land located inland from the bay.

Dominant wildlife in open land areas are waterfowl (at rest or feeding), Hungarian partridge, pheasant, songbirds (meadowlark, field sparrows, horned lark, etc.), white-tailed deer, rabbits, red fox, coyote, and various livestock, including Holstein and brown Swiss cattle.

2.5.2 Woodlands

Woodland habitat is characterized as hardwood and conifer forest land and wood lots with an associated understory of grasses, legumes, and wild herbaceous plants. Woodland habitat originally covered a vast majority of the land in eastern Wisconsin and Michigan's upper peninsula. Due to development and growth of urban areas and agricultural activities in the Lower Fox River valley, few significant tracts (16.2 hectares [40 acres] or more) of woodland habitat are present within 1.6 km (1 mile) of either bank of the river. Those areas that are present are usually thin, elongated areas which border roads or farm fields.

Typical vegetative cover includes oak, maple, poplar, cherry, apple, hawthorn, dogwood, hickory, blackberry, hazelnut, viburnum, and blueberry. Conifers include pine, spruce, cedar, juniper, fir, and tamarack. Birds and wildlife eat the nuts, fruits, buds, catkins, twigs, bark, and foliage that the vegetation provides, as well as using the vegetation for nesting sites and when seeking protective cover from predators. Woodlands are inhabited by upland game birds and passerines, small and large game, as well as other non-game animals that include the invertebrates, insects, reptiles, and amphibians typical of the upper Midwest. Dominant species in these areas include whitetail deer, squirrel, raccoon, ruffed grouse, songbirds, thrushes, and woodpeckers. Many of the species that utilize the open land habitats will seek food and protection within woodlands when necessary.

Within the state of Michigan, significant tracts of woodlands and forests are designated as state or federal lands. Parcels of the Escanaba River State Forest stretch from just north of the city of Menominee to just outside the city of Escanaba, a distance of approximately 45 km (28 miles). Some of this land is located on the shores of the bay, but most of it is inland about 1.2 to 2.4 km (0.75 to 1.5 miles). Smaller tracts of the Escanaba River State Forest are located along the shores of Little Bay de Noc north of Gladstone and throughout Delta

County. Altogether, the Escanaba River State Forest comprises 168,350 hectares (416,000 acres) of land. The Hiawatha National Forest comprises 348,000 hectares (860,000 acres) and is located in the central portion of the UP, running from the north end of Big Bay de Noc to the shores of Lake Superior. Large tracts of land within the Stonington Peninsula are designated as part of the Hiawatha National Forest. Finally, the Lake Superior State Forest comprises over 404,700 hectares (1 million acres) of forested land in the central and eastern UP. The northern portion and eastern side of the Garden Peninsula, as well as much of Summer Island are designated as Lake Superior State Forest land. In addition to these state and federal forests, the J. W. Wells State Park and Beach is located along the west shore of Green Bay between Menominee and Escanaba. Fayette State Park is located on the west side of the Garden Peninsula, just off of Sand Bay on the east shore of Big Bay de Noc.

There is no state or federally designated forest land located along the shores of Green Bay in Wisconsin. However, three forested Wisconsin state parks are located on the Door Peninsula. The largest of these is Peninsula State Park, which is comprised of about 1,520 hectares (3,760 acres) of forest and includes about 32 km (20 miles) of shoreline along the east side of Green Bay. Potawatomi State Park is located on the south side of Sturgeon Bay and comprises about 456 hectares (1,127 acres). Finally, Rock Island is a designated state park and comprises approximately 510 hectares (1,260 acres).

2.5.3 Wetlands

Areas identified and mapped as wetlands by the WDNR along the Lower Fox River are shown on Figures 2-9 through 2-12. Wetland areas along Green Bay, which were identified and mapped by WDNR, USFWS (1981), and Bay Lake Regional Planning Commission (BLRPC), are shown on Figures 2-13 and 2-14.

Wetland habitat is probably the most critical habitat within the Lower Fox River and Green Bay area, providing an important habitat for all wildlife groups. Wetlands provide nesting and feeding areas for many migratory birds, including waterfowl, shorebirds, wading birds, and passerines. Many of these birds feed in or over wetlands. Dominant species include geese and mallards, blue-winged teal, wood ducks, scaup, goldeneye, common and hooded mergansers, bald eagles, osprey, and great blue and black-crowned night herons. Some species of fish seek out wetlands for spawning or foraging purposes, including northern pike, bass, sunfish, yellow perch, carp, alewife, rainbow smelt, and shiners (Brazner and Beals, 1997). Small game and fur-bearing mammals that inhabit wetlands include muskrat, mink, otter, and bats, which utilize wetlands habitat for nesting, feeding, and protective cover (Exponent, 1998). Numerous insects, amphibians, snakes, turtles, and invertebrates live within wetlands.

Both the USFWS (1979) and the Michigan Natural Features Inventory (MNFI) (Minc and Albert, 1998) have developed wetland classifications. The classifications used by Exponent (1998) in the Lower Fox River and the southern portion of Green Bay are, more or less, those of the USFWS (1979), while many of the descriptions for Green Bay are those of the MNFI. Therefore, an effort has been made to identify the wetlands in Green Bay using both classification systems in order to facilitate an understanding of the habitat.

According to the MNFI, there are six types of coastal wetlands found within the Great Lakes, including Green Bay, based on floristic variability (Minc and Albert, 1998). The descriptions are generally similar to those above and, moving from deeper water to the shore, these wetland types include the following:

- **Submergent Marsh:** contains submerged aquatic vegetation (SAV) and/or floating vegetation.

- **Emergent Marsh:** characterized by shallow water or saturated soils with rushes, cattails, and other emergent species.

- **Shoreline or Strand Zone:** located at or just above the waterline and are typically thin zones, usually dominated by herbs.

- **Wet Meadow (herbaceous):** characterized by saturated or periodically flooded soils dominated by sedges, grasses, and other herbs.

- **Shrub Swamp and Swamp Forest:** characterized by periods of standing water and are dominated by woody species adapted to a variety of flooding regimes, including dogwood, cottonwood, tamarack, and spruce.

These are general wetland types and not all types are found within each wetland or wetland complex (Minc and Albert, 1998). These can also be lacustrine (associated with lakes), riverine (associated with rivers and streams), and palustrine (isolated or connected wet areas such as marshes, swamps, and bogs). The wetlands located within Green Bay are primarily lacustrine followed by palustrine and then riverine. The wetland descriptions used by Exponent (1998) are presented below, as well as information pertaining to the typical flora of each wetland type.

Wetlands are characterized by seasonally-flooded basins and swales, as well as open, marshy, swampy, or shallow water areas with water-tolerant vegetation.

Lower Fox River and Green Bay wetland types observed by Exponent (1998) included the following:

- **Emergent/Wet Meadow Wetlands.** These wetlands/wetland complexes are typically present along the west shore and tributary mouths of Green Bay, as well as in the backwater covers of Little Lake Butte des Morts and the Lower Fox River (Exponent, 1998). These wetland areas are a combination of the emergent, shoreline, and wet meadow types defined by MFNI (above). Typical emergent vegetation in these wetlands include cattails, bulrush, arrowhead, assorted rushes, sedges, and reeds (Exponent, 1998). Smartweed, wild millet, wild rice, saltgrass, purple loosestrife, cordgrass, reed canary grass, phragmites, and sagittaria are also common within these wetland complexes. The submergent and floating aquatic vegetation within these marshes primarily consists of water-milfoil, coontail, wild celery, pondweeds, and water lilies (Exponent, 1998).

- **Scrub/Shrub Wetlands.** These wetlands are often found in conjunction with emergent/wet meadow wetland complexes in the Lower Fox River and the southern portion of Green Bay (Exponent, 1998). Shrub willows, small cottonwoods, dogwoods, and small ash, as well as elderberry and buttonbush are typical vegetation. These wetlands are located primarily along the west shore of Green Bay, in association with the emergent/wet meadow wetlands located near tributary deltas, shallows, reefs, and spits. Small and large game utilize the wetlands, as do waterfowl, passerines, and select heron species (Exponent, 1998).

- **Forested Wetlands.** These wetlands occur along the banks of the Lower Fox River and the shorelines of Green Bay throughout the habitat characterization zones (Exponent, 1998). These wetlands are forested with numerous deciduous species, including elm, cottonwood, willow, ash, maple, box elder, dogwood, and sumac (Exponent, 1998). Red and white oaks and large cottonwood typically dominate the canopy of more mature forested areas while white oak, maple, and ash usually dominate the canopy of upland wetland complexes (Exponent, 1998).

Exponent (1998) determined that emergent/wet meadow wetland complexes accounted for 43 percent of all wetlands observed in the assessment area. Shrub/scrub wetlands comprised approximately 27 percent of the wetlands and were located mainly along the west shore of Green Bay, while forested wetlands accounted for 25 percent of the area and were predominantly located in the northern portion of the assessment area (Exponent, 1998). Open water within designated wetland areas accounted for 2 percent of the total area and aquatic beds, excavated ponds, and wetlands smaller than 0.8 hectare (2 acres) in size comprised the remaining 3 percent of the area assessed (Exponent, 1998).

Within the Lower Fox River valley, Exponent (1998) identified only 135 hectares (334 acres) of wetlands within 0.4 km (0.25 mile) of the shore. Of these identified wetlands, 119 hectares (294 acres) or 88 percent were located between Little Lake Butte des Morts and the De Pere dam, in the upper three reaches of the river (Figures 2-9 through 2-11). The wetlands in this part of the river were predominately forested wetland (68.9 hectares or 170 acres) and emergent/wet meadow wetlands (32 hectares or 81 acres). The largest wetland areas are associated with the Stroebe Island Marsh and backwater areas in Little Lake Butte des Morts, the 1,000 Islands wetlands (adjacent to Kaukauna/mouth of Kankapot Creek), and the Little Rapids dam, and account for approximately 87 percent of the wetlands upstream of the De Pere dam (Exponent, 1999). Exponent (1998) only identified 16 hectares (40 acres) of wetlands in the De Pere to Green Bay Reach (Green Bay Zone 1), and these were predominantly emergent/wet meadow and forested wetlands (Figure 2-12). Approximately 60 percent of these wetlands (9.5 hectares/23.4 acres) are associated with marsh at the mouth of the Lower Fox River (Exponent, 1998).

In addition to the wetland analysis, Exponent (1998) documented the presence and areal extent of SAV within each portion of the Lower Fox River, even though it appears that these areas were not classified as wetlands. Approximately 350 hectares (865 acres) of SAV are present in the Lower Fox River, with only about 8 hectares (20 acres) located downstream of the De Pere dam. Approximately 260 hectares (642 acres) of SAV is present within Little Lake Butte des Morts and is likely associated with the Stroebe Island marsh and the other backwater wetlands of Little Lake Butte des Morts. Another 62 hectares (153 acres) of SAV are present in the same part of the river as the 1,000 Islands wetlands; therefore, it is assumed that the SAV is again associated with these wetlands. Only 26 hectares (64 acres) of SAV are present in the Lower Fox River downstream of the Rapide Croche dam (Exponent, 1998). This is likely due to the fact that the river is narrower with faster stream flow velocities; conditions that are not favorable for the establishment of SAV.

In 1981, the USFWS completed a study of the fish and wildlife resources of the Great Lakes coastal wetlands. This study found that there are at least 17,098 hectares (42,250 acres) of wetlands located along the shores of Green Bay (Table 2-3). The wetland/wetland complexes included in Table 2-3 are those over 40.5 hectares (100 acres) in size. According to Dr. Dennis Albert (MNFI), the

40.5-hectare (100-acre) criterion is typically used by MNFI when conducting wetland studies (Albert, 2000). Dr. Albert indicated that although there are a number of fully functioning wetlands under 20.2 hectares (50 acres) along the shores of Green Bay, physical constraints generally keep these wetland areas from expanding. Therefore, controlling losses in the larger wetlands or wetland complexes is the important factor in maintaining the overall wetland area in a given region (Albert, 2000).

Approximately 42 percent of the significant wetland areas are located in Wisconsin while about 58 percent of the wetlands are located in Michigan. As discussed previously, bathymetry and the physical environment of the bay have a significant influence on the size and location of coastal wetlands. Based on these factors, the distribution of wetlands along the east shore of Green Bay is very limited compared to the west shore of the bay and in both Big and Little Bays de Noc (Table 2-3; Figures 2-13 and 2-14).

Slightly more than 569 hectares (1,400 acres) of wetlands are located along the east shore of Green Bay. This represents only 3.3 percent of all the wetland areas larger than 40.5 hectares (100 acres) in the area (Table 2-3). Wetlands along the east side of Green Bay are generally classified as palustrine (marsh or swamp) (USFWS, 1981). Palustrine wetlands generally lack flowing water and have water depths less than 1.8 meters (6 feet) deep. Exponent (1998) described the largest east shore wetlands (from the Lower Fox River to Little Sturgeon Bay) as emergent/wet meadow wetlands. Based on the information provided by Exponent (1998) and the USFWS (1981) descriptions, many of the wetlands along the east shore of Green Bay are emergent/wetland meadow complexes.

The west shore of Green Bay has about 8,000 hectares (19,770 acres) of wetlands (Table 2-3), approximately 47 percent of the Green Bay wetlands greater than 40.5 hectares (100 acres). This includes all shoreline from the mouth of the Lower Fox River to the city of Escanaba, Michigan. From the mouth of the Lower Fox River to the city of Oconto, Exponent (1998) classified slightly more than 50 percent of the wetlands as emergent/wet meadow, while approximately 31 percent were shrub/scrub wetlands. The information provided by USFWS (1981) and Minc and Albert (1998) suggest that wetlands further north of the city of Oconto are similar, as palustrine wetlands are usually found with the lacustrine areas (Table 2-3). Almost all of the west shore wetlands were primarily classified as lacustrine systems by the USFWS (1981). These wetlands are affected by littoral currents, storm-driven wave action, wind action, and ice scour, which are the primary causes of shoreline sediment deposition and erosion (Minc and Albert, 1998). These lacustrine systems have developed in the shallows of the bay and many of them in Wisconsin water are associated with the Green Bay tributary spits or deltas. Only wetlands associated with river deltas are classified as riverine systems (Table 2-3). These include select portions of the Atkinson Marsh (Duck Creek), Oconto Marsh (Oconto River), Peshtigo River Wetland, Cedar River Wetland complex, and Ford River Wetland complex. Other riverine wetlands are associated with the other tributaries; however, these wetlands are usually very small and are not included in Table 2-3.

Wetlands found in both Bays de Noc are predominantly lacustrine systems and are generally similar to the west shore wetlands. Approximately 8,527 hectares (21,070 acres) of wetlands are located in these two bays. This is slightly under 50 percent of the wetlands within Green Bay (Table 2-3). These wetlands have extensive emergent vegetation development (Minc and Albert, 1998). Also, the wet meadow complexes, shrub swamp, and swamp forest wetlands in the UP are typically larger and more areally extensive than further south in Green Bay, primarily due to less development in this region of the bay.

The state of Wisconsin has a number of designated wetlands/wildlife areas located in the Green Bay area (Table 2-4). The largest of these is the Green Bay West Shores Wildlife Area (W.A.), which is comprised of 11 units. The 11 units, along with the area, are listed below, starting near the mouth of the Lower Fox River and moving north along the west shore. The status of an area as either a designated state W.A. or National Wildlife Refuge (N.W.R.) is also indicated.

Currently, 3,015.8 hectares (7,452.1 acres) of land are designated as part of the Green Bay West Shores W.A. However, the WDNR desires to expand this area to a total of 5,639 hectares (13,933 acres) in the future (WDNR, 2000a).

The Gardner Swamp State W.A. lies along the east side of the bay in Door County, located approximately 2.4 km (1.5 miles) south of Little Sturgeon Bay, and covers 478 hectares (1,181 acres) (WDNR, 2000a). In addition, the WDNR is currently planning to establish the Red Banks Glades W.A. in Brown County. This planned W.A. would be approximately 204 hectares (503 acres) and would be located just inland from the bay, like the Gardener Swamp W.A. (WDNR, 2000a).

The city of Green Bay owns and operates the Bay Beach Wildlife Sanctuary, which is located approximately 1.9 km (1.2 miles) east of the Lower Fox River and just south of Green Bay's historic Bay Beach. The sanctuary is approximately 283 hectares (700 acres), of which 24.3 hectares (60 acres) are standing water and lagoon. Wet meadow, emergent, and shrub/scrub wetland areas are all present within the area (Baumann, 2000).

2.5.4 Riverine Habitat of the Lower Fox River

Riverine aquatic systems refer to the rivers and tributaries of the Great Lakes whose water quality, flow rate, and sediment loads are controlled in large part by their drainage basins. Tributary rivers typically have a low flow volume, although the flow volume may vary significantly due to seasonal influences. Tributaries such as the Lower Fox River are also influenced by the amount of the development immediately adjacent to the riverbanks or within the drainage basin. A summary of Green Bay tributaries is shown on Table 2-5.

The Habitat Characterization Assessment (Exponent, 1998) divided the Lower Fox River into two parts, upstream and downstream of the De Pere dam. The upstream portion is comprised of the Little Lake Butte des Morts, Appleton to Little Rapids, and Little Rapids to De Pere reaches, while the downstream portion is comprised of the De Pere to Green Bay Reach. Eight different aquatic habitats were identified within the Lower Fox River (Exponent, 1998). These habitat types, along with the percentage of each type within the river, are listed in Table 2-6 and shown for each reach on Figures 2-9 through 2-12.

The largest category described by Exponent (1998) was the island/peninsula habitat (Table 2-6). Most of the areas where island/peninsula habitat was observed are small, unnamed outcroppings and areas within the Lower Fox River which were formed during lock and dam construction and channelization of the river in the 1800s. A few notable areas for this type of habitat are Stroebe and James Islands in Little Lake Butte des Morts (Figure 2-9), the 1,000 Islands Nature Conservancy near Kaukauna (Figure 2-10), and the unnamed islands associated with the Cedar, Combined, Rapide Croche, and Little Kaukauna locks (Exponent, 1998).

Backwater, cuts, and coves are the second largest habitat category observed within the Lower Fox River (Table 2-6). These areas are relatively undisturbed by human activities and thus are very desirable for wildlife and fish (Exponent, 1998). Additionally, these habitat areas are generally small and scattered throughout the river, making them an important habitat for maintenance of current fish and wildlife populations that use them. These areas are shown on Figures 2-9 through 2-12.

Other habitat types that are important are the dam riffles, submerged rock, piling or ruin environments, and sandbars or silt deposited areas (Nikolai, 1998). Although these two habitats constitute just over 12 percent of the Lower Fox River, game fish are often associated with these areas. Also, fish like walleye prefer rocky substrates with fast-running water for spawning purposes. Based on the fact that the walleye are an important game fish of the Lower Fox River, this habitat is significant.

Besides reviewing the aquatic habitat, Exponent (1998) evaluated the riverbanks and substrate characteristics. The river shoreline was divided into both developed and natural riverbank, with subcategories of each. About 44.6 percent of the river shoreline is protected with either riprap or bulkheads while the remaining 55.4 percent of the river is natural bank (Table 2-7). The shoreline delineation, as classified by Exponent (1998) is shown on Figures 2-9 through 2-12. Slightly more than 22.4 km (13.9 miles) of the 28 km (17.4 miles) of developed shoreline is protected with riprap (Table 2-7). This is about 36 percent of the total shoreline. Exponent (1998) indicated that riprap protection is preferred to bulkheads because the riprap tends to offer some habitat possibilities to fish and wildlife within the river, as some fish will find protection and feeding opportunities and some birds will nest in the crevices and gaps of riprap. Bulkheads offer little in the way of habitat due to the smooth surfaces and vertical walls.

The Lower Fox River has about 34.8 km (21.6 miles) of natural shoreline (Table 2-7). The largest category of natural shoreline was riparian canopy, which includes tree-lined and forested banks of the river. Almost 44 percent of the entire river shoreline was described as riparian canopy (Table 2-7), with about 15.9 km (9.9 miles) of this shoreline situated between the Cedars and Little Kaukauna locks (Figure 2-10). This is one of the least developed portions of the Lower Fox River, with steep banks that inhibit significant agricultural or urban development. Shorelines with either groundcover or wetland comprised almost 6.8 km (4.2 miles) while sand/gravel beaches comprised less than 1 percent of the shore (Table 2-7).

2.5.5 Lacustrine Habitat of Green Bay

The lacustrine habitat of Green Bay is very different than the riverine habitats of the Lower Fox River. Lacustrine systems, like Green Bay, have deeper water, allowing temperature stratifications (thermoclines) to develop (Belonger, 2000). A thermocline is a thin layer of water that has a significant temperature gradient, separating warmer water above from colder water below. The presence of a thermocline provides large water bodies the ability to host many different species of fish and other aquatic organisms that may prefer a warmer or colder temperature environment. Numerous fish species can be found within different areas and at various depths of lacustrine habitat based on the water depth, currents, and temperature. Additionally, water temperature is a significant biological factor and indicator for many aquatic organisms.

Other unique aspects of lacustrine environments are related to water currents, sediment deposition and erosion, and the wetland complexes that develop therein. Unlike rivers, which basically have a unidirectional current (gravitational), lacustrine currents are more complex, variable, and weaker (Maitland and Morgan, 1997). Also, sediment erosion within Green Bay is largely confined to shore and nearshore areas, where wind, wave action, and ice scour are the primary causes for erosion and redeposition. Bottom sediments transported from the Lower Fox River and other tributaries into Green Bay are typically deposited nearby the source mouth. This is evidenced by the thick sediment deposits and shallow water depths at the southern end of the bay (Lower Fox River/Duck Creek mouths) and the spits, shoals, and shallows located near the mouths of the other significant tributaries along the west side of the bay. Lacustrine environments typically develop larger wetlands than riverine systems, especially in areas of extensive shallow water and low current velocities, as described above.

Lacustrine environments are generally categorized based on the biological conditions of the system and the three classifications are eutrophic, oligotrophic, and dystrophic. Lower Green Bay is eutrophic and the northern end is generally oligotrophic. Eutrophic lakes are nutrient rich, usually shallow, turbid waters that may experience oxygen deficiencies under the ice or in deeper areas at certain times of the year (Maitland and Morgan, 1997). Oligotrophic lakes are typically deep, clear waters that are nutrient poor and rarely, if ever, have oxygen deficiencies (Maitland and Morgan, 1997). In addition, Green Bay is also mesotrophic in areas; the mesotrophic classification is an intermediate between eutrophic and oligotrophic conditions.

Inner Bay Water Quality

The southern end of Green Bay is a lacustrine estuary, which is a zone of transition from a riverine to lacustrine environment. An estuary is typically defined as a submerged river mouth, which may extend for some distance into a large body of water. Water depths in Zone 2 are generally less than 1.8 meters (6 feet). This area ranges from eutrophic to hypereutrophic (Sager and Richman, 1991) and it has a long history of being a eutrophic water body.

The silty substrates, shallow water depths, extensive wetlands, and green color were all observed by the earliest explorers of the region. The process of eutrophication is natural and generally occurs over an extended period of time, as fresh waters naturally tend to silt up. The availability of potential nutrients within bottom sediments is typically only released when the water becomes shallow enough that macrophytes utilize them (Maitland and Morgan, 1997). This was the general state of the inner bay (particularly the southern end) when European settlers arrived in the region. The hypereutrophic conditions of the lower bay were likely brought on by development, which greatly accelerated eutrophication. The Lower Fox River served as the primary disposal system for domestic and industrial wastes, which contributed significant quantities of nutrients (particularly phosphorous and nitrogen), to the bay through much of the twentieth century. Also, intense farming with heavy application of fertilizers, especially in the lowland areas of the rivers and lakes, leads to enrichment of runoff waters with nutrients (Maitland and Morgan, 1997), and this has occurred in the Lower Fox River and Green Bay area (Harris, 1993).

The fish die-offs on the east side of the bay in 1938 through 1939 (Wisconsin State Committee on Water Pollution) indicated the impacts of poor water quality and the lack of dissolved oxygen (D.O.) on the inner bay. Water quality and benthic community studies throughout the mid-1900s showed low D.O. and degraded water quality. The results of the benthic community studies will be discussed below. Since waste treatment practices reduced the loads of organic wastes in the 1970s, D.O. concentrations have generally remained above the standard of 5 mg/L (Harris, 1993). However, D.O. concentrations have dropped below 5 mg/L during summer months when algal blooms occur (Harris, 1993). Recurring algal blooms are one sign that the eutrophic conditions of the southern bay continue today.

The shoal extending from Point Au Sable to Long Tail Point reduces the mixing ability within this part of the bay; water south of the shoal is hypereutrophic while water north of this area is classified as eutrophic (McAllister, 1991). There is also a trophic gradient within the inner bay that results from the currents described previously (Section 3.4). Satellite images from 1984 indicated that eutrophic water conditions extended along the east shore of the bay from the mouth of the Lower Fox River to Sturgeon Bay (Sager, 1986). Water along the east shore of the bay was more eutrophic than was the water flowing along the west side of the bay (McAllister, 1991). However, following the reduction of phosphorous and other chemical loadings during the 1980s, the water clarity north of the Long Tail Point improved, allowing reestablishment of wild celery in some west shore wetland areas (Harris, 1990; McAllister, 1991).

Outer Bay Water Quality

The northern half of Green Bay (the outer bay) is generally oligotrophic to mesotrophic (Sager and Richman, 1991). Much of the outer bay, especially in the deep-water areas of the eastern half, is oligotrophic, while conditions become mesotrophic moving south towards and past Chambers Island. Eutrophic conditions may be present in the shallow areas of Big Bay de Noc during the summer, as waters within both Bays de Noc are well mixed (Schneeberger, 2000). Conditions along the northwest shore of Green Bay, from Menominee, Michigan, to the north end of Little Bay de Noc, are suitable areas for mesotrophic conditions. The wetland areas, shallow waters, and bay tributaries located on the western shore likely foster eutrophic conditions, while the cold, oligotrophic waters of Lake Michigan flow along the shoreline. Therefore, depending on the time of year and the local weather conditions, the north and northwest sides of the bay may experience all three water conditions.

2.5.6 Benthic Communities

In the Lower Fox River and Green Bay environment, the benthic macroinvertebrates are primarily bottom-dwelling invertebrates that include adult and larval insects, mollusks, crustaceans, and worms. Given the predominance of fine-grained silt/clay sediments in the river, the predominant species are sediment dwelling and burrow directly into the substrate for most of their life cycle. The benthic macroinvertebrate community plays a vital role in ecosystem functions such as nutrient cycling and organic matter processing, and is an important food resource for the benthic and pelagic fish communities, as well as semi-aquatic organisms such as birds and mammals.

Historical macroinvertebrate surveys completed between 1938 and 1978 examined populations and taxa richness near the mouth of the Lower Fox River and in southern Green Bay. The 1938 through 1939 pollution survey found that oligochaetes and chironomids dominated the benthic communities within this area, although very small numbers of leeches, sowbugs, scuds, clams, and snails were observed at various locations. The oligochaetes and chironomids are thought to be tolerant of organic enrichment and/or degraded habitats like that of the Lower Fox River and southern Green Bay, whereas other species are less tolerant of enriched/degraded habitats. In addition, oligochaetes and chironomids were completely absent in a few locations in the southern bay, suggesting that water quality in this portion of the bay did not support such pollution-tolerant species (Surber and Cooley, 1952). However, the burrowing mayfly (*Hexagenia*) was detected at 16 of 51 stations sampled in 1938 through 1939 (Markert, 1978). *Hexagenia* are considered to be pollution-sensitive or intolerant taxa and their presence was indication that water quality conditions had not reached their worst.

Water quality, as measured by the benthic community populations, deteriorated significantly between 1938 through 1939 and 1952. Comparison of the 1938 through 1939 and 1952 sampling data indicated that both the oligochaete and chironomid populations had increased. Additionally, established populations of both groups were observed at locations as far north as Oconto and Little Surgeon Bay, indicating that the water quality in the southern bay was progressively worsening (Surber and Cooley, 1952). Similar results were noted in 1978 (Markert, 1978). In 1978, the density of oligochaetes and midges was greater than in 1938 through 1939, while the burrowing mayfly (*Hexagenia*) was not observed at all. These results indicated that further degradation of water quality had continued since 1938 through 1939. However, comparison of the 1952 and 1978 sample results indicated that there was some improvement in water quality since the 1950s (Markert, 1978).

A number of studies completed in the late 1980s and 1990s evaluated the macroinvertebrate taxa richness and diversity in the Lower Fox River and Green Bay (Call *et al.*, 1991; Integrated Paper Services [IPS], 1993a, 1993b, 1994, 1995; WDNR, 1996b). Similar to the historic surveys, these studies generally found that the benthic infauna of the Lower Fox River and Green Bay were dominated principally by oligochaetes and chironomids with roundworms, flatworms, scuds, caddisflies, leeches, and sowbugs completing the inventory (IPS, 1993a, 1993b). These studies showed that the benthic macroinvertebrate communities from upstream reference sites and locations in Green Bay far from the mouth of the river were higher in taxa richness than the Lower Fox River sites. Similar to the historical results, mayflies were not found in the Lower Fox River or lower Green Bay, but were found in both the reference sites (WDNR, 1996a [*Caenis* sp.]; Call *et al.*, 1991 [*Hexagenia*]). However, it remains inconclusive if these lower infaunal and species counts were a result of organic enrichment, chemical contamination, poor physical conditions, or other factors.

The 1992 and 1993 results reflect recovery from the severely impaired conditions found in the 1960s and 1970s (IPS, 1994). These results were bolstered in 1994 by the presence of snails, clams, and mussels at the Little Lake Butte des Morts sites in deposits D and POG (IPS, 1995). The results of these early 1990s studies indicated that the density of the benthic community populations had increased significantly compared with studies completed during the 1980s in Little Lake Butte des Morts (IPS, 1995). Downstream of Little Lake Butte des Morts, in deposits N and EE/FF, the 1992 through 1994 benthic community results indicated that benthic community populations increased; however, oligochaetes and chironomids were still dominant and there was no corresponding increase in community diversity to accompany the population increase. Similarly, conditions in the middle and outer portions of Green Bay seemingly reflected an improvement in general water quality due to an increase in scuds and sowbugs, which were typically observed in more northern reaches of the bay (IPS, 1995). However, the presence of zebra mussels probably signals future difficulty for the benthic communities of the Lower Fox River and Green Bay due to the ability of this exotic species to out-compete the local benthic species for food and habitat (IPS, 1995).

2.5.7 Fish

Through the mid-1970s the population levels of fish species, such as walleye and perch, were low within the Lower Fox River and southern Green Bay ecosystems. Contaminants, along with low D.O. conditions brought about by uncontrolled and untreated wastewater dumped into the river, were believed to be a contributing factor causing low population levels. Principal species found within the system were those that could tolerate these conditions, especially bullhead and carp.

With the institution of water quality controls in the mid-1970s, contaminants and D.O. conditions improved. The WDNR undertook a program to reintroduce walleye into the river and bay through a stocking program beginning in 1973. That program was wholly successful; self-sustaining populations of walleye now exist within the river and bay. Recent electrofishing catch data for walleye from De Pere dam to the mouth of the Lower Fox River are shown on Figure 2-15.

In addition to walleye, a number of other species became reestablished in the Lower Fox River and Green Bay, including white and yellow perch, alewife, shad, bass, and other species. Historical anecdotal data from the Oneida tribe and more recent creel survey data from the WDNR indicate that Duck Creek and Suamico tributaries to southern Green Bay were used by numerous fish species (Nelson, 1998).

The WDNR has completed extensive fish surveys in the Lower Fox River and inner Green Bay. However, due to the numerous factors which may effect fish populations, simply reviewing and comparing the population survey results from various years is not valid. Year-to-year fish populations do not necessarily indicate whether conditions within the river/bay are degraded or improving because other environmental, physical, or biological factors may be impacting select fish species at any given time. Select fish surveys for the Lower Fox River have been reviewed to provide data on the types of fish present within the system at given points in time. However, no in-depth analysis of whether these population surveys indicate declining or improving conditions is included. No Green Bay fish surveys are included in this discussion. Rather, the personal observations from WDNR and MDNR personnel familiar with both the commercial and sport fisheries of Green Bay are used.

Due to the fact that environmental degradation of the Lower Fox River and Green Bay either directly or indirectly impacts the resources of the Oneida and Menominee Nation Trust Lands, issues of concern to both tribes are addressed herein. The fisheries of the Lower Fox River and Green Bay are important to the Oneida and Menominee Indian Nations for cultural and historical purposes. The fish supply was historically a major source of protein for many tribal members, as the fish could be dried, canned, salted, or smoked for use throughout the year (Stratus Consulting, 1999b). Fish have historically been a staple part of the diet of the Oneida. When the Oneida came to Wisconsin from New York, a primary reason they chose the land around Duck Creek was because of the abundant waterfowl and fish associated with the creek. Therefore, the fish of Duck Creek became an important resource for the tribe. Duck Creek lies within the Oneida Reservation and PCBs have been found within fish caught in Duck Creek. Therefore, the results of the 1998 Duck Creek fish assessment, completed cooperatively by the USFWS, WDNR, and Oneida Nation, has been summarized and included herein.

Similarly, the Menominee Nation historically celebrated the return of the lake sturgeon ("*Namä'o*" in Menominee) at Keshena Falls on the Wolf River, a tributary of the Lower Fox River (Beck, 1995). The Menominee Indians have lived in Wisconsin longer than any other tribe, and the annual return of the lake sturgeon (*Namä'o*) was a cause for religious celebration and for sustenance after winter, when the availability of food was typically at its lowest (Beck, 1995). Due to the cultural and religious importance of the lake sturgeon to the Menominee, a description of the habitat, spawning, and life cycle of the lake sturgeon is also included.

Lower Fox River/Duck Creek Fish Surveys

In association with water quality studies, the WDNR has conducted multiple fish population surveys of the Lower Fox River, as well as Duck Creek. The surveys were completed during several time periods with a variety of survey gear and for several purposes and are listed in Table 2-8.

The fish catch results from these studies are summarized in Tables 2-9 and 2-10. Table 2-9 summarizes the fish survey results for the Lower Fox River upstream of the De Pere dam while Table 2-10 summarizes fish surveys in the De Pere to Green Bay Reach. The fish observed in Duck Creek during 1995 and 1996 are indicated on Table 2-10 because both these rivers/river reaches are connected directly with Green Bay.

At least 43 different fish species were identified in the Lower Fox River upstream of the De Pere dam (Table 2-9). Twenty-four (24) were game fish and 19 species were non-game fish (as defined by state statute). The 1983 Little Lake Butte des Morts fish survey indicates that approximately 60 percent of the species captured were game fish, and that black bullhead and black crappie were the predominant fish (Table 2-9). More recent surveys in 1998 for Little Lake Butte des Morts showed a more diverse assemblage of species than observed in 1983 (Exponent, 1999). Species captured in 1998 that were absent in the 1983 surveys included bass (both smallmouth and largemouth), longnose gar, shiner (rosyface and golden), and pumpkinseed.

Population results for Little Lake Butte des Morts to the De Pere dam indicate that game fish typically comprise about 30 to 40 percent of the fish captured (Table 2-9). Yellow perch, walleye, white bass, and bullheads have all been the dominant game fish species at one point or another. Carp was the most prevalent fish observed in the Lower Fox River upstream of the De Pere dam. Carp typically accounted for 50 to 90 percent of non-game fish and approximately 50 to 60 percent of the all fish captured in the surveys.

Annual fyke net studies of fish populations have been completed for the De Pere to Green Bay Reach since 1987 (Table 2-10). Due to differences in the lengths of the studies conducted, only the data from April of each year has been summarized on Table 2-10. Game fish account for 70 to 90 percent of the total captured fish population. The dominant game fish typically include yellow perch, one of the primary commercial species in the bay, as well as walleye, white bass, and white perch. Furthermore, walleye is the only other game fish that generally comprises more than 10 percent of the total fish population (Table 2-10). Non-game fish below the De Pere dam are predominantly carp, white sucker, drum, and quillback.

As indicated on Table 2-10, 21 fish species (7 non-game and 14 game fish) that have been observed in the De Pere to Green Bay Reach were also observed in Duck Creek (Cogswell and Bougie, 1998). In addition to the species identified in Table 2-10, 34 other fish species were also observed in Duck Creek. However, many of these were small non-game fish like shiners, chubs, and darters. Cogswell and Bougie (1998) found that the fish-supporting capacity of Duck Creek is limited by several factors, including low water flow, low D.O., high water temperatures, and degraded water quality. Duck Creek is an intermittent stream and has been significantly impacted by the agricultural activities of the watershed. Sediment erosion from tilled fields has been found to account for over 75 percent of the total phosphorous load in the creek (WDNR, 1997). The assessment results indicated that the walleye and northern pike of Green Bay frequented several tributaries during their life. Walleye and northern pike originally tagged within the Lower Fox River were found in Duck Creek, and 46 percent of the northern pike tagged in Duck Creek were recaptured at several locations in Green Bay (Cogswell and Bougie, 1998). Also, the age and size range of the walleye captured in Duck Creek was similar to those in the Lower Fox River during spring (Cogswell and Bougie, 1998). These results indicate that there is fish migration between Green Bay and its tributaries. Similarly, Terry Lychwick, WDNR, indicated that tagging studies in the De Pere to Green Bay Reach (Green Bay Zone 1) and Green Bay Zone 2 revealed that fish migrate between the bay and river (Lychwick, 2000). These study results suggest that there are not separate river and bay fish populations in this area, rather, the fish move to locations where food and habitat characteristics are favorable.

Green Bay Fishery Observations and Habitat

The fish of Green Bay have been categorized in four groups (Table 2-11). These groups include the salmon/trout, benthic, pelagic, and game fish groups. Many of the salmon and trout of the region are found in cold-water fisheries of the northern part of Green Bay. The benthic fish are those that generally feed or live near the bottom of the bay while the pelagic fish are those which typically feed or live in the water column. The game fish listed in Table 2-11 are those fish typically sought by sport or commercial fisherman. The state of Michigan has listed the lake sturgeon and the sauger as threatened species (Table 2-11).

The general spawning areas in Green Bay for each of these groups of fish is shown on Figures 2-16 and 2-17 (NOAA, 1999). As expected, the spawning areas for the salmon/trout species are in the vicinity of the tributaries. The spawning areas for the pelagic and benthic fish are very similar and concentrated mainly in the areas of significant wetlands (Figures 2-13 and 2-14). The game fish spawning areas are similar, but also include additional areas on the east side of Green Bay, indicative that some species, like walleye, prefer gravel beds to the SAV that is associated with the wetlands (Figure 2-17). The spawning areas obtained from the Great Lakes Commission (2000) for large portions of Zone 4 were not identified as specific species and are simply shown as points on Figures 2-16 through 2-20 to indicate locations where fish either spawn or have been observed.

As indicated in Table 2-11, most of the fish being evaluated as part of the food web models are pelagic fish (shiners, gizzard shad, smelt, and alewife). The yellow perch and walleye are the only two game fish included while the carp is the only benthic species included. The Green Bay spawning areas for the food web model fish are shown on Figures 2-18 through 2-20 (NOAA, 1999). As mentioned above, walleye prefer gravel beds for spawning. Such habitat is typically associated with the increased stream flows near the tributary mouths on both the east and west side of the bay. Yellow perch, gizzard shad, alewife, smelt, and carp spawning areas are all associated with the extensive west shore wetlands. The emerald shiner is the only species whose spawning habitat is limited to the east shore of the bay.

The fishery habitat of Green Bay varies considerably based on the water characteristics and bay bathymetry. Green Bay zones 2 and 4 are quite different in terms of their physical characteristics, which affects species distribution and trophic complexity. Green Bay Zone 2 is hypereutrophic (warm and highly productive), while Zone 4 is meso-oligotrophic (cooler and less productive). Related distinguishing characteristics of Zone 4 include lower population densities of fish, less trophic complexity, clearer water, and less human development as compared to Zone 2 (Brazner and Beals, 1997; Sager and Richman, 1991).

The following summary is based on the observations and personal communications of Mike Toneys and Brian Belonger (WDNR) and Phil Schneeberger (MDNR).

Green Bay south of the Peshtigo Reef (west side) and Sturgeon Bay (east side) is generally a warm-water fishery, with eutrophic water conditions, significant plankton populations, and numerous fish species (Toneys, 1999; Belonger, 2000). This fishery is separated from the cold-water fishery to the north by the circular, counterclockwise water currents, one of which runs west from the Peshtigo Reef to Sturgeon Bay on the east side. North of Peshtigo Reef and Sturgeon Bay, the fishery is a cold-water, meso-oligotrophic system with reduced plankton populations and fewer fish species (Schneeberger, 1999).

The general observations of the Green Bay fisheries are described below. Fish with each of these fisheries tend to remain in one area or the other. Tagging studies of yellow perch and smallmouth bass indicate that these fish tend to stay within the area where they were caught (i.e., yellow perch in the warm, south bay waters do not typically migrate to the cold-water fishery of the north bay) (Toneys, 1999). Similarly, the Sturgeon Bay Canal is prone to seiche effects and water temperature changes of 5.5 to 11 degrees centigrade (˚C) (10 to 20 degrees Fahrenheit [˚F]) in a single day. Therefore, fish within Green Bay may move into Lake Michigan and vice-versa, but this is not a significant migration route (Toneys, 1999).

South of the Sturgeon Bay-Peshtigo line, heavily-pursued sport fish include walleye, yellow perch, northern pike, and spotted muskellunge (muskie). North of Sturgeon Bay-Peshtigo, smallmouth bass, brown trout, and salmonids are also pursued (Toneys, 1999; Belonger, 2000). The yellow perch and alewife are the predominant commercial species in the southern area, especially during the summer. During the winter, the lake whitefish become an important commercial species. The whitefish prefer cold waters and are fished in the northern bay year-round. However, when water temperatures decrease south of Sturgeon Bay-Peshtigo, these fish migrate south in pursuit of food (Toneys, 1999; Belonger, 2000). A thermocline has been observed in this area, which tends to form and stay near a depth of 3 to 12 meters (10 to 40 feet), based on weather conditions.

If a consistent northeast wind is experienced, this may push the thermocline down to depths of approximately 18 meters (60 feet) (Belonger, 2000).

In northern Green Bay, walleye, yellow perch, northern pike, splake, chinook salmon, smallmouth bass, white bass, and carp are all sought by sport fishermen. In Michigan, the annual sport catch of walleye may range between 30,000 and 90,000 kg (66,100 and 198,400 pounds) while the yellow perch catch is on the order of 10,000 to 80,000 kg (22,050 to 176,400 pounds) (Schneeberger, 1999). Commercially, the lake whitefish and rainbow smelt are the main species pursued. The annual whitefish catch ranges from 1 million to 1.5 million kg (2.2 million to 3.3 million pounds) while the smelt catch is on the order of 50,000 to 200,000 kg (110,230 to 440,900 pounds) (Schneeberger, 1999).

The commercial fishery for lake whitefish has increased significantly over the last 20 years, and the catches are near an all-time high (Belonger, 2000; Schneeberger, 1999, 2000). In the northern half of Green Bay, the walleye fishery has also increased in the number of fish caught for each hour of fishing and the total numbers of walleyes taken (Schneeberger, 2000).

In addition to these observations, Brazner and Magnuson (1994) found that more fish preferred the nearshore wetland habitats to beaches, which have fewer plants and stronger wave action. In 1997, Brazner indicated that fish populations in the vicinity of undisturbed wetlands were greater than those in disturbed wetlands or beach areas. More forage species and the majority of the game fish captured, including yellow perch and bluegills, were taken in the vicinity of undisturbed wetlands. The highly productive (eutrophic) southern bay provided a better forage base for fishes than did the meso-oligotrophic northern end (Brazner, 1997). This is very important for young fish, which almost all forage on zooplankton at some point during maturation (Brazner, 1997).

The overall patterns of fish abundance, species distribution, and habitat use by fish in Green Bay have been recently well characterized by Brazner and colleagues at the University of Wisconsin (Brazner, 1997; Brazner and Beals, 1997; Brazner and Magnuson, 1994). Each of these papers summarized data collected from 24 stations extending the whole length of Green Bay: eight stations in Zone 2, eight stations in Zone 3, and eight stations in Zone 4. All of these stations were along the western side of Green Bay except for one station on the eastern side of Zone 2, Point Sable. The two habitats targeted for sampling were wetlands (12 stations) and sandy beaches (12 stations). Additionally, half of the stations for each of these two habitats were selected because they were developed, and the other half were selected because they were undeveloped.

These stations were sampled in the summer and fall of 1990 and 1991, and in the spring of 1991. Almost 42,000 fish, representing 54 species and 20 families, were caught and analyzed over these sampling periods. Most of these fish (86 percent) were immature (younger than 2 years old) likely because of the small mesh sampling gear used which favored selection of younger age classes of fish.

The data collected by Brazner and colleagues were analyzed to determine to what degree fish preferentially used different regions of the bay, habitats within those regions, and to what degree human development impacted habitat use. Statistical analyses including cluster analysis, ordination, and discriminant analysis indicated that regional differences most strongly influenced fish assemblages, followed by habitat differences, and the least determining factor was development status.

Approximately half (49 percent) of all the fish collected came from Zone 2, most of them captured in undeveloped wetlands, and only 16 percent came from Zone 4. Not only was abundance greater in Zone 2, but also species richness. Of the regional characteristics measured, turbidity was determined to be the best predictor of fish abundance. Other important regional characteristics included water temperature, conductivity, and pH (Brazner and Beals, 1997).

Habitat differences adequately defined fish assemblages for Green Bay zones 3 and 4, but they were not a good predictor for Zone 2 (Brazner and Beals, 1997). Macrophyte level was the habitat characteristic that best predicted fish assemblages. When macrophyte cover and richness is high, the same is generally true of fish richness and abundance (Brazner and Beals, 1997). An exception to this is where macrophyte cover is so dense that it has limited utility for fish.

Turbidity, in addition to being a primary regional characteristic, is a key limiting factor to macrophyte growth and, therefore, habitat differences (Brazner and Beals, 1997). Areas that are highly turbid, such as Green Bay Zone 2, have less developed macrophytes, whereas Zone 4, which has clear waters, has well developed macrophytes. Overall, these differences have resulted in lower biomass and vegetation-dependent fish in Zone 4 (centrarchids, northern pike, golden shiners) and higher biomass, more turbidity-tolerant fish communities in Zone 2 (gizzard shad, white bass, common carp) (Brazner and Magnuson, 1994). Turbidity in Zone 2 is assumed to be equally influenced by biotic (phytoplankton production) and abiotic (erosion, runoff, and resuspension) factors (Brazner and Beals, 1997). It has been estimated that 70 percent of the water in Zone 2 (Long Tail Point to Point Sable) is composed of Lower Fox River water (Brazner and Beals, 1997).

In terms of trends in individual species, spottail shiners were the most abundant fish, with over 122,000 individuals caught in the spring of 1991 (Brazner, 1997). Catch of this species was not dependent on habitat type, but was dependent on region; 93 percent of the catch was obtained from Zone 2. Excluding these spottail data, spottail shiners were still one of the top five most abundant species caught; the remaining top five species were yellow perch, alewife, spotfin shiner, and bluntnose minnow. Yellow perch represented about 25 percent of the approximately 42,000 fish caught, and spottail shiner represented approximately 22 percent.

For 21 of the 54 fish species caught, either more than 80 percent of the individuals or at least a significant number of them were caught in one zone. These results demonstrate that regional differences were stronger determining factors of fish assemblage than habitat or development. Of these 21 fish species, freshwater drum, white bass, and gizzard shad were caught almost exclusively in Zone 2, and golden shiners, pumpkinseeds, and logperch were most often caught in Zone 4 (Brazner, 1997). The three species that were dominantly caught in Zone 3 (rainbow smelt, trout perch, and banded killfish) were not the most abundant fish caught in this zone.

Specifically, for receptors selected for risk evaluation of the Lower Fox River and Green Bay, the following information was obtained from the Brazner (1997) study:

- Yellow Perch
  - Dominantly found in Green Bay Zone 2 (74 percent)
  - Dominantly found in wetland habitat (74 percent)

- Spottail Shiner
  - Dominantly found in Green Bay Zone 2
  - Dominantly found in beach habitat

- Alewife
  - Dominantly found in beach habitat

- Gizzard Shad
  - Dominantly found in Green Bay Zone 2

- Emerald Shiner
  - Dominantly found in Green Bay Zone 2

- Common Shiner
  - Dominantly found in wetland habitat

- Golden Shiner
  - Dominantly found Green Bay Zone 4
  - Dominantly found in undeveloped wetland habitat

- Common Carp
  - Dominantly found Green Bay Zone 2
  - Dominantly found in undeveloped wetland habitat

- Rainbow Smelt
  - Dominantly found Green Bay Zone 3
  - Dominantly found in beach habitat

Note: trends for brown trout (n = 2) and walleye (n = 9) were not evaluated because an insufficient number of individuals were collected.

Life Histories of Fish Species in the Lower Fox River and Green Bay

The remainder of this section details receptor species descriptions, life history, and food preferences for the important receptor species identified in the Risk Assessment

Shiners (Minnows). Shiner species found in the Lower Fox River and Green Bay include golden shiner (*Notemigonus crysoleucas*), emerald shiner (*Notropis atherinoides*), and common shiner (*Notropis cornutus*). Like carp, shiners are in the family Cyprinidae.

All shiner species are relatively small forage fish that average 5 to 10 cm (2 to 3.9 inches) in length. Golden shiners are silver with a dusky stripe along their side and a small, almost vertical mouth. Common shiners are olive on top with a dark stripe running down the middle of their back, and one or two stripes along their upper sides. Emerald shiners are light olive on top with a dusky stripe along their back, a silver stripe with emerald reflections along their side, and a large mouth.

Shiners generally inhabit shallow areas with limited current and rarely are found in riffles, but common shiners can tolerate some turbidity (Becker, 1983). Frequently these fish are found over similar substrates (sand, mud, gravel), but common and golden shiners are more dependent on vegetation than emerald shiners (Becker, 1983). Water temperatures can strongly influence the distribution of these fish; the preferred temperature is 25 ˚C (77 ˚F), but common and golden shiners have been shown to tolerate temperatures up to 34 ˚C (93 ˚F)

(Becker, 1983). These open-water fish rarely go below the thermocline (11 to 15 meters [36 to 49 feet]). Interestingly, golden shiners have a remarkable ability to survive under low dissolved oxygen conditions. In Michigan lakes when oxygen levels were between 0 and 0.2 mg/kg, golden shiners have survived where other fish have not (Becker, 1983).

Due to the number of species present in Wisconsin, spawning occurs between May and August (Becker, 1983). Shiners are typically stream-spawning fish (USFWS, 1983a), and prefer to spawn over gravel shoals and bottoms or other silt-free, firm substrates where water currents are prevalent and sufficient to supply much-needed dissolved oxygen to the eggs. However, the golden shiner is an exception to this rule, since this species spawns over beds of submerged vegetation and have even been noted to fail to spawn within pools in which aquatic vegetation was absent (Becker, 1983). Most species of shiners will spawn in the nests of other fish. The most important factor affecting spawning is water temperature, with different species' spawning instinct reacting to different water temperature regimes (Becker, 1983). The number of eggs that develop within the female is largely related to age and body weight and dependent upon the species of concern.

Most species of shiners are omnivorous, feeding equally on plant and animal matter (USFWS, 1983a). They are known to feed at the bottom of streams or lakes, in the water column, and near the surface. Males typically grow faster and larger than females, and they range in lengths from about 8.9 to 20.3 cm (3.5 to 8 inches), depending on the age, sex, and species of shiner observed (USFWS, 1983a; Becker, 1983).

Due to their relatively small size, shiners are preyed upon by many game fish, including bass, crappies, walleye, northern pike, and muskellunge. Birds such as pied-billed grebes, mergansers, bitterns, green herons, night herons, kingfishers, and bald eagles also prey on shiners (Becker, 1983).

Gizzard Shad. Gizzard shad (*Dorosoma cepedianum*) is an abundant omnivore in many central and southern United States lakes (Shepherd and Mills, 1996), and are found throughout the Lower Fox River and the southern half of Green Bay. Gizzard shad, along with alewife, are members of the herring family Clupeidae. Adults are generally 28 cm (11 inches) in length. Gizzard shad have a distinctive whip-like dorsal ray. They are silver-blue colored above, silver-white on the sides, and they have six to eight dark stripes on their top and upper sides.

Gizzard shad thrive in warm, fertile, shallow water bodies with soft, muddy bottoms and high turbidity (USFWS, 1985), which essentially describes lower

Green Bay. If few predators abound, gizzard shad populations can quickly explode and become a nuisance. Additionally, gizzard shad are often abundant in large sluggish rivers, lakes, swamps, and bayous (USFWS, 1985), and they often travel in schools close to the surface. Spawning typically occurs between late April/early May through August (Becker, 1983) in shallow rivers and streams, and spawning may extend over a period of 2 weeks for any given female. Females may produce upwards of 380,000 eggs (Becker, 1983) although some researchers have found mean egg production to be about 13,000 eggs per individual (USFWS, 1985). However, after age 2, egg production generally declines, sometimes rapidly.

Gizzard shad typically live less than 6 years, reaching lengths of 28 to 41 cm (11 to 16 inches) and weighing around 0.91 kg (2 pounds). However, specimens ranging up to 52.1 cm (20.5 inches) and weighing 1.6 kg (3.5 pounds) (Becker, 1983) and other specimens age 10 or 11 have been recorded (USFWS, 1985).

Gizzard shad feed in both the limnetic zone and along bottom sediment, with diet being controlled largely by the local environment. Shad captured in open water have been observed to feed on free-floating plankton, whereas shad captured in streams were found to feed on littoral vegetation and small aquatic insect larvae (USFWS, 1985). In lakes, young fish feed almost exclusively on zooplankton while larger fish feed on zooplankton, phytoplankton, insect larvae, and detritus (USFWS, 1985).

An essentially open-water species, living at or near the water surface (Becker, 1983; USFWS, 1985), gizzard shad are preyed on by numerous species. Young-of-the-year (YOY) shad are important to sport fish and waterfowl because of their rapid growth rates, making them a “short and efficient link in the food chain that directly connects basic plant life with sport fish” (Becker, 1983). They are also an important food source for numerous waterfowl and wading birds (Becker, 1983).

Rainbow Smelt. Rainbow smelt (*Osmerus mordax*) are widespread and abundant non-indigenous pelagic planktivores in the Great Lakes (Jones *et al.*, 1995). Smelt are an important prey species for Green Bay, but are not found above the De Pere dam in the Upper Fox River. These fish average 15 to 20 cm (5.9 to 7.9 inches) in length, but despite their small size, they have comparatively large mouths. Rainbow smelt are olive colored on top, and silver with blue or pink iridescence on their sides. They also have a silver stripe on their sides.

Spawning occurs on sandy beaches near river mouths in the Great Lakes between late March and early May when the water temperatures reach 4 ˚C (39 ˚F), and lasts approximately 2 weeks. Specifically, in Lake Michigan, spawning in Green Bay may be a week or two behind spawning in northern Lake Michigan because Green Bay remains covered with ice longer (Becker, 1983). Female smelt typically release no more than 50 eggs during each spawning session and, once released, the eggs sink immediately to the bottom of the stream, where they become attached to the substrate (Becker, 1983). Development of the eggs takes about 20 to 30 days. Once hatched, smelt fry are transparent and about 5.5 to 6 millimeters (mm) (0.22 to 0.24 inches) long (Becker, 1983).

While YOY fish are pelagic, as they age they move towards a bottom existence. The fish often school offshore, prefer cool clear water, and are most abundant in water depths of 18 to 26 meters (59 to 85 feet), although they can be found in water depths of 14 to 64 meters (46 to 210 feet) (Becker, 1983). Optimum temperatures range from 6.1 to 13.3 ˚C (43 to 56 ˚F) and feeding is at a peak at 10 ˚C (50 ˚F). Rainbow smelt reach sexual maturity in approximately 2 years (approximately 170 mm [6.7 inches]) and can live up to 8 years (Becker, 1983). Males live approximately 5 years, reaching a length of about 21.8 cm (8.6 inches), while females typically live about 7 years and reach a length around 310 cm (12.2 inches) (Becker, 1983).

Full-grown smelt subsist principally on larger crustaceans (like opossum shrimp). However, in the inshore waters they may consume large numbers of fishes, including YOY alewife, YOY smelt, and sticklebacks, while other researchers have found them to feed on smelt, shiners, yellow perch, burbot, and rock bass, as well as mayfly larvae and chironomid (Becker, 1983). Smelt have supplanted chubs as the principal food of Lake Superior's trout population and their importance in the food chain in Lake Michigan may be similar. Brook trout, brown trout, lake trout, whitefish, herring, walleye, yellow perch, northern pike, and burbot all prey on smelt.

Rainbow smelt are an exotic species in the Great Lakes, belonging to the family Osmeridae, which is essentially a marine family (Becker, 1983). Smelt were likely introduced into the Great Lakes as forage fish for salmon and trout. The first recorded smelt catch was off the coast of Michigan in 1923 (Becker, 1983). Originally, these fish were regarded as a nuisance species, with hordes of them invading and becoming entangled in nets (UWSGI, 2000). However, in the 1930s, smelt runs up the small streams and tributaries of Lake Michigan developed into an avid sport using dip-nets or seining. The cities of Oconto and Marinette, Wisconsin attracted 20,000 to 30,000 people to festivities scheduled to coincide with these runs (UWSGI, 2000; Becker, 1983). Smelt are only found within the Lake Michigan and Lake Superior basins.

Smelt have suffered occasional die-offs that have significantly reduced the populations. According to local Green Bay fisherman, smelt runs typically last only 1 night, when previously these runs might have lasted anywhere from 1 week to 10 days (Stiller, 1998).

The decline in the commercial smelt catch and the shorter smelt runs in the Green Bay tributaries may be due to a number of factors, including the following:

- Increased predation of smelt by burbot, trout, and salmon (Belonger, 2000), or

- Spawning occurring within the shallow waters and nearshore habitat of Green Bay rather than in the tributaries (Belonger, 2000).

Alewife. Alewife (*Alosa pseudoharengus*) are non-indigenous small anadromous pelagic planktivores that prefer open water and sandy habitats. Alewife, along with shad, sardines, and menhaden, are members of the herring family Clupeidae, which are predominantly marine species. Individuals of these landlocked populations are generally half the size (averaging approximately 16 cm [6 inches] in length) of the marine alewife (approximately 36 cm [14 inches] in length) (Scott and Crossman, 1973). Alewife are blue-green colored on top and silver on the sides, with thin dark stripes on their top and upper sides.

Alewife are abundant in Lake Michigan and Green Bay, and Becker (1983) indicated that alewife constituted 70 to 90 percent of the fish biomass in Lake Michigan. Alewife inhabit all levels of the lake and bay over all bottom types. However, they avoid cold water when possible, and during winter they migrate to the deepest and warmest water of the lake/bay (Becker, 1983). Alewife swim in dense schools and are the major prey of trout, salmon, and other fish in the lake (UWSGI, 2000). In 1974, it was estimated that coho salmon consumed approximately 36 to 45 million kg (80 to 100 million pounds) of alewife, which was about 5 percent of the total alewife biomass (Becker, 1983). Also, more than 8.16 million kg (18 million pounds) have been caught and processed primarily as poultry feed since 1966 (Becker, 1983).

Alewife populations in Lake Michigan have varied widely. In the 1920s in Lake Michigan, sea lampreys were introduced and greatly reduced the number of large predatory fish. Therefore, when the alewife were introduced in the 1940s, they had few predators and populations had an opportunity to increase. In the 1960s and early 1970s, alewife were the dominant forage fish accounting for 70 to 90 percent of fish by weight in Lake Michigan. Lamprey populations peaked in the 1950s, but in the late 1950s lamprey population control methods were found.

Since then, lamprey populations have been markedly reduced. In the early 1980s, alewife populations in Lake Michigan began to decline dramatically (Mason and Brandt, 1996). This decline, and the continued lower levels of alewife, are believed to be related to predation by trout and salmon which are primary predators (Flath and Diana, 1985), and walleye and perch which also prey on alewife. Additionally, alewife die-offs are believed to occur because of rapid temperature changes and wide fluctuations in temperature (Hewett and Stewart, 1989). Severely cold winters and the spring and summer return of alewife to shallow warmer waters can initiate die-offs (Scott and Crossman, 1973). This species is likely more temperature-sensitive than other species because it is naturally adapted to marine conditions where temperature variations are not as dramatic.

Alewife travel in dense schools, move towards nearshore waters in the spring (mid-March and April), and spawn during the early summer. Spawning occurs from June to August. In Lake Michigan, peak spawning occurs in the first 2 weeks of July (Becker, 1983). Preferred temperatures for spawning have been estimated at 13 to 16 ˚C (55 to 61 ˚F) in Lake Ontario, although they can also vary widely from 5 to 22 ˚C (41 to 72 ˚F).

Spawning typically occurs in water less than 3.05 meters (10 feet) deep with no preference concerning bottom type (Becker, 1983). Females produce from 11,000 to 22,000 eggs. In Lake Michigan, schools of 5,000 to 6,000 spawning fish have been observed densely packed in areas of 4.5 to 6 meters (15 to 20 feet) in diameter (Becker, 1983). Alewife typically live less than 8 years, generally reaching lengths of 15.2 to 20.3 cm (6 to 8 inches) and weighing 113 to 227 grams (4 to 8 ounces) (UWSGI, 2000; Becker, 1983). Alewife fry are both phototropic and pelagic, feeding on zooplankton. However, as they grow, the water depth in which the fish feed largely controls the diet. Zooplankton predominate for fish which feed nearshore, while amphipods are consumed in water depths over 9 meters (29.5 feet) deep (Becker, 1983). Additionally, gastropods have been found in alewife captured in the littoral zone, indicating the alewife feed on the bottom to some extent. Researchers have found that alewife consume *Daphnia* preferentially in the southern portion of Green Bay (Becker, 1983). Brandt and Magnuson (1980) found that the distribution of juvenile and adult alewife differs with temperature. YOY alewife reach maximum abundance when daytime water temperatures exceed 17 ˚C (62.5 ˚F) while adult alewife prefer water temperatures of 11 to 14 ˚C (52 to 57 ˚F).

The alewife is an exotic species, first noted in Lake Erie in 1931; by 1953 these fish had made their way throughout the Great Lakes system and were observed in Lake Superior. Although the presence of the alewife has had some positive aspects, there are significant negative consequences associated with this exotic species. Alewife have reduced the number of perch, herring, chubs, and minnows through direct competition with the young of those species for plankton and other small aquatic organisms which comprise the diet of these fish (UWSGI, 2000). Alewife also prey on the young of the species (Becker, 1983). Additionally, annual die-offs litter the beaches, resulting in aesthetically displeasing odors. Alewife have also been known to clog the intake pipes of power plants and municipal water filtration plants (Becker, 1983).

Yellow Perch. Yellow perch (*Perca flavescens*) are native to the Lower Fox River and Green Bay, and are one of the most important fish of Wisconsin and Michigan in terms of both the commercial and sports fishing industries. Along with the walleye, the yellow perch is a member of the perch family Percidae. Yellow perch average 15 to 25 cm (6 to 10 inches) in length. They are green colored on top, whitish on the underside, and they have distinct green-brown vertical bands extending down their yellow sides.

The preferred habitat of yellow perch is found along shoreline areas and in clear lakes with depths of less than 10 meters (33 feet), temperatures of 18 to 21 °C (64 to 70 °F), sand, gravel, or muddy sediments, and modest to moderate amounts of aquatic vegetation (Becker, 1983; Scott and Crossman, 1973, USFWS, 1983b). A study examining the frequency of litoral fishes in a Wisconsin lake determined that yellow perch (YOY and adults) were highly associated with complex macrophyte beds (Weaver *et al.*, 1997). Of the sites examined, the only locations where yellow perch were not caught were two sites having the lowest abundance of vegetation. Turbidity adversely affects growth of juveniles and temperatures of 32 °C (90 °F) can be lethal, but yellow perch are tolerant of low oxygen levels. In Lake Michigan, oxygen levels of 0.1 to 0.3 ppm killed numerous yellow perch, but many survived (Becker, 1983). Bluegill, largemouth bass, and walleye are fish species that cannot survive low oxygen concentrations.

Perch are a schooling species that feed during the day and rest on the bottom at night. Schools of yellow perch may range from 50 to 200 fish and usually are associated with feeding activities conducted during daylight hours.

Yellow perch normally spawn shortly after ice-out in April or early May, when water temperatures range between 7.2 and 11.1 °C (45 and 52 °F), and may continue for 8 to 19 days (Becker, 1983). During spawning, the eggs are usually deposited in sheltered areas and are frequently draped over emergent and submergent vegetation or submerged brush in water depths of 0.6 to 3 meters (2 to 10 feet). Rocks, sand or gravel may be used if submergent vegetation is not available (USFWS, 1983b). The fish may travel long distances prior to spawning. Lake Winnebago perch may swim from 48 to 81 km (30 to 50 miles) up the Fox River before they reach suitable spawning habitat (Becker, 1983). Egg production in the female yellow perch is extremely variable with the individual based on the size of the fish; researchers have observed anywhere from less than 1,000 to 210,000 eggs in select fish in Minnesota and Wisconsin (Becker, 1983), with greater fecundity in larger individuals. Eggs are released in strands up to 2.15 meters (7 feet) in length and up to 10 cm (4 inches) in width (Becker, 1983).

Similar to walleye, yellow perch provide no protection for the eggs or fry (Becker, 1983), which hatch anywhere from 8 to 27 days following spawning. The speed with which hatching occurs depends on water temperature (Becker, 1983). Shorter hatching periods are typically associated with warm water while 27-day hatching periods have been observed in 8.5 to 12 ˚C (47 to 53 ˚F) water (Becker, 1983). Larvae are approximately 0.5 cm (0.2 inch) upon hatching and swim to the surface, where they remain in the upper 0.9 to 1.2 meters (3 to 4 feet) of water for the first 3 to 4 weeks. Microscopic zooplankton are important to the survival of perch fry. If the zooplankton are too large, the young fry perish (Becker, 1983). Young-of-the-year perch continue to consume zooplankton and other aquatic insects until they are quite large. Perch do not typically begin to feed on other fish until they have reached a length of about 18 cm (7 inches) or more, sometime between age 3 and 4 years (Becker, 1983). Mature yellow perch generally range in length from 15 to 25 cm (6 to 10 inches) and weigh 170 to 454 grams (6 to 16 ounces) (UWSGI, 2000). Males reach maturity in about 1 year while females mature in 2 years in Green Bay (Belonger, 2000). In Wisconsin waters, yellow perch generally live about 7 to 10 years (USFWS, 1983b). Brandt and Magnuson (1980), found that the distribution of juvenile and adult perch differs with temperature. Juvenile perch catches are highest in waters 15 to 20 ˚C (59 to 68 ˚F) while catches of adult perch are greatest in waters which are 7 to 8 ˚C (44.5 to 46.5 ˚F).

Young yellow perch are preyed upon by all fish-eating species, including muskie, northern pike, burbot, smallmouth and largemouth bass, bowfins, bullheads, and lampreys (Becker, 1983). However, walleye and yellow perch have a special relationship. Each species preys on the other at different times in the life cycle: large walleye feed on yellow perch, while yellow perch feed on walleye fry. Additionally, perch eggs are eaten by aquatic birds and other animals and the fish are eaten by gulls, terns, mergansers, herons, grebes, ospreys, and kingfishers (Becker, 1983).

Populations of yellow perch in Lake Michigan have widely fluctuated. As previously discussed, yellow perch year-class strength may be inversely related to abundance of alewife (Brandt *et al.*, 1987; Mason and Brandt, 1996). Between 1889 and 1970, average catch rates were 1.1 million kg (2.4 million pounds) per year from Green Bay, but because of the dramatic decline in perch since 1990 (a loss of 80 percent of the population), beginning in January 1997, Wisconsin banned commercial fishing in Lake Michigan and reduced daily recreational limits to five individuals per day. Additional factors that possibly adversely affect the yellow perch populations include the following:

- Increase in white perch populations, which feed on the YOY perch and also compete with adult perch for food; and

- Introduction of zebra mussels into the benthic community, which aggressively compete for the zooplankton species which yellow perch fry and YOY also consume (Belonger, 2000).

Carp. Carp (*Cyprinus carpio*) is an abundant bottom-dwelling species found in southern Green Bay. Along with shiners, carp belong to the minnow and carp family Cyprinidae. Adult carp have been found to range in length from 41 to 58 cm (16 to 23 inches) and weigh from 1 to 10 kg (2 to 22 pounds) (Weber and Otis, 1984). Carp have two distinct barbles on each side of the upper jaw. These fish are gray/gray-green colored on top, have a dark edge on the upper side, and are white to yellow on the underside.

Carp are tolerant of turbidity, low dissolved oxygen, pollution, and rapid temperature changes better than most other fish in North America (Becker, 1983). Part of their ability to tolerate low oxygen is because they can use atmospheric oxygen. Although they are tolerant of a wide range of conditions, they prefer shallow lakes and streams that have abundant aquatic vegetation (Becker, 1983). Carp prefer warm temperatures of close to 32 ˚C (90 ˚F), but this is within the range of temperatures that have been found to be lethal (31 and 34 ˚C [88 to 93 ˚F]), and above a temperature at which carp spawning could occur (Becker, 1983).

Carp have the ability to range widely; some tagged fish have traveled 1,090 km (677 miles), and a carp tagged in Lake Winnebago was recaptured 148 km (92 miles) away (Becker, 1983). Most tagging studies of carp have found that they are generally recaptured within a few kilometers (Becker, 1983). Generally, carp are wary and bolt for vegetation and cover or deeper water with little provocation. The exception to this behavior is during spring, when spawning occurs (Becker, 1983).

Spawning occurs from April to August in Wisconsin and peaks in late May to early June when temperatures range from 18 to 28 ˚C (64 to 82 ˚F) (Becker, 1983; Scott and Crossman, 1973). An investigation of spawning carp in Lake Winnebago and nearby lakes determined that preferred spawning areas were shallow vegetated waters (0.15 to 1.2 meters [0.5 to 3.9 feet] deep) (Weber and Otis, 1984). These preferences have also been supported by other authors (Becker, 1983; Scott and Crossman, 1973). A single female carp may release 50,000 to 620,000 eggs during the primary spawning period (Becker, 1983). Carp eggs float through the water and, due to an adhesive coating surrounding the egg, attach themselves to underwater vegetation, debris, or any other object to which the egg will adhere (USFWS, 1982). Spawning over areas with dense vegetation will increase the success of reproduction, but some studies have indicated that carp will not spawn in water cooler than 16 ˚C (60 ˚F).

Incubation lasts for 3 to 16 days depending on the temperature (Becker, 1983). Four to five days after hatching, young move off vegetation and go to the bottom (Becker, 1983). Through their first summer, carp fry are strongly associated with vegetation as protective cover in 15 to 30 cm (6 to 12 inches) of water (Weber and Otis, 1984). Young carp leave this shallow weedy habitat when they are 76 to 102 mm (3 to 4 inches) and generally too large for predators to consume (Becker, 1983). After the first season of growth, carp are generally 13 to 19 cm (7 to 7.5 inches) long (Scott and Crossman, 1973). Although young carp are food for both birds and other fish, when they reach 1.4 to 1.8 kg (3 to 4 pounds), they are too large to be a prey item. Carp are generally mature at age 2 (males) or 3 (females) and usually live for 9 to 15 years (Becker, 1983).

Carp are omnivorous, feeding equally on plant and animal matter (USFWS, 1982). The fry initially feed on zooplankton, but will also feed on phytoplankton if necessary. As young fish grow, they feed on littoral and later bottom fauna, taking in worms and the larvae of insects as well as vegetation, such as seeds, algae, and detritus (USFWS, 1982). Adult carp are opportunistic feeders, which are able to utilize any available food source (USFWS, 1982; Becker, 1983). Male carp generally mature between 2 and 4 years while female carp take about 3 to 5 years to mature. Typically, carp grow to be about 38 to 56 cm (15 to 22 inches) in length and weigh up to 3.2 kg (7 pounds) (UWSGI, 2000). However, the maximum weight reported for carp in north America is 42.1 kg (93 pounds) (USFWS, 1982).

Carp have been harvested commercially from the Great Lakes since the first recorded catch in 1893 until contaminants closed the fisheries, which occurred in the early 1980s in Green Bay. Carp, especially young carp, are preyed upon by many game fish, including bass, crappies, northern pike, bowfin, turtles, snakes, loons, grebes, and mergansers, and carp eggs are preyed upon by minnows, catfish, and sunfish (Becker, 1983).

Walleye. Walleye (*Stizostedion vitreum*) is a popular, year-round game and commercial fish found in Lake Michigan, generally in areas less than 7 meters (23 feet) deep (Magnuson and Smith, 1987). The walleye is the largest member of the perch family (Percidae—a group that includes sauger, darters, and yellow perch) in North America. It is not a member of the pike family as commonly believed. These fish range in length from 33 to 64 cm (12 to 24 inches) and weigh from 0.45 to 2.3 kg (1 to 5 pounds). Walleye have huge mouths that extend past the eye and strong canine teeth (Becker, 1983). Walleye are yellow-olive/brown colored on top and brassy yellow-blue along the sides. They have 5 to 12 dusky saddles that become less visible as they age (Becker, 1983).

Walleye are found throughout the Fox and Wolf River basins and their connecting lakes, as well as Green Bay (Becker, 1983). Walleye are tolerant of a range of environmental conditions, particularly turbidity and low light, but they are not tolerant of low oxygen levels. Winter kills, because of low oxygen, have occurred in Wisconsin (Becker, 1983). Walleye prefer quiet waters over sand, gravel, and mud substrates (Becker, 1983). They generally rest in deep dark waters during the day and migrate to rocky shoals and weed beds to feed at night, but they may be active during the day if it is cloudy or the waters are turbid (Becker, 1983). Young-of-the-year fish can be found near the sediments in 6 to 10 meters (20 to 33 feet) of water (Scott and Crossman, 1973), but can be caught in surface waters up to lengths of approximately 35 mm (1.3 inches) (WDNR, 1970). Larger fish are generally found in depths of 14 meters (46 feet) or less and form loose schools (Scott and Crossman, 1973). Schooling is common during feeding and spawning.

Between mid-April and early May, walleye migrate to wind-swept, rocky shorelines, flooded wetlands or inlet streams with gravel bottoms to spawn. Preferred spawning habitats are shallow shoreline areas, shoals, riffles, and dam faces with rocky substrate and good water circulation from wave action and currents (USFWS, 1984). The fish may travel long distances during the migration. Lake Winnebago walleye, for instance, may swim 161 km (100 miles) up the Wolf River before they reach suitable spawning habitat (Becker, 1983). The female walleye will lay an average of 50,000 eggs and generally spawns out completely in 1 night. Summer territories and spawning grounds are distinct areas, and walleye may have a homing instinct for spawning grounds. The range of summer area is generally limited to 3 to 8 km (2 to 5 miles), but the recorded range has varied from 0.8 to 110 km (0.5 to 68 miles). A study of walleye in Lake

Poygan found that walleye traveled an average distance 47 km (29 miles) (Becker, 1983).

Walleye spawn soon after ice melts and temperatures reach 3 to 7 °C (37 to 44 °F) and spawning peaks when temperatures are 6 to 10 °C (43 to 50 °F) (Becker, 1983). In Lake Winnebago, the timing of spawning has been recorded as a 2- to 3-week period between the first week in April and the first week in May (WDNR, 1970). Walleye from Green Bay move upstream into the Fox River to spawn; however, their movement is restricted by the De Pere dam (Magnuson and Smith, 1987). Walleye do not build nests and after releasing eggs, they offer no parental care. Spawning occurs at night generally on gravel bottoms, but they can spawn on vegetation. In Lake Winnebago, flooded marsh areas are preferred spawning grounds (Becker, 1983). Continuous flowing water over the eggs is important for hatching success. The time for eggs to hatch is dependent on the water temperature: at 14 °C (57 °F), eggs hatch in about 7 days and when water temperatures are 4 °C (39 °F), eggs hatch in about 26 days (Becker, 1983). Adult walleye provide no protection for the eggs (USFWS, 1984).

Fry move off wetlands a day or two after hatching and obtain an open-water existence. They stay in open water until they are about 30 mm (1.2 inches) and then return to shore around June (Becker, 1983). By the end of July, walleye in Lake Winnebago are about 75 mm (3 inches) or larger. At this size, walleye shift their diet from zooplankton only to include fish and invertebrates, and by fall they are generally 130 mm (5 inches) (Becker, 1983). Female walleye grow faster and become larger than males. Mature walleye generally range in length from 33 to 64 cm (13 to 25 inches) and from 0.5 to 2.3 kg (1 to 5 pounds) (UWSGI, 2000). Males reach maturity in 2 or 3 years, when they are 30 to 34 cm (12 to 13.5 inches) long while females mature in 4 to 5 years at lengths of 38 to 43 cm (15 to 17 inches). In Wisconsin waters, walleye generally live about 7 to 10 years (UWSGI, 2000), but walleye can live more than 20 years (Lychwick, 2000) in Green Bay. However, growth of the walleye is dependent upon the food supply, temperature, and population density (USFWS, 1984).

Brown Trout. Brown trout (*Salmo trutta*) is a popular, seasonally-caught game fish in Green Bay. These fish range in length from 41 to 61 cm (16 to 24 inches) and weigh from 0.9 to 3.6 kg (2 to 8 pounds). Brown trout are light brown to brown-black in color with red and black spots, but on the lower sides and stomach, they are silvery. Brown trout have large jaws.

As compared to other species of trout, brown trout grow faster, live longer, and better tolerate degraded habitats, warm temperatures (up to 29 °C [84 °F]), and turbidity (Becker, 1983). They are fairly common in cold waters of Wisconsin and self-sustaining populations in Lake Michigan are enhanced with stocking. In Green Bay, this species is generally limited to the northern two-thirds of the bay, which contains deeper and colder waters. Preferred temperatures are 10 to 18 ˚C (50 to 64 ˚F) (Becker, 1983).

Brown trout are most often found along the shore in waters no deeper than 15 meters (49 feet) (Becker, 1983) and they have been known to inhabit waters along the west shore of Green Bay from the towns of Oconto and Marinette (Magnuson and Smith, 1987). Wild brown trout fingerlings that were tagged have been found to travel an average of 16 km (10 miles) in 1 year. Hatchery-reared trout released in Wisconsin waters generally remained within 24 km (15 miles) of the release point, but some tagged fish after 1 year were found to range up to 323 km (201 miles) (Becker, 1983).

Spawning occurs when waters are close to 8 ˚C (46 ˚F), in autumn and early winter (October to December). Spawning areas are shallow waters with gravel bottom substrate, generally stream headwaters rather than rocky shores, but spawning does occur in lakes along rocky reefs. Females build nests and males defend them. Unlike salmon, these fish do not die after they spawn and most individuals spawn more than once. During spawning, these fish may school, but when not spawning, crowding is not tolerated (Becker, 1983). Generally, brown trout are sexually mature at 2 years old and live for approximately 7 years.

Brown trout tend to be nocturnal feeders, and food items can include aquatic and terrestrial insects, crustaceans, molluscs, frogs, shrimp, salamanders, and other fish. Zooplankton are an important food source for small brown trout (Becker, 1983). Up to about 229 mm (9 inches), they are insect feeders and past this length they dominantly consume (70 percent of the diet) fish such as young trout, sculpins, minnows, darters, and lampreys (Becker, 1983). Magnuson and Smith (1987) found that brown trout collected in the spring from Green Bay Zone 3 dominantly consumed alewife (73 percent of the diet); rainbow smelt were the other 27 percent of the identified forage fish consumed. Half of the brown trout collected in the fall in this region of the bay had empty stomachs and, therefore, prey consumption was not evaluated (Magnuson and Smith, 1987). Presumably, this was about the same time as their spawning. It is suspected that over the summer, brown trout, like walleye, increase their consumption of rainbow smelt (Magnuson and Smith, 1987).

2.5.8 Birds

The terrestrial and aquatic habitats of the Lower Fox River and Green Bay provide food, protective cover, nesting areas, and resting locations for both regional and migratory birds and waterfowl. Birds associated with the river and bay are divided into seven groups, and include the following:

- Passerines,
- Gulls and terns,
- Diving birds,
- Shorebirds,
- Wading birds,
- Waterfowl, and
- Raptors.

A listing of the common or important birds within each group, along with its status as a threatened or endangered species, is included in Table 2-12. A brief description of each group of birds is presented below. Figure 2-21 shows the general distribution of the birds within these groups throughout Green Bay (NOAA, 1999). As with the fish data in Zone 4, bird data obtained from the Great Lakes Commission (2000) did not differentiate specific species. Therefore, locations where birds of concern either nest or have been observed are simply shown as points.

Passerine Birds

A large number of passerine birds exist within the Lower Fox River and shorelines of Green Bay. Common passerine species include blackbirds, wrens, sparrows, and swallows (Table 2-12). These birds typically feed on insects, seeds, and small invertebrates found through foraging along the ground. A large number of blackbirds, wrens, sparrows, and swallows feed on the insects or insect larvae which are found in and above the surface water of the Lower Fox River and Green Bay. Additionally, typical habitat for these birds include wetlands, open meadows, and grasslands (Exponent, 1998; Harrison and Greensmith, 1993). The blackbirds tend to nest in loose colonies while sparrows and wrens typically nest individually (Harrison and Greensmith, 1993). These birds are migrant to partially migrant, dependent on local winter weather conditions and the supply of food (Harrison and Greensmith, 1993). None of the passerines are listed on state or federal endangered/threatened species lists (Table 2-12).

The red-winged blackbird (*Agelaius phoeniceus*) is the most common bird within this group found in Wisconsin. The annual probability of sighting this bird is well over 95 percent and they typically are found in Wisconsin from late February through late November (Temple *et al.*, 1997). The likelihood of sighting the five other birds in this group ranges from approximately 35 to 55 percent, and these species are usually sighted between April and October (Temple *et al.*, 1997).

Tree swallows (*Tachycineta bicolor*) are also common migratory songbirds that breed in and migrate through the Lower Fox River and Green Bay. Tree swallows nest in semi-colonial groups in natural cavities (trees, posts, streambanks) near water. Tree swallows feed exclusively on insects, predominately aquatic insects. Tree swallow population data is not available from the Lower Fox River and Green Bay because studies of these birds in this region have used artificial nest boxes rather than relying on naturally-nesting populations (Ankley *et al.*, 1993; Custer *et al.*, 1998).

Both the red-winged blackbird and the tree swallow are protected under the Migratory Bird Treaty Act.

Gulls/Terns

The gulls/terns group for the Green Bay area includes two species of gulls and four species of terns (Table 2-12). All six of these species feed on fish, insects, and eggs, and as well as scavenging for other food over open water or in wetland areas (Exponent, 1998; Harrison and Greensmith, 1993). These birds tend to nest in large colonies (Harrison and Greensmith, 1993). The black (*Chilidonias niger*) and Forster's (*Sterna forsteri*) terns prefer to nest in marsh areas while the other four species prefer to nest on the ground, often on remote islands or in areas protected from predators (Exponent, 1998). The annual probability of sighting the tern species in Wisconsin ranges from approximately 25 to 45 percent, while the likelihood of sighting the two gulls is about 65 percent (Temple *et al.*, 1997). The two gulls remain in the area throughout the year, while the terns are migratory and are typically present in Green Bay from April through October (Temple *et al.*, 1997).

Forster's tern, common tern (*Sterna hirundo)*, and the Caspian tern (*Sterna caspia*) are migratory species of colonial waterbirds that breed in the Great Lakes and generally winter in more southern coastal areas. Wisconsin listed the Caspian, common, and Forster's terns as endangered species, while the state of Michigan lists the Caspian and common terns as threatened species (Table 2-12). All three of these terns are protected under the Migratory Bird Treaty Act. Due to their endangered status within Wisconsin, the locations of tern nesting areas in the Lower Fox River and Green Bay area are presented as blocks on the maps, similar to sturgeon, on Figures 2-12 and 2-21.

Based on the protected status of these three terns, a number of studies have been conducted to evaluate the remaining Green Bay populations, as well as the effects of PCB uptake through the consumption of bay fish. These birds typically nest on islands, where they are generally safe from predators. Primary nesting areas for the Forster's tern are Bay Port and Kidney Island, Long Tail Point, and

Oconto Marsh. The primary nesting areas for the common terns are on Kidney Island, while the Caspian tern nesting colonies are located on Gravelly and Gull islands, located just south of Summer Island, between Green Bay and Lake Michigan (Stratus Consulting, 1999c).

Tern populations have generally been increasing over the past 20 years. From 1978 and 1987 the nesting pairs of Forster's tern observed in the state of Wisconsin increased from 136 pairs to 435 pairs, while the population of common terns increased from 60 pairs to 600 pairs between 1979 and 1986. Similarly, the number of Caspian tern nests located on Gravelly and Gull islands increased from about 600 to over 1,000 between 1977–78 and 1991. This increase is reflective of the overall Great Lakes Caspian tern population, which has grown by at least 90 percent since the 1970s (Stratus Consulting, 1999c). These results suggest that the tern populations are recovering within the bay area and should continue to expand to a level which the region can support (Stratus Consulting, 1999c).

Both common and Forster's tern were listed in 1979 as endangered in the state of Wisconsin. To enhance population success, Forster's tern platforms have been placed at several locations in the state, including Green Bay. The six monitored island platforms in Green Bay indicated feeding, but not nesting activity. The use of nesting platforms was discontinued because of challenges associated with their placement and maintenance. For the common tern, fencing and ring-billed gull control have been used to enhance breeding success.

Around the Green Bay area, nesting Forster's terns have been reported since the late 1930s, although they were likely nesting without record prior to this period. The Forster's tern preferred habitat is around wetlands and terns feed mainly on small fish (alewife, emerald shiner, and rainbow smelt) and on some aquatic invertebrates. The uncertain population status for the Forster's tern is further supported by the variability present in historical data (Figure 2-22). Forster's tern population levels are generally believed to have declined over the past 100 years in Wisconsin due in part to marsh draining and other habitat disturbance, plume hunting, and potential chemical contamination (Mossman, 1988). For example, nesting at the Duck Creek Delta was abandoned in 1973, likely because of high water and loss of emergent vegetation; nesting pairs moved to the Bay Port Industrial Tract (Mossman, 1988). In 1987, Kidney Island was the only known nesting location in Green Bay.

Population data reported in June 1997 for the previous year indicates that for both species, population status is uncertain and requires additional study (Matteson, 1998). For the common tern, of the six colony sites recorded in the state, two are in Green Bay within the study area for this report: Kidney Island and Pensaukee Dredge Spoil Island, with an estimated number of breeding pairs of 16 and 75, respectively, for each location. For the Forster's tern, of the nine colony sites recorded in the state, two are within the study area for this report: Long Tail Point and South Oconto Marsh, with an estimated number of breeding pairs of 70 and 45, respectively, for each location.

As with the Forster's tern, both inland and coastal populations of common terns have faced recent historical population declines during the period of the 1950s to the 1980s. It is believed that these declines were due to nesting site competition with ring-billed gulls, decreased adequate habitat, high water levels, human disturbance, predation, and organochlorine contamination (Matteson, 1988). For the Great Lakes region, some of the highest population levels were measured in the 1980s. In southern Green Bay, there were 135 recorded nesting pairs in 1976, 427 in 1985, 577 in 1986, and 280 in 1987. In 1997, one common tern nesting pair was recorded at Kidney Island and 74 nesting pairs were recorded at Pensaukee (Cuthbert, 1998).

Diving Birds

Diving birds include the horned and pied-billed grebes, double-crested cormorants, common loon, and belted kingfisher. All of these birds feed on fish, diving beneath the water to capture their prey; the two grebes also feed on aquatic insects (Exponent, 1998; Harrison and Greensmith, 1993). All of the birds tend to nest along the shore or in wetlands, with the two grebes preferring shallow-water nests, while the cormorant may also nest slightly off the ground (Exponent, 1998; Harrison and Greensmith, 1993). Both the loon and kingfisher are listed as migrant birds, while the other three species are listed as partial migrants (Harrison and Greensmith, 1993).

The annual probability of sighting most of the birds ranges from 50 to over 80 percent in Wisconsin, and the best times are between March and November (Temple *et al.*, 1997). The exception is the horned grebe, which only migrates through the area to locations further north; therefore, the likelihood of sighting this bird is less than 30 percent, and chances are best between March and May and again between September and December (Temple *et al.*, 1997). None of the diving birds are listed on state or federal endangered/threatened species lists.

Double-crested Cormorants. Double-crested cormorants (*Phalacrocorax auritus*) are a migratory species of colonial waterbird that breed in the Great Lakes and generally winter in coastal areas, including Alaska. These birds nest in large communities in a variety of habitats including cliffs, grassy slopes, low bushes, or dead trees. Cormorants consume approximately 20 percent of their body weight each day and on average weigh 1.7 kg (3.7 pounds). The primary food consumed is small fish such as rainbow smelt and alewife and, as available, perch.

Numerous studies have been conducted to evaluate double-crested cormorant populations and the effects of PCBs. Prior to the 1960s, it is estimated that at least several hundred nesting pairs of cormorants were located throughout the state. During the 1960s and 1970s, the population of double-crested cormorants declined significantly and the bird was placed on the Wisconsin Endangered and Threatened Species List in 1972. At this time, only 66 nesting pairs of cormorants were present statewide, and even fewer along the Lower Fox River and into Green Bay. Beginning in 1973, state, academic, and federal agencies (WDNR, USFWS, National Parks Service, University of Wisconsin, Wisconsin Society of Ornithology) combined efforts to catalog the colony location, size, and reproductive success of the double-crested cormorant throughout Wisconsin. Following aggressive measures to protect the bird, cormorant populations recovered dramatically through the late 1970s and 1980s, and in 1986 the cormorant was removed from the Wisconsin Endangered and Threatened Species List. In 1997, 81 percent of the state breeding population, which now numbers more than 10,000 birds, nests in the vicinity of Green Bay (Matteson *et al.*, 1998; Weseloh *et al.*, 1994) which may be due in part to a decrease in commercial fishing and a resulting increase abundance of prey fish. Cormorant nesting locations along Green Bay are shown on Figure 2-21.

Prior to 1979, inland breeding populations exceeded the number of nesting birds on the Great Lakes. Since 1990, however, the Great Lakes population of double-crested cormorants has exceeded the inland population levels by approximately five times (Matteson, 1998). The nesting population in the Green Bay and Lake Michigan region, as of 1997, accounted for 81 percent of the total breeding population. The largest colonies were found in the following four locations: Spider Island, Cat Island, Hat Island, and Jack Island (Stratus Consulting, 1999c) as indicated on Figure 2-23. Of these islands, Cat Island is located closest to the mouth of the Fox River and contains the second highest density of double-crested cormorants.

Shorebirds

The shorebirds group for the Green Bay area includes eight species of plovers, sandpipers, and snipe (Table 2-12). As indicated by the name, birds within this group feed and nest along the shore, typically foraging for small crustaceans, insects, worms, and other invertebrates (Harrison and Greensmith, 1993). These birds nest along the ground, sometimes on rocky or sandy shores and others within marsh or wetland areas.

The common snipe and spotted sandpiper are the most sighted birds within this group in Wisconsin. These birds are generally present from April/May through September/October and have an annual sighting probability of about 50 percent (Temple *et al.*, 1997). The likelihood of sighting the other birds within this group ranges from approximately 15 to 25 percent as these species generally migrate further north. Therefore, these birds generally are present around May, and then may be sighted between late June and October (Temple *et al.*, 1997). The piping plover is very uncommon in the region and it is listed as an endangered species by both states as well as federally (Table 2-12).

Wading Birds

The wading birds group for the Green Bay area includes 13 species of heron, woodcock, rail, egret, bittern, and crane (Table 2-12). As indicated by the name, birds within this group typically feed in shallow, nearshore waters and emergent wetland areas. They typically forage for small fish and crustaceans, amphibians, insects, worms, and other invertebrates (Harrison and Greensmith, 1993).

Within this group, the bitterns, rails, and woodcock are generally small birds, ranging in height from 18 to 51 cm (7 to 20 inches). These birds, along with the sandhill crane, generally nest on the ground. The herons, egrets, and cranes are much larger birds, ranging from 61 to 122 cm (24 to 48 inches). The herons and egrets generally prefer to nest in trees, but will nest in marshes and lowlands if suitable habitat is not available (Harrison, 1979). Rookeries for both the great blue and black-crowned night herons are located in the 1,000 Islands Nature Conservancy as well as in Green Bay (Nikolai, 1998). Herons, woodcock, and cranes are common in Wisconsin and the UP from mid-spring through mid-fall (Temple *et al.*, 1997), as these are all migratory birds. However, the likelihood of sighting a bittern is less than 30 percent while both egrets and rails are very uncommon in the area (Temple *et al.*, 1997). The king rail, least bittern, snowy egret, and yellow rail are all included on one of the state or federal threatened or endangered species lists (Table 2-12). However, yellow rail habitat is maintained in the Seney National Wildlife Refuge, located north of Lake Michigan in the central portion of the UP, where these birds have been consistent summer residents since the 1800s (De Vore, 1999).

Waterfowl

The waterfowl of the Green Bay area includes 21 different species (Table 2-12). These birds typically feed in the water on plants, insects, aquatic organisms, shellfish, crustaceans, and occasionally on small fish (Exponent, 1998; Harrison and Greensmith, 1993). Waterfowl tend to nest in or very near water, generally preferring swamps and marshes to open-water habitat (Exponent, 1998). Some of these birds may nest in loose colonies while others nest individually.

Waterfowl are typically migratory birds; however, the location of their summer and winter destinations plays a significant role of when particular species are present in the Green Bay area. Mallard and black ducks as well as Canada geese are present in the area year-round and the annual probability of sighting for these species ranges from 50 up to about 95 percent (Temple *et al.*, 1997). Coot, teal, ruddy, and wood ducks are all present in the bay from early spring through late fall and are somewhat common, with sighting probabilities ranging from 50 to 75 percent (Temple *et al.*, 1997). A number of species migrate further north into Canada during the summer; some winter in the Green Bay region, while others migrate further south, spending only a short time in the area. The species that winter in the area include mergansers, goldeneye, the greater scaup, and bufflehead. These species are fairly common in the area, with sighting probabilities of 30 to 60 percent (Temple *et al.*, 1997). Species which pass through the region, typically found anywhere between March and May and again in October/November, include the canvasback, redhead, and ring-necked ducks, as well as the lesser scaup, northern shoveler, and whistling swan. These species area also fairly common, with sighting probabilities ranging from 35 to 55 percent (Temple *et al.*, 1997). Being migratory in nature, waterfowl are generally protected under the Migratory Bird Act. However, many of the ducks and geese included in this group are game species, with an established hunting period that occurs during October in Wisconsin and Michigan.

Since at least 1975, WDNR has completed a mid-winter waterfowl survey to evaluate the numbers of migratory waterfowl wintering along the Lower Fox River. The results from these surveys indicate that, overall, the number of migratory waterfowl in the region have increased from between 1,000 to 2,000 individuals in the 1970s to well over 4,000 individuals recently. These populations are controlled by many factors, including the severity of the winter weather and access to an adequate supply of food. However, increases in bird populations, especially among the primarily piscivorus birds, like the goldeneye and the mergansers, suggests that the populations are recovering to some degree (Nikolai, 1998).

Raptors

The raptors included in this group are the bald eagle, osprey, peregrine falcon, and merlin. The bald eagle and the osprey tend to be piscivorus, feeding on suckers, northern pike, muskellunge, bullheads, as well as small mammals, waterfowl, other birds, and carrion (Exponent, 1998; Harrison and Greensmith, 1993). Eagles and ospreys prefer open-water areas, but, when necessary, eagles will hunt in open meadow and light woodlands (Harrison and Greensmith, 1993). The two falcon species typically hunt other birds or small mammals, preferring open land, and are not generally found in heavily-forested areas (MDNR, 2000).

Typically, these birds nest in high places such as the tops of trees or rock ledges (Exponent, 1998; Harrison and Greensmith, 1993). The eagle and osprey are the most common species in Wisconsin, with an annual probability of sighting these two birds around 55 and 45 percent, respectively (Temple *et al.*, 1997). Known active and inactive bald eagle and osprey nesting locations in Green Bay are presented on Figure 2-24. The likelihood of sighting the two falcons is less than 25 percent, as both are uncommon in the area. The eagle will winter within the Green Bay/Lake Michigan area, simply moving as necessary in order to find open water for hunting (MDNR, 2000). However, the osprey and the falcons are migratory birds and generally return to the region from March through October (Temple *et al.*, 1997). The peregrine falcon is listed as an endangered species in both states and federally (Table 2-12). The bald eagle, osprey, and merlin are listed threatened species in Michigan and federally, while in Wisconsin only the osprey is listed as a threatened species (Table 2-12). These birds are also protected under the Migratory Bird Treaty Act.

Bald Eagles. Of the raptors within the Lower Fox River and Green Bay, bald eagles are of special concern because of their federally-protected status, and their known sensitivity to chlorinated hydrocarbons. Eagle populations around the Great Lakes were virtually eliminated in the 1960s—an occurrence believed to be mostly the result of chlorinated hydrocarbon toxicity (Bowerman, 1993). This correlation is supported by the fact that as DDE and PCBs were banned from use in the United States in the mid-1970s, evidence of bald eagle nesting success increased, although there was a lag time of approximately 10 years before bald eagle nesting success noticeably increased.

Bald eagles (*Haliaeetus leucocephalus*) are one of the largest raptors in North America. Their preferred habitat is one in which there is a large water-to-land edge area and where there are large areas of unimpeded view (Palmer, 1988). Eagles are not generally found in areas of high human use (EPA, 1993a). Within the Great Lakes area, some eagles are present on a year-round basis, while others are transient and winter in more southern locations (Palmer, 1988). The Green Bay region contains on of the largest number of nesting eagles in the United States, excluding Alaska (Palmer, 1988).

The return and recovery of bald eagles has been well documented in both Wisconsin and Michigan (Bowerman, 1993; Dykstra and Meyer, 1996), and includes surveys along the Lower Fox River and Green Bay. These studies have been summarized by the USFWS in the Avian Injury report (Stratus Consulting, 1999c). The following section summarizes the information taken principally from those reports.

Bald eagle populations have generally been increasing throughout the Great Lakes (Stratus Consulting, 1999c). However, despite population increases, the eagles nesting on the shores of Lake Michigan still exhibit reproductive rates lower than those of neighboring birds in inland Wisconsin and Michigan (Colborn, 1991; Bowerman, 1993). The overall productivity of Green Bay/Lake Michigan eagles was reported at more than 60 percent below the normal rate of inland Wisconsin eagles (Dykstra and Meyer, 1996).

The return of the bald eagle to Green Bay began in 1974, when a single pair of nesting eagles was observed. Both the WDNR and the MDNR initiated annual surveys, and between 1974 and 1986 only one to two pairs of nesting eagles were observed in Green Bay and the eastern side of the Door Peninsula. Beginning in 1987, nesting pairs increased and by 1997 there were 14 nesting pairs (Figure 2-25) (Stratus Consulting, 1999c). Bald eagles returned much later to the Lower Fox River. The number of breeding pairs of eagles nesting along the Lower Fox River went from one in 1986 to three in 1994 to two since 1995 (Stratus Consulting, 1999c).

Bald eagles arrive back at their nesting territories in the assessment area in February, and the young fledge between early June and July. Depending upon ice conditions, bald eagles may remain in the assessment area during the winter; up to 12 have been recorded in December on the Lower Fox River (Howe *et al.*, 1993). Thus, breeding bald eagles spend a substantial part of the year in the assessment area.

Figures 2-9, 2-10, and 2-24 show the nesting locations within the Lower Fox River and Green Bay. There are two active nests within the Lower Fox River: one within the Little Lake Butte des Morts Reach (Figure 2-9), and one at Kaukauna in the Appleton to Little Rapids Reach (Figure 2-10). Within the bay (Figure 2-24), there is one nest active in Green Bay Zone 2, two nests in Zone 3A, and nine nests were active in Green Bay Zone 4. There are no reported nests in Zone 3B along the Green Bay side of the Door Peninsula, but there is a single active nest at the northernmost tip on the Lake Michigan side.

Overall, nesting success for Wisconsin bald eagles remains high. The most recent census for Wisconsin was conducted by WDNR in 1997, and showed that of the 632 active nests throughout Wisconsin, a total of 739 young were produced. However, productivity within Green Bay bald eagle nests remained significantly reduced, relative to nests in inland Wisconsin and Michigan (Figure 2-26) (Dykstra and Meyer, 1996). Mean annual production rates for the inland nests has been at, or exceeded one young per nesting annually; a rate necessary to maintain a healthy, self-reproducing population (Kubiak and Best, 1991). In contrast, Green Bay nests have oscillated considerably between no to few young in the late 1970s to 1994, to only recently achieving at, or above one per nest (Stratus Consulting, 1999c). By contrast, the nests within the Lower Fox River produced greater than one young per active nest, with the nest at Kaukauna producing two to three per nest since 1988, and the Mud Creek nest (near Little Lake Butte des Morts) between one and three per nest since 1994 (Table 2-13).

Mammals

Important small mammals that utilize the aquatic resources of the Lower Fox River/Green Bay basin include beaver, mink, muskrat, raccoon, and river otter. Beaver is found in several of the feeder streams to the river and bay, and may be an incidental user, but is not considered to be resident. Both muskrat and otter are found in Green Bay. Muskrat are principally habitat-limited to backwater sloughs or marshes. Raccoons are ubiquitous throughout the basin. Otter returned to the Lower Fox River area sometime in the mid-1980s and mink slides and scat are observed during mid-winter surveys; however, populations of both animals are low (Nikolai, 1998).

There is only anecdotal information concerning mink populations along the Lower Fox River (Patnode, 1998). WDNR trapping records show mink upstream of Little Lake Butte des Morts, but there are no records downstream of the lake (WDNR, unpublished data). This information may indicate that the mink population is restricted by lack of appropriate habitat or due to high contaminant levels in this part of the river. A review of studies in which PCB uptake in mink were studied will be included in the BLRA.

A study to evaluate possible impacts to bat populations may also be undertaken by WDNR (Rezabeck, 1998). Like tree swallows and other birds mentioned in the previous section, bats also feed on insects found in and above the waters of the Lower Fox River and Lake Winnebago. A bat colony located in the bluffs of the Niagara escarpment east of the Lower Fox River may be studied as part of such an effort. In addition, there is a likely bat colony in the Red Bank Glades Scientific Area just north of the mouth of the Fox River (Nikolai, 2000).

2.5.9 Mink

A summary of suitable and preferred mink habitat is presented below. In addition, information regarding the domestic production of mink in Wisconsin is also presented because it was mink ranchers and associated researchers who first found that PCBs had a detrimental influence on mink reproduction and mortality. Therefore, a brief summary of the mink farming operations in Wisconsin is included.

Mink Habitat

Mink are semi-aquatic, predatory mammals associated with lakes, streams, rivers, and marshes. Mink are generally nocturnal creatures that feed on fish, crayfish, waterfowl, muskrat, rabbits, and rodents. The availability of prey greatly influences the density and distribution of mink populations in a given area. Mink are active throughout the year, feeding on whatever prey is available (USFWS, 1986). Their dens are generally located near the water's edge and studies suggest mink typically remain within 200 meters (660 feet) of open water. In Michigan, studies indicated that mink are most commonly associated with brushy or wooded areas adjacent to aquatic habitats. Preferable foraging and den areas in wetland environments include dense vegetation and irregular shorelines, while the preferred lacustrine habitat include small oligotrophic lakes with stony shores. Streams or rivers surrounded by either marsh vegetation or abundant downfall/debris provide cover and pools for foraging. Studies in Quebec, Canada show that mink activity decreases as stream flow increases. Additionally, the channelization of rivers in Mississippi and Alabama caused a decline in mink populations as it was accompanied by a decrease in shoreline configuration diversity, loss of aquatic vegetation, and reductions in prey availability and habitat quality (USFWS, 1986).

Channelization of the Lower Fox River has contributed to a general decline of mink habitat in the region. The habitat suitability, as determined by Exponent (1998), was based on shoreline characteristics included in WDNR wetland maps and WISCLAND GIS maps of the project area and are shown for the Lower Fox River on Figures 2-27 through 2-32. The suitability definitions are as follows:

- **Good:** forest shrub/scrub, forest wetland, broadleaf deciduous, or lowland wetland areas;

- **Moderate:** emergent wetland, meadow, or wetland less than 0.8 hectares (2 acres);

- **Marginal:** grassland or agricultural areas;

- **Poor:** golf course, low-intensity urban (obtained from land use maps only); and

- **Unsuitable:** aquatic beds/flats, open water, barren, or high-intensity urban.

As previously discussed, much of the shoreline has been developed between Neenah and Kaukauna and between De Pere and Green Bay. Most of the shoreline in the Little Lake Butte des Morts Reach and between Appleton and Kaukauna is characterized by Exponent as either “poor” or “unsuitable” on Figures 2-27 and 2-28, respectively. This reflects the development of these areas. However, in the less developed areas of the Appleton to Little Rapids and Little Rapids to De Pere reaches, large tracts of the shoreline are characterized as “marginal” to “good” habitat (Figures 2-28 and 2-29, respectively). Mink habitat suitability in the De Pere to Green Bay Reach is largely characterized as “unsuitable” (Figure 2-30), which is similar to the Little Lake Butte des Morts Reach.

Mink habitat suitability for Green Bay zones 2 and 3 is presented on Figures 2-31 and 2-32, respectively. In Zone 3, mink habitat suitability characterization efforts in Green Bay extended only just beyond Marinette on the west side and Sturgeon Bay on the east side. The shoreline in Green Bay zones 2A and 3A, on the west side, are generally characterized as “marginal” to “good” (Figures 2-31 and 2-32, respectively). The habitat in Zone 2B is generally characterized as “poor” to “unsuitable,” although “moderate” to “good” habitat is present with increasing distance from the mouth of the Lower Fox River (Figure 2-31). The habitat suitability in Zone 3B is generally characterized as “moderate” to “good” except in areas where development has occurred, such as the cities of Dyckesville and Sturgeon Bay (Figure 2-32).

Domestic Mink Production in Wisconsin

Due to demand, mink have been raised domestically to provide a reliable source of pelts. Wisconsin has long been a leader in the production of domesticated mink. According to NASS (2000) data, the 82 mink farms in Wisconsin produced the most mink pelts (almost 732,000) in the United States during 1999. Additionally, the NASS (2000) data for Michigan indicate that 13 farms produced 51,000 pelts in 1999.

In the late 1950s and early 1960s, mink ranchers in Wisconsin and other areas bordering the Great Lakes faced a crisis as production rapidly decreased due to the mortality of mink kits and infertility of female mink (Gilbertson, 1988). In the 1960s and 1970s, researchers concluded that PCBs in Great Lakes fish (specifically coho salmon from Lakes Michigan and Erie) adversely affected domestic mink production, causing reproductive failure in the females and mortality in both kits and adults. Female mink that were fed fish containing PCBs often failed to mate, and when they did, the mortality rate of the kits often approached 100 percent (Gilbertson, 1988). PCBs accumulate in the brain, liver, and kidneys of the mink and concentrations of about 5 to 11 ppm were present in these organs following death. Further, a wild mink found in a marsh located along Green Bay had a similar kidney PCB concentration as those observed during laboratory studies (Gilbertson, 1988). These results suggest that PCBs affect both wild and domesticated mink populations.

Wild Mink in the Study Area

Wild mink population estimates for Wisconsin and Michigan are not available. Approximately 22,600 mink were trapped in the state of Wisconsin in 1998 through 1999 (WDNR, 1999b). However, these records do not indicate how many were collected in the counties along the Lower Fox River or Green Bay.

WDNR has approximately 40 laboratory reports (unpublished data) from analysis of mink tissue and organ samples from specimens trapped in 1992 and 1994. The results indicate that PCBs, as well as mercury and other metals, are present in these wild mink tissues/organs. The majority of the mink were trapped within Marinette County, but others were taken in Brown, Oconto, and Winnebago counties as well. Typically, these reports include only general trapping location information. Because these mink were collected more than 6 years ago, assessing the current health and stability of wild mink populations in the area is not practical from these analytical results.

2.5.10 Otter

WDNR harvest records for 1998 through 1999 suggest that otter are present in the counties along the Lower Fox River and west side of Green Bay, but not in counties along the east side of the bay. This may either be due to habitat requirements or it may reflect the influence of chemical contamination. Because the WDNR records do not indicate where selected fur-bearing species are trapped (other than a specific county) it is difficult to assess which factor (habitat or chemical contamination) is more restrictive. WDNR (1999b) records show that a combined 26 otters were collected in Outagamie and Winnebago counties while 56 otters were collected in Marinette and Oconto counties separately in 1998 through 1999. However, only one otter was taken in Brown County (WDNR, 1999b). According to Gilbertson (1988), no otters were trapped in Door and Kewaunee counties in 1984 and the 1998 through 1999 harvest records suggest that this trend continues (WDNR, 1999b).

Endangered and Threatened Species

A number of different animals have been or are currently on the Wisconsin, Michigan, or Federal Endangered and Threatened Species lists. Listed animals which have historically been found in the vicinity of the Lower Fox River or Green Bay include: osprey, common tern, Forster's tern, Caspian tern, and great egret (Matteson *et al.*, 1998). The osprey, common tern, and Forster's tern have nested along the Lower Fox River as well as at upstream locations in Lake Winnebago, Little Lake Butte des Morts, and Lake Poygan. Osprey have been sighted near

Kaukauna and have attempted to nest in the vicinity of Combined locks, while terns have been observed farther upstream. Additionally, Caspian tern and great egret have nested on some of the islands located in Green Bay. Very few nesting pairs have been observed over the past few years and recovery of these populations is slow (Matteson *et al.*, 1998).

In addition to these birds, the WDNR reported a bed of clams or mussels which may be threatened. The sediment bed which these clams/mussels inhabit is approximately 6 meters (20 feet) wide and 30.5 meters (100 feet) long and is located near the mouth of Mud Creek in the Lower Fox River (Szymanski, 1998, 2000).

As mentioned above, populations of both eagles and the double-crested cormorants have recovered to the point where both birds have been removed from the Wisconsin endangered species list. Other populations, specifically, wild mink and otter, have been found to be declining around the Lower Fox River and Green Bay, yet they are not currently listed by state or federal agencies. The endangered and threatened fish and birds of the region were listed on Tables 2-11 and 2-12. The endangered and threatened mammals of the region are listed in Table 2-14.

2.6 Time Trends of Contaminants in Sediment and Fish

A time trends analysis was conducted on sediments and fish tissue within the Lower Fox River and Zone 2 of Green Bay in order to assess whether statistically significant changes in PCB concentrations were occurring. For the purposes of the BLRA, it was important to understand if apparent or implied decreases in PCB concentrations in sediments and fish tissue were real, and if so, determine if the rate of change could be estimated. A brief description of the methods and results is given below. The detailed analysis may be found as Appendix G of the Remedial Investigation (RETEC, 2002a).

2.6.1 Sediment Methods

For sediments, the overall approach was to first review the data for usability, then explore relevant groupings of the data both horizontally and vertically to conduct regression-type analyses for increases or decreases in PCB concentrations over time. All data used in these analyses were from the Fox River database.

Exploratory analysis demonstrated that PCB concentrations varied across locations in the river. To adequately conduct the analysis of time trends, it was necessary to undertake a separate evaluation of the spatial layout; a horizontal evaluation within the river bed and a vertical evaluation with each depth stratum.

The deposit designations used in the RI/FS (e.g., A, POG, EE, or SMU 26, shown on Figures 2-2 through 2-5) were found to be unsuited to defining spatially-cohesive subsets, as many samples had no deposit designation and some deposit designations spanned stretches of a river reach too long to allow adequate assessment and control of spatial structure. Based upon analysis of the spatial layout, 23 distinct geographic "deposit groups" were determined, forming data subsets with spatial structures far more amenable to statistical analysis. These were given designations that reflected the general deposit designations in the RI/FS, with the added benefit that these groups designated non-overlapping spatial sets. The statistical groups analyzed are shown on Figures 2-33 through 2-35.

Depth strata within each deposit group were consistent with the RI/FS: 0 to 10 cm (0 to 4 inches), 10 to 30 cm (0.33 to 1 foot), 30 to 50 cm (1 to 1.6 feet), 50 to 100 cm (1.6 to 3.3 feet), and 100+ cm (3.3+ feet). Sample groups defined by a specific deposit and depth stratum were analyzed separately for the time trends. Depth strata within some deposits were excluded due to either inadequate sample size or lack of time variation. After averaging samples from a common sediment core within a particular stratum, 1,618 observations in 46 combinations of deposit and depth were included in the sediment time trends analysis. PCBs were analyzed as the logarithm of PCB concentration (in μg/kg) due to the approximately lognormal distribution of these values.

Spatial correlation among observations was determined using semivariograms, a common technique in geostatistics. In order to avoid overstating statistical significance of time trends in the presence of spatially-correlated observations, the Window Subsampling Empirical Variance (WSEV) (Heagerty and Lumley, 2000) estimation method was used. WSEV is analogous to averaging observations within cells of a grid, where the grid size is specified such that sample subsets falling into different cells of the grid are approximately independent of each other. The WSEV method yields a proper estimate of variance that can be used to calculate statistical significance.

The WSEV method for handling spatial dependence was used in conjunction with a standard method for estimating time trends; regression analysis. Regression models for log PCB concentration versus time, depth, and linear and quadratic spatial coordinates were fitted using the method of maximum likelihood, which readily incorporates the observations below detection limit without imputation of a value such as half the detection limit. Throughout the analysis, significance levels of $p < 0.05$ from regression analysis or from any other analysis were designated as "statistically significant."

2.6.2 Fish Methods

Like sediments, the approach for examining time trends in fish tissue PCB concentrations was to first review the data, then explore relevant groupings of the data on which to conduct regression-type analyses. In addition to the four reaches of the Lower Fox River, fish time trends were examined in Green Bay Zone 2. This was undertaken to determine whether PCB exposure in Zone 1 and Zone 2 were identical (i.e., represent a single exposure unit), or if there were distinct trends in these two zones for the target fish species. Fish tissue data from those two zones were explored first to ascertain whether they represented a single or separate exposure units (i.e., have different time trends for PCBs). This was conducted to determine whether the data should be combined for a single analysis, or to conduct separate time trends analyses for the two zones.

All data used in these analyses were from the Fox River Database. A total of 1,677 fish samples were available for analysis, divided into three main sample types: fillet without skin, fillet with skin, and whole body. Inadequate sample size presented the greatest obstacle to analysis. There were several cases where there were substantial data, but there was inadequate spread in the years between collections. It should be noted that within the Little Rapids to De Pere Reach, there with no fish groups with both sufficient sample size and time spread. There were over a hundred combinations of reach, species, and sample type with at least one observation, but only 19 of these had sufficient numbers of samples and a sufficient time spread for analysis of time trends. Carp and walleye provided the largest number of observations of any species. These 19 combinations represent 867 samples—over half of all samples of whole body, fillet with skin, and fillet without skin. In addition to the 19 combinations, there were four analyses which could statistically combine samples from the fillet and whole body categories (within a single reach and single species) to come up with a single time trend estimate.

Data on PCBs in fish were analyzed as the logarithm of PCB concentration in micrograms per kilogram. The percent lipid content of samples was significantly associated with PCB concentration in most species and sample types, and was thus used as a normalization term in all analyses.[3]

Regression models for PCB concentrations versus time were fitted using the logarithm of percent lipid content and time as independent variables. A linear spline function was included in some time trends analyses to accommodate

[3] Note that fish concentrations of PCBs were not normalized by dividing by lipid content of samples. Thus, the concentrations are expressed as log micrograms of PCBs per kilogram of tissue rather than per kilogram of lipid.

different rates of change in PCB concentrations during earlier versus later periods. The maximum likelihood method was used to accommodate observations below detection limit. A test for changing trends was also carried out.

The difference in fish PCB concentrations between Green Bay Zone 1 (De Pere to Green Bay Reach) and Green Bay Zone 2 was analyzed using both cross-sectional data (five analyses) and time trends data (three analyses), again controlling for percent lipid content of samples in regression models. All regression models for the fish analysis were fitted using the maximum likelihood method to accommodate the small fraction of observations below the detection limit.

2.6.3 Results

Results of the sediment time trends are presented in Table 2-15, and are represented graphically on Figures 2-33 through 2-35. Seventy percent of all calculated slopes (32 out of 46) were negative. However, only 13 out of the 46 slopes were statistically significant, such that a hypothesis of no change in PCB concentration over time could be rejected. Of those, 10 were negative,[4] and within that subset eight were in the 0- to 10-cm (0- to 4-inch) segment.

Conducting a meta-analysis on the surface sediment data showed a negative trend in all reaches except Appleton to Little Rapids (Table 2-16). A meta-analysis of time trends in surface sediments yielded an average rate of decrease in PCB concentration per year of -18 percent in Little Lake Butte des Morts, +0.6 percent in the Appleton Reach, -10 percent in the Little Rapids Reach, and -15 percent in the De Pere Reach. These trends were statistically significant except for the Appleton Reach.

While those data suggest an overall decline in PCBs in the Lower Fox River, a more careful analysis of the subsurface data suggest that these declines are restricted to the upper 0 to 10 cm (4 inches). While 32 out of the 46 analyses were negative, there is a strong trend toward fewer and weaker negative slopes at increasing depth. Table 2-15 and Figure 2-33 show in general that the subsurface deposits do not show a significant decline in PCB concentrations. For Little Lake Butte des Morts, the figures suggest that there is a generally increasing trend in subsurface PCBs, and an indeterminate mixture of trends that is not distinguishable from zero in the Appleton and De Pere reaches. For Little Rapids to De Pere, there are consistently negative trends in the 10- to 30-cm (0.33- to 1-foot) strata, but in the lower strata, the data are consistent with either zero trend

[4] A negative slope indicates decreasing PCB concentrations; a positive slope indicates increasing PCB concentrations over time.

(30 to 50 cm [1 to 1.6 feet]), or an increasing trend (50 to 100 cm [1.6 to 3.3 feet]).

These results suggest that over time, the surface sediment concentrations of PCBs have been steadily decreasing. However, numerically this was difficult to define, and depended upon the specific deposits or sediment management units. PCB concentrations in sediment suggest declines, but a large fraction of analyses provided little useful trend information. A large fraction of sediment analyses yielded imprecise or inconclusive trends such that positive, negative, or zero trends are consistent with the data.

Like sediment PCB concentrations, fish tissue PCB concentrations showed a significant but slow rate of change throughout the lower Fox River and lower Green Bay (Table 2-17). Initial exploration of the data demonstrated that there were statistically significant declines in tissue PCB concentrations in all species in all reaches. More detailed analyses were then conducted to determine if there had been a constant linear rate of decline, or if significant changes in the rate of decline, or "breakpoints," could be identified. Among fish time trends analyzed, nine out of 19 combinations of reach, species, and sample type showed a statistically significant change in slope during earlier and later periods. In all of the reaches of the river, and in Zone 2, there were steep declines in fish tissue PCB concentrations from the 1970s, but with significant breakpoints in declines beginning around 1980. After the breakpoint, depending upon the fish species, the additional apparent declines were either not significantly different from zero, or were relatively low (5 to 7 percent annually). However, for two species there were increases in PCB concentrations after the breakpoint; walleye in Little lake Butte des Morts and carp in Green Bay Zone 1.

Most slopes were negative, and all statistically significant slopes were negative. Over the period of analyzed data, percentage rates of decrease were usually between -5 and -10 percent per year (compounded). Percent lipid content of tissue was significantly related to PCB concentration in 16 out of the 19 analyses. Specific trends in sediment and fish by reach are discussed below.

Little Lake Butte des Morts

Time trend results for sediments in Little Lake Butte des Morts are presented in Table 2-15 and on Figures 2-33 through 2-35. With the exception of two strata at 10 to 30 cm (0.33 to 1 foot) in two separate deposit groups, slopes are negative (9 out of 11 analyses). However, statistically significant negative slopes (decreasing PCB concentration over time) was found only in surface sediments (0 to 10 cm [0 to 4 inches]) of four deposit groups (AB, D, F, GH). The estimated rates of decrease ranged from 8 to 24 percent per year, with wide confidence intervals for these rates of change; a rate of decrease of as little as 1 to 5 percent and as much as 15 to 43 percent per year. While the slopes were negative, there were no significant trends at deposits C or POG. In fact, for POG the estimated annual slope was -18.6 percent per year, but the upper and lower confidence bound on the estimate ranged from -43.3 to +16.9 percent per year.

When pooled across all deposits, there was an estimated significant ($p < 0.001$) average annual decrease of -15 percent of surface concentrations (Table 2-16) within the period supported by the data. It is important to note that on a reach basis, the 95 percent confidence intervals around the estimated average were 22 percent, up to 8 percent annual rate of decrease.

The only statistically significant increasing trend of PCB concentrations occurs at 10 to 30 cm (0.33 to 1 foot) in Deposit Group D, where the rate of increase is 108 percent per year. The confidence interval for the significantly increasing slope at 10 to 30 cm (0.33 to 1 foot) in Deposit Group D indicates a rate as low as 59 percent and as high as 171 percent per year. The Time Trends Analysis Report noted that this must represent a temporary positive trend because a projection of the PCB concentration even at the minimum of 59 percent per year would yield an absurd 10,000-fold increase in PCB concentration after 20 years.

Caution needs to be used in the interpretation of the estimated average decrease within this reach. As noted previously, there were wide confidence intervals around all estimates for the sediment deposit groups. While the mass-weighted time trend for surface sediments indicated a significant decrease, the fact that the estimate did not include Deposit E, the largest depositional area within the reach, must be considered. There were insufficient data to conduct the analysis for Deposit E, and thus the sediment time trend is somewhat skewed by the lack of inclusion here.

For the fish examined in this reach, an early rapid decline was observed until around 1987, followed by either a slower decline or a flattening without further decline, depending upon the species (Table 2-17). Within this reach, time trends were conducted on carp and walleye (skin-on fillet and whole body), and northern pike and perch (skin-on fillet). For carp, the breakpoints identified for the skin-on fillet and whole body were 1979 and 1987, respectively. Walleye data fillet and whole body data show that the breakpoint occurs between 1987 and 1990. The fillet data suggests no change in concentration after the breakpoint, while the whole body data showed a sharp rate of increase (22 percent per year). However, the latter analysis, when tested, was not significantly different from zero. For northern pike skin-on fillets, the analysis showed no breakpoint, but a constant rate of decline of 12 percent per year. By contrast, yellow perch skin-on fillets declined sharply until 1981, and have since remained at constant levels. A meta-analysis conducted on all fish data combined yields a statistically significant, but slow rate of decline of 4.9 percent (range 2.1 to 7.5 percent decrease) per year.

Appleton to Little Rapids

For this reach, there were only sufficient data to evaluate Deposit Group IMOR, Deposit N (pre-demonstration dredging), and Deposit Group VCC. For these three groupings, surface sediments at IMOR showed an estimated annual increase of 9.9 percent, while the other two showed decreases in total PCB concentrations. While Deposit N surface sediments were found to be significant, there were non-significant increases observed in the subsurface sediments. Again, confidence limits around the estimated mean for all deposits was wide. Meta-analysis for the reach showed a non-significant increase of 0.6 percent per year.

For fish in this reach, the only tissue type with sufficient numbers and time spread of data were walleye skin-on fillet. Analysis of those data showed a relatively constant rate of decline of 10 percent (range 5.6 to 17.9 percent decrease) per year.

Little Rapids to De Pere

Time trends in sediments for this reach have a majority of negative slopes; but two of only three significant slopes were negative and occur in the 0- to 10-cm (0- to 4-inch) and 10- to 30-cm (0.33- to 1-foot) depth strata. One large, positive, statistically significant slope occurs at the 30- to 50-cm (1- to 1.6-foot) depth (Table 2-15, Figure 2-34).

The surface sediment (0 to 10 cm [0 to 4 inches]) in the Lower EE Deposit Group has a significantly negative slope ($p = 0.04$), implying a rate of decrease of 15 percent per year with a 95 percent confidence interval of 2 to 26 percent rate of decrease per year. In the same deposit group, the deeper 30- to 50-cm (1- to 1.6-foot) stratum shows a significantly positive slope, indicating a rate of increase of 23 percent per year and a 95 percent confidence interval of 4 to 46 percent per year. In Deposit Group FF, the 10- to 30-cm (0.33- to 1-foot) layer has a significantly negative slope with a rate of PCB concentration decrease of 20 percent per year with a 95 percent confidence interval of 1 to 35 percent. Again, while the estimates speak to significant decreasing or increasing PCB concentrations over time in these strata and deposit group combinations, the analysis showed wide confidence intervals. For surface sediments, the annual change ranged from an increase of 19.1 percent per year to a decrease of 33 percent per year.

Although only one surface sediment has a statistically significant decline, the mass-based meta-analysis found an overall statistically significant combination of declining PCB concentrations in the reach, with a slope of -0.046 per year ($p = 0.01$), implying a 10 percent per year rate of decrease (95 percent confidence interval: -17 to -2 percent). While some uncertainty may persist in the individual surface deposits, the PCB mass in the surface of this reach appears to be generally declining as of the mass estimation date, 1989 through 1990.

As noted previously, there were not sufficient fish tissue data for analysis of time trends.

De Pere to Green Bay (Zone 1)

The time trends analysis for surface sediments in this reach showed primarily negative slopes (Table 2-15). Statistically significant negative slopes were found in only three combinations of deposit group and depth. SMU Group 2649 showed a significantly negative slope ($p < 0.001$) in the surface deposit (0 to 10 cm [0 to 4 inches]), with a rate of decrease of 13 percent per year (95 percent confidence interval of 8 to 17 percent decrease per year). SMU Group 5067, 0 to 10 cm (0 to 4 inches), also has a significantly negative slope ($p = 0.01$) implying an annual rate of decrease of 21 percent (95 percent confidence interval of 5 to 33 percent). In the same SMU group (5067), at a greater depth of 50 to 100 cm (1.6 to 3.3 feet), a significant ($p = 0.003$) and large positive slope with a rate of increase of 133 percent per year (95 percent confidence interval of 56 to 250 percent) was observed.

It is important to note that an exceptionally high value of PCB concentration in SMU Group 5067 was excluded from the analysis. Sample A3_0-4 had a concentration of 99,000 ppb, whereas all other samples in the 0- to 10-cm (0- to 4-inch) stratum in this deposit ranged from 400 to 7,800 ppb. In a statistical sense, the sample is an "outlier," but that does not imply error in the value of 99,000.

For fish, Green Bay Zone 1 and Zone 2 PCB exposures were found to be significantly different. This difference was determined using two methods: 1) cross-sectional analyses, which compared fish PCB concentrations within a single year (e.g., 1989 data only) between the zones; and 2) estimating the significant differences between time trend slopes calculated separately for the two zones. Four out of five cross-sectional analyses showed statistically significant differences, either in the relationship of lipid content and PCB concentration or in the mean PCB concentration, while controlling for lipid content. All three time trend analyses comparing the two zones showed significantly different trends in the two reaches. Thus, the time trends in the two zones were handled separately.

For Zone 1, there appears to be a significant but slow rate of decline for most fish species tested with no breakpoint identified. The exception to this pattern were carp, which showed a breakpoint in 1995, and steep significant increases in PCB concentrations of 22 percent per year. Other fish tested within the reach included gizzard shad, northern pike, walleye (fillet and whole body), white bass, and white sucker. With the exception noted for carp, all species showed a rate of decline in PCB concentrations of between 5 and 10 percent annually. Combining all data showed that there is an average rate of decline of 7 percent per year.

Green Bay Zone 2

Zone 2 shows decreasing trends with no significant breakpoints in most species tested, including carp. Significant decreases of between 4 and 15 percent annually were found in alewife, carp, and yellow perch. The exception to this was gizzard shad, which showed a significant increasing trend of 6 percent PCBs in tissues per year.

2.6.4 Conclusion

The objective of the time trends analysis was to determine if PCB concentrations in the Lower Fox River were decreasing over time. For PCB concentrations in surface sediment, the data suggest an overall decline. PCB concentrations in surface sediments in the Lower Fox River are generally decreasing over time, but apparent detectable loss is limited to the top 10 cm (4 inches) of sediment. The apparent declines observed in surface sediments is consistent with the continued observed transport of PCBs from the river to Green Bay, as discussed in Section 2.4. The rate of change in surface sediments is both reach- and deposit-specific. The change averages an annual decrease of 15 percent, but ranges from an increase of 17 percent to a decrease of 43 percent. A large fraction of analyses provided little useful information for projecting future trends because of the lack of statistical significance and the wide confidence limits observed. This is especially true for sediments below the top 10 cm (4 inches); changes in the sediment PCB concentrations cannot be distinguished from zero, or no change.

PCB concentrations in fish are also generally decreasing over the analysis period. The changes in PCBs in the sediments are reflected in the significant but slow declines in fish tissue concentrations of between 5 and 7 percent annually. Exceptions to the general overall decline were noted with walleye in Little Lake Butte des Morts, carp in Green Bay Zone 1, and gizzard shad in Zone 2 where significant increases in PCB concentrations were observed. In all reaches, a breakpoint was observed in the fish tissue declines. The presence of an earlier slowing of rates of decrease in fish, along with a more recent phenomenon of changing trends in some species and sample types, suggests that fish time trends are changeable. Since PCBs in fish are derived from PCBs in sediment, the sediment rates of change may also be changeable.

It is important to note that the trends discussed are limited to the period of time for which data existed. These analyses are not suitable for projecting trends; the data do not provide the assurance of a future steady or rapid decline in PCB concentrations. Even though there are a number of negative time trends that suggest PCB declines, future projections of PCB concentrations in sediments and fish are highly uncertain. Over the period of data collection, surface sediments and fish species have, on the average, declined in PCB concentrations. Yet the presence of increases in PCB concentrations in deeper sediments, and of breakpoints and other non-linear phenomena in fish PCB time trends (on the log scale), suggest that the river, its sediment, and its species may be experiencing an arrest or reversal of such a decline. The analyzed data do not assure continued PCB decreases over time.

The time trends analysis dealt strictly with the testing of changes in PCB concentrations over time, and not with the mechanisms that could control changes in sediment and tissue loads. As discussed in Section 2.4, studies have shown that PCBs are being transported out of the Lower Fox River into Green Bay, while PCBs in Green Bay migrate into Lake Michigan. Therefore, PCB dispersal is one factor in the observed PCB declines. In addition, some of the variability observed in the data may be accounted for by changes in river profile, burial, scour by flood or ice, and propeller wash in the lower reaches of the river. As the analysis focused solely on the existing data, these potential mechanisms could not be adequately controlled or accounted for.

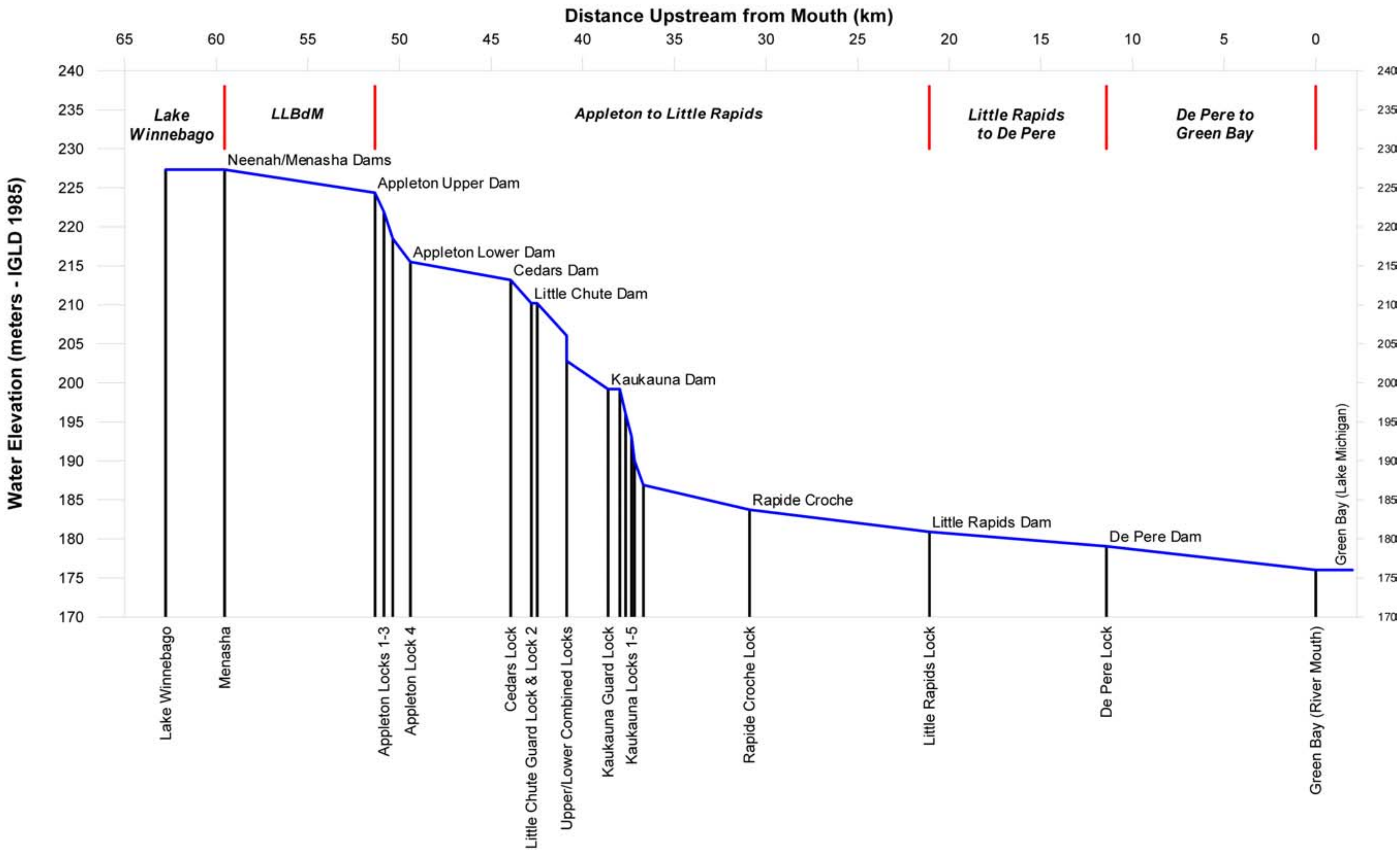
The conclusions of a general decrease in PCB burdens in sediments and fish of the Lower Fox River and in Zone 1 of Green Bay are consistent with findings by other researchers in the Great Lakes. Deceases in PCB concentrations have been observed in Lake Michigan (Offenberg and Baker, 2000; DeVault *et al.*, 1996; Lamon *et al.*, 1998), Lake Ontario (DeVault *et al.*, 1996; Gobas *et al.*, 1995) and Lake Superior (Smith, 2000). The yearly rate of decline for PCBs in biota and sediment of Lake Superior has been estimated at 5 to 10 percent per year (Smith, 2000), which is generally consistent with the trends observed in the Lower Fox River. However, several other researchers have also noted breakpoints, or constant levels of PCBs beginning in the mid- to late 1980s. Lake trout and smelt are reported to have been relatively constant in Lake Ontario since 1985 (Gobas *et al.*, 1995). PCB body burdens in Lake Erie walleye were shown to be declining between the periods of 1977 and 1982, but after that period remained constant through 1990 (DeVault *et al.*, 1996). Time tends analysis for salmonids in Lake Michigan showed generally decreasing tissue concentrations, but upper-bound forecast estimates for lake trout and chinook indicated that there would be a steady, or slightly increasing annual average PCB concentration. These findings are consistent with the time trends analysis for the Lower Fox River, and suggest that there may continue to be slow, gradual declines, or steady-state concentrations for many years to come.

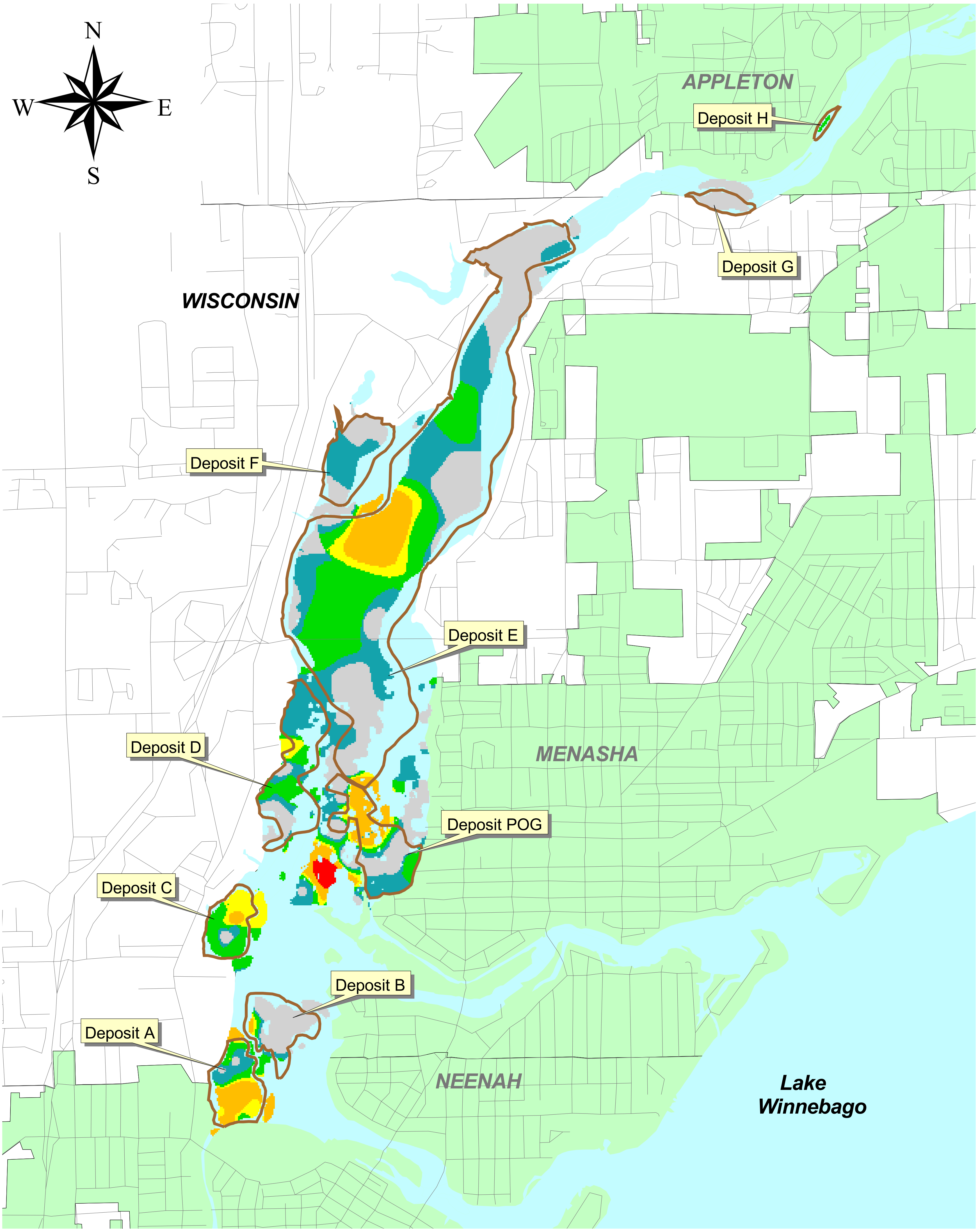
Given the potential for disturbance and redistribution of sediments, which has been observed in the past due to scouring, there is a high degree of uncertainty in projecting future PCB concentrations in sediments and fish. Given this, coupled with similar observations for sediments and fish on other Great Lakes systems, there is too much uncertainty to apply the information to human health or ecological risk analysis. The current Fox River data shows wide confidence limits on slopes. Some important game fish such as walleye or carp, as well as forage fish (gizzard shad) show increasing PCB levels.

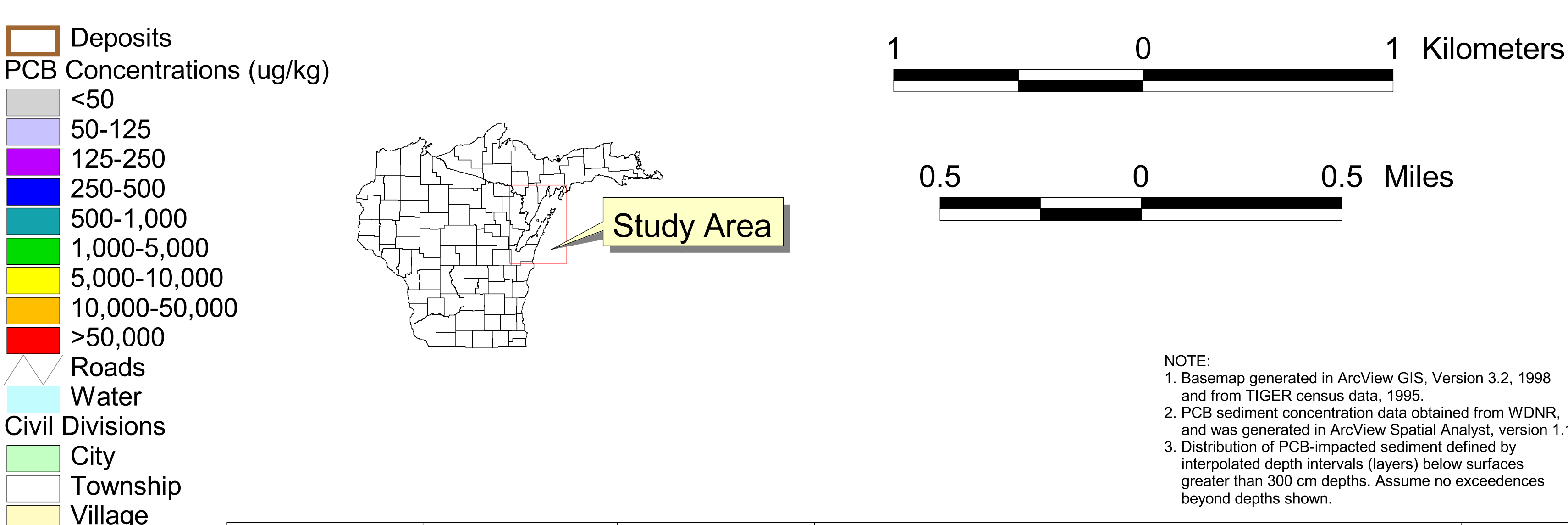
2.7 Section 2 Figures and Tables

Section 2 figures and tables follow page 2-84 and include:

Figure 2-1 Lower Fox River Elevation Profile

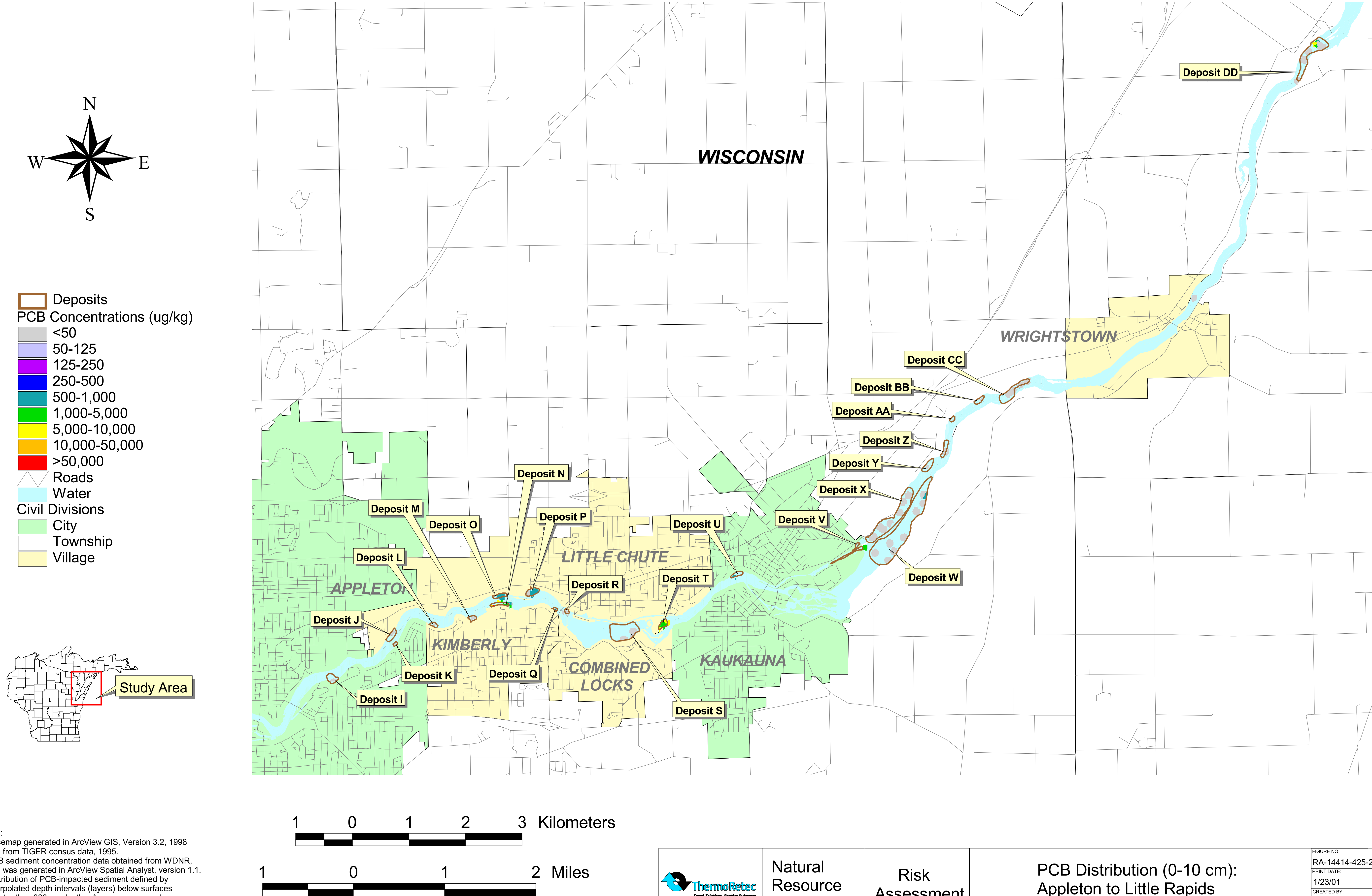






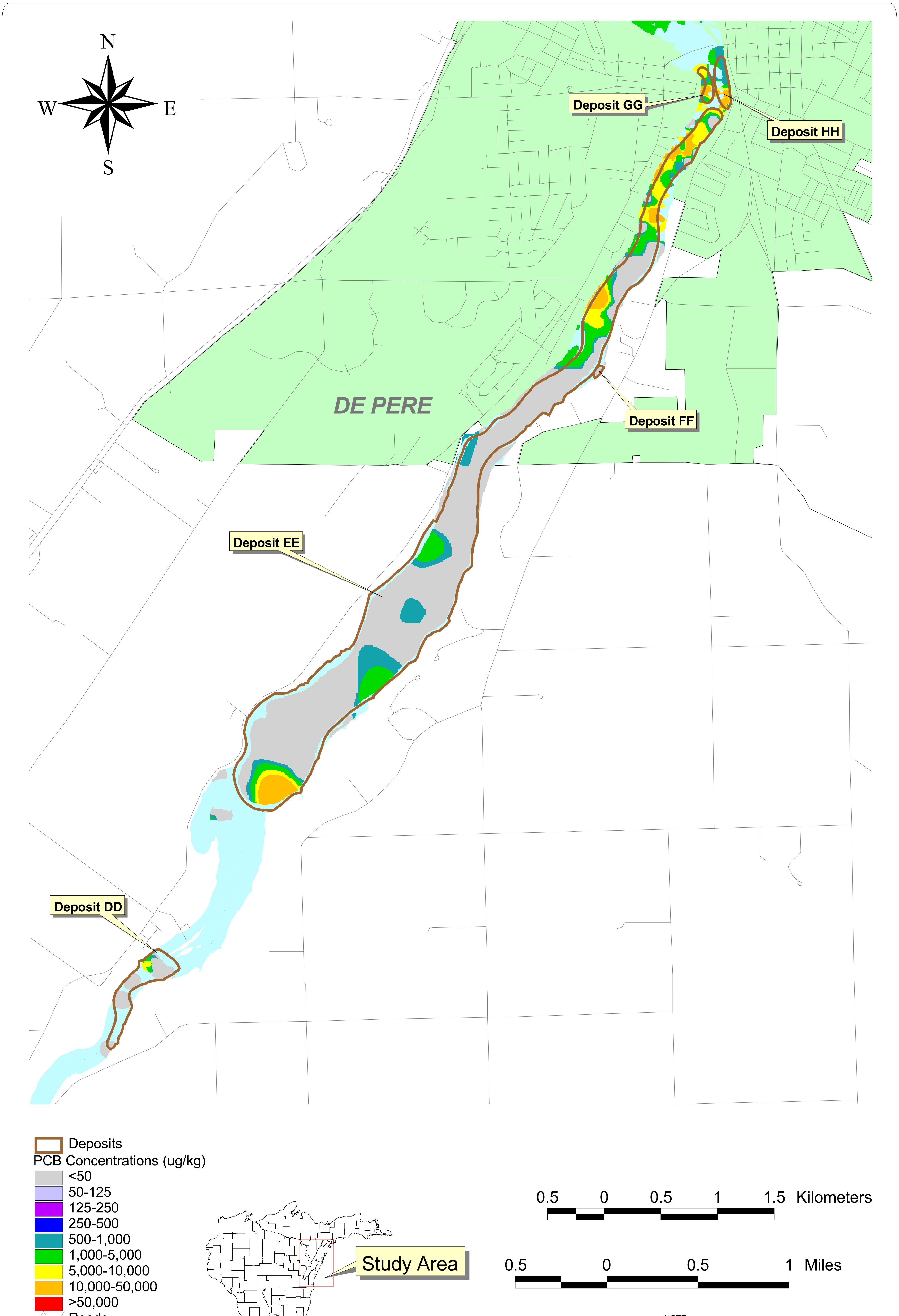
NOTE:
1. Basemap generated in ArcView GIS, Version 3.2, 1998 and from TIGER census data, 1995.
2. PCB sediment concentration data obtained from WDNR, and was generated in ArcView Spatial Analyst, version 1.1.
3. Distribution of PCB-impacted sediment defined by interpolated depth intervals (layers) below surfaces greater than 300 cm depths. Assume no exceedences beyond depths shown.

ThermoRetec	Natural Resource Technology	Risk Assessment	PCB Distribution (0-10 cm): Little Lake Butte des Morts	FIGURE NO: RA-14414-425-2-2
			FIGURE 2-2	PRINT DATE: 1/23/01
				CREATED BY: SCJ
				APPROVED: AGF



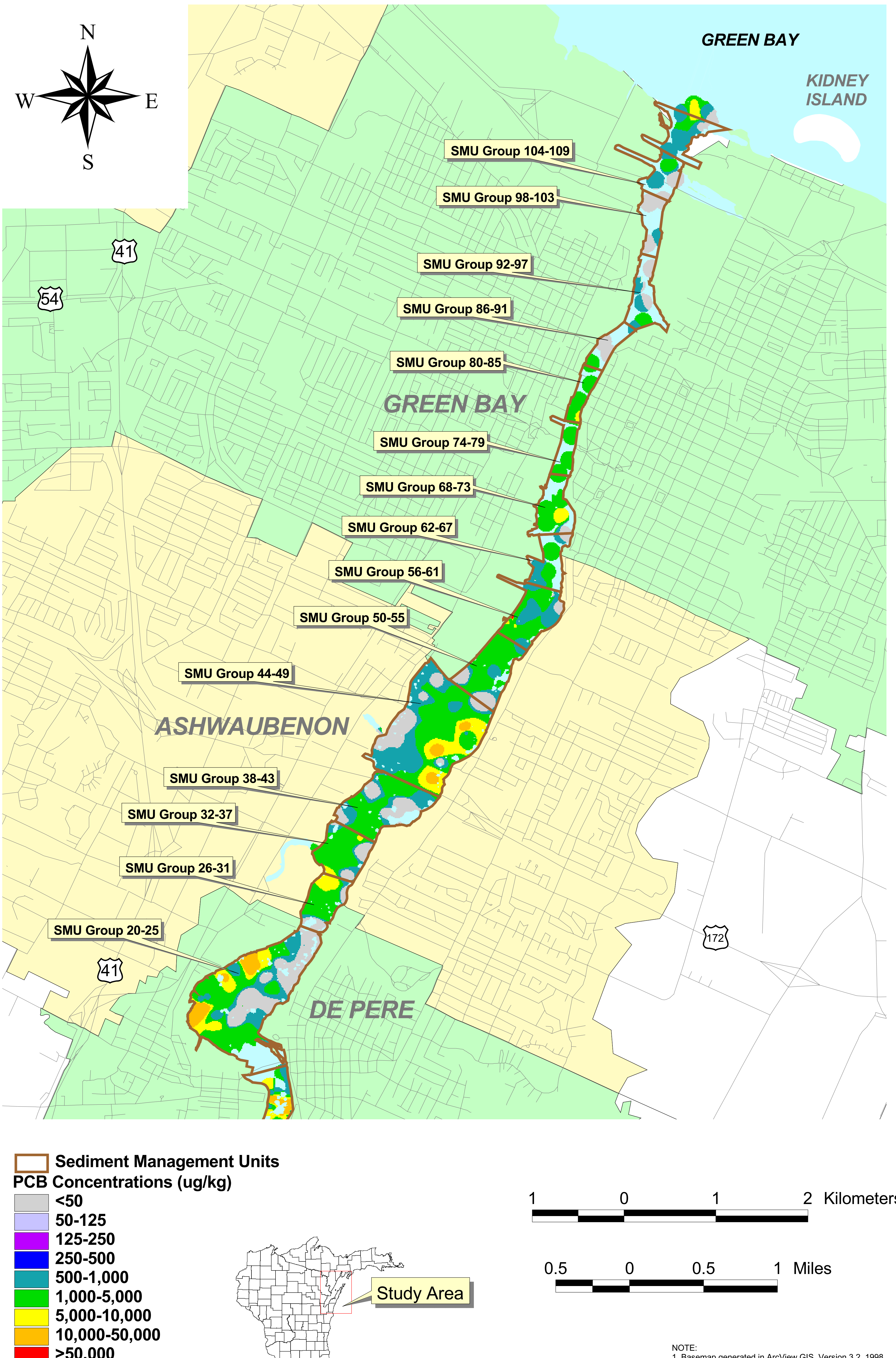
NOTE:
1. Basemap generated in ArcView GIS, Version 3.2, 1998 and from TIGER census data, 1995.
2. PCB sediment concentration data obtained from WDNR, and was generated in ArcView Spatial Analyst, version 1.1.
3. Distribution of PCB-impacted sediment defined by interpolated depth intervals (layers) below surfaces greater than 300 cm depths. Assume no exceedences beyond depths shown.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	PCB Distribution (0-10 cm): Appleton to Little Rapids	FIGURE NO: RA-14414-425-2-3
				PRINT DATE: 1/23/01
				CREATED BY: SCJ
			FIGURE 2-3	APPROVED: AGF



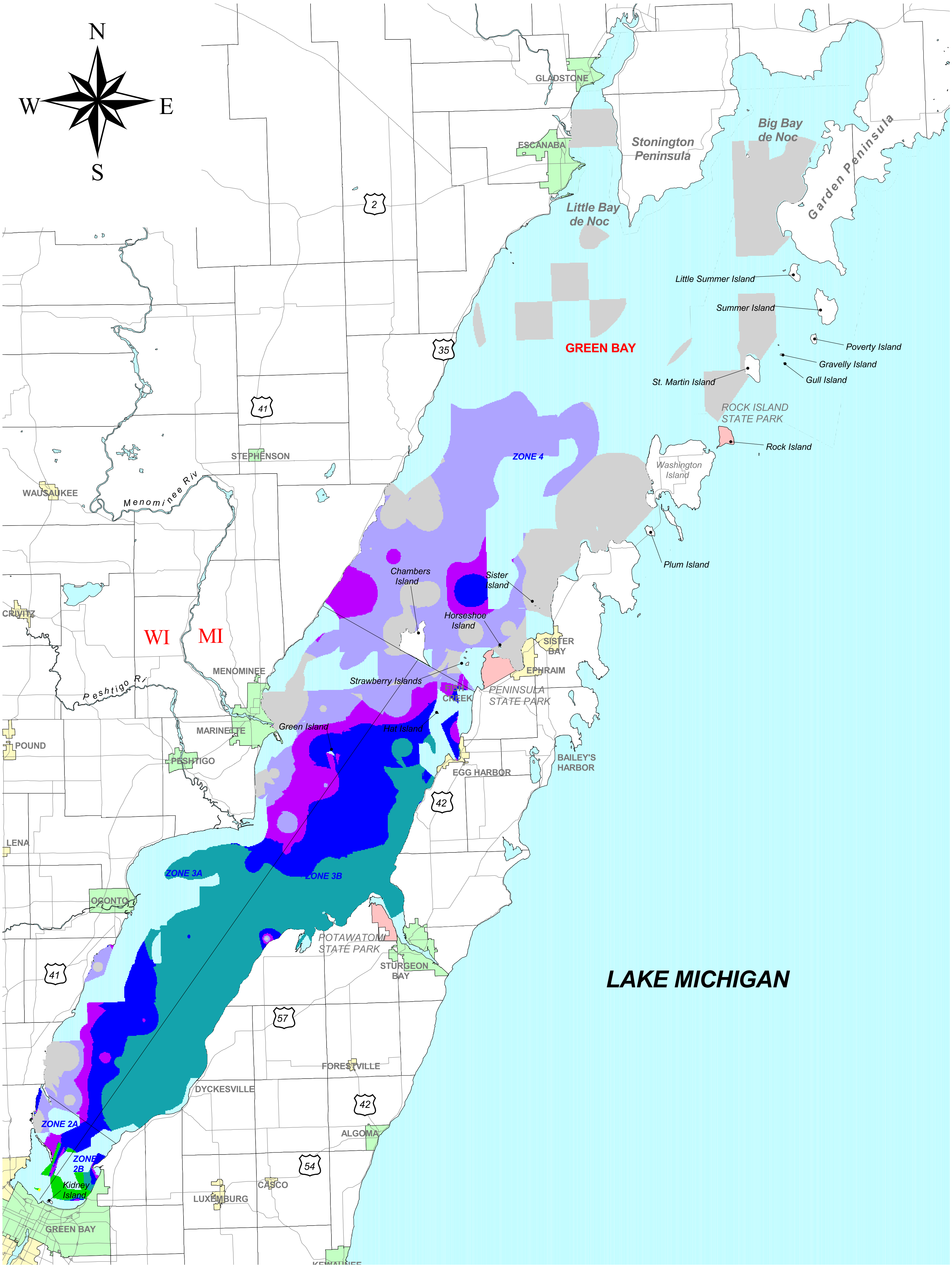
NOTE:
1. Basemap generated in ArcView GIS, Version 3.2, 1998 and from TIGER census data, 1995.
2. PCB sediment concentration data obtained from WDNR, and was generated in ArcView Spatial Analyst, version 1.1.
3. Distribution of PCB-impacted sediment defined by interpolated depth intervals (layers) below surfaces greater than 300 cm depths. Assume no exceedences beyond depths shown.

ThermoRetec	Natural Resource Technology	Risk Assessment	PCB Distribution (0-10 cm): Little Rapids to De Pere	FIGURE NO: RA-14414-425-2-4
			FIGURE 2-4	PRINT DATE: 1/23/01
				CREATED BY: SCJ
				APPROVED: AGF



NOTE:
1. Basemap generated in ArcView GIS, Version 3.2, 1998 and from TIGER census data, 1995.
2. PCB sediment concentration data obtained from WDNR, and was generated in ArcView Spatial Analyst, version 1.1.
3. Distribution of PCB-impacted sediment defined by interpolated depth intervals (layers) below surfaces greater than 300 cm depths. Assume no exceedences beyond depths shown.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	PCB Distribution (0-10 cm): De Pere to Green Bay	FIGURE NO: RA-14414-425-2-5
			FIGURE 2-5	PRINT DATE: 1/23/01
				CREATED BY: SCJ
				APPROVED: AGF

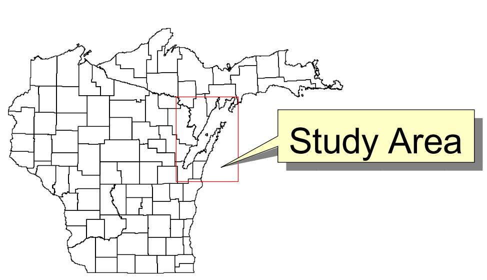


PCB Concentrations (ug/kg)

- <50
- 50-125
- 125-250
- 250-500
- 500-1,000
- 1,000-5,000
- > 5,000
- Roads
- State Parks
- Water

Civil Divisions

- City
- Township
- Village



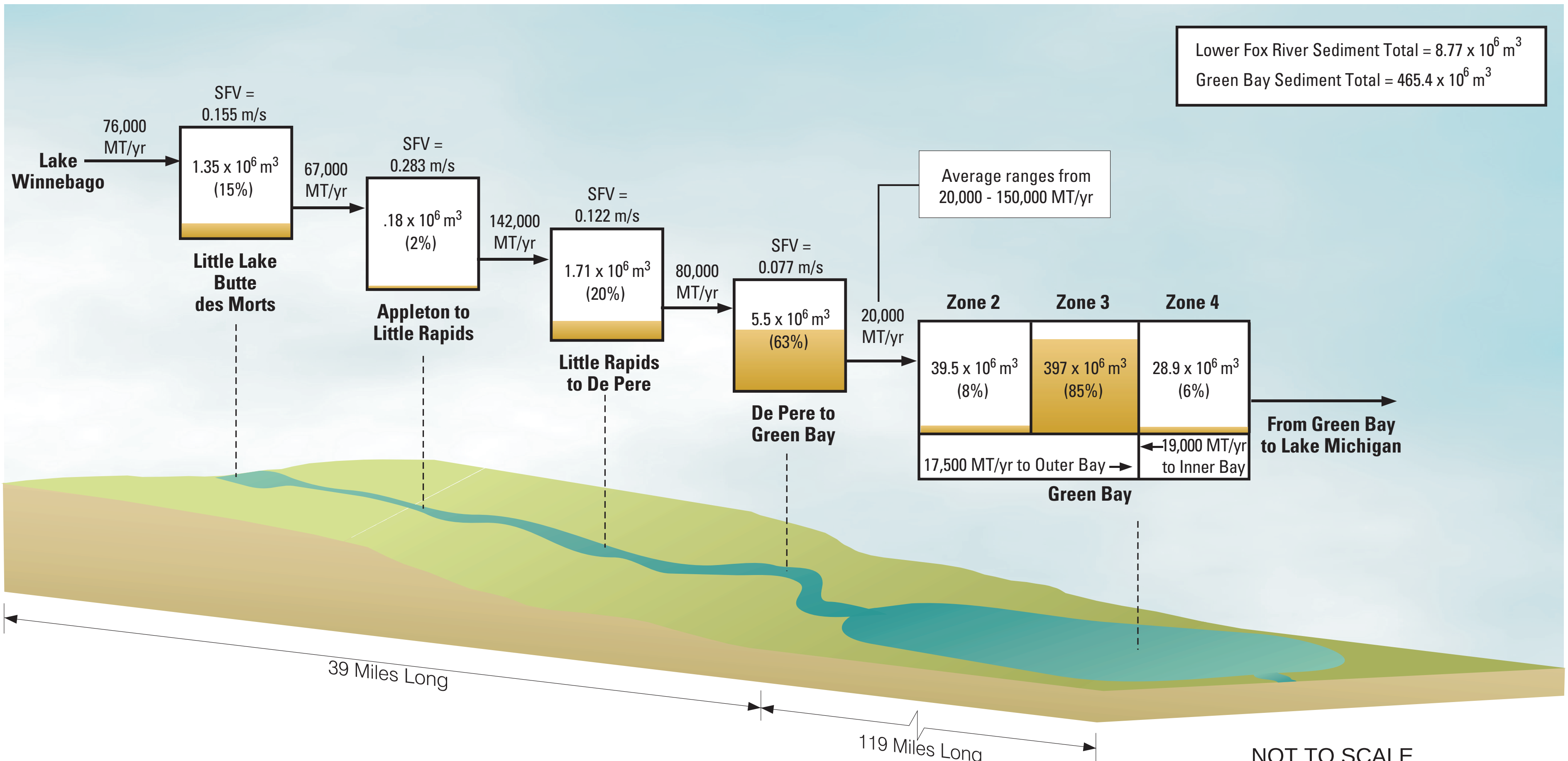
10 0 10 20 Kilometers

10 0 10 Miles

NOTE:
1. Basemap generated in ArcView GIS, Version 3.2, 1998 and from TIGER census data, 1995.
2. PCB sediment concentration data obtained from WDNR, and was generated in ArcView Spatial Analyst, version 1.1.
3. Distribution of PCB-impacted sediment defined by interpolated depth intervals (layers) below surfaces greater than 30 cm depths. Assume no exceedences beyond depths shown.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	PCB Distribution (0-10 cm): Green Bay	FIGURE NO: RA-14414-425-2-6
				PRINT DATE: 1/23/01
				CREATED BY: SCJ
			FIGURE 2-6	APPROVED: AGF

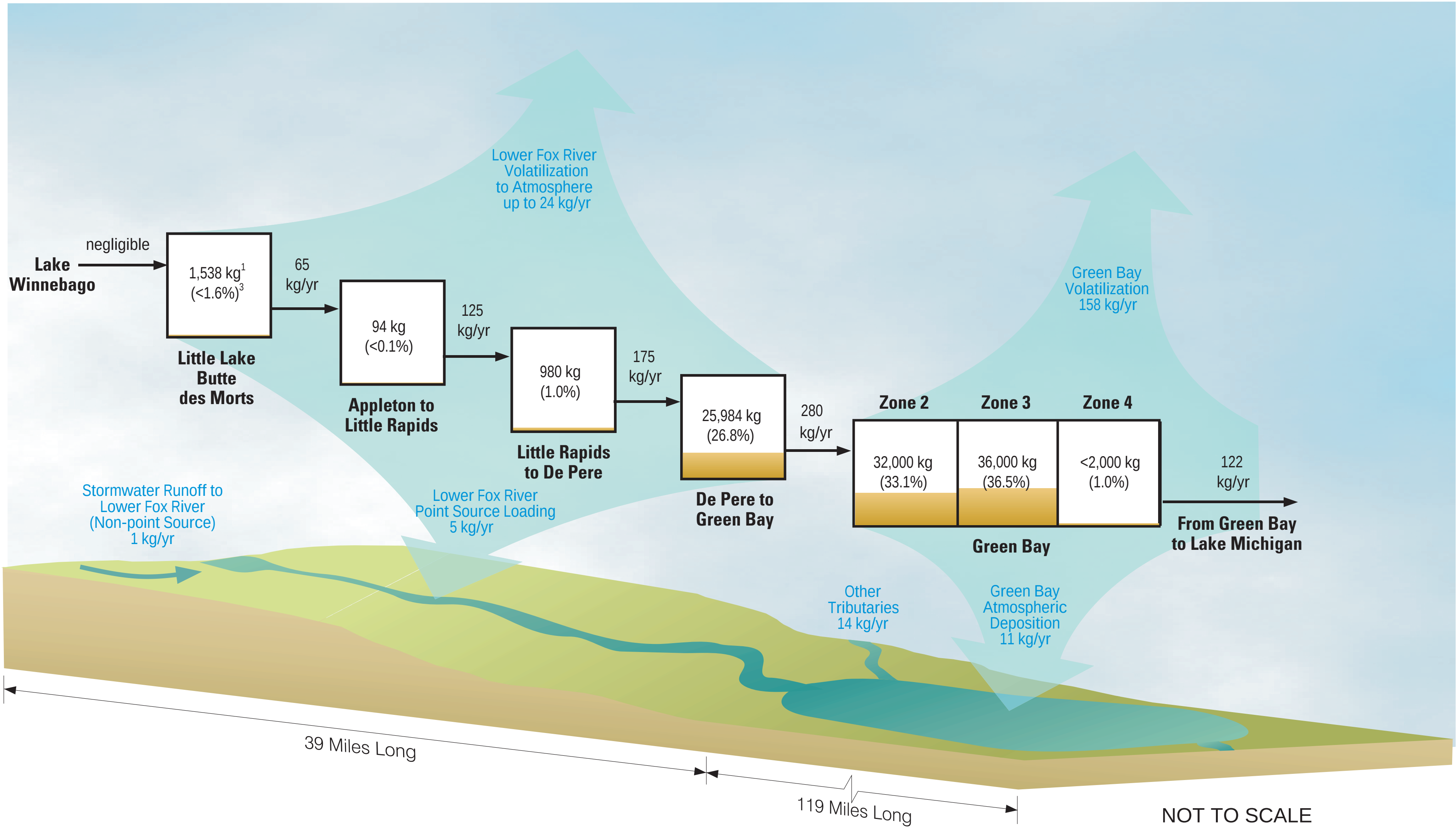
Figure 2-7 Estimated Annual Sediment Transport Rates and Stream Flow Velocities



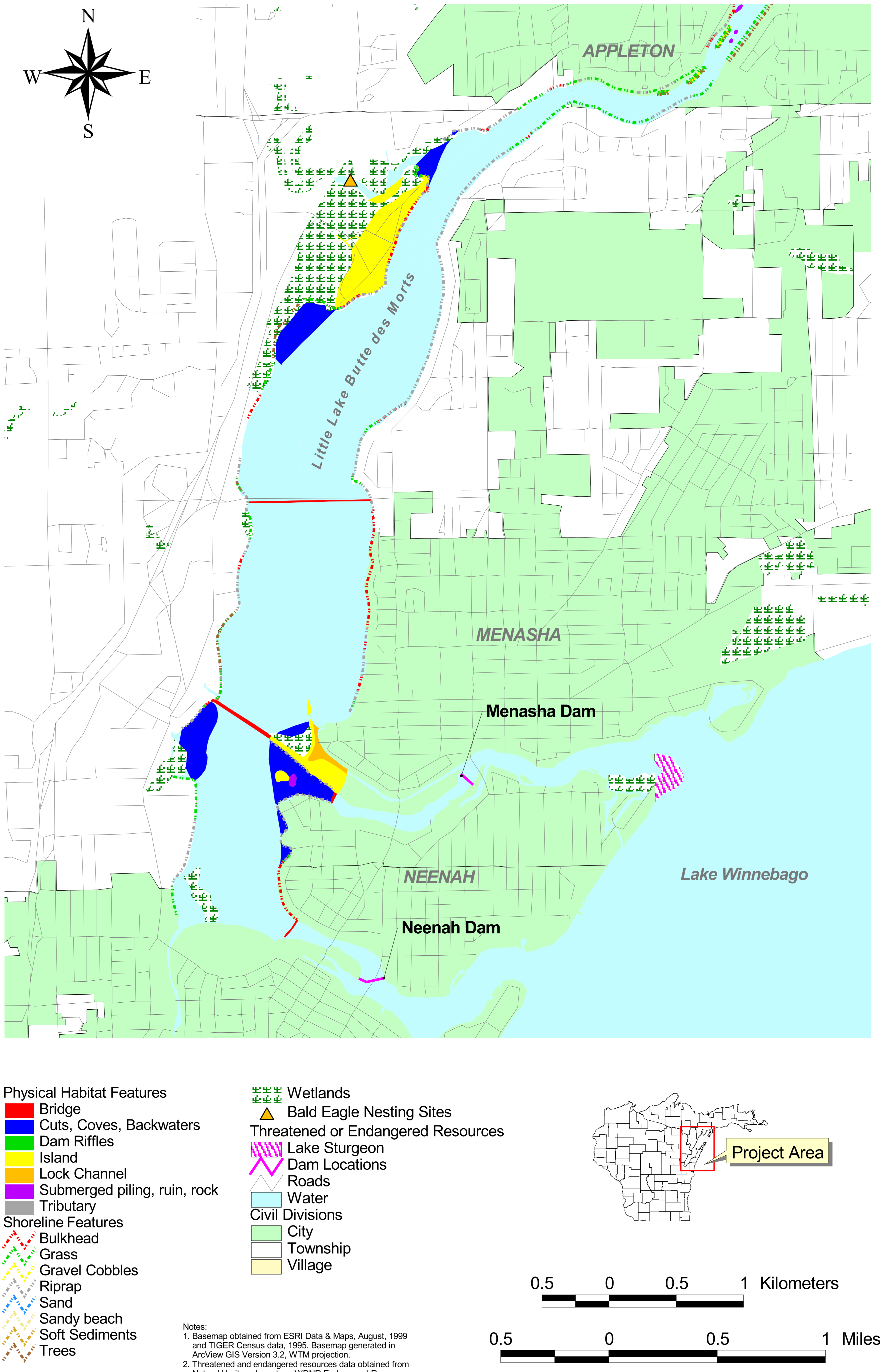
Notes: 1. Sediment volumes contain PCB concentrations > 50 µg/kg PCBs.
2. MT/yr = metric ton per year.
3. Data source for discharge rates is Steuer et al, 1995.
4. Percentages correspond to fraction of total sediment volumes residing in each river reach or bay zone. Volume estimates obtained from tables 5-13, 5-14 and 5-15.
5. SFV = Stream Flow Velocity.
6. The average Stream Flow Velocity for the entire Lower Fox River is 0.137 m/s.
7. 1 x $10^6 m^3$ = one million cubic meters of sediment

F:\PROJECTS\DOCS\4414\DOC\BLRA\DRAFT\FIGS\SEC2FIGS.PDF

Figure 2-8 Lower Fox River and Green Bay System Estimated PCB Mass and Major PCB Flux Pathways

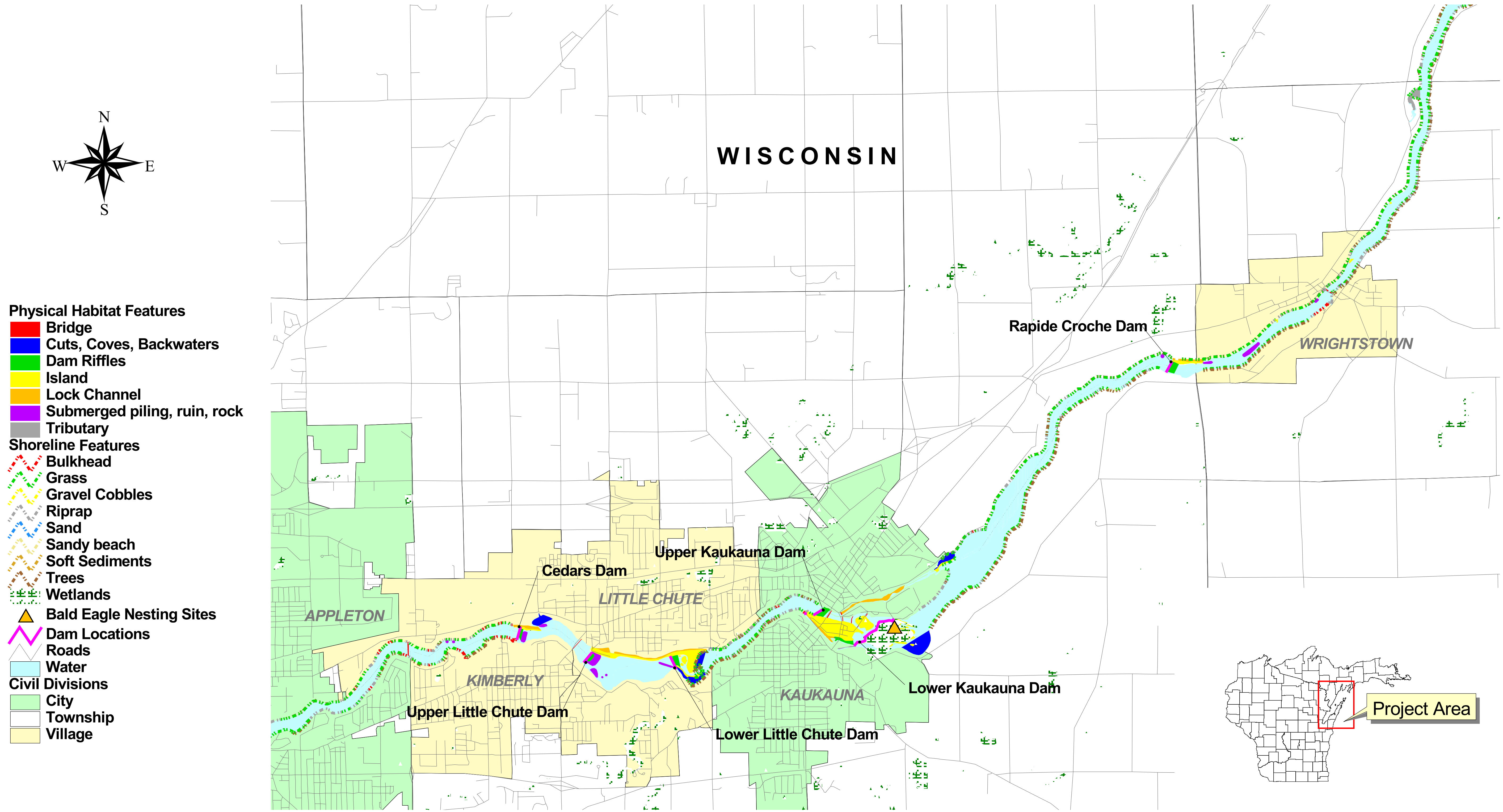


Notes: 1. PCB mass in sediments with PCB concentrations of 50 µg/kg or more.
2. Flux rates are average estimated loading rates per year.
3. Percentages correspond to fraction of total PCB mass in project area residing in each reach or zone. PCB mass estimates obtained from Tables 5-13, 5-14 and 5-15 in the Remedial Investigation.
4. Estimate of PCB loads from WDNR 1995 and www.epa.gov/med/images/gbmassbal.gif



Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Threatened and endangered resources data obtained from Natural Heritage Inventory, WDNR Endangered Resources Program, 1999.
3. Wetlands data obtained from WDNR, 1999.
4. Physical habitat and shoreline features provided by Exponent, 1999.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Lower Fox River Wetland, Habitat, and Animal Distribution: Little Lake Butte des Morts Reach	REFERENCE NO: RA-14414-425-2-9
				CREATED BY: SCJ
				PRINT DATE: 3/14/01
			FIGURE 2-9	APPROVED: AGF

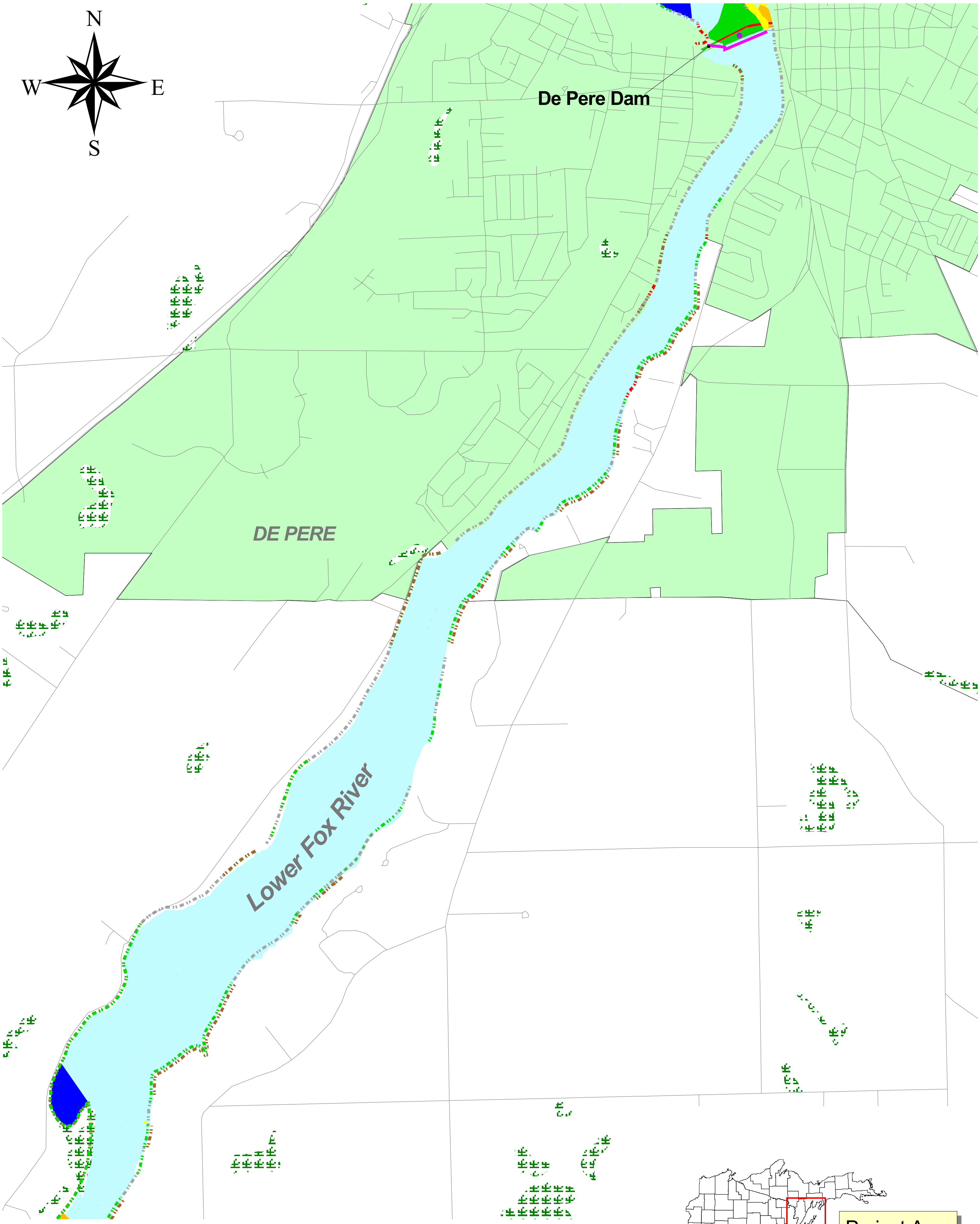


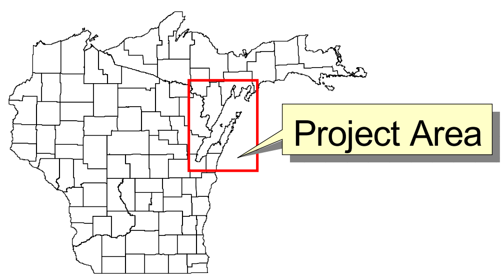
1 0 1 2 3 Kilometers

1 0 1 2 Miles

Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Threatened and endangered resources data obtained from Natural Heritage Inventory, WDNR Endangered Resources Program, 1999.
3. Wetlands data obtained from WDNR, 1999.
4. Physical habitat and shoreline features provided by Exponent, 1999.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Lower Fox River Wetland, Habitat, and Animal Distribution: Appleton to Little Rapids Reach	REFERENCE NO: RA-14414-425-2-10
				CREATED BY: SCJ
				PRINT DATE: 3/14/01
			FIGURE 2-10	APPROVED: AGF



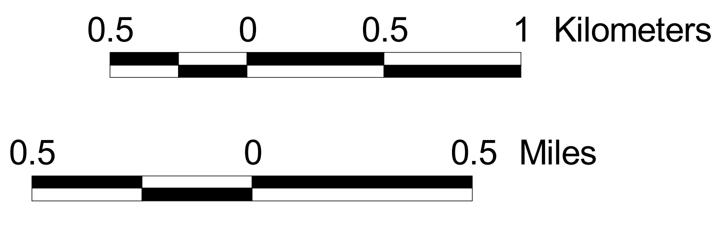


Physical Habitat Features
- Bridge
- Cuts, Coves, Backwaters
- Dam Riffles
- Island
- Lock Channel
- Submerged piling, ruin, rock
- Tributary

Shoreline Features
- Bulkhead
- Grass
- Gravel Cobbles
- Riprap
- Sand
- Sandy beach
- Soft Sediments
- Trees

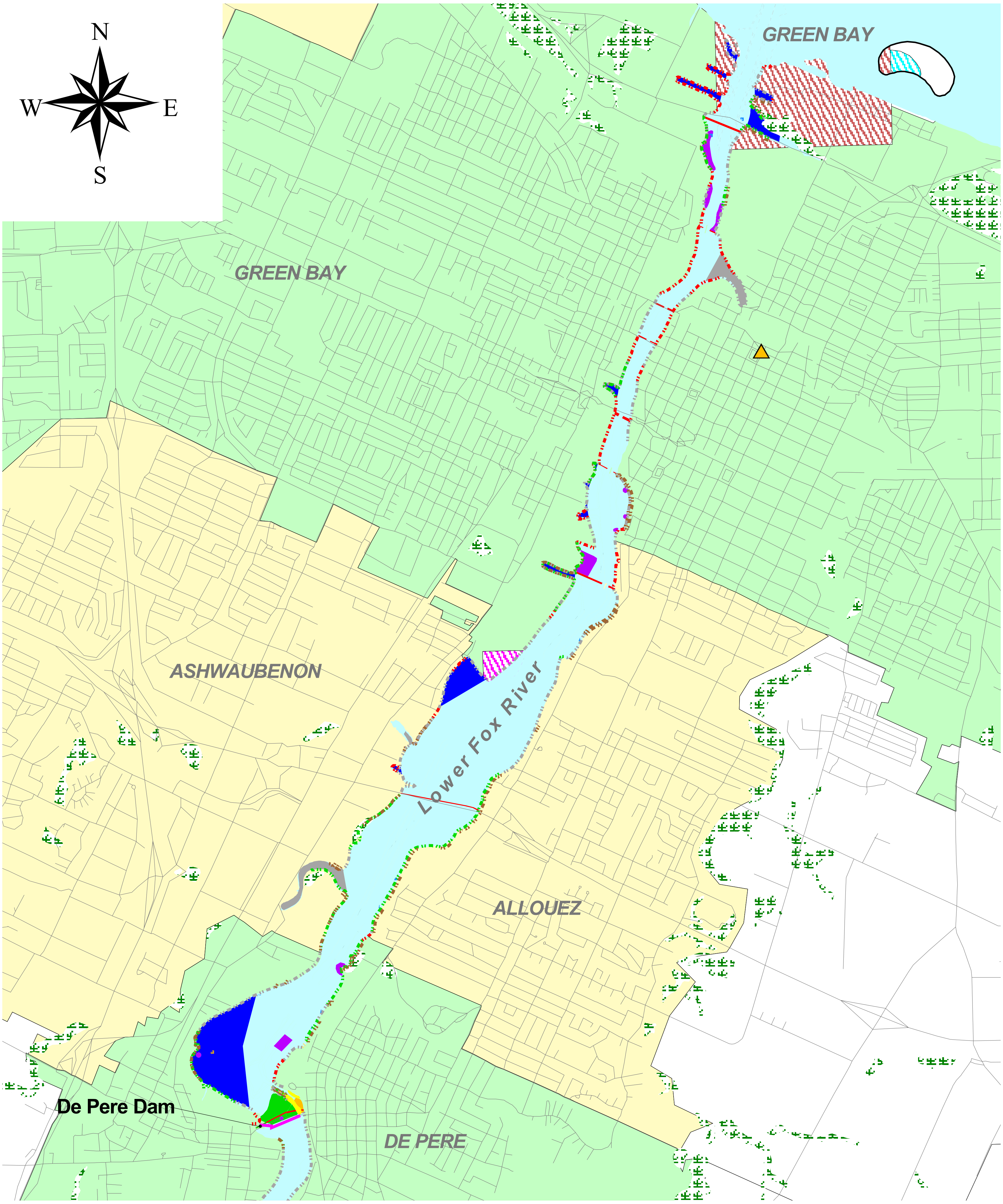
- Wetlands
- Dam Locations
- Roads
- Water

Civil Divisions
- City
- Township
- Village



Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Threatened and endangered resources data obtained from Natural Heritage Inventory, WDNR Endangered Resources Program, 1999.
3. Wetlands data obtained from WDNR, 1999.
4. Physical habitat and shoreline features provided by Exponent, 1999.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Lower Fox River Wetland, Habitat, and Animal Distribution: Little Rapids to De Pere Reach	REFERENCE NO: RA-14414-425-2-11
			FIGURE 2-11	CREATED BY: SCJ
				PRINT DATE: 3/14/01
				APPROVED: AGF



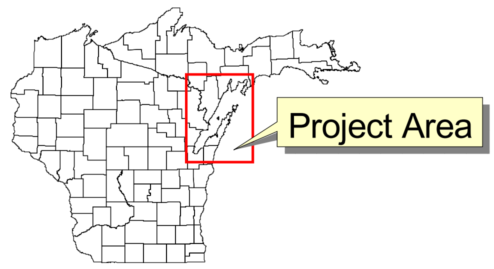
Physical Habitat Features
- Bridge
- Cuts, Coves, Backwaters
- Dam Riffles
- Island
- Lock Channel
- Submerged piling, ruin, rock
- Tributary

Shoreline Features
- Bulkhead
- Grass
- Gravel Cobbles
- Riprap
- Sand
- Sandy beach
- Soft Sediments
- Trees

- Wetlands
- Bald Eagle Nesting Sites

Threatened or Endangered Resources
- Caspian Tern
- Forster's Tern
- Lake Sturgeon
- Dam Locations
- Roads
- Water

Civil Divisions
- City
- Township
- Village

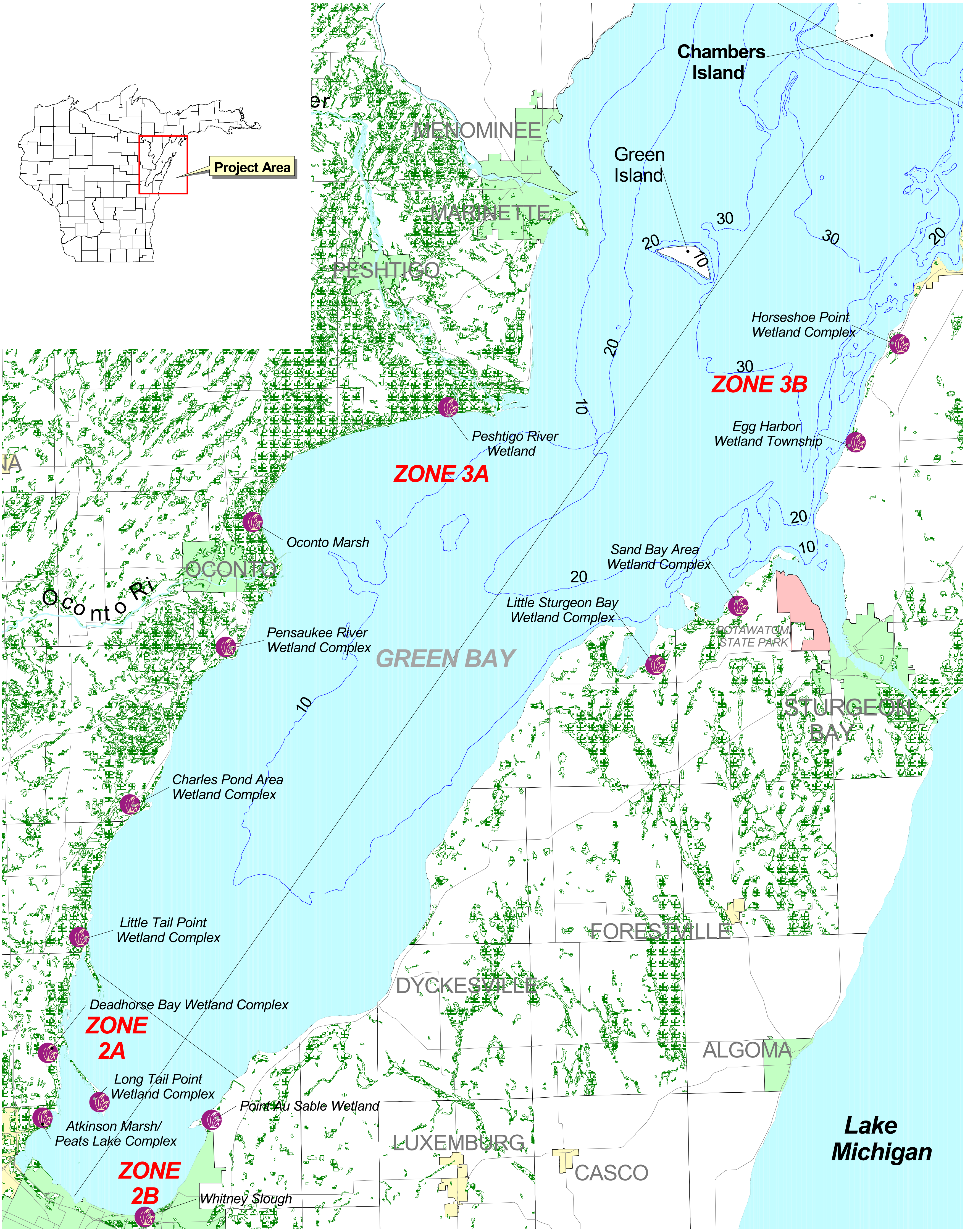


1 0 1 Kilometers

0.5 0 0.5 1 Miles

Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Threatened and endangered resources data obtained from Natural Heritage Inventory, WDNR Endangered Resources Program, 1999.
3. Wetlands data obtained from WDNR, 1999.
4. Physical habitat and shoreline features provided by Exponent, 1999.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Lower Fox River Wetland, Habitat, and Animal Distribution: De Pere to Green Bay Reach	REFERENCE NO: RA-14414-425-2-12
				CREATED BY: SCJ
				PRINT DATE: 3/14/01
			FIGURE 2-12	APPROVED: AGF



Wetland Areas > 40 Hectares (100 acres)
Bathymetry Contours (10 m)
Roads
Wetlands
Wisconsin State Parks
Water

Civil Divisions
City
Township
Village

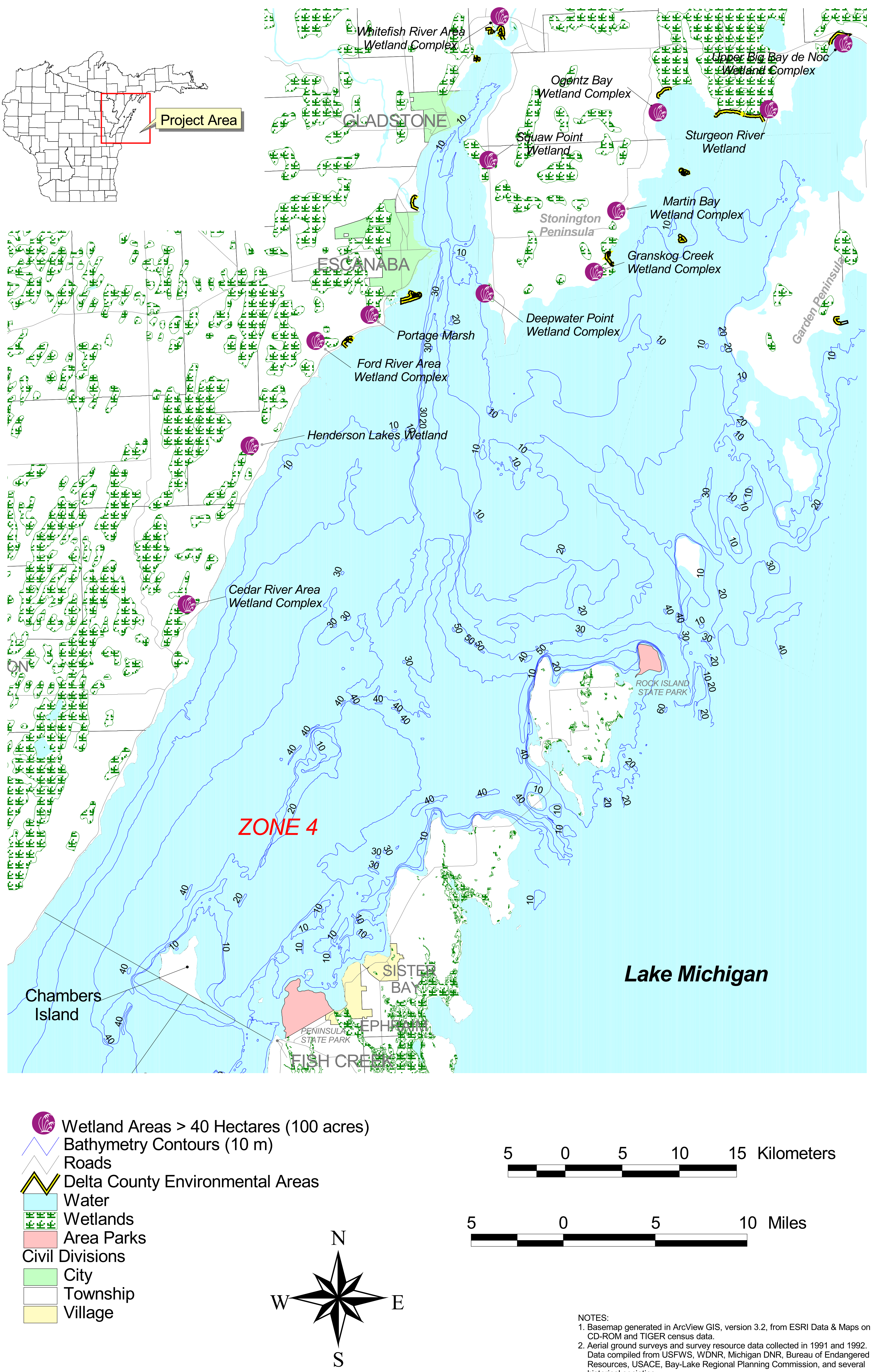
5 0 5 10 Kilometers

5 0 5 Miles

N W E S

NOTES:
1. Basemap generated in ArcView GIS, Version 3.2, from ESRI data and maps on CD-ROM and TIGER census data.
2. Aerial ground surveys and survey resource data collected in 1991 and 1992. Data compiled from USFWS, WDNR, Michigan DNR, Bureau of Endangered Resources, Bay-Lake Regional Planning Commission, USACE, and several historical societies.
3. Bathymetry contours in meters, obtained from NOAA, 1999.

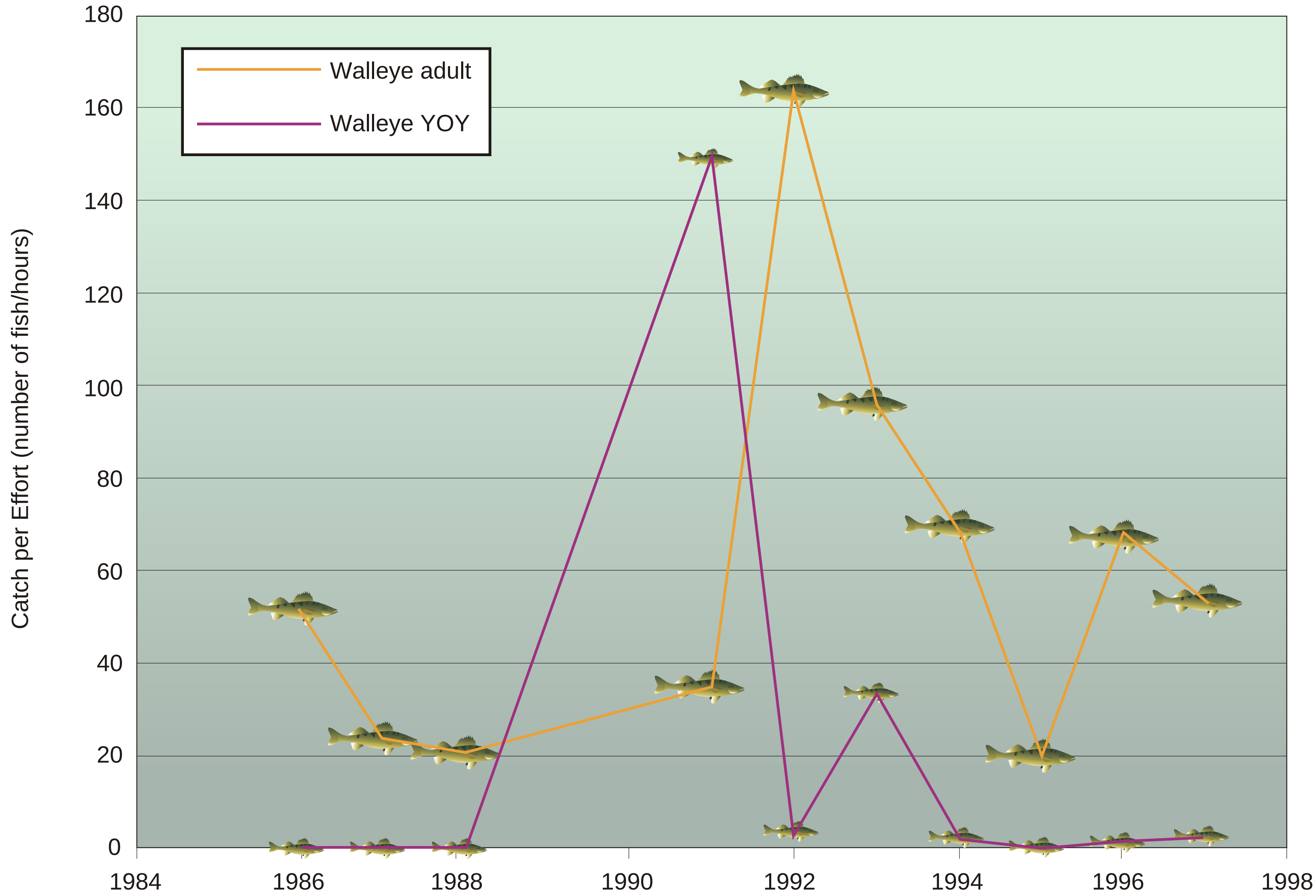
ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Wetland Distribution: Green Bay Zones 2 & 3	DRAWING NO: RA-14414-425-2-13
				PRINT DATE: 1/23/01
				CREATED BY: SCJ
			FIGURE 2-13	APPROVED: AGF



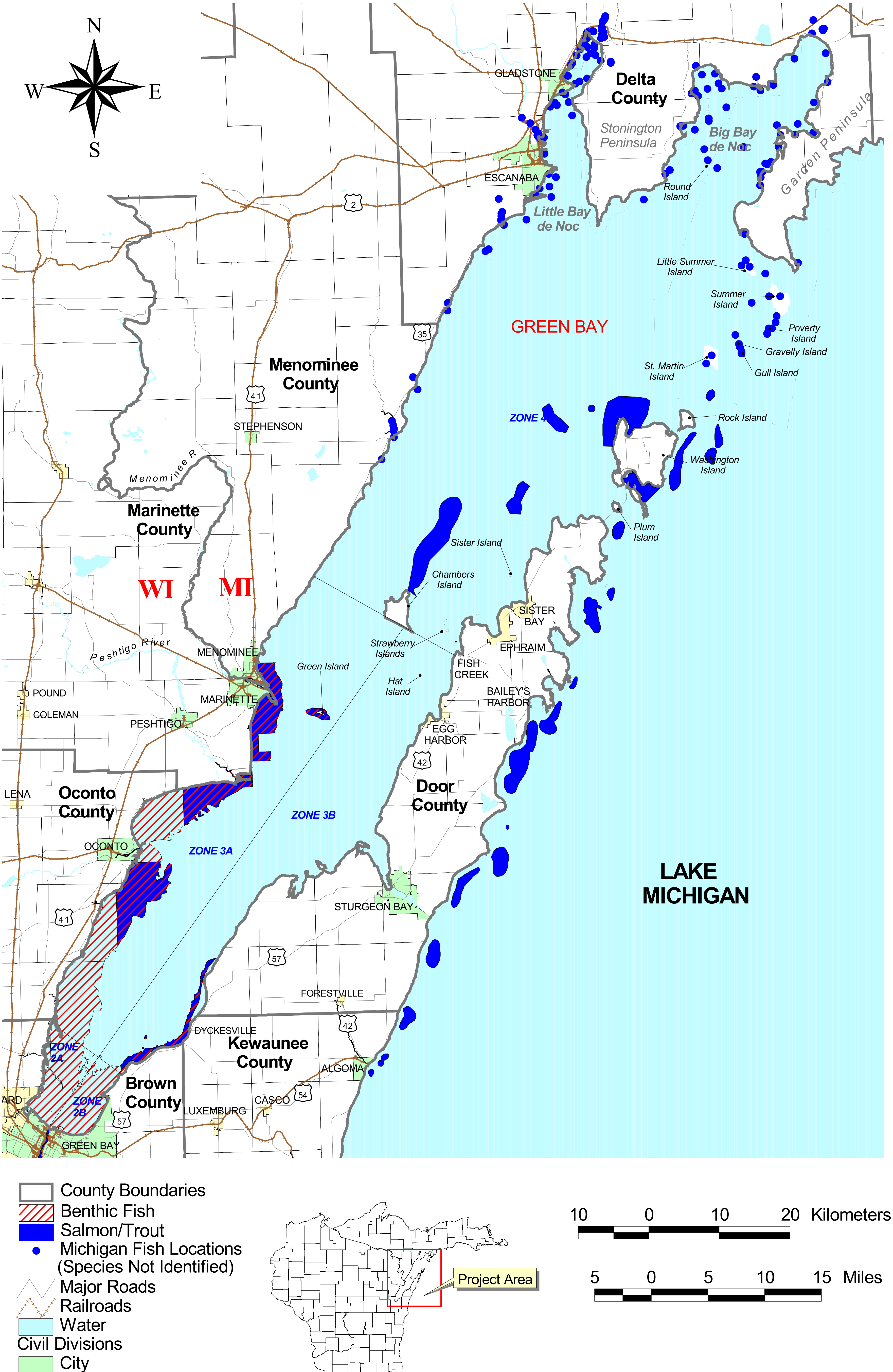
NOTES:
1. Basemap generated in ArcView GIS, version 3.2, from ESRI Data & Maps on CD-ROM and TIGER census data.
2. Aerial ground surveys and survey resource data collected in 1991 and 1992. Data compiled from USFWS, WDNR, Michigan DNR, Bureau of Endangered Resources, USACE, Bay-Lake Regional Planning Commission, and several historical societies.
3. Bathymetry contours in meters, obtained from NOAA, 1999.
4. Delta County Environmental Area Boundaries provided by Michigan Dept. of Environmental Quality.
These are sensitive areas established by MDEQ.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Wetland Distribution: Green Bay Zone 4	DRAWING NO: RA-14414-425-2-14
				PRINT DATE: 1/23/01
				CREATED BY: SCJ
			FIGURE 2-14	APPROVED: AGF

Figure 2-15. Electrofishing Walleye Catch Data in Green Bay Zone 1



ThermoRetecJanuary2001Figure2_15



NOTES:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, version 3.2, WTM projection.
2. Wisconsin fish habitat data obtained from NOAA, 1997 Environmental Sensitivty Index Metadata, and lake trout data obtained from U. of Wisconsin Sea Grant Institute, 1980.
3. Michigan fish locations provided by Great Lakes Commission, 1980.

ThermoRetec
Smart Solutions. Positive Outcomes.

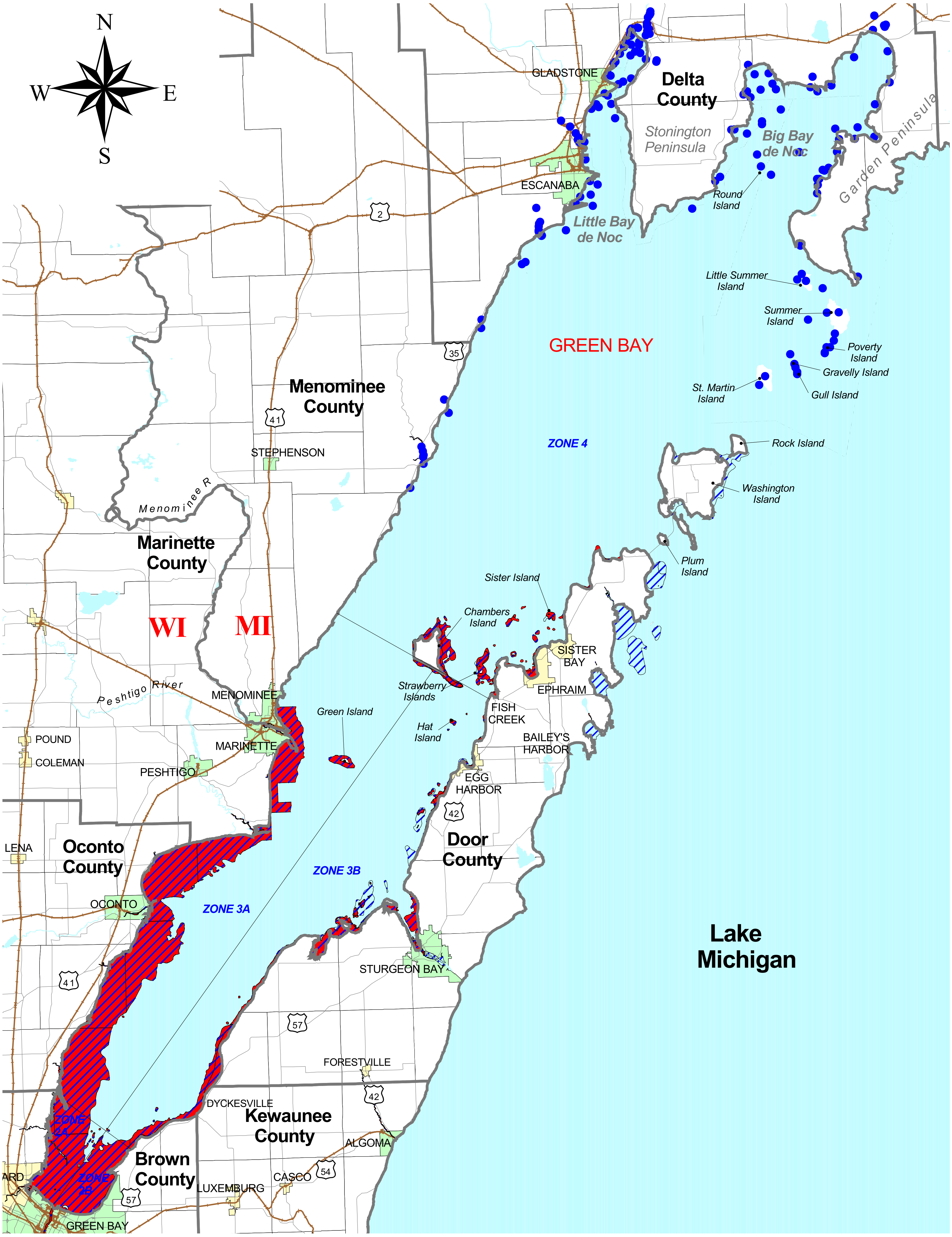
Natural Resource Technology

Risk Assessment

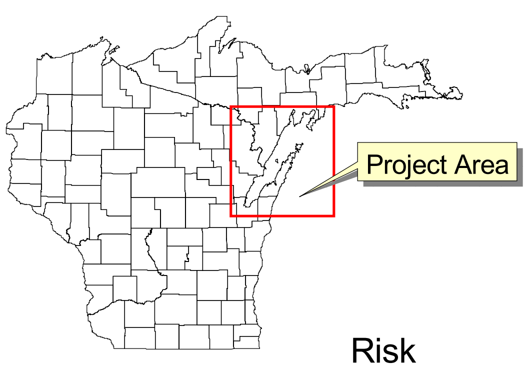
Green Bay Spawning Areas by Fish Types: Salmon/Trout and Benthic Fish

FIGURE 2-16

DRAWING NO: RA-4414-425-2-16
PRINT DATE: 3/14/01
CREATED BY: SCJ
APPROVED: AGF



County Boundaries
Game Fish
Pelagic Fish
Michigan Fish Locations (Species Not Identified)
Major Roads
Railroads
Water
Civil Divisions
City
Township
Village



10 0 10 20 Kilometers

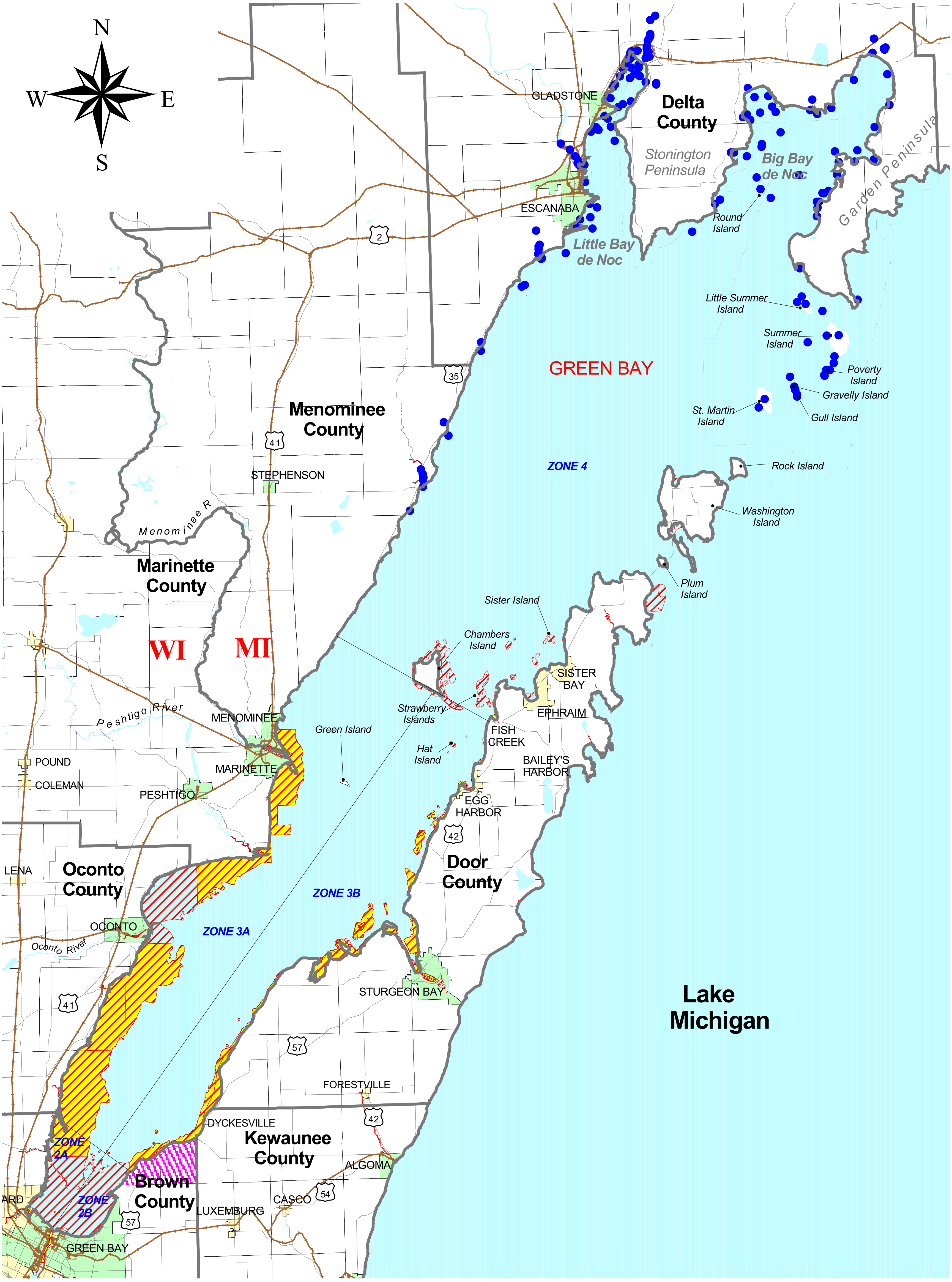
5 0 5 10 15 Miles

Risk Assessment

RA-4414-425-2-17

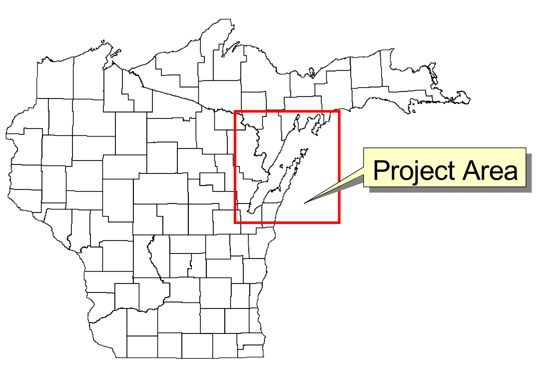
NOTES:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, version 3.2, WTM projection.
2. Wisconsin fish habitat data obtained from NOAA, 1997 Environmental Sensitivity Index Metadata, and lake trout data obtained from U. of Wisconsin Sea Grant Institute, 1980.
3. Michigan fish locations provided by Great Lakes Commission, 2000.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Green Bay Spawning Areas by Fish Species: Pelagic and Game Fish	DRAWING NO: RA-4414-425-2-17
				PRINT DATE: 3/14/01
				CREATED BY: SCJ
			FIGURE 2-17	APPROVED: AGF



County Boundaries
Lake Sturgeon
Yellow Perch
Walleye
Michigan Fish Locations (Species Not Identified)
Major Roads
Railroads
Water

Civil Divisions
City
Township
Village

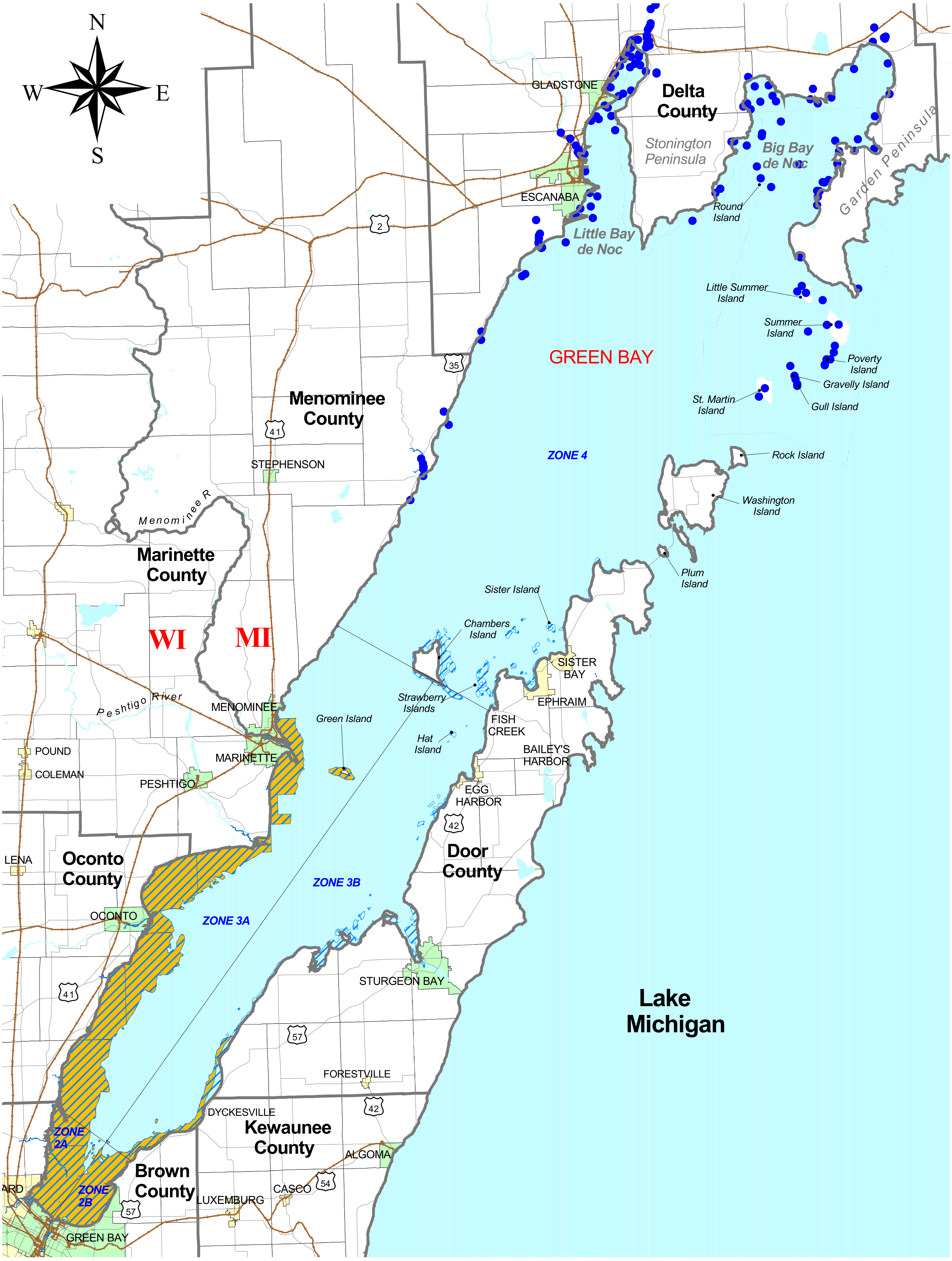


10 0 10 20 Kilometers

5 0 5 10 15 Miles

NOTES:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, version 3.2, WTM projection.
2. Wisconsin fish habitat data obtained from NOAA, 1997 Environmental Sensitivty Index Metadata, and lake trout data obtained from U. of Wisconsin Sea Grant Institute, 1980.
3. Michigan fish locations provided by Great Lakes Commission, 2000.
4. Door Peninsula fish habitat data obtained from U. of Wisconsin Sea Grant Institute, 1980.
5. According to Phillip Schneeberger of MDNR (telecon 1999), Walleye commonly spawn in the Whitefish, Escanaba, Ford, Cedar, and Menominee tributary rivers. Yellow Perch commonly use the shallow waters of both bays De Noc.

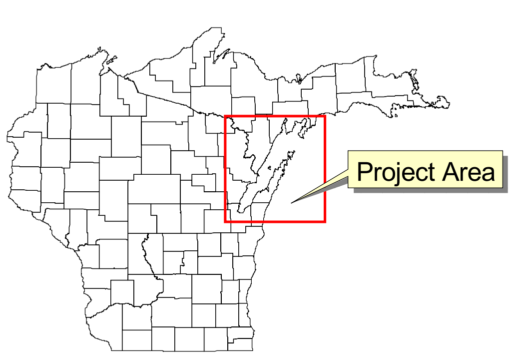
ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Green Bay Spawning Areas by Fish Species: Walleye, Yellow Perch, and Sturgeon	DRAWING NO: RA-4414-425-2-18
				PRINT DATE: 3/14/01
				CREATED BY: SCJ
			FIGURE 2-18	APPROVED: AGF



- County Boundaries
- Alewife
- Carp
- Michigan Fish Locations (Species Not Identified)
- Major Roads
- Railroads
- Water

Civil Divisions

- City
- Township
- Village

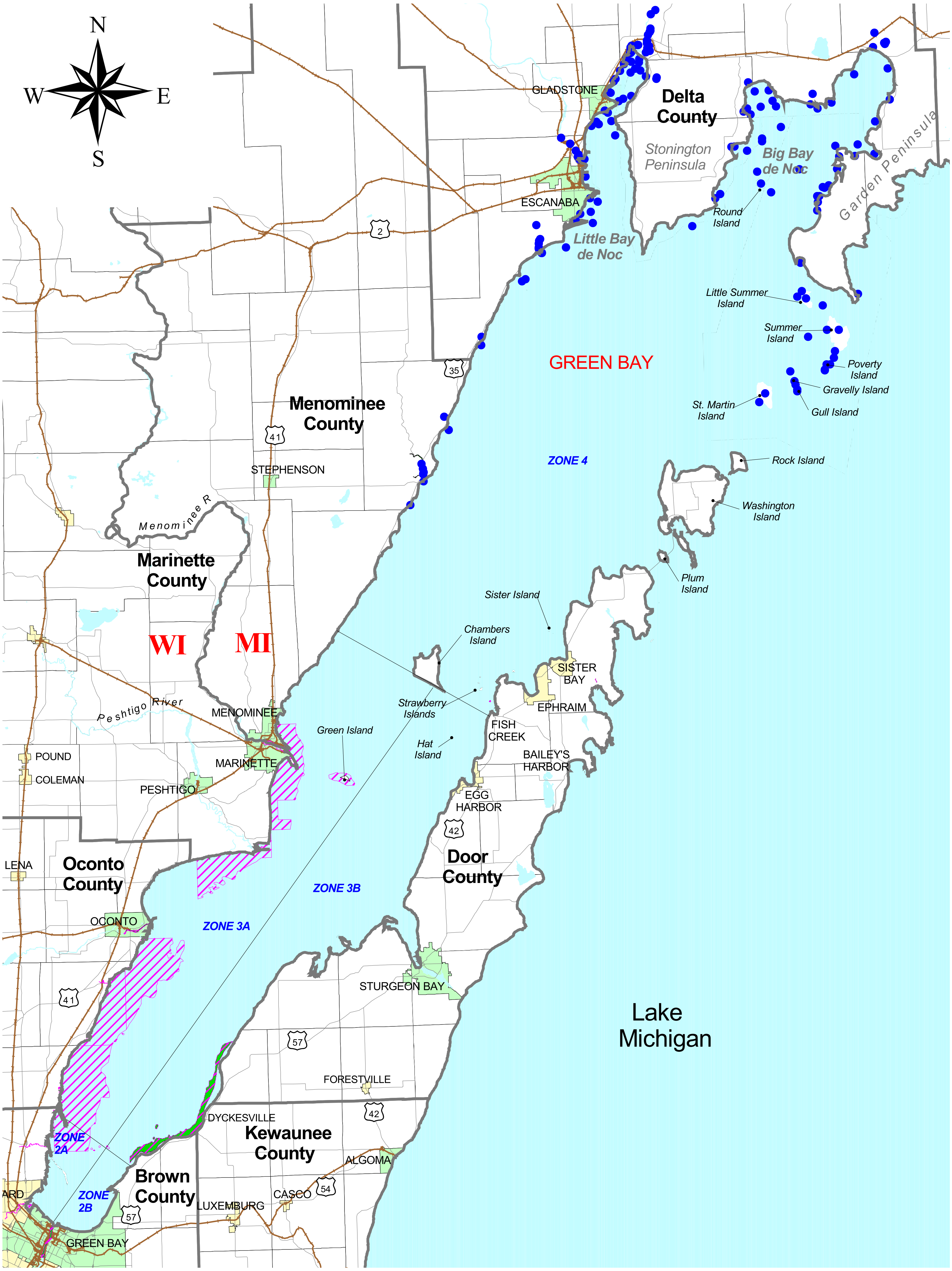


10 0 10 20 Kilometers

5 0 5 10 15 Miles

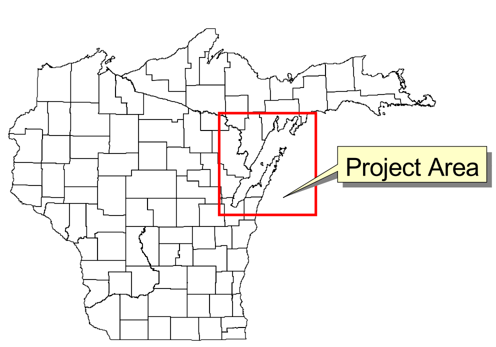
NOTES:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, version 3.2, WTM projection.
2. Wisconsin fish habitat data obtained from NOAA, 1997 Environmental Sensitivty Index Metadata, and from U. of Wisconsin Sea Grant Institute, 1980.
3. Michigan fish locations obtained from Great Lakes Commission, 2000.
4. According to Phillip Schneeberger of MDNR (telecon 1999), carp spawning is concentrated in the northern end of Little Bay de Noc, and along the shorelines of Big Bay de Noc.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Green Bay Spawning Areas by Fish Species: Carp and Alewife	DRAWING NO: RA-4414-425-2-19
				PRINT DATE: 3/14/01
				CREATED BY: SCJ
			FIGURE 2-19	APPROVED: AGF



County Boundaries
Gizzard Shad
Emerald Shiner
Michigan Fish Locations (Species Not Identified)
Major Roads
Railroads
Water

Civil Divisions
City
Township
Village

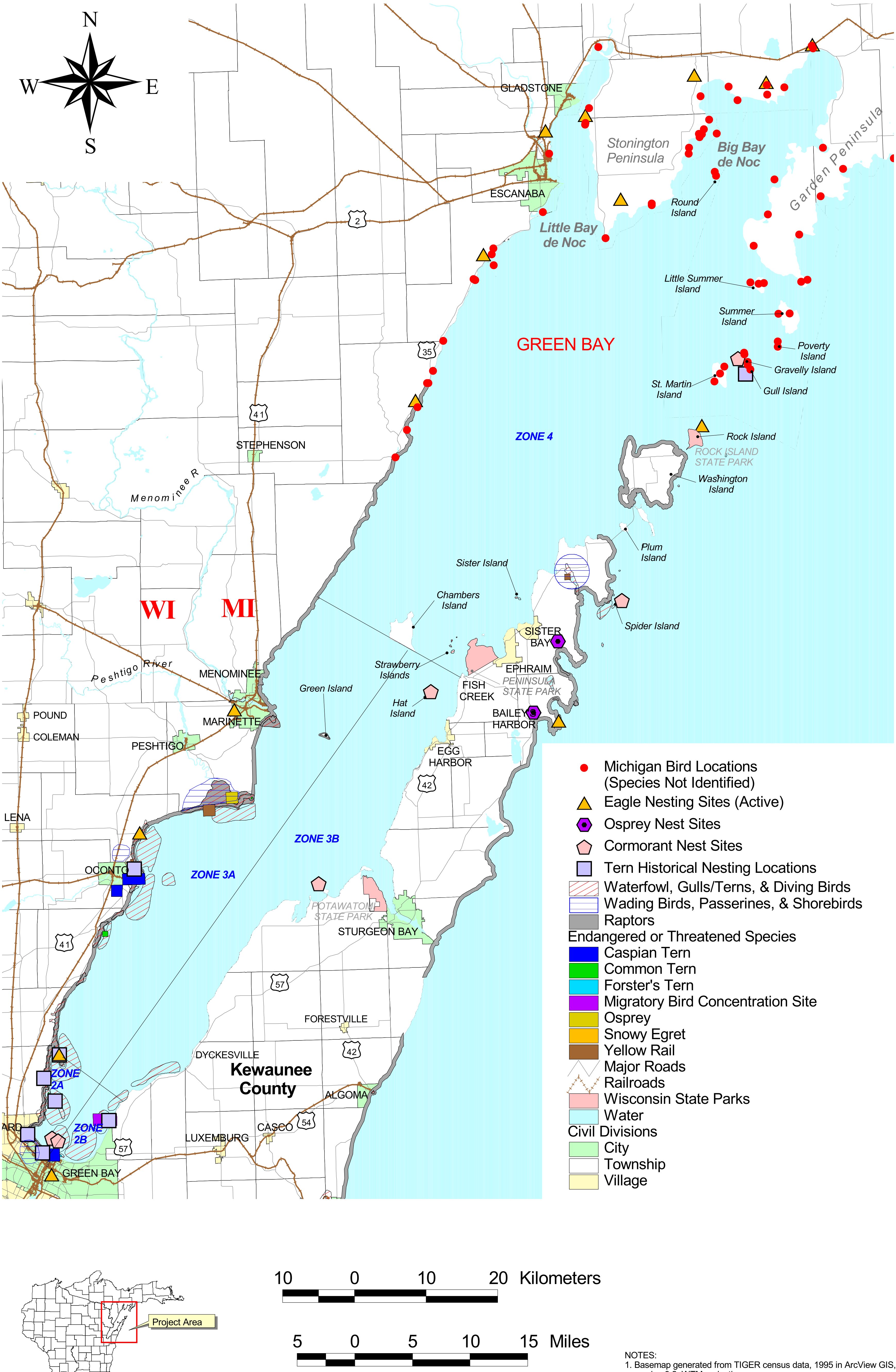


10 0 10 20 Kilometers

5 0 5 10 15 Miles

NOTES:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, version 3.2, WTM projection.
2. Wisconsin fish habitat data obtained from NOAA, 1997 Environmental Sensitivty Index Metadata, and lake trout data obtained from U. of Wisconsin Sea Grant Institute, 1980.
3. Michigan fish locations obtained from Great Lakes Commission, 2000.
4. According to Phillip Schneeberger of MDNR (telecon 1999), these fish spawn in the shallow waters of both bays of De Noc, but gizzard shad are rare.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Green Bay Spawning Areas by Fish Species: Emerald Shiners and Gizzard Shad	DRAWING NO: RA-4414-425-2-20
				PRINT DATE: 3/14/01
				CREATED BY: SCJ
			FIGURE 2-20	APPROVED: AGF



NOTES:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, version 3.2, WTM projection.
2. Wisconsin bird habitat data obtained from NOAA, 1997 Environmental Sensitivty Index Metadata, and from U. of Wisconsin Sea Grant Institute, 1980.
3. Michigan bird locations obtained from Great Lakes Commission, 2000.
4. Bird nesting sites obtained from USFWS/Stratus, 1999 Bird Injury Report and S. Stubevoll of WDNR, 1998.
5. Threatened and endangered resources provided by Natural Heritage Inventory, WDNR Endangered Resources Program, 1999.

ThermoRetec
Smart Solutions. Positive Outcomes.

Natural Resource Technology

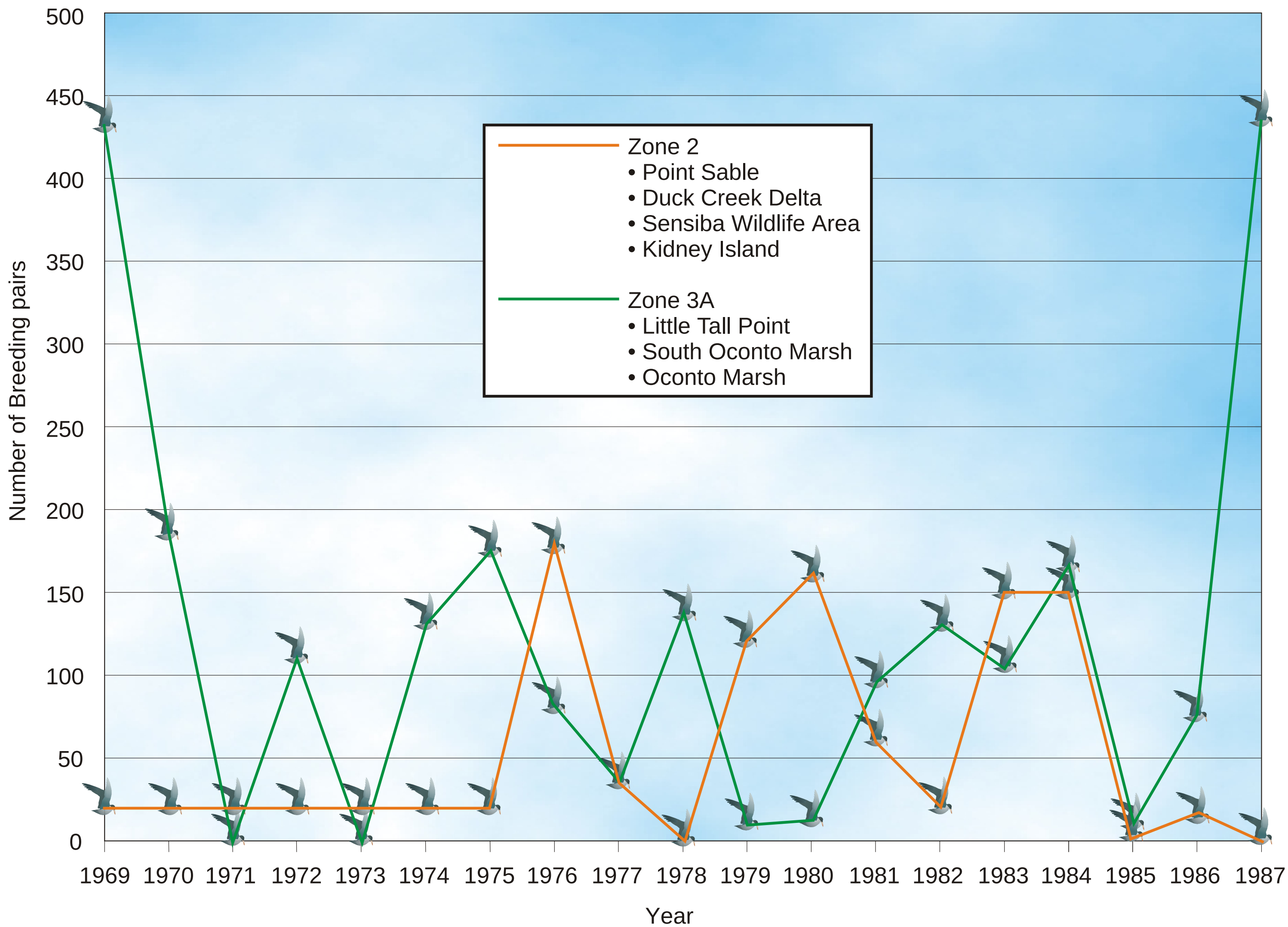
Risk Assessment

Distribution of Birds in Green Bay: Select Species and Groups

FIGURE 2-21

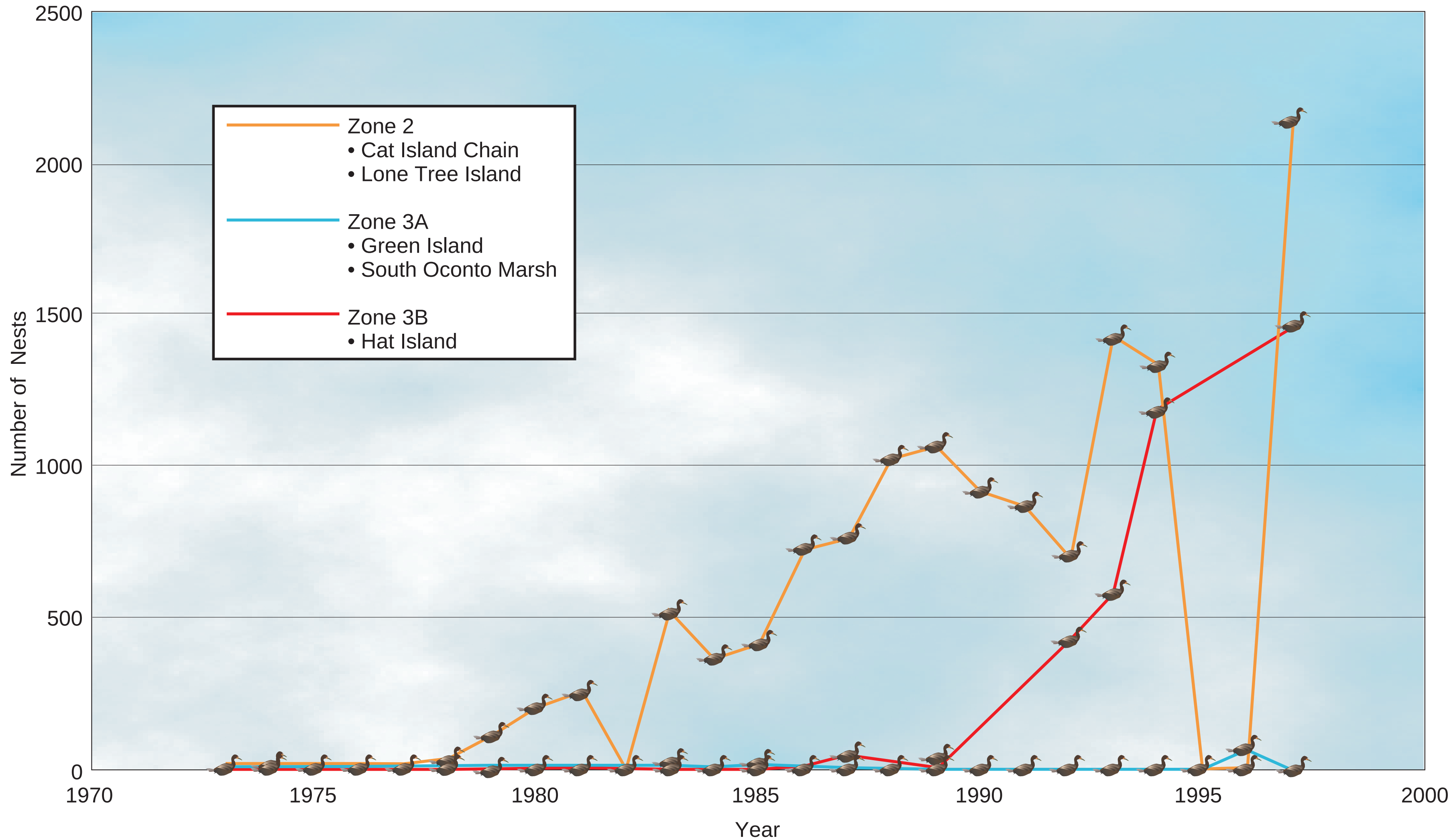
DRAWING NO: RA-4414-425-2-21
PRINT DATE: 3/14/01
CREATED BY: SCJ
APPROVED: AGF

Figure 2-22. Forster's Tern Population Data in Green Bay

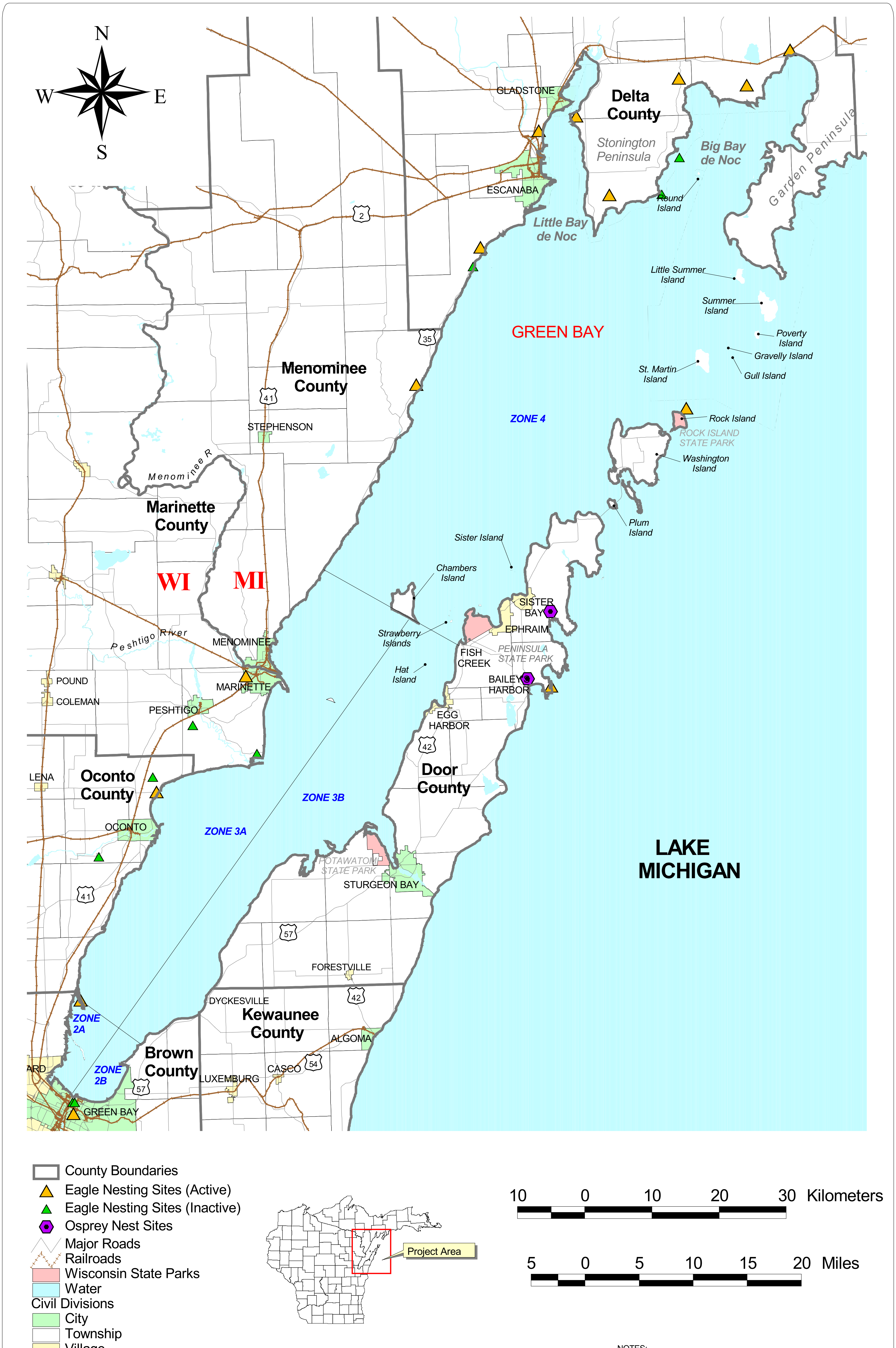


ThermoRetecJanuary2001Figure2_22

Figure 2-23. Number of Double-Crested Cormorant Nests in Zones 2 and 3 of Green Bay



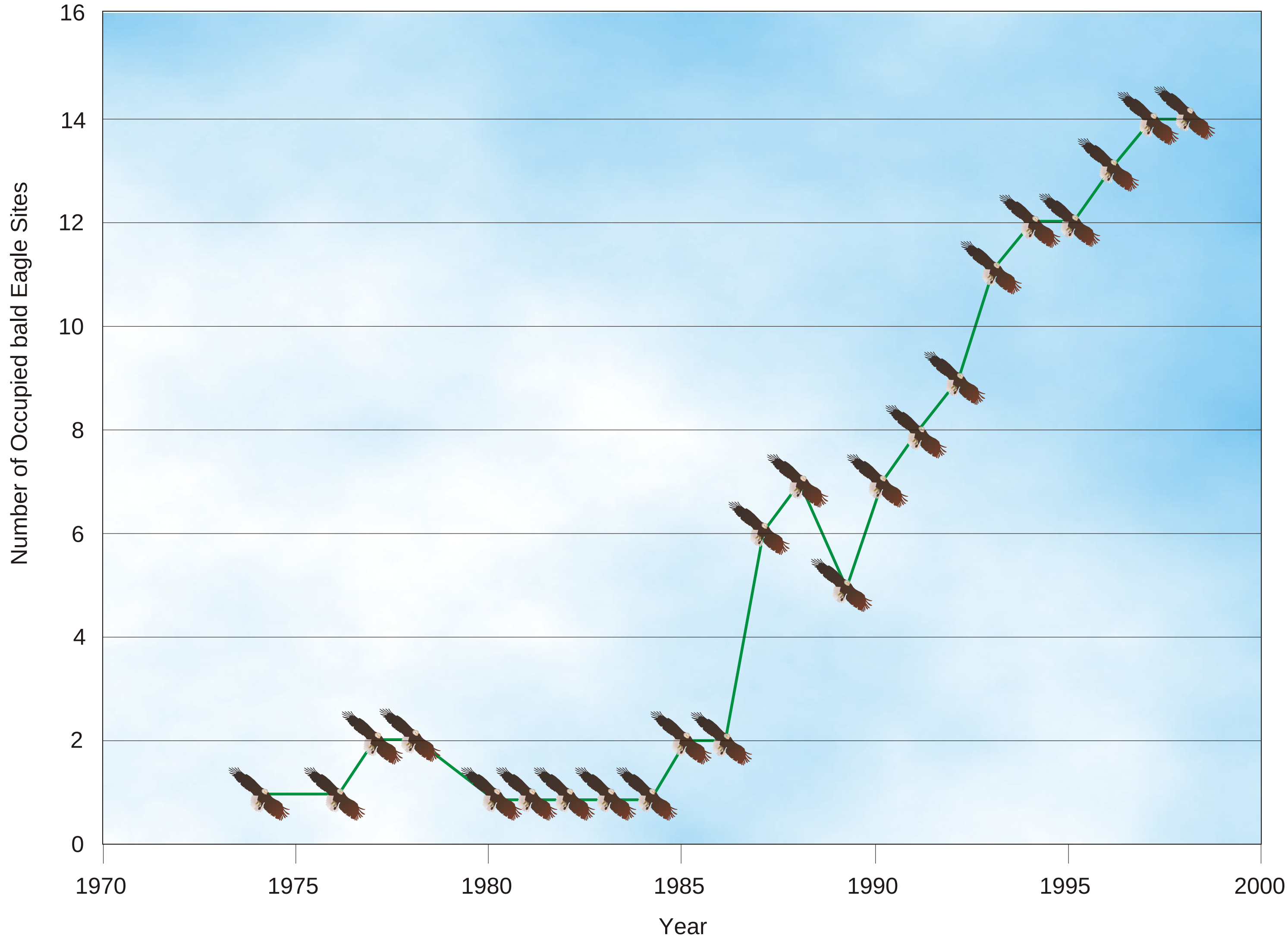
ThermoRetecJanuary2001Figure2_23



NOTES:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, version 3.2, WTM projection.
2. Wisconsin data provided by S. Stubenvoll, WDNR.
3. Michigan data from USFWS, 1999.

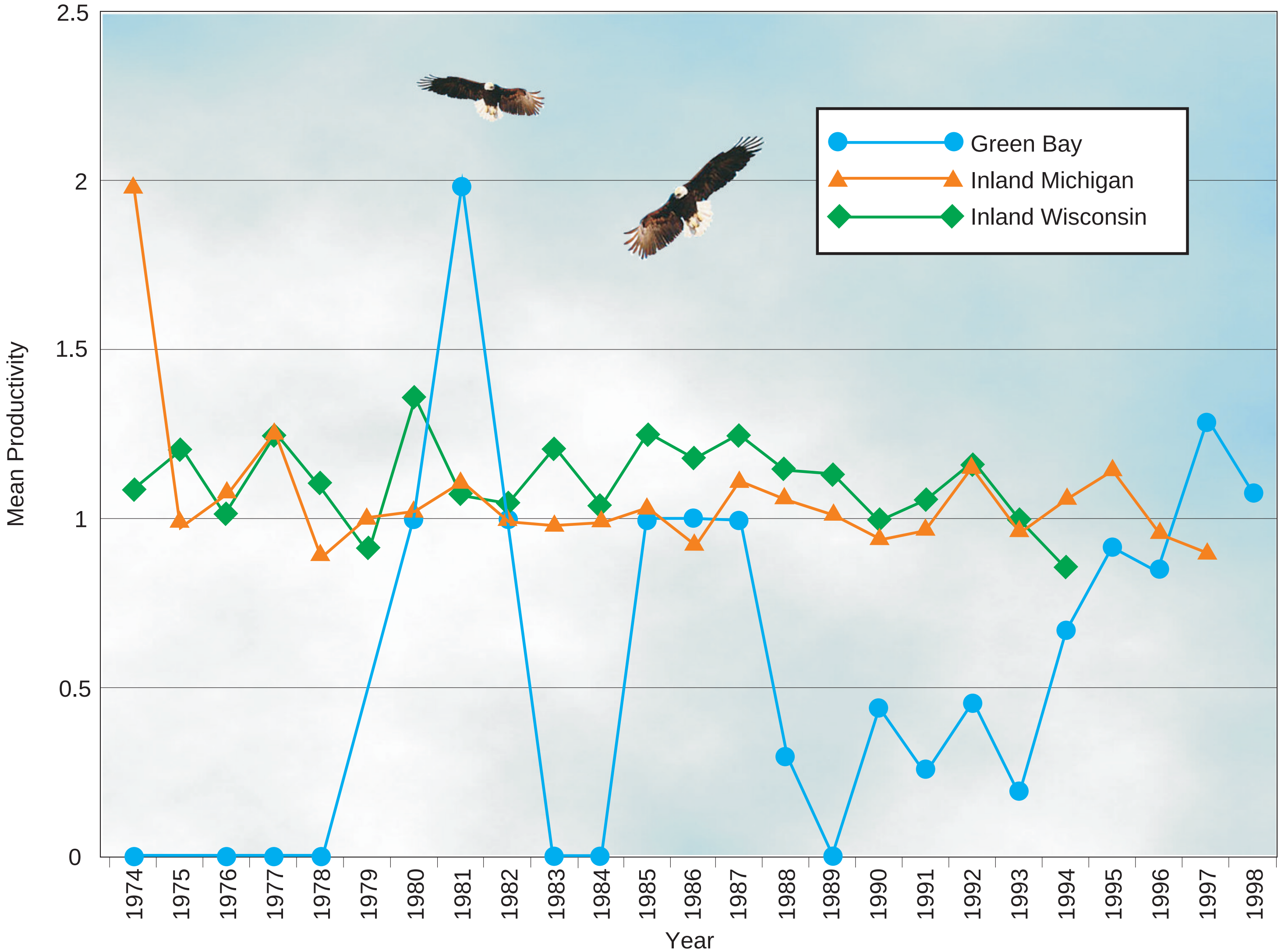
ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Distribution of Birds in Green Bay: Eagle and Osprey Locations	DRAWING NO: RA-4414-425-2-24
			FIGURE 2-24	PRINT DATE: 3/14/01
				CREATED BY: SCJ
				APPROVED: AGF

Figure 2-25. Number of Occupied Bald Eagle Nesting Sites on Green Bay



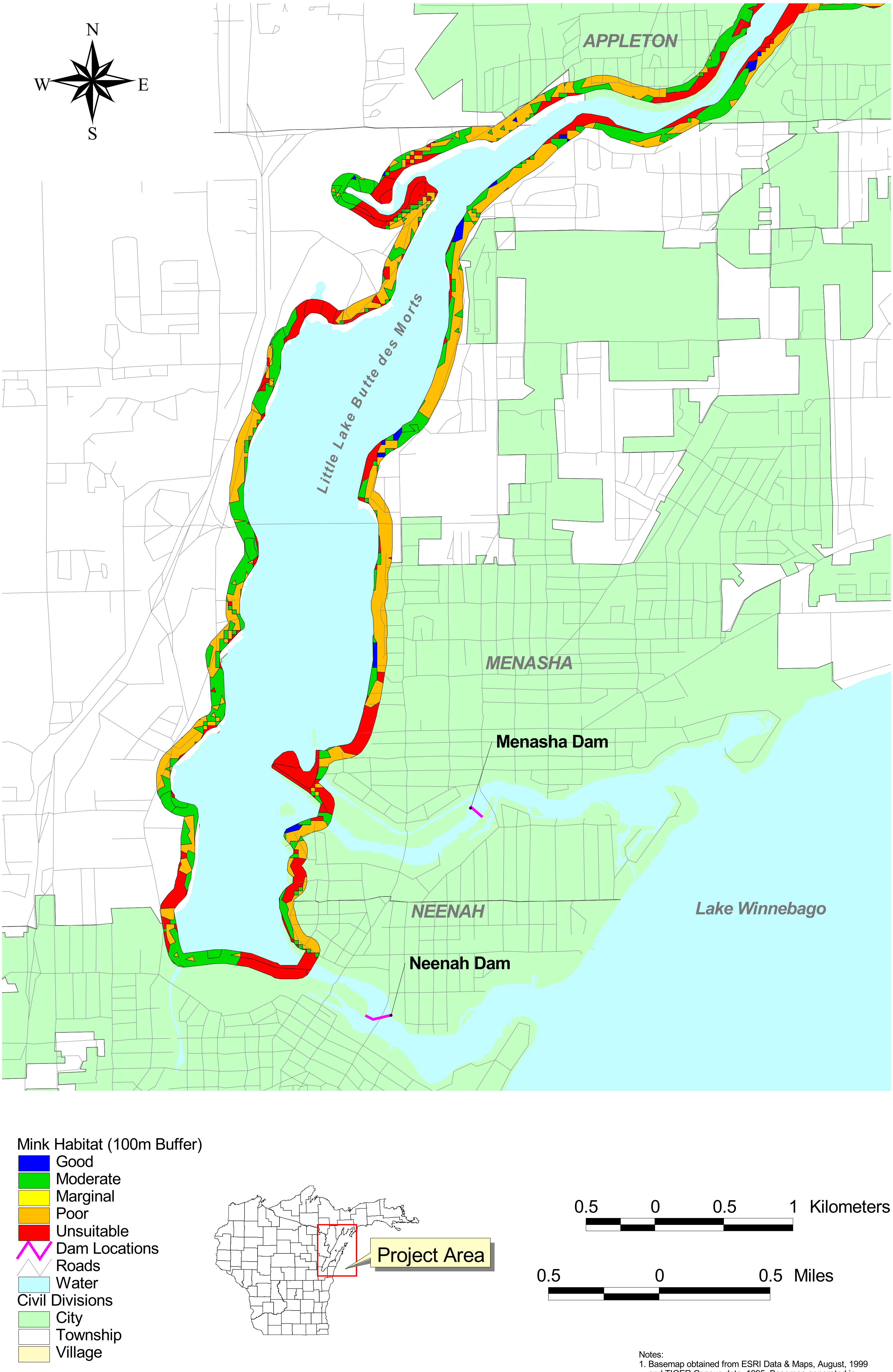
ThermoRetecJanuary2001Figure2_25

Figure 2-26 Mean Annual Productivity of Bald Eagles Nesting on Green Bay, Inland Michigan, and Inland Wisconsin



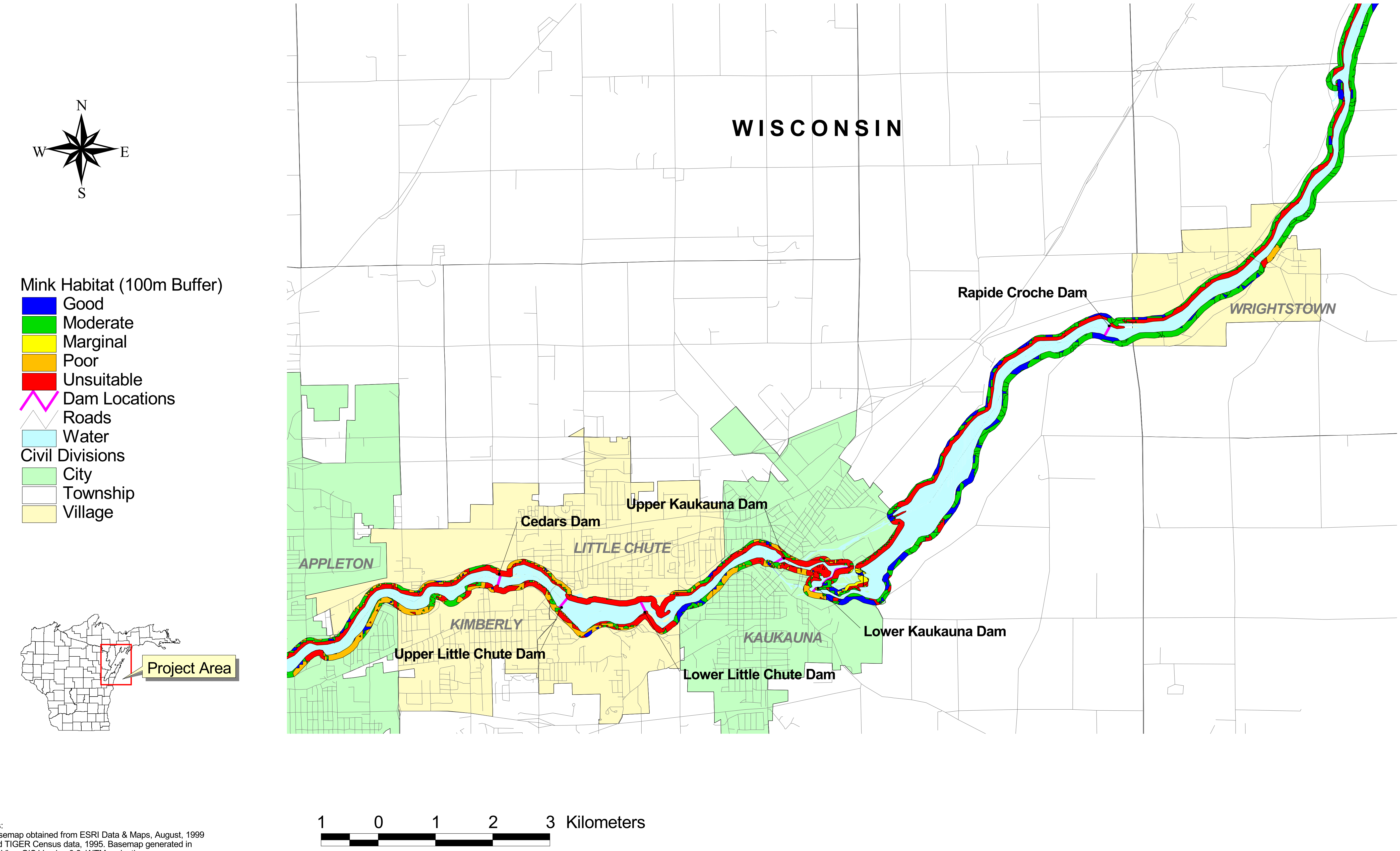
Note: Adapted from USFW 1999.

F:\PROJECTS\DOCS\4414\DOC\BLRA\DRAFT\FIGS\SEC2FIGS.PDF



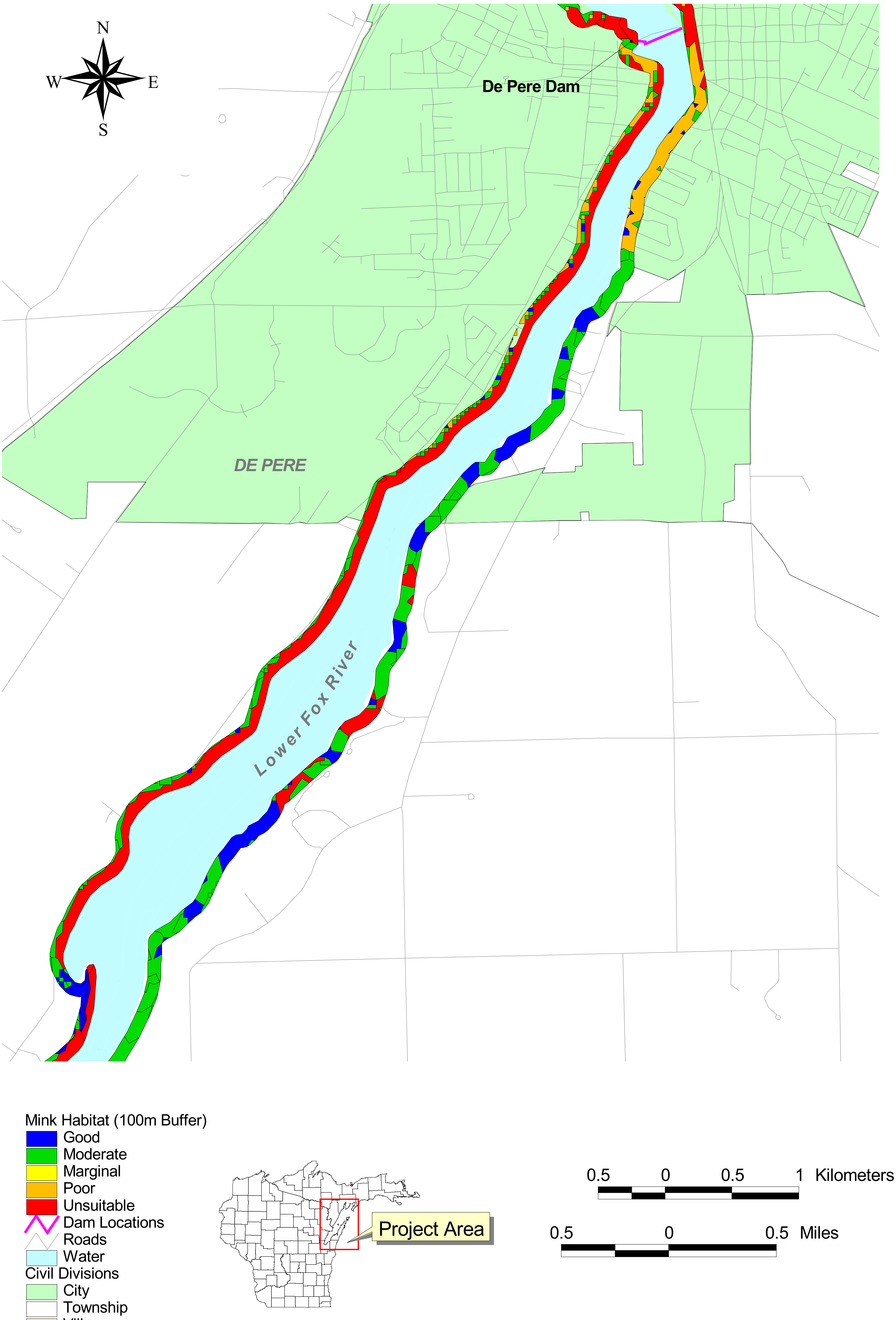
Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Mink data obtained from Exponent, 2000.
3. Suitability Index based on WISCLAND land use maps and WDNR wetland maps. Good = forest shrub/scrub or lowland wetland. Moderate = emergent wetland, meadow. Marginal = grassland, agricultural acres. Poor = low intensity, urban, or golf course. Unsuitable = mud plats, open water, high intensity urban.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Lower Fox River Mink Habitat Suitability: Little Lake Butte des Morts Reach	REFERENCE NO: RA-4414-425-2-27
				CREATED BY: SCJ
				PRINT DATE: 3/14/01
			FIGURE 2-27	APPROVED: AGF



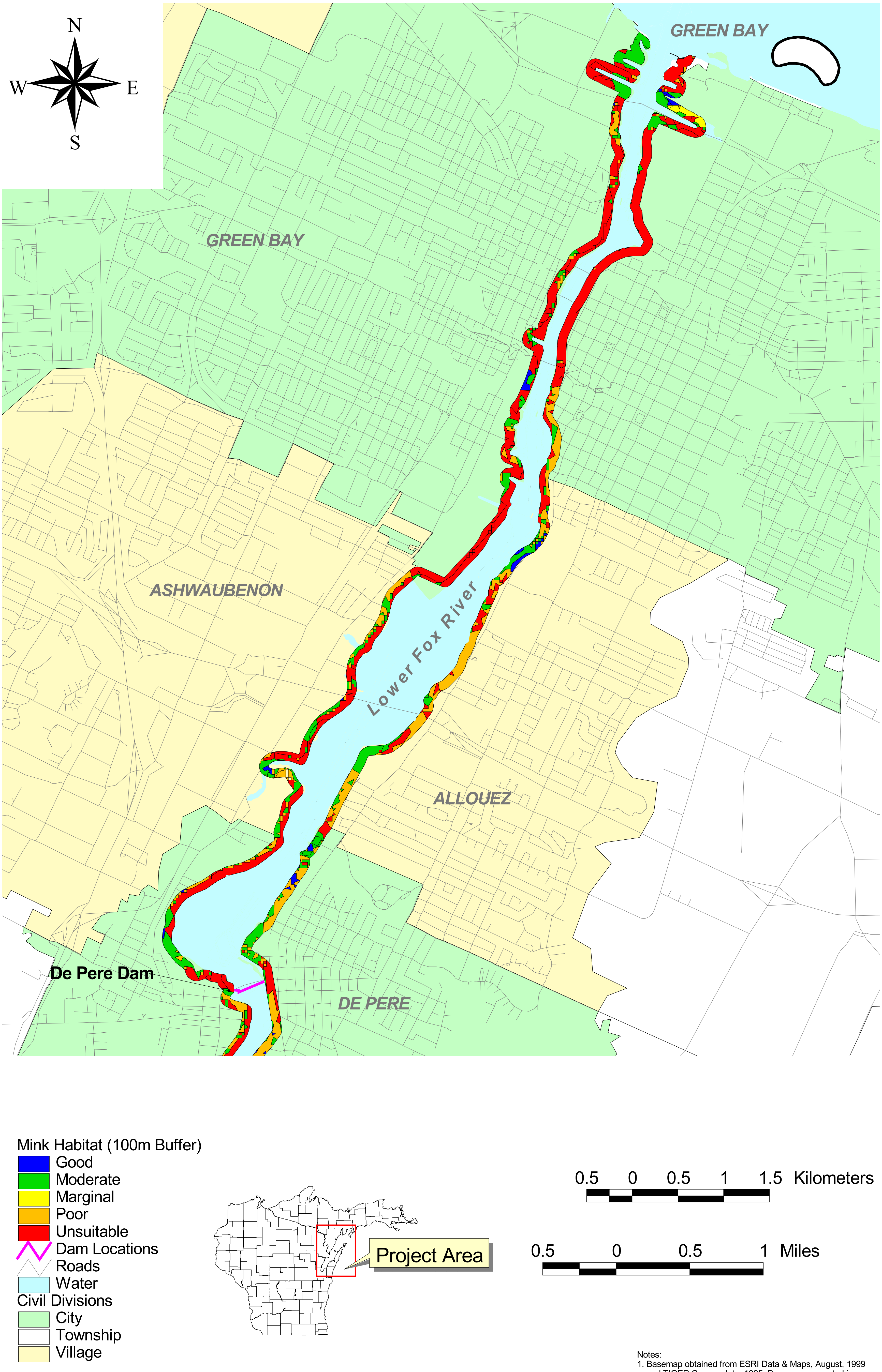
Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Mink data obtained from Exponent, 2000.
3. Suitability Index based on WISCLAND land use maps and WDNR wetland maps. Good = forest shrub/scrub or lowland wetland. Moderate = emergent wetland, meadow. Marginal = grassland, agricultural acres. Poor = low intensity, urban, or golf course. Unsuitable = mud plats, open water, high intensity urban.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Lower Fox River Mink Habitat Suitability: Appleton to Little Rapids Reach	REFERENCE NO: RA-4414-425-2-28
				CREATED BY: SCJ
				PRINT DATE: 3/14/01
			FIGURE 2-28	APPROVED: AGF



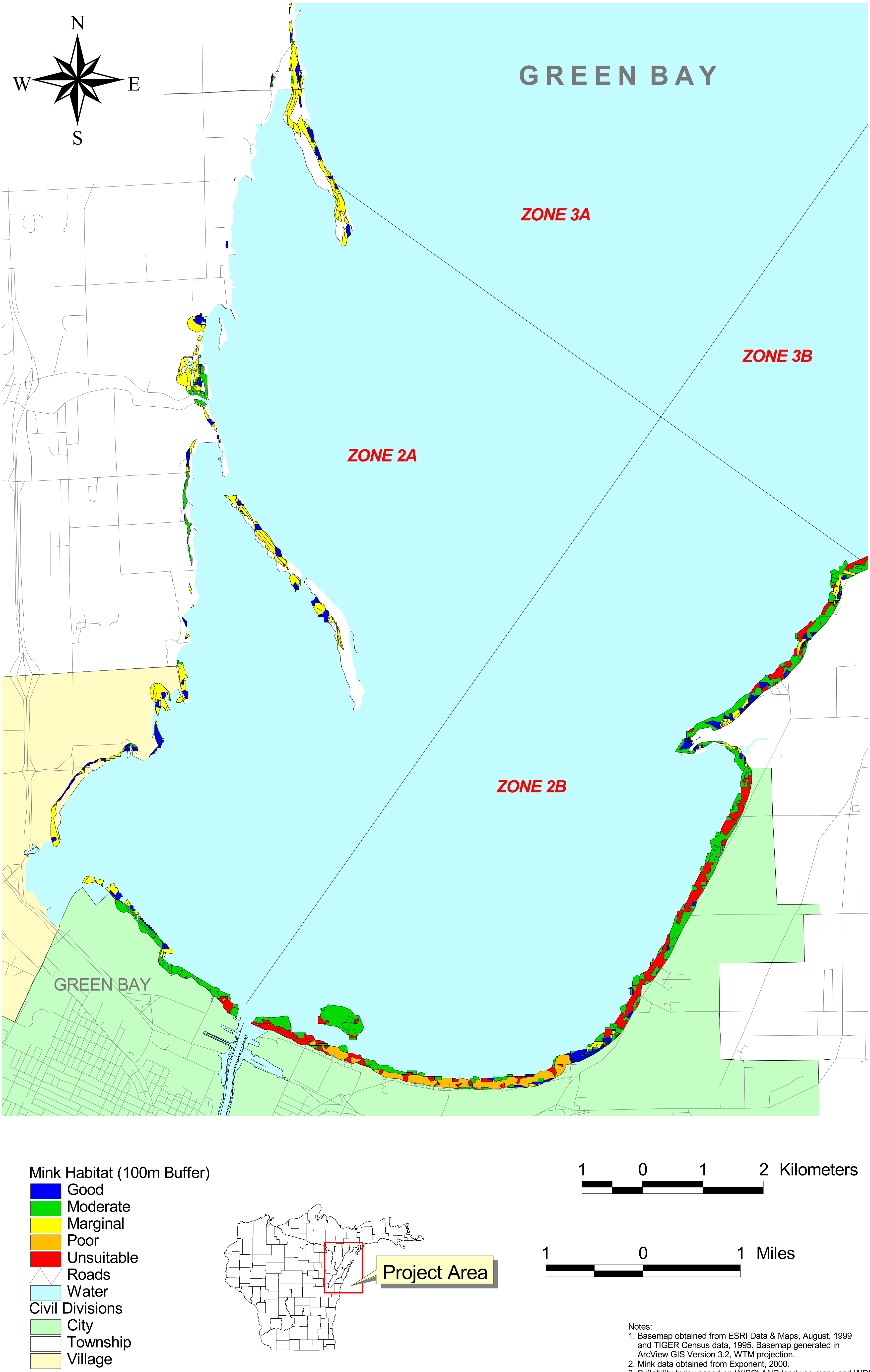
Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Mink data obtained from Exponent, 2000.
3. Suitability Index based on WISCLAND land use maps and WDNR wetland maps. Good = forest shrub/scrub or lowland wetland. Moderate = emergent wetland, meadow. Marginal = grassland, agricultural acres. Poor = low intensity, urban, or golf course. Unsuitable = mud plats, open water, high intensity urban.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Lower Fox River Mink Habitat Suitability: Little Rapids to De Pere Reach	REFERENCE NO: RA-4414-425-2-29
				CREATED BY: SCJ
				PRINT DATE: 3/14/01
			FIGURE 2-29	APPROVED: AGF



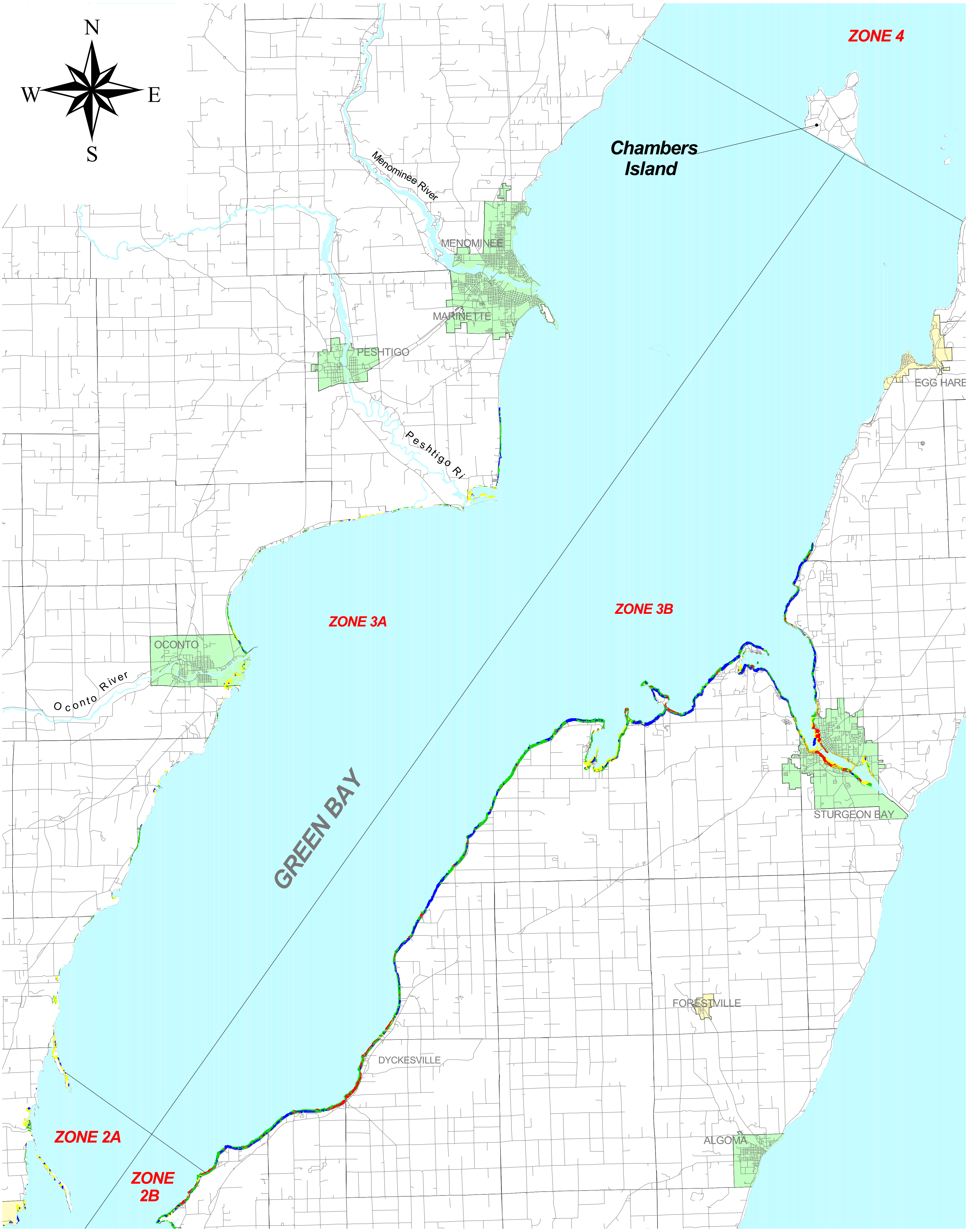
Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Mink data obtained from Exponent, 2000.
3. Suitability Index based on WISCLAND land use maps and WDNR wetland maps. Good = forest shrub/scrub or lowland wetland. Moderate = emergent wetland, meadow. Marginal = grassland, agricultural acres. Poor = low intensity, urban, or golf course. Unsuitable = mud plats, open water, high intensity urban.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Lower Fox River Mink Habitat Suitability: De Pere to Green Bay Reach	REFERENCE NO: RA-4414-425-2-27
				CREATED BY: SCJ
				PRINT DATE: 3/14/01
			FIGURE 2-30	APPROVED: AGF



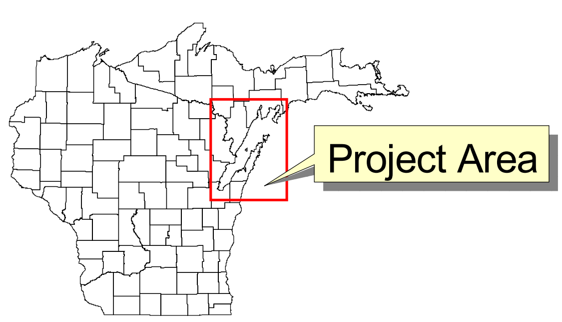
Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Mink data obtained from Exponent, 2000.
3. Suitability Index based on WISCLAND land use maps and WDNR wetland maps. Good = forest shrub/scrub or lowland wetland. Moderate = emergent wetland, meadow. Marginal = grassland, agricultural acres. Poor = low intensity, urban, or golf course. Unsuitable = mud plats, open water, high intensity urban.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Green Bay Mink Habitat Suitability: Zone 2	REFERENCE NO: RA-4414-425-2-31 CREATED BY: SCJ PRINT DATE: 3/14/01 APPROVED: AGF
			FIGURE 2-31	



Mink Habitat (100m Buffer)
- Good
- Moderate
- Marginal
- Poor
- Unsuitable
- Roads
- Water

Civil Divisions
- City
- Township
- Village



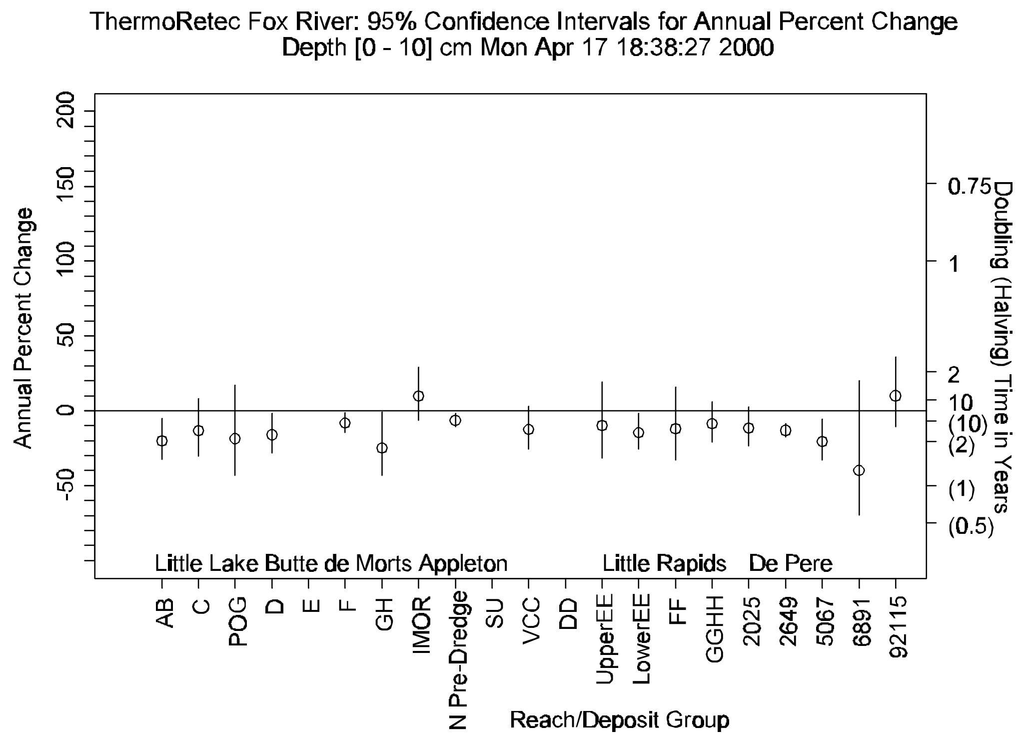
3 0 3 6 9 Kilometers

3 0 3 6 Miles

Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Mink data obtained from Exponent, 2000.
3. Suitability Index based on WISCLAND land use maps and WDNR wetland maps. Good = forest shrub/scrub or lowland wetland. Moderate = emergent wetland, meadow. Marginal = grassland, agricultural acres. Poor = low intensity, urban, or golf course. Unsuitable = mud plats, open water, high intensity urban.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Green Bay Mink Habitat Suitability: Zone 3	REFERENCE NO: RA-4414-425-2-32
				CREATED BY: SCJ
				PRINT DATE: 3/14/01
			FIGURE 2-32	APPROVED: AGF

Figure 2-33 Time Trends of PCBs in Sediments for Depths from 0 to 10 cm and from 10 to 30 cm



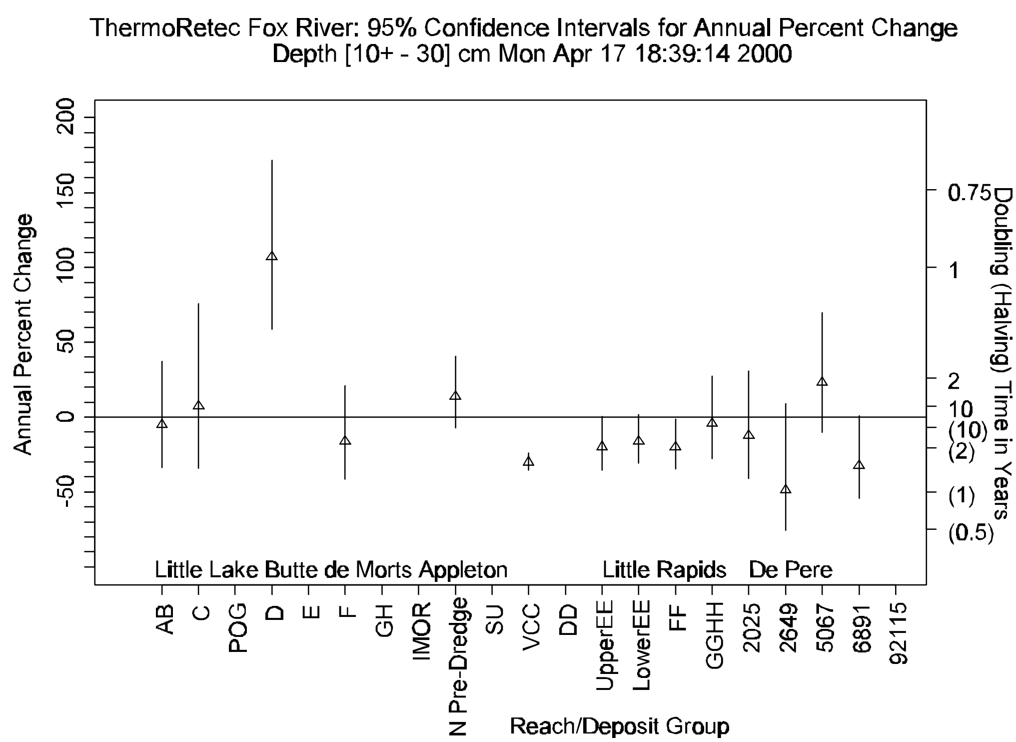
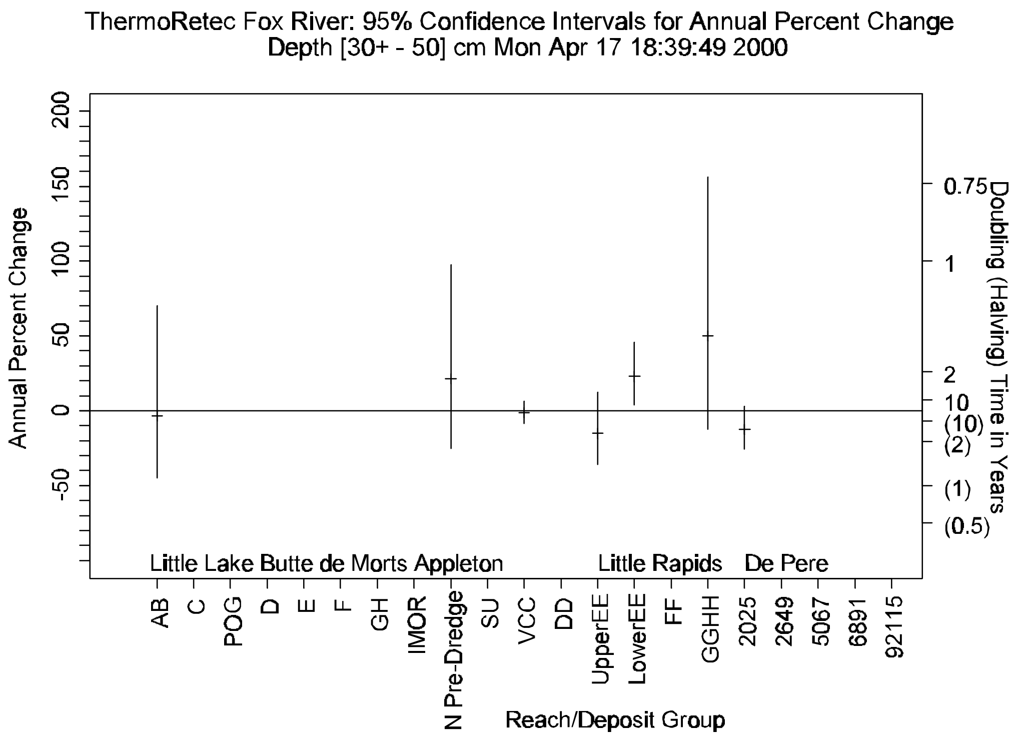


Figure 2-34 Time Trends of PCBs in Sediments for Depths from 30 to 50 cm and from 50 to 100 cm



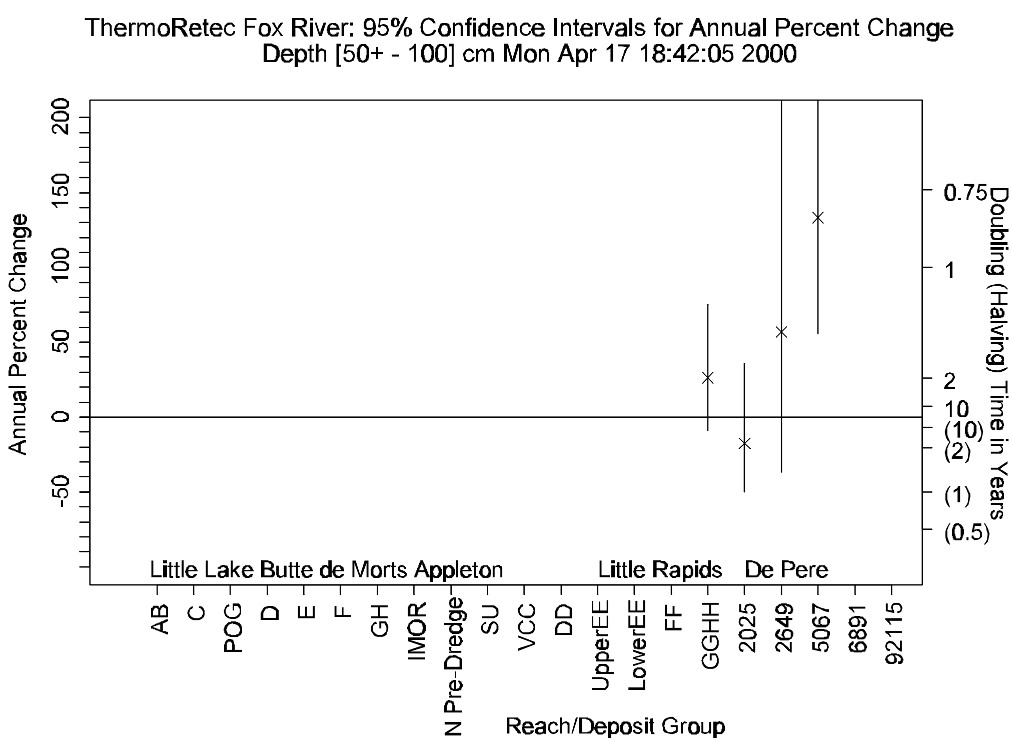
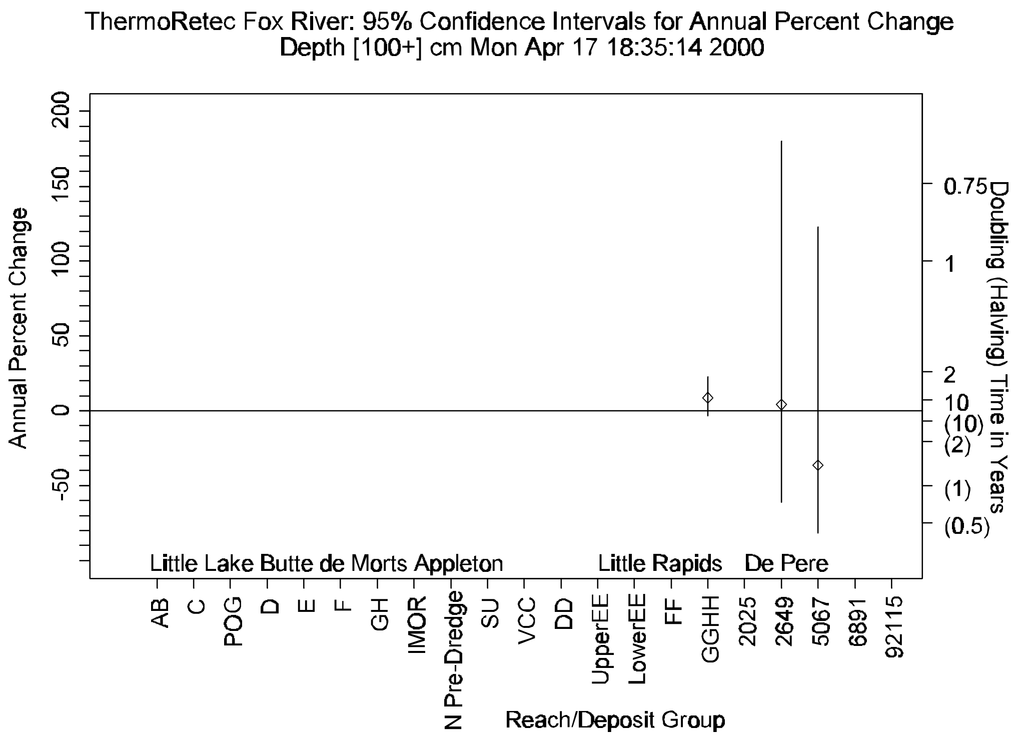


Figure 2-35 Time Trends of PCBs in Sediments for Depths over 100 cm



[THIS PAGE LEFT INTENTIONALLY BLANK.]

Table 2-1 Reach and Contaminant Deposit Designations for the Lower Fox River

Reach	Description	Deposits or Sediment Management Units (SMUs)
Little Lake Butte des Morts	Little Lake Butte des Morts from Neenah and Menasha dams to outlet	Deposits A–H and POG
Appleton to Little Rapids	Little Lake Butte des Morts outlet to Little Rapids (Little Kaukauna dam)	Deposits I–DD
Little Rapids to De Pere	Little Rapids (Little Kaukauna dam) to De Pere dam	Deposits EE–HH
De Pere to Green Bay	De Pere dam to river mouth into Green Bay	SMUs 20–115

Table 2-2 Zone Designations for Green Bay

Green Bay Zone Description
Zone 1 is identical to, and will be referred to hereinafter as, the De Pere to Green Bay Reach of the Fox River, discussed above.
Zone 2 extends from the mouth of the Lower Fox River to a line about 12.2 km (7.6 miles) from the mouth of the river. This line crosses the bay near Little Tail Point on the west side of the bay and near Red Banks/Point Vincent on the east side of the bay, approximately 10 km (6.2 miles) south of Dyckesville, Wisconsin.
Zone 3 extends from the northern boundary of Zone 2 to a line just south of Chambers Island. The northern boundary of Zone 3 is located about 86.7 km (53.9 miles) north of the mouth of the Lower Fox River. Therefore, Zone 3 extends for a distance of approximately 74.5 km (46.3 miles). The boundary line of Zone 3 connects Beattie Point, in the Michigan UP to Fish Creek, Wisconsin on the Door Peninsula.
Zone 4 (Figure 1-2) includes the remainder of Green Bay north of Chambers Island, including both Big and Little Bays de Noc. The distance from the south side of Chambers Island to the northern shores of Big Bay de Noc is approximately 101 km (63 miles).

Table 2-3 Major Green Bay Wetland Areas/Complexes

Wetland Area or Complex	State	Areal Extent		Wetland Type
		Acres	Hectares	
East Shore of Green Bay				
Horseshoe Point Wetland Complex	WI	272	110.1	P
Egg Harbor Township Wetland	WI	130	52.6	P
Sand Bay Area Wetland/Complex	WI	120	48.6	L
Little Sturgeon Bay Wetland Complex	WI	315	127.5	P
Point Au Sable Wetland	WI	112	45.3	L/P
Whitney Slough	WI	457	184.9	P
West Shore of Green Bay				
Atkinson Marsh/Peats Lake Complex	WI	509	206.0	L/P/R
Deadhorse Bay Wetland Complex	WI	322	130.3	L/P
Long Tail Point Wetland Complex	WI	163	66.0	L/P
Little Tail Point Wetland Complex	WI	210	85.0	P/L
Charles Pond Area Wetland Complex	WI	170	68.8	L/P
Pensaukee River Wetland Complex	WI	490	198.3	L
Oconto Marsh	WI	9,370	3,791.9	L/P/R
Peshtigo River Wetland	WI	5,040	2,039.6	L/P/R
Cedar River Area Wetland Complex	MI	1,556	629.7	L/P/R
Henderson Lakes Wetland	MI	253	102.4	P
Ford River Area Wetland Complex	MI	389	157.4	L/R
Portage Marsh	MI	1,302	526.9	L
North Shore of Green Bay				
Whitefish River Area Wetland Complex	MI	641	259.4	L
Squaw Point Wetland	MI	729	295.0	L/P
Deepwater Point Wetland Complex	MI	265	107.2	L
Granskog Creek Wetland Complex	MI	729	295.0	L
Sand Bay Wetland Complex	MI	181	73.2	P
Martin Bay Wetland Complex	MI	514	208.0	L
Ogontz Bay Wetland Complex	MI	1,759	711.8	L
Sturgeon River Wetland	MI	6,697	2,710.2	L
Upper Big Bay de Noc Wetland Complex	MI	9,555	3,866.8	L
Wetland Areal Total		**Acres**	**Hectares**	**Sq. Miles**
East Shore Wetland Totals		1,406	569	2.2
West Shore Wetland Totals		19,774	8,002	30.9
North Shore Wetland Totals		21,070	8,527	32.9
Wisconsin Wetland Total		17,680	7,155	27.6
Michigan Wetland Total		24,570	9,943	38.4
Total Wetlands Area		**42,250**	**17,098**	**66**

Notes:

[1] This table only includes wetlands and complexes larger than 100 acres in 1981 (USFWS, 1981).

L - Lacustrine wetland.

P - Palustrine wetland.

R - Riverine wetland.

Table 2-4 Green Bay West Shore Wildlife Area Units

Unit	Hectares (Acres)	Unit	Hectares (Acres)
Peats Lake/South Shore	163.6 (404.3)	Pensaukee W.A.	164.1 (405.6)
Long Tail Point N.W.R.	52.3 (129.3)	Pecor Point	35.3 (87.1)
Sensiba W.A.	317.8 (785.4)	Oconto Marsh	362.7 (896.2)
Little Tail	86.0 (212.4)	Rush Point	74.2 (183.3)
Tibbet-Suamico	106.7 (263.6)	Peshtigo Harbor W.A.	1,609.4 (3,976.9)
Charles Point	43.7 (108.0)	**Total Area**	**3,015.8 (7,452.1)**

Table 2-5 Summary of Green Bay Tributaries

Tributary	State	Drainage Area km^2 (mi^2)	Mean Discharge m^3/s (cfs)	Population Total
Lower Fox	WI	16,394 (6,330)	149 (5,262)	306,360
Duck-Pensaukee	WI	780 (301)	2.9 (101.6)	66,890
Suamico	WI	157 (60.7)	0.95 (33.4)	N/A
Oconto	WI	2,416 (933)	15.9 (560)	25,650
Peshtigo	WI	2,991 (1,155)	20 (704)	30,770
Menominee	WI/MI	10,748 (4,150)	78 (2,750)	57,320
Door - Kewaunee	WI	N/A	N/A	47,410
Cedar - Ford	MI	2,199 (849)	N/A	18,250
Escanaba	MI	2,383 (920)	23 (828)	7,570
Tacoosh	MI	75 (29)	N/A	N/A
Rapid	MI	352 (136)	N/A	N/A
Whitefish	MI	811 (313)	N/A	N/A
Fishdam - Sturgeon	MI	766 (296)	5.3 (188)	2,170
			Total:	**562,390**

Note:

N/A - Not available.

Table 2-6 Lower Fox River Habitats

Habitat Type	Description	Upstream of De Pere Dam	Downstream of De Pere Dam	River Totals
Lock Channels	These border the dams and provide habitat for fish, birds, and wildlife.	9.74%	0.38%	10.12%
Bridge Abutments	These create eddies which attract forage fish feeding on plankton. Swallows also nest beneath bridges.	0.01%	< 0.01%	0.01%
Backwaters, cuts, & coves	These serve as refuge and foraging sites for fish and wildlife. Piscivorous birds feed in these areas.	20.93%	6.91%	27.84%
Islands & Peninsulas	These provide habitat for birds and wildlife. The shores and shallows provide spawning grounds.	43.16%	0.48%	43.64%
Tributaries	Wetlands often develop at the mouths and provide habitat for fish, birds, and wildlife.	2.10%	4.09%	6.19%
Dam Riffles	Turbulent water is preferred spawning habitat of walleye and other fish. These areas attract many fish to feed, which attracts piscivorous birds.	4.22%	1.56%	5.78%
Submerged rock, piling, or ruins	Outcroppings, rocky shallows, and abandoned former piers and pilings provide excellent habitat for aquatic organisms and nesting or roosting sites for birds.	3.49%	2.93%	6.42%
Deadfall and overhang	Features vegetated shoreline, offering favorable habitat for fish, wildlife, and piscivorous birds and nesting sites for passerines. Habitat density upstream of De Pere dam was generally moderate to high while downstream it was generally low.			

Note:

Prepared from information compiled by Exponent (1998).

Table 2-7 Lower Fox River Shoreline and Substrate Types

Shoreline Type & Distance (km)	Upstream of De Pere Dam						Downstream of De Pere Dam					LFR Shoreline Totals	
	Area 1	Area 2	Area 3	Area 4	Area 5	Totals	Area 1	Area 2	Area 3	Area 4	Totals	Distance	Percent
Developed Shoreline													
Riprap	5.99	1.85	3.12	1.73	4.46	**17.15**	1.44	1.46	0.66	1.67	**5.24**	**22.39**	**35.7%**
Bulkhead	1.88	1.18	0.00	0.20	0.19	**3.46**	0.08	0.17	0.61	1.33	**2.18**	**5.64**	**9.0%**
Total	7.87	3.03	3.12	1.94	4.65	**20.61**	1.52	1.63	1.28	2.99	**7.42**	**28.03**	**44.6%**
Natural Shoreline													
Riparian Canopy	1.48	2.89	7.93	7.96	3.91	**24.16**	1.79	0.72	0.43	0.41	**3.35**	**27.51**	**43.8%**
Groundcover/wetland	2.17	1.48	1.95	0.20	0.47	**6.27**	0.55	0.02	0.00	0.00	**0.57**	**6.84**	**10.9%**
Sand/gravel	0.00	0.00	0.00	0.10	0.28	**0.38**	0.00	0.02	0.00	0.00	**0.02**	**0.41**	**0.6%**
Total	3.65	4.37	9.88	8.26	4.65	**30.81**	2.34	0.77	0.43	0.41	**3.94**	**34.75**	**55.4%**
Total Shoreline (km)	**11.51**	**7.40**	**13.00**	**10.20**	**9.30**	**51.41**	**3.86**	**2.40**	**1.70**	**3.40**	**11.36**	**62.78**	**100.0%**
River Substrate Types and Area (km^2)													
Type 1	1.62	0.00	1.85	0.01	3.23	**6.70**	1.89	1.62	0.49	0.95	**4.95**	**11.65**	**53.3%**
Type 2	2.70	0.15	0.37	0.05	0.15	**3.43**	0.11	0.09	0.00	0.00	**0.19**	**3.62**	**16.6%**
Type 3	1.08	1.35	1.85	1.71	0.23	**6.21**	0.06	0.00	0.00	0.01	**0.07**	**6.28**	**28.8%**
Type 4	0.00	0.00	0.00	0.00	0.15	**0.15**	0.04	0.00	0.01	0.04	**0.09**	**0.24**	**1.1%**
Type 5	0.00	0.00	0.02	0.01	0.02	**0.05**	0.00	0.00	0.00	0.00	**0.00**	**0.05**	**0.2%**
Total Coverage (km^2)	**5.40**	**1.50**	**4.08**	**1.78**	**3.78**	**16.54**	**2.10**	**1.70**	**0.50**	**1.00**	**5.30**	**21.84**	**100.0%**

Notes:

Prepared from information compiled by Exponent (1998).

Descriptions of the Areas (Exponent, 1998).

Area 1 - Little Lake Butte des Morts to Appleton lock 1.
Area 2 - Appleton lock 1 to Cedars lock.
Area 3 - Cedars lock to Rapide Croche lock.
Area 4 - Rapide Croche lock to Little Kaukauna lock.
Area 5 - Little Kaukauna Lock to De Pere dam.

Area 1 - De Pere dam to Highway 172 bridge.
Area 2 - Highway 172 bridge to Ft. Howard (Ft. James) RR trestle.
Area 3 - Ft. Howard RR trestle to E. Mason Street bridge.
Area 4 - E. Mason Street bridge to mouth of the Fox River.

Descriptions of Substrate Types (Exponent, 1998).

Type 1 - Soft, aqueous, silty sediments.
Type 2 - Semicompact to compact sands and/or clay.
Type 3 - Compact sand, gravel, or cobble deposits.
Type 4 - Combination of Types 1 and 2.
Type 5 - Cobble/boulder-size rocks.

Table 2-8 Lower Fox River/Duck Creek Fish Surveys

Study Area	Time Period	Reference	Purpose
Little Lake Butte des Morts to De Pere	1976	Marinac & Coble	Determine species present and relative abundance
Rapide Croche to Wrightstown	1976	Langhurst	Evaluate stocks as water quality improves in the future
Little Lake Butte des Morts to Wrightstown	1977	Meyers	Community and populations
Little Lake Butte des Morts	1983	Meyers	Evaluate northern pike populations and spawning areas
Little Lake Butte des Morts to Wrightstown	1993/94	Brook & Lychwick	Fisheries and habitat status
Little Rapids to De Pere	1994/95	Lychwick	Population surveys
De Pere to Green Bay	1987/98	Lychwick	Evaluate early spring spawning populations
Duck Creek Assessment	1995/96	Cogswell/Bougie	Populations survey spring through fall

Table 2-9 Lower Fox River Fish Species Composition

Species	Little Lake Butte des Morts 1983 Total Catch	Little Lake Butte des Morts 1983 Percent of Catch	Little Lake Butte des Morts to Little Rapids 1976–1977 Total Catch	1976–1977 Percent of Catch	1993–1994 Total Catch	1993–1994 Percent of Catch
Non-Game Fish [A]						
Alewife	0	0.0%	0	0.0%	0	0.0%
Bowfin	0	0.0%	0	0.0%	0	0.0%
Burbot	77	1.4%	2	0.0%	0	0.0%
Carp	1,995	36.1%	2,997	52.9%	533	54.1%
Creek Chub	0	0.0%	1	0.0%	0	0.0%
Drum (freshwater)	0	0.0%	137	2.4%	73	7.4%
Gizzard Shad	0	0.0%	11	0.2%	4	0.4%
Shortnose Gar	0	0.0%	5	0.1%	2	0.2%
Longnose Gar	0	0.0%	1	0.0%	0	0.0%
Redhorse	0	0.0%	0	0.0%	0	0.0%
Silver Lamprey	0	0.0%	0	0.0%	0	0.0%
Emerald Shiner	0	0.0%	82	1.4%	7	0.7%
Golden Shiner	0	0.0%	6	0.1%	1	0.1%
Spotfin Shiner	0	0.0%	4	0.1%	0	0.0%
Spottail Shiner	0	0.0%	1	0.0%	0	0.0%
White Sucker	180	3.3%	527	9.3%	3	0.3%
Quillback Carpsucker	1	0.0%	157	2.8%	15	1.5%
Log Perch	0	0.0%	42	0.7%	0	0.0%
Trout Perch	0	0.0%	43	0.8%	38	3.9%
Total: Non-game fish	**2,253**	**40.8%**	**4,016**	**70.9%**	**676**	**68.6%**
Game Fish						
Bluegill	2	0.0%	1	0.0%	0	0.0%
Rock Bass	0	0.0%	27	0.5%	3	0.3%
Largemouth Bass	0	0.0%	0	0.0%	0	0.0%
Smallmouth Bass	0	0.0%	6	0.1%	1	0.1%
White Bass	8	0.1%	46	0.8%	189	19.2%
Yellow Bass	1	0.0%	0	0.0%	0	0.0%
Black Bullhead	1,407	25.5%	933	16.5%	0	0.0%
Brown Bullhead	83	1.5%	0	0.0%	0	0.0%
Yellow Bullhead	0	0.0%	11	0.2%	0	0.0%
Channel Catfish	0	0.0%	1	0.0%	0	0.0%
Flathead Catfish	0	0.0%	0	0.0%	1	0.1%
Black Crappie	1,540	27.9%	96	1.7%	7	0.7%
White Crappie	0	0.0%	0	0.0%	0	0.0%
Spotted Muskie	0	0.0%	0	0.0%	0	0.0%
Northern Pike	171	3.1%	59	1.0%	12	1.2%
White Perch	0	0.0%	0	0.0%	0	0.0%
Yellow Perch	22	0.4%	360	6.4%	18	1.8%
Pumpkinseed	0	0.0%	15	0.3%	0	0.0%
Sauger	0	0.0%	0	0.0%	7	0.7%
Green Sunfish	2	0.0%	0	0.0%	0	0.0%
Brook Trout	0	0.0%	0	0.0%	0	0.0%
Lake Trout	0	0.0%	0	0.0%	0	0.0%
Rainbow Trout	0	0.0%	0	0.0%	0	0.0%
Walleye	34	0.6%	94	1.7%	72	7.3%
Total: Game Fish	**3270**	**59.2%**	**1649**	**29.1%**	**310**	**31.4%**
Totals	**5,523**	**100%**	**5,665**	**100%**	**986**	**100%**

Table 2-9 Lower Fox River Fish Species Composition (Continued)

Species	Little Rapids to De Pere					
	1975–1976		1983–1985		1994–1995	
	Total Catch	Percent of Catch	Total Catch	Percent of Catch	Total Catch	Percent of Catch
Non-Game Fish [A]						
Alewife	221	3.4%	0	0.0%	46	0.5%
Bowfin	1	0.0%	0	0.0%	1	0.0%
Burbot	0	0.0%	156	0.8%	4	0.0%
Carp	3,425	53.1%	12,570	65.1%	2,611	28.2%
Creek Chub	1	0.0%	0	0.0%	0	0.0%
Drum (freshwater)	156	2.4%	1,661	8.6%	928	10.0%
Gizzard Shad	3	0.0%	2,903	15.0%	1,081	11.7%
Shortnose Gar	5	0.1%	0	0.0%	6	0.1%
Longnose Gar	1	0.0%	2	0.0%	0	0.0%
Redhorse	0	0.0%	36	0.2%	76	0.8%
Silver Lamprey	0	0.0%	0	0.0%	0	0.0%
Emerald Shiner	1	0.0%	1	0.0%	71	0.8%
Golden Shiner	1	0.0%	0	0.0%	0	0.0%
Spotfin Shiner	0	0.0%	0	0.0%	55	0.6%
Spottail Shiner	0	0.0%	0	0.0%	77	0.8%
White Sucker	648	10.0%	545	2.8%	24	0.3%
Quillback Carpsucker	15	0.2%	92	0.5%	208	2.2%
Log Perch	0	0.0%	0	0.0%	37	0.4%
Trout Perch	1	0.0%	4	0.0%	315	3.4%
Total: Non-game fish	**4,479**	**69.4%**	**17,970**	**93.0%**	**5,540**	**59.8%**
Game Fish						
Bluegill	2	0.0%	5	0.0%	38	0.4%
Rock Bass	7	0.1%	69	0.4%	110	1.2%
Largemouth Bass	0	0.0%	1	0.0%	1	0.0%
Smallmouth Bass	0	0.0%	10	0.1%	493	5.3%
White Bass	174	2.7%	85	0.4%	293	3.2%
Yellow Bass	0	0.0%	0	0.0%	1	0.0%
Black Bullhead	1,024	15.9%	61	0.3%	0	0.0%
Brown Bullhead	0	0.0%	9	0.0%	0	0.0%
Yellow Bullhead	0	0.0%	11	0.1%	1	0.0%
Channel Catfish	2	0.0%	34	0.2%	411	4.4%
Flathead Catfish	0	0.0%	8	0.0%	11	0.1%
Black Crappie	188	2.9%	290	1.5%	269	2.9%
White Crappie	0	0.0%	0	0.0%	2	0.0%
Spotted Muskie	0	0.0%	0	0.0%	1	0.0%
Northern Pike	46	0.7%	228	1.2%	57	0.6%
White Perch	0	0.0%	0	0.0%	327	3.5%
Yellow Perch	396	6.1%	112	0.6%	535	5.8%
Pumpkinseed	59	0.9%	2	0.0%	1	0.0%
Sauger	1	0.0%	19	0.1%	9	0.1%
Green Sunfish	2	0.0%	0	0.0%	10	0.1%
Brook Trout	0	0.0%	0	0.0%	0	0.0%
Lake Trout	0	0.0%	0	0.0%	0	0.0%
Rainbow Trout	0	0.0%	0	0.0%	0	0.0%
Walleye	74	1.1%	404	2.1%	1,153	12.4%
Total: Game Fish	**1975**	**30.6%**	**1348**	**7.0%**	**3723**	**40.2%**
Totals	**6,454**	**100%**	**19,318**	**100%**	**9,263**	**100%**

Notes:

[A] As Listed in Wisconsin State Statute Chapter 29.01.

[B] No differentiation made between shortnose/longnose gar. Value listed for shortnose gar represents both species.

[C] No differentiation made between bullheads (black, brown, yellow). Value listed for black bullhead represents all three species.

Table 2-10 Lower Fox River Fish Populations in the De Pere to Green Bay Reach

Species	1987		1988		1989		1990		1991		1992	
	Catch	% Catch	Catch	% Catch	Catch	% Catch	Catch	% Catch	Catch	% Catch	Catch	% Catch
Non-Game Fish												
Alewife*	3	0.0%	-	0.0%	-	0.0%	-	0.0%	1	0.0%	-	0.0%
Burbot	19	0.1%	25	0.1%	12	0.1%	12	0.1%	12	0.1%	12	0.1%
Carp*	1,220	5.4%	659	3.7%	1,322	6.6%	886	9.6%	863	4.6%	1,382	8.7%
Drum (freshwater)*	259	1.1%	210	1.2%	998	5.0%	652	7.1%	391	2.1%	1,242	7.8%
Gar	28	0.1%	20	0.1%	35	0.2%	17	0.2%	9	0.0%	58	0.4%
Gizzard Shad*	2	0.0%	8	0.0%	4	0.0%	104	1.1%	13	0.1%	34	0.2%
Longnose Sucker	4	0.0%	2	0.0%	6	0.0%	-	0.0%	3	0.0%	12	0.1%
Mooneye	-	0.0%	-	0.0%	1	0.0%	-	0.0%	-	0.0%	8	0.1%
Quillback	30	0.1%	7	0.0%	72	0.4%	176	1.9%	280	1.5%	866	5.4%
Redhorse*	16	0.1%	12	0.1%	17	0.1%	11	0.1%	22	0.1%	17	0.1%
Trout-perch*	2	0.0%	5	0.0%	10	0.1%	7	0.1%	-	0.0%	32	0.2%
White Sucker*	1,554	6.9%	1,002	5.6%	2,071	10.4%	724	7.9%	852	4.5%	817	5.1%
Total Non-Game Fish	**3,137**	**13.9%**	**1,950**	**10.9%**	**4,548**	**22.8%**	**2,589**	**28.2%**	**2,446**	**13.0%**	**4,480**	**28.1%**
Game Fish												
Black Bullhead*	274	1.2%	608	3.4%	960	4.8%	599	6.5%	64	0.3%	18	0.1%
Black Crappie*	413	1.8%	181	1.0%	602	3.0%	427	4.6%	730	3.9%	255	1.6%
Bluegill*	4	0.0%	2	0.0%	29	0.1%	53	0.6%	10	0.1%	17	0.1%
Brook Trout	1	0.0%	-	0.0%	1	0.0%	-	0.0%	-	0.0%	1	0.0%
Brown Bullhead	5	0.0%	10	0.1%	13	0.1%	1	0.0%	-	0.0%	1	0.0%
Channel Catfish	52	0.2%	55	0.3%	125	0.6%	315	3.4%	74	0.4%	238	1.5%
Flathead Catfish	-	0.0%	2	0.0%	10	0.1%	22	0.2%	8	0.0%	35	0.2%
Hydrid Muskie	-	0.0%	39	0.2%	4	0.0%	4	0.0%	2	0.0%	12	0.1%
Largemouth Bass*	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%
Muskie*	1	0.0%	-	0.0%	-	0.0%	2	0.0%	1	0.0%	1	0.0%
Northern Pike*	94	0.4%	116	0.6%	222	1.1%	79	0.9%	127	0.7%	192	1.2%
Pumpkinseed*	2	0.0%	3	0.0%	3	0.0%	4	0.0%	-	0.0%	1	0.0%
Rainbow Trout*	-	0.0%	-	0.0%	-	0.0%	13	0.1%	9	0.0%	1	0.0%
Rock Bass*	26	0.1%	13	0.1%	49	0.2%	46	0.5%	13	0.1%	23	0.1%
Sauger	1	0.0%	-	0.0%	-	0.0%	1	0.0%	5	0.0%	12	0.1%
Smallmouth Bass*	6	0.0%	3	0.0%	4	0.0%	14	0.2%	19	0.1%	13	0.1%
Walleye	3,017	13.4%	1,531	8.6%	1,781	8.9%	635	6.9%	1,392	7.4%	1,957	12.3%
White Bass*	723	3.2%	534	3.0%	357	1.8%	419	4.6%	962	5.1%	766	4.8%
White Perch*	-	0.0%	-	0.0%	3	0.0%	137	1.5%	5	0.0%	212	1.3%
Yellow Bullhead*	6	0.0%	7	0.0%	20	0.1%	7	0.1%	2	0.0%	-	0.0%
Yellow Perch*	14,763	65.5%	12,797	71.7%	11,220	56.2%	3,817	41.6%	12,889	68.7%	7,718	48.4%
Total Game Fish	**19,388**	**86.1%**	**15,901**	**89.1%**	**15,403**	**77.2%**	**6,595**	**71.8%**	**16,312**	**87.0%**	**11,473**	**71.9%**
Total Fish	**22,525**	**100.0%**	**17,851**	**100.0%**	**19,951**	**100.0%**	**9,184**	**100.0%**	**18,758**	**100.0%**	**15,953**	**100.0%**

Table 2-10 Lower Fox River Fish Populations in the De Pere to Green Bay Reach (Continued)

Species	1993 Catch	1993 % Catch	1994 Catch	1994 % Catch	1995 Catch	1995 % Catch	1996 Catch	1996 % Catch	1997 Catch	1997 % Catch	1998 Catch	1998 % Catch
Non-Game Fish												
Alewife*	2	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%
Burbot	38	0.2%	35	0.3%	38	0.8%	16	0.4%	23	1.0%	34	0.4%
Carp*	216	0.9%	866	6.7%	102	2.2%	161	3.6%	129	5.6%	218	2.8%
Drum (freshwater)*	156	0.7%	533	4.1%	86	1.9%	63	1.4%	55	2.4%	420	5.3%
Gar	7	0.0%	25	0.2%	5	0.1%	-	0.0%	-	0.0%	8	0.1%
Gizzard Shad*	1	0.0%	84	0.6%	5	0.1%	1	0.0%	-	0.0%	-	0.0%
Longnose Sucker	3	0.0%	3	0.0%	1	0.0%	-	0.0%	2	0.1%	1	0.0%
Mooneye	1	0.0%	3	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%
Quillback	554	2.4%	239	1.8%	54	1.2%	72	1.6%	8	0.3%	72	0.9%
Redhorse*	55	0.2%	73	0.6%	10	0.2%	41	0.9%	17	0.7%	107	1.4%
Trout-perch*	7	0.0%	1	0.0%	27	0.6%	-	0.0%	1	0.0%	-	0.0%
White Sucker*	824	3.6%	1,807	13.9%	204	4.4%	256	5.7%	121	5.3%	848	10.8%
Total Non-Game Fish	**1,864**	**8.2%**	**3,669**	**28.2%**	**532**	**11.5%**	**610**	**13.6%**	**356**	**15.5%**	**1,708**	**21.7%**
Game Fish												
Black Bullhead*	21	0.1%	51	0.4%	2	0.0%	12	0.3%	8	0.3%	8	0.1%
Black Crappie*	33	0.1%	281	2.2%	35	0.8%	20	0.4%	2	0.1%	22	0.3%
Bluegill*	1	0.0%	1	0.0%	2	0.0%	2	0.0%	-	0.0%	1	0.0%
Brook Trout	1	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%
Brown Bullhead	-	0.0%	2	0.0%	2	0.0%	-	0.0%	-	0.0%	-	0.0%
Channel Catfish	44	0.2%	369	2.8%	46	1.0%	27	0.6%	10	0.4%	227	2.9%
Flathead Catfish	3	0.0%	23	0.2%	1	0.0%	4	0.1%	3	0.1%	21	0.3%
Hydrid Muskie	1	0.0%	9	0.1%	-	0.0%	-	0.0%	-	0.0%	1	0.0%
Largemouth Bass*	-	0.0%	-	0.0%	1	0.0%	-	0.0%	-	0.0%	-	0.0%
Muskie*	1	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	8	0.1%
Northern Pike*	19	0.1%	135	1.0%	24	0.5%	17	0.4%	37	1.6%	120	1.5%
Pumpkinseed*	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%
Rainbow Trout*	-	0.0%	6	0.0%	-	0.0%	-	0.0%	-	0.0%	-	0.0%
Rock Bass*	16	0.1%	4	0.0%	8	0.2%	17	0.4%	4	0.2%	18	0.2%
Sauger	16	0.1%	25	0.2%	2	0.0%	8	0.2%	2	0.1%	25	0.3%
Smallmouth Bass*	6	0.0%	20	0.2%	22	0.5%	27	0.6%	21	0.9%	40	0.5%
Walleye	3,442	15.1%	3,952	30.4%	1,024	22.1%	1,539	34.4%	1,509	65.9%	3,821	48.6%
White Bass*	333	1.5%	267	2.1%	60	1.3%	219	4.9%	11	0.5%	140	1.8%
White Perch*	159	0.7%	1,450	11.2%	327	7.1%	325	7.3%	55	2.4%	866	11.0%
Yellow Bullhead*	1	0.0%	-	0.0%	2	0.0%	1	0.0%	-	0.0%	-	0.0%
Yellow Perch*	16,843	73.9%	2,729	21.0%	2,546	54.9%	1,647	36.8%	272	11.9%	829	10.6%
Total Game Fish	**20,940**	**91.8%**	**9,324**	**71.8%**	**4,104**	**88.5%**	**3,865**	**86.4%**	**1,934**	**84.5%**	**6,147**	**78.3%**
Total	**22,804**	**100.0%**	**12,993**	**100.0%**	**4,636**	**100.0%**	**4,475**	**100.0%**	**2,290**	**100.0%**	**7,855**	**100.0%**

Note:

* Indicates that this fish species was observed in Duck Creek during the 1995/1996 survey assessment (Cogswell and Bougie, 1998).

Table 2-11 Green Bay - Common and Important Fish Species

Common Name	Species Name	Food Web	Wisconsin Listing	Michigan Listing	Federal Listing
Salmon and Trout					
Atlantic salmon	*Salmo salar*				
Brown trout	*Salmo trutta*				
Chinook salmon (king)	*Oncorhynchus tshawytscha*				
Coho salmon (silver)	*Oncorhynchus kisutch*				
Pink salmon (humpy)	*Oncorhynchus gorbuscha*				
Rainbow trout (steelhead)	*Salmo gairdneri*				
Brook trout	*Slavelinus fontinalis*				
Lake trout	*Slavelinus namaycush*				
Benthic Fish					
Black bullhead	*Ictaluras melas*				
Brown bullhead	*Ictalurus nebulosus*				
Carp	*Cyprinus carpio*	✓			
Channel catfish	*Ictalurus punctatus*				
Yellow bullhead	*Ictalurus natalis*				
Shorthead redhorse	*Moxostoma macrolepidotum*				
Silver redhorse	*Moxostoma anisurum*				
White sucker	*Catostomus commersoni*				
Pelagic Fish					
Common shiner	*Notropis cornutus*	✓			
Emerald shiner	*Notropis atherinoides*	✓			
Gizzard shad	*Dorosoma cepedianum*	✓			
Lake sturgeon	*Acipenser fulvescens*			▼	
Rainbow smelt	*Osmerus mordax*	✓			
Redfin shiner	*Notropis umbratilis*	✓			
Spottail shiner	*Notropis hudsonius*	✓			
Alewife	*Alosa pseudoharengus*	✓			
Game Fish					
Lake whitefish	*Coregonus clupeaformis*				
Muskellunge	*Esox masquinongy*				
Northern pike	*Esox lucius*				
Sauger	*Stizostedion canadense*			▼	
Walleye	*Stizostedion vitreum*	✓			
Yellow perch	*Perca flavescens*	✓			
Black crappie	*Pomoxis nigromaculatus*				
Bluegill	*Lepomis macrochirus*				
Largemouth bass	*Micropterus salmoides*				
Pumpkinseed	*Lepomis gibbosus*				
Rock bass	*Ambloplites rupestris*				
Smallmouth bass	*Micropterus dolomieui*				
White bass	*Morone chrysops*				

Notes:

◆ - Delisted.
✚ - Endangered.
▼ - Threatened.
✓ - Included in Risk Assessment food web models.

Table 2-12 Lower Fox River and Green Bay - Common and Important Bird Species

Common Name	Species Name	Food Web	Wisconsin Listing	Michigan Listing	Federal Listing
Raptors					
Bald eagle	*Haliaeetus leucocephalus*	✓	◆	▼	▼
Merlin	*Falco Columbarius*			▼	
Osprey	*Pandion haliaetus*		▼	▼	
Peregrine falcon	*Falco peregrinus*		✚	✚	✚
Gulls and Terns					
Black tern	*Chilidonias niger*				
Caspian tern	*Sterna caspia*		✚	▼	
Common tern	*Sterna hirundo*	✓	✚	▼	
Forster's tern	*Sterna fosteri*	✓	✚		
Herring gull	*Larus argentatus*				
Ring-billed gull	*Larus delawarensis*				
Diving Birds					
Belted kingfisher	*Megaceryle alcyon*				
Common loon	*Gavia immer*				
Double-crested cormorant	*Phalacrocorax auritus*	✓			
Horned grebe	*Podiceps auritus*				
Pied-billed grebe	*Podilymbus podiceps*				
American white pelican	*Pelecanus erythrorhynchos*				
Passerine Bird					
Brewer's blackbird	*Euphagus cyanocephalus*				
Marsh wren	*Cistothorus palustris*				
Red-winged blackbird	*Agelaius phoeniceus*				
Sedge wren	*Cistothorus platensis*				
Swamp sparrow	*Melospiza georgiana*				
Yellow-headed blackbird	*Xanthocephalus xanthocephalus*				
Shorebird					
Common snipe	*Capella gallinago*				
Dunlin	*Calidris alpina*				
Least sandpiper	*Calidris minutilla*				
Pectoral sandpiper	*Calidris melanotos*				
Piping plover	*Charadrius melodus*		✚	✚	✚▼
Sanderling	*Calidris alba*				
Semipalmated sandpiper	*Calidris pusilla*				
Spotted sandpiper	*Actitis macularia*				

Table 2-12 Lower Fox River and Green Bay - Common and Important Bird Species (Continued)

Common Name	Species Name	Food Web	Wisconsin Listing	Michigan Listing	Federal Listing
Wading Birds					
American bittern	*Botaurus lentiginosus*				
American woodcock	*Philohela minor*				
Black-crowned night heron	*Nycticorax nycticorax*				
Cattle egret	*Bubulcus ibis*				
Great blue heron	*Ardea herodias*				
Green-backed heron	*Butorides striatus*				
King rail	*Rallus elegans*			✚	
Least bittern	*Ixobrychus exilis*			▼	
Sandhill crane	*Grus canadensis*				
Snowy egret	*Egretta thula*		✚		✚
Sora rail	*Porzana carolina*				
Virginia rail	*Rallus limicola*				
Yellow rail	*Coturnicops noveboracensis*		▼	▼	
Waterfowl					
American coot	*Fulica americana*				
Black duck	*Anas rubripes*				
Blue-winged teal	*Anas discors*				
Bufflehead	*Bucephala albeola*				
Canada goose	*Branta canadensis*				
Canvasback	*Aythya valisineria*				
Common goldeneye	*Bucephala clangula*				
Common merganser	*Mergus merganser*				
Common moorhen	*Gallinula chloropus*				
Greater scaup	*Aythya marila*				
Green-winged teal	*Anas crecca*				
Lesser scaup	*Aythya affinis*				
Mallard	*Anas platyrhynchos*				
Northern shoveler	*Anas clypeata*				
Oldsquaw	*Clangula hyemalis*				
Red-breasted merganser	*Mergus serrator*				
Redhead	*Aythya americana*				
Ring-necked duck	*Aythya collaris*				
Ruddy duck	*Oxyura jamaicensis*				
Whistling swan (tundra swan)	*Olor columbianus*				
Wood duck	*Aix sponsa*				

Notes:

◆ - Delisted.
▼ - Threatened.
✚ - Endangered.
✓ - Included in Risk Assessment food web models.

Table 2-13 Productivity (large young raised per active nest) of Fox River Bald Eagles from 1988 to 1998

Nest Name	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Kaukauna, Wisconsin	2	1	0	3	3	3	1	3	2	2	3
Mud Creek, Wisconsin							2	3	1	2	3
East River, Wisconsin							0				
Productivity Summary, All Nests											
Number of active nests	1	1	1	1	1	1	3	2	2	2	2
Number of young reared	2	1	0	3	3	3	3	6	3	4	6
Young/active nest	2	1	0	3	3	3	1	3	1.5	2	3

Note:
A blank cell indicates that the nesting territory was unoccupied in that year.
Source:
USFWS and WDNR bald eagle productivity databases.

Table 2-14 Endangered and Threatened Mammal Species of the Lower Fox River and Green Bay

List	Endangered	Threatened
Wisconsin	Timber wolf and pine marten	None
Michigan	Timber wolf, cougar, lynx, prairie vole, and Indiana bat	Least shrew
Federal	Timber wolf, gray bat, Indiana bat, and Ozark big-eared bat	Lynx

Table 2-15 Results of Sediment Time Trends Analysis for the Lower Fox River

Deposit Group	Depth Range (cm)	Log_{10} (PCB) Time Trend Slope Estimate	WSEV Standard Error	WSEV *p*-Value	Statistically Significant Slopes	Estimated Annual Compound Percent Increase in PCB Level	Estimated Annual Compound Percent Increase in PCB Level	
							95% Confidence Interval Lower-bound	95% Confidence Interval Upper-bound
Little Lake Butte des Morts								
AB	0–10	-0.0970	0.0348	0.0131	*	-20.03	-32.52	-5.22
	10–30	-0.0213	0.0647	0.7535		-4.78	-33.86	37.09
	30–50	-0.0144	0.1113	0.8995		-3.26	-44.95	70.02
C	0–10	-0.0612	0.0342	0.1481		-13.15	-30.22	8.09
	10–30	0.0317	0.0770	0.7018		7.57	-34.24	75.95
POG	0–10	-0.0893	0.0567	0.1900		-18.59	-43.33	16.95
D	0–10	-0.0755	0.0317	0.0307	*	-15.96	-28.06	-1.83
	10–30	0.3168	0.0454	0.0009	***	107.39	58.51	171.33
F	0–10	-0.0373	0.0136	0.0252	*	-8.23	-14.62	-1.37
	10–30	-0.0760	0.0749	0.3246		-16.06	-41.67	20.81
GH	0–10	-0.1244	0.0541	0.0443	*	-24.91	-43.12	-0.88
Appleton								
IMOR	0–10	0.0412	0.0255	0.1810		9.95	-6.57	29.38
N Pre-dredge	0–10	-0.0281	0.0065	0.0233	*	-6.26	-10.64	-1.65
	10–30	0.0572	0.0440	0.2061		14.08	-7.48	40.67
	30–50	0.0846	0.0932	0.3877		21.50	-25.22	97.40
VCC	0–10	-0.0582	0.0275	0.0878		-12.53	-25.65	2.90
	10–30	-0.1537	0.0164	0.000001	***	-29.81	-35.42	-23.72
	30–50	-0.0060	0.0151	0.6984		-1.37	-8.71	6.55

Table 2-15 Results of Sediment Time Trends Analysis for the Lower Fox River (Continued)

Deposit Group	Depth Range (cm)	Log_{10} (PCB) Time Trend Slope Estimate	WSEV Standard Error	WSEV *p*-Value	Statistically Significant Slopes	Estimated Annual Compound Percent Increase in PCB Level	Estimated Annual Compound Percent Increase in PCB Level	
							95% Confidence Interval Lower-bound	95% Confidence Interval Upper-bound
Little Rapids								
Upper EE	0–10	-0.0447	0.0435	0.3618		-9.79	-31.68	19.13
	10–30	-0.0944	0.0429	0.0554		-19.53	-35.64	0.62
	30–50	-0.0712	0.0536	0.2173		-15.11	-35.80	12.25
Lower EE	0–10	-0.0682	0.0193	0.0387	*	-14.53	-25.81	-1.53
	10–30	-0.0759	0.0390	0.0695		-16.03	-30.58	1.58
	30–50	0.0900	0.0330	0.0213	*	23.02	3.86	45.72
FF	0–10	-0.0549	0.0557	0.3400		-11.87	-32.94	15.82
	10–30	-0.0962	0.0390	0.0389	*	-19.87	-34.86	-1.43
GGHH	0–10	-0.0394	0.0231	0.1643		-8.66	-21.23	5.90
	10–30	-0.0182	0.0596	0.7631		-4.10	-27.73	27.25
	30–50	0.1762	0.1008	0.1188		50.02	-12.18	156.27
	50–100	0.1012	0.0700	0.1586		26.23	-9.16	75.42
	100+	0.0365	0.0249	0.1587		8.76	-3.50	22.57

Table 2-15 Results of Sediment Time Trends Analysis for the Lower Fox River (Continued)

Deposit Group		Depth Range (cm)	Log_{10} (PCB) Time Trend Slope Estimate	WSEV Standard Error	WSEV *p*-Value	Statistically Significant Slopes	Estimated Annual Compound Percent Increase in PCB Level	Estimated Annual Compound Percent Increase in PCB Level 95% Confidence Interval Lower-bound	95% Confidence Interval Upper-bound
De Pere									
SMU Group	2025	0–10	-0.0528	0.0231	0.0838		-11.45	-23.58	2.61
		10–30	-0.0556	0.0750	0.4796		-12.02	-40.91	31.01
		30–50	-0.0580	0.0322	0.1016		-12.50	-25.81	3.20
		50–100	-0.0847	0.1058	0.4306		-17.72	-50.17	35.85
	2649	0–10	-0.0608	0.0109	0.00001	***	-13.06	-17.41	-8.48
		10–30	-0.2882	0.1440	0.0764		-48.50	-75.68	9.04
		50–100	0.1957	0.1419	0.2399		56.93	-36.65	288.69
		100+	0.0177	0.1548	0.9146		4.15	-61.29	180.26
	5067	0–10	-0.0998	0.0345	0.0136	*	-20.53	-33.17	-5.49
		10–30	0.0912	0.0649	0.1800		23.37	-10.26	69.61
		50–100	0.3677	0.0684	0.0030	**	133.17	55.54	249.55
		100+	-0.1963	0.2223	0.4112		-36.36	-81.81	122.65
	6891	0–10	-0.2208	0.0944	0.1013		-39.86	-69.89	20.11
		10–30	-0.1685	0.0765	0.0550		-32.16	-54.45	1.03
	92115	0–10	0.0413	0.0426	0.3493		9.97	-10.91	35.75

Notes:

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

Table 2-16 Mass-weighted Combined Time Trend for 0 to 10 cm Depth by Reach

Deposit Group	Log_{10}(PCB) Time Trend Slope Estimate	WSEV Standard Error	PCB Mass (kg)	*p*-value	Annual Percent Change in PCB Concentration	Percent Change 95% Lower-bound	Percent Change 95% Upper-bound
Little Lake Butte des Morts							
AB	-0.09705	0.034798	71.7				
C	-0.06124	0.03423	25.4				
POG	-0.08935	0.056669	113.5				
D	-0.07554	0.031669	32.1				
F	-0.0373	0.013582	142.5				
GH	-0.12443	0.054119	15.7				
Reach, Combined	**-0.07071**	**0.01831**	**400.9**	**0.0001*****	**-15.0**	**-21.8**	**-7.7**
Appleton							
IMOR	0.041186	0.025457	13.7				
N Pre-dredge	-0.02805	0.006544	6.9				
VCC	-0.05816	0.02746	5.2				
Reach, Combined	**-0.01135**	**0.01217**	**25.9**	**0.9**	**0.6**	**-5.9**	**7.5**
Little Rapids							
Upper EE	-0.04473	0.043487	85.0				
Lower EE	-0.06819	0.019322	25.4				
FF	-0.05486	0.055669	36.7				
GGHH	-0.03936	0.023149	131.6				
Reach, Combined	**-0.04567**	**0.018764**	**278.7**	**0.01***	**-10.0**	**-17.3**	**-2.0**
De Pere							
SMU Group 2025	-0.05279	0.02305	225.6				
SMU Group 2649	-0.06078	0.010894	356.8				
SMU Group 5067	-0.09978	0.034549	92.4				
SMU Group 6891	-0.22081	0.094396	72.1				
SMU Group 92115	0.041293	0.042639	37.1				
Reach, Combined	**-0.07296**	**0.012829**	**784.0**	**<0.0001*****	**-15.5**	**-20.2**	**-10.4**

Notes:

* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

Table 2-17 Results of Fish Time Trends Analysis on the Lower Fox River

Species	Type	Sample Size	Year of Breakpoint	Percent Change per Year	95% Confidence Interval		*p*-Value
					LCL	UCL	
Little Lake Butte des Morts							
Carp	fillet on skin	55	1979	-6.15	-10.9	-1.1	0.0177
Carp	whole fish	40	1987	0.71	-12.3	15.6	0.9172
Northern Pike	fillet on skin	19		-11.83	-16.7	-6.7	0.0003
Walleye	fillet on skin	63	1990	3.44	-7.8	16.0	0.5576
Walleye	whole fish	18	1987	21.47	-3.5	52.9	0.0874
Yellow Perch	fillet on skin	34	1981	0.73	-5.0	6.8	0.8025
Combined				**-4.86**			**0.0055**
Appleton to Little Rapids							
Walleye	fillet on skin	30		-9.97	-15.7	-3.9	0.0028
De Pere to Green Bay (Zone 1)							
Carp	whole fish	90	1995	21.76	2.2	45.0	0.0277
Gizzard Shad	whole fish	19		-5.07	-7.2	-2.9	0.0002
Northern Pike	fillet on skin	40		-9.95	-13.0	-6.8	<0.0001
Walleye	fillet on skin	120		-7.19	-8.7	-5.6	<0.0001
Walleye	whole fish	58		-8.11	-10.4	-5.8	<0.0001
White Bass	fillet on skin	58		-4.72	-7.5	-1.8	<0.0001
White Sucker	fillet on skin	44		-7.90	-10.3	-5.5	<0.0001
Combined				**-6.89**			**<0.0001**
Green Bay Zone 2							
Alewife	whole fish	44		-3.96	-7.8	0.0	0.0497
Carp	fillet on skin	28		-5.06	-11.8	2.2	0.1557
Carp	whole fish	57	1983	-15.54	-19.5	-11.4	0.0000
Gizzard Shad	whole fish	32		5.91	1.2	10.8	0.0144
Yellow Perch	fillet on skin	19		-10.75	-16.8	-4.2	0.0038
Combined				**-5.11**			**0.0000**

3 Summary of the Screening Level Risk Assessment

This section summarizes the relevant pathways, COPCs, and uncertainties that were identified in the SLRA. The purpose is to provide context for conducting the BLRA.

The SLRA for the Lower Fox River and Green Bay focused on the potential for human health and ecological risks associated with chemicals in sediments, surface waters, and biota. The SLRA was conducted using the most conservative exposure and effects scenarios in an effort to identify which of the over 300 contaminants previously identified potentially posed risks to human and ecological receptors. Data from 16 separate comprehensive studies conducted on the Fox River and Green Bay by state, federal, university, and private parties were used to assess risk. These studies and additional studies are further used for the BLRA risk assessment (Section 4). The objective of the screening was to identify a smaller list of contaminants that would be carried through to the baseline risk assessment.

3.1 Human Health Screening Level Risk Assessment

3.1.1 Potential Pathways at Risk

The important critical receptors and exposure pathways identified were:

- Recreational anglers and high-intake consumers exposed to chemicals through fish ingestion,
- Hunters exposed to chemicals in waterfowl through waterfowl ingestion,
- Recreational water users exposed to chemicals in surface water and/or sediments through direct contact,
- Drinking water users exposed to chemicals in surface water collected from either the Lower Fox River or Green Bay by municipal water authorities,
- Local residents exposed to chemicals volatilized from surface water via inhalation, and
- Marine construction workers exposed to chemicals in sediment through direct contact.

Of those pathways, the first three were considered to represent the most significant exposure pathways. Risk-based screening concentrations (RBSCs) were developed to screen all contaminants found in the river and Green Bay based on those pathways.

3.1.2 Chemicals of Potential Concern

COPCs were determined by comparing the maximum detected concentrations of contaminants to RBSCs. The RBSCs are concentrations in various media that are intended to be protective of the critical receptors identified previously. The RBSCs were concentrations developed from conservative risk assessment equations. RBSCs were developed for three exposure pathways: fish ingestion, waterfowl ingestion, and direct contact with sediment. The chemicals with maximum detected concentrations that exceeded RBSCs in one or more media included PCBs, dioxins, furans, potentially carcinogenic PAHs, selected semivolatile organic compounds (SVOCs), pesticides, and a number of inorganic chemicals.

COPCs that exceeded RBSCs were ranked based upon relative risk ratios, which are the maximum detected concentration divided by the RBSC. For almost all media and all exposure pathways, PCBs had the highest relative risk ratios; generally one to three orders of magnitude greater than any other compound. Of the three exposure pathways evaluated, the highest relative risk ratios were for PCBs, dioxins, and furans for the fish ingestion pathway. Dieldrin, DDE, and arsenic also had relative risk ratios within an order of magnitude of the relative risk ratios of PCBs for some exposure pathways.

3.2 Ecological Screening Level Risk Assessment

3.2.1 Potential Pathways at Risk

For the ecological SLRA, generic aquatic receptors identified in the river/bay were water column and sediment-dwelling invertebrates, fish, and fish-eating wildlife (birds and mink). Exposure pathways for these receptors included uptake of dissolved chemicals in surface water, ingestion of contaminated sediments, and biomagnification from prey (fish and insects) into insectivorous or piscivorous mammals or birds.

Exposure estimates were determined for specific receptor groups. For example, exposures to fish were distinguished between benthic fish and pelagic fish. Each of these groups has a different trophic role and, therefore, potentially different exposure. Similarly, birds were grouped as omnivorous, piscivorous, or insectivorous.

3.2.2 Chemicals of Potential Concern

The following chemicals were identified as ecological COPCs in sediments, tissues, and waters from the Lower Fox River and Green Bay: arsenic, lead, mercury, PCBs, DDT/DDD/DDE, dieldrin, and TCDD/TCDF.[5] Risks from PCBs were two to three orders of magnitude higher (hazard quotients [HQs] greater than 5,000) than any of the metals (HQs of 8 to 41), chlorinated pesticides (HQs of 7 to 51), and PAHs (HQs of 2 to 39). An HQ is the ratio of an exposure point concentration and an effect threshold concentration. HQs are unitless values that are calculated for the estimation of risk.

3.3 Chemicals of Potential Concern for the Baseline Risk Assessment

As defined in the Superfund Risk Assessment Guidance (EPA, 1997a), following the completion of the SLRA, a Scientific Management Decision Point (SMDP) was necessary to review the results of the SLRA. The technical team of risk managers, collectively referred to as the Biological Technical Assistance Group (BTAG), were assembled during the SLRA process to specifically address SMDPs and provide technical review. The resource agencies, risk assessors, and technical personnel in the BTAG included:

- Wisconsin Department of Natural Resources;
- U.S. Fish and Wildlife Service;
- U.S. Environmental Protection Agency, Region 5;
- U.S. Environmental Protection Agency, Environmental Response Team;
- National Oceanic and Atmospheric Administration;
- Menominee Nation; and
- Oneida Nation.

Based on the SLRA, the risk managers determined that: 1) potential adverse effects from contaminants in the Lower Fox River and Green Bay are present, and the BLRA is warranted, and 2) the list of chemicals identified as potential risk drivers identified in the SLRA could be focused to a more limited number for the BLRA based upon the magnitude of risk, spatial extent of the contaminants, and presence of fish consumption advisories.

The SMDP was formalized in a memo from WDNR dated August 3, 1998 (Appendix A). The memo identified and justified which chemicals should be

---

[5] Although 2,3,7,8-TCDD is the most toxic dioxin congener, all structurally related dioxin and furan congeners will be evaluated for toxicity based on the toxicity equivalency method. The dioxin and furan congeners that will be evaluated are those that have been measured in site media and those that have toxic equivalency factors (TEFs).

carried forward into the BLRA, based on the potential for either human health or ecological risk. Of the 75 chemicals that were above screening level risk criteria, only those with the most potential for adverse risk were carried forward as BLRA COPCs. The process used to narrow this list of COPCs was as follows:

- Spatial extent of the chemical over the study area reaches identified in the SLRA,

- Magnitude of the chemical sediment Hazard Quotient (HQ), and

- Presence of consumption advisories.

The retained COPCs include: PCBs (expressed as total and PCB coplanar congeners), dioxin and furan congeners, DDT and its metabolites DDE, and DDD, dieldrin, arsenic, lead, and mercury. Sediment HQs were greatest for PCBs based on both human heath and ecological risk-based screening levels.

4 Sediment, Water, and Tissue Chemistry Data

This section describes the data set used for both the human health and ecological risk assessments. As part of the remedial investigation/feasibility study (RI/FS), several state, federal, university, and private-party studies conducted for the Lower Fox River and Green Bay were identified, and requests were made for electronic copies of the study data. These data were assembled into the Fox River Database (FRDB) as shown in Table 4-1. This list of data sets includes data that were used as part of the SLRA as well as additional data sets.

"Electronic Data" collected from the various resources were incorporated into the FRDB. Requests were submitted for sediment, tissue, and water data. Data were provided in various file formats, including document files (i.e., Word, WordPerfect), spreadsheets, ASCII files, database tables, and drawings (i.e., CADD, GIS files). The data were extracted from the files into individual database tables for standardization prior to inclusion into the FRDB.

The reduced and standardized data sets were compiled into a database for use in support of the ongoing risk assessment (RA) and RI/FS. The database currently contains 474,218 records from 35 individual data sets representing sediment, tissue, air, and pore water data. The data in the FRDB were collected primarily between 1989 and 1998 along the Fox River from Lake Winnebago to northern Green Bay. This information has been grouped in multiple ways to facilitate risk assessment calculations, summarizing the data by river stretch or Green Bay zone, species (common name), and sample type. Not all records in the FRDB were used for the risk assessment; data were limited based on species, year, location, tissue, and analyte. Specific data sets used for the risk assessment are presented in Table 4-2.

Total PCBs are the most frequently found analyte in the database. Table 4-3 presents the number of total PCB samples by year and media type, along with the quality assurance (QA) status of the data, which is also presented on Figure 4-1. Tables 4-4 and 4-5 contain a breakdown of the total PCB tissue data over time and by type of ecological receptor. 1989 was used as a cut-off date for inclusion of data for the evaluation of risk for several reasons: 1) the contribution of these data towards assessing risk was considered to be less advantageous than the greater accuracy obtained by evaluating risk based on more current data, 2) no data collected prior to 1989 were validated, and 3) although data collected in 1989 were not validated, the total number of samples collected in this year is more than 30 percent of all samples collected. Data validation is a process that is conducted to determine the quality of the data. A QA status of "supporting" is given to data when the precise quality of the data is not known. However, it was assumed that these data were of sufficient quality for inclusion in the risk assessment. A complete description of the FRDB, quality assurance, and quality control issues is given in the *2000 Fox River Data Management Summary Report* (EcoChem, 2000).

4.1 Section 4 Figure and Tables

Section 4 figure and tables follow this page and include:

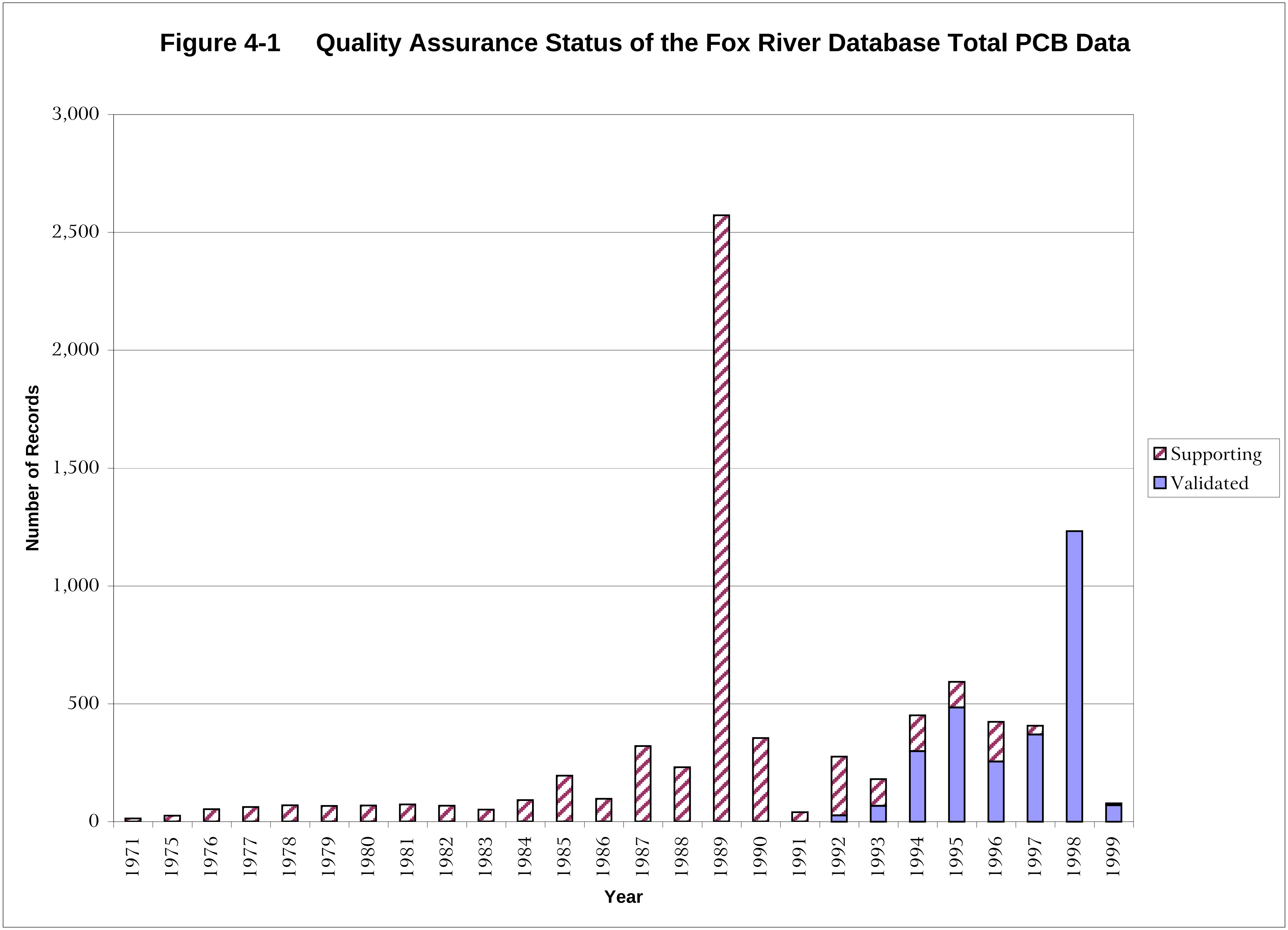


Figure 4-1 Quality Assurance Status of the Fox River Database Total PCB Data
Number of Records
3,000
2,500
2,000
1,500
1,000
500
0
1971
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
Year
Supporting
Validated

[THIS PAGE LEFT INTENTIONALLY BLANK.]

Table 4-1 Description of All Records Contained in the Fox River Database

Data Source	Number of Samples	Matrices[1]	Analyses Conducted[2]	Number of Records	Number of Files in Delivery	File Type
1989/90 Fox River Mass Balance Study	1,967	S, W	PCB-A, PCB-C, W	25,457	6	Spreadsheet
1989/90 Green Bay Mass Balance Study (GLNPO)	2,069	S, T, W	B, PCB-C, W	201,701	91	Database
1992/93 BBL Deposit A Data Collection	117	S, W	M, P/H, PCB-A, SVOA, V, W	1,094	1	Spreadsheet
1993 Triad Assessment	27	S	B, M, P/H, PCB-A, SVOA, W	631	11	Spreadsheet
1993-1996 Tree Swallow Data Collection	200	T	B, DXN, P/H, V, W	5,429	2	Database
1994 GAS Sediment Collection	253	S	DXN, M, P/H, PCB-A, SVOA, V, W	5,654	6	Spreadsheet
1994 Woodward-Clyde Deposit A Sediment Collection	66	S	PCB-A, W	585	12	Spreadsheet
1994-1995 Cormorant Data Collection	193	T	B, DXN, P/H, PCB-C, W	6,178	2	Database
1995 WDNR Sediment Data Collection	488	S	M, PCB-A, W	6,433	8	Spreadsheet
1996 BBL Sediment/Tissue Data Collection	25	S, T	B, PCB-C, W	2,771	6	Spreadsheet
1996 WDNR Tissue Data Collection	200	T	B, PCB-A, W	1,673	1	Spreadsheet
1997 Demonstration Project Data - Deposit N	10	S	M, PCB, W	83	1	Spreadsheet
1997 Demonstration Project Data - Segment 56/57	295	S, W	DXN, M, P/H, PCB-A, SVOA, V, W	3,114	12	Spreadsheet
1997 USFWS Waterfowl Tissue Data Collection	70	T	B, P/H, PCB, V, W	1,680	2	Database
1997 WDNR Caged Fish Bioaccumulation Study Data	25	S, T	B, PCB-C, W	1,672	2	Spreadsheet
1998 BBL Sediment/Tissue Data Collection	1,315	S, T, W	B, M, P/H, PCB-A, PCB-C, RAD, SVOA, W	18,824	1	Database
1998 Deposit N Post-Dredge	43	S	PCB-A, PCB-C, W	690	8	Spreadsheet
1998 Deposit N Pre-Dredge	53	S	PCB-A, PCB-C, W	1,437	6	Spreadsheet
1998 FRG/Exponent Database Data Collection	225	T	B, M, P/H, PCB-A, PCB-C, W	17,708	3	Database
1998 RETEC RI/FS Supplemental Data Collection	252	S, T	B, DXN, M, P/H, PCB-A, PCB-C, SVOA, V, W	10,781	1	ASCII
1998 WDNR Fish Consumption Data	130	T	B, M, PCB-A, W	777	1	ASCII
1998/1999 Deposit N Sediment Remediation Data	197	T, W	PCB-C, W	10,264	1	Spreadsheet
Ankley and Call	62	PW, S, T, W	DXN, M, P/H, PCB, SVOA, W	1,607	0	Hardcopy
Deposit N Operational Monitoring Data	12	S	M, PCB-A, W	123	1	Spreadsheet
Fox River Fish Consumption Advisory Data	1,766	S, T	B, DXN, M, P/H, PCB-A, PCB-C, SVOA, V, W	11,620	2	ASCII
Lake Michigan Fish Consumption Advisory Data	434	T	B, DXN, M, P/H, PCB-A, W	6,979	1	Database
Lake Michigan Mass Balance Study	6,987	A, S, T, W	M, P/H, PCB-C, V, W	91,621	211	Database
Lake Michigan Tributary Monitoring Data	88	W	M, P/H, PCB-C, V	5,722	5	Spreadsheet
Lower Fox River Background Metals Assessment	14	W	M	78	1	Spreadsheet
Minergy Mineralogical Data	15	S	W	219	1	Spreadsheet
Stromberg Eagle Data Collection	31	T	B, DXN, P/H, PCB-A, PCB-C, SVOA, V, W	954	1	ASCII
1996 USFWS NRDA Tissue Data Collection	376	T	DXN, P/H, PCB-A, PCB-C, W	15,401	4	Spreadsheet
USGS NAWQA Data	441	S, T, W	B, M, P/H, PCB, SVOA, V, W	11,879	21	Spreadsheet
WDNR Tissue Data Collection	417	T	B, M, P/H, PCB-A	2,532	3	Database
WPDES Permit Influent Data	8	W	B, DXN, M, P/H, PCB-A, RAD, SVOA, V, W	847	1	Spreadsheet
Total: 35 Data Sets	**18,871**			**474,218**	**436**	

[1]**Matrices**
S - Sediment
T - Tissue
W - Water
PW - Sediment Pore Water
A - Ambient Air

[2]**Analyses**
PCB-A - PCB Aroclor
PCB-C - PCB Congener
PCB - Total PCB only
M - Metals
W - Wet Chemistry (including all physical and conventional data)
V - Volatiles
SVOA - Semivolatiles
P/H - Pesticides/Herbicides
DXN - Dioxins
B - Biological

Table 4-2 Number of Records Evaluated as Part of the Baseline Risk Assessment - All COPCs

Source	Data Set	Total	Water	Sediment
Sediment and Water Data				
1989/90 Mass Balance Sediment Data	1989/90 Fox River Mass Balance Study	1,207		1,207
1989/90 Mass Balance Water Column Data	1989/90 Fox River Mass Balance Study	502	502	
1993 Triad Assessment	1993 Triad Assessment	59		59
1994 Sediment Data - SAIC and GAS	1994 GAS Sediment Collection	571		571
1995 Sediment data collection - WDNR	1995 WDNR Sediment Data Collection	684		684
1996 BBL Sediment Data collected for FRG	1996 BBL Sediment/Tissue Data Collection	68		68
1997 Deposit N demonstration project	1997 Demonstration Project Data - Deposit N	12		12
1997 Segment 56/57 demonstration project	1997 Demonstration Project Data - Segment 56/57	374	8	366
1998 BBL Sediment/Tissue Data collected for FRG	1998 BBL Sediment/Tissue Data Collection	1,389	329	1,060
1998 Deposit N Operational Monitoring	Deposit N Operational Monitoring Data	20		20
1998 Deposit N Post-Dredge Sediment Data	1998 Deposit N Post-Dredge1	18		18
1998 Deposit N Post-Dredge Sediment Data	1998 Deposit N Post-Dredge2	43		43
1998 Deposit N Pre-Dredge Sediment Data	1998 Deposit N Pre-Dredge	103		103
1998 RI/FS Supplemental Data Collection	1998 RETEC RI/FS Supplemental Data Collection	528		528
1998/1999 Deposit N Sediment Remediation Data	1998/1999 Deposit N Sediment Remediation Data	298	298	
Caged fish associated sediment samples 1997 demo projects	1997 WDNR Caged Fish Bioaccumulation Study Data	35		35
Fish Contaminant Study Data	Fox River Fish Consumption Advisory Data	8		8
Fox River background metals assessment data	Lower Fox River Background Metals Assessment	20	20	
GLNPO Data - GB water congener data	1989/90 Green Bay Mass Balance Study (GLNPO)	1,681	1,681	
GLNPO Data - other water data	1989/90 Green Bay Mass Balance Study (GLNPO)	944	944	
GLNPO Data - sediment congener data	1989/90 Green Bay Mass Balance Study (GLNPO)	1,732		1,732
LLBdM RI/FS Deposit A - 1992, 1993 BBL	1992/93 BBL Deposit A Sediment Data Collection	112		112
LLBdM RI/FS Deposit A - 1992, 1993 BBL	1992/93 BBL Deposit A Water Data Collection	12	12	
LMMB Focus Group LHTP - Wisconsin State Lab of Hygiene	Lake Michigan Mass Balance Data3	4	4	
LMMB Focus Group LHTP - Wisconsin State Lab of Hygiene	Lake Michigan Mass Balance Data4	166	166	
LMMB Focus Group LHTP - Wisconsin State Lab of Hygiene	Lake Michigan Mass Balance Data5	35	35	
LMMB Focus Group LHTP - Wisconsin State Lab of Hygiene	Lake Michigan Tributary Monitoring Data	213	213	
LMMB Focus Group WWTH - University of Wisconsin Water Quality Laboratory	Lake Michigan Mass Balance Data2	52	52	
Lake Michigan Tributary Monitoring Study	Lake Michigan Tributary Monitoring Data	166	166	
USGS National Water Quality Assessment Program (NAWQA)	USGS NAWQA Data	10		10
WPDES Permit influent samples	WPDES Permit Influent Data	50	50	
Woody Clyde Deposit A Sediment Samples - 1994	1994 Woodward-Clyde Deposit A Sediment Collection	66		66
Total Number of Sediment and Water Records Ecological and Human Health Risk Assessment		**11,182**	4,480	6,702

Table 4-2 Number of Records Evaluated as Part of the Baseline Risk Assessment - All COPCs (Continued)

Source	Data Set	Total	Water	Sediment
Tissue Data for the Ecological Assessment				
1996 Fish tissue collection - WDNR	1996 WDNR Tissue Data Collection	35		
1998 BBL Sediment/Tissue Data collected for FRG	1998 BBL Sediment/Tissue Data Collection	20		
1998 FRG-Exponent's Database	1998 FRG/Exponent Database Data Collection	821		
1998 RI/FS Supplemental Data Collection	1998 RETEC RI/FS Supplemental Data Collection	623		
Cormorant data - 1994-1995	1994-1995 Cormorant Data Collection	1,430		
Fish Consumption Study Data	1998 WDNR Fish Consumption Data	5		
Fish Contaminant Study Data	Fox River Fish Consumption Advisory Data	385		
GLNPO Data - fish congener data	1989/90 Green Bay Mass Balance Study (GLNPO)	1,251		
GLNPO Data - other carp data	1989/90 Green Bay Mass Balance Study (GLNPO)	194		
GLNPO Data - other fish data	1989/90 Green Bay Mass Balance Study (GLNPO)	640		
KPatnode Tissue Data	WDNR Tissue Data Collection	5		
NRDA Tissue Data Collection	USFWS NRDA Tissue Data Collection	734		
State of Michigan Fish Consumption Advisory Data	Lake Michigan Fish Consumption Advisory Data	210		
Tree Swallow data - 1993-1996	1993-1996 Tree Swallow Data Collection	591		
Total Number of Tissue Records - Ecological Risk		**6,944**		
Tissue Data for the Human Health Assessment				
1996 Fish tissue collection - WDNR	1996 WDNR Tissue Data Collection	81		
1996 NRDA Waterfowl data	1997 USFWS Waterfowl Tissue Data Collection	88		
1998 BBL Sediment/Tissue Data collected for FRG	1998 BBL Sediment/Tissue Data Collection	54		
1998 FRG-Exponent's Database	1998 FRG/Exponent Database Data Collection	468		
Fish Consumption Study Data	1998 WDNR Fish Consumption Data	120		
Fish Contaminant Study Data	Fox River Fish Consumption Advisory Data	1,754		
KPatnode Tissue Data	WDNR Tissue Data Collection	69		
NRDA Tissue Data Collection	USFWS NRDA Tissue Data Collection	22		
State of Michigan Fish Consumption Advisory Data	Lake Michigan Fish Consumption Advisory Data	638		
Total Number of Tissue Records - Human Health Risk		**3,294**		
	Total Number of Records Evaluated for Risk:	**21,420**		

Table 4-3 Distribution of Existing Sediment, Water, and Tissue Data in the Lower Fox River and Green Bay over Time - Total PCBs Only

Year	Number of Samples Analyzed for Total PCBs				QA Status		
	Sediment	Tissue (Caged)	Tissue (Resident)	Water	Validated	Supporting	Blank
1971			14			14	
1975			26			26	
1976			53			53	
1977			62			62	
1978			70			70	
1979			67			67	
1980			69			69	
1981			73			73	
1982			68			68	
1983			51			51	
1984			92			92	
1985			195			195	
1986			97			97	
1987	203		118			321	
1988	161		70			231	
1989	1,354		604	615		2,573	
1990	104		54	197		355	
1991			40			40	
1992	35		233	8	27	249	
1993	70		106	5	67	114	
1994	296		122	54	299	152	21
1995	484		87	40	484	109	18
1996	8		416		255	169	
1997	288		119		370	37	
1998	528	20	375	310	1,233		
1999	43	6	9	20	70	8	
TOTAL	**3,574**	**26**	**3,290**	**1,249**	**2,805**	**5,295**	**39**

8,139 Records

Summary of Data Query

TOTAL RECORDS	474,218	
Total PCBs (lipid normalized)	80	(not used)
Total Aroclor	215	(not used)
"TOTAL PCBs" Query	9,710	used
YEAR = "1000"	31	discarded
	9,679	
Locations outside of project area	1,540	discarded
Total # of samples in query	8,139	

Notes:

1. Resident caged tissue includes fathead minnows only.
2. Refer to the resident tissue worksheet tables for a breakdown of tissue types for the Lower Fox River and Green Bay.
3. The data query was for all samples collected over time for "total PCBs" analysis, and includes the sum of PCB congeners analyses.
4. The data query was limited to the four reaches of Lower Fox River and the four zones of Green Bay.
5. Samples without a year or location designation were eliminated from the data query.
6. The database does not have any air samples for total PCBs analysis.
7. Approximately 100 of the water samples collected in 1998 were from the Deposit N and SMU 56/57 demonstration project studies (during dredging).

Table 4-4 Distribution of Resident Tissue Samples over Time in the Lower Fox River - Total PCBs Only

Year	Fish																Birds					Mammals	Other
	Benthic Fish				Game Fish				Pelagic Fish				Trout				Raptors	Swallow	Upland Game Bird	Waterfowl		Fur Bearer	Insect/ Invertebrate
	No. of Samples	No. of Species	No. of Fillet Samples	No. of Whole Fish Samples	No. of Samples	No. of Species	No. of Fillet Samples	No. of Whole Fish Samples	No. of Samples	No. of Species	No. of Fillet Samples	No. of Whole Fish Samples	No. of Samples	No. of Species	No. of Fillet Samples	No. of Whole Fish Samples	No. of Samples	No. of Samples	No. of Samples	No. of Samples	No. of Species	No. of Samples	No. of Samples
1971	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	6	2	7	0	11	4	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	24	3	18	6	12	3	10	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	24	3	10	9	14	3	5	8	0	0	0	0	4	1	3	0	0	0	0	0	0	0	0
1979	12	3	0	8	16	3	9	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1980	36	4	16	11	25	5	10	9	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0
1981	23	3	4	14	18	3	7	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	28	3	13	5	24	6	12	3	2	1	2	0	0	0	0	0	0	0	0	0	0	0	0
1983	8	3	3	2	10	5	5	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	8	2	5	2	14	7	7	0	0	0	0	0	0	0	0	0	0	0	1	3	1	1	1
1985	15	3	12	0	35	4	24	0	0	0	0	0	0	0	0	0	1	0	0	12	1	0	0
1986	16	4	9	2	18	3	12	2	1	1	0	1	0	0	0	0	0	0	0	28	1	0	0
1987	34	5	33	1	43	7	42	1	1	1	0	1	0	0	0	0	0	0	0	22	1	0	0
1988	7	2	7	0	6	2	6	0	0	0	0	0	0	0	0	0	0	0	0	6	1	0	0
1989	42	3	5	24	38	1	12	26	20	2	0	20	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
1991	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	20	2	12	8	111	9	103	9	4	1	0	4	0	0	0	0	0	0	0	0	0	0	0
1993	15	1	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	51	0	0	0	0	1
1994	10	2	0	5	13	3	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
1996	109	6	20	84	185	7	131	34	13	3	0	13	0	0	0	0	0	0	0	0	0	0	0
1997	3	1	0	3	17	1	0	0	0	0	0	0	0	0	0	0	0	0	0	22	2	0	0
1998	93	4	75	48	198	7	163	59	17	3	0	17	0	0	0	0	0	0	0	0	0	0	10
1999	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Notes:

1. No piscivorous birds were collected in the Lower Fox River.
2. No cormorants were collected in the Lower Fox River.

Table 4-5 Distribution of Resident Tissue Samples over Time in Green Bay - Total PCBs Only

Year	Fish																Birds									Mammals		Other
	Benthic Fish				Game Fish				Pelagic Fish				Trout				Cormorant		Piscivorous Birds		Raptors	Swallow		Waterfowl		Deer	Fur Bearer	
	No. of Samples	No. of Species	No. of Fillet Samples	No. of Whole Fish Samples	No. of Samples	No. of Species	No. of Fillet Samples	No. of Whole Fish Samples	No. of Samples	No. of Species	No. of Fillet Samples	No. of Whole Fish Samples	No. of Samples	No. of Species	No. of Fillet Samples	No. of Whole Fish Samples	No. of Samples	No. of Species	No. of Samples	No. of Species	No. of Samples	No. of Samples	No. of Species	No. of Samples	No. of Species	No. of Samples	No. of Samples	No. of Samples
1971	0	0	0	0	0	0	0	0	0	0	0	0	14	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1975	7	1	0	0	18	1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	15	3	20	0	20	8	28	0	1	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	5	2	11	0	21	3	36	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1978	7	2	6	1	9	2	7	2	7	3	4	1	5	1	5	1	0	0	0	0	0	0	0	0	0	0	0	0
1979	8	4	0	8	17	4	8	9	9	3	0	9	5	3	0	5	0	0	0	0	0	0	0	0	0	0	0	0
1980	3	1	3	0	4	3	4	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	15	1	0	15	13	2	12	0	0	0	0	0	4	1	4	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	5	1	5	0	4	1	4	0	0	0	0	0	5	1	5	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	12	3	10	2	13	4	13	0	4	1	2	2	4	2	4	0	0	0	0	0	0	0	0	0	0	0	0	0
1984	8	3	8	0	23	6	23	0	9	4	4	4	20	4	20	0	0	0	0	0	0	0	0	4	2	0	0	0
1985	0	0	0	0	3	2	2	0	4	3	0	3	125	5	120	0	0	0	0	0	0	0	0	0	0	0	0	0
1986	5	1	5	0	9	3	9	0	2	1	0	2	3	2	3	0	0	0	1	1	0	0	0	13	1	0	0	1
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	16	3	1	0	0
1988	20	2	20	0	11	2	11	0	10	1	11	0	0	0	0	0	0	0	0	0	0	0	0	10	2	0	0	0
1989	166	1	28	77	101	2	35	66	169	3	0	169	68	3	29	39	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	22	3	22	0	9	2	0	9	22	2	22	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	5	1	5	0	16	2	10	0	18	3	12	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	10	1	0	10	35	3	25	10	7	2	0	7	46	5	43	3	0	0	0	0	0	0	0	0	0	0	0	0
1993	6	2	2	4	0	0	0	0	2	1	0	2	16	2	16	0	0	0	0	0	0	15	1	0	0	0	0	0
1994	0	0	0	0	19	2	19	0	4	1	0	4	16	3	16	0	60	1	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	1	1	0	0	4	1	0	4	0	0	0	0	80	1	0	0	0	0	0	0	0	0	0	1
1996	0	0	0	0	60	3	20	24	0	0	0	0	29	4	10	19	0	0	15	2	0	0	0	5	1	0	0	0
1997	0	0	0	0	71	2	0	15	0	0	0	0	1	1	0	0	0	0	5	1	0	0	0	0	0	0	0	0
1998	12	2	0	12	32	4	10	22	8	2	0	8	0	0	0	0	0	0	0	0	0	0	0	2	1	0	0	3
1999	0	0	0	0	8	1	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0

Notes:

1. No reptiles were collected in Green Bay.
2. No upland game birds were collected in Green Bay.
3. Date query included all sample body types. The number of whole samples included whole fish and whole fish composites for fish, and whole body for birds.

5 Human Health Risk Assessment

5.1 Overview

This section presents the baseline human health risk assessment for the Lower Fox River and Green Bay system. The baseline risk assessment quantitatively evaluates cancer risks and noncancer health hazards associated with exposure to chemicals in fish, waterfowl, sediment, surface water and air in the Lower Fox River and Green Bay. This risk assessment fulfills the NRC (2001) recommendation that sites be evaluated using a scientific risk-based framework so that different approaches for remediating PCB-contaminated submerged sediments can be compared in terms of the efficacy and human and ecological risks associated with each approach. A number of potential receptors are evaluated in this baseline risk assessment, but the receptors that experience the highest calculated cancer risks and noncancer health hazards are individuals who consume fish from the river and bay that are contaminated with PCBs. The baseline risk assessment evaluates potential risks and health hazards for baseline conditions in the absence of any remedial action or institutional controls, such as fish advisories, that might alter the behavior of receptors. Relative risks associated with other potential remedial actions are discussed in the Feasibility Study.

The baseline human health risk assessment uses the results of the Screening Level Risk Assessment (SLRA) (RETEC, 1998b) as a starting point. The human health evaluation in the SLRA presented a conceptual site model that identified potential sources of chemicals to the Lower Fox River, migration routes for chemicals through the Fox River and into Green Bay, and receptors (e.g., representative groups of people that could be exposed to chemicals in sediment, surface water, or air) for the Lower Fox River and Green Bay. The human health evaluation in the SLRA compared the concentrations of chemicals in fish tissue, waterfowl tissue, and sediment to Risk-Based Screening Concentrations (RBSCs). The chemicals with the most significant exceedances of RBSCs were retained for more detailed evaluation in the baseline human health risk assessment (Lynch and Webb, 1998). These chemicals of potential concern (COPCs) are:

- PCBs (total and/or Aroclor 1242),
- Dioxins,
- Furans,
- DDT/DDE/DDD,
- Dieldrin,
- Arsenic,

- Lead, and
- Mercury.

Section 5.2 begins by restating the conceptual site model from the human health evaluation in the SLRA. A major part of the conceptual site model is the identification of potential receptors and exposure pathways. The receptors are:

- Recreational anglers,
- High-intake fish consumers,
- Hunters,
- Drinking water users,
- Local residents,
- Recreational water users (swimmers and waders), and
- Marine construction workers.

Following the presentation of the conceptual site model, the results of the SLRA for polynuclear aromatic hydrocarbons (PAHs) are revisited. In the SLRA, PAHs were screened out. This screening was based, in part, on the fact that PAHs, although lipophilic like PCBs, dioxins/furans, dieldrin, DDT, DDE, and DDD, are metabolized by fish. Therefore, although PAHs were detected in sediments, they are not expected to bioaccumulate and biomagnify up the food chain as PCBs, dioxins/furans, and chlorinated pesticides do. At the time of the SLRA, there were no data for PAHs in fish. In the fall of 1998, fish samples were submitted for analysis and the results of these analyses are reviewed in Section 5.3. The evaluation indicates that PAHs were detected infrequently in fish samples and the risks associated with ingestion of fish containing PAHs are two orders of magnitude lower than those associated with ingestion of fish containing PCBs.

Following the conceptual site model, the intake equations, and intake assumptions used to estimate intakes for each receptor are presented (Section 5.4). Next, the procedures used to develop exposure point concentrations are presented in Section 5.5, which also summarizes the field data used in the risk assessment.

To evaluate the calculated intakes, dose-response functions are needed for each COPC. Dose-response information is provided in the dose-response assessment, including critical health effects for each COPC, cancer slope factors, and reference doses (Section 5.6).

Section 5.7 provides a baseline risk characterization, where the calculated intakes are combined with the dose-response information to calculate human health cancer risks and noncancer hazard indices for each receptor. These cancer risks and hazard indices are generated for different reaches in the Lower Fox River and for Green Bay. The highest cancer risks and hazard indices are calculated for recreational anglers and high-intake fish consumers due to ingestion of fish containing PCBs. These risks and hazard indices are more than 10 times higher than the risks and hazard indices for the next most exposed receptor, the hunter.

Lead was identified as a COPC in the SLRA, but lead cannot be evaluated by conventional risk assessment techniques. Specifically, lead is not evaluated as a carcinogen and there are no reference doses for lead. Instead, potential health effects for lead are evaluated using phamacokinetic models. In Section 5.8, the lead data in each medium is revisited in greater detail. The result of this evaluation is that lead is not considered to be of concern from a human health perspective in any medium.

The baseline risk characterization in Section 5.7 indicates that the highest cancer risks and noncancer hazard indices are for anglers as a result of exposure to PCBs from ingestion of fish. A detailed evaluation of such exposures is provided in Section 5.9. In this evaluation, the fish concentration data is investigated in more detail, a range of intake assumptions for recreational anglers and high-intake fish consumers are presented, and the cancer risks and hazard indices for exposure to different fish species using the range of intake assumptions are also presented. This section also provides a probabilistic risk assessment, an evaluation of a risk assessment performed by Exponent (2000) for the Fox River Group, and an evaluation of the potential for young children to experience adverse health effects from exposure to PCBs. Finally, this section provides risk-based concentrations of PCBs in fish for different cancer risk and hazard index values.

Section 5.10 provides an uncertainty and sensitivity analysis that describes the uncertainties and limitations in the data sets and the effects of different assumptions on the results.

Section 5.11 provides a summary of the human health risk assessment.

5.2 Sources, Migration Routes, Human Receptors, and Exposure Pathways

There are a large number of people who are potentially exposed, either directly or indirectly, to chemicals in the Lower Fox River and Green Bay. Land use along the Lower Fox River currently includes a mixture of agricultural, residential, light and heavy industrial, conservancy, and wetland areas. The Lower Fox River valley once had and may still have the greatest concentration of pulp and paper industries in the world, with numerous paper mills located on the 40-mile stretch of the Lower Fox River. Numerous townships, villages, and cities are located along the Lower Fox River. This corridor from Lake Winnebago to Green Bay, including the counties around Green Bay, is the second-largest urbanized area in the state of Wisconsin, with a population of about 640,000 (Census Bureau, 1992). The SLRA identified the greatest risk resulting from ingestion of fish containing PCBs. Based on information supplied by the Wisconsin Department of Natural Resources for 1999 (WDNR, 1999d), the following number of fishing licenses were issued in counties encompassing the Lower Fox River or bordering Green Bay.

Brown	36,633
Calumet	3,950
Door	7,506
Kewaunee	3,758
Marinette	16,013
Oconto	11,486
Outagamie	31,812
Winnebago	25,136

The total number of licenses in these counties is 136,294. Brown and Outagamie counties encompass the Lower Fox River and have a total of 68,445 licenses.

Figure 5-1 illustrates potential source media, migration routes, exposure media, and human receptors for chemicals present in the Lower Fox River and Green Bay system. Chemicals enter the Lower Fox River from a variety of sources. The primary sources of toxic chemicals are industrial and municipal wastewater discharges, discharges from stormwater systems, flows from tributary water bodies (i.e., Lake Winnebago, rivers, creeks, and streams), discharges from groundwater, and atmospheric deposition. The SLRA identified that the greatest risk associated with the Lower Fox River was exposures associated with ingestion of fish containing PCBs. The principal source of PCBs has been from discharges of industrial wastewater. Once in the Lower Fox River, chemicals such as PCBs may partition to bottom sediments, be associated with suspended sediments, or be dissolved in surface water. As water and sediment migrate downstream, chemicals will also migrate, eventually discharging to Green Bay. Once in Green Bay, the migration process will continue through the bay, although deposition of suspended sediment is more prevalent since water flow in Green Bay is considerably slower than in the Lower Fox River. Chemicals in Green Bay will continue to migrate in the dissolved and suspended particulate phases to Lake Michigan. This process is considerably slower than the migration of chemicals in the Lower Fox River, since the flow of water is considerably slower in Green Bay than in the Lower Fox River. Chemicals may also volatilize from surface water to air or may be transformed by chemical and microbial processes. Finally, chemicals, such as PCBs, may bioaccumulate and biomagnify through the food chain from sediment and surface water to aquatic vegetation, benthic organisms, fish, and waterfowl.

Once chemicals have entered the Lower Fox River and Green Bay system, exposures can occur to people through a variety of mechanisms. Table 5-1 provides a list of human receptors and exposure pathways that are considered in the human health risk assessment. These receptors are:

- Recreational anglers,
- High-intake fish consumers,
- Hunters,
- Drinking water users,
- Local residents,
- Recreational water users, and
- Marine construction workers.

These receptors and their associated exposure pathways are also presented on Figure 5-1.

Recreational anglers, which includes a subset of high-intake fish consumers, are individuals who fish in the Lower Fox River and Green Bay. The Lower Fox River supports a variety of sport and non-sport fish. Sport fish species observed in the Lower Fox River include walleye, black crappie, northern pike, perch, bass, and catfish. Non-sport fish include carp, gizzard shad, freshwater drum, and white sucker. Similar fish species have been observed in Green Bay; in addition, salmon, sturgeon, lake trout, and burbot are commonly found there. Recreational anglers may be exposed to constituents in the river, such as PCBs, through ingestion of fish, inhalation of chemicals volatilized into the air from the surface water, incidental ingestion of water during fishing, and dermal contact with water during fishing. The exposures via water ingestion and dermal contact are likely to be sporadic, since recreational anglers are not intentionally entering the water.

High-intake fish consumers are individuals in the recreational angler population that eat significantly more fish than typical recreational anglers. High-intake fish consumers include individuals who would not be able to meet their daily nutritional requirements if they could not supplement their diet with sport-caught fish. Such high-intake fish consumers have often been termed subsistence anglers. In particular, Native Americans, Hmong, and Laotians may have portions of their populations engaged in subsistence fishing. Regardless of racial or ethnic background, individuals with low incomes are more likely to engage in high levels of fish consumption, often greater than the average recreational angler. The exposure pathways for the high-intake fish consumer are the same as those for the recreational angler.

Consumption of fish caught in the Lower Fox River/Green Bay has been recognized as a health issue since 1977, when the first fish advisories were issued. Fish advisories are still in effect for PCBs in the Lower Fox River and Green Bay (WDH/WDNR, 1998). Current fish advisories for PCBs are summarized in Table 5-2. These fish advisories are based on the relationship between tissue concentrations of PCBs in individual size classes and species of fish, and on a health protective value of 0.05 microgram of polychlorinated biphenyl per kilogram of body weight per day (μg-PCB/kg-BW/day) (as described in Anderson *et al.*, 1993). This value falls between the reference doses for Aroclor 1254 (0.02 μg-PCB/kg-BW/day) and Aroclor 1016 (0.07 μg-PCB/kg-BW/day) as discussed later in this section. This value is also consistent with a lifetime cancer risk level of about 10^{-4}. The fish advisories have been developed with the knowledge that there are significant nutritional benefits from eating fish. Fish are an excellent source of protein and are low in saturated fats (WDH/WDNR, 1998). Thus, the advisories have been developed with the understanding that there is a trade-off between consuming fish and being exposed to PCBs, on the one hand, and consuming fish and experiencing the nutritional benefits of the fish as a food source, on the other hand. With that trade-off in mind, the advisories describe precautions that should be taken by anglers and their families before consuming fish that have been caught from the Lower Fox River or Green Bay. These advisories are for trimmed and skinned fish, and assume an average meal size of 227 grams (0.5 pound) for a 70-kg adult based upon findings in a variety of studies of fish consumption, as discussed in detail later in this section. In addition, the fish advisory document (WDH/WDNR, 1998) provides advice for properly trimming, skinning, and cooking fish to reduce potential exposures to PCBs and other lipophilic chemicals. Despite these fish advisories, a high percentage of anglers and their families are often unaware of specific advisories and others choose to ignore them (West *et al.*, 1989, 1993). Tilden *et al.* (1997) found that 60 percent of women and 80 percent of ethnic minorities who had eaten sport fish were unaware of fish consumption advisories.

Hunters are individuals who hunt waterfowl in the Lower Fox River and Green Bay. These individuals may be exposed to chemicals through ingestion of waterfowl. Like anglers, these individuals may also be exposed to constituents in the river through inhalation of chemicals volatilized into the air from the surface water, incidental ingestion of water during hunting, and dermal contact with water during hunting. The exposures via ingestion and dermal contact are likely to be low for this receptor, since hunters may not come in contact with the water at all.

It should be noted that hunters may also hunt mammals, such as deer, that may eat vegetation, drink water, and contact sediment along the Lower Fox River or Green Bay. However, deer are likely to obtain only a small fraction (which may approach zero) of their daily food requirement from vegetation in the Lower Fox River or Green Bay. Therefore, deer are likely to have lower exposure to constituents in the Lower Fox River and Green Bay than waterfowl. This is true despite the fact that waterfowl are migratory and only spend a portion of the year in the Lower Fox River and Green Bay area. Additionally, it is difficult to determine the extent to which chemical concentrations in deer are due to exposure to chemicals in the Lower Fox River and Green Bay as opposed to exposure to chemicals in other areas, such as forested areas and farm fields. Therefore, the evaluation of hunters has been limited to hunting waterfowl.

Drinking water users are individuals that use water taken directly from the Lower Fox River as a source of drinking water. Lake Winnebago is used as a primary source of drinking water, but no part of the Lower Fox River is used as a primary water source. From Lake Winnebago to the dam at Appleton, the Lower Fox River serves as a secondary source of drinking water for the communities of Neenah, Menasha, and Appleton. All river water is treated prior to joining the water-distribution systems in these communities. From the dam in Appleton to the discharge point at Green Bay, the Lower Fox River is not used as a drinking water source. Green Bay is classified as a drinking water source, but does not actually supply drinking water to any communities near the Fox River. The city of Green Bay acquires its drinking water from Lake Michigan. The nearest community that takes water from Green Bay is Marinette, which is 40 to 50 miles from Green Bay. Potential exposures associated with direct use of water include ingestion; dermal contact during bathing, cooking and other household uses of water; and inhalation of chemicals volatilized into the air during showering and other uses.

Local residents are individuals who live next to the Lower Fox River or Green Bay. There are homes located along the water throughout the length of the Lower Fox River, except in downtown Green Bay. Potential exposures associated with living next to the river include inhalation of chemicals volatilized into the air from the surface water.

Recreational water users are individuals who wade, swim, jet ski, or water ski on the river or in the bay. Several parks are located on the Lower Fox River shoreline, although there are no public beach areas on the river where people are known to swim. Nonetheless, the potential exists for swimming to occur in the river. There are a number of public beaches in Green Bay. Potential exposures associated with recreational water use include inhalation of chemicals volatilized into the air from the surface water, incidental ingestion of water, dermal contact with water, incidental ingestion of sediment, and dermal contact with sediment or sediment pore water.

Marine construction workers are individuals engaged in dredging or construction activities within the river or bay. These activities could include navigational dredging of the harbors on Lower Fox River or Green Bay, and construction projects that may occur in the river and along the Green Bay shoreline. Potential exposures associated with construction activities or navigational dredging include inhalation of chemicals volatilized into the air from the surface water, incidental ingestion of and dermal exposure to water during work activities, and incidental ingestion of and dermal exposure to sediment during work activities.

Table 5-1 lists the primary receptor groups and their associated exposure pathways for the Lower Fox River and Green Bay. While more receptor groups could have been developed, the human health assessment has focused on the dominant receptor groups and exposure pathways. It is possible for an individual to live next to the river (the local resident), use the river for recreational activities (the recreational water user), fish from the river (recreational angler), hunt waterfowl from the river (hunter), and obtain drinking water from the river (drinking water user). The exposures to such an individual would be a combination of the exposures to the five receptor groups identified in parentheses. Such an individual is likely to be rare and, therefore, is not discussed in detail in the risk characterization. However, such rare receptors are mentioned in the uncertainty analysis. The primary goal of Table 5-1 is to identify key receptor groups so that potential risks can be estimated for representative receptors in the Lower Fox River and Green Bay.

5.3 Evaluation of Polynuclear Aromatic Hydrocarbons (PAHs) in Whole Body Fish Tissue Samples

In September 1998, whole body fish tissue samples were collected and analyzed for polynuclear aromatic hydrocarbons (PAHs), PCBs, pesticides, and dioxins/furans. The fish species sampled were carp, walleye, and shiners, and the samples were collected from the following three reaches: Little Lake Butte des Morts, Little Rapids to De Pere, and De Pere to Green Bay. This sampling was conducted in order to provide supplemental data for the risk assessment. This data included analysis for PAHs in fish tissue, which previously had not been analyzed. The samples were analyzed for additional chemicals including PCBs and 2,3,7,8-TCDD.

A summary of selected results of the supplemental sampling is presented in Table 5-3. This table indicates the maximum detected concentration, the average concentration, and the frequency of detection of each PAH constituent analyzed in the fish tissue samples. The results for total PCBs and 2,3,7,8-TCDD are also listed in this table to provide some comparative information.

5.3.1 Screening Evaluation

Next, a screening evaluation was performed on these data to determine the potential for adverse human health effects. As was done in the Screening Level Risk Assessment, each constituent is compared to its risk-based screening concentration (RBSC). The RBSCs for the fish ingestion scenario are based on conservative exposure assumptions for high-intake fish consumers (RETEC, 1998b). It should be noted that in RETEC (1998b), high-intake fish consumers are referred to as “subsistence anglers,” and the subscript “SA” is an abbreviation for a “subsistence angler.” The equation and exposure parameters used to calculate high-intake fish consumers RBSCs ($RBSC_{SA\text{-}fish}$) for carcinogenic chemicals are as follows:

$$RBSC_{SA-fish} = \frac{TR \times BW \times ATc}{FIR \times EF \times ED \times FI \times SF}$$

where:

- TR = target risk = 1.0×10^{-6},
- BW = body weight = 70 kg,
- ATc = averaging time (carcinogenic) = 25,550 days,
- FIR = fish ingestion rate = 0.14 kilograms per day (kg/day),
- EF = exposure frequency = 365 days per year (days/yr),
- ED = exposure duration = 70 years,
- FI = fraction ingested from Fox River = 100%, and
- SF = oral cancer slope factor (chemical-specific).

The equation and exposure parameters used to calculate high-intake fish consumer RBSCs ($RBSC_{SA\text{-}fish}$) for non-carcinogenic chemicals are as follows.

$$RBSC_{SA-fish} = \frac{THQ \times BW \times ATnc \times RfD}{FIR \times EF \times ED \times FI}$$

where:

- THQ = target hazard quotient = 0.1,
- $ATnc$ = averaging time (non-carcinogenic) = 25,550 days, and
- RfD = chronic oral reference dose (chemical-specific).

The other parameters in the equation were defined above.

Exposure assumptions used to calculate the $RBSC_{SA\text{-}fish}$ are consistent with the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.*, 1993), which has been adopted by all eight states in the Great Lakes basin. An average daily fish ingestion rate of 140 grams per day (g/day) was used to calculate the $RBSC_{SA\text{-}fish}$; this corresponds to the ingestion rate assumed in Anderson *et al.* (1993) for unrestricted consumption of sport fish. It is also the maximum fish consumption rate assumed for anglers in the 1996 Fox River Risk Assessment (GAS/SAIC, 1996), which was intended to be representative of a subsistence level of fish consumption. This ingestion rate (140 g/day) is comparable to EPA's default subsistence fish ingestion rate of 132 g/day (EPA, 1991a), and corresponds to about 4.3 meals per week (assuming a meal size of 227 grams, or 0.5 pound). An exposure duration of 70 years (corresponding to an average lifetime of 70 years) was assumed, consistent with Anderson *et al.* (1993). It should be noted that Anderson *et al.* (1993) used an average lifetime of 70 years, while EPA's Exposure Factors Handbook (1997b) revised this number to 75 years. For screening purposes, no reduction in constituent concentrations due to cooking and cleaning of fish was assumed.

Table 5-4 presents the oral reference doses and cancer slope factors that are available for the chemicals detected in fish tissue. These toxicity criteria were obtained from the EPA's Integrated Risk Information System (IRIS) or from the Health Effects Assessment Summary Tables (HEAST). For some PAHs, no toxicity criteria were available; therefore, surrogate criteria from structurally similar PAHs were used to calculate RBSCs. Table 5-4 also presents the calculated RBSCs for each chemical.

The results of the screening evaluation are presented in Table 5-5. For each PAH that was detected in fish tissue, the maximum detected concentration was compared to its corresponding $RBSC_{SA\text{-}fish}$. If the maximum detected concentration was greater than the $RBSC_{SA\text{-}fish}$, the chemical was identified as a potential constituent of interest for the fish ingestion pathway. If the maximum detected concentration was less than the $RBSC_{SA\text{-}fish}$, the PAH was eliminated from further evaluation for the fish ingestion pathway. The screening was also performed for total PCBs and 2,3,7,8-TCDD.

5.3.2 Calculation of Cancer Risks

As indicated in Table 5-5, the maximum detected concentrations of benzo(a)anthracene, benzo(a)pyrene, benzo(b)fluoranthene, benzo(k)fluoranthene, dibenz(a,h)anthracene, and indeno(1,2,3-cd)pyrene exceeded their respective RBSCs. For each of these PAHs, the cancer risk was calculated based on the maximum concentration and the exposure assumptions used to derive the RBSC. The equation used to calculate the cancer risk is as follows.

$$\text{Cancer Risk} = \frac{\text{Maximum Detection}}{RBSC_{SA-fish}} \times 10^{-6}$$

This calculation was also done for total PCBs and 2,3,7,8-TCDD, whose maximum concentrations exceeded their respective RBSCs.

The calculated cancer risks for each chemical with a maximum detected concentration above the RBSC are also presented in Table 5-5. Only two of the PAHs, benzo(a)pyrene and dibenz(a,h)anthracene, were found to have associated cancer risks above the 10^{-4} risk level. The calculated cancer risks for total PCBs and 2,3,7,8-TCDD also exceeded the 10^{-4} risk level. This risk level is associated with an increased chance of developing cancer of 1 in 10,000, and is the upper end of the range of acceptable risks (10^{-6} to 10^{-4}) that is generally used when making cleanup decisions under Superfund.

5.3.3 Results of PAH Evaluation

Although the results of this evaluation show that two PAHs may be present at levels exceeding a 10^{-4} cancer risk, several things should be noted. First, the calculated cancer risks are two orders of magnitude below those for PCBs. Second, each PAH was only detected in two out of 12 samples whereas PCBs were detected in all samples. Third, the data are for whole fish samples, while people eat, with rare exceptions, fillets. PAHs are readily metabolized, which is reflected in the low number of detections, and are less likely to accumulate in the fillet than in other organs of the fish. Thus, the use of whole body samples is conservative. Finally, the exposure assumptions used to calculate RBSCs and the associated risks are very conservative. Taking all this into account, actual exposure to PAHs from ingestion of fish is likely to be significantly below that estimated here and below that estimated for PCBs. Therefore, exposure to PAHs is not considered further.

5.4 Intake Assumptions for Potential Receptors

This section describes the intake assumptions used for calculating the intake by potential receptors in the Lower Fox River and Green Bay. This discussion is divided into three parts: the first part provides a general overview of intake assumptions; the second part presents intake equations applicable to the receptors in the river and bay; and the third part discusses assumptions used for specific receptors in the river and bay. The exposure assumptions presented are based primarily on EPA risk assessment guidance (EPA, 1989c, 1991a, 1997b).

5.4.1 Overview of Intake Assumptions

This section provides a general discussion of the assumptions used to calculate intakes from various exposure pathways. Exposure pathways are defined as a direct contact route between a receptor and an impacted medium. Exposure pathways are determined for receptors based on the receptors' expected activities at the site. In order to translate exposures to potentially impacted media into intakes or doses, intake assumptions must be specified. These intake assumptions consider the number of times a receptor is expected to contact a particular medium, the duration of the contact, and the mechanisms that enable chemicals in impacted media to be potentially assimilated by the receptor (EPA, 1989c, 1997b).

Generally, the intake or dose of a particular chemical by a receptor is calculated with the equation:

$$I = \frac{C \cdot CR}{BW} \cdot \frac{EF \cdot ED}{AT}$$

where:

I	=	the chemical intake (milligrams per kilogram of body weight per day [mg/kg-BW/day]),
C	=	the chemical concentration (e.g., milligrams per kilogram of soil [mg/kg-soil] or milligrams per liter of water [mg/L-water]),
CR	=	contact rate or the amount of impacted medium contacted per event (e.g., liters per day [L/day]),
EF	=	exposure frequency (days/yr),
ED	=	exposure duration (years),
BW	=	the average body weight of the receptor (kg), and
AT	=	averaging time of the exposure (days).

This equation calculates an intake that is normalized over the body weight of the individual and the duration of the exposure.

Since the intake or dose is combined with quantitative indices of toxicity (chemical-specific dose-response information such as reference doses or cancer slope factors) to give a measure of potential health effects, the intake or dose must be calculated in a manner that is compatible with the quantitative dose-response information for the chemicals used in the analysis. Two different types of health effects are considered in this analysis: non-threshold (carcinogenic) effects and threshold (non-carcinogenic) effects.

For carcinogenic effects, the relevant intake is the total cumulative intake averaged over a lifetime, because the quantitative dose-response function for carcinogens is based on the assumption that cancer results from cumulative lifetime exposures to carcinogenic agents. The cumulative intake or dose is then averaged over a lifetime to provide an estimate of intake or dose of carcinogens expressed in units of milligrams per kilogram per day (mg/kg-day). Thus, for potentially carcinogenic chemicals, the averaging time (*AT*) is equal to 75 years (EPA, 1997b).

In this analysis, non-carcinogenic effects are evaluated for potential chronic exposures. The relevant intake or dose is based on the daily intake averaged over the exposure period. The quantitative dose-response function for non-carcinogenic effects is based on the assumption that effects occur once a threshold dose resulting from exposure is attained (EPA, 1989c). For non-carcinogenic effects, the averaging time (*AT*) is equal to the period of exposure for the receptor.

5.4.2 Generalized Assumptions for Exposure Analysis

In this section, the calculated intake or dose per event is discussed for seven routes of exposure: ingestion of fish, ingestion of waterfowl, ingestion of water, dermal contact with water, inhalation of volatiles, incidental ingestion of sediment, and dermal contact with sediment.

Ingestion of Fish

The intake or dose for the ingestion of fish pathway is calculated based on the equation (EPA, 1989c, 1997b):

$$I_{ing\text{-}f} = \frac{Cfish \cdot RF \cdot IR \cdot CF \cdot ABS \cdot EF \cdot ED}{BW \cdot AT}$$

where:

$I_{ing\text{-}f}$ = intake from ingestion of fish (mg/kg-BW/day),
Cfish = chemical concentration in fish (milligrams per kilogram of fish [mg/kg-fish]),
RF = reduction factor (unitless),
IR = fish ingestion rate (grams of fish per day [g-fish/day]),
CF = conversion factor (10^{-3} kilograms per gram [kg/g]),
ABS = ingestion absorption factor (fraction absorbed),
EF = exposure frequency (days/yr),
ED = exposure duration (years),

BW = body weight (kg), and
AT = averaging time (days).

The concentrations of the chemicals in fish (*Cfish*) are discussed in Section 5.5. The reduction factor (*RF*) is a number between 0 and 1 that describes the fraction of the chemicals originally in the fresh caught fish remaining after the fish has been gutted, scaled, trimmed, and cooked. The ingestion rate (*IR*) is the amount of fish ingested per day or event. The absorption factor (*ABS*) is the fraction of chemical absorbed during ingestion and is chemical-specific, although it is generally assumed to be 100 percent. This assumption is also reasonable. The oral cancer slope factors and oral reference doses for COPCs are generally based on ingestion studies in animals. Therefore, it is expected that absorption from ingestion of fish will be similar to absorption in the animal study, so setting *ABS* to 100 percent is reasonable. For example, the cancer slope factors for PCBs are based on an oral feeding study (Brunner *et al*., 1996), the oral reference dose for Aroclor 1016 is based on oral feeding studies (Barsotti and Van Miller, 1984; Levin *et al*., 1988; Schantz *et al*., 1989, 1991), and the oral reference dose for Aroclor 1254 is also based on ingestion of PCBs in a gelatin capsule (Arnold *et al*., 1993a, 1993b; Tryphonas *et al*., 1989, 1991a, 1991b). Thus, absorption after ingestion of fish is likely to be similar to absorption in the studies used as the basis for the oral cancer slope factors and oral reference doses. The exposure frequency (*EF*), exposure duration (*ED*) and body weight (*BW*) are described in the intake assumptions for specific receptors. The averaging time (*AT*) was discussed previously.

It should be noted that the chemical concentration in fish (*Cfish*), the reduction factor (*RF*) and the fish ingestion rate (*IR*) are closely related. This relationship is discussed briefly here and in more detail in Section 5.4.3. In this analysis, *Cfish* is the concentration of COPCs in raw fish, generally skin on fillet. The variable *IR* refers to the uncooked weight of the fish portion that is eaten. Trimming will reduce the mass of fish consumed and will reduce the concentration if fatty parts with higher concentrations are trimmed. Cooking will also reduce the mass of fish, principally through water loss, but also through volatilization of COPCs. In many cases, the overall tissue concentrations after trimming and cooking are similar to the concentrations in the raw, uncooked fish, but the mass of fish has been reduced, so the total mass of COPC in the cooked fish is less than in the uncooked fish. In other cases, the tissue concentrations of COPCs after trimming and cooking are less than the concentrations in the raw, uncooked fish. In these cases, the total COPCs in the fish portion has been reduced by concentration reduction as well as reduction in the mass of fish (Anderson *et al*., 1993).

Ingestion of Waterfowl

The intake or dose for the ingestion of waterfowl pathway is calculated based on the equation (EPA, 1989c, 1997b):

$$I_{ing-wf} = \frac{CWF \cdot RF \cdot IR \cdot CF \cdot ABS \cdot EF \cdot ED}{BW \cdot AT}$$

where:

I_{ing-wf}	=	intake from ingestion of waterfowl (mg/kg-BW/day),
CWF	=	chemical concentration in waterfowl (milligrams per kilogram of waterfowl [mg/kg-waterfowl]),
RF	=	reduction factor (unitless),
IR	=	waterfowl ingestion rate (grams of waterfowl per day [g-waterfowl/day]),
CF	=	conversion factor (10^{-3} kg/g),
ABS	=	ingestion absorption factor (fraction absorbed),
EF	=	exposure frequency (days/yr),
ED	=	exposure duration (years),
BW	=	body weight (kg), and
AT	=	averaging time (days).

The concentrations of the chemicals in waterfowl (*CWF*) are discussed in Section 5.5. The reduction factor (*RF*) is a number between 0 and 1 that describes the fraction of the chemical originally in the waterfowl remaining after the waterfowl has been gutted, trimmed, and cooked. The ingestion rate (*IR*) is the amount of waterfowl ingested per day or event. The absorption factor (*ABS*) is the fraction of chemical absorbed during ingestion and is chemical-specific, although it is generally assumed to be 100 percent. As discussed for the fish ingestion pathway, this assumption is also reasonable since the oral cancer slope factors and oral reference doses for COPCs are generally based on ingestion studies in animals. The exposure frequency (*EF*), exposure duration (*ED*), and body weight (*BW*) are described in the intake assumptions for specific receptors. The averaging time (*AT*) was discussed previously.

As with ingestion of fish, the chemical concentration in waterfowl (*CWF*), the reduction factor (*RF*) and the waterfowl ingestion rate (*IR*) are closely related. This inter-relationship is investigated in the assumptions for the hunter, which are presented in Section 5.4.3.

Ingestion of Water

The intake or dose from ingestion of water is calculated using the equation (EPA, 1989c, 1997b):

$$I_{ing-w} = \frac{CW \cdot IR \cdot ABS \cdot EF \cdot ED}{BW \cdot AT}$$

where:

I_{ing-w} = intake from ingestion of water (mg/kg-BW/day),
CW = concentration of chemical in water (milligrams per liter [mg/L]),
IR = ingestion rate (L/day),
ABS = ingestion absorption factor (fraction absorbed),
EF = exposure frequency (events per year [events/yr]),
ED = exposure duration (years),
BW = body weight (kg), and
AT = averaging time (days).

Concentrations of chemicals in water (*CW*) are discussed in Section 5.5. The ingestion rate (*IR*) is the amount of water ingested per day. The absorption factor (*ABS*) used in this equation is chemical-specific, but is generally assumed to be 100 percent. As discussed for the fish ingestion pathway, this assumption is reasonable since the oral cancer slope factors and oral reference doses for COPCs are generally based on ingestion studies in animals. The exposure frequency (*EF*), exposure duration (*ED*), and body weight (*BW*) are described in the intake assumptions for specific receptors. The averaging time (*AT*) was discussed previously.

Dermal Contact with Water

The absorbed intake or dose from dermal contact with water is calculated using the equation (EPA, 1992a):

$$I_{der-w} = \frac{CW \cdot SA \cdot PC \cdot ET \cdot EF \cdot ED \cdot CF}{BW \cdot AT}$$

where:

I_{der-w} = absorbed intake from dermal contact with water (mg/kg-BW/day),
CW = concentration of chemical in water (mg/L),
SA = exposed skin surface area (square centimeters [cm^2]) = $TBS \cdot FBE$,
TBS = total body surface area (cm^2),
FBE = fraction of body exposed (unitless),
PC = permeability constant (centimeters per hour [cm/hr]),
ET = exposure time (hours per day [hrs/day]),
EF = exposure frequency (days/yr),
ED = exposure duration (years),
CF = volumetric conversion factor (liters per 1,000 cubic centimeters [L/1,000 cc]),

BW = body weight (kg-BW), and
AT = averaging time (days).

The concentrations of chemicals in water (*CW*) are discussed in Section 5.5. The skin surface area (*SA*) exposed to water is the product of the total body surface area (*TBS*) and the fraction of body exposed (*FBE*). The variable *FBE* is highly dependent on the nature of the activity being conducted, ranging from nearly 100 percent for showering or swimming to 5 percent or less for workers contacting water during work activities. In addition, dermal absorption may vary for different skin types and locations on the body. The permeability constants (*PC*) are chemical-specific and describe the rate at which the chemical moves from water through the skin. The exposure time (*ET*), exposure frequency (*EF*), exposure duration (*ED*), and body weight (*BW*) are described in the intake assumptions for specific receptors. The averaging time (*AT*) was discussed previously.

The permeability constants (*PC*) were set to permeability coefficients or *Kp* values obtained from EPA's *Dermal Exposure Assessment: Principles and Application* (EPA, 1992a). In this guidance, measured values of *Kp* are available for some constituents. These values were used when available. For other constituents, values for *Kp* were calculated using the following chemical structure activity relationships (Potts and Guy, 1992, as reported in EPA, 1992a):

$$\log Kp = -2.72 + 0.71 \cdot \log K_{ow} - 0.0061 \cdot MW$$

In this equation, K_{ow} is the octanol-water partition coefficient and *MW* is the molecular weight in grams per mole (g/mole). The values for a number of organic COPCs were calculated in EPA (1992a) using this equation and are presented in Table 5-6. The value for PCBs is based on hexachlorobiphenyl, while the value for dioxins/furans is based on 2,3,7,8-TCDD. Values for inorganic compounds are also presented in Table 5-6. The value for arsenic is the default value for inorganics of 0.001 cm/hr (EPA, 1992a). The value for lead in Table 5-6 is a measured value for lead acetate provided in EPA (1992a). The value for mercury is a measured value for mercuric chloride (EPA, 1992a).

For PCB Aroclors, PCB congeners, dioxin congeners except 2,3,7,8-TCDD, and furan congeners, there were no values for *Kp* in EPA (1992a). Thus, values for *Kp* were calculated for these COPCs using the above equation. The inputs (K_{ow}, *MW*) and results (*Kp*) are presented in Table 5-7 for these COPCs. The sources of the K_{ow} and *MW* values were Mackay *et al*. (1992a, 1992b).

It should be noted that the structure activity relationship provided above was developed for chemicals with much higher solubilities and lower values of K_{ow} than the organic COPCs considered in this assessment. Therefore, there is significant uncertainty associated with the use of these permeability coefficients to assess dermal uptake from water.

Inhalation of Volatiles

For inhalation, the dose per event is estimated using the formula (EPA, 1989c, 1997b):

$$I_{inhal} = \frac{CA \cdot IR \cdot ABS \cdot ET \cdot EF \cdot ED}{BW \cdot AT}$$

where:

- I_{inhal} = intake from inhalation (mg/kg-BW/day),
- CA = concentration of chemical in air (milligrams per cubic meter [mg/m^3]),
- IR = inhalation rate (cubic meters per hour [m^3/hr]),
- ABS = inhalation absorption factor (fraction absorbed),
- ET = exposure time (hrs/day),
- EF = exposure frequency (days/yr),
- ED = exposure duration (years),
- BW = body weight (kg), and
- AT = averaging time (days).

The concentrations of chemicals in the air (*CA*) are the ambient air concentrations of chemicals volatilized from the surface water and are discussed in Section 5.5. The inhalation rate (*IR*) is the average rate of respiration for individuals per hour. This rate is dependent on the age and the average activity level of the individual and is selected specifically for each receptor. The inhalation absorption factor (*ABS*) is chemical-specific, but is assumed to be 1 (or 100 percent) for all chemicals and receptors, implying that all of the inhaled chemicals are assimilated into the body. This is an appropriately conservative and, consequently, health-protective assumption. This assumption is reasonable since inhalation cancer slope factors and inhalation reference doses are generally derived based on the delivered dose from inhalation and not the absorbed dose. Exposure time (*ET*), exposure frequency (*EF*), and exposure duration (*ED*) are dependent on the exposure scenario for the individual receptors and are defined in the intake assumptions for each receptor. The body weight (*BW*) is also receptor-specific. The averaging time (*AT*) was discussed previously.

Incidental Ingestion of Sediment

The intake or dose for the incidental ingestion of sediment pathway is calculated based on the equation (EPA, 1989c, 1997b):

$$I_{ing-s} = \frac{CS \cdot IR \cdot CF \cdot FI \cdot ABS \cdot EF \cdot ED}{BW \cdot AT}$$

where:

I_{ing-s}	=	intake from incidental ingestion of sediment (mg/kg-BW/day),
CS	=	chemical concentration in sediment (milligrams per kilogram of sediment [mg/kg-sediment]),
IR	=	incidental sediment ingestion rate (milligrams of sediment per day [mg-sediment/day]),
CF	=	conversion factor (10^{-6} kilograms per milligram [kg/mg]),
FI	=	fraction of daily incidental sediment ingestion occurring on-site (unitless),
ABS	=	ingestion absorption factor (fraction absorbed),
EF	=	exposure frequency (days/yr),
ED	=	exposure duration (years),
BW	=	body weight (kg), and
AT	=	averaging time (days).

The concentrations of the chemicals in sediment (*CS*) are discussed in Section 5.5. The ingestion rate (*IR*) is the amount of sediment incidentally ingested per day or event. The fraction ingested (*FI*) is the percent of the daily intake of sediment that occurs at the site. The absorption factor (*ABS*) is the fraction of chemical absorbed during ingestion and is chemical-specific, but is generally assumed to be 1 (or 100 percent). The exposure frequency (*EF*), exposure duration (*ED*) and body weight (*BW*) are described in the intake assumptions for specific receptors. The averaging time (*AT*) was discussed previously.

The sediment absorption factors used in this analysis are presented in Table 5-8. With one exception, these factors are 100 percent, which conservatively assumes all chemicals present in the sediment are absorbed to the same extent that the chemical was absorbed in the toxicological study or studies used as the basis for either the oral cancer slope factor or oral reference dose. While it is likely that chemicals are not absorbed as readily from ingested sediment as from food (the vehicle generally used in animal studies to deliver the chemical), no or very limited experimental studies exist for quantifying absorption from sediment or soil for any COPCs except arsenic. The absorption factor for arsenic was set to 32 percent based on a study by Freeman *et al.* (1993). The study by Freeman *et al.* (1993) evaluated the bioavailability of arsenic in soil, and these results are assumed to be applicable to sediment. The oral cancer slope factor for arsenic is based on epidemiological data for individuals exposed to high levels of arsenic in well water. In the study by Freeman *et al.* (1993), the bioavailability of arsenic via ingestion of soils was estimated to be 24 percent with a standard deviation of 3.2 percent (Freeman *et al.*, 1993). This bioavailability value was based on a comparison of excretion data from two groups of prepubescent male and female SPF New Zealand white rabbits, each of which was administered varying levels of arsenic either in soil or intravenously. The experimentally-derived bioavailability value of 24 percent for arsenic was adjusted upwards to 30 percent for this analysis, which is about two standard deviations above the mean and provides a conservative estimate of the bioavailability of arsenic in soil for the inadvertent ingestion scenarios. Since bioavailability in soil was measured relative to intravenously-administered arsenic, this absorption factor must be modified relative to the absorption of arsenic in the epidemiological study used to derive the cancer slope factors and reference doses. The absorption of arsenic from water is estimated to be 95 percent (Dollarhide, 1993). Thus, the soil absorption factor is 0.30/0.95, or 32 percent, and this value was used in this analysis for absorption of arsenic from incidentally ingested sediment.

Dermal Contact with Sediment

The absorbed intake or dose per event from dermal contact with sediment is estimated using the equation (EPA, 1989c, 1992b):

$$I_{der-s} = \frac{CS \cdot CF \cdot SA \cdot AF \cdot ABS \cdot FC \cdot EF \cdot ED}{BW \cdot AT}$$

where:

- I_{der-s} = absorbed dose from dermal contact with sediment (mg/kg-BW/day),
- CS = concentration of the chemical in sediment (mg/kg),
- CF = conversion factor (10^{-6} kg/mg),
- SA = exposed skin surface area (square centimeters per event [cm^2/event]) $= TBS \cdot FBE$,
- TBS = total body surface area (cm^2),
- FBE = fraction of the body exposed (unitless),
- AF = sediment adherence factor (milligrams per square centimeter [mg/cm^2]),
- ABS = skin absorption factor (unitless),
- FC = fraction of the day that contact with sediment occurs at the site (unitless),
- EF = exposure frequency (events/yr),
- ED = exposure duration (years),

BW = body weight (kg), and
AT = averaging time (days).

Concentrations of chemicals in sediment (*CS*) are discussed in Section 5.5. The skin surface area (*SA*) exposed to sediment is the product of the total body surface area (*TBS*) and the fraction of body exposed (*FBE*). The fraction of body exposed (*FBE*) is dependent on the nature of the activity being conducted and the age and type of the individuals involved. The sediment adherence factor (*AF*) is the density of sediment adhering to the exposed fraction of the body. The skin absorption factor (*ABS*) is the percentage of the chemical absorbed during dermal contact with sediment. The fraction of the day that contact occurs (*FC*) is the percent of time that sediment contact occurs at the site. The exposure frequency (*EF*), exposure duration (*ED*), and body weight (*BW*) are receptor-specific. The averaging time (*AT*) was discussed previously.

The dermal absorption factors used in this analysis are presented in Table 5-9. EPA Region III performed a review of dermal absorption data and developed dermal absorption factors for absorption from soil for a number of chemicals (EPA, 1995a). Absorption factors are used to reflect the desorption of the chemical from soil and the absorption of the chemical across the skin and into the bloodstream (EPA, 1989c). The Region III guidance (EPA, 1995a) summarizes chemical-specific and general (for classes of compounds) absorption factors that have been found in the limited database available. The factors were compiled from existing national guidance and peer-reviewed scientific literature. It is recommended that these numbers be used as defaults for the *ABS* parameter when calculating reasonable maximum exposures (RME) to soil in the absence of chemical-specific and site-specific information (EPA, 1995a). For this evaluation, it was assumed that dermal absorption from sediment would be similar to dermal absorption from soil. A value of 6 percent is recommended for PCBs (EPA, 1995a). A value of 3 percent is recommended for chlorinated dioxins/furans based on the dermal absorption of 2,3,7,8-TCDD (EPA, 1995a). The 10 percent value is recommended as a conservative assumption of *ABS* for pesticides, including dieldrin and DDT and its metabolites (EPA, 1995a). A value of 3.2 percent is recommended for arsenic while 1 percent is recommended for all other metals and inorganics (EPA, 1995a).

5.4.3 Specific Intake Assumptions for Receptors

As discussed previously, the critical receptors associated with the Lower Fox River and Green Bay are:

- Recreational anglers,
- High-intake fish consumers,

- Hunters,
- Drinking water users,
- Local residents,
- Recreational water users, and
- Marine construction workers.

A detailed discussion of the intake assumptions for evaluating potential exposures to these receptors is provided below. For some of these receptors, two exposure scenarios are presented: a reasonable maximum exposure or RME scenario (to represent high-end exposures) and a central tendency exposure or CTE scenario (to represent more typical exposures). Differences in intake assumptions for the two scenarios are described in the subsections below.

Overview of Key Assumptions for Anglers

This subsection provides detailed discussion of several intake parameters for the recreational anglers and high-intake fish consumers. These parameters are the daily fish ingestion rate (*IR*), exposure frequency (*EF*), reduction factor (*RF*), and exposure duration (*ED*). The parameters *IR* and *EF* are discussed separately for recreational anglers and high-intake fish consumers. The discussion of *ED* applies to the hunter as well as the two angler populations. All these parameters are discussed in detail in Appendix B1, where probability distributions for each parameter are presented.

Ingestion Rate and Exposure Frequency for Recreational Anglers. There are reportedly about 136,000 individuals with fishing licenses (WDNR, 1999d) who reside in counties immediately adjacent to the Lower Fox River and Green Bay. Ten percent of the angler population, or about 14,000 anglers, could be considered high-intake fish consumers (i.e., individuals who consume fish at more than the 90th percentile of the distribution of fish ingestion rates). Table 5-10 summarizes intake assumptions for the general recreational angler population based on three surveys of the recreational angling population: a 1989 survey of Michigan anglers (West *et al*., 1989), a 1993 follow-up survey of Michigan anglers (West *et al.*, 1993), and a 1989 study of Wisconsin anglers (Fiore *et al*., 1989). Two types of intake assumptions are provided; one based on upper-bound values, termed the reasonable maximum exposure (RME) scenario, and one based on mean or median values, termed the central tendency exposure (CTE) scenario.

The intake assumptions which differ between the studies are the daily ingestion rate (*IR*) and the exposure frequency (*EF*). West *et al*. (1989, 1993) estimated the average amount of fish consumed at each meal (*IR*) by showing anglers a picture of an 8-ounce (227-g) portion of cooked fish and asked if they ate more, less, or about this much fish at each meal. The responses were used to derive a distribution of fish consumption per meal. West *et al*. (1989, 1993) also determined a distribution of the number of meals per year (*EF*) of sport-caught fish that were consumed. These data were combined by EPA (1997b) and SAIC (1995) in a probabilistic analysis to determine a distribution of fish consumed per day normalized over 365 days per year. These values of *IR* and *EF* are reported in Table 5-10 for the two West *et al.* studies. For the 1989 study, the 95th percentile for *IR* is 39 g/day (RME) and the mean is 12 g/day (CTE). Since the data were normalized over 365 days per year, *EF* is 365 days per year for both the RME and CTE scenarios. For the 1993 study, the 95th percentile for *IR* is 78 g/day (RME) and the mean is 17 g/day (CTE). Once again, since the data were normalized over 365 days per year, *EF* is 365 days per year for both the RME and CTE scenarios.

In the Fiore *et al.* (1989) study, the number of meals of sport fish consumed each year were determined. Fiore *et al.* did not determine the quantity of fish consumed in each meal during their study. However, the Wisconsin Department of Health and Social Services performed follow-up studies where various quantities of uncooked fish were shown to anglers and these studies demonstrated that a typical meal size is 8 ounces (227 grams) of uncooked fish. These studies are the basis for the 8 ounces of uncooked fish which is used in the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.,* 1993) to determine acceptable concentrations of PCBs in fish. Again, it is important to note that all eight states in the Great Lakes basin have fish consumption advisories that have been developed in whole or in part using this protocol (Clark, 2000). With this background, the amount of fish consumed per meal (*IR*) was set to 227 g/day for both the RME and CTE scenarios. The number of meals consumed per year (*EF*) was set to 59 days/yr for the RME scenario and 18 days/yr for the CTE scenario.

Table 5-10 presents values of *IR* and *EF* for each study using the basis in each study. To allow intake assumptions to be compared directly, values of *IR* and *EF* are also provided for each study using common bases. First, annualized values of *IR* are provided by computing the total amount of fish consumed each year and dividing this total by 365 days per year. The basis for these values is labeled "Annualized IR" in Table 5-10 with *EF* set equal to a constant value of 365 days per year for all studies. Second, the normalized number of meals per year (*EF*) are provided by computing the total amount of fish consumed each year and dividing this total by an average meal size of 227 grams per meal (g/meal). The basis for these values is labeled "Normalized Meals per Year" in Table 5-10 with *IR* set equal to a constant value of 227 g/meal for all studies. Based on this comparison, the highest intakes are for West *et al.* (1993), while West *et al*. (1989) and Fiore *et al.* (1989) have almost identical intakes.

Ingestion Rate and Exposure Frequency for High-intake Fish Consumers. High-intake fish consumers are individuals who consume greater quantities of fish than typical recreational anglers. Three such populations are considered here:

- Low-income minorities,
- Native Americans, and
- Hmong or Hmong/Laotians.

The number of low-income minority anglers is not known, but the 1993 West *et al.* study identified about 2.8 percent of the angling population surveyed as low-income minority. The low-income minority population was about 37 percent of the total number of minority anglers in the 1993 West *et al.* study. If the general angling population is 136,000 individuals based on the number of fishing licenses issued (WDNR, 1999d) then the number of low-income minority anglers is about 3,800 individuals. The two Native American tribes residing closest to the Lower Fox River and Green Bay are the Oneida and Menominee. The number of anglers in these tribes is not known at this time, although the Oneida currently have about 6,800 people living on the reservation in Brown or Outagamie counties or the Milwaukee area, and about 1,750 people living elsewhere in Wisconsin. Hutchison and Kraft (1994) indicate that the population of Hmong in Green Bay-Brown County was 2,000 individuals in the 1990 census. Hutchison and Kraft (1994) report that about 58 percent of these households have at least one family member who fishes. If there are similar numbers of people in angling and non-angling households, then approximately 1,200 Hmong live in households where at least one person fishes.

Table 5-11 summarizes intake assumptions for the populations of high-intake fish consumers. As with the recreational angler, values for the amount of fish consumed per meal (*IR*) and the number of meals per year (*EF*) varied depending on the study used as the basis. West *et al.* (1993) provides consumption data for low-income, minority anglers. The intake rates developed in this study are daily intakes averaged over a year. Based on the results of the study, *IR* is 110 g/day for the RME scenario and 43 g/day for the CTE scenario, and *EF* is 365 days/yr. The RME intake rate of 110 g/day for the high-intake fish consumer is only slightly greater than the RME intake rate of 78 g/day for the recreational angler.

There are no sport fish consumption data currently available for the two tribes closest to the Lower Fox River and Green Bay. Peterson *et al*. (1994) evaluated the fish consumption patterns of the Chippewa tribe in northern Wisconsin. Their data indicate that these individuals consume about 50 percent more fish (sport fish and commercial fish) than the general Wisconsin anglers surveyed by Fiore *et al*. (1989). The *Exposure Factors Handbook* (EPA, 1997b) states that "several studies show that intake rates of recreationally caught fish among Native Americans with state fish licenses (West *et al.*, 1989; Ebert *et al.*, 1993) are somewhat higher (50 to 100 percent) than intake rates among other anglers." While Peterson *et al*. (1994) did not specifically identify intake rates for sport-caught fish, their result of 50 percent higher consumption of fish overall was applied to the Fiore *et al.* (1989) data. Thus, *IR* was assigned the value of 227 g/day based on the follow-up to the Fiore *et al*. (1989) study, and *EF* was assigned a value of 89 days per year for the RME scenario and 27 days/yr for the CTE scenario.

The Menominee tribe reviewed these assumptions and indicated that the Menominee angling patterns are similar to the Chippewa. They indicated that the Menominee have a high period of fishing in the winter (ice fishing) in addition to a high period of fishing in the spring. Thus, the estimates provided in Table 5-11 could underestimate fish consumption rates for the Menominee.

There are two studies of sport fish consumption patterns for Hmong or Hmong and Laotians living in Green Bay. The first study (Hutchison and Kraft, 1994) surveyed overall sport fish consumption patterns for Hmong. The second study (Hutchison, 1999) examined consumption of fish from the Lower Fox River between the De Pere dam and the mouth of the river at Green Bay for Hmong and Laotians. Hutchison (1994) also performed another study of angling habits which focused on Hmong living in Sheboygan, Wisconsin. The first study (Hutchison and Kraft, 1994), which examined the consumption of all sport fish, generated an average frequency of 34 meals/yr and a 95th percentile of 130 meals/yr (based on 2.5 meals per week; see Table 5-12). The second study (Hutchison, 1999), which examined consumption of fish caught from the Lower Fox River from De Pere to the river mouth in Green Bay, generated an average of 12 meals/yr and a 95th percentile of 52 meals/yr (see Table 5-13). In the first study (Hutchison and Kraft, 1994), it was noted that the Lower Fox River was the preferred fishing location for only 17 percent of anglers surveyed, so the first study probably overestimates fish consumption from the Lower Fox River and Green Bay within the Hmong angling population. In the second study (Hutchison, 1999), it was noted that anglers who fish in the Lower Fox River from De Pere to the river mouth may also fish in Little Lake Butte des Morts, which is also part of the Lower Fox River, so the second study may underestimate fish consumption from the Lower Fox River and Green Bay. The study by Hutchison (1999) also asked respondents if they were aware of the fish advisories on the Lower Fox River and whether these advisories had caused them to alter their angling behavior. Many respondents indicated that they were aware of the advisories and that they ate less fish from the Lower Fox River as a result. Thus, the estimates developed by Hutchison (1999) underestimate the amount of fish that might be consumed if there were no fish advisories.

The results of both studies are presented in Table 5-11. For the first study (Hutchison and Kraft, 1994), *EF* is set to 130 days/yr for the RME scenario and 34 days/yr for the CTE scenario. For the second study (Hutchison, 1999), *EF* is set to 52 days/yr for the RME scenario and 12 days/yr for the CTE scenario. The size of the meal was not quantified in either study, but Hutchison (1994) did estimate meal size in his study of Hmong fish habits in Sheboygan, Wisconsin. Table 5-14 summarizes the results of showing anglers 0.33- and 0.5-pound servings of raw fillets and asking the anglers how much fish they ate at each meal. The most frequent response was "other," but for the respondents who identified 0.33, 0.5, or 1 pound as the meal size, the average is 0.52 pounds, or about 8 ounces (227 grams). Thus, the amount of fish consumed per meal (*IR*) was set to 227 g/day.

To allow intake assumptions to be compared directly, values of *IR* and *EF* are provided in Table 5-11 for each study using common bases, as discussed previously for recreational anglers. Annualized values of *IR* ("Annualized IR") and values of *EF* based on a normalized quantity of fish consumed per meal ("Normalized Meals per Year") are provided in Table 5-11. Based on this comparison, the highest intake is for the low-income minority angler, followed by the Hmong angler based on Hutchison and Kraft (1994), then the Native American angler and, finally, the Hmong/Laotian angler based on Hutchison (1999).

Reduction Factors. This section discusses the reduction factors (*RF*) used for fish. The reduction factor for fish (RF_{fish}) depends on how the fish is sampled and analyzed to generate a fish concentration (*Cfish*) and the meal size used in the evaluation. In this analysis, *Cfish* is the concentration of COPCs in raw fish, generally skin-on fillet. Trimming will reduce the mass of fish consumed and will reduce the concentration if fatty parts with higher concentrations are trimmed (Anderson *et al.,* 1993; Zabik *et al.,* 1993; Stachiw *et al.,* 1988; Zabik *et al.,* 1982). Cooking will also reduce the mass of fish, principally through water loss, but also through volatilization of COPCs (Anderson *et al.,* 1993; Zabik *et al.,* 1993; Stachiw *et al.,* 1988; Zabik *et al.,* 1982). In many cases, the overall tissue concentrations after trimming and cooking are similar to the concentrations in the raw, uncooked fish, but the mass of fish has been reduced, so the total mass of COPCs in the cooked fish is less than in the uncooked fish. In other cases, the tissue concentrations of COPCs after trimming and cooking are less than the concentrations in the raw, uncooked fish. In these cases the total mass of COPCs in the fish portion has been reduced by concentration reduction as well as reduction in the mass of fish (Anderson *et al.*, 1993).

The meal size estimated by West *et al.* (1989, 1993), Fiore *et al.* (1989) and Hutchison (1994) are all about 227 grams (or 8 ounces) on average. The meal size for West *et al.* (1989, 1993) is for cooked fish, whereas the meal size for Fiore *et al.* (1989) and Hutchison (1994) are for uncooked portions. Given the qualitative nature of estimating meal size by respondents to the various surveys, reduction factors have been determined for an uncooked portion. This approach is consistent with the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.*, 1993).

In the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory*, Anderson *et al.* (1993) review the effects of trimming fat, skin removal, and cooking on the reduction of chemical concentrations in fish. For PCBs, DDT, mirex, and DDE, they report reductions from trimming ranging from 43 to 90 percent and recommend a value of 20 percent for reduction due to trimming. For PCBs, DDT, DDE, dieldrin, and mirex, they report reductions of 0 to 80 percent due to cooking, with most values between 20 and 70 percent. They recommend using 30 percent as the reduction factor for cooking. Since skin accumulates lipophilic chemicals and most of the fillet data available for the Lower Fox River and Green Bay are from samples with the skin on, a reduction factor of 50 percent (20 percent for trimming and 30 percent for cooking) was used in this analysis for organic chemicals. In addition, West *et al.* (1993) reported that 43.9 percent of anglers did not trim the fat, and 36.5 percent did not remove the skin. Since mercury is not lipophilic, no reduction by trimming and cooking has been applied. Similarly, no reduction has been applied for arsenic or lead.

Exposure Duration. This section discusses the basis for the values used for the exposure duration (*ED*) for anglers and hunters. Appendix B1 presents a calculation of the time the potentially exposed population of anglers is expected to catch fish in the Lower Fox River and Green Bay. The fundamental assumption used in this analysis presented in Appendix B1 is that the number of years the angler or hunter fishes or hunts is equal to the number of years the angler or hunter lives in the Lower Fox River and Green Bay region. The calculation presented in Appendix B1 recognizes that different anglers and hunters will spend different times in the area and, therefore, generate a probability distribution for *ED*. This probability distribution depends on the age of a receptor (person) when that individual moves into the region, and the percent of times a move is within the region (as opposed to moving out of the region). Depending on the assumptions made for these two parameters, the mean of the probability distribution of *ED* ranges between 18 years and 33 years. The 95 percent value ranges between 25 and 75 years.

ED values of 30 years for the CTE scenario and 50 years for the RME scenario were established based on professional judgment prior to developing the probabilistic analysis described in Appendix B1. These CTE and RME values are, however, consistent with the probability distributions, so these values are retained as the CTE and RME values for this analysis.

Recreational Anglers

Recreational anglers are individuals who fish in the Lower Fox River and Green Bay for recreational purposes. The Lower Fox River and Green Bay support a variety of sport and non-sport fish as discussed previously. Recreational anglers are exposed to chemicals in the river and bay through the ingestion of fish. These individuals are also exposed to chemicals in the river and bay through incidental ingestion of water during fishing, dermal contact with water during fishing, and inhalation of chemicals volatilized into the air from surface water. The exposures via water ingestion and dermal contact are likely to be sporadic, since recreational anglers are not intentionally entering the water.

For the recreational angler, intake assumptions are provided for an RME scenario and a CTE scenario. The intake assumptions for the RME scenario are provided in Table 5-15, and the intake assumptions for the CTE scenario are provided in Table 5-16. The intake assumptions for the RME scenario are discussed first. After all the intake assumptions for the RME scenario are presented, the intake assumptions for the CTE scenario that differ from those in the RME scenario are discussed.

The body weight (*BW*) for the recreational angler was set to 71.8 kg, for the average adult female and male body weight (EPA, 1997b). The exposure frequency (*EF*) is pathway-specific.

The exposure duration (*ED*) is discussed in the previous subsection.

The averaging time (*AT*) for evaluating carcinogenic effects is 365 days/yr over a 75-year lifetime, or 27,375 days (EPA, 1997b). The *AT* for evaluating non-carcinogenic effects is the exposure duration (50 years) multiplied by 365 days/yr (EPA, 1989c), or 18,250 days.

For the fish ingestion pathway, the ingestion rate (*IR*) was based on the West *et al.* (1989, 1993) studies. For the RME scenario, the average of the West *et al.* (1989, 1993) values in Table 5-10, 59 g/day, was used for *IR* and *EF* was set to

365 days/yr. The reduction factor (*RF*) to account for chemical loss due to trimming and cooking is a chemical-specific value and is discussed in Section 5.5. The absorption factors (*ABS*) for ingestion of fish are assumed to be 100 percent for all chemicals.

For the incidental surface water ingestion pathway, the RME value for *EF* is 95 days/yr, which assumes the number of fishing events equals the number of fish meals per year for this receptor. The daily incidental ingestion rate (*IR*) for surface water was 20 milliliters per day (ml/day), which is based on the approximate amount for one mouthful of water. It was conservatively assumed that incidental ingestion of water would occur once every 10 fishing trips, so the fraction ingested (*FI*) was assumed to be 10 percent. The absorption factors (*ABS*) for incidental ingestion of surface water are also assumed to be 100 percent for all chemicals.

For the dermal contact with surface water pathway, the RME value for *EF* is 95 days/yr, the same as for incidental ingestion of water. The exposure time (*ET*) for contact with surface water is assumed to be 15 minutes throughout the day, or 0.25 hr/day. The total body surface area (*TBS*) used for the RME exposure scenario was 21,850 cm^2 (the average of the upper-bound values for adult men and women; EPA, 1997b). It was assumed that hands and forearms were the exposed body parts that would come in contact with water. This corresponds to a fraction of the body exposed (*FBE*) as 5.15 percent (the average for men and women; EPA, 1997a), and an exposed skin area (*SA*) of 1,125 cm^2. The dermal permeability constants (*PC*) are chemical-specific and were assumed to be equal to the *Kp* values presented in Table 5-6.

For the volatile inhalation pathway, it was assumed the recreational angler could potentially inhale constituents each day they fish, so the value for *EF* is 95 days/yr. Exposure time (*ET*) was set at 6 hrs/day, based on professional judgment. The inhalation rate (*IR*) for an angler was assumed to be 1.0 m^3/hr, which is the EPA's recommended value for adults involved in light activity (EPA, 1997b). The absorption factor (*ABS*) for inhalation was conservatively assumed to be 100 percent for all chemicals.

Table 5-16 provides a list of specific intake assumptions for the recreational angler to evaluate a CTE scenario. Many of the exposure assumptions are similar to the RME scenario; however, the following values are different. The exposure duration (*ED*) was set to 30 years, the assumed average time an individual lives in the Lower Fox River and Green Bay area. As a result, the non-carcinogenic averaging time (*AT*) is equal to 10,950 days. For the fish ingestion pathway, the ingestion rate (*IR*) for the CTE scenario is 15 g/day, which is the average of the CTE values for West *et al.* (1989, 1993) in Table 5-10. Using the assumption that the number of fishing events equals the number of fish meals, the *EF* for each surface water pathway was changed to 24 days/yr. The total body surface area was set to 18,150 cm^2, which represents the average of the mean values for adult men and women (EPA, 1997b). Subsequently, the surface area exposed to water (5.15 percent of the total) is equal to 935 cm^2.

High-intake Fish Consumers

High-intake fish consumers are individuals who would not be able to meet their daily nutritional requirements if they could not supplement their diet with sport-caught fish. Thus, the frequency with which a high-intake fish consumer will consume potentially contaminated fish is significantly higher for the high-intake fish consumer, as opposed to the recreational angler. The exposure pathways for the high-intake fish consumer are the same as those for the recreational angler.

For the high-intake fish consumer, intake assumptions are provided for an RME scenario and a CTE scenario. The intake assumptions for the RME scenario are provided in Table 5-17, and the intake assumptions for the CTE scenario are provided in Table 5-18. The intake assumptions for the RME scenario are discussed first. After all the intake assumptions for the RME scenario are presented, the intake assumptions for the CTE scenario that differ from those in the RME scenario are discussed.

The body weight (*BW*) for the high-intake fish consumer was set to 71.8 kg (EPA, 1997b). The exposure frequency (*EF*) is pathway-specific. For the RME exposure scenario, the exposure duration (*ED*) was set to 50 years, the same as for the recreational angler.

For the fish ingestion pathway, the ingestion rate (*IR*) and exposure frequency were determined from the data for Hutchison and Kraft (1994) in Table 5-11. The value of *IR* is 227 g/day and *EF* is 130 days per year. The reduction factor (*RF*) to account for chemical loss due to trimming and cooking is a chemical-specific value and is discussed in Section 5.5. The absorption factors (*ABS*) for ingestion of fish are assumed to be 100 percent for all chemicals.

For the incidental surface water ingestion pathway, the value for *EF* is 130 days/yr, based on the assumption that the number of fishing events is equal to the number of fish meals per year for this receptor. The daily incidental ingestion rate (*IR*) for surface water was 20 ml/day, which is based on the approximate amount for one mouthful of water. It was assumed that incidental ingestion of water would occur once every 10 fishing trips, so the fraction ingested (*FI*) was conservatively assumed to be 100 percent. The absorption factors (*ABS*) for incidental ingestion of surface water are also assumed to be 100 percent for all chemicals.

For the dermal contact with surface water pathway, the *EF* is 130 days/yr, the same as for incidental ingestion of water. The exposure time (*ET*) for contact with surface water is assumed to be 30 minutes throughout the day, or 0.5 hr/day. The total body surface area (*TBS*) used for the RME exposure scenario was 21,850 cm^2 (the average of the upper-bound values for adult men and women; EPA, 1997a). It was assumed that hands were the exposed body parts that would come in contact with water. This corresponds to a fraction of the body exposed (*FBE*) as 5.15 percent (the average for men and women; EPA, 1997b), and an exposed skin area (*SA*) of 1,125 cm^2. The dermal permeability constants (*PC*) are chemical-specific and were assumed to be equal to the *Kp* values presented in Table 5-6.

For the volatile inhalation pathway, it was assumed the high-intake fish consumer could potentially inhale constituents each day they fish, so the value for *EF* is 130 days/yr. Exposure time (*ET*) was set at 4 hrs/day, based on professional judgment. The inhalation rate (*IR*) for an angler was assumed to be 1.0 m^3/hr, which is the EPA's recommended value for adults involved in light activity (EPA, 1997b). The absorption factor (*ABS*) for inhalation was conservatively assumed to be 100 percent for all chemicals.

Table 5-18 provides a list of specific intake assumptions for the high-intake fish consumer to evaluate the CTE scenario. Many of the exposure assumptions are similar to the RME scenario; however, the following values are different. The exposure duration (*ED*) was set to 30 years, the same value used for the recreational angler for the CTE scenario. As a result, the non-carcinogenic averaging time (*AT*) is equal to 10,950 days. For the fish ingestion pathway, the exposure frequency (*EF*) is 34 days/yr based on data from Hutchison and Kraft (1994) presented in Table 5-11. Using the assumption that the number of fishing events equals the number of fish meals, the *EF* for each surface water pathway was changed to 34 days/yr. The total body surface area was set to 18,150 cm^2, which represents the average of the mean values for adult men and women (EPA, 1997b). Subsequently, the exposed surface area (5.15 percent of the total) is equal to 935 cm^2.

Hunters

Hunters are individuals who hunt waterfowl in the Lower Fox River and Green Bay. These individuals may be exposed to chemicals through ingestion of waterfowl. Like anglers, these individuals may also be exposed to constituents in the river and bay through inhalation of chemicals volatilized into the air from the surface water, incidental ingestion of water contacted during hunting, and dermal contact with water contacted during hunting. The exposures via water ingestion and dermal contact are likely to be low for this receptor, since hunters may not contact the water at all.

For the hunter, intake assumptions are provided for an RME scenario and a CTE scenario. The intake assumptions for the RME scenario are provided in Table 5-19, and the intake assumptions for the CTE scenario are provided in Table 5-20. The intake assumptions for the RME scenario are discussed first. After all the intake assumptions for the RME scenario are presented, the intake assumptions for the CTE scenario which differ from those in the RME scenario are discussed.

The body weight (*BW*) for the hunter was set to 71.8 kg (EPA, 1997b). The exposure frequency (*EF*) is pathway-specific. The exposure duration (*ED*) is 50 years, based on the same assumptions of population mobility that were used for the recreational angler. The averaging time (*AT*) for evaluating carcinogenic effects is 365 days/yr over a 75-year lifetime, while the *AT* for evaluating non-carcinogenic effects is the exposure duration multiplied by 365 days/yr (EPA, 1989c), or 18,250 days.

For the waterfowl ingestion pathway, the value for *EF* is the number of meals per year and was set at 12 meals per year for the RME scenario, based on information presented by Amundson (1984). In this study, Illinois goose hunters were surveyed to establish eating habits and consumption rates. The group of hunters was selected on the basis of having claimed to shoot an average of five or more geese per year. The survey included questions regarding the consumption frequency of the hunters and their family members. The results of the survey indicated an average consumption of approximately three geese per year, with a maximum of about six geese per year. Because the Amundson (1984) study only considered Canada geese, and not other commonly eaten waterfowl such as duck, these values have been doubled for the RME and CTE scenarios in this assessment (i.e., values of 12 meals/yr and 6 meals/yr are incorporated). The representative meal size (*IR*) was set to 110 g/meal (reasonable maximum from Pao *et al*., 1982). This is likely to be the meal size after cooking.

The reduction factor (*RF*) to account for chemical loss due to cooking is set equal to 100 percent based on information presented by Amundson (1984). One goal of this study was to determine the influence of cooking on raw residue levels in edible portions of Canada geese. Amundson sampled raw breast skin and raw breast meat for dieldrin, heptachlor, DDE, and Aroclor 1254. The birds were then baked for 3 hours, and the tissues were sampled again. Although concentrations of all chemicals showed reduction in skin samples after cooking, results were inconclusive for the breast meat samples. Both DDE and Aroclor 1254 showed a slight increase in concentration after cooking. Because of the inconclusive results, the reduction factor was conservatively set to 100 percent (i.e., no reduction) for all constituents. The absorption factors (*ABS*) for ingestion of waterfowl are assumed to be 100 percent for all chemicals.

For the incidental surface water ingestion pathway, the *EF* for a hunter is 12 days/yr, which assumes the number of days when hunting occurs equals the number of waterfowl meals per year for this receptor. The daily incidental ingestion rate (*IR*) for surface water was 20 ml/day, which is based on the approximate amount for one mouthful of water. Exposure is assumed to occur 10 percent of the time the hunter visits the site, so the fraction ingested (*FI*) was assumed to be 10 percent. The absorption factors (*ABS*) for incidental ingestion of surface water are assumed to be 100 percent for all chemicals.

For the dermal contact with surface water pathway, the *EF* is 12 days/yr, the same as for incidental ingestion of water. The exposure time (*ET*) for contact with surface water is assumed to be 15 minutes throughout the day, or 0.25 hr/day. The total body surface area (*TBS*) used for the RME scenario was 21,850 cm^2 (the average of the upper-bound values for adult men and women; EPA, 1997b). It was assumed that only the hands of a hunter would be exposed to surface water. This corresponds to a fraction of the body exposed (*FBE*) as 5.15 percent (the average for men and women; EPA, 1997b), and an exposed skin area (*SA*) of 1,125 cm^2. The fraction of the surface water contacted at the site (*FC*) was assumed to be 100 percent, which is conservative and health protective. The dermal permeability constants (*PC*) are chemical-specific and were assumed to be equal to the *Kp* values presented in Table 5-6.

For the volatile inhalation pathway, it was assumed the hunter could potentially inhale constituents each day they hunted, so the value for *EF* is 12 days/yr. Exposure time (*ET*) was set at 8 hrs/day, based on professional judgment. The inhalation rate (*IR*) for a hunter was assumed to be 1.0 m^3/hr, which is the EPA's recommended value for adults involved in light activity (EPA, 1997b). The absorption factor (*ABS*) for inhalation was conservatively assumed to be 100 percent for all chemicals.

Table 5-20 provides a list of specific intake assumptions for the hunter to evaluate the CTE scenario. Many of the exposure assumptions are similar to the RME scenario; however, the following values are different. The exposure duration (*ED*) was set to 30 years, the assumed average time an individual lives in the Lower Fox River and Green Bay area. As a result, the non-carcinogenic averaging time (*AT*) is equal to 10,950 days. For the waterfowl ingestion pathway, the exposure frequency (*EF*) was equal to 6 meals/yr (Amundson, 1984). Using the assumption that the number of hunting events equals the number of waterfowl meals, the *EF* values for surface water pathways were changed to 6 days/yr. The total body surface area was set to 18,150 cm^2, which represents the average of the mean values for adult men and women (EPA, 1997b). Subsequently, the surface area exposed to water (5.15 percent of the total) is equal to 935 cm^2.

Drinking Water Users

Drinking water users are individuals that use water from the Lower Fox River or Green Bay as either a primary or secondary source of drinking water. Potential exposures associated with direct use of water include ingestion; dermal contact during bathing, cooking, and other household uses of water; and inhalation of chemicals volatilized into the air during showering and other uses.

Table 5-21 provides a list of the specific intake assumptions used for the drinking water users. Specific assumptions have been made only for the RME scenario. In addition, the assumptions for this receptor have been divided into two age groups, a young child 1 to 6 years of age and an older child and adult who is 7 years or older.

The averaging time (*AT*) for evaluating carcinogenic effects is 365 days/yr over a 75-year lifetime. To be consistent with EPA conventions for evaluating drinking water exposure, the duration of time spent in a residence is used to specify the total exposure period. For the RME scenario, the upper-bound value of 30 years in a residence (EPA, 1997b) has been used, with the first 6 years as a young child and the remaining 24 years as an older child and adult. The *AT* for evaluating non-carcinogenic effects is 365 days/yr over 30 years.

The exposure frequency (*EF*) is 350 days/yr, the value presented in EPA (1991a) for a resident. The exposure duration (*ED*) and body weight (*BW*) are specific to the age group. For the time period as a young child, the exposure duration (*ED*) is 6 years; the *ED* for the older child and adult is 24 years. The body weight for a child is 16.6 kg (based on the average values for boys and girls age 1 to 6; EPA, 1997b) and for an adult is 71.8 kg (EPA, 1997b).

For the water ingestion pathway, the daily ingestion rate (*IR*) was 1.5 L/day for the young child and 2.3 L/day for the older child and adult. These are the upper-percentile values presented in EPA (1997b) for a child age 3 to 5 and an adult, respectively. The absorption factors (*ABS*) for ingestion of water are assumed to be 100 percent for all chemicals.

For the dermal contact with water pathway, the fraction of the body assumed to be exposed (*FBE*) was conservatively assumed to be 100 percent, since contact with water would occur during bathing or showering. For young children of ages 1 through 6 years, the total body surface area (*TBS*) was set to the average of values for male and female children between 5 and 6 years of age in EPA (1997b), which provides values of *TBS* for different percentiles. Values of *TBS* between the 50^{th} and 75^{th} percentiles for male and female children were averaged to yield a value of 8,105 cm^2 for young children. The *TBS* for an older child or adult (ages 7 through 31) was the average of the upper-bound values for adult men and women presented in EPA (1997b) of 21,850 cm^2. Specifying *FBE* as 100 percent results in exposed surface areas (*SA*) of 8,105 cm^2 and 21,850 cm^2 for the young child and older child/adult, respectively.

Exposure time (*ET*) for the young child is 20 minutes, or 0.33 hr/day, the average time spent in the bath (EPA, 1997b). For the older child and adult, *ET* is estimated to be 15 minutes, or 0.25 hr/day. This is the average time spent bathing (20 minutes) or showering (10 minutes) each day (EPA, 1997b). Presumably, all the household water is from the site, so the fraction contacted (*FC*) equals 100 percent. The dermal permeability constants (*PC*) are chemical-specific were assumed to be equal to the *Kp* values presented in Table 5-6.

For the volatile inhalation pathway, an inhalation rate (*IR*) of 1.0 m^3/hr was used to evaluate exposure for both the young child and older child/adult. These values are based on the inhalation rates for an adult or child engaged in light activities (EPA, 1997b). The exposure times (*ET*) used were the same as those for the dermal contact pathway, 0.33 hr/day and 0.25 hr/day for the young child and older child/adult, respectively. The absorption factor (*ABS*) for inhalation was conservatively assumed to be 100 percent for all chemicals.

Local Residents

Local residents are individuals who live next to the Lower Fox River or Green Bay. There are homes located along the water throughout the length of the Lower Fox River, except in downtown Green Bay. Potential exposures associated with living next to the river include inhalation of chemicals volatilized into the air from the surface water.

Table 5-22 provides a list of the specific intake assumptions used for the local residents to evaluate the RME scenario. Separate assumptions have not been made for RME and CTE scenarios, as the pathway is restricted to volatile inhalation only. As with the drinking water user, intake assumptions have been developed for two age groups, the younger child aged 1 to 6 years and the older child aged 7 years or older.

The averaging time (*AT*) for evaluating carcinogenic effects is 365 days/yr over a 75-year lifetime. The duration of time spent in a residence is used to specify the total exposure period. Since this individual is assumed to live next to the river or Green Bay, if they move it is unlikely to be to another house as close to the river or Green Bay. Thus, the time spent at one residence was used to specify the exposure period, so the averaging time (*AT*) for evaluating non-carcinogenic effects is 365 days/yr over 30 years.

The exposure frequency (*EF*) is 350 days/yr, the value presented in EPA (1991a) for a resident. The exposure duration (*ED*) and body weight (*BW*) are receptor-specific. For the time period as a young child, the exposure duration (*ED*) is 6 years; the *ED* for the older child and adult is 24 years (EPA, 1991a). The body weight for a child is 16.6 kg (based on the average values for boys and girls age 1 to 6; EPA, 1997b) and for an adult is 71.8 kg (EPA, 1997b).

For the volatile inhalation pathway, an inhalation rate (*IR*) of 0.42 m^3/hr over a 24-hour day (*ET*) was used to evaluate exposure for the young child. An *IR* of 0.55 m^3/hr over a 24-hour day was used for the older child/adult. These values are based on the daily rates of 10 cubic meters per day (m^3/day) and 13.3 m^3/day presented in EPA (1997b). The absorption factor (*ABS*) for inhalation was conservatively assumed to be 100 percent for all chemicals.

Recreational Water Users

The recreational water user has been divided into two receptors for this analysis, an adult who swims in the river or bay and an older child who wades along the shore of the river or bay. Potential exposures associated with swimming and wading include inhalation of chemicals volatilized into the air from the surface water, incidental ingestion of water, dermal contact with water, incidental ingestion of sediment, and dermal contact with sediment or sediment pore water.

Table 5-23 provides a list of the specific intake assumptions used for the swimmer, who is assumed to be an adult. The body weight (*BW*) was set to 71.8 kg (EPA, 1997b). The exposure frequency of 18 days/yr was based on a conservative estimate of swimming once per week for the warmest 4 months of the year. The exposure duration (*ED*) was set at 30 years, which is the default exposure duration for a resident (EPA, 1991a). This value of *ED* is the same as that used for the CTE anglers and hunter based on population mobility data. The averaging time (*AT*) for evaluating carcinogenic effects is 365 days/yr over a 75-year lifetime, while the *AT* for evaluating non-carcinogenic effects is *ED* multiplied by 365 days/yr, or 10,950 days.

For the incidental surface water ingestion pathway, the incidental ingestion rate (*IR*) was 20 ml/day, which is based on the approximate amount for one mouthful of water. All of this exposure is assumed to occur at the site, so the fraction ingested (*FI*) was conservatively assumed to be 100 percent. The absorption factors (*ABS*) for incidental ingestion of surface water are also assumed to be 100 percent for all chemicals.

For the dermal contact with surface water pathway, the exposure time (*ET*) for swimming was set to 1 hr/day, the average time for swimming per event (EPA, 1997b). The total body surface area (*TBS*) was 21,850 cm^2 (the average of the upper-bound values for adult men and women; EPA, 1997b). The fraction of the body exposed (*FBE*) was assumed to be 100 percent, since this receptor would be completely submerged while swimming. Specifying *FBE* as 100 percent results in an exposed surface area (*SA*) of 21,850 cm^2. The dermal permeability constants (*PC*) are chemical-specific and were assumed to be equal to the *Kp* values presented in Table 5-6.

For the volatile inhalation pathway, the exposure time (*ET*) is assumed to be 1 hr/day, the same as the time spent swimming. The inhalation rate (*IR*) for a swimmer was assumed to be 3.2 m^3/hr, which is the EPA's recommended value for an adult engaged in heavy activity (EPA, 1997b). The absorption factor (*ABS*) for inhalation was conservatively assumed to be 100 percent for all chemicals.

The daily incidental ingestion rate (*IR*) for sediment was 5 milligrams per day (mg/day), which is one-tenth the daily soil ingestion rate presented for an adult in EPA (1997b). It is highly unlikely that significant sediment ingestion would occur, and in the absence of guidance on this pathway, the above rate was based on professional judgment. All of this exposure is assumed to occur at the site during the event; thus, the fraction ingested (*FI*) was conservatively assumed to be 100 percent. The absorption factors (*ABS*) are chemical-specific and are presented in Table 5-8.

For the dermal contact with sediment pathway, it was assumed that the feet were the only exposed body parts that would come in contact with sediment. This corresponds to a fraction of the body exposed (*FBE*) as 6.75 percent (the average value for men and women; EPA, 1997b), and an exposed skin area (*SA*) of 1,475 cm^2. The sediment adherence factor (*AF*) of 1.0 mg/cm^2 was based on the upper value for soil contact from EPA's Dermal Guidance (1992a). The dermal absorption factors (*ABS*) are chemical-specific and are presented in Table 5-9. It should be noted that the absorption factors for direct contact with sediment are based on contact with soil and are typically based on longer term absorption studies (such as 24 hours or longer [EPA, 1992a]). The swimmer probably spends little time standing in the sediment, since their primary activity is swimming, not wading. If it is conservatively estimated that the swimmer spends 15 minutes standing in sediments (one-fourth of the total time spent in the water), then this is considerably shorter than the duration of a typical dermal absorption experiment. For example, EPA (1992a) estimated 0.6 to 6 percent absorption of PCBs from soil after 24 hours of contact. Since 15 minutes (or 0.25 hour) is about 1 percent of 24 hours, actual absorption is expected to be less than that observed in the experimental studies. To account for this, the parameter *FC* (fraction of daily contact occurring at the site) was set to 5 percent, which is five times greater than 0.25 hour per 24 hours or 1 percent.

As an alternative to evaluating sediments with the above methodology, the analysis for the swimmer includes the option to evaluate dermal contact with sediment pore water instead of contact with actual sediments. The exposure factors for the dermal contact with sediment pore water are similar to those used for the dermal contact with surface water pathway. The exposure time (*ET*) was equal to 15 minutes, or 0.25 hr/day. As with sediment contact, it was assumed that the feet were the only body parts that could be exposed to sediment pore water. Therefore, the *FBE* of 6.75 percent and *SA* of 1,475 cm^2 identified above were incorporated into this intake calculation. The *PC* values were presented in Table 5-6.

Table 5-24 provides a list of the specific intake assumptions used for the wader, who is assumed to be an older child between the ages of 9 and 18. The body weight (*BW*) was set to 51 kg, which is the average of the mean body weights of boys and girls from age 9 to age 18 (EPA, 1997b). The exposure frequency of 18 days/yr was based on a conservative estimate of wading once per week for the warmest 4 months of the year. The exposure duration (*ED*) was set at 10 years, based on the age range of the older child. The averaging time (*AT*) for evaluating carcinogenic effects is 365 days/yr over a 75-year lifetime, while the *AT* for evaluating non-carcinogenic effects is *ED* multiplied by 365 days/yr, or 3,650 days.

For the incidental surface water ingestion pathway, the incidental ingestion rate (*IR*) was 20 ml/day, which is based on the approximate amount for one mouthful of water. Since ingestion of surface water is unlikely while wading, exposure is assumed to occur during only 10 percent of the visits to the site; therefore, the fraction of exposure time ingestion occurs (*FI*) was assumed to be 10 percent. The absorption factors (*ABS*) for incidental ingestion of surface water are assumed to be 100 percent for all chemicals.

For the dermal contact with surface water pathway, the exposure time (*ET*) for wading was set to 0.5 hour per day, based on professional judgment. The total body surface area (*TBS*) was 14,400 cm^2 (the average of the 50^{th} percentile values for girls and boys between ages 9 and 18; EPA, 1997b). The fraction of the body exposed (*FBE*) was 22.9 percent, which corresponds to the feet and lower legs of older children. Specifying *FBE* as 22.9 percent results in an exposed surface area (*SA*) of 3,298 cm^2. The dermal permeability constants (*PC*) are chemical-specific and were assumed to be equal to the *Kp* values presented in Table 5-6.

For the volatile inhalation pathway, the exposure time (*ET*) is assumed to be 0.5 hr/day, the same as the time spent wading. The inhalation rate (*IR*) for an older child while wading was assumed to be 1.2 m^3/hr, which is the EPA's recommended value for children engaged in moderate activity (EPA, 1997b). The absorption factor (*ABS*) for inhalation was conservatively assumed to be 100 percent for all chemicals.

The daily incidental ingestion rate (*IR*) for sediment was 5 mg/day, which is one-tenth the daily soil ingestion rate presented for an older child in EPA (1997b). It is highly unlikely that significant sediment ingestion would occur, and in the absence of guidance on this pathway, the above rate was based on professional judgment. All of this exposure is assumed to occur at the site during the event; thus, the fraction ingested (*FI*) was conservatively assumed to be 100 percent. The absorption factors (*ABS*) are chemical-specific and are presented in Table 5-8.

For the dermal contact with sediment pathway, it was assumed that the feet were the only exposed body parts that would come in contact with sediment. This corresponds to a fraction of the body exposed (*FBE*) as 7.37 percent (the average value for boys and girls between the ages of 9 and 18; EPA, 1997b), and an exposed skin area (*SA*) of 1,061 cm^2. The sediment adherence factor (*AF*) of 1.0 mg/cm^2 was based on the upper value for soil contact from EPA's Dermal Guidance (1992a). The dermal absorption factors (*ABS*) are chemical-specific and are presented in Table 5-9. It should be noted that the absorption factors for direct contact with sediment are based on contact with soil and are typically based on longer-term absorption studies (such as 24 hours or longer [EPA, 1992a]). The wader is assumed to spend 30 minutes in contact with sediments, which, as indicated above, is considerably shorter than the duration of a typical dermal absorption experiment. Since 30 minutes (or 0.5 hour) is about 2 percent of 24 hours, actual absorption is expected to be less than that observed in the experimental studies. To account for this, the parameter *FC* (fraction of daily contact occurring at the site) was set to 10 percent, which is five times greater than 0.5 hour per 24 hours or 2 percent.

As an alternative to evaluating sediments with the above methodology, the analysis for the wader includes the option to evaluate dermal contact with sediment pore water instead of contact with actual sediments. The exposure factors for the dermal contact with sediment pore water are similar to those used for the dermal contact with surface water pathway. The exposure time (*ET*) was equal to 30 minutes, or 0.5 hr/day. As with sediment contact, it was assumed that the feet were the only body parts that could be exposed to sediment pore water. Therefore, the *FBE* of 7.37 percent and *SA* of 1,061 cm^2 identified above were incorporated into this intake calculation. The *PC* values were presented in Table 5-6.

Marine Construction Workers

Marine construction workers are individuals engaged in dredging or construction activities within the river or bay. Potential exposures associated with construction activities or navigational dredging include inhalation of chemicals volatilized into the air from the surface water, incidental ingestion of and dermal exposure to water contacted during work activities, and incidental ingestion of and dermal exposure to sediment contacted during work activities.

Table 5-25 provides a list of the specific intake assumptions used for the marine construction workers. Specific assumptions have been made only for the RME scenario. The body weight (*BW*) was set to 71.8 kg (EPA, 1997b). The exposure frequency (*EF*) of 24 days/yr was based on an estimated dredging frequency of 2 days per month. The exposure duration (*ED*) was set at 25 years, the value specified for a worker in EPA (1991a). The averaging time (*AT*) for evaluating carcinogenic effects is 365 days/yr over a 75-year lifetime, while the *AT* for evaluating non-carcinogenic effects is *ED* multiplied by 365 days/yr, or 9,125 days (EPA, 1989c).

For the incidental surface water ingestion pathway, the incidental ingestion rate (*IR*) was 20 ml/day, which is based on the approximate amount for one mouthful of water. All of this exposure is assumed to occur at the site, so the fraction ingested (*FI*) was conservatively assumed to be 100 percent. The absorption factors (*ABS*) for incidental ingestion of surface water are also assumed to be 100 percent for all chemicals.

For the dermal contact with surface water pathway, the exposure time (*ET*) for the worker was set to 30 minutes, or 0.5 hr/day, based on an assumption that exposure might occur for a total of 0.5 hour during the workday. The total body surface area (*TBS*) used for the RME scenario was 21,850 cm^2 (the average of the upper-bound values for adult men and women; EPA, 1997b). It was assumed that hands and forearms were the exposed body parts that would come in contact with water. This corresponds to a fraction of the body exposed (*FBE*) as 11.6 percent (the average for men and women; EPA, 1997b), and an exposed skin area (*SA*) of 2,535 cm^2. The dermal permeability constants (*PC*) are chemical-specific and were assumed to the equal to the *Kp* values presented in Table 5-6.

For the volatile inhalation pathway, the exposure time (*ET*) is the full work day, or 8 hrs/day. The inhalation rate (*IR*) for the RME scenario was assumed to be 1.5 m^3/hr, which is the EPA's recommended value for an outdoor worker engaged in moderate activity (EPA, 1997b). The absorption factor (*ABS*) for inhalation was conservatively assumed to be 100 percent for all chemicals.

The daily incidental ingestion rate (*IR*) for sediment was 25 mg/day, which is one-half the daily soil ingestion rate presented for an adult in EPA (1997b). It is not likely that sediment ingestion would occur, and in the absence of guidance on this pathway, the above rate was selected based on professional judgment. All of this exposure is assumed to occur with site sediments; thus, the fraction ingested (*FI*) was conservatively assumed to be 100 percent. The absorption factors (*ABS*) are chemical-specific and are presented in Table 5-8.

For the dermal contact with sediment pathway, it was assumed that the hands were the only exposed body part that would come in contact with sediment. This corresponds to a fraction of the body exposed (*FBE*) as 5.15 percent (the average for men and women; EPA, 1997b), and an exposed skin area (*SA*) of 1,125 cm^2. The sediment adherence factor (*AF*) of 1.0 mg/cm^2 was based on the upper value for soil contact from EPA's Dermal Guidance (1992a). The fraction of the sediment contacted from the site (*FC*) was assumed to be 100 percent, which is conservative and health protective. The dermal absorption factors (*ABS*) are chemical-specific and are presented in Table 5-9. As previously noted, these absorption factors are based on direct contact with soil over an extended period of time, and are likely to significantly overestimate actual intake for this receptor.

5.5 Exposure Point Concentrations

Exposure point concentrations are representative concentrations of COPCs in media (e.g., sediment, surface water, fish) that a receptor is assumed to contact. Exposure point concentrations are required for the following exposure media:

- Fish,
- Waterfowl,
- Water via ingestion,
- Water via dermal contact,
- Sediment,
- Sediment pore water,

- Indoor air during bath,
- Indoor air during shower, and
- Outdoor air.

These exposure point concentrations are determined either directly from measurements of the applicable exposure medium or through the application of mathematical models that translate measured concentrations in source media to exposure point concentrations in exposure media. In theory, the concentrations in source media can vary with time, so the appropriate concentration for estimating exposure to a particular receptor is an average concentration over the exposure period. Thus, the time-averaged source concentrations and resulting exposure point concentrations can be different for different receptors for the same exposure medium. However, the change in source concentration with time is very difficult to assess. For this analysis, all source concentrations are treated as being constant in time. Therefore, an exposure point concentration can be estimated for each exposure medium and used for multiple receptors. It should be noted that the Lower Fox River and Green Bay mass balance modeling is used to evaluate the effect of time on the concentration of PCBs in sediment and, through bioaccumulation, fish. This evaluation is presented in the alternative-specific risk assessment in the Feasibility Study.

5.5.1 Determination of Exposure Point Concentrations

The exposure point concentrations for each exposure medium were determined as follows. For fish, the measured fish concentration ($Cfish_{meas}$) was used as the source concentration and was multiplied by a reduction factor (RF_{fish}) to yield the exposure point concentration in fish ($Cfish_{EPC}$).

$$Cfish_{EPC} = RF_{fish} \cdot Cfish_{meas}$$

The reduction factors for fish (RF_{fish}) were discussed previously.

For waterfowl, the measured concentration in waterfowl (CWF_{meas}) was multiplied by a reduction factor (RF_{WF}) to yield the exposure point concentration in waterfowl (CWF_{EPC}).

$$CWF_{EPC} = RF_{WF} \cdot CWF_{meas}$$

The reduction factors for waterfowl (RF_{WF}) were discussed previously.

For evaluating ingestion and dermal contact with water, measured concentrations in water were used. For many chemicals, both total and dissolved (filtered) concentrations were measured. For evaluating ingestion of water, the total concentration was used. For evaluating dermal contact with water, the dissolved concentration was used.

For evaluating ingestion exposure to sediment, measured concentrations in sediment were used. For evaluating dermal contact exposures to sediment, exposures were estimated either: 1) by using measured concentrations in sediment and assuming a fraction of the chemical in sediment is absorbed through the skin, or 2) by using measured sediment concentrations (C_{sed}) to estimate sediment pore water concentrations (C_{pw}) and using the sediment pore water concentration to estimate dermal absorption. The equation for estimating the sediment pore water concentration is:

$$C_{pw} = TF_{sdpw} \cdot C_{sed}$$

In this expression, TF_{sdpw} is the sediment to pore water transfer factor.

For evaluating inhalation exposures to air, measured concentrations in water were used with mathematical models of volatilization and air dispersion to estimate air concentrations. For calculating concentrations in indoor air during a bath (C_{ab}), the concentration in the bath water (C_{wb}) was multiplied by a bath water to air transfer factor (TF_{bwa}).

$$C_{ab} = TF_{bwa} \cdot C_{wb}$$

The measured dissolved concentrations were used as the concentrations in the bath water.

For calculating concentrations in indoor air during a shower (C_{as}), the concentration in the shower water (C_{ws}) was multiplied by a shower water to air transfer factor (TF_{sh}).

$$C_{as} = TF_{sh} \cdot C_{ws}$$

The measured dissolved concentrations were used as the concentrations in the shower water.

For calculating concentrations in outdoor air (C_{oa}) as a result of volatilization from surface water, the concentration in the surface water (C_{sw}) was multiplied by a surface water to air transfer factor (TF_{swoa}).

$$C_{oa} = TF_{swoa} \cdot C_{sw}$$

The measured dissolved concentrations were used as the concentrations in the surface water.

The Lower Fox River is approximately 40 miles long. To facilitate the evaluation of this water body, the data were divided into four reaches as discussed previously. The four reaches for the Lower Fox River are:

- Little Lake Butte des Morts,
- Appleton to Little Rapids,
- Little Rapids to De Pere, and
- De Pere to Green Bay.

Green Bay was evaluated as a single entity.

5.5.2 Source Concentrations

For each reach in the Lower Fox River and Green Bay, source concentrations were developed for the following media:

- Fish tissue,
- Waterfowl tissue,
- Water (total),
- Water (dissolved), and
- Sediment.

Fish Tissue

Fish tissue samples were available from a number of locations along the Lower Fox River, as well as Green Bay, Lake Winnebago, and other locations. This assessment included samples from Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, De Pere to Green Bay, and Green Bay as a whole. For this evaluation, the fish concentrations for the De Pere to Green Bay reach reflect fish data from De Pere to Green Bay and Zone 2 of Green Bay because these two areas have very similar habitat and fish swim freely between the two areas. The fish concentrations for Green Bay reflect fish data from zones 3A, 3B, and 4 of Green Bay.

Sample types for fish tissue consist of fillet, fillet and skin, and whole body. Sample data for fillet (skin-off and skin-on) were used to determine representative concentrations.

Data from only certain fish species were included in the evaluation. Because the risk assessment addresses fish ingestion, the species selected include those fish species that a person would reasonably eat, regardless of restrictions proposed in consumption advisories. These fish species were selected based on edible species listed in West *et al.* (1993), Anderson *et al.* (1993), and WDH/WDNR (1998) and are:

Bass (white, largemouth, smallmouth)	Pike (northern)
Bluegill	Pumpkinseed
Bowfin	Redhorse (shorthead, northern)
Bullhead (black, brown)	Rockbass
Burbot	Salmon (Chinook, Coho)
Carp	Sauger
Catfish (channel, flathead)	Smelt (rainbow)
Chub (bloater)	Splake
Cisco (lake herring)	Sucker (white, longnose)
Crappie (black)	Sunfish (green)
Drum (sheepshead)	Trout (lake, brown, brook, rainbow)
Muskellunge (musky)	Walleye
Perch (white, yellow)	Whitefish

All of the species listed above were sampled at some time and placed in the Lower Fox River and Green Bay system. The most commonly sampled species were walleye, carp, trout, and bass. Data for all edible fish species were combined and evaluated by sample type and by location. Statistics were generated for these data subsets, and two representative concentrations were determined:

- An upper-bound (conservative) concentration equal to the 95 percent upper confidence limit on the arithmetic mean (95% UCL) or the maximum detected concentration, whichever is lower (EPA, 1992d); and

- An average concentration equal to the arithmetic mean.

To calculate the average concentration, one-half the sample detection limit was used for results that were non-detect, as recommended by EPA (1989c). Due to variations in detection limits, (e.g., some reported detection limits exceeded maximum detected concentrations), in some cases the calculated average concentration actually exceeded the maximum detected value. In these cases, the 95% UCL was also used as the average concentration. Additional details on the statistical evaluation of the data is provided in Appendix B2.

Waterfowl Tissue

Waterfowl and other bird tissue samples were available from a number of locations in the Lower Fox River and Green Bay vicinity. This assessment included samples from Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, De Pere to Green Bay, and Green Bay as a whole.

Sample types for bird tissue consist of muscle, muscle and skin, whole body, and some egg and organ samples. For this risk assessment, only sample data for muscle tissue (skin-off and skin-on) were used to determine representative concentrations.

Data from only certain bird species were included in the evaluation. Because the risk assessment addresses waterfowl ingestion, the species selected include those which a person would hunt and reasonably eat. Some species, such as the common loon and the pied-billed grebe, are protected and were not included in the data set. Other bird species, such as the swallow and the gull, would not likely be eaten by a person, and were excluded as well. Confirmation of species likely to be eaten was obtained from personal communication with the Pennsylvania Game Commission (September 24, 1998). The following waterfowl and bird species included in this assessment are:

Blue-winged Teal
Bufflehead
Canada Goose
Canvasback
Common Goldeneye
Common Merganser
Gadwall
Greater Scaup
Green-winged Teal
Hooded Merganser
Lesser Scaup
Mallard
Northern Shoveler
Pintail
Red-breasted Merganser
Ring-neck Duck
Ring-neck Pheasant
Ruddy Duck
Scaup
White-winged Scoter
Wood Duck
Woodcock

Data for each of these species were combined and evaluated by location. Statistics were generated for these data subsets, and two representative concentrations were determined:

- An upper-bound (conservative) concentration equal to the lower of the 95% UCL and maximum detected concentration (EPA, 1992d), and

- An average concentration equal to the arithmetic mean.

To calculate the average concentration, one-half the sample detection limit was used for results that were non-detect (EPA, 1989c). Due to variations in detection limits, in some cases the calculated average concentration actually exceeded the maximum detected value. In these cases, the 95% UCL was also used as the average concentration. Additional details on the statistical evaluation of the data are provided in Appendix B2.

Surface Water

Surface water samples were available from a number of locations along the Lower Fox River and in Green Bay. This assessment included samples from Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, De Pere to Green Bay, and Green Bay as a whole.

Surface water data were provided for total, particulate, dissolved, and filtered samples. For the purposes of this risk assessment, dissolved and filtered samples were assumed to be similar and were grouped together. Particulate data were not used. Representative concentrations were developed for total and combined dissolved and filtered data sets in each location. Statistics were generated for these data subsets, and two representative concentrations were determined:

- An upper-bound (conservative) concentration equal to the lower of the 95% UCL and maximum detected concentration (EPA, 1992d), and

- An average concentration equal to the arithmetic mean.

To calculate the average concentration, one-half the sample detection limit was used for results that were non-detect (EPA, 1989c). Due to variations in detection limits, in some cases the calculated average concentration actually exceeded the maximum detected value. In these cases, the 95% UCL was also used as the average concentration. Additional details on the statistical evaluation of the data are provided in Appendix B2.

Sediment

Sediment samples were available from a number of locations along the Lower Fox River and in Green Bay. This assessment included samples from Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, De Pere to Green Bay, and Green Bay as a whole.

Sediment data were provided for surface and subsurface samples. For the purposes of this risk assessment, only surface sediment samples were included as a potential contact medium, although it should be noted that deeper sediments could come to the surface after storm events. Surface sediment is defined as any depth range whose shallow depth is zero (e.g., 0 to 6 inches, 0 to 2 feet). Except for total PCBs, representative concentrations were developed for surface sediments in each location using the data “as is” for each location. Statistics were generated for these data subsets, and two representative concentrations were determined:

- An upper-bound (conservative) concentration equal to the lower of the 95% UCL and maximum detected concentration (EPA, 1992d), and

- An average concentration equal to the arithmetic mean.

To calculate the average concentration, one-half the sample detection limit was used for results that were non-detect (EPA, 1989c). Due to variations in detection limits, in some cases the calculated average concentration actually exceeded the maximum detected value. In these cases, the 95% UCL was also used as the average concentration. Additional details on the statistical evaluation of the data are provided in Appendix B2.

For total PCBs, the representative sediment concentrations in the Lower Fox River and Green Bay were determined using vertically- and horizontally-interpolated data developed in a three-step process. First, a grid was established for each reach of the Lower Fox River and each zone of Green Bay. Second, data from the nearest sampling locations to each grid point were horizontally interpolated to provide a concentration of total PCBs at each grid point. If there was no sampling data within 1,000 feet of a grid point, no value was assigned (indicated by "ND" for "no data"). Prior to the horizontal interpolation, the data at each sampling location were vertically interpolated onto standard vertical intervals. The top interval was 0 to 10 cm. The data from this top interval was used in the risk assessment. Third, the data assigned to each grid point were used to generate a mean, a 95% UCL, and a maximum value for each reach. The representative total PCB concentration was the 95% UCL or maximum value, whichever was lower (EPA, 1992d). In performing these statistical calculations, the grid points with an "ND" assigned to them were not included. The parts of the river or bay with an "ND" are generally believed to have little or no soft sediments. Therefore, the concentrations of total PCBs in these locations are believed to be low. Thus, the effect of not including these grid points in the statistical calculations is believed to bias the numbers high, which is conservative and health protective. Additional details on the statistical evaluation of the data are provided in Appendix B2.

Results

Tables 5-26 through 5-30 present upper-bound measured concentrations for Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, De Pere to Green Bay, and Green Bay, respectively. The upper-bound measured concentrations are the lower of the 95% UCL on the arithmetic mean or the maximum detected concentration. Tables 5-31 through 5-35 present average measured concentrations for Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, De Pere to Green Bay, and Green Bay, respectively. The average concentrations are the arithmetic mean or the maximum detected concentration, whichever is lower.

5.5.3 Transfer Factors and Exposure Point Concentrations

Using the source concentrations described previously coupled with transfer factors, exposure point concentrations were developed for the following media:

- Shower air,
- Bath air,
- Outdoor air, and
- Sediment pore water.

The transfer factors used in this analysis are presented in Appendix B3. The resulting exposure point concentrations for each receptor in each location are provided in Appendix B4.

5.6 Dose-response Assessment

5.6.1 Overview

The purpose of the dose-response assessment is to identify the relationship between the magnitude of COPCs to which receptors may be exposed (dose) and the likelihood of an adverse health effect (response). Both non-carcinogenic (i.e., threshold) and carcinogenic (i.e., non-threshold) health effects are considered in the dose-response assessment. The information provided in the dose-response assessment is combined with the results of the exposure assessment (Sections 5.4 and 5.5) to provided an estimate of potential health risk.

Dose-response information used in this risk assessment is provided in the EPA's Integrated Risk Information System (IRIS) (EPA, 1998c) or Health Effects Assessment Summary Tables (HEAST) (EPA, 1997c). The following paragraphs describe the non-carcinogenic and carcinogenic dose-response methodologies that will be incorporated into the Lower Fox River and Green Bay risk assessment.

Non-carcinogenic Dose-response

Compounds with known or potential non-carcinogenic effects are generally assumed to have a dose below which no adverse effect is observed, or conversely, above which an effect may be seen. In laboratory experiments, this dose is known as the No Observed Adverse Effect Level (NOAEL). In the absence of a NOAEL, the Lowest Observed Adverse Effect Level (LOAEL) may be used. It is important to note that a NOAEL or LOAEL may not be an appropriate measure of effects for all chemicals or toxic endpoints, but these values are general assumptions that may be used to evaluate non-carcinogenic effects. By applying uncertainty factors to the NOAEL or the LOAEL, the EPA has developed Reference Doses (RfDs) and Reference Concentrations (RfCs) for oral and inhalation exposures to compounds with potential non-carcinogenic effects (EPA, 1998c). RfDs and RfCs are available for chronic, subchronic, and (in some cases) acute exposures. Chronic RfDs are applicable to exposures lasting 7 or more years, while subchronic RfDs are applicable to exposures lasting less than 7 years (EPA, 1989c).

Uncertainty factors account for uncertainties associated with the dose-response value, such as the effect of using an animal study to derive a human dose-response value, extrapolating from the high doses used in the laboratory experiment to the low doses typically encountered in environmental settings, and evaluating sensitive subpopulations. For compounds with potential non-carcinogenic effects, the RfD and RfC provide reasonable certainty that, if the specified exposure dose (in the case of the RfD) or exposure concentration (in the case of the RfC) is below the threshold, then no non-carcinogenic health effects are expected to occur even if daily exposure were to occur for a lifetime. RfDs are expressed in terms of milligrams of compound per kilogram of body weight per day (mg/kg-day).

Oral RfDs are provided by EPA in IRIS or HEAST. Inhalation RfDs can be calculated from RfCs. The equation for converting an RfC into an inhalation RfD depends on whether the units of the RfC are mg/m^3 or micrograms per cubic meter (μg/m^3).

$$RfD_i = 0.286\ (m^3/kg\text{-}day) \cdot RfC_i\ (mg/m^3)$$

$$RfD_i = 2.86 \times 10^{-4} [(mg/\mu g)(m^3/kg\text{-}day)] \cdot RfC_i\ (\mu g/m^3)$$

Dermal intakes from either water or sediment are calculated as absorbed doses. To evaluate these absorbed doses, an oral RfD based on an absorbed dose must be developed. This is accomplished by adjusting the oral RfD for the absorption efficiency in the study used as the basis for this oral toxicity parameter. The oral RfD is translated into an RfD suitable for evaluating the absorbed dose from dermal exposure using the following equation:

$$RfD_d = EFF_o \cdot RfD_o$$

where:

RfD_d = reference dose for evaluating absorbed dermal doses (mg/kg-day),
RfD_o = reference dose for evaluating administered ingestion doses (mg/kg-day), and
EFF_o = absorption efficiency in the study used to develop an oral reference dose.

Carcinogenic Dose-response

For carcinogenic effects, the relevant intake is the total cumulative intake averaged over a lifetime because the quantitative dose-response function for carcinogens is based on the assumption that cancer results from cumulative lifetime exposures to carcinogenic agents. In other words, it is assumed that a finite level of risk is associated with any dose above zero. The dose-response model also assumes that there is a linear relationship throughout the range of doses and observable responses. For carcinogenic effects, EPA uses a two-step evaluation in which the chemical is assigned a weight-of-evidence classification, and then an oral cancer slope factor (CSF) and/or an inhalation unit risk factor (URF) is calculated. The weight-of-evidence classification is based on the likelihood of the compound being a human carcinogen. Group A compounds are classified as human carcinogens, Group B compounds are probable human carcinogens, Group C compounds are possible human carcinogens, Group D compounds are not classifiable as to human carcinogenicity, and Group E compounds have evidence of non-carcinogenicity for humans.

In the second part of the evaluations, CSFs and URFs are calculated for compounds that are known or probable human carcinogens. The EPA developed mathematical models that extrapolate observed responses at high doses or concentrations used in animal studies to predict responses in humans at the low doses or concentrations encountered in environmental situations. The models developed by the EPA assume no threshold and usually use animal as well as human data to develop an estimate of the carcinogenic potency of a compound. This numerical estimate is referred to by the EPA as the CSF for oral exposures and the URF for inhalation exposures. The mathematical models used by EPA assume that carcinogenic dose-response is linear at low doses.

Oral CSFs are expressed in terms of $(\text{mg/kg-day})^{-1}$, which represents the risk per average daily dose in mg/kg-day. Inhalation URFs are expressed in terms of $(\mu g/m^3)^{-1}$, which represents the risk per average concentration in air in units of $\mu g/m^3$. The inhalation cancer slope factors (CSF_i) can be calculated from inhalation URF_i values with the following equation:

$$CSF_i = 3{,}500\ [(\mu g/m^3)/(mg/kg\text{-}day)] \cdot URF_i(\mu g/m^3)$$

The oral CSF is translated into a CSF suitable for evaluating the absorbed dose from dermal exposure using the following equation:

$$CSF_d = \frac{CSF_o}{EFF_o}$$

where:

CSF_d = cancer slope factor for evaluating absorbed dermal doses $(mg/kg\text{-}day)^{-1}$,

CSF_o = cancer slope factor for evaluating administered ingestion doses $(mg/kg\text{-}day)^{-1}$, and

EFF_o = absorption efficiency in the study used to develop the oral cancer slope factor.

5.6.2 Polychlorinated Biphenyls

Much information has been published on polychlorinated biphenyls (PCBs) in the past few years and a majority of the PCB review was obtained from recent literature compilations and evaluations (ATSDR and EPA, 1999; ATSDR, 1997; EPA, 1996d; Johnson *et al.*, 1998a; Cogliano, 1998). In addition, individual studies were cited particularly regarding neurobehavioral effects from exposure to PCBs, including pre- and post-natal effects (Lonky *et al.*, 1996; Jacobson and Jacobson, 1996; Huisman *et al.*, 1995a, 1995b; Koopman-Esseboom *et al.*, 1996).

PCBs are mixtures of synthetic organic chemicals which take on forms from oily liquids to waxy solids, depending on the arrangement of their common components (EPA, 1996d). There are 209 individual chlorinated biphenyl compounds, known as congeners. PCBs are often evaluated as one of seven commercially available mixtures of congeners, which contain a large percentage of all the PCBs produced and sold in the United States. Some PCB mixtures are referred to by the industrial trade name, Aroclor. The seven common Aroclors include 1016, 1221, 1232, 1242, 1248, 1254, and 1260, and the numbers indicate the number of carbon atoms and percent chlorine by weight (ATSDR, 1997). For example, Aroclor 1254 means that the molecule contains 12 carbon atoms (the first two digits) and approximately 54 percent chlorine by weight (second two digits).

Because of natural environmental processes (i.e., partitioning, chemical transformation, and preferential bioaccumulation) PCBs in the environment occur as mixtures of congeners, and their composition (and thus their toxicity) differs from the commercial mixtures. The following sections describe the range of cancer slope factors to be used, the key carcinogenic studies used to derive those slope factors, the mechanisms of carcinogenicity, the dioxin-like properties of some PCBs and their assigned toxicity equivalency factors, and the noncancer effects of PCBs.

Effect of Environmental Processes

In the environment, PCBs occur as mixtures whose compositions differ from commercial mixtures. This is because after release into the environment, mixture composition changes over time, through partitioning, chemical transformation, and preferential bioaccumulation.

Partitioning is the process by which different fractions of a mixture separate into air, water, sediment, and soil. Through partitioning, PCBs:

- Adsorb to organic materials, sediments, and soils; adsorption tends to increase with chlorine content of the PCBs and organic content of the other material (Callahan *et al.*, 1979); and

- Volatilize or disperse as aerosols, especially congeners with low chlorine content, as they tend to be more volatile and also more soluble in water (Callahan *et al.*, 1979).

Biodegradation is another environmental process by which chemical transformation of PCBs can occur. Biodegradation can occur through:

- Anaerobic bacteria in sediments by selectively removing chlorines from meta and para positions;

- Aerobic bacteria removing chlorines from PCBs with low chlorine content and breaking open the carbon rings through oxidation (Abramowicz, 1990); PCBs with higher chlorine content are extremely resistant to oxidation and hydrolysis; and

- Photolysis, which can slowly break down congeners with high chlorine content.

The dechlorination of PCBs by anaerobic bacteria and photolysis is not synonymous with detoxification, as congeners having carcinogenic activity can be formed through dechlorination (Brown and Wagner, 1990). Furthermore, the dechlorination processes are slow and altered PCB mixtures persist in the environment for many decades.

Most studies of PCB-contaminated sites demonstrate that a threshold PCB concentration must exist before anaerobic dechlorination can occur. The threshold PCB concentration level is site-specific. At different sites, thresholds have been shown to range between 10 mg/kg and 50 mg/kg. The threshold PCB concentration level for the Lower Fox River is approximately 30 mg/kg. For sediment deposits in the Lower Fox River with average concentrations greater than 30 mg/kg, an approximate 10 percent reduction in PCB mass was estimated due to anaerobic processes. No PCB reductions due to anaerobic processes can be accounted for in deposits with average PCB concentration less than 30 mg/kg. No aerobic PCB degradation has been documented in the Lower Fox River (RETEC, 2002b).

Preferential bioaccumulation is another important environmental process that occurs in living organisms where:

- PCBs are highly soluble in lipids and are absorbed by fish and other animals.

- Rates of metabolism and elimination are slow and vary by congener; thus, each species in the food chain retains persistent congeners that prove resistant to metabolism and elimination (Oliver and Niimi, 1988).

- Congeners with higher chlorine content are bioaccumulated through the food chain, producing residues that are considerably different from the original Aroclors (Lake *et al.*, 1992; Oliver and Niimi, 1988).

- Bioaccumulated PCBs in humans appear to be more persistent in the body and could be more toxic than Aroclors (as they are in animals) (Hovinga *et al.*, 1992; ATSDR, 1997); for example, a study comparing mink fed a given quantity of Aroclor 1254 with mink fed Great Lakes fish contaminated with one-third that quantity of bioaccumulated PCBs (plus other chemicals) found similar liver and reproductive toxicity (Hornshaw *et al.*, 1983).

Absorption and Retention

PCBs can be absorbed through ingestion, inhalation, and dermal exposure, after which they are transported similarly through the circulatory system. Thus, it seems logical to expect similar internal effects from different exposure routes.

PCBs are eliminated through metabolism, which occurs primarily in the liver (Matthews and Anderson, 1975; ATSDR, 1997). Metabolism rates are generally lower with high chlorine content, but chlorine position is also important (Matthews and Anderson, 1975). In addition to variability by congener, there is human variability in metabolism and elimination. People with decreased liver function, including inefficient metabolic capacities in infants whose capacity to fully metabolize and eliminate PCBs has not been developed (Calabrese and Sorenson, 1977), have less capacity to metabolize PCBs than people in the general population.

Retention of PCBs occurs in the body long after exposure stops and the biological activity of persistent congeners is also maintained. For example, the half-lives of various Aroclors and total PCBs in the body are:

- 2.6 years for Aroclor 1242 and 4.8 years for Aroclor 1254 in workers exposed to PCBs (Phillips *et al.*,1989),

- 3.1 years for Aroclor 1242 and 6.5 years for Aroclor 1254 in exposed workers (Steele *et al*., 1986),

- 2 years for Aroclor 1242 and 16 years for Aroclor 1260 in exposed workers (Steele *et al*., 1986), and

- 8 years for total serum PCBs in non-occupational exposures (Steele *et al.*, 1986).

Exposure to PCBs by eating contaminated fish yields even longer persistence of these congeners (Hovinga *et al*., 1992; ATSDR, 1997). The half-life values assigned to these congeners must be applied with caution because the half-life estimates assigned to a mixture can underestimate long-term persistence due to the composition of its components.

PCBs can cross human skin and increase body burden. Dermal exposure can contribute significantly to body burdens of workers and can be a major route of environmental exposure (ATSDR, 1997). Quantitatively, dermal exposure would pose lower risks, because PCBs are substantially but incompletely absorbed through the skin (Wester *et al.*, 1983, 1987, 1990, 1993).

Health Effects of PCBs - Literature Review

Several studies have been conducted and presented in the scientific literature regarding public health implication of PCBs and other toxic substances in the Great Lakes area. Papers have also been written which review and summarize the research findings from these numerous studies. The majority of the studies focus on exposure via fish consumption, as this route of exposure has been demonstrated to be the most significant. The collective weight of evidence from these studies indicates that exposure to PCBs found in fish can cause developmental, reproductive, immune, and neurobehavioral problems.

Two recent publications highlight some of the major research findings associated with exposure to PCBs: *Public Health Implications of Persistent Toxic Substances in the Great Lakes and St. Lawrence Basins*, by Johnson *et al.* (1998a) and *Public Health Implications of Exposure to Polychlorinated Biphenyls (PCBs)*, coauthored by the Agency for Toxic Substances and Disease Registry (ATSDR) of the U.S. Public Health Service, in the U.S. Department of Health and Human Services, and the EPA (ATSDR and EPA, 1999). These papers present findings in wildlife populations, laboratory studies, and in human populations that indicate a positive correlation between consumption of fish from the Great Lakes area and levels of PCBs in the body. Some of these studies include the following.

- **Hanrahan *et al.* (1997).** Frequent fish consumers (including Wisconsin anglers) had a significantly greater PCB serum level than infrequent consumers, and the total number of years of eating Great Lakes sport fish was the best predictor of PCB body burden. In a similar study (Falk *et al.*, 1999), regression analyses indicated that PCB body burden was greater in men than in women, and that lake trout and salmon consumption were significant predictors of PCB body burden.

- **Humphrey (1983).** A study of Lake Michigan fish eaters indicated that PCB levels in breast milk and maternal serum correlates with consumption of contaminated fish.

- **Anderson *et al.* (1998).** In a study of Great Lakes sport fish consumers, serum was analyzed for several constituents, including PCBs. The study group consumed an average of 49 Great Lakes sport fish meals per year, placing them in a relatively high-exposure subpopulation. The overall mean coplanar PCB levels were 10.5 times greater than selected background levels in the general population.

- **Stewart *et al*. (1999).** A study of Great Lakes fish consumers concluded that maternal consumption of fish increased the risk of prenatal exposure to the most heavily chlorinated PCB homologues. PCBs were measured in umbilical cord blood as well as breast milk, and the highest concentrations correlated to the groups that consumed the most fish.

- **Humphrey *et al*. (2000).** PCB congeners were measured in a group of Lake Michigan residents aged 50 and over (fish eaters and non-fish eaters). The evaluation indicated significant PCB exposure in the fish eaters. Furthermore, it was determined that a select subset of congeners that were most prevalent could be used as indicator congeners in blood analysis.

Many studies present findings that health effects are associated with exposure to PCBs via fish consumption. A few of the exposure studies of human populations are summarized below.

- **Courval *et al.* (1997).** A study of Michigan anglers indicated that with increasing sport-caught fish consumption (of fish contaminated with persistent toxic substances), there were increased odds for conception failure.

- **Michigan/Maternal Infant Cohort Study (Fein *et al.*, 1984b; Jacobson *et al.*, 1985, 1990a, 1990b).** Developmental disorders and cognitive deficits were noted in offspring of mothers exposed to persistent toxic substances for 6 years before and during pregnancy via fish consumption. A follow-up study (Jacobson and Jacobson, 1996) showed that neurodevelopmental deficits assessed at birth were still persistent at age 11.

- **Lonky *et al.*, (1996).** Newborns of high-fish-consuming mothers exhibited a greater number of abnormal reflexes, less mature autonomic responses, and less attention to visual/auditory stimuli in comparison to newborns of no- or low-fish-consuming mothers.

- **Smith (1984) and Humphrey (1988).** Maternal serum PCB levels during pregnancy (of women who consumed contaminated Great Lakes/St. Lawrence fish) were positively associated with the number and type of infectious illnesses which occurred in infants.

- **Kostyniak *et al.* (1999).** A study of nursing mothers who consumed sport-caught fish from Lake Ontario evaluated PCB levels in breast milk. The higher-fish-consuming groups had higher levels of PCBs in breast milk. The study concluded that an inverse relationship exists between the concentration of PCBs and the overall duration of lactation for these women.

Additional studies report health effects associated with PCB exposure by other routes, such as ingestion of cooking oil. In two separate cases in Taiwan and Japan, PCB-contaminated bottles of rice oil and cooking oil resulted in an outbreak of illness (referred to as Yu-Cheng and Yusho disease, respectively) which included chloracne, hyperpigmentation, and meibomian gland dilation (Rogan *et al*., 1988). Even several years after the incident, women who were exposed to the contaminated oil gave birth to infants with abnormalities. The exposed children were small for gestational age and had abnormalities of the lungs, skin, and teeth. In addition, these children exhibited a delay in mental and psychomotor development. Follow-up studies of the Taiwan case have shown that neurobehavioral deficits and developmental delays may persist in older children (Chen *et al.*, 1992; Guo *et al.*, 1995; Chao *et al.*, 1997). However, it should be noted that these results may have been associated with the presence of dibenzofurans which were also present in the contaminated oil.

The following studies associate neurological impairments in infants with mothers who were exposed to PCBs.

- **Huisman *et al.* (1995a, 1995b).** This study revealed that PCBs, dioxins, and furans present in breast milk were associated with reduced neonatal neurologic optimality in breast-fed infants 2 to 3 weeks old. In addition, increased hypertonia in these infants was associated with high levels of coplanar PCBs in breast milk. These effects were also noted when the group of children was studied at 18 months old (Huisman *et al.*, 1995b); however at 42 months of age, the effects were no longer observed (Lanting *et al.*, 1998).

- **Koopman-Esseboom *et al.* (1996).** Exposure to PCBs and dioxins in infants (*in utero* as well as via breast-feeding) was evaluated to determine the effects on mental and psychomotor development. The authors found that prenatal PCB exposure had a small negative effect on psychomotor development at 3 months, although at 7 and 18 months psychomotor development was comparable between breast-fed and formula-fed infants. PCB/dioxin exposure did not appear to significantly influence mental development in any age group.

The following studies associate immunological effects with individuals exposed to PCBs.

- **Tryphonas (1995).** Effects on the immune system were studied in the Yu-Cheng and Yusho populations. Adverse effects included persistent respiratory distress (in half of Yu-Cheng persons studied); decreases in antibody levels 2 years after exposure (normal at 3 years); decrease in percentage of T-lymphocytes (Yu-Cheng) and increase in T-helper cells and decrease in T-suppressor cells (Yusho) 14 years after exposure; and enhanced responses to mitogens (Guo *et al.*, 1995).

- **Weisglas-Kuperus *et al.* (1995).** Studies of infants exposed to PCBs and dioxins pre- and postnatally indicated lower monocyte and granulocyte counts for 3-month-old infants, and increased total T-cell counts and cytotoxic T-cell counts for children 18 months old.

- **Hagmar *et al.* (1995).** Elevated PCB serum levels were significantly correlated with a decrease in natural killer cells. This was also found to occur with p,p'-DDT and two PCB congeners. No changes were observed for other lymphocyte cells.

- **Weisglas-Kuperus *et al.* (2000).** The effects of prenatal exposure to PCBs and dioxins were shown to persist into childhood and might be associated with a greater susceptibility to infectious diseases.

Some studies have not been able to demonstrate a positive correlation between PCB exposure and adverse health effects. However, these studies should be viewed as inconclusive, rather than evidence that supports PCBs are **not** associated with adverse health effects. Some examples of these studies are presented below.

- **Dar *et al.* (1992).** PCB serum levels were measured in a population of pregnant women from the Green Bay, Wisconsin area. A positive correlation was found between the PCB serum levels and the amount of Lake Michigan fish consumed in the past and present. In addition, reproductive outcome measures were evaluated for newborns of these women. For mothers who gained less than 34 pounds during their pregnancy, a positive correlation was found between mothers' PCB serum levels and birth size. This finding was contrary to results from other studies. However, in contrast with other studies, the population did not include high-end fish consumers, so PCB exposure may have been insufficient to create adverse noncancer responses.

- **Schantz *et al.* (1996).** A study was designed to assess the effects of PCBs and DDE in elderly Great Lakes sport anglers. Results were presented at the Health Conference '97 Great Lakes and St. Lawrence (Schantz *et al.*, 1997). The levels of PCBs measured in serum were clearly elevated in the fish eaters versus the non-fish eaters and relative to typical background levels. However, adjusted results of the study indicated that PCB and DDE levels did not impair fine motor function. A similar study (Schantz *et al.*, 1999) corroborated the previous findings.

- **Buck *et al.* (1999).** This study was conducted to determine potential reproductive effects of exposure to PCBs via consumption of Lake Ontario fish. Paternal fish consumption histories were evaluated, and correlated to the length of time taken for their partner to become pregnant. The study concluded that Lake Ontario fish consumption does not increase the risk of conception delay.

To summarize, the vast weight of evidence from human population studies indicates that exposure to PCBs, including PCBs found in fish from the Great Lakes area, can cause a variety of adverse health effects. These include developmental, immunological, reproductive, and neurobehavioral problems. Continuing research will provide more information on the human health effects of PCBs and the implications to populations at higher risk of exposure.

Carcinogenicity

Several studies demonstrate the carcinogenic effects of PCBs in rats and mice. Table 5-36 summarizes these key studies in addition to key human epidemiological studies.

New toxicity information from a cancer study of four commercial mixtures (Aroclor 1016, 1242, 1254, and 1260) demonstrates that all PCB mixtures can cause cancer, although different mixtures have different potencies (Brunner *et al.*, 1996). All mixtures induced liver tumors when fed to female rats; Aroclor 1260 also induced liver tumors in male rats (Brunner *et al.*, 1996). The importance of this data is that these four mixtures contain overlapping groups of congeners that, together, span the range of congeners most often found in environmental mixtures.

It is also important to note that some studies have concluded that PCBs are not carcinogenic in humans based upon negative epidemiological studies (Kimbrough *et al*., 1999). ATSDR, with the concurrence of an expert panel, concluded that the Kimbrough study could not be used to dismiss the potential carcinogenicity of PAHs (Bove *et al*., 1999). The ATSDR identified several inadequacies in the Kimbrough study, and they provided references to extensive studies on carcinogenicity in animals, as well as studies that suggest a relationship between PCB exposures and excess cancer in humans.

Mechanism of Carcinogenicity. Several mechanisms have been proposed for the carcinogenicity of PCBs including:

- Tumor-promoting activity in liver or lung from Aroclor 1254 and some congeners with four to six chlorines (Silberhorn *et al.*, 1990).

- Induction of mixed-function oxidases (i.e., phenobarbital-type inducers, 3-methylcholanthrene-type inducers, and mixed inducing properties), resembling chlorinated dibenzo-p-dioxins and dibenzofurans in structure and toxicity (Buchmann *et al.*, 1986, 1991) and present in mixtures with either high or low chlorine content.

- Dihydroxy metabolites of PCBs with low chlorine content are activated to reactive intermediates that produce oxidative DNA damage (Oakley *et al.*, 1996)—possible for environmental PCB association with human breast cancer.

- A highly significant statistical relationship between PCB blood levels and increased probability of non-Hodgkin lymphoma (Rothman *et al.*, 1997), and immune system suppression in association with the immunosuppressive characteristics of non-Hodgkin lymphoma from dioxin-like and non-dioxin-like congeners (Hardell *et al.*, 1996).

- Possible endocrine disruption similar to both dioxin-like and non-dioxin-like congeners (Birnbaum, 1994; Birnbaum and DeVito, 1995).

- Induction of thyroid carcinomas similar to 2,3,7,8-TCDD by increasing the metabolism and excretion of the thyroid hormone (NTP, 1983; McClain, 1989).

As demonstrated by these various mechanisms, different PCB congeners are capable of inducing cancer by different mechanisms.

Dioxin-like Congeners of PCBs. Relatively few PCB congeners resemble 2,3,7,8-TCDD in structure, toxicity, and as just indicated, in carcinogenic mechanism. However, it is important to recognize that both dioxin-like and non-dioxin-like mechanisms contribute to the overall PCB toxicity. The similarities these dioxin-like PCB congeners have in common with dioxin include:

- Similar carcinogenic mechanisms (endocrine disruption and induction of thyroid cancer via thyroid hormone regulation),

- Some PCB congeners acting as 3-methylcholanthrene-type inducers or possessing other dioxin-like inducing capacity,

- Toxic responses similar to dibenzo-p-dioxins and dibenzofurans, all acting through the aryl hydrocarbon receptor, and

- Persistence and accumulation in the food chain.

It is important to consider the contribution of these congeners to total dioxin equivalents. In some cases, PCBs can contribute more dioxin-like toxicity than chlorinated dibenzo-p-dioxins and dibenzofurans (Ahlborg *et al.*, 1994). The use of dioxin toxicity equivalency factors (TEFs) for dioxin-like congeners is discussed in the next section. It is also recognized that since the mechanism of PCB toxicity often varies from the mechanism of dioxins and furans for cancer induction, the use of TEFs is still undergoing evaluation.

Derivation and Application of Cancer Slope Factors. Previous assessments developed a single dose-response slope (7.7 per mg/kg-day average lifetime exposure) for evaluating PCB cancer risks (EPA, 1988). This slope factor was used by default for any PCB mixture because before 1996, only commercial mixtures with 60 percent chlorine (Aroclor 1260) had been adequately tested.

Brunner *et al.*'s cancer study (1996) of four commercial mixtures (Aroclor 1016, 1242, 1254, and 1260) demonstrated that all PCB mixtures can cause cancer, although different mixtures have different potencies (Cogliano, 1998). The resulting new upper-bound slopes are lower than the previous slope factor of 7.7 per mg/kg-day which was based upon Aroclor 1260. The new approach to assessing the cancer risk from environmental PCBs distinguishes among PCB mixtures by using information on environmental processes. Environmental processes have profound effects that can decrease or increase toxicity, so toxicity of an environmental mixture is only partly determined by the original commercial mixture. This new EPA approach, which has undergone external peer review, considers:

- A range of upper-bound potency estimates for PCB mixtures, plus a range of central estimates, with guidance for choosing estimates from these ranges to reflect the effect of environmental processes affecting a mixture's toxicity.

- A tiered approach that can use site-specific congener information when available (i.e., presence or absence of congeners and metabolites that contribute to cancer induction), but can be adapted if information is limited to total PCBs encountered through each pathway.

- An approach that assesses risks from different exposure pathways, less-than-lifetime and early-life exposures, and mixtures containing dioxin-like compounds.

- Application of EPA's proposed cancer guidelines (EPA, 1996b) in the quantitative dose-response assessment, including the cross-species scaling factor and discussion of circumstances affecting cancer risk.

- Extrapolation of doses below the experimental range, considering both linear and nonlinear approaches.

The new approach (EPA, 1996b) involves a tiered approach, using exposure pathways to choose appropriate potency values. The highest observed potency of 1 $(mg/kg\text{-}day)^{-1}$ (central slope) or 2 $(mg/kg\text{-}day)^{-1}$ (upper-bound slope) is appropriate for pathways where environmental processes tend to increase risk such as:

- Food chain exposure, including fish consumption;

- Sediment and soil ingestion;

- Dust and aerosol inhalation;

- Dermal exposure, if an absorption factor has been applied to reduce the external dose;

- Presence of dioxin-like, tumor-promoting, or persistent congeners in other media; and

- Early-life exposure (all pathways and mixtures).

Lower potencies of 0.3 $(mg/kg\text{-}day)^{-1}$ (central slope) or 0.4 $(mg/kg\text{-}day)^{-1}$ (upper-bound slope) are appropriate for pathways where environmental processes tend to decrease risk:

- Ingestion of water-soluble congeners;

- Inhalation of evaporated congeners; and

- Dermal exposure, if no absorption factor has been applied to reduce the external dose.

The lowest potencies of 0.04 $(mg/kg\text{-}day)^{-1}$ (central slope) or 0.07 $(mg/kg\text{-}day)^{-1}$ (upper-bound slope) are appropriate when:

- Congener or isomer analyses verify that congeners with more than four chlorines comprise less than 0.5 percent of total PCBs.

Table 5-37 summarizes the cancer slope factors that are used in this analysis. These values are summarized by pathway and persistence (i.e., whether the mixture of PCBs has more than 0.5 percent congeners with more than four chlorines—high persistence). For dermal contact with sediment, absorbed doses are calculated, so the higher potencies of 1 $(mg/kg\text{-}day)^{-1}$ (central) and 2 $(mg/kg\text{-}day)^{-1}$ (upper-bound) are applicable for this pathway. For dermal contact with water, absorbed doses are also calculated; however, lower molecular weight PCBs with fewer chlorine atoms per molecule are expected to preferentially partition to water. Thus, the lower potencies of 0.3 $(mg/kg\text{-}day)^{-1}$ (central) and 0.4 $(mg/kg\text{-}day)^{-1}$ (upper-bound) are appropriate for analysis of this pathway. No adjustment for the oral to dermal route was made, since the absorption of PCBs, particularly lower molecular weight PCBs, is over 90 percent via ingestion (ATSDR, 1997). Therefore, the cancer slope factor for evaluating absorbed dermal doses is essentially the same as the cancer slope factor for evaluating administered ingestion doses.

The dioxin toxicity equivalency factor (TEF) approach will also be applied. Table 5-38 presents TEFs for PCB congeners that are believed to exhibit dioxin-like characteristics. TEFs have been developed by the EPA (1996d) and by the World Health Organization (WHO, 1997). The TEFs can be used two ways. TEFs can be multiplied by the dioxin cancer slope factors (next section) to estimate cancer slope factors for specific congeners. The former approach is utilized in this analysis. Alternatively, concentrations of PCB congeners can be multiplied by TEFs to give an equivalent concentration of 2,3,7,8-TCDD. For many congeners, the EPA and WHO values are the same; however, for PCB-77 there is a five times greater EPA TEF, and for PCB-170 and PCB-180 a TEF from WHO is not available. In addition, WHO provides a TEF for PCB-81, while EPA does not. This risk assessment incorporates the EPA TEFs into the calculations.

Noncancer Effects

Overview of Noncancer Effects. PCBs have significant human health effects other than cancer, including neurotoxicity, reproductive and developmental toxicity, immune system suppression, liver damage, chloracne, skin irritation, and endocrine disruption (EPA, 1996d; ATSDR, 1997; ATSDR and EPA, 1999). These toxic effects have been observed from acute and chronic exposures to PCB mixtures with varying chlorine content. A more detailed discussion of these effects is presented in the following section.

Cases of severe chloracne were reported in a work environment in which PCB air levels were found to be between 5.2 and 6.8 mg/m^3. The workers developing chloracne had been exposed for 2 to 4 years. Other analyses revealed worker complaints of dry sore throat, skin rash, gastrointestinal disturbances, eye irritation, and headache at work area concentrations of 0.013 to 0.15 mg PCBs per cubic meter (PCB/m^3). Higher blood PCB levels are associated with higher serum triglyceride and/or cholesterol levels, as well as high blood pressure. Air PCB concentrations as low as 0.1 mg/m^3 can produce toxic effects, and exposure to levels producing no overt toxicity can affect liver function. Recovery after termination of exposure occurs, but is slow and depends upon the amount of PCBs stored in adipose tissue (Clayton and Clayton, 1981).

Human exposures to PCBs resulting in toxic effects have been documented from the ingestion of rice oil contaminated with "Kanechlor 400" in Japan (resulting in Yusho or rice oil disease) or from industrial exposure. Clinical symptoms of poisoning included acne-like skin eruptions (chloracne), eyelid edema, conjunctival discharge, skin and nail pigmentation, and hyperkeratosis. Yusho patients are estimated to have ingested approximately 0.07 mg/kg-day for at least 50 days. The rice oil was found to be contaminated with polychlorinated dibenzofuran, which is believed to have played a significant role in the observed toxicity (Bandiera *et al.*, 1984; Kashimoto *et al.*, 1981).

Bioaccumulated mixtures are of greatest concern, because they appear to be more toxic than commercial mixtures and more persistent in the body (Hovinga *et al.*, 1992). Two highly exposed populations are exposed to bioaccumulated mixtures. One is nursing infants, for whom average intake of total PCBs was estimated at 1.5 to 27 micrograms per kilogram per day (μg/kg-day) (ATSDR, 1997), 3 to 11 μg/kg-day (WHO, 1993), or 2.1 μg/kg-day (Kimbrough, 1995), compared to 0.2 μg/kg-day estimated for adults (WHO, 1993; Kimbrough, 1995). Dietary intake varies widely, often depending on proximity to where PCBs were released into the environment. Using the narrower range (3 to 11 μg/kg-day), average daily intake for a 5-kg nursing infant would be 15 to 55 μg, about triple the average adult intake, and approximately 50-fold higher when adjusted for body weight.

Fein *et al.* (1984a, 1984b) studied the effects of low-level chronic exposure to PCBs in pregnant women and their newborn offspring from consumption of Lake

Michigan fish. Low levels of PCBs were reported to cause decreases in birth weight, head circumference, and gestational age of the newborn. PCBs were apparently transmitted to the fetus across the placenta and to the newborn through breast milk. Behavioral deficiencies, including immaturity of reflexes and depressed responsiveness, were reportedly observed in infants exposed to PCBs (Fein *et al.*, 1984a, 1984b).

The second highly exposed population to bioaccumulated mixtures is people whose diet is high in game fish, game animals, or products of animals contaminated through the food chain (EPA, 1996d). For example, recreational or high-intake fish consumers and their families who frequently eat fish from a contaminated source have higher PCB exposures than the general population (Johnson *et al.*, 1998a; ATSDR, 1997; ATSDR and EPA, 1999; Anderson *et al.*, 1998; Hanrahan *et al*., 1997).

Reference Doses for PCB Aroclors. Two of the PCB Aroclors have oral reference doses available on IRIS, Aroclor 1016, and Aroclor 1254. The studies that the RfDs are based on, the critical target organs, and the confidence in the RfDs along with the uncertainty and modifying factors are detailed below. In this assessment, the oral RfD for Aroclor 1254 has been used to evaluate Aroclors 1221, 1232, 1242, 1248, and 1260 as well.

Aroclor 1016. The oral RfD of 7.0E-5 mg/kg-day is based on a series of reports that evaluated perinatal toxicity and long-term neurobehavioral effects of Aroclor 1016 in the same group of infant monkeys (Barsotti and Van Miller, 1984; Levin *et al.*, 1988; Schantz *et al.*, 1989, 1991). Aroclor 1016 was administered to groups of eight adult female rhesus monkeys via diet in concentrations of 0, 0.25, and 1.0 ppm for approximately 22 months. Exposure began 7 months prior to breeding and continued until offspring were weaned at age 4 months. A decrease in birth weight in the high-dose group was significantly lower in controls (*p*, 0.01) (Barsotti and Van Miller, 1984). The offspring of the high-dose group were significantly ($p < 0.05$) impaired in behavioral testing (Schantz *et al.*, 1989). Behavioral and neurological dysfunctions, including deficits in visual recognition and short-term memory, also have been observed in infants of human mothers who consumed fish contaminated with PCB mixtures (Fein *et al.*, 1984a, 1984b; Jacobson *et al.*, 1985, 1984; Gladen *et al.*, 1988; Huisman *et al.*, 1995a, 1995b; Lanting *et al.*, 1998; Koopman-Esseboom *et al.*, 1996).

The RfD is based on the low dose of 0.25 ppm (0.007 mg/kg-day) from the Schantz *et al.* (1989, 1991) studies. This dose was considered a NOAEL. An uncertainty factor of 100 is applied to account for sensitive individuals, extrapolation from monkeys to humans, limitations in the database, and partial extrapolation from subchronic exposure to chronic. A modifying factor of 1 indicates that no modification was done. The study, the database, and the RfD carry a medium level of confidence according to EPA, since essentially only one group of monkeys was examined.

The absorption of PCBs through ingestion has been estimated to be over 90 percent, particularly for mixtures such as Aroclor 1016 with the lowest number of chlorine atoms per PCB molecule (ATSDR, 1997). Therefore, an absorption factor of 1.0 was assumed for this Aroclor, so that the dermal RfD is the same as the oral RfD.

Aroclor 1254. The oral RfD of 2.0E-5 mg/kg-day was obtained from studies conducted by Arnold *et al.* (1993a, 1993b) and Tryphonas *et al.* (1989, 1991a, 1991b). Groups of 16 adult female rhesus monkeys ingested gelatin capsules of Aroclor 1254 at dosages of 0, 5, 20, 40, or 80 micrograms per kilogram per day (μg/kg-day) for more than 5 years. After 25 months of exposure, the monkeys had achieved a pharmacokinetic steady-state based on PCB concentrations in adipose tissue and/or blood (Tryphonas *et al.*, 1989). General health status was evaluated daily, and body weight measurements, feed conversion ratio calculations, and detained clinical evaluation were performed weekly throughout the study. Analyses of clinical signs of toxicity were limited to the occurrence of eye exudate, inflammation and/or prominence of the eyelid Meibomian (tarsal) glands, and particular changes in finger- and toe-nails (prominent nail beds, separation from nail beds, elevated nail beds, and nails folding on themselves). Monkeys that ingested 5 to 80 μg/kg-day doses of Aroclor 1254 showed ocular exudate, prominence and inflammation of the Meibomian glands, and distortion in nail bed formation. These changes were seen at the lowest dose tested and a dose-dependent response was demonstrated. Similar changes have been documented in humans for accidental oral ingestion of PCBs (EPA, 1998a). The RfD for Aroclor 1254 is based on the low dose of 5 μg/kg-day from the study. An uncertainty factor of 300 was applied to account for sensitive individuals, extrapolation from rhesus monkeys to humans, interspecies extrapolation, and the extrapolation of a subchronic to chronic study. The modifying factor of 1 indicates that no modification was done. The study, the database, and the RfD carry a medium level of confidence according to EPA.

The absorption of PCBs through ingestion has been estimated to be 75 to 100 percent for PCB mixtures (ATSDR, 1997), although mixtures with higher chlorine content appear to have somewhat lower absorption. An absorption factor of 90 percent was used to translate the oral RfD to an RfD suitable for evaluating dermal exposure. The conversion is as follows:

$$2 \times 10^{-5} \ mg/kg\text{-}day * 0.9 = 1.8 \times 10^{-5} \ mg/kg\text{-}day$$

5.6.3 Polychlorinated Dibenzo-p-dioxins and Dibenzofurans

The polychlorinated dibenzodioxins (dioxins) include 75 individual compounds, and the polychlorinated dibenzofurans (furans) include 135 individual compounds. These individual compounds are technically referred to as congeners. Both PCDDs and PCDFs have eight positions on their molecules where chlorine atoms can substitute for hydrogen atoms. Only seven of the 75 congeners of PCDDs are thought to have dioxin-like toxicity; these have chlorine substitutions in the 2, 3, 7, and 8 positions. Only 10 of the 135 possible congeners of PCDFs are thought to have dioxin-like toxicity; these have substitutions in the 2, 3, 7, and 8 positions. The toxicities of dioxin and furan congeners are evaluated relative to the toxicity of 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD), the most extensively studied of the dioxin and furan congeners.

Non-carcinogenic effects from short-term or long-term exposure to dioxins/furans are numerous. These effects can range from nose, throat, and lung irritation to headaches, dizziness, nausea, vomiting, nervous system and skin disorders, and potential damage to the liver, pancreas, circulatory and respiratory systems, depending on the duration and severity of exposure (Sittig, 1991).

The carcinogenicity of dioxins has been thoroughly investigated through numerous studies and experiments to determine its potential impacts to human health. Of the data that are available, there is sufficient evidence to conclude that 2,3,7,8-TCDD is carcinogenic in experimental animals (Class B2). A number of experiments with rats and mice has demonstrated that the incidence of liver tumors consistently increased in males and females with the dermal and oral administration of 2,3,7,8-TCDD (McGregor *et al.*, 1998). In addition, other cancers have been observed in experimental animals such as lymphomas, alveolar and bronchiolar adenomas and carcinomas, and thyroid follicular cell adenomas depending on the animal species, sex, and route of administration (McGregor *et al.*, 1998).

Human data on the carcinogenicity of dioxins is inconclusive, but there is limited epidemiological evidence in humans to support the carcinogenicity of 2,3,7,8-TCDD. Various investigations show a weak link between occupational and environmental exposures of 2,3,7,8-TCDD and carcinogenicity in humans. The most important information on the carcinogenicity of 2,3,7,8-TCDD related to human exposure has been done through cohort studies in areas with varying degrees of 2,3,7,8-TCDD contamination. Overall, an increased risk for all cancers combined was seen across the cohort studies rather than for any specific site (McGregor *et al.*, 1998). The largest magnitude of increase generally occurred in subcohorts considered to have the highest 2,3,7,8-TCDD exposure within cohort groups. Most commonly, lung cancers were observed amongst these more highly exposed subcohorts (McGregor *et al.*, 1998).

Information on the carcinogenicity of furans is less available than that for dioxins. There have been no long-term studies on experimental animals with furans to adequately determine the carcinogenicity of these compounds (McGregor *et al.*, 1998). The results are likewise for human data. A few epidemiological cases studies were followed to investigate exposure to furans, but the data showed inadequate evidence to conclude the carcinogenicity of furans in humans (McGregor *et al.*, 1998).

Derivation of Cancer Slope Factor

Based on a study done by Kociba *et al.* (1978) the EPA has derived a cancer slope factor of 150,000 $(mg/kg\text{-}day)^{-1}$ for both the oral and inhalation exposure routes associated with 2,3,7,8-TCDD. Calculations were based on the increased incidence of tumors of the lungs and liver in female rats fed diets containing 2,3,7,8-TCDD for 2 years (EPA, 1985b). This value is currently under review and is subject to change with further investigation. In this analysis, the oral CSF is used to evaluate absorbed doses estimated for the dermal pathway.

For risk assessment purposes, oral and inhalation CSFs have been derived using toxicity equivalency factors (TEFs) for the dioxin/furan congeners. This procedure involves assigning individual TEFs to the dioxin or furan congeners. TEFs are estimates of the toxicity of dioxin-like compounds relative to the toxicity of 2,3,7,8-TCDD, which is assigned a TEF of 1.0. All other congeners have TEF values that are equal to or less than the TEF of 2,3,7,8-TCDD; these TEFs range from 0.00001 to 1.0. TEF values for dioxin and furan congeners are presented in Table 5-39. TEFs have been developed by the EPA (1989b) and WHO (1997). The TEFs can be used two ways. TEFs can be multiplied by the CSF for 2,3,7,8-TCDD to yield a CSF for the specific congener. Alternatively, the concentration of the congener can be multiplied by its TEF to calculate an equivalent concentration of 2,3,7,8-TCDD. For many congeners, the EPA and WHO values are the same; however, for 2,3,7,8-PCDD the WHO TEF is twice that of EPA's, and for OCDD and OCDF, the EPA TEF is 10 times greater than the WHO value. This risk assessment incorporates the EPA TEFs into the calculations.

Derivation of Reference Dose

No RfDs for either ingestion or inhalation are available on IRIS. An oral RfD of 10^{-9} mg/kg-day (1 picogram per kilogram per day [pg/kg-day]) had previously been established for 2,3,7,8-TCDD, but this value has been withdrawn from IRIS. This value will be used in this evaluation for 2,3,7,8-TCDD to evaluate non-carcinogenic effects of oral and dermal exposure (EPA policy). The non-carcinogenic effects of inhalation exposure will not be evaluated.

5.6.4 Dieldrin

Dieldrin is a chlorinated organic pesticide and causes a variety of non-carcinogenic effects when short-term acute exposure or long-term chronic exposure occurs. Such effects include nausea, dizziness, headaches, muscle twitches, convulsions, and skin and eye disorders (Sittig, 1991).

Several toxicological studies of dieldrin done on animals have yielded sufficient evidence to conclude it is a carcinogenic compound (Class B2). Dieldrin, which is structurally related to compounds which produce tumors in rodents (aldrin, chlordane, heptachlor epoxide, and chlorendic acid), caused benign liver tumors and hepatocarcinomas at different dose levels in various strains of mice of both sexes when administered orally.

Human carcinogenic data for dieldrin is inadequate to draw the same conclusions reached by animal studies. Two studies which followed workers exposed to aldrin and to dieldrin reported no increased incidence of cancer. Both studies were limited in their ability to detect an excess of cancer deaths. Van Raalte (1977) observed two cases of cancer (gastric and lymphosarcoma) among 166 pesticide manufacturing workers exposed 4 to 19 years and followed from 15 to 20 years. Exposure was not quantified, and workers were also exposed to other organochlorine pesticides (endrin and telodrin). The number of workers studied was small, the mean age of the cohort (47.7 years) was young, the number of expected deaths was not calculated, and the duration of exposure and of latency was relatively short. Recent data have also linked dieldrin exposure to increased incidence of breast cancer (Hoyer *et al*., 1998). Organochlorines are believed to mimic the effects of estrogen, which promotes tumor growth in breast cancer. A Danish study of over 7,000 women monitored for 19 years found that women with the highest levels of dieldrin in their blood were twice as likely to develop breast cancer as women with the lowest levels.

Derivation of Cancer Slope Factors

The oral and inhalation cancer slope factor of 1.6E+01 $(mg/kg\text{-}day)^{-1}$ is based on the geometric mean of 13 slope factors calculated from liver carcinoma data in both sexes of several strains of mice fed diets of dieldrin. Inspection of the data indicated no strain or sex specificity of carcinogenic response. For this assessment, the oral CSF is used to evaluate absorbed doses for the dermal exposure pathway.

Derivation of Reference Dose

The oral reference dose of 5.0E-05 mg/kg-day for dieldrin was calculated based on an experiment by Walker *et al.* (1969) where dieldrin was administered to rats for 2 years at dietary concentrations approximately equal to 0, 0.005, 0.05, and 0.5 mg/kg-day. Body weight, food intake, and general health remained unaffected throughout the 2-year period, although at 0.5 mg/kg-day all animals became irritable and exhibited tremors and occasional convulsions. No effects were seen in various hematological and in clinical chemistry parameters. At the end of 2 years, females fed 0.05 and 0.5 mg/kg-day had increased liver weights and liver-to-body weight ratios ($p < 0.05$). Evidence of hepatic lesions were considered to be characteristic of exposure to an organochlorine insecticide. The LOAEL was identified as 0.05 mg/kg-day and the NOAEL as 0.005 mg/kg-day. For this assessment, the oral RfD is used to evaluate absorbed doses for the dermal exposure pathway.

5.6.5 DDT, DDE, and DDD

DDT is a chlorinated organic pesticide that is generally made up of a complex mixture of DDT isomers and metabolites. DDD and DDE are the metabolites most commonly associated with technical-grade DDT and result from degradation of the mixture. DDT, DDD, and DDE are structurally very similar, so their behavior in the environment is similar as well (ICF, 1985).

DDT and its metabolites, DDD and DDE, have been classified by EPA as probable human carcinogens based on adequate studies in animals and inadequate studies in humans (Class B2). Human exposure to DDT is primarily by ingestion of contaminated food. By EPA estimates, total intake of DDT each year for the average U.S. resident is less than 3 milligrams per year (mg/yr) (Sittig, 1991). Points of attack include the central nervous system, liver, kidneys, skin, and peripheral nervous system. DDT is of moderate toxicity to man and most other organisms. However, its extremely low solubility in water (0.0012 mg/L) and high solubility in fat (100,000 ppm) result in great bioconcentration (Sittig, 1991). Symptoms of overexposure include paresthesia of the tongue, lips, and face; tremors; apprehension; dizziness; confusion; malaise; headache; convulsions; paresis of the hands; vomiting; and irritation of the eyes and skin (Sittig, 1991).

Exposure to DDT may also result in behavioral and cognitive effects. A study by Eriksson *et al*. (1990a) indicated that DDT (along with a metabolite conjugated to a fatty acid, DDOH-PA) affects muscarinic cholinergic receptors in the neonatal mouse brain when administered to suckling mice during periods of rapid brain growth. In a follow-up study, Eriksson *et al*. (1990b) found that neonatal exposure to a single low oral dose of DDT and DDOH-PA can lead to a permanent hyperactive condition in adult mice.

Derivation of Cancer Slope Factors

EPA has derived an oral cancer slope factor for DDT and DDE of 0.34 (mg/kg-day)$^{-1}$. In addition, the 0.34 (mg/kg-day)$^{-1}$ also serves as the inhalation cancer slope factor for DDT. The oral cancer slope factor for DDD, a structural analog to DDT and DDE, is 0.24 (mg/kg-day)$^{-1}$ based on extrapolation of data from a study done by Tomatis *et al.* (1974) where evidence of liver tumors was discovered in mice fed a diet of DDD. For this assessment, the oral CSFs are used to evaluate absorbed doses for the dermal pathways.

Derivation of Reference Dose

An oral RfD has been established for DDT of 0.0005 mg/kg-day based on a NOAEL of 0.05 mg/kg-day from a 27-week rat feeding study in which liver lesions were the observed effect (Laug *et al.*, 1950). The uncertainty factor associated with this value is 100. No RfDs have been established for the inhalation route of exposure by DDT, or for either route by DDE and DDD. For this assessment, the oral RfD is used to evaluate absorbed doses for the dermal exposure pathways.

5.6.6 Arsenic

The toxicity of arsenic depends upon its chemical form along with the route, dose, and duration of exposure. In general, arsenites (As^{3+}) are potentially more toxic than arsenates, soluble arsenic compounds are potentially more toxic than insoluble compounds, and inorganic arsenic compounds are potentially more toxic than organic derivatives (EPA, 1985a).

There is sufficient evidence that arsenic is a human carcinogen. Arsenic exposure has been linked to skin cancers and cancers of multiple organs (liver, kidney, lung and bladder) associated with oral exposure and inhalation exposure. EPA classifies arsenic as a Class A human carcinogen. There is inadequate evidence for the carcinogenicity of arsenic chemicals in animals.

Acute toxic effects are generally seen following ingestion of inorganic arsenic compounds; these include throat constriction, epigastric pain, vomiting, and watery diarrhea. The lethal dose for humans is reported to be 1.0 to 2.6 mg/kg-BW (Vallee *et al.*, 1960). While these effects were observed in controlled laboratory situations, the most relevant effects for the Lower Fox River and Green Bay risk assessment are long-term subchronic or chronic effects from exposure to low concentrations of arsenic.

Derivation of Cancer Slope Factors

The EPA has provided an oral CSF of 1.5 (mg/kg-day)$^{-1}$ in IRIS (EPA, 1998c). This oral CSF is based on a 1977 study, conducted by Tseng (1977), of a Taiwan population that was exposed to arsenic contamination of a water supply (EPA, 1998c). There has not been consistent demonstration of arsenic carcinogenicity in test animals for various chemical forms administered by different routes to several species. As a result, the uncertainties associated with ingested inorganic arsenic are such that estimates could be modified downwards as much as an order of magnitude relative to risk estimates associated with most other carcinogens (EPA, 1998c).

The majority of tests in which experimental animals were exposed orally to a variety of arsenic compounds produced negative results regarding carcinogenicity (Hueper and Payne, 1962; Byron *et al.*, 1967). A few studies have, however, reported tumorigenic effects of arsenic treatment (Schrauzer *et al.*, 1978). Epidemiological studies conducted in the U.S. have failed to correlate the incidence of skin cancer with arsenic in drinking water (Morton *et al.*, 1976; Goldsmith *et al.*, 1972). A dose-response relationship between the occurrence of skin cancer and arsenic consumption in the drinking water of Taiwanese, however, was reported by Tseng (1977). Arsenic exposure at certain doses may produce a pattern of skin disorders, hyperpigmentation, and keratosis that may develop into basal or squamous cell carcinoma (EPA, 1985a). Several epidemiological studies of workers occupationally exposed to arsenic have reported a correlation between this exposure and mortality due to respiratory cancer (Higgins *et al.*, 1982; Enterline and Marsh, 1982; Brown and Chu, 1983).

To evaluate dermal exposures, a CSF based on an absorbed dose must be calculated. The oral CSF is based on an epidemiological study of people ingesting arsenic in their drinking water. Dollarhide (1993) reported that 95 percent of ingested arsenic in water is absorbed. Therefore, the CSF on an absorbed dose is 1.5 $(mg/kg\text{-}day)^{-1}/0.95$ or 1.6 $(mg/kg\text{-}day)^{-1}$.

The EPA has reported the unit risk for arsenic to be 4.3E-03 ($\mu g/m^3$). The inhalation slope factor of 1.5E+01 $(mg/kg\text{-}day)^{-1}$ was calculated using the equations presented earlier. The unit risk was based on the results of two studied populations of smelter workers (EPA, 1984b). Observed lung cancer incidence was significantly increased over expected values. Mixed results regarding carcinogenicity were reported in arsenic inhalation studies (Ishinishi *et al.*, 1977; Ivankovic *et al.*, 1979).

Derivation of Reference Dose

Subchronic effects from oral exposure to arsenic include hyperpigmentation (melanosis), multiple arsenical keratoses, sensory-motor polyneuropathy, persistent chronic headache, lethargy, gastroenteritis, and mild iron deficiency anemia. Chronic oral exposure of humans to inorganic arsenic compounds has been reported to cause skin lesions, peripheral vascular disease, and peripheral neuropathy (Silver and Wainman, 1952).

A chronic and subchronic oral RfD has been established for arsenic of 0.0003 mg/kg-day. This value was derived from the Tseng (1977) study which investigated the relationship between peripheral circulatory disease characterized by gangrene of the extremities and the arsenic concentrations in drinking water of over 40,000 residents of Taiwan. This study established a NOAEL of 0.001 to 0.017 mg/L for blackfoot disease. The uncertainty factor used in establishing the RfD was 3, to account for the lack of data on reproductive effects and for potentially sensitive individuals in the population.

Dermal exposure to trivalent arsenic compounds (As^{3+}) could result in local hyperemia due to the corrosivity of the arsenic compound (Sittig, 1991). Arsenic trioxide and pentoxide are capable of producing skin sensitization and contact dermatitis.

To evaluate dermal exposures, an RfD based on an absorbed dose must be calculated. The oral RfD is based on the same epidemiological study that is the basis for the oral CSF, so the absorption factor of 95 percent reported by Dollarhide (1993) is applicable here. Therefore, the RfD based on an absorbed dose is 0.0003 mg/kg-day $*$ 0.95 or 0.00029 mg/kg-day.

Inhalation reference doses have not been developed for arsenic. The symptoms of chronic inhalation exposure to arsenic compounds are similar to those associated with chronic oral toxicity. Later symptoms from chronic inhalation of arsenic may include conjunctivitis, perforation of the nasal septum, skin lesions, and inflammation of the respiratory tract mucous membranes (Sittig, 1991). While not a likely exposure for the Lower Fox River and Green Bay, acute toxicity from inhalation exposure to arsenic adsorbed to particulate matter may result in conjunctivitis and pharyngitis.

5.6.7 Lead

Lead can be absorbed by the oral, inhalation, or dermal exposure routes. Once absorbed, lead is distributed to the various organs of the body, with most distribution occurring to bones, kidneys, and liver (EPA, 1984a). Placental transfer to the developing fetus is possible (Bellinger *et al.*, 1987). Inorganic lead is not known to be biotransformed within the body.

Although not applicable to the Lower Fox River and Green Bay assessment, cases of acute lead poisoning in humans are not common and have not been studied in experimental animals as thoroughly as chronic lead poisoning. Symptoms of acute lead poisoning from deliberate ingestion by humans may include vomiting, abdominal pain, hemolysis, liver damage, and reversible tubular necrosis (EPA, 1984a).

Lead and most lead chemicals are classified by the EPA as Class B2 probable human carcinogens, resulting from sufficient evidence of carcinogenicity in experimental animals and inadequate evidence of carcinogenicity in humans. The classification was a result of recent studies reporting that lead salts, primarily phosphates and acetates, administered by the oral route or by injection, produce renal tumors in rats. No quantitative estimate of cancer potency has been developed for lead compounds. EPA has also considered it inappropriate to develop an RfD since many of the health effects associated with lead intake occur essentially without a threshold (EPA, 1998c).

Subacute exposures in humans reportedly may produce a variety of neurological effects including dullness, restlessness, irritability, poor attention span, headaches, muscular tremor, hallucinations, and loss of memory. Nortier *et al.* (1980) report encephalopathy and renal damage to be the most serious complications of chronic toxicity in man and the hematopoietic system to be the most sensitive. For this reason, most data on the effects of lead exposure in humans are based upon blood lead levels. The effects of lead on the formation of hemoglobin and other hemoproteins, causing decreased levels, are reportedly detectable at lower levels of lead exposure than in any other organ system (Betts *et al.*, 1973). Peripheral nerve dysfunction is observed in adults at levels of 30 to 50 micrograms per deciliter of blood (μg/dl-blood). Children's nervous systems are reported to be affected at levels of 15 μg/dl-blood and higher (Benignus *et al.*, 1981). In high doses, lead compounds may potentially cause abortions, premature delivery, and early membrane rupture (Rom, 1976).

EPA guidance (1994b) recommends the use of the EPA Integrated Exposure Uptake/Biokinetic (IEUBK) Model for determining blood lead levels for children exposed to lead in soil, dust, and paint. The model recommends a benchmark of "either 95 percent of the sensitive population having blood lead levels below 10 micrograms per deciliter (μg/dl) or a 95 percent probability of an individual having a blood lead level below 10 μg/dl." The blood action level is not considered a threshold level below which no adverse effects are expected because of the possibility that some adverse effects may occur at lower blood levels than 10 micrograms per liter (μg/L).

The EPA Technical Review Workgroup for Lead developed a biokinetic model for non-residential adult exposure to lead in soil (EPA, 1996c). This model is a simplified representation of lead biokinetics to predict quasi-steady-state blood lead concentrations among adults who have relatively steady patterns of site exposures. The model incorporates a simplified slope factor approach, much like the model proposed by Bowers *et al.* (1994). The model assumes a baseline lead level based on average blood lead levels for adults. Media-specific ingestion and absorption parameters are assessed for the adult population, and a biokinetic slope factor that relates uptake of lead into the body to blood lead levels is estimated. Thus, adult blood lead levels are calculated based on statistical information concerning baseline exposures to lead primarily from dietary lead and an assessment of current exposure to lead in soil and dust. In addition to soil and dust exposure, the model can be applied to assess the exposure pathways of ingestion of fish and waterfowl for the Lower Fox River and Green Bay assessment (Maddaloni, 1998).

5.6.8 Mercury

Mercury has been classified by the EPA as Group D; i.e., not classifiable as to human carcinogenic potential (EPA, 1998c). The dose-response assessment for mercury, therefore, is based on non-carcinogenic health endpoints. IRIS reports verified oral reference doses for mercuric chloride and methylmercury. These values were used to evaluate inorganic and organic mercury, respectively. An inhalation RfC for elemental mercury is reported in HEAST (EPA, 1997c). This risk assessment also includes an evaluation of total mercury, which incorporates the oral RfD from methylmercury and the inhalation RfC from mercuric chloride. This was done in order to conservatively estimate health effects for mercury when the class (i.e., organic or inorganic) was unknown, and in the absence of an oral RfD for elemental mercury.

Derivation of Oral Reference Doses

Mercuric Chloride. The oral RfD for mercuric chloride is 3.0E-04 mg/kg-day (EPA, 1998c). It is based on three subchronic studies with Brown Norway rats using oral or subcutaneous dosing regimens (EPA, 1987). The target effect was autoimmune effects in the kidney. The RfD was based on a consensus opinion of a panel of mercury experts that met on October 26–27, 1987 to review issues concerning the health effects of inorganic mercury. The panel's main conclusion was that the most sensitive adverse effect for mercury was formation of mercuric ion-induced autoimmune glomerulonephritis. The results from studies in the Brown rat were determined to be the best ones available for risk assessment. Because this animal is a good surrogate for sensitive humans, the uncertainty factor should be reduced by a factor of 10 from the normal factor that would be used when based on a LOAEL in a subchronic animal study ($10 \times 10 \times 10 \times 10 = 10{,}000$). Thus, the uncertainty factor used is 1,000. EPA's confidence in the oral RfD is high. For this risk assessment, the oral RfD is used to evaluate absorbed doses for the dermal exposure pathway.

An acute oral Minimal Risk Level (MRL) for inorganic mercury of 0.007 mg/kg-day for renal/urinary effects was developed by ATSDR (1998b).

Methylmercury. The oral RfD for methylmercury is 1.0E-04 (EPA, 1998c). It is based on a benchmark dose in maternal hair equivalent to maternal blood and body burden levels associated with developmental neurologic abnormalities in the offspring. The data is based on effects seen in Iraq when mothers were exposed to methylmercury-treated grain in bread.

An uncertainty factor of 10 is used in deriving the RfD from the benchmark dose of 1.1 μg/kg-day. This factor is based on a factor of 3 for variability in the human population, a factor of 3 for lack of a two-generation reproductive study, and a factor of 3 for lack of data on the effect of exposure duration on developmental neurotoxicity and adult paresthesia. For this assessment, the oral RfD is used to evaluate absorbed doses for the dermal exposure pathway.

EPA's confidence in the RfD is medium. It should be noted, however, that there is a scientific debate concerning the appropriateness of using the Iraqi poisoning data for RfD derivation. Both reanalysis of the Iraqi data and recent data from human populations in the Seychelles Islands who consumed mercury-containing fish for long periods of time indicated that the RfD may be somewhat higher than the current EPA value (Crump *et al.*, 1995; Meyers *et al.*, 1994).

Derivation of the Inhalation Reference Dose

The Health Effects Assessment Summary Tables (EPA, 1997c) report an inhalation reference concentration for elemental mercury of 0.3 $\mu g/m^3$ for subchronic and chronic exposures. This corresponds to an RfD of 8.75E-05 mg/kg-day using the equations presented earlier for translating an RfC to an inhalation RfD. The reported value was based on several occupational studies involving exposed workers evaluated for neurotoxic effects. An uncertainty factor of 30 was applied to the concentration of 9 $\mu g/m^3$ to develop the reference concentration (EPA, 1997c). No inhalation RfCs were reported for other forms of mercury.

5.6.9 Summary of Toxicity Criteria

The EPA-derived toxicity criteria used in this risk assessment are presented in Tables 5-40 and 5-41. Table 5-40 summarizes the cancer slope factors for each chemical of potential concern, and Table 5-41 summarizes the chronic reference dose. As stated previously, chronic reference doses apply to exposure periods of 7 years or longer. In this assessment, chronic RfDs have been used to evaluate all receptors.

Three different measures of PCB concentrations are available. First, in all samples where PCBs were analyzed, a total concentration of PCBs (total PCBs) was determined (either the sum of Aroclors or the sum of congeners). Second, for a number of samples, the concentrations of individual Aroclors and other congeners are available. Therefore, the potential toxicity of PCBs was evaluated three ways. First, potential cancer and noncancer effects were evaluated based on the concentrations of total PCBs using the cancer slope factors presented in Table 5-40 (based on the values for the highest risk and persistence in Table 5-37) and the reference dose for Aroclor 1254. Second, potential cancer and noncancer effects were evaluated based on the concentrations of each Aroclor. The cancer slope factors for the lowest risk and persistence in Table 5-37 were used for Aroclor 1016, while the cancer slope factors for the highest risk and persistence in Table 5-38 were used for all other Aroclors. The RfD for Aroclor 1016 was used for this Aroclor, while the RfD for Aroclor 1254 was used for that Aroclor and Aroclors 1221, 1232, 1242, 1248, and 1260. Third, potential cancer effects were evaluated based on the concentrations of individual PCB congeners. The cancer slope factors for the individual congeners were developed by multiplying the TEFs for congeners in Table 5-38 by the cancer slope factors for 2,3,7,8-TCDD.

The cancer slope factors for individual dioxin and furan congeners were derived by applying the TEF (refer to Table 5-39) to the cancer slope factor for 2,3,7,8-TCDD. For the pesticides (dieldrin, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT) and arsenic, cancer slope factors were obtained directly from EPA sources as discussed previously. In addition, the reference doses for dieldrin, 4,4'-DDT, and arsenic were obtained from EPA sources as discussed previously.

The recent paper by Hurley *et al*. (1998) suggests that much of the mercury in the Lower Fox River is in an inorganic, not organic (i.e., methylmercury), form. To evaluate the influence of the different forms of mercury on its toxicity, the analysis was designed to evaluate three types of mercury: total, organic, and inorganic. For total mercury, the most conservative RfDs were chosen: the oral RfD for methylmercury and the inhalation RfD for elemental mercury. For organic mercury, the oral RfD for methylmercury was used. Since methylmercury does not have an inhalation RfD, no RfD was assigned to the inhalation pathway for organic mercury. For inorganic mercury, the oral RfD for mercuric chloride was used, while the inhalation RfD for elemental mercury was assigned to the inhalation pathway.

5.7 Baseline Risk Characterization

5.7.1 Overview

In Section 5.4, intake assumptions were formulated for each receptor, while in Section 5.5, exposure point concentrations were estimated for media that receptors may potentially contact. These intake assumptions and exposure point concentrations can be combined to generate intakes. Section 5.6 presented toxicological parameters used to estimate potential human health effects associated with chronic exposures. In this section, the intakes are combined with the toxicological parameters to estimate potential human health effects. Two types of potential health effects are evaluated: carcinogenic and non-carcinogenic. Carcinogenic effects are quantified by estimating the probability of contracting cancer based on site-related exposure. Non-carcinogenic effects are quantified by estimating a hazard index.

Cancer risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to a potential carcinogen. In order to estimate the cancer risk, the intake (defined as a lifetime average daily dose, or LADD) is multiplied by the cancer slope factor:

$$Risk = LADD \cdot CSF$$

For each pathway, this calculation is performed for each chemical considered to be potentially carcinogenic, and the risks are summed to obtain the total risk due to that pathway. The total cancer risk for a particular receptor is then calculated as the sum of the risks from all exposure pathways. Wisconsin uses a risk level of 10^{-5} for evaluating cumulative cancer risks in the evaluation of sites under Chapter NR 700 while Superfund uses a risk level of 10^{-6} as the point at which risk management decisions may be considered. Risk management decisions most frequently made under Superfund are in the cancer risk range of 10^{-6} to 10^{-4}.

Potential non-carcinogenic effects were evaluated by calculating a chronic hazard index. For a single compound and intake route, the hazard quotient (HQ) is the ratio of the intake (defined as an average daily dose or ADD) to a reference dose:

$$HQ = \frac{ADD}{RfD}$$

The reference dose is a threshold dose or intake which is conservatively chosen so that if the estimated intake is less than the reference dose (i.e., the hazard index is less than 1.0), there is almost no possibility of an adverse health effect.

However, if the intake exceeds the reference dose (the hazard index exceeds 1.0), this does not indicate an adverse health effect is expected, only that a conservative threshold is exceeded. For each pathway, an HQ is derived for all appropriate chemicals. HQs for all chemicals and exposure pathways are summed to obtain the total hazard index (HI) for that receptor. The State of Wisconsin under Chapter NR 700 and EPA under Superfund both use an HI of 1.0 as a point at which risk management decisions may be considered.

A relatively large number of receptors are evaluated in a number of reaches in the Lower Fox River and Green Bay. To facilitate the computation of cancer risks and hazard indices, unit risks and unit hazard indices were calculated for each receptor and pathway by utilizing unit exposure point concentrations in the equations for calculating risks and hazard indices. For each receptor in each location, the unit risks and hazard indices were subsequently multiplied by actual concentrations to determine risks and hazard indices for that receptor in that location.

The remainder of this section presents the cancer risks and hazard indices by receptor. Unit risks and unit hazard indices for each receptor are presented in Appendix B4 along with cancer risks and noncancer hazard indices for each chemical and each exposure pathway in each location. In this section, summary tables of cancer risks and hazard indices are presented for each receptor. The summary tables for cancer risks are divided into two parts. In the first part, risks calculated using total PCB concentrations are provided along with risks for other chemicals. This part of each summary table includes risks for the following groups of chemicals:

- **Total PCBs:** the results based on the concentrations of total PCBs;
- **Total Dioxins/Furans:** the sum of the results for all dioxin and furan congeners;
- **Total Pesticides:** the sum of the results for dieldrin, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT; and
- **Arsenic:** the only inorganic that is considered carcinogenic.

The second part of each table contains a focused evaluation of risks due to PCBs. Cancer risks are calculated separately for total PCB data, the Aroclor data, and the congener data.

Similarly, the tables for hazard indices are divided into two parts. In the first part, hazard indices are calculated using total PCB concentration data along with hazard indices for other chemicals. This part of each summary table includes hazard indices for the following groups of chemicals:

- **Total PCBs:** the results based on the concentrations of total PCBs;
- **Total Dioxins/Furans:** the sum of the results for all dioxin and furan congeners;
- **Total Pesticides:** the results for dieldrin, 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT;
- **Arsenic**; and
- **Mercury:** the results using the concentration of total mercury.

The second part of each table with hazard indices contains a focused evaluation of hazard indices due to PCBs. Hazard indices are calculated separately for total PCB data and Aroclor data.

5.7.2 Recreational Angler

Risk and Hazard Index Equations

For the recreational angler, potential exposures occur via ingestion of fish, incidental ingestion of water, dermal contact with water, and inhalation of outdoor air. The equation used to calculate risks for this receptor for chemical *i* is:

$$\begin{aligned} R_i = {} & URFfsh1\text{-}ing\text{-}c_i \cdot RF_{fishi} \cdot Cfish_{measi} \\ & + URFw2\text{-}ing\text{-}c_i \cdot C_{sw-ti} \\ & + URFw2\text{-}d\text{-}c_i \cdot C_{sw-di} \\ & + URFa2\text{-}inh\text{-}c_i \cdot TF_{swoai} \cdot C_{sw-di} \end{aligned}$$

where:

R_i	=	cancer risk for chemical *i*,
$URFfsh1\text{-}ing\text{-}c_i$	=	unit risk factor for chemical *i* for ingestion of fish (kg/mg),
Rf_{fishi}	=	reduction factor for chemical *i* for fish (milligrams per milligram [mg/mg]),
$Cfish_{measi}$	=	measured concentration of chemical *i* in fish (mg/kg),
$URFw2\text{-}ing\text{-}c_i$	=	unit risk factor for chemical *i* for incidental ingestion of surface water (liters per milligram [L/mg]),
C_{sw-ti}	=	measured total concentration of chemical *i* in water (mg/L),

$URFw2\text{-}d\text{-}c_i$	=	unit risk factor for chemical *i* for dermal contact with surface water (L/mg),
$C_{sw\text{-}di}$	=	measured dissolved concentration for chemical *i* in water (mg/L),
$URFa2\text{-}inh\text{-}c_i$	=	unit risk factor for chemical *i* for inhalation of outdoor air (cubic meters per milligram [m^3/mg]), and
Tf_{swoai}	=	transfer factor for volatilization from surface water to outdoor air (liters per cubic meter [L/m^3]).

The total risk for all chemicals is obtained by summing the individuals values of R_i for each chemical.

The equation used to calculate hazard indices is:

$$\begin{aligned} HI_i = {} & UHIfsh1\text{-}ing\text{-}c_i \cdot RF_{fishi} \cdot Cfish_{measi} \\ & + UHIw2\text{-}ing\text{-}c_i \cdot C_{sw\text{-}ti} \\ & + UHIw2\text{-}d\text{-}c_i \cdot C_{sw\text{-}di} \\ & + UHIa2\text{-}inh\text{-}c_i \cdot TF_{swoai} \cdot C_{sw\text{-}di} \end{aligned}$$

The variables in this equation have been defined previously except:

Hi_i	=	hazard index for chemical *i*,
$UHIfsh1\text{-}ing\text{-}c_i$	=	unit hazard index for chemical *i* for ingestion of fish (kg/mg),
$UHIw2\text{-}ing\text{-}c_i$	=	unit hazard index for chemical *i* for incidental ingestion of surface water (L/mg),
$UHIw2\text{-}d\text{-}c_i$	=	unit hazard index for chemical *i* for dermal contact with surface water (L/mg), and
$UHIa2\text{-}inh\text{-}c_i$	=	unit hazard index for chemical *i* for inhalation of outdoor air (m^3/mg).

The unit risks and hazard indices are presented in Appendix B4, the transfer factors are in Appendix B3, and the measured concentrations and reduction factors were discussed previously.

Cancer Risks and Hazard Indices

Table 5-42 presents the cancer risks for the recreational angler using reasonable maximum exposure (RME) assumptions and upper-bound exposure point concentrations, while Table 5-43 presents the chronic hazard indices for this same receptor. Tables 5-44 and 5-45 present the cancer risks and chronic hazard indices for the recreational angler using RME assumptions and average exposure point concentrations. Tables 5-46 and 5-47 present the cancer risks and chronic hazard indices for the recreational angler using central tendency exposure (CTE) assumptions and average exposure point concentrations. The table below provides a summary of the cancer risks and hazard indices for the various exposure assumptions.

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Cancer Risks					
RME with Upper-bound Concentrations	2.0E-03	2.8E-03	4.2E-04	1.9E-03	2.0E-03
RME with Average Concentrations	1.6E-03	2.2E-03	3.4E-04	1.5E-03	1.8E-03
CTE with Average Concentrations	2.4E-04	3.3E-04	5.2E-05	2.3E-04	2.7E-04
Hazard Indices					
RME with Upper-bound Concentrations	76.2	107.1	17.9	59.8	55.9
RME with Average Concentrations	59.1	83.9	14.6	52.8	53.2
CTE with Average Concentrations	15.0	21.3	3.7	13.4	13.5

The results above indicate that cancer risks for the recreational angler exceed a risk of 1.0×10^{-6} for all areas under all exposure scenarios. The results by pathway (Tables 5-42, 5-44, and 5-46) indicate that in each case, the cancer risk for the fish ingestion pathway comprises essentially 100 percent of the total risk, and that total PCBs are the driving chemical, being responsible for over 80 percent of the risk in each reach in the Lower Fox River and over 70 percent of the risk in Green Bay. In addition, the hazard indices for each reach and exposure scenario exceed 1.0. As with the results for cancer risks, the fish ingestion pathway comprises essentially 100 percent of the total hazard index, and total PCBs are the driving chemical (refer to Tables 5-43, 5-45, and 5-47).

5.7.3 High-intake Fish Consumer

Risk and Hazard Index Equations

For the high-intake fish consumer, potential exposures occur via ingestion of fish, incidental ingestion of water, dermal contact with water, and inhalation of outdoor air. The equations used to calculate cancer risks and hazard indices for this receptor are identical to those presented above for the recreational angler.

The unit risks and unit hazard indices for the high-intake fish consumer are presented in Appendix B4, the transfer factors are in Appendix B3, and the measured concentrations and reduction factors were discussed previously.

Cancer Risks and Hazard Indices

Table 5-48 presents the cancer risks for the high-intake fish consumer using RME assumptions and upper-bound exposure point concentrations, while Table 5-49 presents the chronic hazard indices for this same receptor. Tables 5-50 and 5-51 present the cancer risks and chronic hazard indices for the high-intake fish consumer using RME assumptions and average exposure point concentrations. Tables 5-52 and 5-53 present the cancer risks and chronic hazard indices for the high-intake fish consumer using CTE assumptions and average exposure point concentrations. The table below provides a summary of the cancer risks and hazard indices for the various exposure assumptions.

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Cancer Risks					
RME with Upper-bound Concentrations	2.7E-03	3.8E-03	5.7E-04	2.6E-03	2.9E-03
RME with Average Concentrations	2.1E-03	3.0E-03	4.7E-04	2.1E-03	2.4E-03
CTE with Average Concentrations	3.4E-04	4.7E-04	7.3E-05	3.3E-04	3.8E-04
Hazard Indices					
RME with Upper-bound Concentrations	104.3	146.8	24.5	82.0	86.6
RME with Average Concentrations	80.9	114.9	20.0	72.4	72.8
CTE with Average Concentrations	21.2	30.1	5.2	18.9	19.0

The results above indicate that cancer risks for the high-intake fish consumer exceed a risk of 1.0×10^{-6} for all areas under all exposure scenarios. The results by pathway (Tables 5-48, 5-50, and 5-52) indicate that in each case, the cancer risk for the fish ingestion pathway comprises essentially 100 percent of the total risk, and that total PCBs are the driving chemical, being responsible for over 80 percent of the risk in each reach in the Lower Fox River and over 70 percent of the risk in Green Bay. In addition, the hazard indices for each area and exposure scenario exceed 1.0. As with the results for cancer risks, the fish ingestion pathway comprises essentially 100 percent of the total hazard index, and total PCBs are the driving chemical (refer to Tables 5-49, 5-51, and 5-53).

5.7.4 Hunter

Risk and Hazard Index Equations

For the hunter, potential exposures occur via ingestion of waterfowl, incidental ingestion of water, dermal contact with water, and inhalation of outdoor air. The equation used to calculate risks for this receptor for chemical *i* is:

$$\begin{aligned} R_i = {} & URFfd1\text{-}ing\text{-}c_i \cdot RF_{WF_i} \cdot CWF_{measi} \\ & + URFw2\text{-}ing\text{-}c_i \cdot C_{sw\text{-}ti} \\ & + URFw2\text{-}d\text{-}c_i \cdot C_{sw\text{-}di} \\ & + URFa2\text{-}inh\text{-}c_i \cdot TF_{swoai} \cdot C_{sw\text{-}di} \end{aligned}$$

The variables in this equation have been defined previously except:

$URFfd1\text{-}ing\text{-}c_i$	=	unit risk factor for chemical *i* for ingestion of waterfowl (kg/mg),
RF_{WFi}	=	reduction factor for chemical *i* for waterfowl (mg/mg), and
CWF_{measi}	=	measured concentration of chemical *i* in waterfowl (mg/kg).

The total risk for all chemicals is obtained by summing the individuals values of R_i for each chemical.

The equation used to calculate hazard indices is:

$$\begin{aligned} HI_i = {} & UHIfd1\text{-}ing\text{-}c_i \cdot RF_{WF_i} \cdot CWF_{measi} \\ & + UHIw2\text{-}ing\text{-}c_i \cdot C_{sw\text{-}ti} \\ & + UHIw2\text{-}d\text{-}c_i \cdot C_{sw\text{-}di} \\ & + UHIa2\text{-}inh\text{-}c_i \cdot TF_{swoai} \cdot C_{sw\text{-}di} \end{aligned}$$

The variables in this equation have been defined previously except:

$UHIfd1\text{-}ing\text{-}c_i$	=	unit hazard index for chemical *i* for ingestion of waterfowl (kg/mg)

The unit risks and unit hazard indices are presented in Appendix B4, the transfer factors are in Appendix B3, and the measured concentrations and reduction factors were discussed previously.

Cancer Risks and Hazard Indices

Table 5-54 presents the cancer risks for the hunter using RME assumptions and upper-bound exposure point concentrations, while Table 5-55 presents the chronic hazard indices for this same receptor. Tables 5-56 and 5-57 present the cancer risks and chronic hazard indices for the hunter using RME assumptions and average exposure point concentrations. Tables 5-58 and 5-59 present the cancer risks and chronic hazard indices for the hunter using CTE assumptions and average exposure point concentrations. The table below provides a summary of the cancer risks and hazard indices for the various exposure assumptions.

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Cancer Risks					
RME with Upper-bound Concentrations	6.1E-05	5.3E-05	8.3E-05	5.5E-05	6.1E-05
RME with Average Concentrations	3.2E-05	3.6E-05	3.0E-05	1.6E-05	3.0E-05
CTE with Average Concentrations	9.7E-06	1.1E-05	9.1E-06	4.7E-06	8.9E-06
Hazard Indices					
RME with Upper-bound Concentrations	1.7	2.0	3.1	2.0	2.1
RME with Average Concentrations	0.94	1.3	1.1	0.59	0.84
CTE with Average Concentrations	0.47	0.66	0.57	0.30	0.42

The results above indicate that cancer risks for the hunter exceed a risk of 1.0×10^{-6} for all areas and scenarios with the upper-bound and average concentrations (Tables 5-54 and 5-56). The results by pathway (Tables 5-54, 5-56, and 5-58) indicate that in each case, the cancer risk for the waterfowl ingestion pathway comprises nearly 100 percent of the total risk, and that total PCBs are commonly the driving chemical, being responsible for over 73 percent of the risk in each reach in the Lower Fox River and over 74 percent of the risk in Green Bay.

The hazard indices for several reaches exceed 1.0 under the two RME scenarios; however, the hazard indices are only slightly above this value. In addition, for the CTE scenario, all hazard indices are below 1.0. As with the results for cancer risks, the waterfowl ingestion pathway comprises over 96 percent of the total hazard index and total PCBs are the driving chemical (refer to Tables 5-55, 5-57, and 5-59).

5.7.5 Drinking Water User

Risk and Hazard Index Equations

For the drinking water user, potential exposures occur via ingestion of water, dermal contact with water, and inhalation of indoor air. The equation used to calculate risks for this receptor for chemical *i* is:

$$\begin{aligned} R_i &= URFw1\text{-}ing\text{-}c_i \cdot C_{sw-ti} + URFw2\text{-}ing\text{-}c_i \cdot C_{sw-ti} \\ &+ URFw1\text{-}d\text{-}c_i \cdot C_{sw-di} + URFw2\text{-}d\text{-}c_i \cdot C_{sw-di} \\ &+ URFw1av\text{-}inh\text{-}c_i \cdot TF_{bwai} \cdot C_{sw-di} + URFw2av\text{-}inh\text{-}c_i \cdot TF_{shi} \cdot C_{sw-di} \end{aligned}$$

The variables in this equation have been defined previously except:

$URFw1\text{-}ing\text{-}c_i$	=	unit risk factor for chemical *i* for incidental ingestion of surface water by a young child (L/mg),
$URFw1\text{-}d\text{-}c_i$	=	unit risk factor for chemical *i* for dermal contact with surface water by a young child (L/mg),
$URFw1av\text{-}inh\text{-}c_i$	=	unit risk factor for chemical *i* for inhalation of indoor air by a young child (m^3/mg),
Tf_{bwai}	=	transfer factor for chemical *i* for volatilization from bath water to air (L/m^3),
$URFw2av\text{-}inh\text{-}c_i$	=	unit risk factor for chemical *i* for inhalation of indoor air by an adult (m^3/mg), and
Tf_{shi}	=	transfer factor for chemical *i* for volatilization from shower water to air (L/m^3).

The total risk for all chemicals is obtained by summing the individual values of R_i for each chemical.

The equation used to calculate hazard indices is:

$$\begin{aligned} HI_i &= UHIw1\text{-}ing\text{-}c_i \cdot C_{sw-ti} + UHIw2\text{-}ing\text{-}c_i \cdot C_{sw-ti} \\ &+ UHIw1\text{-}d\text{-}c_i \cdot C_{sw-di} + UHIw2\text{-}d\text{-}c_i \cdot C_{sw-di} \\ &+ UHIw1av\text{-}inh\text{-}c_i \cdot TF_{bwai} \cdot C_{sw-di} + UHIw2av\text{-}inh\text{-}c_i \cdot TF_{shi} \cdot C_{sw-di} \end{aligned}$$

The variables in this equation have been defined previously except:

$UHIw1\text{-}ing\text{-}c_i$	=	unit hazard index for chemical *i* for incidental ingestion of surface water by a young child (L/mg),

$UHIw1\text{-}d\text{-}c_i$	=	unit hazard index for chemical *i* for dermal contact with surface water by a young child (L/mg),
$UHIw1av\text{-}inh\text{-}c_i$	=	unit hazard index for chemical *i* for inhalation of indoor air by a young child (m^3/mg), and
$UHIw2av\text{-}inh\text{-}c_i$	=	unit hazard index for chemical i for inhalation of indoor air by an adult (m^3/mg).

The unit risks and unit hazard indices are presented in Appendix B4, the transfer factors are in Appendix B3, and the measured concentrations were discussed previously.

Cancer Risks and Hazard Indices

Table 5-60 presents the cancer risks for the drinking water user using RME assumptions and upper-bound exposure point concentrations, while Table 5-61 presents the chronic hazard indices for this same receptor. The table below provides a summary of the cancer risks and hazard indices for each reach and for Green Bay.

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Cancer Risks					
RME with Upper-bound Concentrations	2.6E-07	1.6E-07	2.1E-07	3.8E-05	4.2E-08
Hazard Indices					
RME with Upper-bound Concentrations	3.6	0.10	3.2	0.33	0.19

The results above indicate that cancer risks for the drinking water user are below a risk of 1.0×10^{-6} for all areas except the De Pere to Green Bay Reach. The results by pathway (Table 5-60) indicate that for each area, the cancer risk for the direct contact with surface water pathways (ingestion and dermal contact) comprise over 97 percent of the total risk. Total PCBs are the driving chemical for all areas except the De Pere to Green Bay Reach, being responsible for essentially 100 percent of the risk in each area. For the De Pere to Green Bay Reach, arsenic is the driving chemical, contributing over 98 percent of the overall risk. It should be noted that arsenic was detected in only one surface water sample out of four samples collected from this reach, and this was the only sample with detected levels of arsenic in the seven samples from the Lower Fox River. Therefore, the exposure point concentration was based on this single detection of arsenic, and may be overly conservative. Finally, it should also be noted that water from this reach of the Lower Fox River is not used for drinking water.

The hazard indices for two reaches slightly exceed 1.0, while the other two reaches and Green Bay are below this level. As with the results for cancer risks, the direct contact with surface water pathways comprise the majority of the total hazard index. Total PCBs are the driving chemical in the Appleton to Little Rapids Reach (55 percent), while arsenic contributes the most in the De Pere to Green Bay Reach (47 percent), and the other areas are driven by mercury (over 92 percent) (refer to Table 5-61).

Hazard indices above 1.0 in the Little Lake Butte des Morts Reach and the Little Rapids to De Pere Reach are due to mercury. However, the exposure point concentrations for mercury in surface water are based on limited data from the past 10 years. These data include water samples for a variety of permits that utilized generalized methods for mercury analysis, not analytical methods targeted specifically to quantitate mercury concentrations at low levels. A recent study by Hurley *et al.* (1998) presented the results of surface water and sediment sampling that was targeted specifically at mercury in the Lower Fox River and utilized analytical methods that allowed low concentrations of mercury to be quantitated. The study by Hurley *et al.* (1998) measured water concentrations at several locations in the Lower Fox River over time. Samples collected between 1994 and 1996 from several locations along the Lower Fox River indicated a range of total mercury concentrations from 0.0018 to 0.182 μg/L, with an average concentration of 0.0292 μg/L. In contrast, the detected total mercury concentrations included in the Lower Fox River database used in this risk assessment ranged from 0.0002 to 7.14 μg/L with an average of 3.4 μg/L. Since the mercury data from the study by Hurley *et al.* (1998) is more comprehensive than the data assembled for the Lower Fox River database and the data of Hurley *et al.* (1998) was collected to specifically measure mercury at low concentrations, an additional evaluation of the hazard indices to the drinking water user has been conducted, utilizing the maximum detected concentration of mercury in the Lower Fox River from the more recent data from Hurley *et al.* (1998) as a cap to the exposure point concentration in each area. If the exposure point concentration exceeded the 0.182 μg/L measured by Hurley *et al.* (1998), then this value was included in the hazard index calculation. This was done for dissolved mercury concentrations as well as total concentrations, which is quite conservative because the data from Hurley *et al.* (1998) indicate dissolved concentrations remain somewhat constant around 0.001 μg/L.

The results based on the mercury data from Hurley *et al*. (1998) are presented in Table 5-62 and are summarized below. The first row restates the total hazard indices calculated with the data from the Lower Fox River database while the second row presents the total hazard indices calculated with mercury data from Hurley *et al.* (1998).

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Hazard Indices					
RME with Upper-bound Concentrations	3.6	0.10	3.2	0.33	0.19
RME with Upper-bound Concentrations and Recent Mercury Data	0.18	0.10	0.16	0.33	0.19

The hazard indices for the drinking water user are below 1.0 when incorporating the more recent mercury data from Hurley *et al.* (1998).

5.7.6 Local Resident

Risk and Hazard Index Equations

For the local resident, potential exposures occur via inhalation of outdoor air. The equation used to calculate risks for this receptor for chemical *i* is:

$$R_i = URFa1\text{-}inh\text{-}c_i \cdot TF_{swoai} \cdot C_{sw\text{-}di} + URFa2\text{-}inh\text{-}c_i \cdot TF_{swoai} \cdot C_{sw\text{-}di}$$

The variables in this equation have been defined previously except:

$URFa1\text{-}inh\text{-}c_i$ = unit risk factor for chemical *i* for inhalation of outdoor air by a young child (m^3/mg)

The equation used to calculate hazard indices is:

$$HI_i = UHIa1\text{-}inh\text{-}c_i \cdot TF_{swoai} \cdot C_{sw\text{-}di} + UHIa2\text{-}inh\text{-}c_i \cdot TF_{swoai} \cdot C_{sw\text{-}di}$$

The variables in this equation have been defined previously except:

$UHIa1\text{-}inh\text{-}c_i$ = unit hazard index for chemical *i* for inhalation of outdoor air by a young child (m^3/mg)

The unit risks and unit hazard indices are presented in Appendix B4, the transfer factors are in Appendix B3, and the measured concentrations were discussed previously.

Cancer Risks and Hazard Indices

Table 5-63 presents the cancer risks for the local resident using RME assumptions and upper-bound exposure point concentrations, while Table 5-64 presents the chronic hazard indices for this same receptor. The table below provides a summary of the cancer risks and hazard indices for each reach and for Green Bay.

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Cancer Risks					
RME with Upper-bound Concentrations	1.2E-07	6.8E-08	8.8E-08	1.3E-07	3.8E-08
Hazard Indices					
RME with Upper-bound Concentrations	3.8	0.043	1.2	0.004	0.24

The results above indicate that cancer risks for the local resident are well below a risk of 1.0×10^{-6} for all areas. Inhalation of volatiles in outdoor air is the only applicable pathway for this receptor, and total PCBs are the only carcinogenic volatile constituents present in outdoor air (refer to Table 5-63). Similarly, total mercury is the only volatile constituent present in outdoor air having an inhalation reference dose. The hazard indices for the Appleton to Little Rapids Reach, De Pere to Green Bay Reach, and for Green Bay are below the target hazard index of 1.0, while the hazard indices for the local resident in the other areas slightly exceed 1.0 (refer to Table 5-64).

Elevated hazard indices for the Little Lake Butte des Morts Reach, the Little Rapids to De Pere Reach, and Green Bay are due to mercury. However, as discussed in Section 5.7.5, the concentrations of mercury in surface water used in the exposure calculations are based on limited data from the past 10 years. Therefore, an additional evaluation of the hazard indices to the local resident has been conducted, utilizing the maximum detected concentration of mercury in the Lower Fox River from the more recent and comprehensive study by Hurley *et al.* (1998) to cap the surface water concentrations of each area. If the dissolved or total concentration of mercury exceeded the maximum total concentration of mercury of 0.182 μg/L measured by Hurley *et al.* (1998), then this value was used as the surface water concentration and the hazard indices were recalculated.

The results based on the more recent mercury data are presented in Table 5-65 and are summarized below. The first row restates the total hazard indices calculated with the data from the Lower Fox River database while the second row presents the total hazard indices calculated with mercury data from Hurley *et al.* (1998).

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Hazard Indices					
RME with Upper-bound Concentrations	3.8	0.043	1.2	0.004	0.24
RME with Upper-bound Concentrations and Recent Mercury Data	0.097	0.043	0.086	0.004	0.24

The hazard indices for the local resident are below 1.0 when incorporating the more recent mercury data from Hurley *et al.* (1998).

5.7.7 Recreational Water User

Risk and Hazard Index Equations

For both recreational water users (swimmer and wader), potential exposures occur via incidental ingestion of water, dermal contact with water, inhalation of outdoor air, ingestion of sediment, and dermal contact with sediment or sediment pore water. Assuming dermal contact with sediment, the equation used to calculate risks for this receptor for chemical i is:

$$\begin{aligned} R_i = {} & URFw2\text{-}ing\text{-}c_i \cdot C_{sw\text{-}ti} + URFw2\text{-}d\text{-}c_i \cdot C_{sw\text{-}di} \\ & + URFa2\text{-}inh\text{-}c_i \cdot TF_{swoai} \cdot C_{sw\text{-}di} \\ & + URFsd1\text{-}ing\text{-}c_i \cdot C_{sedi} + URFsd1\text{-}d\text{-}c_i \cdot C_{sedi} \end{aligned}$$

The variables in this equation have been defined previously except:

$URFsd1\text{-}ing\text{-}c_i$ = unit risk factor for chemical i for ingestion of sediment (kg/mg), and

$URFsd1\text{-}d\text{-}c_i$ = unit risk factor for chemical i for dermal contact with sediment (kg/mg).

Assuming dermal contact with sediment pore water, the equation used to calculate risks for chemical i is the same as that above with the exception of the final expression, which is replaced by

$$URFw3{-}d{-}c_i \cdot TF_{sdpwi} \cdot C_{sedi}$$

where:

$URFw3\text{-}d\text{-}c_i$ = unit risk factor for chemical *i* for dermal contact with sediment pore water (L/mg), and

Tf_{sdpwi} = transfer factor for chemical *i* for sediment to pore water (kilograms per liter [kg/L]).

The equation used to calculate hazard indices is:

$$\begin{aligned} HI_i = {} & UHIw2{-}ing{-}c_i \cdot C_{sw-ti} + UHIw2{-}d{-}c_i \cdot C_{sw-di} \\ & + UHIa2{-}inh{-}c_i \cdot TF_{swoai} \cdot C_{sw-di} \\ & + UHIsd1{-}ing{-}c_i \cdot C_{sedi} + UHIsd1{-}d{-}c_i \cdot C_{sedi} \end{aligned}$$

The variables in this equation have been defined previously except:

$UHIsd1\text{-}ing\text{-}c_i$ = unit hazard index factor for chemical *i* for ingestion of sediment (kg/mg), and

$UHIsd1\text{-}d\text{-}c_i$ = unit hazard index for chemical *i* for dermal contact with sediment (kg/mg).

As indicated above for the cancer risk equation, the final expression in the above equation is replaced if dermal contact with sediment pore water is evaluated rather than dermal contact with sediment, as follows:

$$UHIw3{-}d{-}c_i \cdot TF_{sdpwi} \cdot C_{sedi}$$

where:

$UHIw3\text{-}d\text{-}c_i$ = unit hazard index for chemical *i* for dermal contact with sediment pore water (L/mg)

The unit risks and unit hazard indices are presented in Appendix B4, the transfer factors are in Appendix B3, and the measured concentrations were discussed previously.

Cancer Risks and Hazard Indices

Table 5-66 presents the cancer risks for the swimmer (recreational water user) using RME assumptions and upper-bound exposure point concentrations, while Table 5-67 presents the chronic hazard indices for this same receptor. The table below provides a summary of the cancer risks and hazard indices for each reach and for Green Bay.

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Cancer Risks					
RME with Upper-bound Concentrations	2.2E-07	7.3E-08	8.1E-08	2.0E-07	5.2E-08
Hazard Indices					
RME with Upper-bound Concentrations	0.059	0.008	0.022	0.015	0.004

The results above indicate that cancer risks for the swimmer are well below a risk of 1.0×10^{-6} for all areas. The results by pathway (Table 5-66) indicate that the cancer risk for the direct contact with sediment pathways (incidental ingestion and dermal contact) comprise the majority of the total risk for all reaches in the Lower Fox River (between 65 and 91 percent) and for Green Bay (92 percent). Arsenic is the driving chemical for the De Pere to Green Bay Reach and Green Bay, being responsible for 58 and 86 percent of the total risk in each area. In the other reaches, total PCBs drives the risk, comprising from 64 to 77 percent of the total risk.

The results above also indicate that hazard indices for the swimmer are well below 1.0 for all reaches. The results by pathway (Table 5-67) indicate that the hazard indices for the direct contact with surface water pathways (incidental ingestion and dermal contact) comprise the majority of the total hazard index for the De Pere to Green Bay Reach (71 percent). The hazard indices for the direct contact with sediment pathways (incidental ingestion and dermal contact) comprise the majority of the total hazard index for the Appleton to Little Rapids and Little Rapids to De Pere reaches (74 and 44 percent). The volatile inhalation pathway comprises the majority of the hazard index for the Little Lake Butte des Morts Reach and Green Bay (55 and 45 percent). Total PCBs are the driving chemicals for the Appleton to Little Rapids, Little Rapids to De Pere, and De Pere to Green Bay reaches, being responsible for between 63 and 96 percent of the total hazard index in each area. The remaining areas are driven by mercury (50 to 59 percent).

Tables 5-68 and 5-69 present the cancer risks and chronic hazard indices for the wader (recreational water user), also using RME assumptions and upper-bound exposure point concentrations. The table below provides a summary of the cancer risks and hazard indices for each reach and for Green Bay.

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Cancer Risks					
RME with Upper-bound Concentrations	5.0E-07	9.9E-08	1.1E-07	2.5E-07	7.4E-08
Hazard Indices					
RME with Upper-bound Concentrations	0.11	0.010	0.019	0.022	0.003

The results above indicate that cancer risks for the wader are well below a risk of 1.0×10^{-6} for all areas. The results by pathway (Table 5-68) indicate that for all areas, the cancer risk for the direct contact with sediment pathways comprise over 97 percent of the total risk. For the wader, arsenic is the driving chemical for the De Pere to Green Bay Reach and Green Bay, being responsible for 63 and 90 percent, respectively, of the total risk. For the other reaches, total PCBs drive the risk, comprising between 69 and 84 percent of the total risk.

The results above also indicate that hazard indices for the wader are well below 1.0 for all areas. The results by pathway (Table 5-69) indicate that for all areas, the hazard indices for the direct contact with sediment pathways comprise 83 percent or more of the total hazard index. Total PCBs is the driving chemical for all areas, being responsible for 54 to 97 percent of the total hazard index in each area.

5.7.8 Marine Construction Worker

Risk and Hazard Index Equations

For the marine construction worker, potential exposures occur via incidental ingestion of water, dermal contact with water, inhalation of outdoor air, ingestion of sediment, and dermal contact with sediment. The equations used to calculate risks and hazard indices are identical to those presented above for the recreational water user (not including the option for dermal contact with sediment pore water).

The unit risks are presented in Appendix B4, the transfer factors are in Appendix B3, and the measured concentrations were discussed previously.

Cancer Risks and Hazard Indices

Table 5-70 presents the cancer risks for the marine construction worker using RME assumptions and upper-bound exposure point concentrations, while Table 5-71 presents the chronic hazard indices for this same receptor. The table below provides a summary of the cancer risks and hazard indices for each reach and for Green Bay.

Exposure Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Cancer Risks					
RME with Upper-bound Concentrations	1.5E-06	2.2E-07	2.8E-07	5.5E-07	1.5E-07
Hazard Indices					
RME with Upper-bound Concentrations	0.27	0.011	0.065	0.018	0.012

The results above indicate that cancer risks for the marine construction worker are below a risk of 1.0×10^{-6} for all but two areas. The calculated cancer risks slightly exceed the 10^{-6} level in the Little Lake Butte des Morts and Appleton to Little Rapids reaches. The results by pathway (Table 5-70) indicate that for each area, the cancer risk for the direct contact with sediment pathways (incidental ingestion and dermal contact) comprise over 96 percent of the total risk. Total PCBs are the driving chemical for the Little Lake Butte des Morts Reach, the Little Rapids to De Pere Reach, and the Appleton to Little Rapids Reach, being responsible for 74 to 88 percent of the total risk in each area. In the De Pere to Green Bay Reach and Green Bay, arsenic drives the risk with 53 and 85 percent of the total.

Hazard indices for each reach and for Green Bay are well below 1.0. The direct contact with sediment pathways comprise the majority (50 to 97 percent) of the total hazard index for the Appleton to Little Rapids, Little Rapids to De Pere, and De Pere to Green Bay reaches. For the other areas, the volatile inhalation pathway comprises the majority of the hazard index (60 to 75 percent). Total PCBs are the driving chemicals for the Appleton to Little Rapids and De Pere to Green Bay reaches, comprising 94 and 86 percent of the total hazard index for each area (refer to Table 5-71). Mercury is the driving chemical for the Little Lake Butte des Morts Reach, Little Rapids to De Pere Reach, and Green Bay, contributing 52 to 79 percent of the total hazard index.

5.7.9 Summary of Cancer Risks and Hazard Indices

In order to provide a comparison among all receptors and all reaches of the Lower Fox River and Green Bay, summary tables of the cancer risks and hazard indices have been included as Tables 5-72 and 5-73, respectively. This information is also presented graphically (by area) in Figures 5-2 through 5-11.

Cancer risks exceeding 1.0×10^{-6} were identified for the recreational anglers, high-intake fish consumers, hunters, and drinking water users. Cancer risks for the marine construction worker slightly exceed the 1.0×10^{-6} level in the Little Lake Butte des Morts Reach. Cancer risks as high as 3.8×10^{-3} were calculated for high-intake fish consumers, while risks as high as 2.8×10^{-3} were calculated for recreational anglers. There are relatively small differences in the RME risks between these two populations. These values are 45 and 34 times greater than the next highest risks calculated for any other receptor; the receptor with the next highest risks being the hunter with a risk of 8.3×10^{-5}. For the recreational anglers and high-intake fish consumers, the cancer risks are driven by the ingestion of PCBs in fish tissue (over 80 percent for reaches of the Lower Fox River and over 68 percent in Green Bay). For the hunters, the cancer risks are driven by the ingestion of PCBs in waterfowl tissue. The risks to drinking water users exceed the 10^{-6} level only in the De Pere to Green Bay Reach (3.8×10^{-5}). This exceedance is due to arsenic, and the arsenic concentration used in the calculation is the value detected in one of four water samples from this reach. Arsenic was detected only once in the seven samples collected from the Lower Fox River, so it is quite possible that actual arsenic concentrations are lower than those used in this analysis; therefore, the risks associated with arsenic in this reach may be overstated. Additionally, the water in this reach is not currently used as a source of drinking water and there are no plans to use it as such in the foreseeable future (this reach of the Lower Fox River is not classified for use as a source of drinking water).

Noncancer hazard indices exceeding 1.0, which indicate the potential for adverse effects, have been identified for the recreational anglers, high-intake fish consumers, hunters, drinking water users, and local residents. While the hazard indices for the hunter, drinking water user, and local resident exceed 1.0, the maximum calculated hazard index for these receptors was 3.8, only slightly above 1.0. In comparison, hazard indices for the high-intake fish consumers and recreational anglers reach maximum values of 147 and 107, respectively, more than two orders of magnitude above 1.0. As found for cancer risks, there are not large differences in the maximum hazard indices between the two populations of fish consumers. Exposure to PCBs in fish is responsible for over 86 percent of the hazard index for recreational anglers and high-intake fish consumers in the Lower Fox River and over 88 percent of the hazard index for recreational anglers and high-intake fish consumers in Green Bay. For the hunter, PCBs are responsible for over 95 percent of the total hazard index in the Lower Fox River and over 91 percent of the total hazard index in Green Bay.

Noncancer hazard indices exceeding 1.0 for the drinking water user and local resident are due to mercury. The mercury surface water concentrations in the

Lower Fox River database were obtained from a variety of sources that did not necessarily use analytical methods intended to quantitate low concentrations of this chemical. The study by Hurley *et al.* (1998) measured dissolved and total mercury in surface water from several locations on the Lower Fox River with much finer temporal resolution than the data included in the Fox River database. When using more recent mercury data in the hazard index calculations for the drinking water user and local resident, the resulting hazard indices were below 1.0.

EPA guidance for risk characterization (EPA, 1995b, 1995c) indicates that an important step in the risk characterization process is the identification of subpopulations that may be highly exposed or highly susceptible. This evaluation of cancer risks and noncancer hazard indices indicates that the receptors with the highest risks and hazard indices are recreational anglers and high-intake fish consumers. Since calculated cancer risks exceed the 10^{-6} level by more than three orders of magnitude and calculated hazard indices exceed 1.0 by up to two orders of magnitude, the number of people included in these subpopulations is important to consider.

As was previously noted in Section 5.4.3, there are approximately 136,000 individuals with fishing licenses (WDNR, 1999d) living in communities adjacent to the Lower Fox River and Green Bay. The entire population of this area is estimated to be on the order of 640,000 (Census Bureau, 1992), which indicates that as many as 21 percent of the residents are active anglers. The most highly exposed recreational anglers are estimated to be about 10 percent (greater than the upper 90th percentile) of the licensed angler population, or about 14,000 anglers. In addition to licensed anglers, their family members (who may not be licensed anglers) can be exposed to PCBs in fish. The population of high-intake fish consumers, the most highly exposed subpopulation evaluated in this risk assessment, includes about 3,800 persons considered low-income minority anglers, 1,200 Hmong anglers residing in the Green Bay area, and 6,800 Oneida living in the Lower Fox River, Green Bay, and Milwaukee areas. For the recreational anglers and high-intake fish consumers, the exposure route of primary concern is ingestion of fish containing PCBs. The calculated cancer risks were as high as 2.8×10^{-3} for the recreational angler and 3.8×10^{-3} for the high-intake fish consumer. This is about three orders of magnitude above the risk level of 10^{-6}. Put differently, this represents a chance of approximately four in 1,000 that an individual could contract cancer in their lifetime as a result of consuming fish caught from the Lower Fox River or Green Bay. This estimate is actually an upper 95 percent confidence limit of the probability, and the actual risks may be much lower.

The calculated hazard indices were as high as 107 for the recreational angler and 147 for the high-intake fish consumer, again not showing large differences between these two groups. As discussed in Section 5.6.2, the noncancer health effects associated with exposure to PCBs include reproductive effects (e.g., conception failure in highly-exposed women [Courval *et al.*, 1997]), developmental effects (e.g., neurological impairments in highly-exposed infants and children [Lonky *et al.*, 1996; Jacobson and Jacobson, 1996; Huisman *et al.*, 1995a, 1995b; Lanting *et al.*, 1998; Koopman-Esseboom *et al.*, 1996]), and immune system suppression (e.g., increased incidence of infectious disease in highly-exposed infants [Smith, 1984; Humphrey, 1988], effects on T-cell counts in adults and infants [Tryphonas, 1995; Weisglas-Kuperus *et al.*, 1995] or the possibility of increased susceptibility to infectious diseases in children exposed prenatally to PCBs and dioxins [Weisglas-Kuperus *et al.*, 2000]). All of these noncancer health effects are extensively documented in animal studies (ATSDR, 1997).

Population estimates for hunters are more difficult to define. The Wisconsin Department of Natural Resources estimated that there are approximately 3,000 individuals in Brown County with licenses to hunt waterfowl. Brown County includes the city of Green Bay and has a population of about 200,000 people (Census Bureau, 1992). Assuming that the same ratio of licenses to people applies elsewhere in the Green Bay to Lake Winnebago corridor where the overall population is 640,000 people, the number of individuals licensed to hunt waterfowl in the Lower Fox River/Green Bay area is about 9,600 people. For the hunter, the exposure route of primary concern is the ingestion of waterfowl containing PCBs. The calculated risks for this receptor were as high as 8.3×10^{-5}, slightly less than two orders of magnitude above the risk level of 10^{-6}. This represents a chance of one in 10,000 that an individual could contract cancer as a result of consuming hunted waterfowl. The hazard indices were as high as 3.1, which is about three times greater than the value of 1.0. The noncancer health effects associated with exposure to PCBs for the hunter are similar to those described previously for recreational and high-intake fish consumers.

The angling subpopulations (recreational anglers and high-intake fish consumers) have been identified as the most highly-exposed receptor populations. In addition, the elevated cancer risks and noncancer hazard indices are attributable mainly to PCB exposure via fish ingestion. Consequently, to further evaluate these subgroups, a focused evaluation of exposure to PCBs in fish by recreational anglers and high-intake fish consumers is presented in Section 5.9.

5.8 Evaluation of Lead

Based on an evaluation of data available at the time, lead was identified as a chemical of potential concern in the Screening Level Risk Assessment (RETEC, 1998b). Since then, more data from the Lower Fox River and Green Bay, as well as background and reference data, have become available. This section will provide an evaluation of all existing lead data to determine whether or not lead is likely to pose a significant risk to human health.

5.8.1 Sediment

Several surface sediment samples were analyzed for lead from the Little Lake Butte des Morts, Appleton to Little Rapids, Little Rapids to De Pere, and De Pere to Green Bay reaches. In addition, samples from background and reference locations (including Lake Winnebago) were analyzed for lead. Table 5-74 summarizes the lead data for surface sediment samples.

The human health screening criteria for contact with lead used in the Screening Level Risk Assessment (RETEC, 1998b) was the value for residential soil of 400 mg/kg (EPA, 1996e). Little Lake Butte des Morts and Little Rapids to De Pere were the only reaches which contain a maximum lead concentration exceeding this screening value. For the Little Rapids to De Pere Reach, the maximum detected concentration of lead was 1,400 mg/kg. The next highest detection in this area is 297 mg/kg, which is well below the screening value. The average lead concentration in surface sediments from the Little Rapids to De Pere Reach was 159 mg/kg, also well below the screening value. For the Little Lake Butte des Morts Reach, three out of 27 samples exceeded the 400 mg/kg screening value. However, the maximum detected concentration of lead was 522 mg/kg, only slightly above the screening value. The average lead concentration in surface sediments from the Little Lake Butte des Morts Reach was 171 mg/kg, well below the screening value.

Based on these results, it is unlikely that the lead concentrations detected in sediments from the Lower Fox River would pose a direct contact risk to human health. Only four samples out of 157 on-site surface sediment samples contained concentrations exceeding the screening value. In addition, this screening value is conservative in that it is protective of daily soil contact by a young child in a residential setting. Exposure to sediments of the Lower Fox River is significantly less than residential soil exposure. Therefore, no further evaluation of direct contact exposure to lead in sediments is warranted for the human health risk assessment.

5.8.2 Surface Water

A number of surface water samples have been collected from the Lower Fox River and from intakes at several of the industries along the river. Both filtered and unfiltered data are available for the river samples, while only unfiltered samples are available for the intake samples. Lead was detected in each sample collected at concentrations ranging from non-detect to 5.3 μg/L (the maximum concentration from the filtered samples was 0.124 μg/L).

A comparison of the detected concentrations to the screening criteria available for lead in surface water indicate that lead is not present in concentrations that might pose a risk to human health. The action level for lead in water is 15 μg/L (EPA, 2000b) and is intended to be protective of individuals (including young children) who drink the water on a daily basis. EPA (1993b) also provides an ambient water quality criterion of 50 μg/L for human health. The maximum concentrations in both filtered and unfiltered water samples are below each of these screening criteria. Although water from the Lower Fox River is not routinely used as a drinking water source, these data indicate that such use of the water would not result in unacceptable exposure to lead. Therefore, no further evaluation of direct exposure to lead in surface water is warranted for the human health risk assessment.

5.8.3 Fish Tissue

Several fish tissue samples were analyzed for lead from the Little Lake Butte des Morts and De Pere to Green Bay reaches, and from Green Bay. The majority of these were whole fish samples, but a small percentage of fillet samples were available as well. Samples were collected between 1977 and 1986 and included a wide variety of fish species and types (e.g., bottom feeders, predators, pelagic fish).

The analyses consistently report a detection limit of 5 mg/kg (with one exception of 0.5 mg/kg). Out of 111 samples, eight (or 7.2 percent) were reported as detections; however, every one of these detections was also equal to 5 mg/kg. Essentially, lead was not detected in any of the fish tissue samples at a concentration above the reporting limit. This is not an unusual finding, as the detected concentrations in both sediment and surface water were relatively low, and lead does not significantly bioaccumulate. For these reasons, no further evaluation of lead in fish tissue is warranted for the human health risk assessment.

5.8.4 Waterfowl Tissue

In 1984, 12 tissue (muscle) samples from a variety of waterfowl were collected and analyzed for lead. These samples were collected from locations near Little

Lake Butte des Morts, Green Bay, and reference locations (including Dunbar and Navarino Wildlife Areas). Lead was not detected in any of these samples, which all reported detection limits of 5 mg/kg. In 1996, 10 tissue samples (of unknown type) from Canada geese were collected from the Green Bay area and various other reference locations (including Milwaukee and Hurakon). Lead was detected in the Green Bay samples at concentrations ranging from 0.05 to 0.09 mg/kg. The concentrations of lead in the reference location samples ranged from 0.03 to 0.13 mg/kg.

The detected concentrations of lead in waterfowl from the Green Bay area are similar to those from reference and background locations. In addition, due to the migratory nature of Canada geese, these concentrations would be nearly impossible to attribute to any one location. Therefore, no further evaluation of lead in waterfowl tissue is warranted for the human health risk assessment.

5.9 Focused Evaluation of Exposures to PCBs from Fish Ingestion

In Section 5.7, cancer risks and noncancer hazard indices were calculated for a variety of receptors. The receptors with the highest cancer risks and hazard indices were recreational anglers and high-intake fish consumers, and almost all the cancer risk and hazard index were due to exposure to PCBs from ingestion of fish. In this section, a focused evaluation of exposure to PCBs via ingestion of fish is performed.

The section begins by reviewing fish tissue data (Section 5.9.1). Next, the equations used to estimate exposure to total PCBs from ingestion of fish and their associated risks are presented (Section 5.9.2). Then, fish intake assumptions for recreational anglers and high-intake fish consumers based on data provided in Section 5.4.3 are reviewed (Section 5.9.3). These assumptions are used to calculate cancer risks and hazard indices for these receptors to illustrate the sensitivity of cancer risks and hazard indices to different assumptions (Section 5.9.4). The exposure assumptions in the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.*, 1993) are also presented along with cancer risks and hazard indices associated with these assumptions (Section 5.9.5).

Many of the exposure assumptions used to calculate exposure are derived from probability distributions. These distributions may reflect variability, uncertainty, or both. A probabilistic risk assessment of the assumptions used for the recreational angler and high-intake fish consumer is presented in Appendix B1 and is summarized in Section 5.9.6. This appendix also includes an evaluation of the assumptions used by Exponent (2000) in their risk assessment of angler exposure to PCBs in fish from the Lower Fox River. The Exponent (2000) risk assessment was performed for the Fox River Group. The evaluation of the Exponent (2000) risk assessment is summarized in Section 5.9.7.

Section 5.9.8 presents a qualitative and quantitative discussion of potential exposures of PCBs to young children, a population sensitive to PCB exposure due to possible developmental health effects. Finally, risk-based concentrations in fish are calculated for different cancer risk and hazard index values (Section 5.9.9).

5.9.1 Concentrations of Total PCBs in Fish

The database of fish tissue concentrations (fillet and skin) for total PCBs includes samples from the species listed in Table 5-75. The most widely fished species include walleye, bass (especially white bass), perch, trout, and salmon, although all the species in Table 5-75 may be caught and eaten.

The concentrations of PCBs in fish over time were examined in Section 2. Different species and sample types (whole body and skin-on fillet) were analyzed over the reaches of the Lower Fox River and zones of Green Bay. The fish concentration data were fitted either with a double exponential function, or a single exponential function (whichever fit the data better). Approximately half of the data sets were best fitted by a double exponential function, and half were best fitted by a single exponential function.

In many cases, the concentrations in fish declined with time. In some cases, the concentrations remained essentially constant over time and in a few cases, the concentrations in fish appeared to increase. For the risk analyses conducted, the concentrations of PCBs in fish are assumed to be constant over time. Such an approach is appropriately conservative and protective of human health. While it might be possible to predict future PCB concentrations in fish, there is substantial uncertainty in such projections. First, historical trends may not be accurate predictors of future trends. The fact that some time trends fit a double exponential function where the concentrations declined at a faster rate in the early eighties than in the late nineties suggests that future declines could be at an even slower rate. Second, the historical data is typically available for a period of 15 to 25 years, whereas the exposure periods of interest are 30 to 50 years. Thus, using historical data to predict future concentrations requires the additional assumption that the historical data will accurately reflect future concentrations over future time periods that are two to three times longer than the historical time period. The use of historical data from a 25-year period to predict concentrations over the next 5 years will give far more reliable results than the use of this same historical data to predict concentrations over the next 50 years. Third, there is not sufficient data to evaluate time trends in every species that people typically eat for every reach of the Lower Fox River and every zone of Green Bay.

The remainder of this section discusses concentrations of PCBs in fish using the most recent data (i.e., data from 1989 or 1990 to the present). Table 5-76 presents total PCB concentration data for each reach of the Lower Fox River. The data are summarized for all fish samples and for carp, perch (including white perch and yellow perch), walleye, and white bass. For each group, data are presented for all samples, including all samples collected in the 1990s. The data for the De Pere to Green Bay Reach include fish samples from this reach and from Zone 2 of Green Bay. Since these two areas provide similar habitat and fish can swim freely between them, the fish from the two areas were combined. The data for walleye are from 1989 on for the De Pere to Green Bay Reach. The following statistics are provided: the number of samples, the number of samples where PCBs were detected, the minimum detected concentration, the median or 50th percentile concentration, the average concentration, the 95th percentile concentration, the maximum detected concentration, and the standard deviation. These data indicate that the average concentrations for all fish samples in the 1990s are lower than the average of all fish samples by factors ranging from 1.8 to 4.4 in the various reaches of the Lower Fox River.

For the Appleton to Little Rapids Reach, no carp fillet samples were available from the 1990s data. However, carp whole body samples were available for this reach. As discussed in Section 7, a fillet-to-whole body ratio of 0.53 was developed for carp. This ratio was multiplied by the whole body concentration to estimate a fillet concentration. Table 5-77 presents the number of fillet samples, average fillet concentration, number of whole body samples, and average whole body concentration for each reach of the Lower Fox River and each zone of Green Bay. Table 5-77 also presents the result of using the whole body concentration multiplied by the fillet-to-whole body ratio to estimate the fillet concentration. For the Appleton to Little Rapids Reach, the mean total PCB fillet concentration was estimated to be 1.368 mg/kg. This value was used in the risk calculations for the Appleton to Little Rapids Reach.

Table 5-78 presents total PCB concentration data in Green Bay. As with the Lower Fox River, the data are summarized for all fish samples, and for carp, perch, walleye, and white bass. For each group except all fish samples and walleye, data are presented for all samples, including all samples collected in the 1990s. For walleye, the data from 1989 are included in the data set for the 1990s. The walleye data from 1989 are also included in the all fish sample data set. These data indicate that the average concentrations for all fish samples in the 1990s are lower than the average of all fish samples by factors ranging from 1.6 to 3.4 in the zones of Green Bay.

To provide perspective on the fish concentration data, fish concentrations in Lake Winnebago were examined. Table 5-79 presents the available fillet-on-skin fish data for Lake Winnebago. The average concentration of PCBs in Lake Winnebago fish is 63 μg/kg. For all fish samples in the 1990s in the various reaches of the Lower Fox River, the average concentrations range from 603 μg/kg to 1,344 μg/kg. In Green Bay zones, the average concentrations range from 907 μg/kg to 1,268 μg/kg. These concentrations are nine to 21 times higher than the background concentration of 63 μg/kg.

5.9.2 Equations for Calculating Cancer Risks, Hazard Indices, and Target Concentrations in Fish

This section presents the equations used to calculate cancer risks and hazard indices from ingestion of fish. These are essentially a restatement of the equations presented in Section 5.4.2. Also presented in this section are the equations used to calculate target concentrations in fish tissue (i.e., concentrations in fish associated with a particular cancer risk or hazard index level).

Cancer Risk Evaluation

The equation used to assess cancer risks from ingestion of fish is:

$$R = I \cdot CSFo$$

where:

R	=	cancer risk,
I	=	intake from ingestion of fish averaged over a lifetime (mg/kg-day), and
CSFo	=	oral cancer slope factor [$(\text{mg/kg-day})^{-1}$].

The intake from fish ingestion averaged over a lifetime is given by:

$$I = \frac{Cfish \cdot IR \cdot RF \cdot ABS \cdot CF \cdot EF \cdot ED}{BW \cdot ATc}$$

where:

Cfish	=	concentration in fish (mg/kg),
IR	=	fish ingestion rate (g/day),
RF	=	reduction factor due to trimming and cooking fish (mg/mg),
ABS	=	absorption factor for ingestion of fish (mg/mg),

CF = 10^{-3} kg/g,
EF = exposure frequency (days/yr),
ED = exposure duration (years),
BW = body weight (kg), and
ATc = averaging time for cancer risks (days).

The intake equation can be rewritten as:

$$I = Cfish \cdot IntFacC$$

$$IntFacC = \frac{IR \cdot RF \cdot ABS \cdot CF \cdot EF \cdot ED}{BW \cdot ATc}$$

where:
$IntFacC$ = intake factor for cancer risk $[(mg/kg)^{-1}]$

The equation for assessing cancer risks from ingestion of fish can be rewritten as:

$$R = Cfish \cdot IntFacC \cdot CSFo$$

This equation can be rearranged to give the fish concentration for a particular target risk (*TR*):

$$Cfish = \frac{TR}{IntFacC \cdot CSFo}$$

Noncancer Effects Evaluation

The equation for calculating the chronic hazard index from ingestion of fish is:

$$HI = \frac{I}{RfDo}$$

where:
HI = chronic, noncancer hazard index,
I = intake from ingestion of fish averaged over the exposure period (mg/kg-day), and
$RfDo$ = oral reference dose for chronic, noncancer effects (mg/kg-day).

The intake from fish ingestion averaged over the exposure period is given by:

$$Inc = \frac{Cfish \cdot IR \cdot RF \cdot ABS \cdot CF \cdot EF \cdot ED}{BW \cdot ATnc}$$

These variables are the same as before except:

ATnc = averaging time for chronic, noncancer effects (days)

The intake equation can be rewritten:

$$I = Cfish \cdot IntFacNC$$

$$IntFacNC = \frac{IR \cdot RF \cdot ABS \cdot CF \cdot EF \cdot ED}{BW \cdot ATnc}$$

where:

IntFacNC = intake factor for chronic, noncancer effects $[(mg/kg)^{-1}]$

The equation for calculating the chronic hazard index from ingestion of fish can be rewritten as:

$$HI = \frac{Cfish \cdot IntFacNC}{RfDo}$$

This equation can be rearranged to give the fish concentration for a particular target hazard index (*THI*):

$$Cfish = \frac{THI \cdot RfDo}{IntFacNC}$$

5.9.3 Intake Assumptions for Recreational Anglers and High-intake Fish Consumers and Toxicological Parameters

This section presents the intake assumptions and toxicological parameters used to solve the previously defined equations for recreational anglers and high-intake fish consumers. Table 5-80 presents the values for the recreational anglers. Intake assumptions for a reasonable maximum exposure (RME) scenario and for a central tendency exposure (CTE) scenario are presented for three studies of fish ingestion: the 1989 and 1993 surveys of Michigan anglers by West *et al.* (1989, 1993) and the 1989 survey of Wisconsin anglers by Fiore *et al.* (1989).

Also included in Table 5-80 are assumptions based on an average of the 1989 and the 1993 survey of Michigan anglers. All parameters in Table 5-80 except *IR* (the average daily fish ingestion rate) are identical for the two studies. Thus, for the case entitled “Average of Michigan Studies,” the *IR* values from the 1989 and

1993 studies were averaged. These average values were used to calculate exposures to the recreational angler in the baseline risk characterization presented in Section 5.7. The rationale for this averaging is discussed in Section 5.4.3.

Table 5-81 provides the values for the high-intake fish consumers. Intake assumptions for an RME scenario and a CTE scenario are presented for three subpopulations: low-income minority high-intake fish consumers using data from West *et al.* (1993); Native American high-intake fish consumers using data from Fiore *et al.* (1989) that were modified as described in Section 5.3; and Hmong high-intake fish consumers using data from Hutchison and Kraft (1994). The data from Hutchison and Kraft (1994) are used for the Hmong rather than the data from Hutchison (1998), because the study by Hutchison and Kraft (1994) examined fishing patterns by Hmong from all locations (i.e., all reaches of the Lower Fox River and Green Bay as well as other locations such as Lake Winnebago) while the study by Hutchison (1998) only considered fishing from the De Pere to Green Bay Reach. Thus, the study by Hutchison and Kraft (1994) provides a more comprehensive picture of the fishing habits of the Hmong and, consequently, is used here.

All the values in Tables 5-80 and 5-81 were discussed in detail in Section 5.4.3, but selected values are reviewed briefly here.

RF = The reduction factor that provides the fraction of total PCBs remaining in the fish after cooking. Based on data reviewed by Anderson *et al*. (1993), a reduction factor of 50 percent was selected, as discussed in Section 5.4.3 under the subsection entitled "Overview of Possible Fish Ingestion Assumptions."

ABS = The absorption factor is assumed to be 1.0 for evaluating both cancer and noncancer effects. The cancer slope factor for PCBs is derived to be used with an absorption factor of 1.0. The *RfD* for Aroclor 1254 is based on a study where adult female rhesus monkeys were exposed to PCBs through ingestion of gelatin capsules, so their absorption is presumed to be similar to the absorption from ingestion of fish, which is believed to be quite high (PCBs in food are absorbed with an efficiency of 75 to 100 percent).

ED = As discussed in Section 5.4.3, this value is set to 50 years for the RME scenario and 30 years for the CTE scenario.

BW = The body weight is taken from EPA's *Exposure Factors Handbook* (EPA, 1997b) and is set to 71.8 kg for both the RME and CTE scenarios.

ATc = The averaging time for calculating the average daily intake over a lifetime was 75 years multiplied by 365 days/yr from EPA's *Exposure Factors Handbook* (EPA, 1997b).

ATnc = The averaging time for calculating the average daily dose over the exposure period is 365 days/yr multiplied by the exposure duration (*ED*).

CSFo = The oral slope factor was set to 2 $(mg/kg\text{-}day)^{-1}$ as specified in EPA (1996d) for evaluating fish ingestion.

RfDo = The oral reference dose for Aroclor 1254 of 2.0×10^{-5} mg/kg-day was used as discussed in Section 5.6.9.

The values for *IR* (fish ingestion rate) and *EF* (exposure frequency) vary for each scenario and each study in Tables 5-80 and 5-81. These values are discussed in detail in Section 5.4.3 under the subsection entitled "Overview of Possible Fish Ingestion Assumptions." This discussion is not repeated here.

5.9.4 Cancer Risks and Hazard Indices for Recreational Anglers and High-intake Fish Consumers

Tables 5-82 and 5-83 present the calculated cancer risks for the recreational angler in each reach of the Lower Fox River and each zone of Green Bay, respectively. Tables 5-84 and 5-85 present the calculated hazard indices for the recreational angler in each reach of the Lower Fox River and each zone of Green Bay. Cancer risks and hazard indices are presented for RME and CTE scenarios for the 1989 Michigan angler study (West *et al.*, 1989), the 1993 Michigan angler study (West *et al.*, 1993), the average of the two Michigan studies, and the 1989 Wisconsin angler study (Fiore *et al.*, 1989). The most recent average fish concentration data in Tables 5-77 and 5-79 were used in this analysis.

Also presented in these tables are the risks calculated for the background concentration of PCBs in fish in Lake Winnebago. The risks associated with background concentrations in fish range from 2.1×10^{-5} to 4.6×10^{-5} for the RME scenario and from 3.9×10^{-6} to 6.0×10^{-6} for the CTE scenario. The hazard indices associated with this background concentration in fish range from 0.8 to 1.7 for the RME scenario and from 0.2 to 0.4 for the CTE scenario.

For the Lower Fox River, the range of risks estimated for the recreational anglers are provided in the following table. Risks are provided for the RME and CTE scenarios and for all fish samples in the 1990s, carp samples in the 1990s, and perch, walleye, and white bass samples in the 1990s. It should be noted that the term "Lowest Risk" refers to the lowest risk to recreational anglers in Table 5-82, not the lowest possible risk. The lowest possible risk is 0 (i.e., the risk of eating no fish from the Lower Fox River). Similarly, the term "Highest Risk" refers to the highest risk to recreational anglers in Table 5-82, not the highest possible risk. Thus, the ranges presented in the table below represent the range of values in Table 5-82 and reflect differences in intake assumptions and fish concentrations.

Fish Samples/Scenario	Lowest Risk	Median Risk	Highest Risk
All Fish Samples			
RME Scenario	2.1×10^{-4}	4.5×10^{-4}	9.7×10^{-4}
CTE Scenario	3.8×10^{-5}	6.9×10^{-5}	1.3×10^{-4}
All Carp Samples			
RME Scenario	1.1×10^{-3}	1.4×10^{-3}	2.3×10^{-3}
CTE Scenario	2.0×10^{-4}	2.3×10^{-4}	3.0×10^{-4}
All Perch, Walleye, and White Bass Samples			
RME Scenario	7.0×10^{-5}	3.2×10^{-4}	1.7×10^{-3}
CTE Scenario	1.3×10^{-5}	5.2×10^{-5}	2.2×10^{-4}

Figure 5-12 presents the range of risks to the recreational angler in the Lower Fox River for all fish samples in the 1990s. Also presented in Figure 5-12 are the range of risks for the high-intake fish consumers which will be discussed shortly. For the RME and CTE scenarios, all risks exceed the 10^{-6} level. The highest risks are for carp. The highest risk, median risk, and lowest risk for carp are higher than the corresponding risks for all fish samples. The risks for perch, walleye, and white bass, three of the most commonly sought-after fish by anglers, show greater variation. The lowest risk in this group is lower than the lowest risk for all fish samples, but the highest risk for perch, walleye, and white bass samples is higher than the highest risk for all fish samples. The median risk for all perch, walleye, and white bass samples is similar to the median risk for all fish samples.

To illustrate how cancer risks vary by reach, the maximum risks for the recreational angler calculated for all fish samples are presented by river reach in the table below.

Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay
RME	7.0×10^{-4}	6.6×10^{-4}	4.4×10^{-4}	9.7×10^{-4}
CTE	9.1×10^{-5}	8.6×10^{-5}	5.7×10^{-4}	1.3×10^{-4}

Figure 5-13 plots these cancer risks by river reach for the recreational anglers. The maximum cancer risks to high-intake fish consumers are also presented in Figure 5-13. The maximum risks to recreational anglers occur in the De Pere to Green Bay Reach and the minimum risks occur in the Little Rapids to De Pere Reach.

For Green Bay, the range of risks estimated for the recreational anglers are provided in the following table. As before, risks were calculated using concentration data from fish collected in the 1990s plus walleye data from 1989.

Fish Samples/Scenario	Lowest Risk	Median Risk	Highest Risk
All Fish Samples			
RME Scenario	3.2×10^{-4}	5.0×10^{-4}	9.8×10^{-4}
CTE Scenario	5.9×10^{-5}	8.4×10^{-5}	1.3×10^{-4}
All Carp Samples			
RME Scenario	NA	NA	NA
CTE Scenario	NA	NA	NA
All Perch, Walleye, and White Bass Samples			
RME Scenario	2.3×10^{-4}	5.2×10^{-4}	1.4×10^{-3}
CTE Scenario	4.2×10^{-5}	7.8×10^{-5}	1.9×10^{-4}

Figure 5-14 presents the range of risks for recreational anglers in Green Bay for all fish samples in the 1990s plus walleye data from 1989. For the RME and CTE scenarios, all risks exceed the 10^{-6} level. The median risk for all fish samples is similar to the median risk for perch, walleye, and white bass, three of the most commonly sought-after fish by anglers.

To illustrate how cancer risks vary by zone, the maximum risks calculated for all fish samples are presented by zone in the table below for recreational anglers.

Scenario	Zone 3A	Zone 3B	Zone 4
RME	9.8×10^{-4}	7.5×10^{-4}	6.9×10^{-4}
CTE	1.3×10^{-4}	9.8×10^{-5}	9.0×10^{-5}

Figure 5-15 plots these cancer risks by zone. The maximum cancer risks occur in Zone 3A and the minimum risks occur in Zone 4.

For the Lower Fox River, the range of hazard indices estimated for the recreational anglers are provided in the following table. Hazard indices are provided for the RME and CTE scenarios and all fish samples in the 1990s, carp samples in the 1990s, and perch, walleye, and white bass samples in the 1990s.

Fish Samples/Scenario	Lowest HI	Median HI	Highest HI
All Fish Samples			
RME Scenario	7.7	16.8	36.5
CTE Scenario	2.4	4.3	8.0
All Carp Samples			
RME Scenario	40.5	53.9	86.2
CTE Scenario	12.4	14.6	18.8
All Perch, Walleye, and White Bass Samples			
RME Scenario	2.6	12.1	62.3
CTE Scenario	0.8	3.3	13.6

Figure 5-16 presents the range of hazard indices for recreational anglers in the Lower Fox River for all fish samples in the 1990s. For the RME and CTE scenarios, all hazard indices exceed 1.0. The highest hazard indices are for carp. The median hazard index for all fish samples is similar to the median hazard index for perch, walleye, and white bass.

To illustrate how hazard indices vary by reach, the maximum hazard index calculated for all fish samples are presented by river reach in the table below for recreational anglers.

Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay
RME	26.1	24.7	16.4	36.5
CTE	5.7	5.4	3.6	8.0

Figure 5-17 plots these hazard indices by river reach. The maximum hazard indices occur in the De Pere to Green Bay Reach and the minimum hazard indices occur in the Little Rapids to De Pere Reach.

For Green Bay, the range of hazard indices estimated for the recreational anglers are provided in the following table.

Fish Samples/Scenario	Lowest Risk	Median Risk	Highest Risk
All Fish Samples			
RME Scenario	12.1	18.9	36.9
CTE Scenario	3.7	5.3	8.0
All Carp Samples			
RME Scenario	NA	NA	NA
CTE Scenario	NA	NA	NA
All Perch, Walleye, and White Bass Samples			
RME Scenario	8.7	19.4	53.1
CTE Scenario	2.6	4.9	11.6

Figure 5-18 presents the range of hazard indices for recreational anglers in Green Bay for all fish samples in the 1990s. For the RME and CTE scenarios, all hazard indices exceed 1.0. The median hazard index for all fish samples is similar to the median hazard index for perch, walleye, and white bass.

To illustrate how hazard indices vary by zone, the maximum hazard indices for recreational anglers calculated for all fish samples are presented by zone in the table below.

Scenario	Zone 3A	Zone 3B	Zone 4
RME	36.9	28.2	25.8
CTE	8.0	6.2	5.6

Figure 5-19 plots these hazard indices by zone for the recreational angler. The maximum hazard indices occur in Zone 3A and the minimum hazard indices occur in Zone 4.

Tables 5-86 and 5-87 present the calculated cancer risks for the high-intake fish consumer in each reach of the Lower Fox River and each zone of Green Bay, respectively. Tables 5-88 and 5-89 present the calculated hazard indices for the high-intake fish consumer in each reach of the river and each zone of the bay. Cancer risks and hazard indices are presented for RME and CTE scenarios for a low-income minority angler, based on the data from West *et al.* (1993); a Native American angler using data from Peterson *et al*. (1994) and Fiore *et al*. (1989); and a Hmong angler based on data from Hutchison and Kraft (1994).

Also presented in these tables are the risks calculated for the background concentration of PCBs in fish in Lake Winnebago. The risks associated with this background concentration in fish range from 1.9×10^{-5} to 6.4×10^{-5} for the RME scenario and from 2.6×10^{-6} to 1.5×10^{-5} for the CTE scenario. The hazard indices associated with this background concentration in fish range from 0.7 to 2.4 for the RME scenario and from 0.2 to 0.9 for the CTE scenario.

For the Lower Fox River, the range of risks estimated for the high-intake fish consumers are provided in the following table. Risks are provided for the RME and CTE scenarios and for all fish samples in the 1990s, carp samples in the 1990s, and perch, walleye, and white bass samples in the 1990s.

Fish Samples/Scenario	Lowest Risk	Median Risk	Highest Risk
All Fish Samples			
RME Scenario	1.8×10^{-4}	5.5×10^{-4}	1.4×10^{-3}
CTE Scenario	2.5×10^{-5}	9.9×10^{-5}	3.2×10^{-4}
All Carp Samples			
RME Scenario	3.0×10^{-4}	1.1×10^{-3}	3.2×10^{-3}
CTE Scenario	4.2×10^{-5}	2.1×10^{-4}	7.6×10^{-4}
All Perch, Walleye, and White Bass Samples			
RME Scenario	4.6×10^{-5}	3.1×10^{-4}	2.3×10^{-3}
CTE Scenario	6.3×10^{-6}	5.9×10^{-5}	5.5×10^{-4}

Figure 5-12 presents the range of risks in the Lower Fox River for all fish samples in the 1990s for the high-intake fish consumers. For the RME and CTE scenarios, all risks exceed the 10^{-6} level. The highest risks are for carp. The median risk for all fish samples is similar to the median risk for perch, walleye, and white bass, three of the most commonly sought-after fish by anglers.

To illustrate how cancer risks vary by reach, the maximum risks for high-intake fish consumers calculated for all fish samples are presented by river reach in the table below.

Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay
RME	9.8×10^{-4}	9.3×10^{-4}	6.2×10^{-4}	1.4×10^{-3}
CTE	2.3×10^{-4}	2.2×10^{-4}	1.4×10^{-4}	3.2×10^{-4}

Figure 5-13 plots these cancer risks by river reach for the high-intake fish consumers. The maximum cancer risks to high-intake fish consumers occur in the De Pere to Green Bay Reach and the minimum risks occur in the Little Rapids to De Pere Reach.

For Green Bay, the range of risks estimated for the high-intake fish consumers are provided in the following table.

Fish Samples/Scenario	Lowest Risk	Median Risk	Highest Risk
All Fish Samples			
RME Scenario	2.9×10^{-4}	7.1×10^{-4}	1.4×10^{-3}
CTE Scenario	4.0×10^{-5}	1.2×10^{-4}	3.3×10^{-4}
All Carp Samples			
RME Scenario	NA	NA	NA
CTE Scenario	NA	NA	NA
All Perch, Walleye, and White Bass Samples			
RME Scenario	2.0×10^{-4}	6.4×10^{-4}	2.0×10^{-3}
CTE Scenario	2.8×10^{-5}	1.1×10^{-4}	4.7×10^{-4}

Figure 5-14 presents the range of risks in Green Bay for all fish samples in the 1990s for the high-intake fish consumers. For the RME and CTE scenarios, all risks exceed the 10^{-6} level. The median risk for all fish samples is similar to the median risk for perch, walleye, and white bass, three of the most commonly sought-after fish by anglers.

To illustrate how cancer risks vary by zone, the maximum risks for the high-intake fish consumer calculated for all fish samples are presented by zone in the table below.

Scenario	Zone 3A	Zone 3B	Zone 4
RME	1.4×10^{-3}	1.1×10^{-3}	9.7×10^{-4}
CTE	3.3×10^{-4}	2.5×10^{-4}	2.3×10^{-4}

Figure 5-15 plots these cancer risks for the high-intake fish consumer by zone. The maximum cancer risks occur in Zone 3A and the minimum risks occur in Zone 4.

For the Lower Fox River, the range of hazard indices estimated for the high-intake fish consumers are provided in the following table. Hazard indices are provided for the RME and CTE scenarios and all fish samples in the 1990s, carp samples in the 1990s, and perch, walleye, and white bass samples in the 1990s.

Fish Samples/Scenario	Lowest Risk	Median Risk	Highest Risk
All Fish Samples			
RME Scenario	6.8	20.8	51.5
CTE Scenario	1.6	6.2	20.1
All Carp Samples			
RME Scenario	11.4	38.6	121.5
CTE Scenario	2.6	12.6	47.5
All Perch, Walleye, and White Bass Samples			
RME Scenario	1.7	11.7	87.9
CTE Scenario	0.4	3.7	34.4

Figure 5-16 presents the range of hazard indices for high-intake fish consumers in the Lower Fox River for all fish samples in the 1990s. For the RME and CTE scenarios, all hazard indices exceed 1.0. The highest hazard indices are for carp. The median hazard index for all fish samples is similar to the median hazard indices for perch, walleye, and white bass.

To illustrate how hazard indices vary by reach, the maximum hazard index for high-intake fish consumers calculated for all fish samples are presented by river reach in the table below.

Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay
RME	36.8	34.9	23.1	51.5
CTE	14.4	13.6	9.0	20.1

Figure 5-17 plots these hazard indices for high-intake fish consumers by river reach. The maximum hazard indices occur in the De Pere to Green Bay Reach and the minimum hazard indices occur in the Little Rapids to De Pere Reach.

For Green Bay, the range of hazard indices estimated for the high-intake fish consumers are provided in the following table.

Fish Samples/Scenario	Lowest Risk	Median Risk	Highest Risk
All Fish Samples			
RME Scenario	10.7	26.5	52.0
CTE Scenario	2.5	7.3	20.3
All Carp Samples			
RME Scenario	NA	NA	NA
CTE Scenario	NA	NA	NA
All Perch, Walleye, and White Bass Samples			
RME Scenario	7.6	24.0	74.9
CTE Scenario	1.8	7.0	29.3

Figure 5-18 presents the range of hazard indices for high-intake fish consumers in Green Bay for all fish samples in the 1990s. For the RME and CTE scenarios, all hazard indices exceed 1.0. The median hazard index for all fish samples is similar to the median hazard index for perch, walleye, and white bass.

To illustrate how hazard indices vary by zone, the maximum hazard indices for high-intake fish consumers calculated for all fish samples are presented by zone in the table below.

Scenario	Zone 3A	Zone 3B	Zone 4
RME	52.0	39.8	36.4
CTE	20.3	15.6	14.2

Figure 5-19 plots these hazard indices for high-intake fish consumers by zone. The maximum hazard indices occur in Zone 3A and the minimum hazard indices occur in Zone 4.

While difficult to quantify, it should be noted that anglers can potentially be exposed to PCBs via ingestion of fish caught from tributaries to the Lower Fox River or Green Bay to the extent that fish migrate upstream into these tributaries.

5.9.5 Cancer Risks and Hazard Indices Associated with Intake Assumptions from the Great Lakes Sport Fish Advisory Task Force

For additional perspective, cancer risks and noncancer hazard indices were also calculated using the exposure assumptions in the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.*, 1993). The intake assumptions are provided in Table 5-90. These values are provided for four fish consumption scenarios: unlimited consumption, one meal per week, one meal per month, and six meals per year. The parameters in Table 5-90 are the same as those in Tables 5-80 and 5-81 except for *IR*, *EF*, *ED*, and *ATnc*. The fish ingestion rate, *IR*, was set to 227 g/day (about 8 ounces), the same assumption used for the 1989 Wisconsin angler study (Fiore *et al.*, 1989), the Native American high-intake fish consumer (Peterson, *et al.*, 1994; Fiore *et al.*, 1989), and the Hmong/Laotian high-intake fish consumer (Hutchison and Kraft, 1994; Hutchison, 1999). The exposure frequency, *EF*, is set by the exposure scenario (e.g., one meal per week translates into an *EF* of 52 days/yr). The value of *EF* for the unlimited consumption scenario is 225 days/yr. This was calculated by Anderson *et al.* (1993) to be an average daily intake of fish of 140 g/day, which is the 90th percentile of fish consumption rates for recreational anglers reported in the 1989 version of EPA's *Exposure Factors Handbook* (EPA, 1989a). The value of 140 g/day is calculated as:

$$\frac{(227\ g/day \times 225\ days)}{356\ days}$$

Tables 5-91 and 5-92 present the calculated cancer risks for each fish consumption scenario in each reach of the Lower Fox River and each zone of Green Bay, respectively. Tables 5-93 and 5-94 present the calculated hazard indices for each fish consumption scenario in each reach of the Lower Fox River and each zone of Green Bay. The most recent average fish concentration data in Tables 5-77 and 5-78 were used in this analysis. Also presented in these tables are the risks calculated for the background concentration of PCBs in fish in Lake Winnebago.

It should be noted that the cancer risks and hazard indices presented in Tables 5-91 through 5-94 are for generic fish consumption **scenarios** and **do not** represent cancer risks or hazard indices based upon actual fish consumption behavior.

The following table summarizes the estimated cancer risks for the four fish consumption scenarios in each reach of the Lower Fox River using the concentration of PCBs for all fish samples. All risks are greater than the 10^{-6} target. Estimated risks for unlimited consumption are similar to those estimated in the focused evaluation for high-intake fish consumers under the RME scenario. However, the maximum cancer risk for unlimited consumption is greater than the maximum cancer risk for a high-intake fish consumer in the focused evaluation.

Reach	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Little Lake Butte des Morts	1.9×10^{-3}	4.4×10^{-4}	1.0×10^{-4}	5.1×10^{-5}
Appleton to Little Rapids	1.8×10^{-3}	4.2×10^{-4}	9.7×10^{-5}	4.9×10^{-5}
Little Rapids to De Pere	1.2×10^{-3}	2.8×10^{-4}	6.4×10^{-5}	3.2×10^{-5}
De Pere to Green Bay	2.7×10^{-3}	6.2×10^{-4}	1.4×10^{-4}	7.2×10^{-5}

The following table summarizes the estimated cancer risks for the four fish consumption scenarios in each zone of Green Bay using the concentration of PCBs for all fish samples. As in the previous table, all risks are greater than the 10^{-6} target. Estimated risks for unlimited consumption are similar to those estimated in the focused evaluation for high-intake fish consumers under the RME scenario. However, the maximum cancer risk for unlimited consumption is greater than the maximum cancer risk for a high-intake fish consumer in the focused evaluation.

Zone	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Green Bay Zone 3A	2.7×10^{-3}	6.3×10^{-4}	1.4×10^{-4}	7.2×10^{-5}
Green Bay Zone 3B	2.1×10^{-3}	4.8×10^{-4}	1.1×10^{-4}	5.5×10^{-5}
Green Bay Zone 4	1.9×10^{-3}	4.4×10^{-4}	1.0×10^{-4}	5.1×10^{-5}

The following table summarizes the estimated hazard indices for the four fish consumption scenarios in each reach of the Lower Fox River using the concentration of PCBs for all fish samples. All hazard indices are greater than the target of 1.0 with the exception of the six-meals-per-year scenario in the Little Rapids to De Pere Reach. Estimated hazard indices for unlimited consumption are similar to those estimated in the focused evaluation for high-intake fish consumers under the RME scenario. However, the maximum hazard index for unlimited consumption is greater than the maximum hazard index for a high-intake fish consumer in the focused evaluation.

Reach	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Little Lake Butte des Morts	48.0	11.1	2.6	1.3
Appleton to Little Rapids	45.5	10.5	2.4	1.2
Little Rapids to De Pere	30.1	7.0	1.6	0.8
De Pere to Green Bay	67.2	15.5	3.6	1.8

The following table summarizes the estimated hazard indices for the four fish consumption scenarios in each zone of Green Bay using the concentration of PCBs for all fish samples. All hazard indices are greater than the target of 1.0. Estimated hazard indices for unlimited consumption are similar to those estimated in the focused evaluation for high-intake fish consumers under the RME scenario. However, the maximum hazard index for unlimited consumption is greater than the maximum hazard index for a high-intake fish consumer in the focused evaluation.

Zone	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Green Bay Zone 3A	67.8	15.7	3.6	1.8
Green Bay Zone 3B	51.9	12.0	2.8	1.4
Green Bay Zone 4	47.5	11.0	2.5	1.3

5.9.6 Summary of Probabilistic Risk Assessment

Appendix B1 expands upon the focused evaluation of exposure to PCBs in fish provided in this section, by providing a probabilistic assessment of risks and hazard indices for receptors potentially exposed to PCBs present in fish in the Lower Fox River and Green Bay. The probabilistic risk evaluation presented in Appendix B1 was performed in accordance with draft EPA guidance (EPA, 1999), and accounts for variability, as well as uncertainty in some of the intake assumptions. In this context, variability represents the true diversity or heterogeneity in a variable. For example, body weight varies throughout the population. The more that body weight is studied, the better the variation is characterized, but no amount of study will eliminate the variation in body weight. Uncertainty represents a lack of knowledge about a particular variable. The more that a particular variable is studied, the more the uncertainty is reduced.

The probabilistic risk assessment is intended to support and complement the point estimates of risks and hazard indices. The probabilistic risk assessment is not intended to be the principal basis for decisions regarding the need for remedial action at a site. EPA guidance specifies that point estimates of risks and hazard indices calculated using point estimates of intake parameters for RME and CTE scenarios are the principal basis for such decisions. Therefore, the probabilistic risk assessment presented in Appendix B1 does not supercede the point estimate evaluation presented in Section 5.9.4, but is intended to supplement and complement the point estimates of risks and hazard indices.

In Appendix B1, a probabilistic evaluation of risks and hazard indices was performed. In this analysis, the influence of variability was examined by developing probability distributions for the following exposure parameters: fish concentration, fish ingestion rate, exposure frequency, reduction factor, exposure duration, and body weight. For the concentration of PCBs in fish, the following distributions were used:

- Concentration distribution developed by Exponent (2000) in their probabilistic risk assessment for the entire Lower Fox River,

- Concentration distribution developed from data for all fish species in the Little Lake Butte des Morts Reach, and

- Concentration distribution developed from data for all fish species in the De Pere to Green Bay Reach.

For fish ingestion rate and exposure frequency, distributions were developed for the following categories of anglers:

- Recreational anglers, and
- High-intake fish consumers.

For reduction factor, exposure duration, and body weight, distributions were developed and applied to all receptors. For each category of angler, probability distributions were developed for fish ingestion rate and exposure frequency using different studies as the basis for the distributions. For example, for the recreational anglers, studies by West *et al*. (1989, 1993), Fiore *et al*. (1989), and Exponent (2000) were used to develop four sets of probability distributions for fish ingestion rate and exposure frequency. These different sets of distributions provide a measure of the uncertainty in estimating the distribution of fish ingestion rate and exposure frequency for recreational anglers. Similarly, for the high-intake fish consumer, a study by West *et al.* (1993) for low-income minority anglers and studies by Hutchison and Kraft (1994) and Hutchison (1999) for Hmong and Laotians were used to develop three sets of probability distributions for fish ingestion rate and exposure frequency. Once again, these different sets of distributions provide a measure of the uncertainty in estimating the distribution of fish ingestion rate and exposure frequency for high-intake fish consumers. The procedures used were consistent with EPA guidance on probabilistic risk assessment (EPA, 1999).

The main results of the probabilistic risk assessment for the Little Lake Butte des Morts and De Pere to Green Bay reaches are summarized in Tables 5-95 through 5-98. These tables provide summary statistics for the calculated risks and hazard indices, including percentile values, and the mean and standard deviation of each distribution. As a point of reference, the CTE and RME values calculated in Section 5.9.4 are also reported in the tables. Figures 5-20 through 5-23 provide a visual comparison of the CTE and RME values with selected values of the risk and hazard index distributions.

These tables and figures show the following.

- The deterministic CTE estimates of risk and hazard index provided in Section 5.9.4 are generally close to the means of the respective probability distributions of risk and hazard index. This is consistent with the interpretation of the CTE as the average risk or hazard index for the exposed population.

- The deterministic RME estimates of risk and hazard index provided in Section 5.9.4 are generally within the 90th to 95th percentiles of the respective probability distributions of risk and hazard index. This is consistent with the interpretation provided in EPA (1999) of the RME as a plausible high-end risk or hazard index for the exposed population.

Consistent with EPA (1999), the results of the four studies of recreational angler fish intakes were combined to evaluate the uncertainty associated with the determination of probability distributions of risks and hazard indices for recreational anglers. Similarly, the three studies of high-intake fish consumers were also combined. The results of the uncertainty analysis for the Little Lake Butte des Morts and De Pere to Green Bay reaches are summarized in Tables 5-99 and 5-100 and on Figures 5-24 through 5-31.

In Tables 5-99 and 5-100 and on Figures 5-24 through 5-31, the ranges of risk or hazard index for a particular percentile of the distribution and mean of the distribution are presented. This range is reflective of the uncertainty associated with the estimate of risk or hazard index at each percentile and at the mean. The data presented in these tables and figures show that the uncertainty in the estimate of the probability distributions of risk and hazard index is moderate, as reflected by the fact that the maximum and minimum values for the ranges are generally within a factor of 10 of each other.

5.9.7 Evaluation of Exponent Risk Assessment

In addition to a probabilistic risk assessment, Appendix B1 presents the assumptions used in the probabilistic risk assessment prepared by Exponent (2000) on behalf of the Fox River Group and compares the results generated for the Exponent (2000) assumptions with the results of the deterministic risk assessment presented in Sections 5.9.2, 5.9.3, and 5.9.4. Risks and hazard indices were calculated in Section 5.9.4 for an RME scenario and a CTE scenario for the four reaches of the Lower Fox River and three zones within Green Bay. Different values of risk and hazard indices were calculated based on different assumptions regarding intake parameters, primarily fish ingestion rate, exposure frequency, exposure duration, and concentrations of PCBs in fish. Exponent (2000) used a probabilistic approach to calculate probability distributions of risks and hazard indices over the whole Lower Fox River, independent of the reach.

The two risk assessments provide different outputs (point value estimates of risks and hazard indices for RME and CTE scenarios in Section 5.9.4, and probability distributions of risk and hazard indices for Exponent [2000]). As such, the results of the two risk assessments are not directly comparable. To better understand the fundamental similarities and differences between the two approaches, RME and CTE values were developed from the Exponent (2000) distributions for each intake parameter and unit risks and unit hazard indices were calculated for the RME and CTE scenarios. Unit risks and unit hazard indices are the risks and hazard indices associated with a concentration of 1 mg/kg PCBs in fish. By calculating unit risks and unit hazard indices, the influence of different fish concentrations in Exponent (2000) as compared to Section 5.9.4 is removed.

The comparison with Exponent assumptions indicated that the intake assumptions used by Exponent (2000) result in generally lower unit risks and hazard indices than the assumptions presented in Section 5.9.3 for recreational anglers. The differences between the unit risks and hazard indices calculated using Exponent (2000) assumptions and the assumptions presented in Section 5.9.3 for recreational anglers depend on the study used in Section 5.9.3 to estimate fish intake assumptions. This difference is generally greatest for the survey of Michigan anglers by West *et al.* (1993), and least for the survey of Wisconsin anglers by Fiore *et al*. (1989).

It should be noted that high-intake fish consumers were evaluated in Sections 5.9.3 and 5.9.4, where high-intake fish consumers are a subset of the recreational angler population who are more highly exposed than the general population of recreational anglers. Three populations of high-intake fish consumers were identified in these sections: low-income minorities, Native Americans, and Hmong/Laotians. Exponent (2000) argued that these populations did not eat significantly more fish from the Lower Fox River and Green Bay, so Exponent (2000) did not evaluate exposures and health effects for these specific populations. Since Exponent (2000) did not explicitly evaluate exposures to high-intake fish consumers, a comparison could not be performed.

5.9.8 Evaluation of PCB Exposures to Young Children

This section presents qualitative and quantitative evaluations of PCB exposure to young children. Three evaluations are presented. In the first evaluation, the potential for long-term developmental effects from short-term (even one-time) exposure is reviewed qualitatively. In the second evaluation, the potential for elevated exposures to PCBs as a result of the transfer of PCBs from a mother to her fetus and infant child is also reviewed qualitatively. In the third evaluation, doses and hazard quotients are calculated for a young child, aged 1 to 7 years, as a result of fish ingestion.

Potential Long-term Developmental Effects from Short-term Exposures

This section discusses the evidence that short-term exposures to high doses of PCBs (even one-time exposures) can result in long-term developmental effects to young children. The discussion is qualitative because there is insufficient toxicological data to make quantitative estimates of potential health effects. This section focuses on exposures to individuals in Taiwan and Japan as a result of PCB contamination of rice oil or cooking oil. These exposures resulted in an outbreak of illness (referred to as Yu-Cheng and Yusho disease, respectively) which included chloracne, hyperpigmentation, and Meibomian gland dilation (Rogan *et al.*, 1988).

These exposures also resulted in significant health effects to infants born to mothers in both Taiwan and Japan. While the effects were similar to those discussed in the next subsection, the source of PCB exposure (rice or cooking oil ingestion) is different from the source of the exposures described in the next subsection (fish ingestion). Also, the ingestion of the contaminated rice and cooking oil is believed to have resulted in much higher short-term exposures than the ingestion of contaminated fish described in the next subsection.

Even several years after the incident, women who were exposed to the contaminated oil gave birth to infants with abnormalities. The exposed children were small for gestational age and had abnormalities of the lungs, skin, and teeth. In addition, these children exhibited a delay in mental and psychomotor development. Follow-up studies of the Taiwan case have shown that neurobehavioral deficits and developmental delays may persist in older children (Chen *et al.*, 1992; Guo *et al.*, 1995; Chao *et al.*, 1997). However, it should be noted that these results may have been associated with the presence of dibenzofurans which were also present in the contaminated oil.

Effects on the immune system were also studied in the Yu-Cheng and Yusho populations (Tryphonas, 1995). Adverse effects included persistent respiratory distress (in half of Yu-Cheng persons studied); decreases in antibody levels 2 years after exposure (normal at 3 years); decrease in percentage of T-lymphocytes (Yu-Cheng) and increase in T-helper cells and decrease in T-suppressor cells (Yusho) 14 years after exposure; and enhanced responses to mitogens (Guo *et al.*, 1995).

Exposure to the Fetus and Infant from the Mother

This section discusses potential exposures to fetuses and infants from mothers who consumed PCB-contaminated fish. For the fetal stage, exposure occurs via transfer from the mother to the fetus across the placenta. For the infant stage, exposure occurs via transfer from the mother to the infant through breast milk. Transfer of maternal PCBs across the placenta and into breast milk can clearly result in significant exposures *in utero* and to a nursing infant (Dekoning and Karmaus, 2000). Exposure to PCBs in breast milk is estimated to be a major contributor to a child's body burden at 42 months of age (Lanting *et al.*, 1998) and to account for over 10 percent of an individuals cumulative PCB intake through 25 years of age (Patandin *et al.*, 1999).

In Section 5.6.2, a number of studies were reviewed that present evidence that such exposures result in a variety of developmental, neurological, and immune system effects. From a developmental perspective, Fein *et al.* (1984a, 1984b) studied the effects of low-level chronic exposure to PCBs in pregnant women and their newborn offspring from consumption of Lake Michigan fish and reported that low levels of PCBs caused decreases in birth weight, head circumference, and gestational age of the newborn.

From a neurological perspective, Fein *et al.* (1984a, 1984b) also reported immaturity of reflexes and depressed responsiveness in infants exposed to PCBs. Newborns of high-fish-consuming mothers exhibited a greater number of abnormal reflexes, less mature autonomic responses, and less attention to visual/auditory stimuli in comparison to newborns of no- or low-fish-consuming mothers (Lonky *et al.*, 1996). PCBs, dioxins, and furans present in breast milk were associated with reduced neonatal neurologic optimality in breast-fed infants 2 to 3 weeks old (Huisman *et al.*, 1995a, 1995b).

From an immune system perspective, Smith (1984) and Humphrey (1988) found that maternal serum PCB levels during pregnancy (of women who consumed PCB-contaminated Great Lakes/St. Lawrence fish) were positively associated with the number and type of infectious illnesses which occurred in infants. In infants exposed to PCBs and dioxins pre- and postnatally, Weisglas-Kuperus *et al.* (1995) found lower monocyte and granulocyte counts for 3-month-old infants, and increased total T-cell counts and cytotoxic T-cell counts for children 18 months old. Weisglas-Kuperus *et al.* (2000) also found the effects of prenatal exposure to

PCBs and dioxins persisted into childhood and might be associated with a greater susceptibility to infectious diseases.

Unfortunately, methods to model exposures due to placental transfer or breast-feeding are not well established. PCB exposures *in utero* are based on the mother's current and past history of PCB exposures. PCB exposures in breast milk depend not only on maternal PCB exposure levels, but can also be significantly influenced by factors such as maternal age, number of children, length of time between children, and duration of breast-feeding (Vartiainen *et al.*, 1998; Rogan *et al.*, 1986). A mother's body burden of PCBs has been estimated to decrease 20 percent for every 3 to 6 months of breast-feeding (Patandin *et al.*, 1999; Rogan and Gladen, 1985), after which PCB body burdens are gradually restored. Well-established methodologies for evaluating PCB exposures in pregnant women and nursing children are not available at this point. Therefore, it is also not possible (through available data or modeling) to make a relevant, direct comparison between exposure levels estimated for anglers in this risk assessment (reported in mg/kg-day) and exposure levels for pregnant women and nursing children reported in human studies (typically reported as PCB concentrations in blood or breast milk), without introducing a considerable level of uncertainty.

However, since a variety of developmental effects (Fein *et al.,* 1984a, 1984b), neurological effects (Fein *et al.,* 1984a, 1984b; Lonky *et al.,* 1996; Huisman *et al.,* 1995a, 1995b), and immune system effects (Smith, 1984; Humphrey, 1988; Weisglas-Kuperus *et al.,* 1995, 2000) have been observed in infants and children whose mothers consumed fish known to be contaminated with PCBs, it seems plausible that PCB exposures for at least some women consuming fish from the Lower Fox River and Green Bay could be in the same range of PCB exposure levels at which these effects have been observed.

Exposure to a Young Child from Fish Ingestion

This section provides a quantitative evaluation of potential exposure to a young child (age 1 through 7 years) as a result of eating fish. Chronic hazard indices are calculated for a recreational angler child and a high-intake fish consumer child. Calculations are performed for the Little Lake Butte des Morts and the De Pere to Green Bay reaches. The results are compared to results for the adult receptors in these reaches. A 7-year exposure period was chosen because this is the shortest period which is still considered chronic exposure (EPA, 1989c). Cancer risks were not calculated, because cancer risks depend on the cumulative dose over a lifetime. Thus, cancer risks for a young child based on 7 years of exposure are expected to be less than cancer risks for an adult over 30 years (CTE scenario) or 50 years (RME scenario) of exposure. The Little Lake Butte des Morts and De Pere to Green Bay reaches were selected because these two reaches have the highest population density of all river reaches and bay zones and are expected to have the most fishing activity.

As presented previously in Section 5.9.2, the equation for calculating the chronic hazard index from ingestion of fish is:

$$HI = \frac{Inc}{RfDo}$$

where:

- HI = chronic, noncancer hazard index,
- Inc = intake from ingestion of fish averaged over the exposure period (mg/kg-day), and
- $RfDo$ = oral reference dose for chronic, noncancer effects (mg/kg-day).

The chronic oral reference dose (*RfDo*) used in this assessment for PCBs is 2.0×10^{-5} mg/kg-day. The intake from fish ingestion averaged over the exposure period is calculated for the young child using the same equation presented for adults (refer to Section 5.9.2):

$$Inc = \frac{Cfish \cdot IR_C \cdot RF \cdot ABS \cdot CF \cdot EF \cdot ED_C}{BW_C \cdot ATnc_C}$$

These intake parameters are the same for the child receptor as those used for the adult receptor with the exception of the fish ingestion rate for the child (IR_C), the exposure duration (ED_C), body weight (BW_C), and non-carcinogenic averaging time ($ATnc_C$).

The fish ingestion rate for the child (IR_C) is calculated using a child-to-adult fish ingestion ratio. Limited data are available on fish ingestion rates for young children. However, these data may be compared to ingestion rates for older children and adults that were measured from the same study. By comparing the ingestion rates between children and adults (from the same study), a ratio may be calculated. This ratio can then be applied to the adult fish ingestion rates selected for use in the focused risk assessment presented in Section 5.9.3.

Two studies providing information on both adult and child fish ingestion rates were found to be appropriate for determining a child-to-adult fish ingestion ratio. The first study, conducted by the EPA (1996f), compiled survey data collected by the U.S. Department of Agriculture (USDA) on intake rates for major food groups. The second study was the West *et al.* (1989) study of Michigan anglers, described previously in this report. Table 5-101 provides the fish ingestion rates for young children in various age groups and the fish ingestion rates for older children and adults from the two studies identified above. The child ingestion rate (measured in grams of fish per day) was divided by the adult ingestion rate (from the same study) to determine a child-to-adult fish ingestion ratio ($Ratio_{CAFI}$). Table 5-101 demonstrates that the ratios range from 0.35 to 0.83, with an average ratio of 0.60. Although the calculated ratios are for children ranging in ages from 1 to 14 years, the calculated average ratio was used to represent children from age 1 through 7 years.

The average child-to-adult fish ingestion ratio was then applied to the adult fish ingestion rate (IR_A) to determine the child fish ingestion rate for each study examined in the focused risk assessment:

$$IR_C = IR_A \cdot Ratio_{CAFI}$$

The exposure duration (ED_C) for a child from ages 1 through 7 is 7 years; this value is used for both the RME and CTE scenarios. The average body weight for a child of this age group (BW_C) is 17.8 kg. This value was calculated using the average of the mean body weights of boys and girls ages 1 through 7 years, as presented in the draft *Child-Specific Exposure Factors Handbook* (EPA, 2000c). The non-carcinogenic averaging time ($ATnc_C$) is equivalent to 365 days/yr multiplied by the exposure duration. Since the ED_C for the young child is determined to be 7 years, the resulting $ATnc_C$ is 2,555 days.

The above factors are presented in Tables 5-102 and 5-103 for the recreational angler child and the high-intake fish consumer child, respectively. Intake assumptions for the recreational angler child are presented for the same fish ingestion studies as those used for the adults: the 1989 survey of Michigan anglers by West *et al.* (1989), the 1993 survey of Michigan anglers by West *et al.* (1993), the average of the two Michigan studies, and the 1989 survey of Wisconsin anglers by Fiore *et al.* (1989). Similarly, intake assumptions for the high-intake fish consumer child are presented for the same fish ingestion studies as those used for adults: West *et al.* (1993) for low-income minorities, Peterson *et al*. (1994) and Fiore *et al*. (1989) for Native Americans, Hutchison and Kraft (1994) for Hmong, and Hutchison (1999) for Hmong and Laotians.

Table 5-104 presents the calculated hazard indices for the recreational angler child in the Little Lake Butte des Morts and De Pere to Green Bay reaches. Hazard indices are presented for RME and CTE scenarios for each of the four angler studies. The most recent average fish concentration data in Table 5-76 were used in this analysis. Also presented in this table are the hazard indices calculated for the background concentration of PCBs in fish in Lake Winnebago.

For the two reaches, the range of hazard indices estimated for the recreational angler children are provided in the following table. Hazard indices are provided for the RME and CTE scenarios and for all fish sampled in the 1990s. The first number in each cell within the table is the hazard index for the young child, while the number after the "/" symbol is the hazard index for the adult from the results presented in Table 5-84. The ranges presented in the table below represent the range of values in Tables 5-84 and 5-104 and reflect differences in intake assumptions and fish concentrations. The calculated hazard indices are about 2.4 times greater for the child than for the adult.

Fish Samples/Scenario	Lowest HI Child/Adult	Median HI Child/Adult	Highest HI Child/Adult
All Fish Samples			
RME Scenario	29.7/12.3	45.8/19	88.4/36.5
CTE Scenario	9.1/3.7	13.1/5.4	19.3/8

Table 5-105 presents the calculated hazard indices for the high-intake fish consumer child in the Little Lake Butte des Morts and De Pere to Green Bay reaches. Hazard indices are presented for RME and CTE scenarios for each of the four angler studies. The most recent average fish concentration data in Table 5-76 were used in this analysis. Also presented in this table are the hazard indices calculated for the background concentration of PCBs in fish in Lake Winnebago.

For the two reaches, the range of hazard indices estimated for the high-intake fish consumer children are provided in the following table. Hazard indices are provided for the RME and CTE scenarios and for all fish samples in the 1990s. The first number in each cell within the table is the hazard index for the young child, while the number after the "/" symbol is the hazard index for the adult from the results presented in Table 5-88. The ranges presented in the table below represent the range of values in Tables 5-88 and 5-105 and reflect differences in intake assumptions and fish concentrations. The calculated hazard indices are about 2.4 times greater for the child than for the adult.

Fish Samples/Scenario	Lowest HI Child/Adult	Median HI Child/Adult	Highest HI Child/Adult
All Fish Samples			
RME Scenario	26.2/10.8	64.1/26.5	124.6/51.5
CTE Scenario	6.0/2.5	18.1/7.5	48.7/20.1

5.9.9 Risk-based Concentrations in Fish

As discussed in Section 5.9.2, the equations for calculating cancer risk from ingestion of fish can be rearranged to calculate a concentration of total PCBs in fish for a specified risk level. Similarly, the equation for calculating hazard index from ingestion of fish can be rearranged to calculate a concentration of total PCBs in fish for a specified hazard index level. Table 5-106 presents risk-based concentrations of total PCBs in fish for recreational anglers for risk levels of 10^{-6}, 10^{-5}, 10^{-4}, and for an HI of 1.0. Figure 5-32 plots these risk-based fish concentrations for each set of intake assumptions and exposure scenarios; and for risks levels of 10^{-6}, 10^{-5}, 10^{-4}, and an HI of 1.0. Table 5-107 presents risk-based concentrations of total PCBs in fish for high-intake fish consumers for risk levels of 10^{-6}, 10^{-5}, 10^{-4}, and an HI of 1.0. Figure 5-33 plots these risk-based fish concentrations for each set of intake assumptions and exposure scenario; and for risk levels of 10^{-6}, 10^{-5}, 10^{-4}, and an HI of 1.0.

The risk-based fish concentrations for the recreational angler cover a range of about three orders of magnitude (1.4×10^{-3} mg/kg to 1.6 mg/kg). For a given set of assumptions, the risk-based fish concentration for an HI of 1.0 always falls between the risk-based fish concentrations for the 10^{-5} and 10^{-4} cancer risk level. The table below presents the risk-based fish concentrations for recreational anglers averaged over the West *et al*. (1989, 1993) and Fiore *et al*. (1989) studies.

Risk or Hazard Index Level	RME (mg/kg)	CTE (mg/kg)
Target Risk = 10^{-6}	0.0024	0.014
Target Risk = 10^{-5}	0.024	0.14
Target Risk = 10^{-4}	0.24	1.4
Target HI = 1.0	0.063	0.22

The risk-based fish concentrations for the high-intake fish consumer cover a range of about three orders of magnitude (9.8×10^{-4} mg/kg to 2.4 mg/kg) and the risk-based fish concentration for a target hazard index of 1.0 always falls in between the risk-based fish concentrations for risk levels of 10^{-5} and 10^{-4}. The table below presents the results of averaging the risk-based fish concentrations using the intake assumptions for the low-income minority, Native American, and Hmong/Laotian anglers. The values based on the study by Hutchison and Kraft (1994) were used in the averages.

Risk or Hazard Index Level	RME (mg/kg)	CTE (mg/kg)
Target Risk = 10^{-6}	0.0014	0.0078
Target Risk = 10^{-5}	0.014	0.078
Target Risk = 10^{-4}	0.14	0.78
Target HI = 1.0	0.038	0.12

Risk-based fish concentrations were also calculated using the exposure assumptions in the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.*, 1993). These risk-based concentrations are provided in Table 5-108 for cancer risks of 10^{-6}, 10^{-5}, 10^{-4}, and an HI of 1.0. These concentrations are plotted on Figure 5-34. These concentrations range from 5.0×10^{-4} mg/kg to 1.9 mg/kg, spanning more than three orders of magnitude depending on the selected cancer risk level and exposure scenario. The risk-based concentration for an HI of 1.0 is between the risk-based concentrations for cancer risks of 10^{-5} and 10^{-4}.

In Table 5-108, the RfD of 2.0×10^{-5} mg/kg-day for Aroclor 1254 was used, which yields a risk-based fish concentration of 0.02 mg/kg for unlimited consumption. When Anderson *et al.* (1993) derived their risk-based fish concentrations, they used an RfD of 5.0×10^{-5} mg/kg-day based on a weight-of-evidence approach that considered epidemiological and animal studies. The risk-based fish concentration that Anderson *et al*. (1993) derived was 0.05 mg/kg for unlimited consumption.

It is interesting to note that the average of the RME risk-based fish concentrations for an HI of 1.0 for the recreational angler (0.063 mg/kg) and high-intake fish consumer (0.038 mg/kg) is also 0.05 mg/kg. The average value of 0.038 mg/kg for the high-intake fish consumer does not include the risk-based fish concentration for Hutchison (1999) since this study underestimates potential fish consumption in the Lower Fox River. The value of 0.05 mg/kg from Anderson *et al.* (1993) falls between the average RME and CTE risk-based concentrations at a 10^{-5} risk level for the recreational angler (0.024 mg/kg to 0.14 mg/kg) and the high-intake fish consumer (0.014 mg/kg to 0.078 mg/kg). The range of values for the high-intake fish consumer does not include the risk-based fish concentration based on the Hutchison (1999) study.

5.10 Uncertainty Analysis

The uncertainties in the human health risk assessment reflect the uncertainties in the two principal components of the risk assessment: the exposure assessment and toxicity assessment. The exposure assessment includes the identification of COPCs, the identification and screening of receptors, the development of intake assumptions, and the calculation of exposure point concentrations. The COPCs were determined based on a screening level risk assessment for the Lower Fox River and Green Bay. Thus, of the various chemicals analyzed in media from the river and bay, the COPCs represent the chemicals which will cause the most significant health effects. Therefore, the baseline human health risk assessment is unlikely to underestimate cancer risks or noncancer health effects because of influences from chemicals that were screened out.

The receptors potentially most exposed were retained for quantitative analysis and reasonable maximum exposures (RMEs) were estimated for each receptor. For selected receptors, exposure assumptions reflecting more typical exposures or central tendency exposures (CTEs) were also developed so that a range of exposures and associated health effects could be determined.

In particular, RME and CTE assumptions were developed for recreational anglers, high-intake fish consumers, and hunters. For recreational anglers and high-intake fish consumers, the critical exposure pathway is ingestion of fish. For recreational anglers, a variety of fish ingestion surveys were evaluated, including the 1989 and 1993 Michigan angler studies of West *et al.* (1989, 1993) and the 1989 Wisconsin angler study of Fiore *et al.* (1989). The data from the two studies by West *et al.* (1989, 1993) are considered the most representative, so these studies were used to estimate fish ingestion rates for the recreational angler. Thus, both RME and CTE fish ingestion assumptions are based on recent surveys of anglers that have undergone peer review.

For the high-intake fish consumers, three subpopulations were examined: low-income minority anglers, Native American anglers, and Hmong/Laotian anglers. For the low-income minority anglers, the data from West *et al.* (1993) was used. For the Native American subpopulation, the data from Peterson *et al.* (1994) was used to adjust data from Fiore *et al.* (1989) to develop fish intake assumptions. For the Hmong/Laotian anglers, data from Hutchison and Kraft (1994), Hutchison (1994), and Hutchison (1999) were used to develop fish intake assumptions. Of the various studies, those of Hutchison and Kraft (1994) and Hutchison (1994) for the Hmong are most specific to the Lower Fox River and Green Bay. Therefore, this study was used for the high-intake fish consumer. The study of Hutchison (1999) monitored actual fishing behavior of Hmong/Laotian anglers in the De Pere to Green Bay Reach, but this study indicated that this behavior was influenced by the existing fish advisories on the river. Therefore, the Hutchison and Kraft (1994) study was used since this study monitored angling behavior from any water body, not just the Lower Fox River and Green Bay. The influence of alternative assumptions for the recreational angler and high-intake fish consumer were investigated in the focused evaluation of fish ingestion.

For calculating exposures to anglers, the concentrations of PCBs in fish were assumed to remain constant. In the focused risk assessment, the most recent fish concentration data (i.e., the fish concentration data from 1990 through 1998) were used to calculate this constant concentration. Over a very long period of time (e.g., 50 to 100 years or more), PCB concentrations in fish are expected to decline. In the shorter term, it is not clear whether or not significant concentration declines will be observed. In the time trends analysis, concentrations of PCBs in fish declined in some cases, remained constant in other cases, and even appeared to increase in a few cases. Given this uncertainty in the time trend of the fish concentration data, it was assumed that the concentrations remained constant, which is a conservative and health protective assumption. It should be noted that the influence of declines in PCB concentrations in fish over time is assessed as part of the alternative-specific risk assessment in the Feasibility Study.

The focus of the exposure and risk assessment of anglers was on adult exposures via fish consumption. The inclusion of a fish ingestion scenario for young children increased the PCB dose per body weight by a factor that is between two and three times greater than the PCB dose per body weight for adults. In addition, the possibility of prior maternal PCB exposures via fish consumption leading to fetal and nursing infant exposures also adds to the uncertainty regarding resultant exposures and risks. These maternal exposures to PCBs in fish can lead to underestimations of exposure and risk.

For hunters, the critical exposure pathway is ingestion of hunted waterfowl. The waterfowl intake assumptions were based on information on the amount of hunted waterfowl that is consumed by hunters that was collected by Amundson (1984). Thus, the intake assumptions for this critical pathway were based on empirical data.

For other exposure pathways for the recreational angler, high-intake fish consumer, and hunter, and for the exposure pathways for all other receptors, conservative default assumptions from the EPA's *Exposure Factors Handbook* (1997b) or conservative assumptions based on professional judgment were used. Therefore, the exposures calculated for these pathways are unlikely to underestimate actual exposures.

For all receptors, exposure point concentrations were estimated in accordance with EPA guidance, which is designed to be conservative. Consequently, the intakes estimated in the exposure assessment are unlikely to underestimate most actual intakes.

As for the toxicity assessment, two types of health effects were evaluated: cancer risks and non-carcinogenic effects. To determine cancer risks, cancer slope factors were found for potentially carcinogenic compounds. However, cancer slope factors are not based upon animal studies where exposure occurs during fetal and infant development. Organisms are particularly sensitive to adverse chemical effects during early life stages. Cancer extrapolation techniques, which use the upper confidence limits of the slope of the dose-response curve, may provide sufficient protection even if early life exposures are not included. To determine non-carcinogenic effects, reference doses were obtained. As with cancer slope factors, reference doses are developed with the intent of not underestimating noncancer effects. While there tends to be conservatism in cancer slope factors and reference doses, there are factors that might increase cancer risks and noncancer hazard indices beyond those derived in this assessment. For instance, the distribution of PCB congeners that bioaccumulate in fish and wildlife do not resemble the distribution of PCB congeners in Aroclors which have been tested in toxicological studies (Cogliano, 1998). Overall, these bioaccumulated PCB congeners are more persistent than PCB congeners found in Aroclors, and the bioaccumulated PCB congeners may also be more toxic than the PCB congeners found in Aroclors tested in toxicological studies (Cogliano, 1998). The distribution of PCB congeners that bioaccumulate in humans is also different than the distribution of PCB congeners in Aroclor mixtures, and these bioaccumulated PCB congeners are also more persistent. It is therefore possible that the distribution of PCB congeners that bioaccumulate in humans are more toxic than the distributions of PCB congeners found in the Aroclors used in toxicological studies (Cogliano, 1998). A final factor which has not been accounted for in the risk assessment is possible synergistic effects from chemical mixtures.

Additionally, two reference doses have been developed for PCBs, one for Aroclor 1016, the other for Aroclor 1254. The reference dose for Aroclor 1016 has undergone external peer review, while the reference dose for Aroclor 1254 has undergone internal peer review within EPA. The reference dose for Aroclor 1254, which is 3.5 times lower than the value for Aroclor 1016, was used in this assessment to evaluate the noncancer effects of exposure to total PCBs. Since the reference dose for Aroclor 1254 is lower than that for Aroclor 1016, this is conservative. In addition, since higher molecular weight PCB congeners tend to preferentially bioaccumulate in fish and since Aroclor 1254 contains more high molecular weight PCB congeners than Aroclor 1016, the use of the reference dose for Aroclor 1254 is appropriate.

Uncertainties associated with the risk characterization portion of the risk assessment for the Lower Fox River and Green Bay result from the uncertainties associated with the exposure and toxicity assessment. The key uncertainties include concentrations of PCBs in sediment and fish over time, the mixture of fish species consumed by individual anglers, the amount of fish caught and eaten from the Lower Fox River and Green Bay over a lifetime, fetal and infant exposures to PCBs, and toxicological criteria based on Aroclor mixtures rather than individual congeners. The exposure assumptions chosen for anglers appear to be balanced, being appropriately protective, but not overly conservative. Further support for this conclusion is found in the quantitative probabilistic analysis presented in Section 5.9. This analysis evaluated the influence of exposure assumptions for anglers and demonstrated that estimates of cancer risks and hazard indices, based on CTE and RME intake assumptions, fell within the desired range of risks and hazard indices on the distributions of risk and hazard index calculated in the probabilistic assessment.

5.11 Summary and Conclusions

5.11.1 Summary

This section presents the baseline human health risk assessment for the Lower Fox River and Green Bay system. The baseline human health risk assessment included the following:

- Identified chemicals of potential concern (COPCs) and performed additional evaluations of PAHs and lead;

- Provided an exposure assessment that identified receptors and exposure pathways, developed intake assumptions for receptors, and determined exposure point concentrations;

- Presented a dose-response assessment for COPCs that reviewed the toxicological characteristics of each COPC and identified cancer slope factors and reference doses;

- Provided a baseline risk characterization where cancer risks and noncancer hazard indices were calculated for each identified receptor population;

- Presented a focused analysis of exposure to PCBs through ingestion of fish for the two receptors with the highest cancer risks and hazard indices: recreational anglers and high-intake fish consumers; and

- Provided a qualitative uncertainty analysis.

The results for the baseline risk characterization and focused risk characterization are summarized below.

Baseline Risk Characterization

In the baseline risk characterization, cancer risks and noncancer hazard indices were calculated for the following receptors:

- Recreational anglers,
- High-intake fish consumers,
- Hunters,
- Drinking water users,
- Local residents,
- Recreational water users (swimmers and waders), and
- Marine construction workers.

To evaluate exposures to these receptors, intake equations were presented and intake assumptions were developed for each receptor. For all receptors, reasonable maximum exposure (RME) assumptions were developed. For the recreational angler, high-intake fish consumer, and hunter (the receptors with the highest exposures), central tendency exposure (CTE) assumptions were also developed. The calculated intakes were combined with the dose-response information to calculate human health cancer risks and noncancer hazard indices for each receptor. A summary of the cancer risks and hazard indices for each receptor are presented in Tables 5-109 and 5-110, respectively.

The State of Wisconsin uses a risk level of 10^{-5} for evaluating cumulative cancer risks in the evaluation of sites under Chapter NR 700, while Superfund uses a risk level of 10^{-6} as the point at which risk management decisions may be considered. Risk management decisions most frequently made under Superfund are in the range of 10^{-6} to 10^{-4}. Wisconsin under Chapter NR 700 and EPA under Superfund both use an HI of 1.0 as a point at which risk management decisions may be considered.

Cancer risks exceeding 1.0×10^{-6} were identified for the recreational anglers, high-intake fish consumers, hunters, and drinking water users. Cancer risks for the marine construction worker slightly exceed the 1.0×10^{-6} level in the Little Lake

Butte des Morts Reach. Cancer risks as high as 3.8×10^{-3} were calculated for high-intake fish consumers, while risks as high as 2.8×10^{-3} were calculated for recreational anglers. These values are 46 and 34 times greater than the next highest risks calculated for any other receptor; the receptor with the next highest risks being the hunter with a risk of 8.3×10^{-5}. For the anglers, the cancer risks are driven by the ingestion of PCBs in fish tissue (over 80 percent for reaches of the Lower Fox River and over 68 percent in Green Bay). For the hunters, the cancer risks are driven by the ingestion of PCBs in waterfowl tissue. The risks to drinking water users exceed the 10^{-6} level only in the De Pere to Green Bay Reach (3.8×10^{-5}). This exceedance is due to arsenic, and the arsenic concentration used in the calculation is the value detected in one of four water samples from this reach. Arsenic was detected only once in the seven samples collected from the Lower Fox River, so it is quite possible that actual arsenic concentrations are lower than those used in this analysis; therefore, the risks associated with arsenic in this reach may be overstated. Additionally, the water in this reach is not currently used as a source of drinking water and there are no plans to use it as such in the foreseeable future (this reach of the Lower Fox River is not classified for use as a source of drinking water).

Noncancer hazard indices exceeding 1.0 have been identified for the recreational anglers, high-intake fish consumers, hunters, drinking water users, and local residents. As noncancer hazard indices become greater than 1.0, the potential for adverse noncancer health effects becomes greater. While the hazard indices for the hunter, drinking water user, and local resident exceed 1.0, the maximum calculated hazard index for these receptors was 3.8, only slightly above 1.0. In comparison, noncancer hazard indices for anglers reached a maximum of 147, more than two orders of magnitude above 1.0. Exposure to PCBs in fish is responsible for over 86 percent of the hazard index for anglers in the Lower Fox River and over 88 percent of the hazard index for anglers in Green Bay. For the hunter, PCBs are responsible for over 95 percent of the total hazard index in the Lower Fox River and over 91 percent of the total hazard index in Green Bay.

Hazard indices for drinking water users and local residents exceeding 1.0 are due to mercury. The mercury surface water concentrations in the Lower Fox River database were obtained from a variety of sources that did not necessarily use analytical methods intended to quantitate low concentrations of this chemical. The study by Hurley *et al.* (1998) measured dissolved and total mercury in surface water from several locations on the Lower Fox River with much finer temporal resolution than the data included in the Lower Fox River database. When using more recent mercury data in the hazard index calculations for the drinking water user and local resident, the resulting hazard indices were below 1.0.

EPA guidance for risk characterization (EPA, 1995b, 1995c) indicates that an important step in the risk characterization process is the identification of subpopulations that may be highly exposed or highly susceptible. This evaluation of cancer risks and noncancer hazard indices indicates that the receptors with the highest risks and hazard indices are recreational anglers and high-intake fish consumers. Since calculated cancer risks exceed the 10^{-6} level by more than three orders of magnitude and calculated noncancer hazard indices exceed 1.0 by more than two orders of magnitude, the number of people included in these subpopulations is important to consider.

There are approximately 136,000 individuals with fishing licenses (WDNR, 1999d) living in counties adjacent to the Lower Fox River and Green Bay. The entire population of this area is estimated to be on the order of 640,000 (Census Bureau, 1992), which indicates that as many as 21 percent of the residents are active anglers. In addition to licensed anglers, their family members (who may not be anglers) can be exposed to PCBs in fish. The population of high-intake fish consumers, the most highly exposed subpopulation evaluated in this risk assessment, is estimated to be on the order of 5,000 people for the Lower Fox River and Green Bay area, including 3,800 low-income minority anglers, 1,200 Hmong anglers, and an unspecified number of Native American anglers.

For the recreational anglers and high-intake fish consumers, the exposure route of primary concern is ingestion of fish containing PCBs. The calculated cancer risks were as high as 2.8×10^{-3} for the recreational angler and 3.8×10^{-3} for the high-intake fish consumer, showing only small differences in these two groups of anglers. These calculated risks are over three orders of magnitude above the risk level of 10^{-6}. Put differently, the risks to the high-intake fish consumer represents a maximum incremental increased risk of contracting cancer in a lifetime of approximately four in 1,000 as a result of consuming fish caught from the Lower Fox River or Green Bay. The calculated noncancer hazard indices were as high as 107 for recreational anglers and 147 for the high-intake fish consumers, showing only small differences between these two groups of anglers. These values are more than 100 times the value established to protect people from long-term adverse noncancer health effects. As discussed in Section 5.6.2, the noncancer health effects associated with exposure to PCBs include reproductive effects (e.g., conception failure in highly-exposed women [Courval *et al.*, 1997]), developmental effects (e.g., neurological impairments in highly-exposed infants and children [Lonky *et al.*, 1996; Jacobson and Jacobson, 1996; Huisman *et al.*, 1995a, 1995b; Lanting *et al.*, 1998; Koopman-Esseboom *et al.*, 1996]), and immune system suppression (e.g., increased incidence of infectious disease in highly-exposed infants [Smith, 1984; Humphrey, 1988], effects on T-cell counts in adults and infants [Tryphonas, 1995; Weisglas-Kuperus *et al.*, 1995] or the possibility of increased susceptibility to infectious diseases in children exposed prenatally to PCBs and dioxins [Weisglas-Kuperus *et al.*, 2000]). All of these noncancer health effects are extensively documented in animal studies (ATSDR, 1997).

Population estimates for hunters are more difficult to define. The Wisconsin Department of Natural Resources estimated that there are approximately 3,000 individuals in Brown County with licenses to hunt waterfowl. Brown County encompasses the city of Green Bay and has a population of about 200,000 people (Census Bureau, 1992). Assuming that the same ratio of licenses to people applies elsewhere in the Green Bay to Lake Winnebago corridor where the overall population is 640,000 people (Census Bureau, 1992), the number of individuals licensed to hunt waterfowl in the Lower Fox River/Green Bay area is about 9,600 people. For the hunter, the exposure route of primary concern is the ingestion of waterfowl containing PCBs. The calculated risks for this receptor were as high as 8.3×10^{-5}, nearly two orders of magnitude above the risk level of 10^{-6}. This represents a maximum incremental increased risk of contracting cancer in a lifetime of one in 10,000 as a result of consuming hunted waterfowl. The hazard indices were as high as 3.1, which is about three times the value established to protect people from long-term adverse health effects. The noncancer health effects associated with exposure to PCBs for the hunter are similar to those described previously for recreational anglers and high-intake fish consumers.

Focused Risk Characterization

The baseline risk characterization, where cancer risks and noncancer hazard indices were calculated for a range of receptors, indicated that the receptors with the highest risks and hazard indices were recreational anglers and high-intake fish consumers due to exposure to PCBs in fish. Consequently, a focused evaluation of exposure to PCBs in fish by recreational anglers and high-intake fish consumers was performed. This focused evaluation included the following:

- A detailed evaluation of PCB fish data;
- Restatement of equations for calculating risks and hazard indices from fish ingestion and development of equations for calculating risk-based concentrations in fish;
- Development of intake assumptions for recreational anglers and high-intake fish consumers and restatement of toxicological parameters of PCBs;

- Calculation of cancer risks and noncancer hazard indices using a range of intake assumptions for recreational anglers and high-intake fish consumers and a variety of fish species;

- Evaluation of cancer risks and noncancer hazard indices using the intake assumptions for anglers in the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al*., 1993);

- Summary of the probabilistic risk assessment for recreational anglers and high-intake fish consumers in Appendix B1;

- Summary of the evaluation of the risk assessment performed by Exponent (2000) on behalf of the Fox River Group;

- Qualitative and quantitative evaluation of PCB exposures to young children; and

- Calculation of risk-based concentrations in fish using the intake assumptions for recreational anglers and high-intake fish consumers, and the intake assumptions for anglers in the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.*, 1993).

This section summarizes the first item and the last six items in this list.

PCB Concentrations in Fish. As discussed in Section 2, an analysis of the trends in PCB concentrations in fish over time was performed and concentrations of PCBs in fish were shown to vary with time. In many cases, the concentrations in fish declined with time. In some cases, the concentrations remained essentially constant over time and in a few cases, the concentrations in fish appeared to increase.

For the risk analyses conducted, the concentrations of PCBs in fish are assumed to be constant over time. Such an approach is appropriately conservative and protective of human health. While it might be possible to predict future PCB concentrations in fish, there is substantial uncertainty in such projections. First, historical trends may not be accurate predictors of future trends. Second, the historical data is typically available for a period of 15 to 25 years, whereas the exposure periods of interest are 30 to 50 years. Thus, using historical data to predict future concentrations requires the additional assumption that the historical data will accurately reflect future concentrations over time periods that are two to three times longer than the historical time period. Third, there is not sufficient data to evaluate time trends in every species that people typically eat for every reach of the Lower Fox River and every zone of Green Bay.

Cancer Risks and Hazard Indices for Recreational Anglers and High-intake Fish Consumers. Cancer risks and hazard indices were calculated for recreational anglers and high-intake fish consumers in each reach of the Lower Fox River and each zone in Green Bay using a range of intake assumptions developed for these receptors. For recreational anglers, RME and CTE assumptions were developed from the 1989 and 1993 Michigan angler studies of West *et al.* (1989, 1993) and the 1989 Wisconsin angler study of Fiore *et al.* (1989). Intake assumptions based on the average of the intakes developed in the 1989 Michigan angler study and 1993 Michigan angler study were also developed. For high-intake fish consumers, three subpopulations were examined: low-income minority anglers, Native American anglers, and Hmong/Laotian anglers. RME and CTE assumptions were developed for each subpopulation. The cancer risks and hazard indices were calculated using the average concentrations of all fish samples, carp, perch, walleye, and white bass. The fish data from the 1990s in addition to walleye data in Green Bay from 1989 were used to calculate these concentrations.

Table 5-111 summarizes the cancer risks and hazard indices for the recreational anglers and high-intake fish consumers in the Lower Fox River and Green Bay. This table provides a lowest, median, and highest risk or hazard index. The "lowest" value does not represent the lowest possible risk or hazard index (which is zero, corresponding with eating no fish from the Lower Fox River or Green Bay), but represents the lowest value calculated using the intake assumptions provided for each angler group. Similarly, the "highest" value does not represent the highest possible risk or hazard index, but represents the highest value calculated with the intake assumptions provided for each angler group. Also provided in Table 5-111 are the cancer risks and hazard indices that result from using the concentration of PCBs in fish from Lake Winnebago in the risk and hazard index equations. These data from Lake Winnebago represent background concentrations.

The highest cancer risks based on all fish samples are for the RME scenario and are 9.8×10^{-4} for the recreational angler and 1.4×10^{-3} for the high-intake fish consumer, showing only small differences between these two groups of anglers. These values are three orders of magnitude above the 10^{-6} risk level. For the RME scenario, cancer risks range from 2.1×10^{-4} to 9.8×10^{-4} for the recreational angler and from 1.8×10^{-4} to 1.4×10^{-3} for the high-intake fish consumer. For the CTE scenario, the risks are four to eight times lower than the corresponding risks for the RME scenario. This variation reflects differences in intake assumptions and variations in fish concentrations by river reach and Green Bay zone. The highest calculated risks are for carp. The lowest, median, and average risk for carp are all higher than the corresponding values for all fish samples indicating that carp concentrations are systematically among the highest compared to other fish species. The risks calculated for perch, walleye, and white bass are grouped together as these species are among the most commonly sought-after fish by anglers. The highest risks in this group are always higher than the highest risks for all fish samples. The lowest risk is often lower than the lowest risk for all fish samples and the median risk is often similar to the median risk for all fish samples. This indicates that the PCB concentrations in these three species show more variation than the PCB concentrations in carp. The maximum risk of 9.8×10^{-4} for the recreational angler is about 21 times greater than the maximum risk of 4.6×10^{-5} calculated using the fish concentrations from Lake Winnebago, which represents background. The maximum risk of 1.4×10^{-3} for the high-intake fish consumer is also about 21 times greater than the maximum risk calculated with the average fish concentration from Lake Winnebago.

The highest hazard indices based on all fish samples are for the RME scenario and are 36.9 for recreational anglers and 52.0 for high-intake fish consumers, showing only small differences between these two groups of anglers. These values significantly exceed an HI of 1.0. The highest hazard indices are for carp, reaching 86.2 for recreational anglers and 121.5 for high-intake fish consumers. The maximum hazard indices of 36.9 for the recreational anglers and 52.0 for the high-intake fish consumers are approximately 21 times greater than the hazard indices calculated using the Lake Winnebago fish data for each receptor.

To show how risks and hazard indices vary by river reach and Green Bay zone, the maximum cancer risks and noncancer hazard indices calculated for recreational anglers and high-intake fish consumers in each reach of the Lower Fox River and each zone of Green Bay are provided in Table 5-112. These maximum risks and hazard indices were calculated using the average concentrations of all fish samples in the 1990s (plus walleye data from 1989 in Green Bay). In the Lower Fox River, the highest risks and hazard indices occur in the De Pere to Green Bay Reach, while the lowest risks and hazard indices occur in the Little Rapids to De Pere Reach. In Green Bay, the highest risks and hazard indices are in Zone 3A, while the lowest risks and hazard indices are in Zone 4.

Cancer Risks and Hazard Indices Associated with Intake Assumptions from the Great Lakes Sport Fish Advisory Task Force. For additional perspective, cancer risks and hazard indices were also calculated using the exposure assumptions in the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.*, 1993). Intake assumptions were provided for four fish consumption scenarios: unlimited consumption, one meal per week, one meal per month, and six meals per year. The resulting cancer risks and hazard indices for each river reach and Green Bay zone were compared to results for recreational anglers and high-intake fish consumers. The cancer risks range from 3.2×10^{-5} to 2.7×10^{-3} and the hazard indices range from 0.8 to 67.8. The maximum cancer risks and hazard indices estimated for the unlimited consumption scenario are higher than the maximum risks and hazards for the high-intake fish consumers, although these values are comparable.

Summary of Probabilistic Risk Assessment. A probabilistic evaluation of exposure to PCBs in fish was provided in Appendix B1. This evaluation was prepared consistent with EPA guidance on probabilistic risk assessment (EPA, 1999), and supports and complements the point estimates of risks and hazard indices calculated in the focused evaluation of exposure to PCBs in fish.

The main results of the probabilistic evaluation are as follows.

- The deterministic CTE estimates of risk and hazard index provided in the focused evaluation are generally close to the means of the respective probability distributions of risk and hazard index. This is consistent with the interpretation of the CTE as the average risk or hazard index for the exposed population.

- The deterministic RME estimates of risk and hazard index provided in the focused evaluation are generally within the 90th to 95th percentiles of the respective probability distributions of risk and hazard indices. This is consistent with the interpretation provided in EPA (1999) of the RME as a plausible high-end risk or hazard index for the exposed population.

- The uncertainty in the estimate of the probability distributions of risk and hazard index is moderate, as reflected by the fact that the maximum and minimum values for the ranges are generally within a factor of 10 of each other.

Evaluation of Exponent Risk Assessment. The probabilistic risk assessment prepared by Exponent (2000) on behalf of the Fox River Group was evaluated in Appendix B1, and its assumptions were compared (wherever possible) to the results of the focused evaluation of exposure to PCBs in fish. This comparison could only be performed for recreational anglers, since Exponent (2000) did not evaluate exposures to high-intake fish consumers.

The comparison of Exponent (2000) assumptions with the assumptions used in the focused evaluation of recreational anglers was accomplished by calculating unit risks and unit hazard indices. These are the risks and hazard indices associated with unit concentrations of PCBs in fish (i.e., 1 mg/kg). This comparison indicated that the intake assumptions used by Exponent (2000) result in generally lower unit risks and hazard indices than the assumptions presented earlier in this section for recreational anglers. The differences between the unit risks and hazard indices calculated using Exponent (2000) assumptions and the assumptions presented earlier for recreational anglers depend on the study used to estimate fish intake assumptions. This difference is generally greatest for the survey of Michigan anglers by West *et al.* (1993), and least for the survey of Wisconsin anglers by Fiore *et al*. (1989).

Evaluation of PCB Exposure to Young Children. This section discussed potential health effects to young children from exposure to PCBs. This exposure includes transfer of PCBs from the mother across the placenta to the fetus, transfer from the mother to an infant through breast milk, and exposure to young children as a result of consuming contaminated fish. Transfer of maternal PCBs across the placenta and into breast milk can clearly result in significant exposures *in utero* and to a nursing infant (Dekoning and Karmaus, 2000). Exposure to PCBs in breast milk is estimated to be a major contributor to a child's body burden at 42 months of age (Lanting *et al.*, 1998) and to account for over 10 percent of an individual's cumulative PCB intake through 25 years of age (Patandin *et al.*, 1999). Two types of exposures to the mother were examined, short-term, high-level exposures and longer-term exposures to lower levels through fish ingestion.

The discussion of potential adverse health effects from short-term, high-level exposures relied on the adverse health effects observed in individuals from Taiwan and Japan who unknowingly ate cooking oil or rice oil contaminated with PCBs. These exposures resulted in an outbreak of short-term illnesses (including chloracne, a severe skin condition associated with high-level exposures to PCBs, dioxins, or furans), but also resulted in a variety of developmental, neurological, and immune system effects in the children born to women who suffered these exposures. These adverse health effects suggest that short-term, high-level exposures to PCBs (even one-time exposures) can have long-term consequences for the children born to women who suffer such exposures. It should be noted that the health effects reported in these studies could be associated with the presence of furans in the cooking oil and rice oil and not necessarily the presence of PCBs in this oil.

The discussion of potential adverse health effects from longer-term exposures to lower levels through fish ingestion indicated that such exposures also result in a variety of developmental, neurological, and immune system effects in the children born to women who suffered these exposures. No attempt was made to quantitatively evaluate such exposures, because methods to model exposures due to placental transfer or breast-feeding are not well established. However, since a variety of developmental, neurological, and immune system effects have been observed in infants and children whose mothers consumed fish known to be contaminated with PCBs, it seems plausible that PCB exposures for at least some women consuming fish from the Lower Fox River and Green Bay could be in the same range of PCB exposure levels at which these effects have been observed.

A quantitative evaluation of potential exposure to a young child (age 1 through 7 years) as a result of eating fish was performed. Chronic hazard indices were calculated for a recreational angler child and a high-intake fish consumer child for the Little Lake Butte des Morts and the De Pere to Green Bay reaches and the results were compared to results for the adult receptors in these reaches. A 7-year exposure period was chosen because this is the shortest period which is still considered chronic exposure (EPA, 1989c).

For the two reaches, the hazard indices estimated for the recreational angler children ranged from 29.7 to 88.4 for the RME scenario and from 9.1 to 19.3 for the CTE scenario. The hazard indices estimated for the high-intake fish consumer child ranged from 26.2 to 124.6 for the RME scenario and from 6 to 48.7 for the CTE scenario. In all cases, the calculated hazard indices are about 2.4 times greater for the child than for the adult.

Risk-based Concentrations in Fish. Using the range of intake assumptions for recreational anglers and high-intake fish consumers, a range of risk-based concentrations in fish were determined for specific cancer risk and hazard index levels. These risk-based concentrations were developed for cancer risks of 10^{-6}, 10^{-5}, 10^{-4}, and an HI of 1.0 and are presented in Table 5-113. The risk-based fish concentrations for the recreational angler covered a range of about three orders of magnitude (1.4×10^{-3} mg/kg to 1.6 mg/kg). For a given set of assumptions, the risk-based fish concentration for an HI of 1.0 always fell between the risk-based fish concentrations for the 10^{-5} and 10^{-4} cancer risk levels. To be fully protective of recreational anglers from adverse noncancer effects, PCB concentrations in fish as low as 0.037 mg/kg are indicated. Similarly, the risk-based fish concentrations for the high-intake fish consumer(s) covered a range of about three orders of magnitude (9.8×10^{-4} mg/kg to 2.4 mg/kg) and the risk-based fish concentration for an HI of 1.0 always fell in between the risk-based fish concentrations for risk levels of 10^{-5} and 10^{-4}. To be fully protective of high-intake fish consumer(s) from adverse noncancer effects, PCB concentrations in fish as low as 0.026 mg/kg are indicated.

Risk-based fish concentrations were also calculated using the intake assumptions in the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson *et al.*, 1993). Intake assumptions were provided for four fish consumption scenarios: unlimited consumption, one meal per week, one meal per month, and six meals per year. The resulting risk-based fish concentrations are provided in Table 5-113. These concentrations range from 5.0×10^{-4} mg/kg to 1.9 mg/kg, spanning more than three orders of magnitude depending on the selected cancer risk level and exposure scenario. The risk-based fish concentration for an HI of 1.0 is between the risk-based fish concentrations for cancer risks of 10^{-5} and 10^{-4}.

When Anderson *et al*. (1993) derived their risk-based fish concentration of 0.05 mg/kg for unlimited consumption, they used an RfD of 5.0×10^{-5} mg/kg-day based on a weight-of-evidence evaluation of epidemiological and animal studies, whereas the risk-based fish concentration in Table 5-113 of 0.02 mg/kg for an HI of 1.0 and unlimited consumption is based on the RfD of 2.0×10^{-5} mg/kg-day for Aroclor 1254.

It is interesting to note that the average of the RME risk-based fish concentrations for an HI of 1.0 for the recreational angler (0.063 mg/kg) and high-intake consumer (0.038 mg/kg) is also 0.05 mg/kg. The average value of 0.038 mg/kg for the high-intake fish consumer does not include the risk-based fish concentration for Hutchison (1999), since this study underestimates potential fish consumption in the Lower Fox River. The value of 0.05 mg/kg from Anderson *et al.* (1993) falls between the average RME and CTE risk-based fish concentrations at a 10^{-5} risk level for the recreational angler (0.024 to 0.14 mg/kg) and the high-intake fish consumer (0.014 to 0.078 mg/kg). The range of values for the high-intake fish consumer does not include the risk-based fish concentration based on the Hutchison (1999) study.

5.11.2 Conclusions

This risk assessment fulfills the NRC (2001) recommendation that sites be evaluated using a scientific risk-based framework so that different approaches for remediating PCB-contaminated submerged sediments can be compared in terms of the efficacy and human and ecological risks associated with each approach. The BLRA essentially evaluates risk assuming a no action remedial alternative. Relative risks associated with other potential remedial actions are discussed in the Feasibility Study.

This human health risk assessment for the Lower Fox River and Green Bay calculated cancer risks and noncancer hazard indices for the following receptors:

- Recreational anglers,
- High-intake fish consumers,
- Hunters,
- Drinking water users,
- Local residents,
- Recreational water users (swimmers and waders), and
- Marine construction workers.

The highest cancer risks and noncancer hazard indices were calculated for recreational anglers and high-intake fish consumers due primarily to consumption of fish containing PCBs. Using fish concentration data from 1990 on (and walleye data from 1989 in Green Bay), the cancer risks were as high as 9.8×10^{-4} for recreational anglers and 1.4×10^{-3} for high-intake fish consumers. These risks are more than 1,000 times greater than the 10^{-6} cancer risk level, which is the point at which risk management decisions may be made under Superfund. These risks are more than 100 times greater than the 10^{-5} cancer risk level used by Wisconsin in evaluating sites under Chapter NR 700.

The hazard indices were as high as 36.9 for the recreational angler and 52.0 for the high-intake fish consumer, far in exceedance of the value of 1.0 established to protect people from long-term adverse noncancer health effects. Noncancer hazard indices were also calculated for young children eating fish for the Little Lake Butte des Morts and De Pere to Green Bay reaches, the two reaches with the greatest population density. The hazard indices were approximately 2.4 times those found for adults or as high as 88.4 for children of recreational anglers and 124.6 for children of high-intake fish consumers. The noncancer health effects associated with exposure to PCBs include reproductive effects (Courval *et al.*, 1997), developmental effects (Lonky *et al.*, 1996; Jacobson and Jacobson, 1996; Huisman *et al.*, 1995a, 1995b; Lanting *et al.*, 1998; Koopman-Esseboom *et al.*, 1996; Johnson *et al.*, 1998a), and immunological effects (Smith, 1984; Humphrey, 1988; Tryphonas, 1995; Weisglas-Kuperus *et al.*, 1995, 2000). All of these noncancer health effects are extensively documented in animal studies (ATSDR, 1997). To provide perspective on the number of individuals who are potentially exposed, there are approximately 136,000 recreational anglers based on fishing licenses and approximately 5,000 high-intake fish consumers. The high-intake fish consumers include low-income minority anglers (about 3,800), Native American anglers (number is not known), and Hmong/Laotian anglers (about 1,200).

Cancer risks and hazard indices were calculated by river reach and Green Bay zone. However, there was relatively little difference between the highest risk in any reach or zone, which occurred in Green Bay Zone 3A, and the lowest risk in any reach or zone, which occurred in the Little Rapids to De Pere Reach. The risk in the De Pere to Green Bay Reach is 2.2 times greater than the risk in the Little Rapids to De Pere Reach.

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

The only other receptors with cancer risks exceeding 10^{-6} were the hunters and drinking water users. Cancer risks for the marine construction worker slightly exceed the 1.0×10^{-6} level in the Little Lake Butte des Morts Reach. The risks to the hunter were as high as 8.3×10^{-5}, but were at least 10 times lower than the risks to the anglers. The risk to the hunter was due to ingestion of PCBs in waterfowl. The risk to drinking water users exceeded 10^{-6} only in the De Pere to Green Bay Reach. This exceedance was due to arsenic in surface water and the arsenic value was from one detected value in a total of four samples. A more systematic sampling of this water for arsenic might show this single detected value to be anomalous. Additionally, the water in this reach is not currently used as a source of drinking water and there are no plans to use it as such in the foreseeable future (this reach of the Lower Fox River is not classified for use as a source of drinking water). The cancer risks to drinking water users in all other reaches of the Lower Fox River and zones of Green Bay were below the 10^{-6} level, as were the cancer risks for the local residents and recreational water users (swimmers and waders).

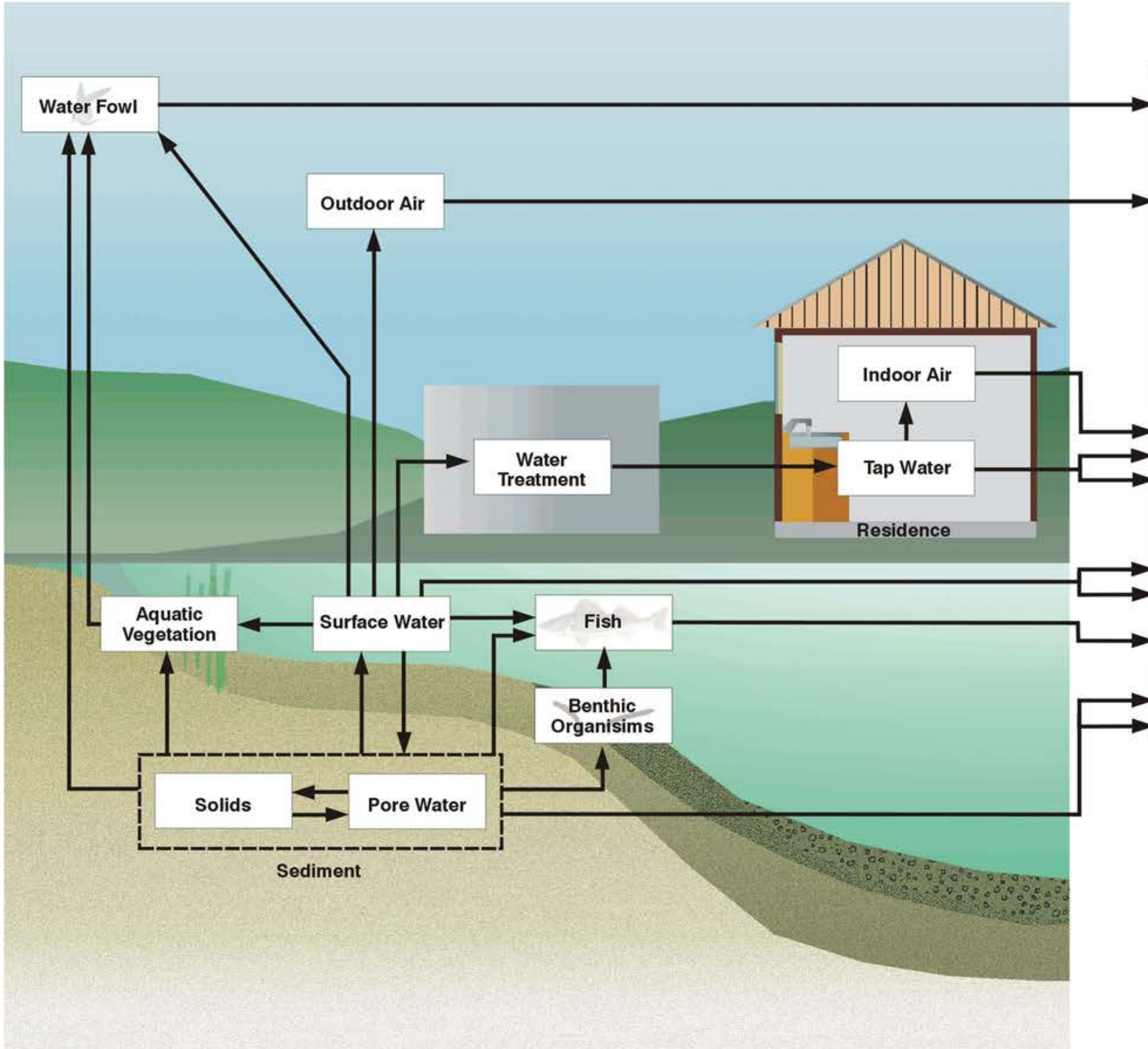
The only other receptors with hazard indices exceeding 1.0 were the hunter, drinking water user, and local resident. The highest hazard index for these receptors was 3.8, only slightly above 1.0. These hazard indices are at least 38 times lower than the hazard indices for the anglers. The hazard indices were below 1.0 for the recreational water users and marine construction workers in all reaches of the Lower Fox River and zones of Green Bay.

Recreational anglers and high-intake fish consumers are at greatest risk for contracting cancer or experiencing noncancer health effects. The highest cancer risks are more than 20 times greater than background risks calculated for eating fish from Lake Winnebago (which is a background location relative to the Lower Fox River and Green Bay). The primary reason for these elevated risks and hazard indices is ingestion of fish containing PCBs.

5.12 Section 5 Figures and Tables

Section 5 figures and tables follow page 5-154 and include:

Figure 5-1. Potential Source Media, Chemical Migration Routes, Human Receptors, and Exposure Pathways

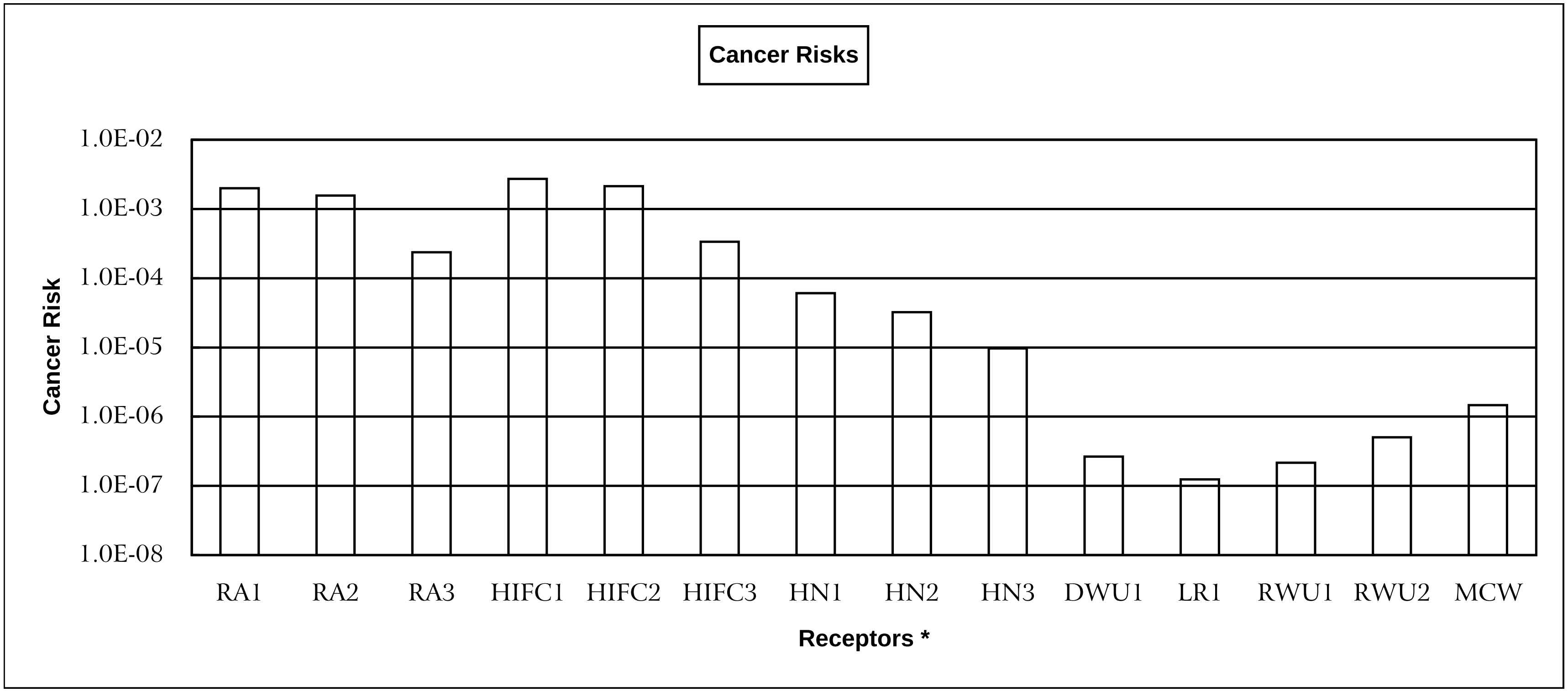


Exposure Pathway	Recreational Angler	High Intake Fish Consumer	Hunter	Drinking Water User	Local Residents	Recreational Water User	Marine Construction Worker
Ingestion (Water Fowl)			●				
Inhalation (Outdoor Air)	○	○	○		●	○	○
Inhalation (Indoor Air)				●			
Ingestion (Tap Water)				●			
Dermal Contact (Tap Water)				●			
Ingestion (Surface Water)	○	○	○			●	○
Dermal Contact (Surface Water)	○	○	○			●	○
Ingestion (Fish)	○	●					
Ingestion (Sediment)						○	●
Dermal Contact (Sediment)						○	●

○ Potentially Complete Pathway

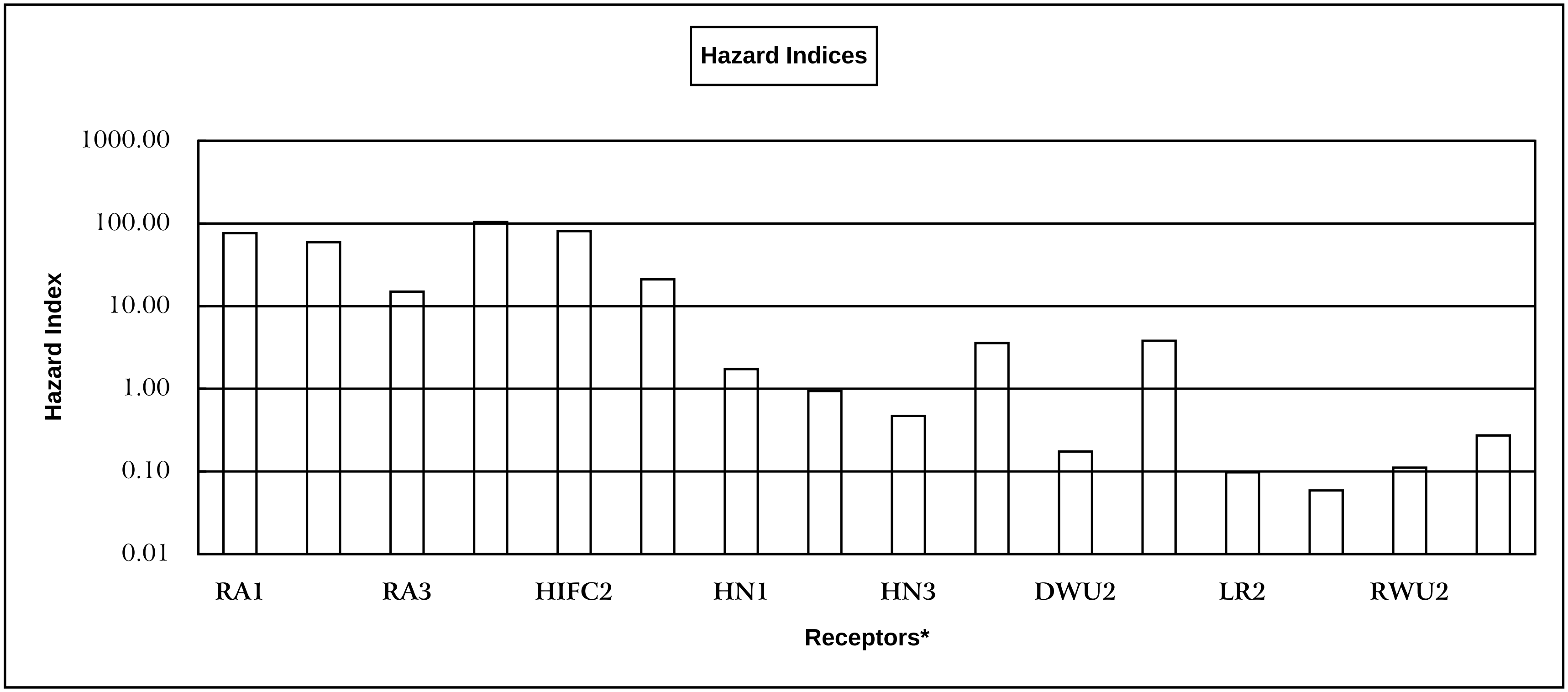
● Receptor with Highest Exposure for this Pathway

Figure 5-2 Cancer Risks for the Little Lake Butte des Morts Reach



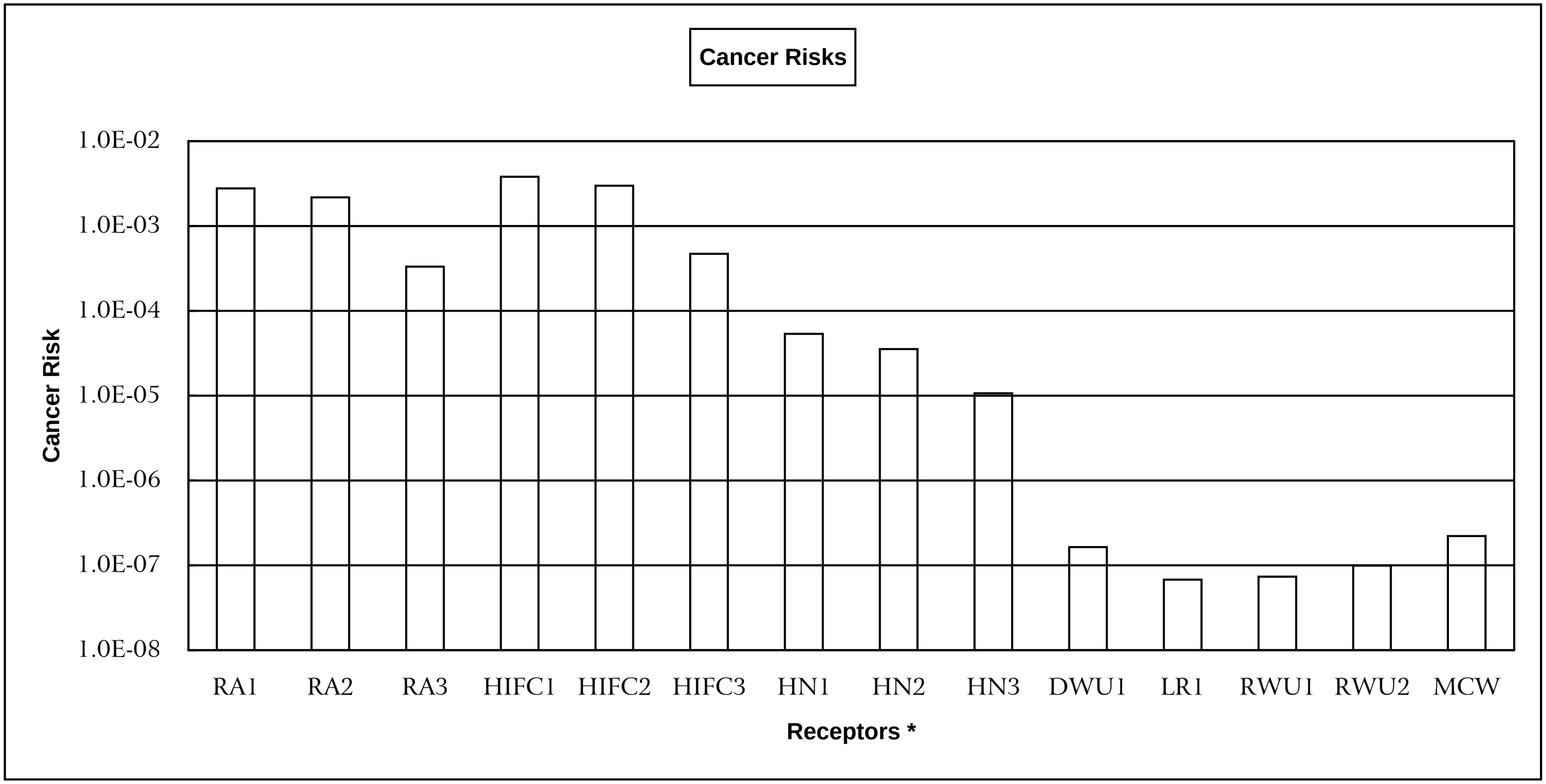
* Key for Receptors		
RA1 - Recreational Angler (RME/Uppb)		
RA2 - Recreational Angler (RME/Average)	HN1 - Hunter (RME/Uppb)	LR1 - Local Resident (RME/Uppb)
RA3 - Recreational Angler (CTE/Average)	HN2 - Hunter (RME/Average)	RWU1 - Swimmer (RME/Uppb)
HIFC1 - High-intake Fish Cons. (RME/Uppb)	HN3 - Hunter (CTE/Average)	RWU2 - Wader (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)	DWU1 - Drinking Water User (RME/Uppb)	MCW - Construction Worker (RME/Uppb)
HIFC3 - High-intake Fish Cons. (CTE/Average)		

Figure 5-3 Hazard Indices for the Little Lake Butte des Morts Reach



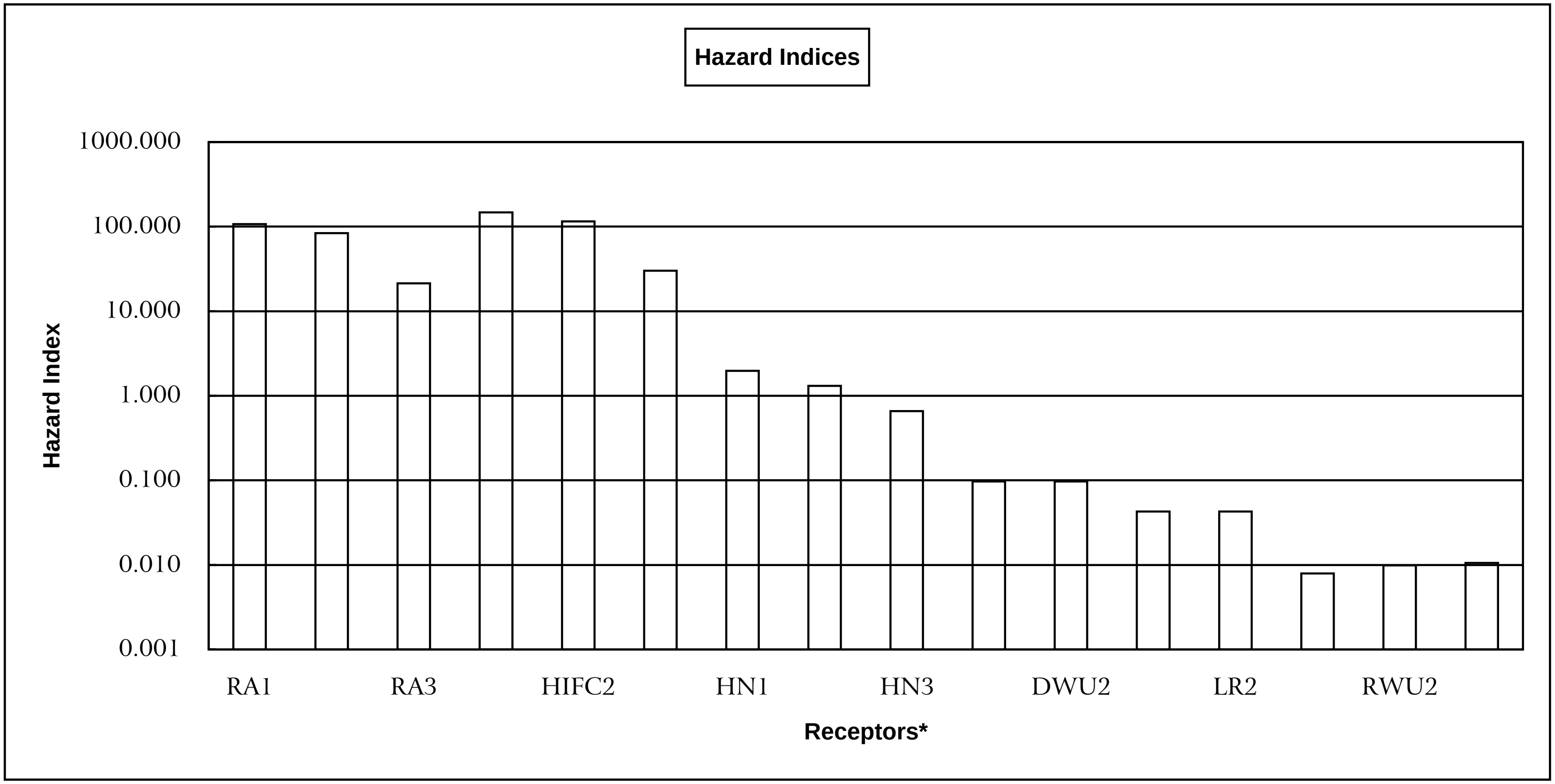
* Key for Receptors		
RA1 - Recreational Angler (RME/Uppb)	HN1 - Hunter (RME/Uppb)	LR1 - Local Resident (RME/Uppb)
RA2 - Recreational Angler (RME/Average)	HN2 - Hunter (RME/Average)	LR2 - Local Resident (RME/Uppb and Recent Mercury Data)
RA3 - Recreational Angler (CTE/Average)	HN3 - Hunter (CTE/Average)	
HIFC1 - High-intake Fish Cons. (RME/Uppb)	DWU1 - Drinking Water User (RME/Uppb)	RWU1 - Swimmer (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)	DWU2 - Drinking Water User (RME/Uppb and Recent Mercury Data)	RWU2 - Wader (RME/Uppb)
HIFC3 - High-intake Fish Cons. (CTE/Average)		MCW - Construction Worker (RME/Uppb)

Figure 5-4 Cancer Risks for the Appleton to Little Rapids Reach



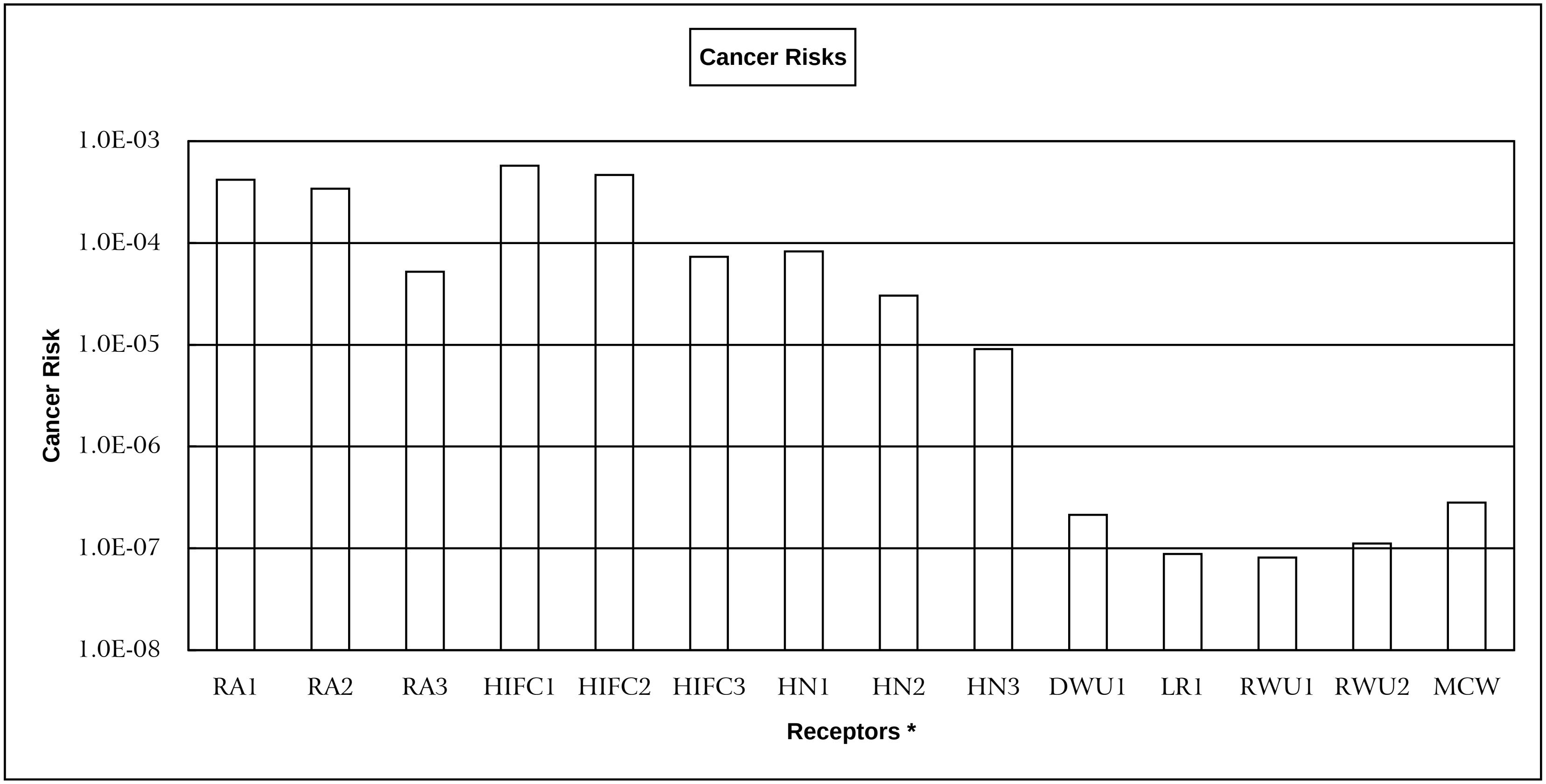
* Key for Receptors		
RA1 - Recreational Angler (RME/Uppb)		
RA2 - Recreational Angler (RME/Average)	HN1 - Hunter (RME/Uppb)	LR1 - Local Resident (RME/Uppb)
RA3 - Recreational Angler (CTE/Average)	HN2 - Hunter (RME/Average)	RWU1 - Swimmer (RME/Uppb)
HIFC1 - High-intake Fish Cons. (RME/Uppb)	HN3 - Hunter (CTE/Average)	RWU2 - Wader (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)	DWU1 - Drinking Water User (RME/Uppb)	MCW - Construction Worker (RME/Uppb)
HIFC3 - High-intake Fish Cons. (CTE/Average)		

Figure 5-5 Hazard Indices for the Appleton to Little Rapids Reach



* Key for Receptors		
RA1 - Recreational Angler (RME/Uppb)	HN1 - Hunter (RME/Uppb)	LR1 - Local Resident (RME/Uppb)
RA2 - Recreational Angler (RME/Average)	HN2 - Hunter (RME/Average)	LR2 - Local Resident (RME/Uppb and Recent Mercury Data)
RA3 - Recreational Angler (CTE/Average)	HN3 - Hunter (CTE/Average)	
HIFC1 - High-intake Fish Cons. (RME/Uppb)	DWU1 - Drinking Water User (RME/Uppb)	RWU1 - Swimmer (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)	DWU2 - Drinking Water User (RME/Uppb and Recent Mercury Data)	RWU2 - Wader (RME/Uppb)
HIFC3 - High-intake Fish Cons. (CTE/Average)		MCW - Construction Worker (RME/Uppb)

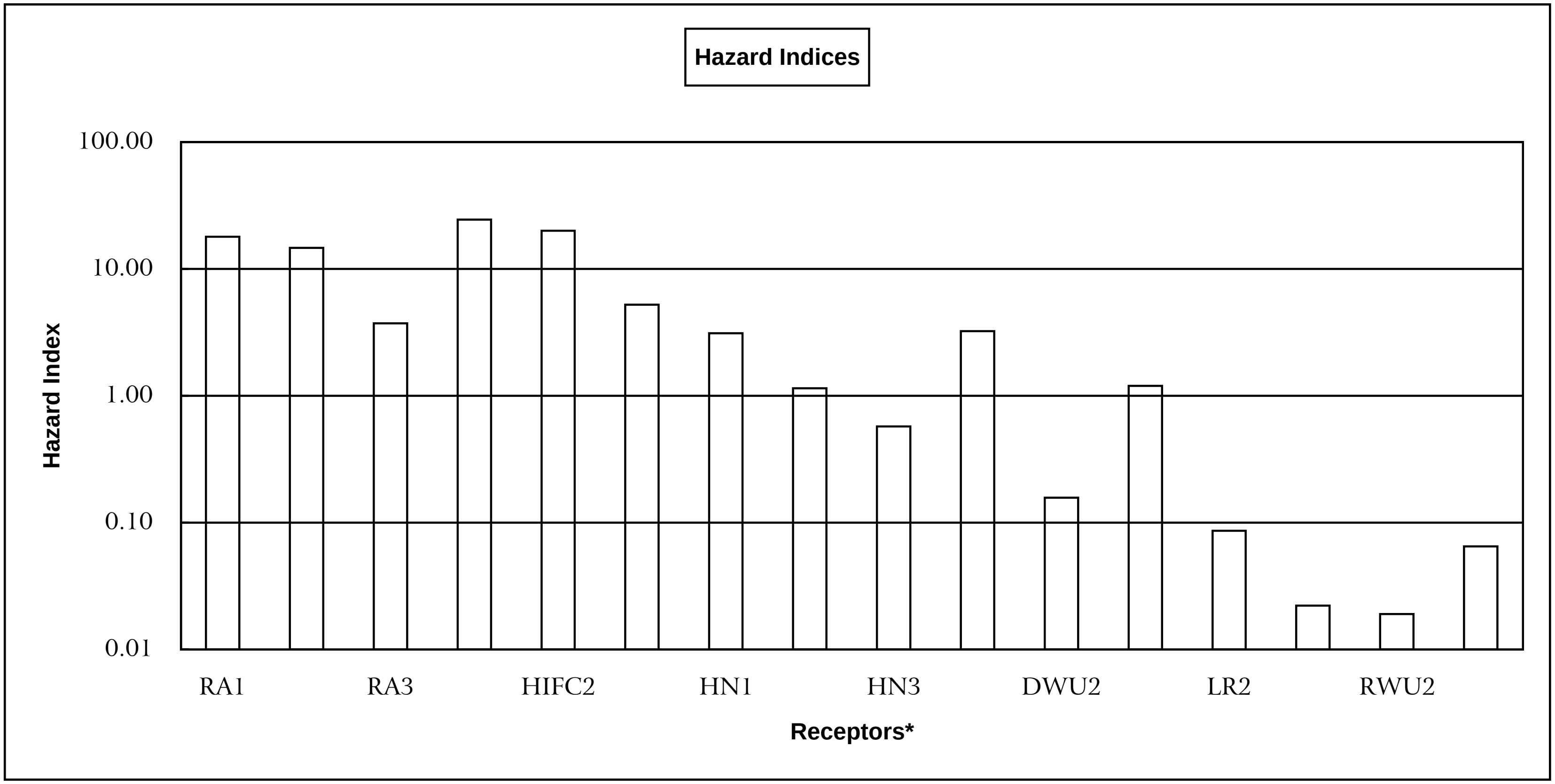
Figure 5-6 Cancer Risks for the Little Rapids to De Pere Reach



*** Key for Receptors**

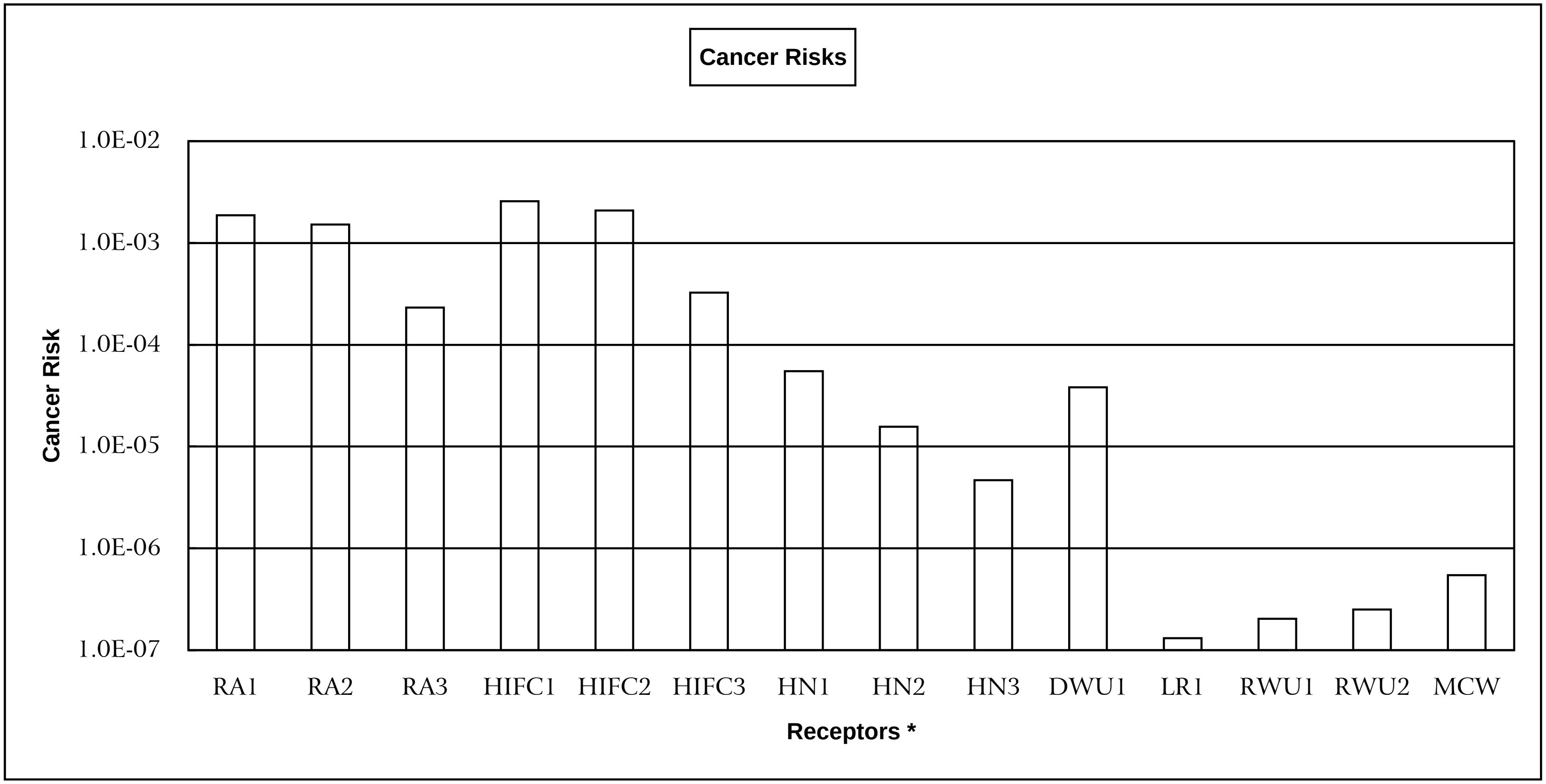
RA1 - Recreational Angler (RME/Uppb)
RA2 - Recreational Angler (RME/Average)
RA3 - Recreational Angler (CTE/Average)
HIFC1 - High-intake Fish Cons. (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)
HIFC3 - High-intake Fish Cons. (CTE/Average)
HN1 - Hunter (RME/Uppb)
HN2 - Hunter (RME/Average)
HN3 - Hunter (CTE/Average)
DWU1 - Drinking Water User (RME/Uppb)
LR1 - Local Resident (RME/Uppb)
RWU1 - Swimmer (RME/Uppb)
RWU2 - Wader (RME/Uppb)
MCW - Construction Worker (RME/Uppb)

Figure 5-7 Hazard Indices for the Little Rapids to De Pere Reach



* Key for Receptors		
RA1 - Recreational Angler (RME/Uppb)	HN1 - Hunter (RME/Uppb)	LR1 - Local Resident (RME/Uppb)
RA2 - Recreational Angler (RME/Average)	HN2 - Hunter (RME/Average)	LR2 - Local Resident (RME/Uppb and Recent Mercury Data)
RA3 - Recreational Angler (CTE/Average)	HN3 - Hunter (CTE/Average)	
HIFC1 - High-intake Fish Cons. (RME/Uppb)	DWU1 - Drinking Water User (RME/Uppb)	RWU1 - Swimmer (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)	DWU2 - Drinking Water User (RME/Uppb and Recent Mercury Data)	RWU2 - Wader (RME/Uppb)
HIFC3 - High-intake Fish Cons. (CTE/Average)		MCW - Construction Worker (RME/Uppb)

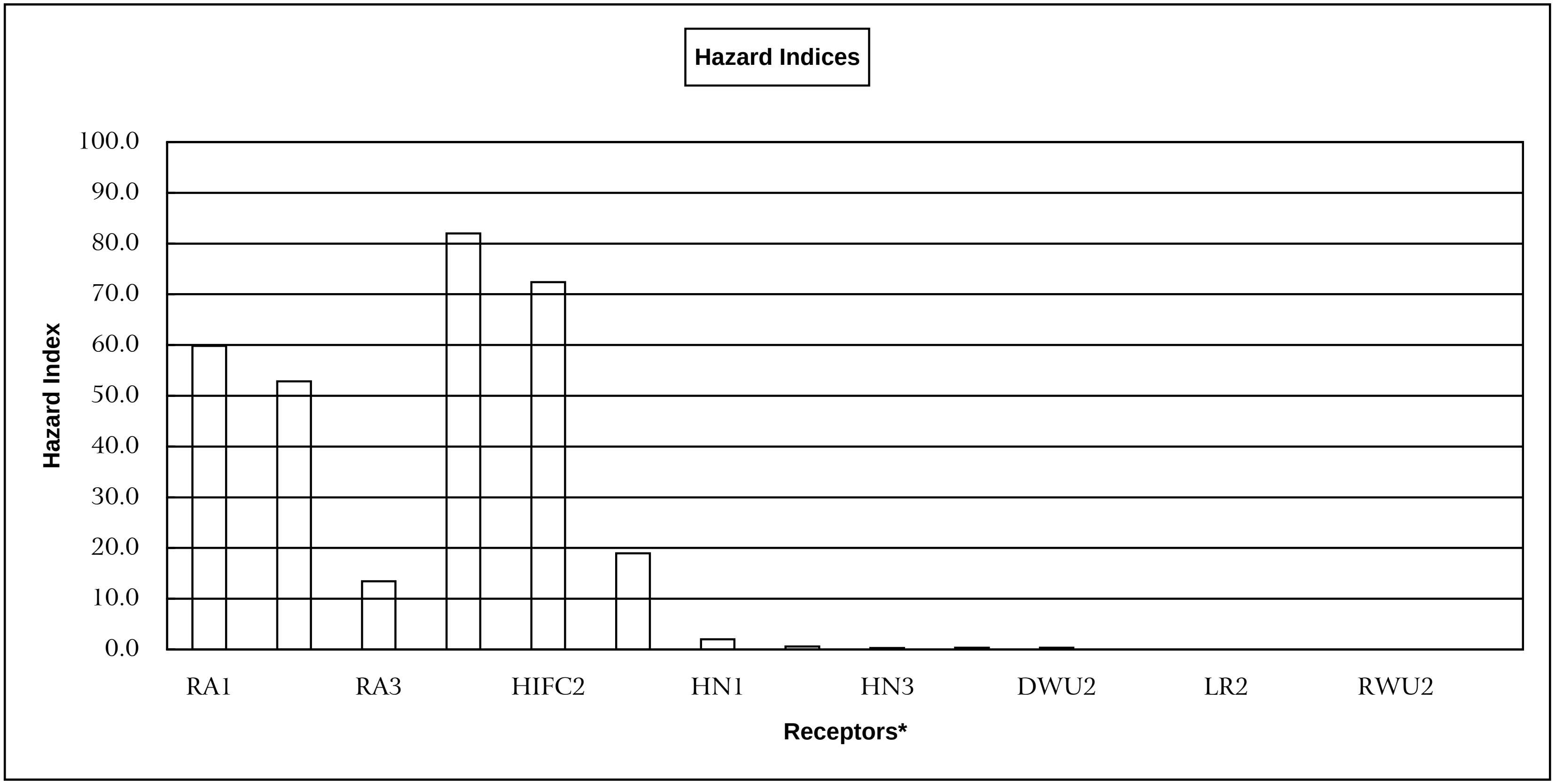
Figure 5-8 Cancer Risks for the De Pere to Green Bay Reach



*** Key for Receptors**

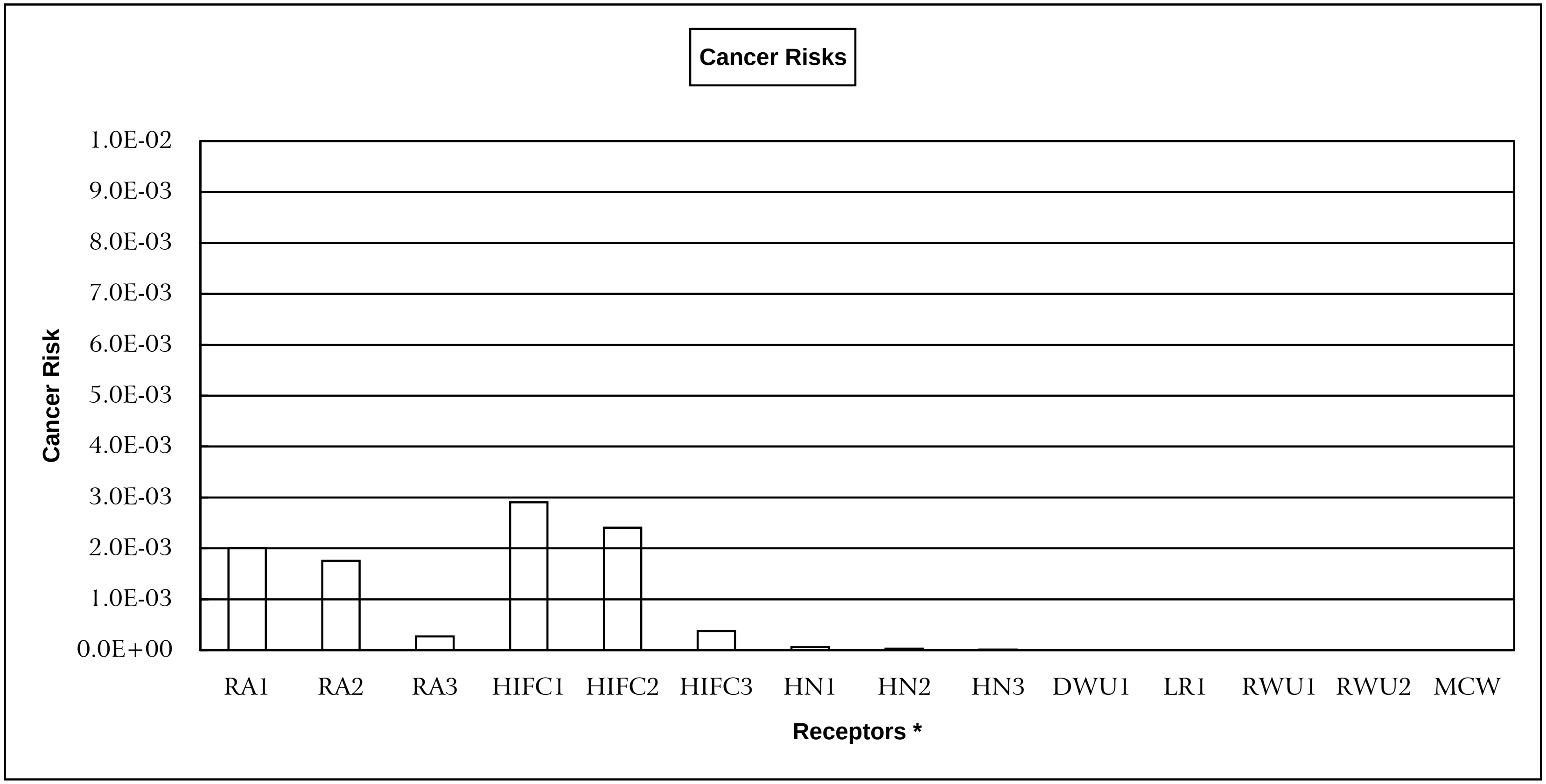
RA1 - Recreational Angler (RME/Uppb)
RA2 - Recreational Angler (RME/Average)
RA3 - Recreational Angler (CTE/Average)
HIFC1 - High-intake Fish Cons. (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)
HIFC3 - High-intake Fish Cons. (CTE/Average)
HN1 - Hunter (RME/Uppb)
HN2 - Hunter (RME/Average)
HN3 - Hunter (CTE/Average)
DWU1 - Drinking Water User (RME/Uppb)
LR1 - Local Resident (RME/Uppb)
RWU1 - Swimmer (RME/Uppb)
RWU2 - Wader (RME/Uppb)
MCW - Construction Worker (RME/Uppb)

Figure 5-9 Hazard Indices for the De Pere to Green Bay Reach



* Key for Receptors		
RA1 - Recreational Angler (RME/Uppb)	HN1 - Hunter (RME/Uppb)	LR1 - Local Resident (RME/Uppb)
RA2 - Recreational Angler (RME/Average)	HN2 - Hunter (RME/Average)	LR2 - Local Resident (RME/Uppb and Recent Mercury Data)
RA3 - Recreational Angler (CTE/Average)	HN3 - Hunter (CTE/Average)	
HIFC1 - High-intake Fish Cons. (RME/Uppb)	DWU1 - Drinking Water User (RME/Uppb)	RWU1 - Swimmer (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)	DWU2 - Drinking Water User (RME/Uppb and Recent Mercury Data)	RWU2 - Wader (RME/Uppb)
HIFC3 - High-intake Fish Cons. (CTE/Average)		MCW - Construction Worker (RME/Uppb)

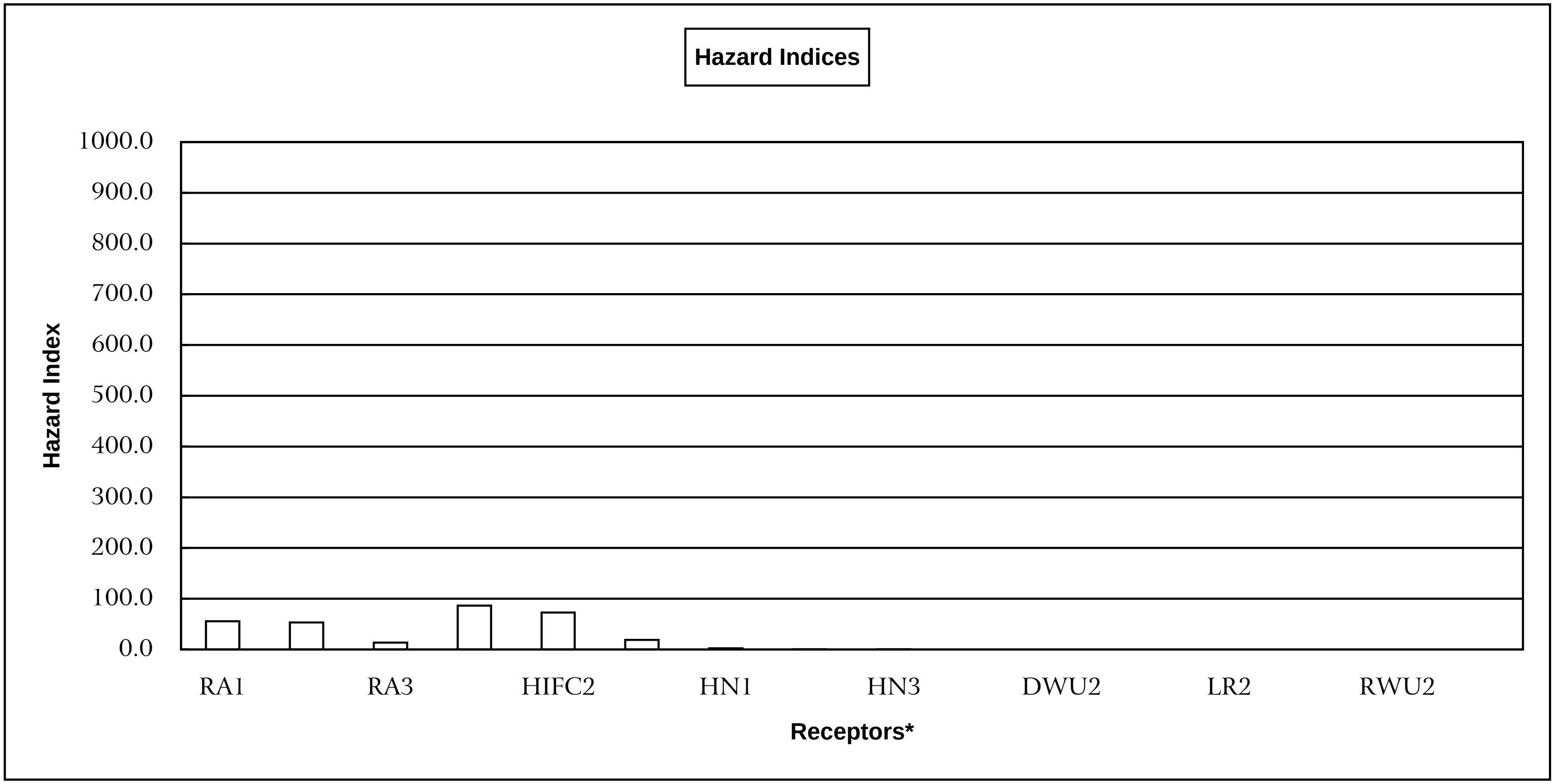
Figure 5-10 Cancer Risks for Green Bay



*** Key for Receptors**

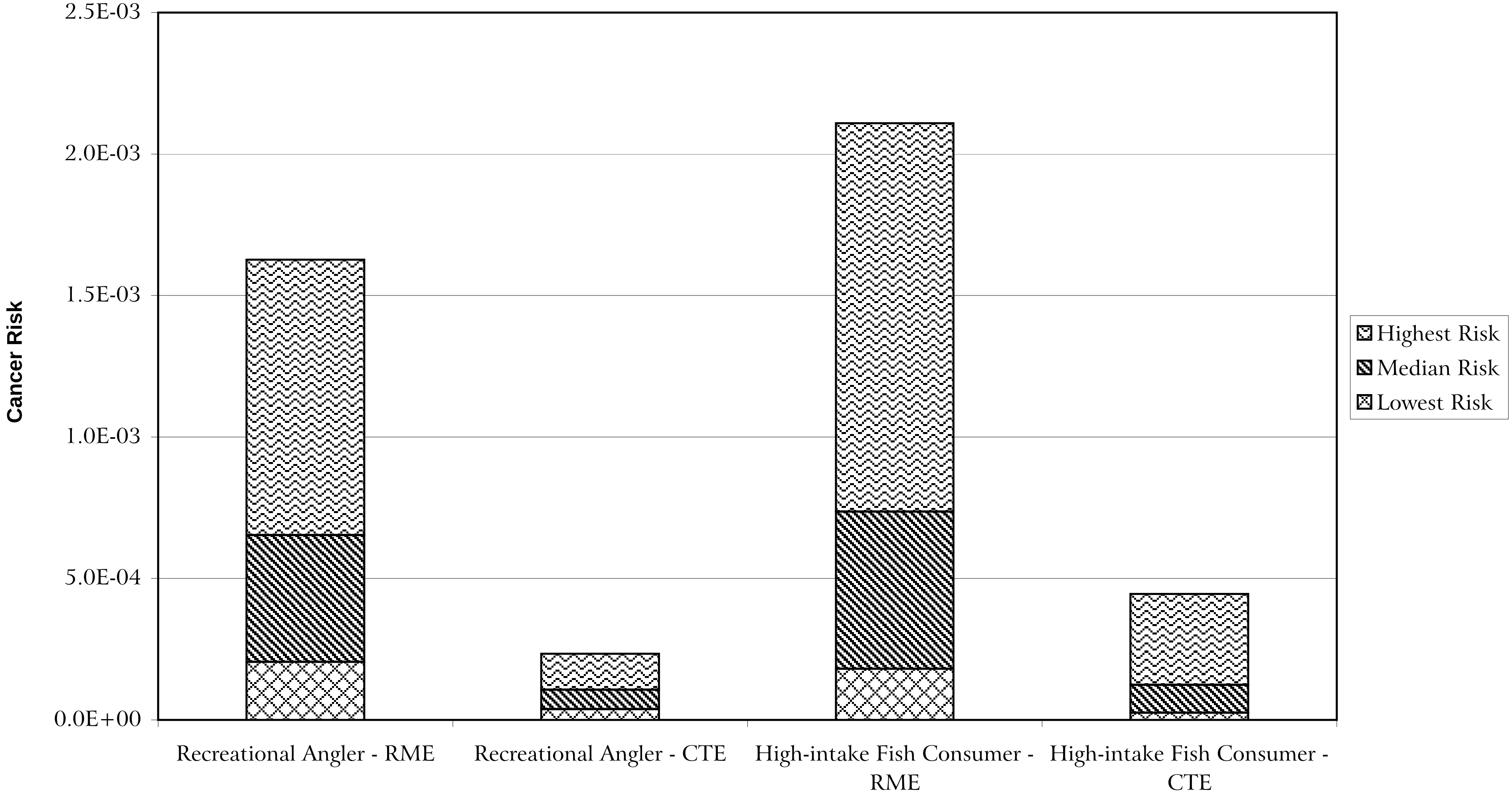
RA1 - Recreational Angler (RME/Uppb)
RA2 - Recreational Angler (RME/Average)
RA3 - Recreational Angler (CTE/Average)
HIFC1 - High-intake Fish Cons. (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)
HIFC3 - High-intake Fish Cons. (CTE/Average)
HN1 - Hunter (RME/Uppb)
HN2 - Hunter (RME/Average)
HN3 - Hunter (CTE/Average)
DWU1 - Drinking Water User (RME/Uppb)
LR1 - Local Resident (RME/Uppb)
RWU1 - Swimmer (RME/Uppb)
RWU2 - Wader (RME/Uppb)
MCW - Construction Worker (RME/Uppb)

Figure 5-11 Hazard Indices for Green Bay



* Key for Receptors		
RA1 - Recreational Angler (RME/Uppb)	HN1 - Hunter (RME/Uppb)	LR1 - Local Resident (RME/Uppb)
RA2 - Recreational Angler (RME/Average)	HN2 - Hunter (RME/Average)	LR2 - Local Resident (RME/Uppb and Recent Mercury Data)
RA3 - Recreational Angler (CTE/Average)	HN3 - Hunter (CTE/Average)	
HIFC1 - High-intake Fish Cons. (RME/Uppb)	DWU1 - Drinking Water User (RME/Uppb)	RWU1 - Swimmer (RME/Uppb)
HIFC2 - High-intake Fish Cons. (RME/Average)	DWU2 - Drinking Water User (RME/Uppb and Recent Mercury Data)	RWU2 - Wader (RME/Uppb)
HIFC3 - High-intake Fish Cons. (CTE/Average)		MCW - Construction Worker (RME/Uppb)

Figure 5-12 Range of Cancer Risks for Recreational Anglers and High-intake Fish Consumers in the Lower Fox River



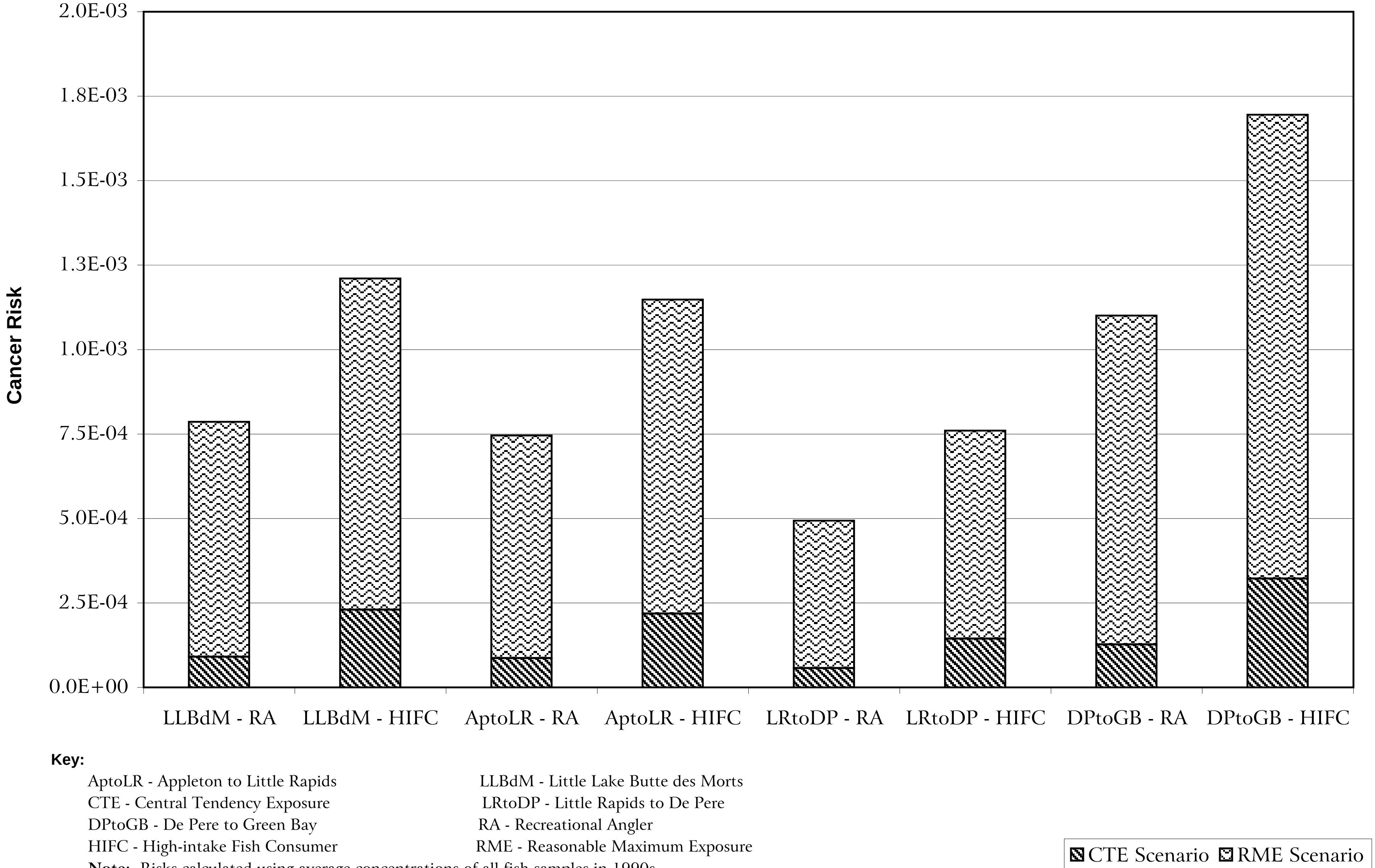
Key:

CTE - Central Tendency Exposure

RME - Reasonable Maximum Exposure

Note: Risks calculated using average concentrations of all fish samples in 1990s.

Figure 5-13 Maximum Hazard Indices for Recreational Anglers and High-intake Fish Consumers in the Lower Fox River

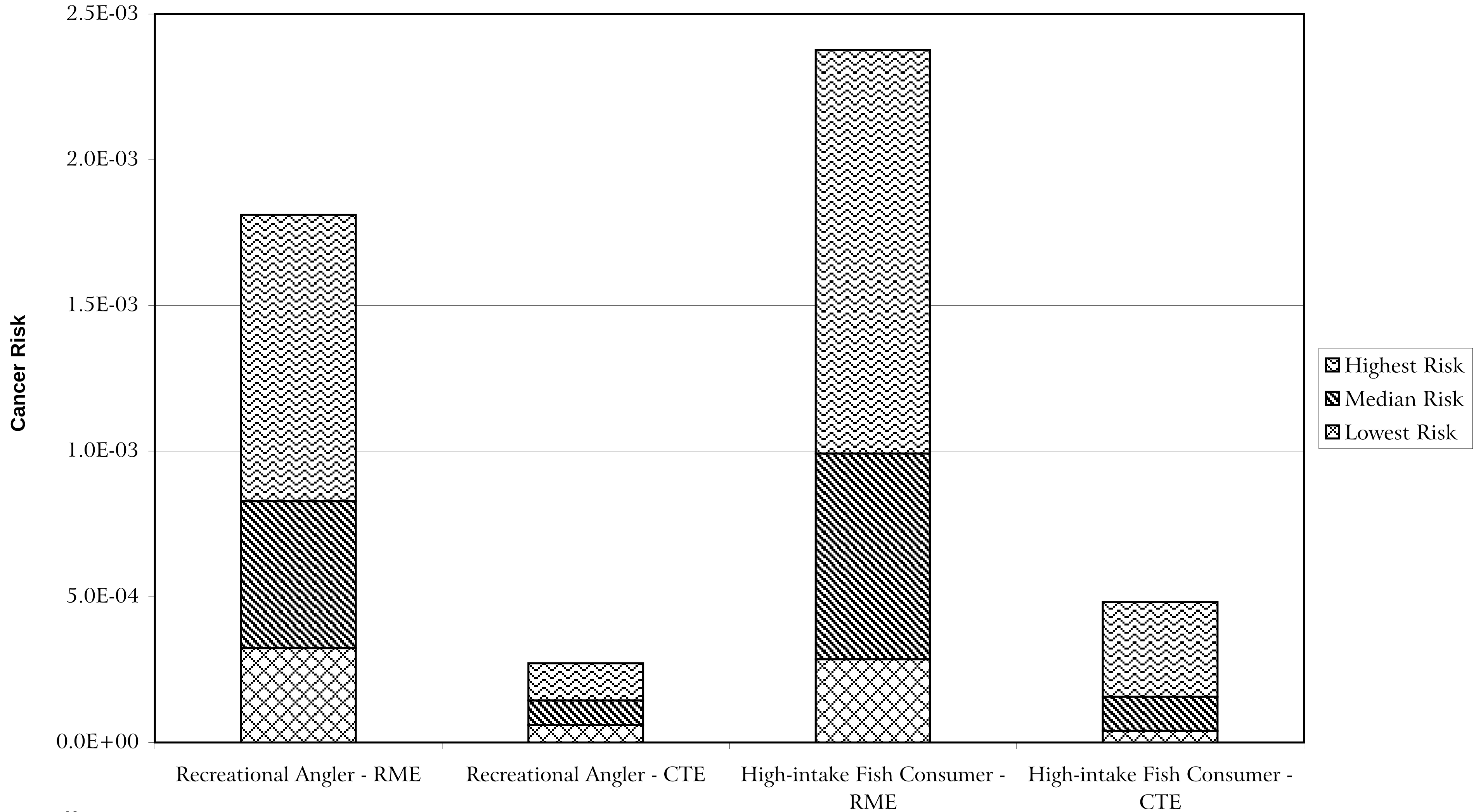


Key:

AptoLR - Appleton to Little Rapids
CTE - Central Tendency Exposure
DPtoGB - De Pere to Green Bay
HIFC - High-intake Fish Consumer
LLBdM - Little Lake Butte des Morts
LRtoDP - Little Rapids to De Pere
RA - Recreational Angler
RME - Reasonable Maximum Exposure

Note: Risks calculated using average concentrations of all fish samples in 1990s.

Figure 5-14 Range of Cancer Risks for Recreational Anglers and High-intake Fish Consumers in Green Bay



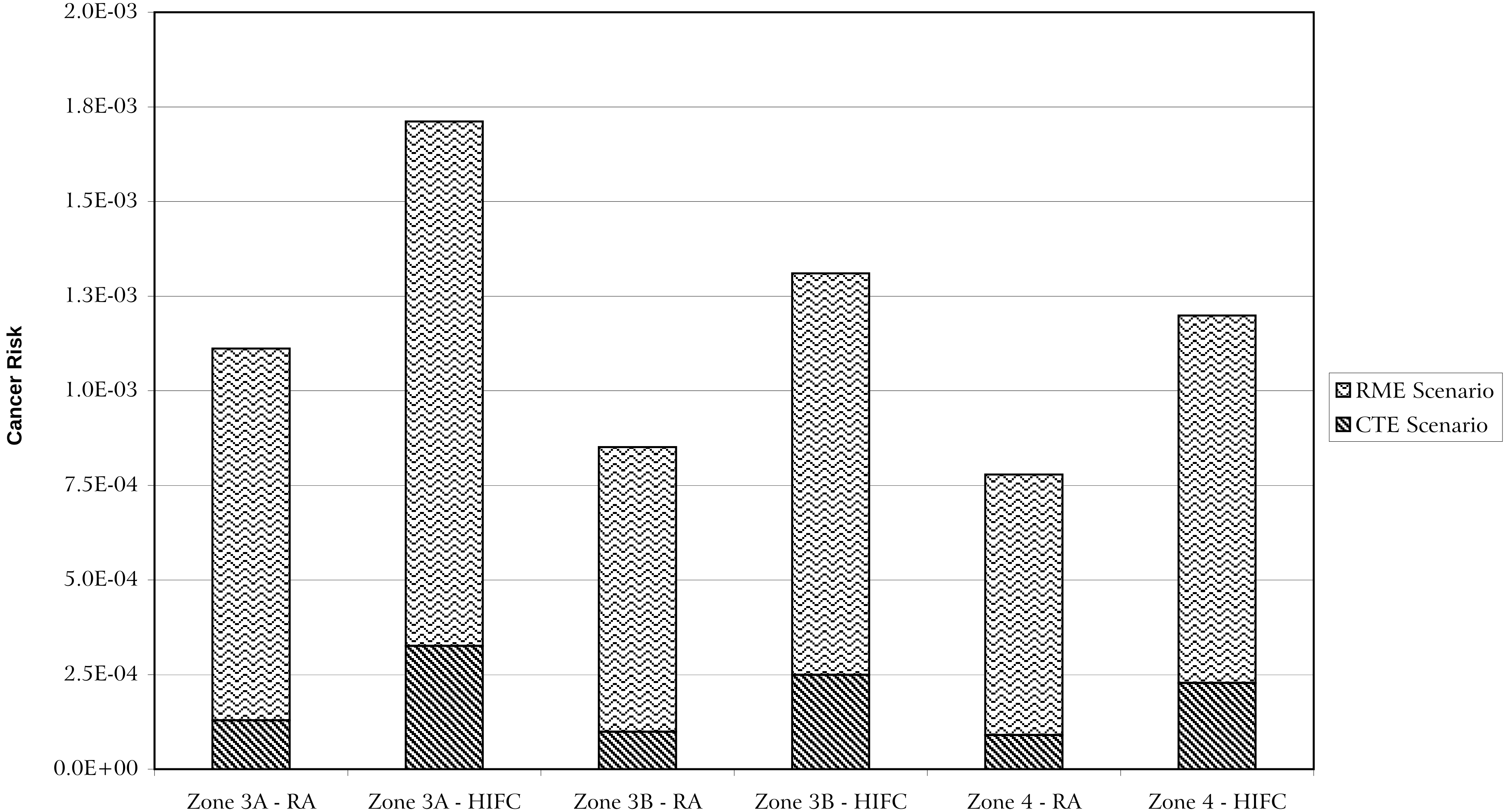
Key:

CTE - Central Tendency Exposure

RME - Reasonable Maximum Exposure

Note: Risks calculated using average concentrations of all fish samples in 1990s plus walleye samples in 1989.

Figure 5-15 Maximum Cancer Risks for Recreational Anglers and High-intake Fish Consumers by Zone in Green Bay

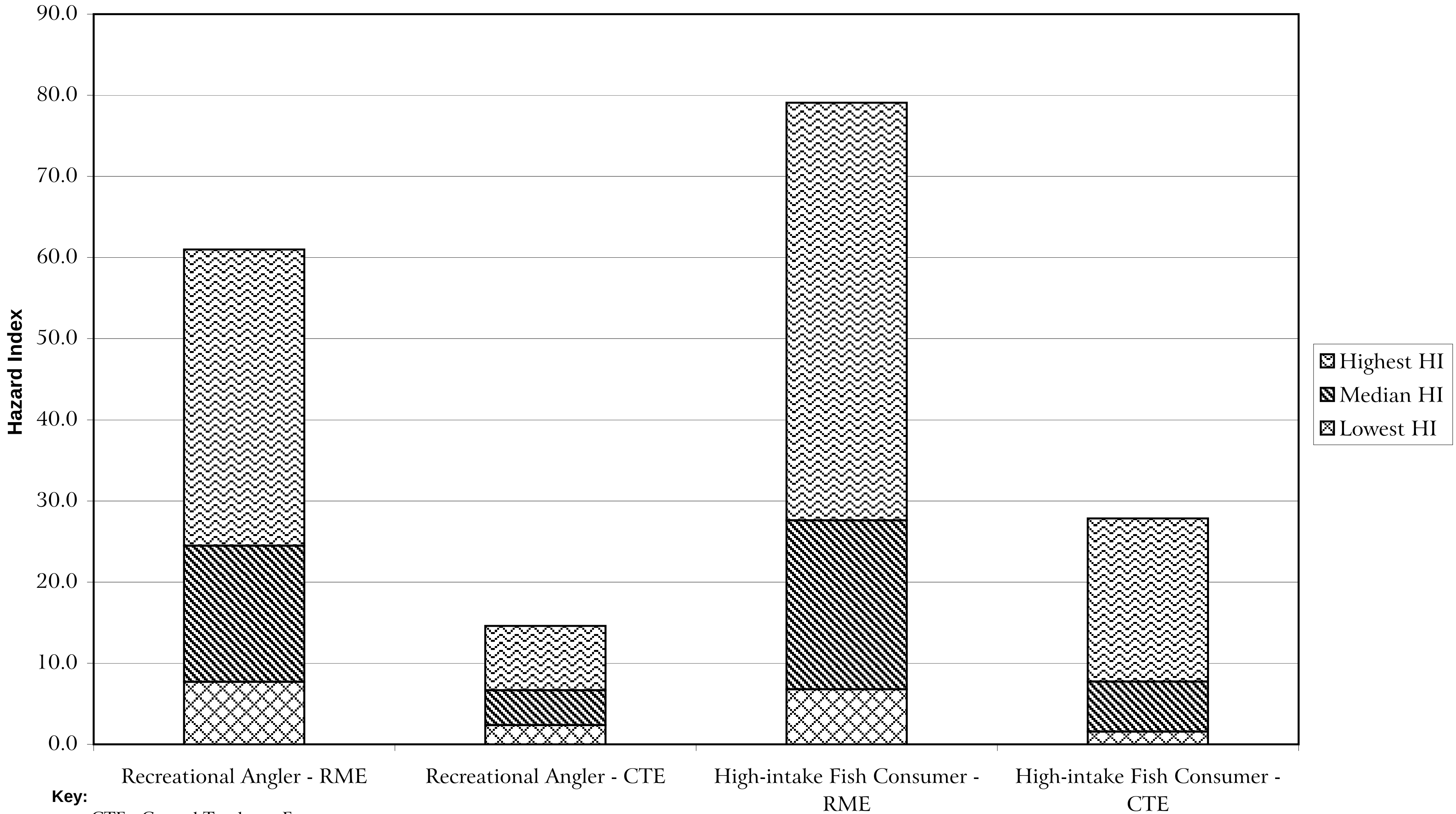


Key:

CTE - Central Tendency Exposure
RA - Recreational Angler
HIFC - High-intake Fish Consumer
RME - Reasonable Maximum Exposure

Note: Risks calculated using average concentrations of all fish samples in 1990s plus walleye samples in 1989.

Figure 5-16 Range of Hazard Indices for Recreational Anglers and High-intake Fish Consumers in the Lower Fox River



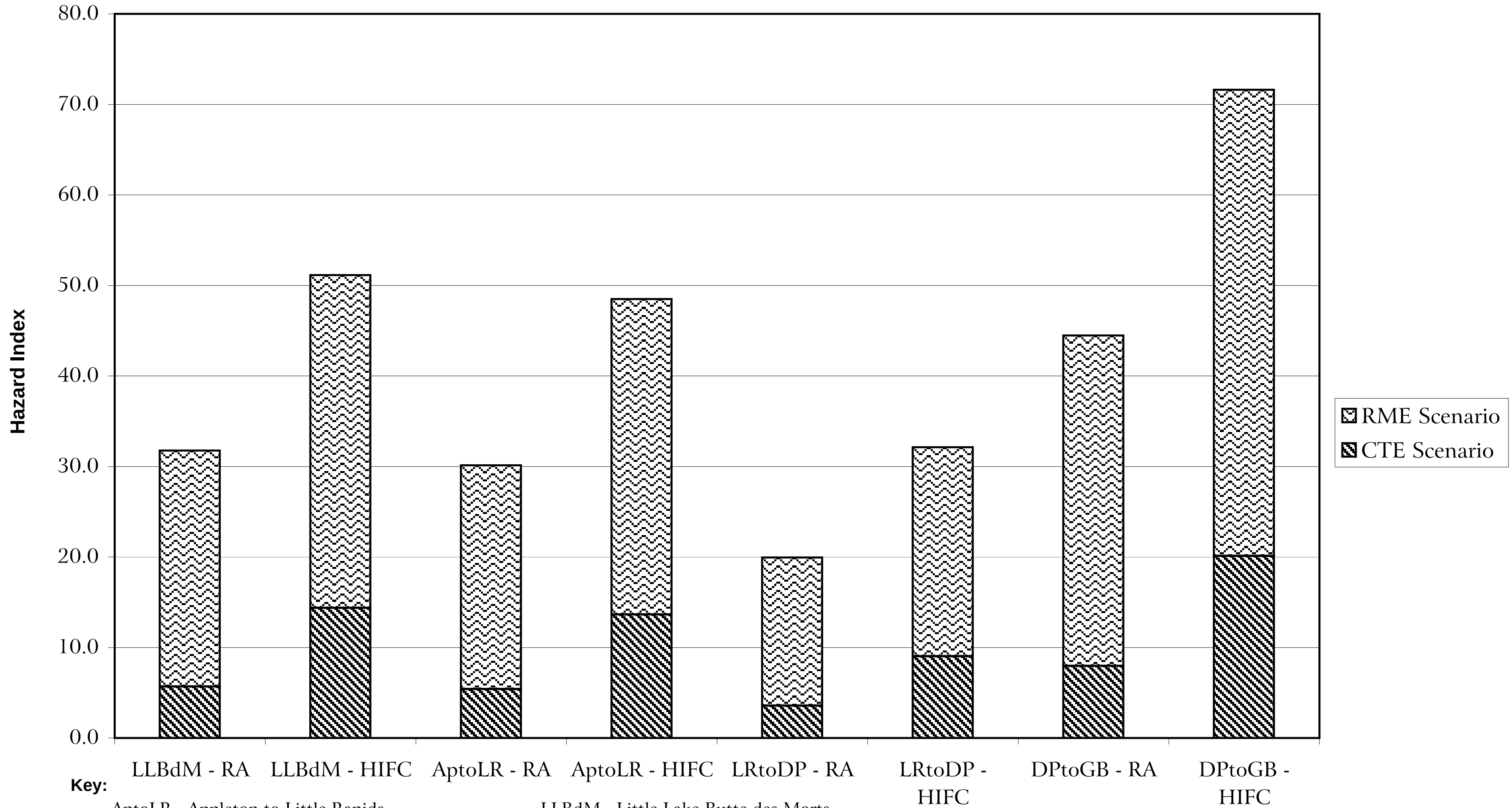
Key:

CTE - Central Tendency Exposure

RME - Reasonable Maximum Exposure

Note: Risks calculated using average concentrations of all fish samples in 1990s.

Figure 5-17 Maximum Hazard Indices for Recreational Anglers and High-intake Fish Consumers by Reach in the Lower Fox River

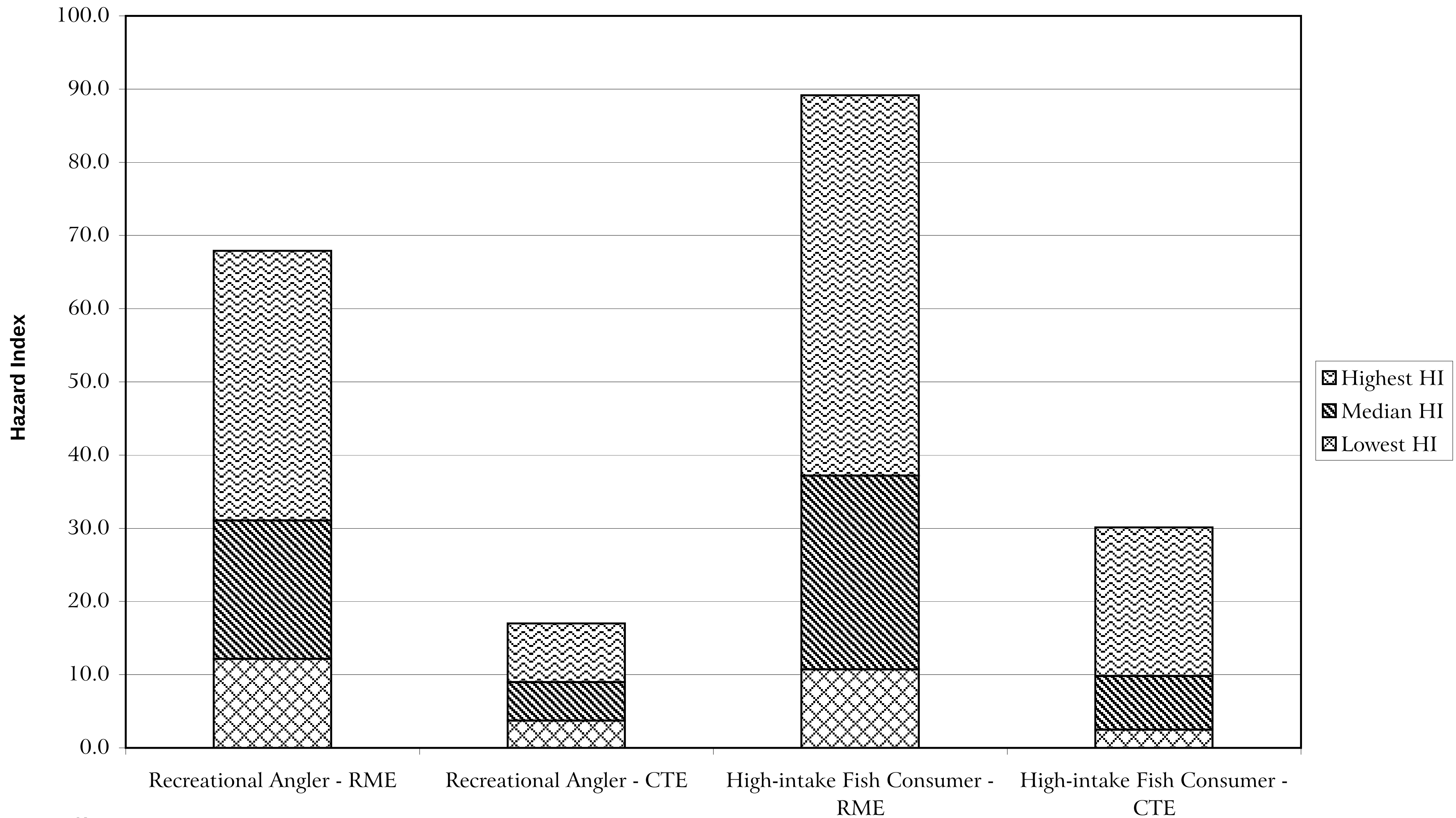


Key:

AptoLR - Appleton to Little Rapids
CTE - Central Tendency Exposure
DPtoGB - De Pere to Green Bay
HIFC - High-intake Fish Consumer
LLBdM - Little Lake Butte des Morts
LRtoDP - Little Rapids to De Pere
RA - Recreational Angler
RME - Reasonable Maximum Exposure

Note: Risks calculated using average concentrations of all fish samples in 1990s.

Figure 5-18 Range of Hazard Indices for Recreational Anglers and High-intake Fish Consumers in Green Bay



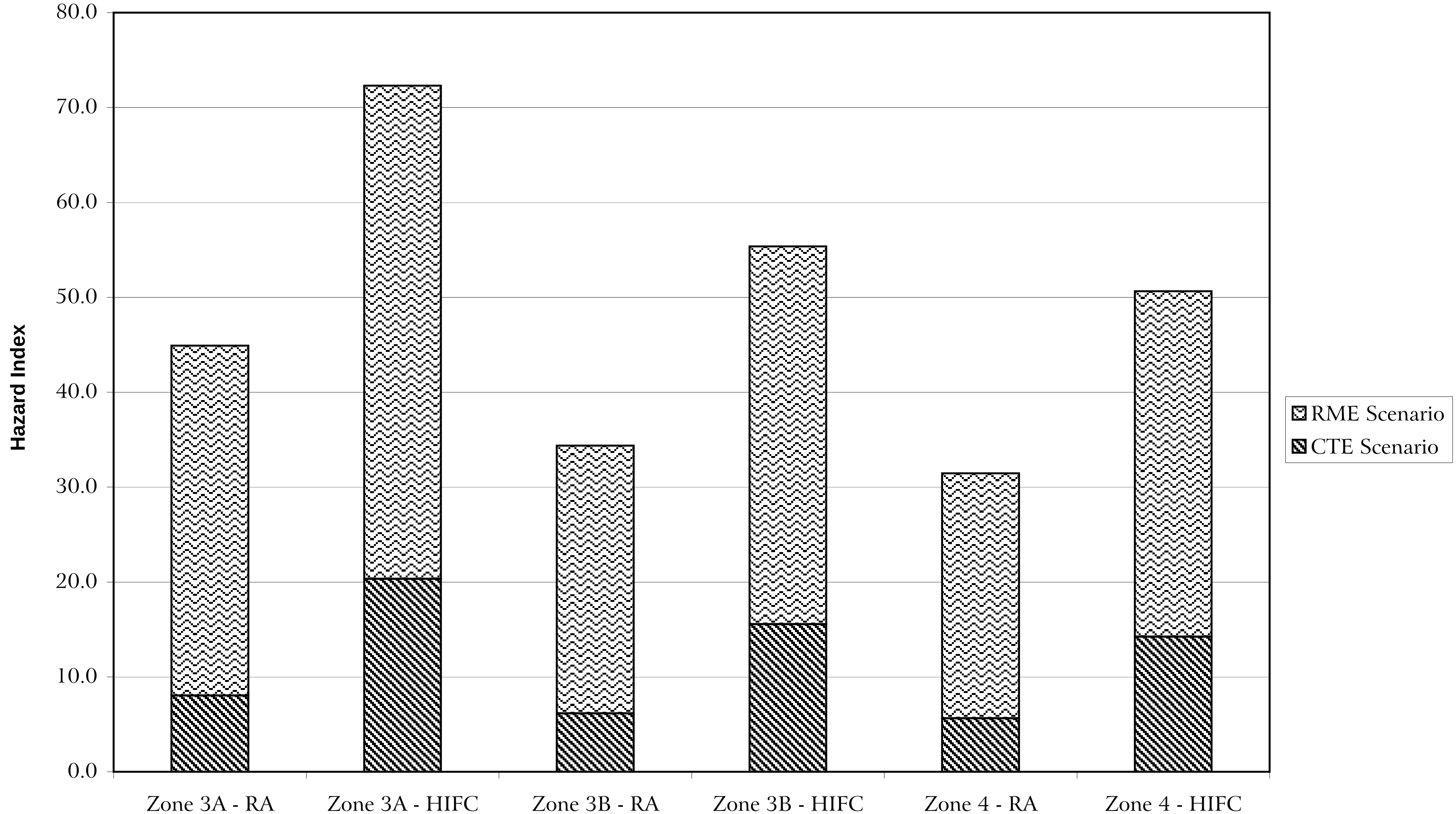
Key:

CTE - Central Tendency Exposure

RME - Reasonable Maximum Exposure

Note: Risks calculated using average concentrations of all fish samples in 1990s.

Figure 5-19 Maximum Hazard Indices for Recreational Anglers and High-intake Fish Consumers by Zone in Green Bay



Key:

CTE - Central Tendency Exposure
RA - Recreational Angler
HIFC - High-intake Fish Consumer
RME - Reasonable Maximum Exposure

Note: Risks calculated using average concentrations of all fish samples in 1990s plus walleye samples in 1989.

Figure 5-20 Comparison of CTE and RME Risk Values with Distribution Data - Little Lake Butte des Morts Reach

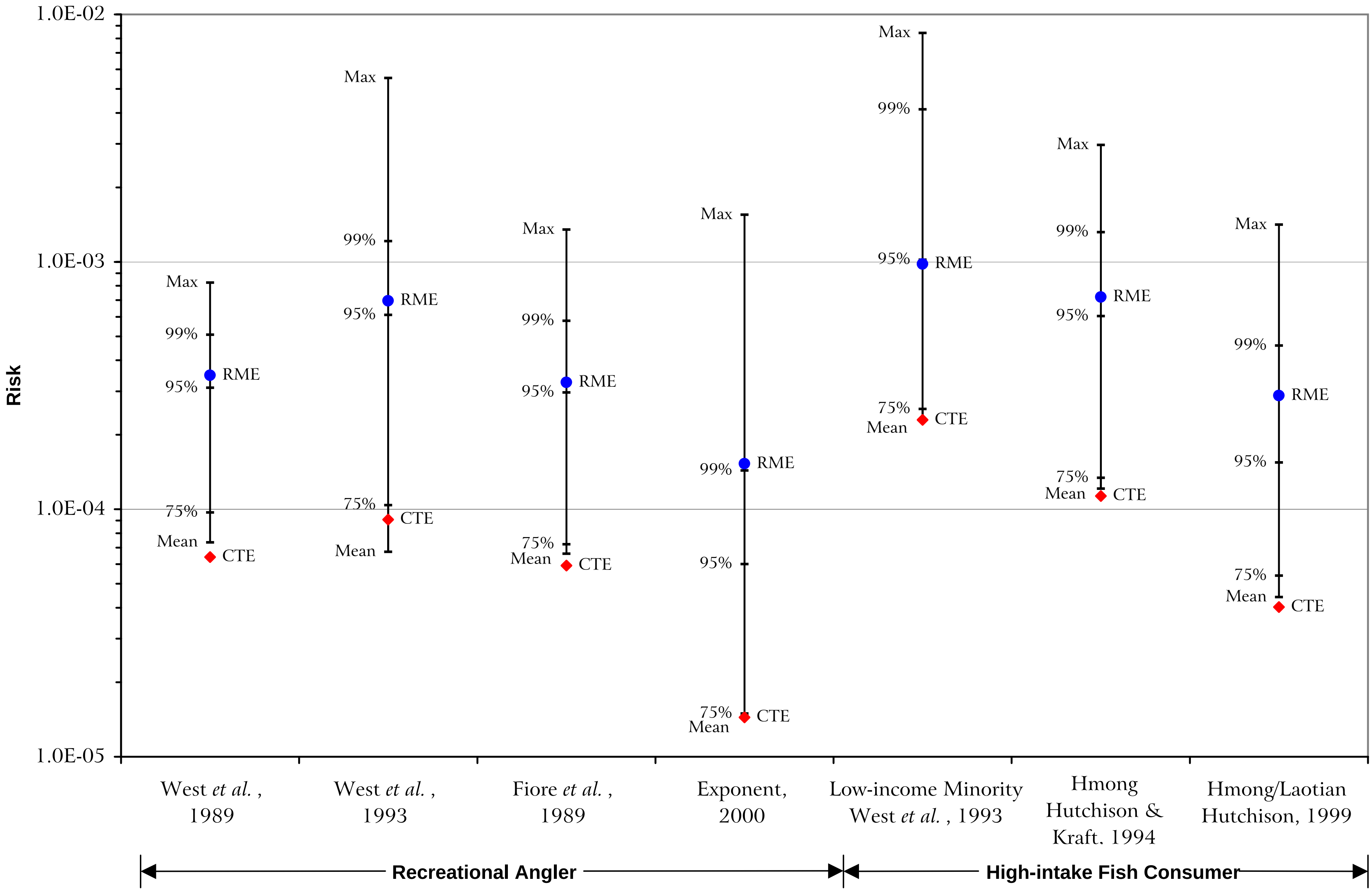


Figure 5-21 Comparison of CTE and RME Hazard Index Values with Distribution Data - Little Lake Butte des Morts Reach

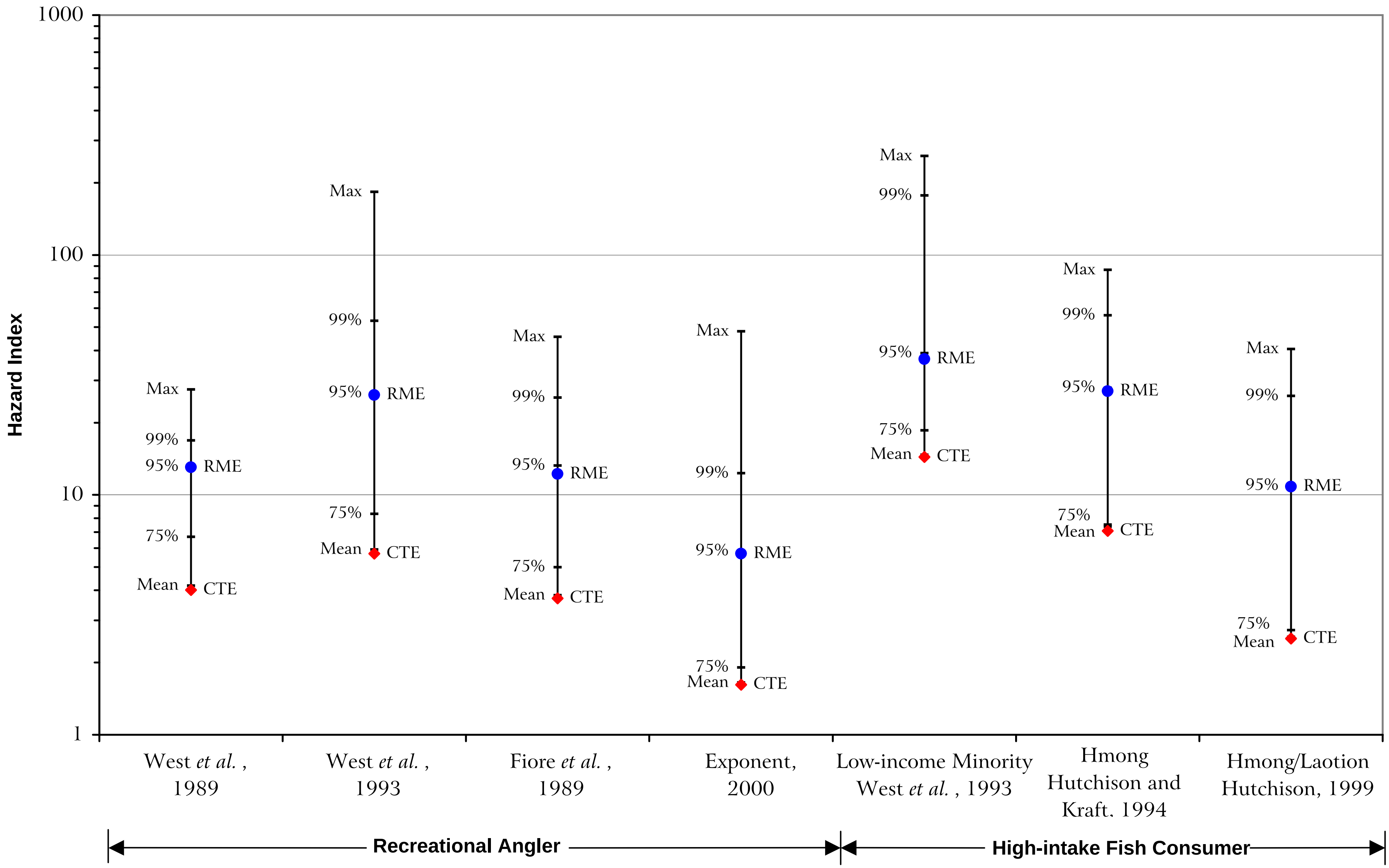


Figure 5-22 Comparison of CTE and RME Risk Values with Distribution Data - De Pere to Green Bay Reach

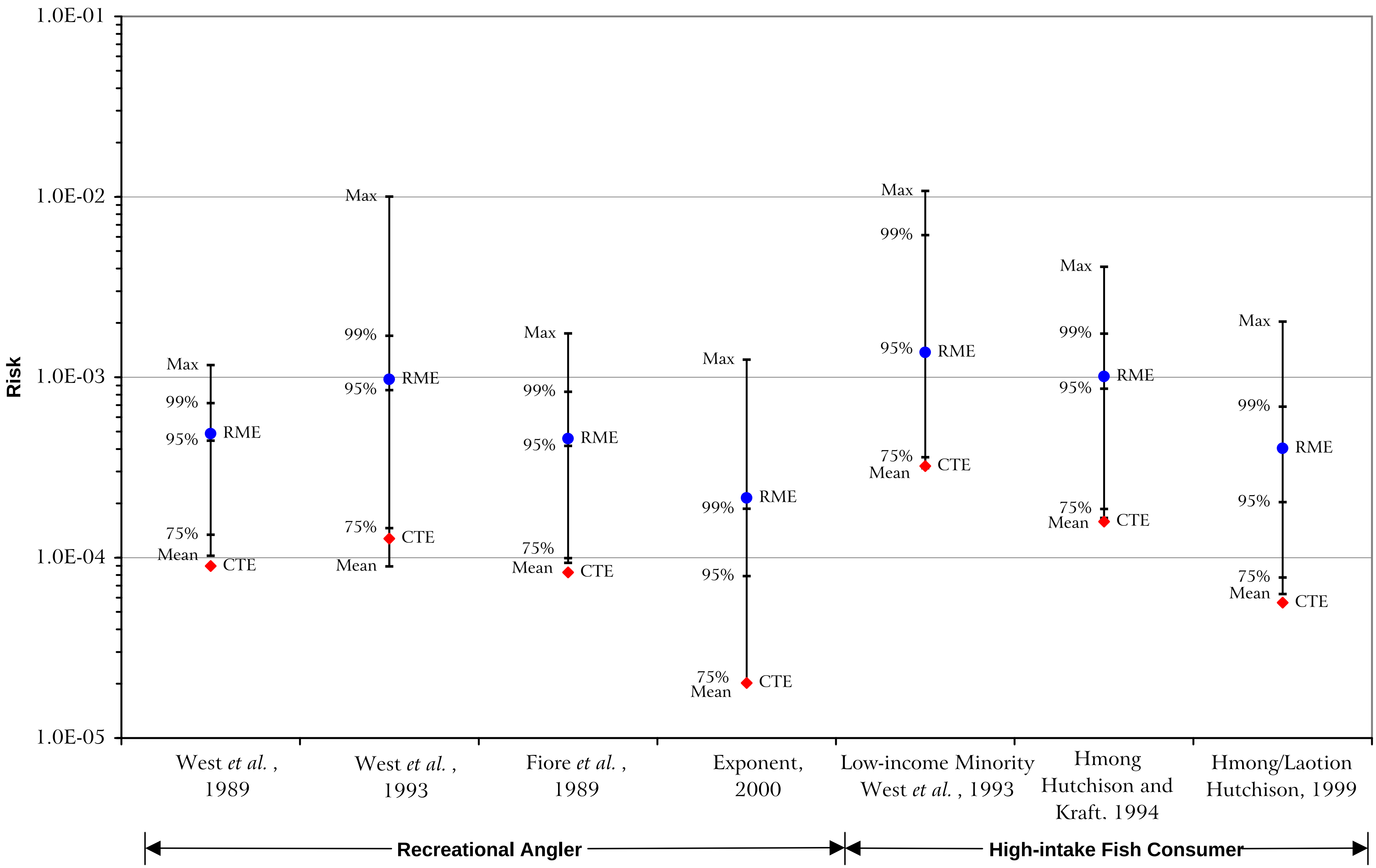


Figure 5-23 Comparison of CTE and RME Hazard Index Values with Distribution Data - De Pere to Green Bay Reach

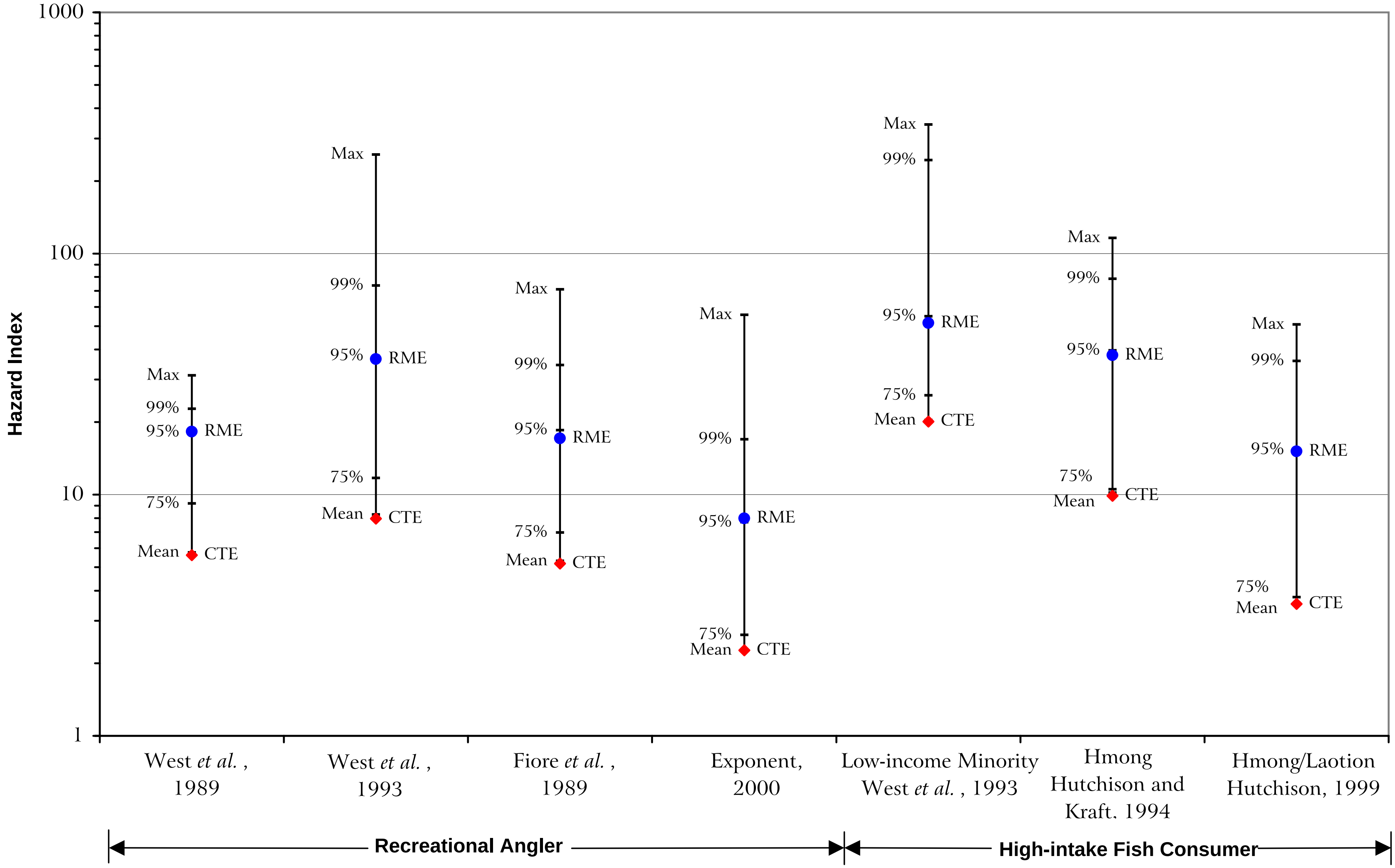


Figure 5-24 Risk Variability Evaluation for Recreational Angler - Little Lake Butte des Morts Reach

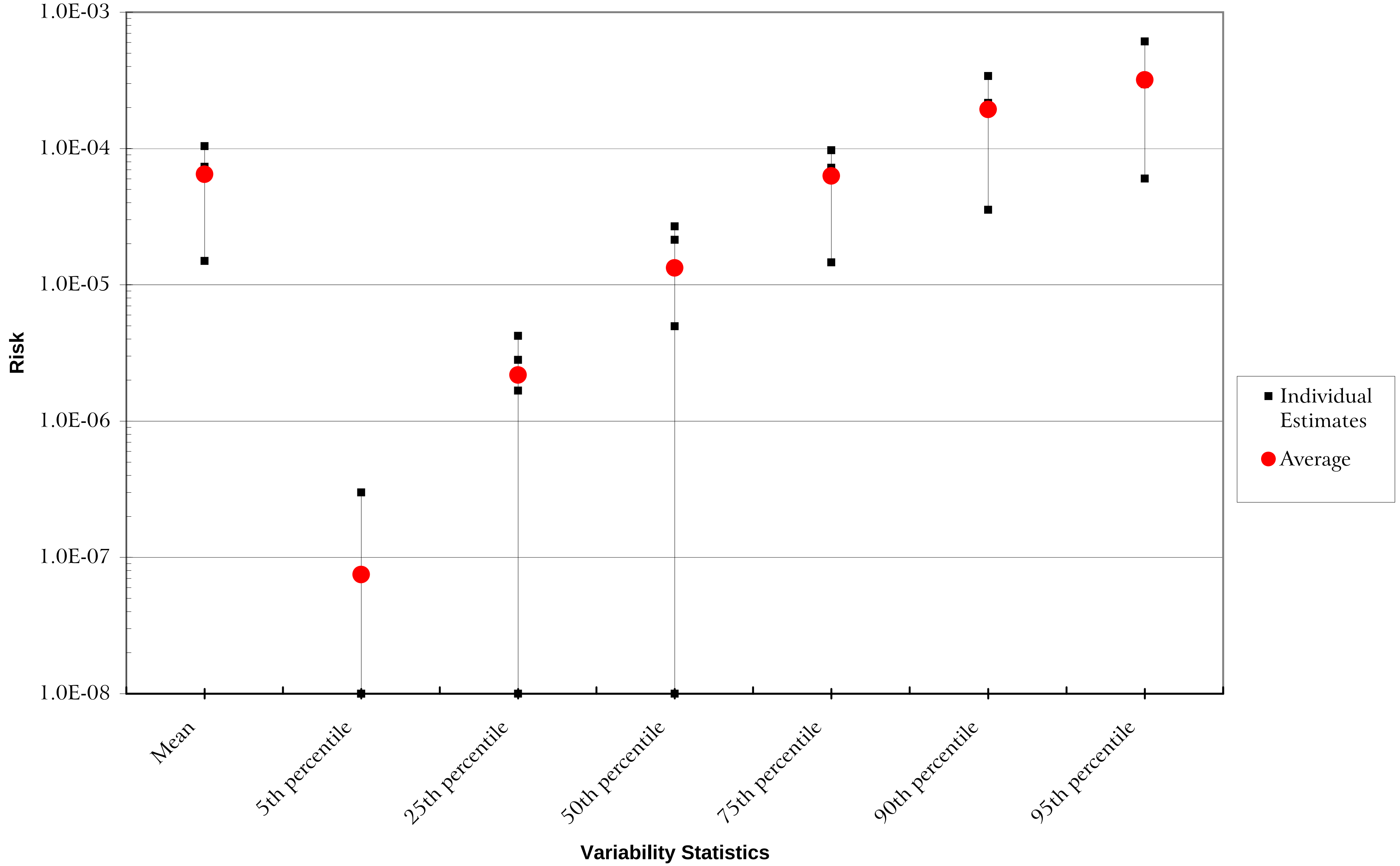


Figure 5-25 Hazard Index Variability Evaluation for Recreational Angler - Little Lake Butte des Morts Reach

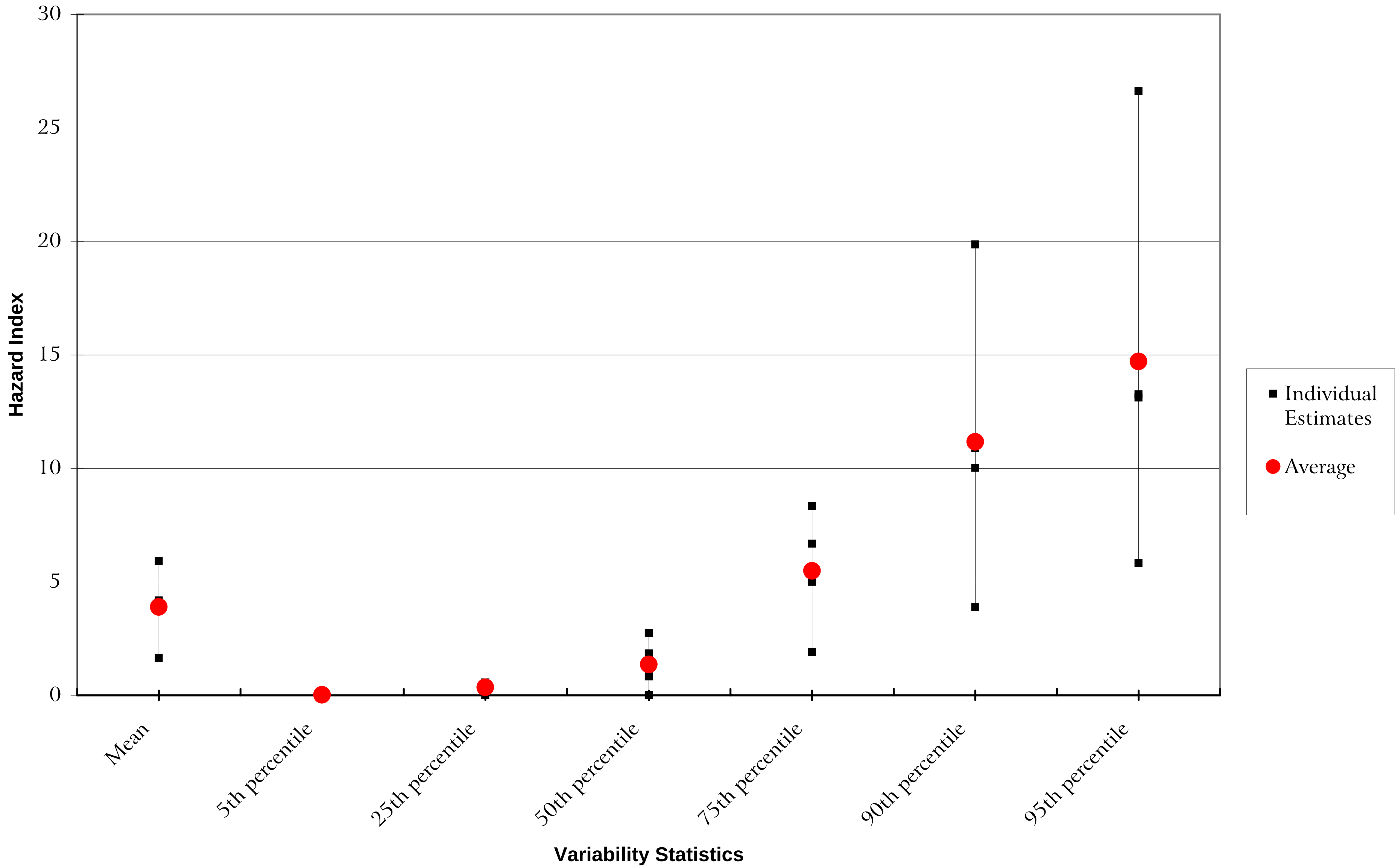


Figure 5-26 Risk Variability Evaluation for Recreational Angler - De Pere to Green Bay Reach

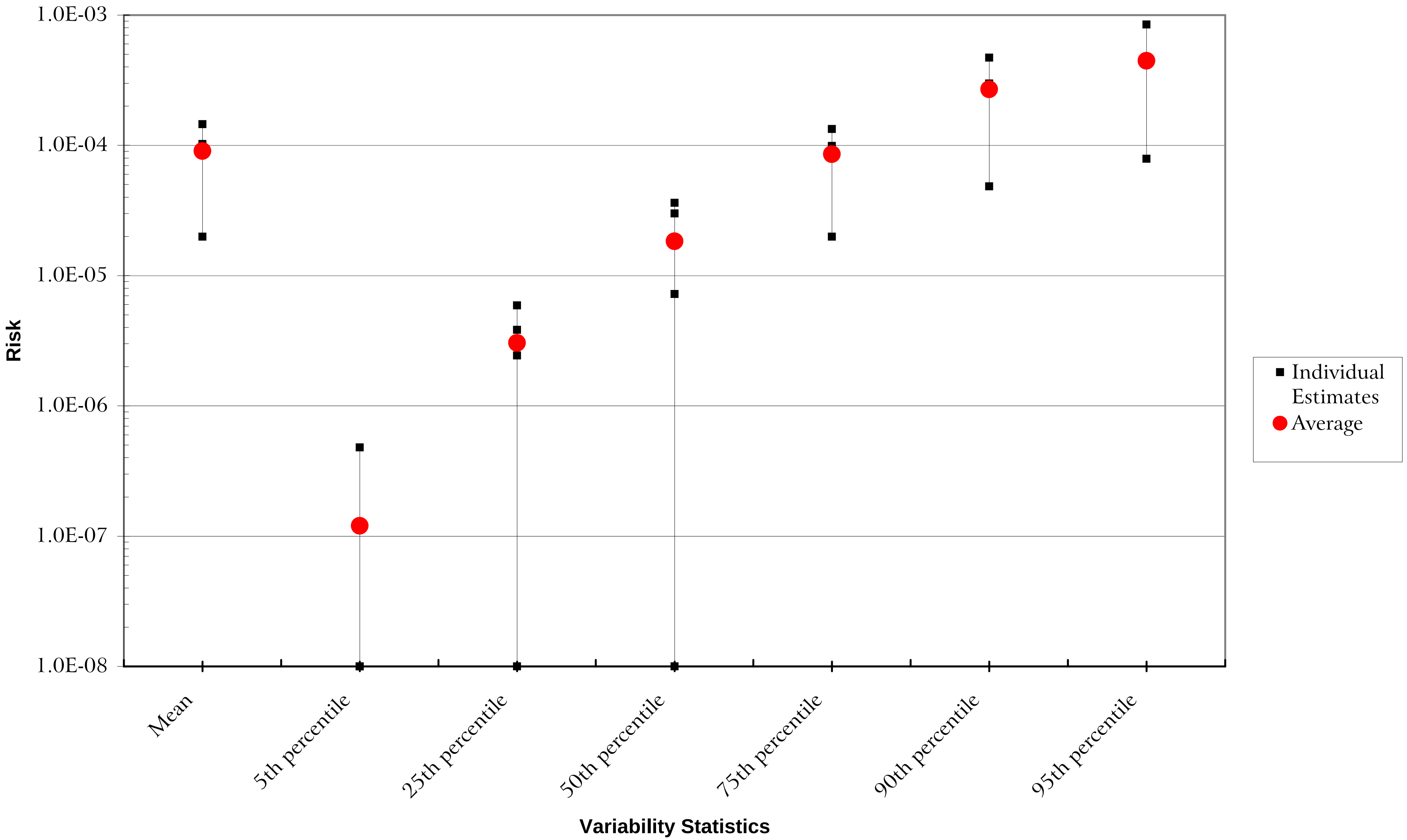


Figure 5-27 Hazard Index Variability Evaluation for Recreational Angler - De Pere to Green Bay Reach

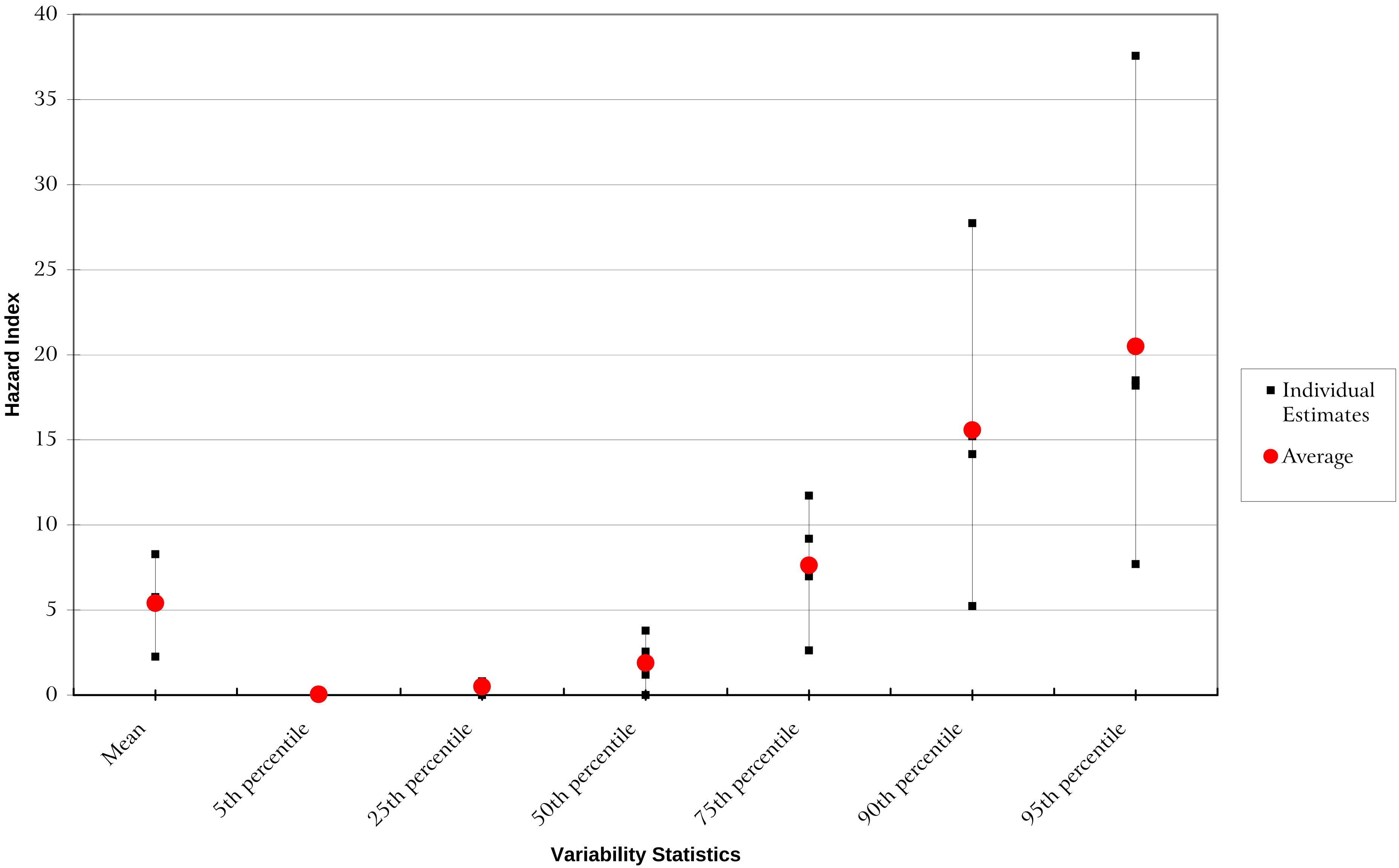


Figure 5-28 Risk Variability Evaluation for High-intake Fish Consumer - Little Lake Butte des Morts Reach

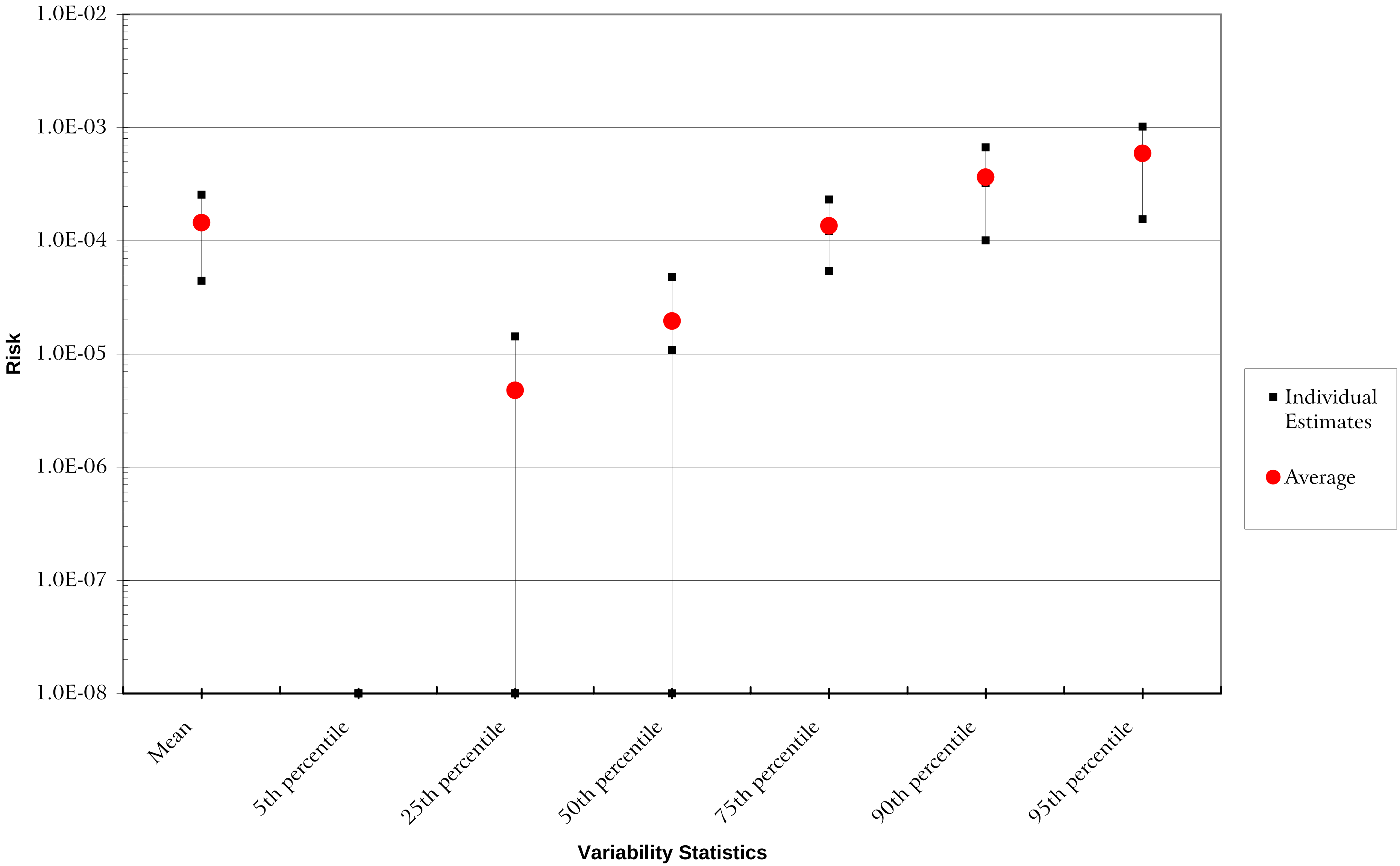


Figure 5-29 Hazard Index Variability Evaluation for High-intake Fish Consumer - Little Lake Butte des Morts Reach

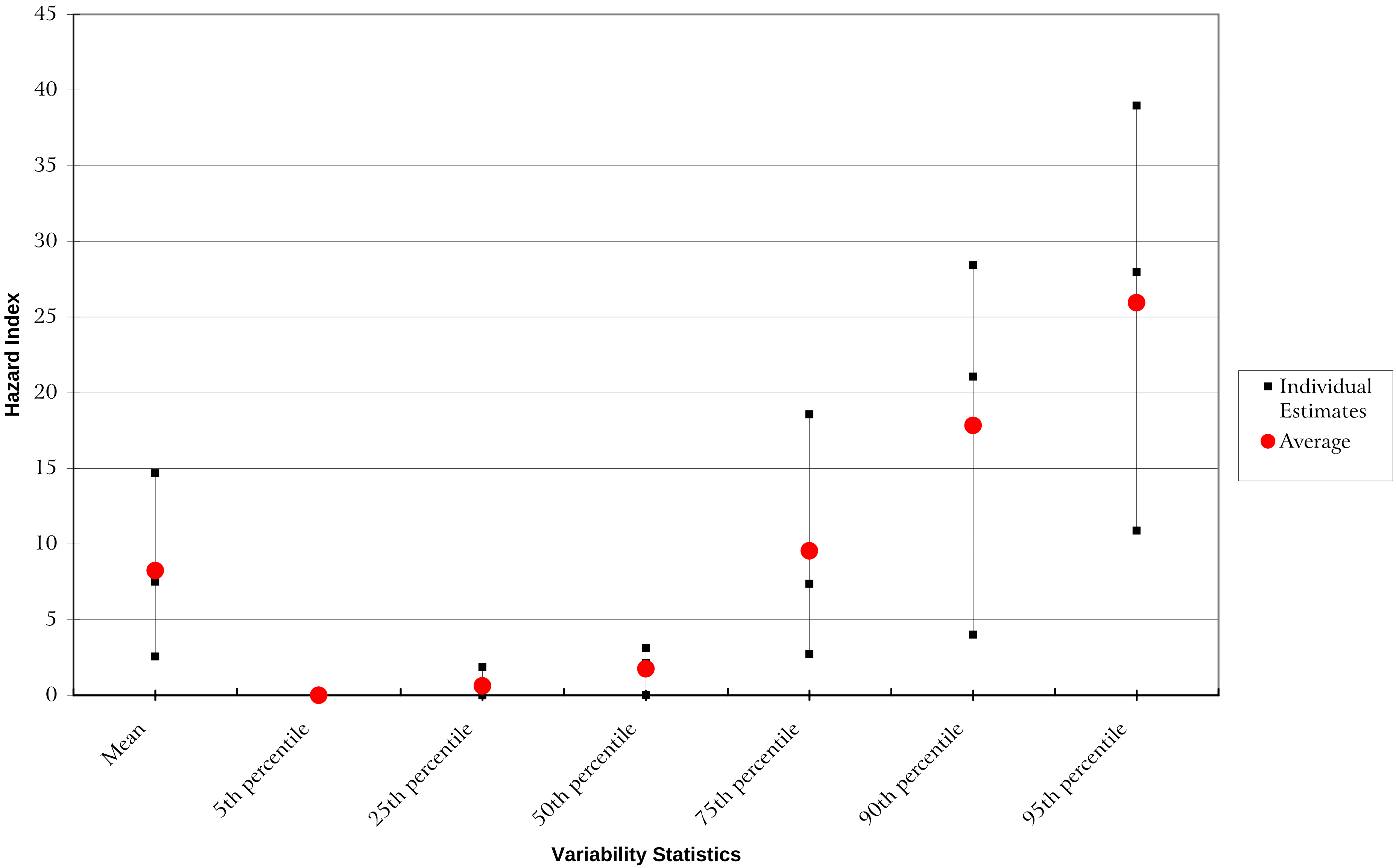


Figure 5-30 Risk Variability Evaluation for High-intake Fish Consumer - De Pere to Green Bay Reach

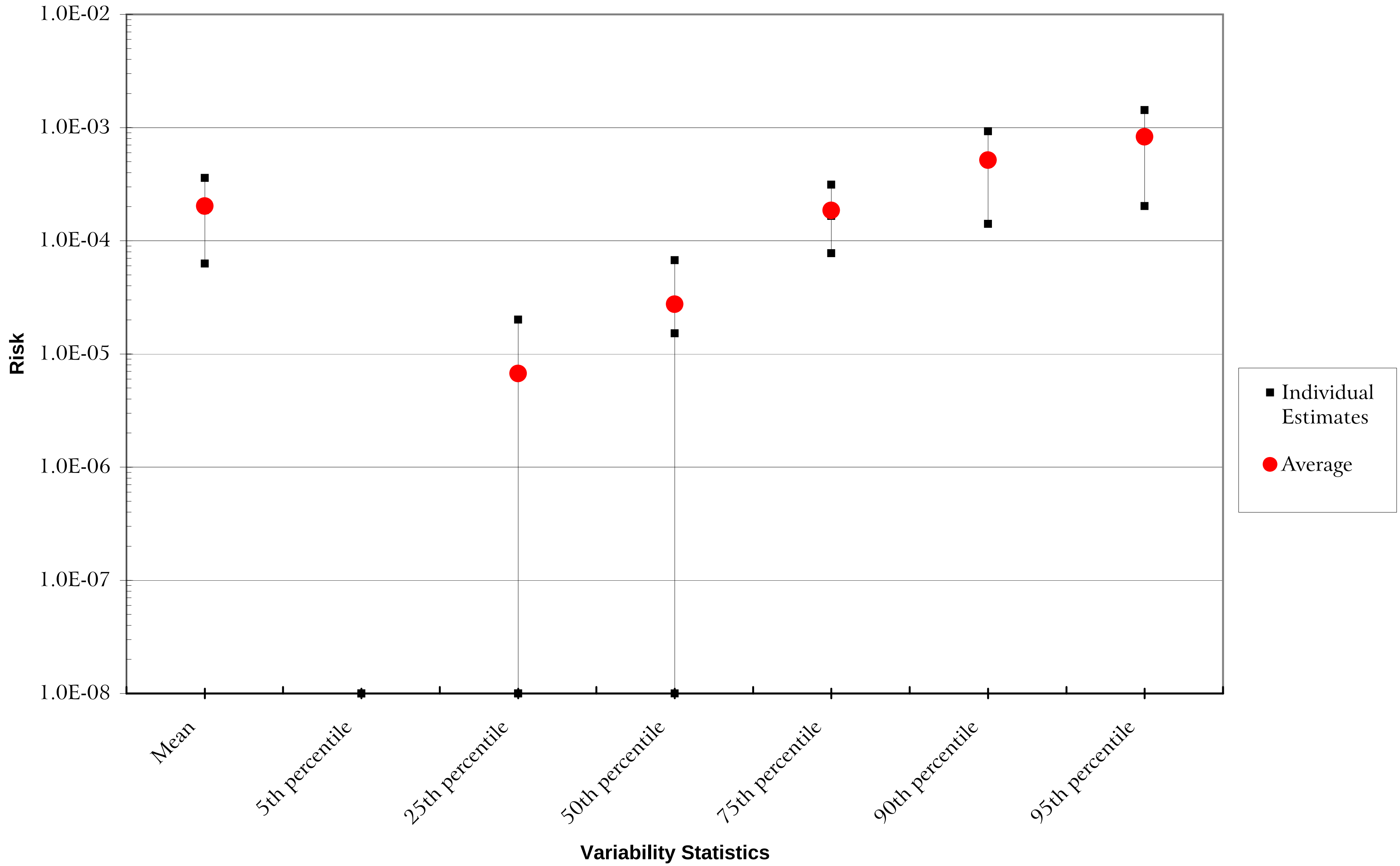


Figure 5-31 Hazard Index Variability Evaluation for High-intake Fish Consumer - De Pere to Green Bay Reach

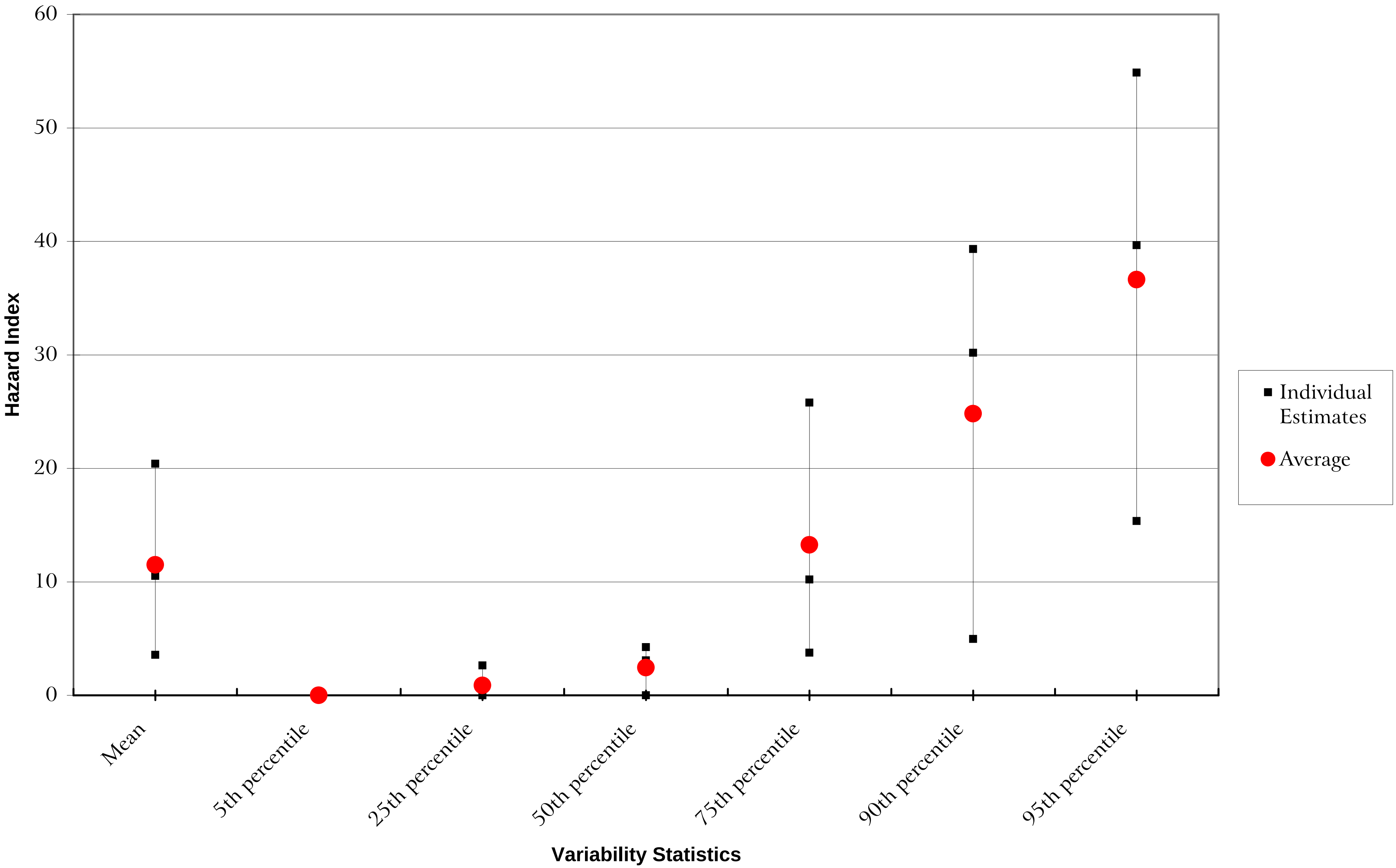
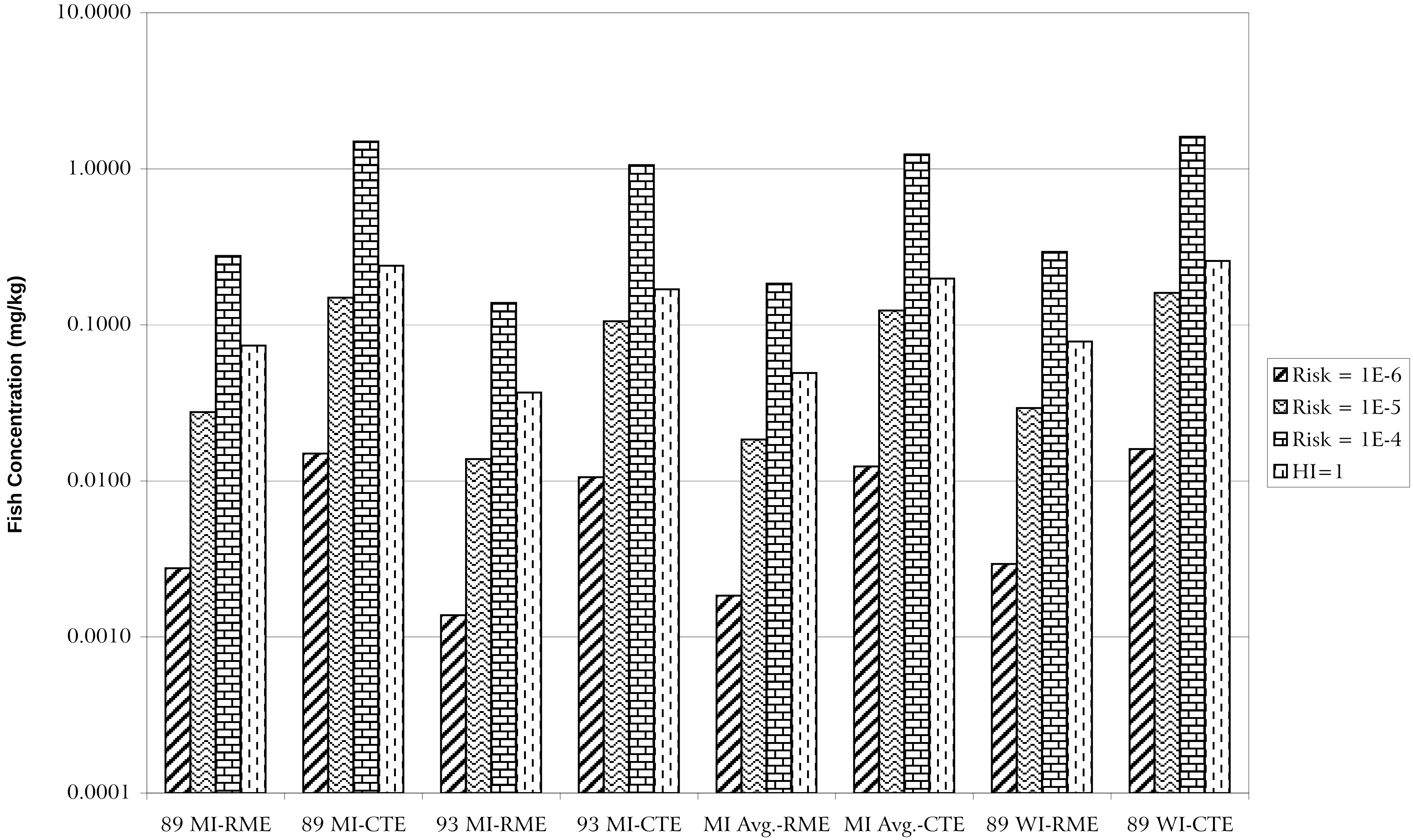


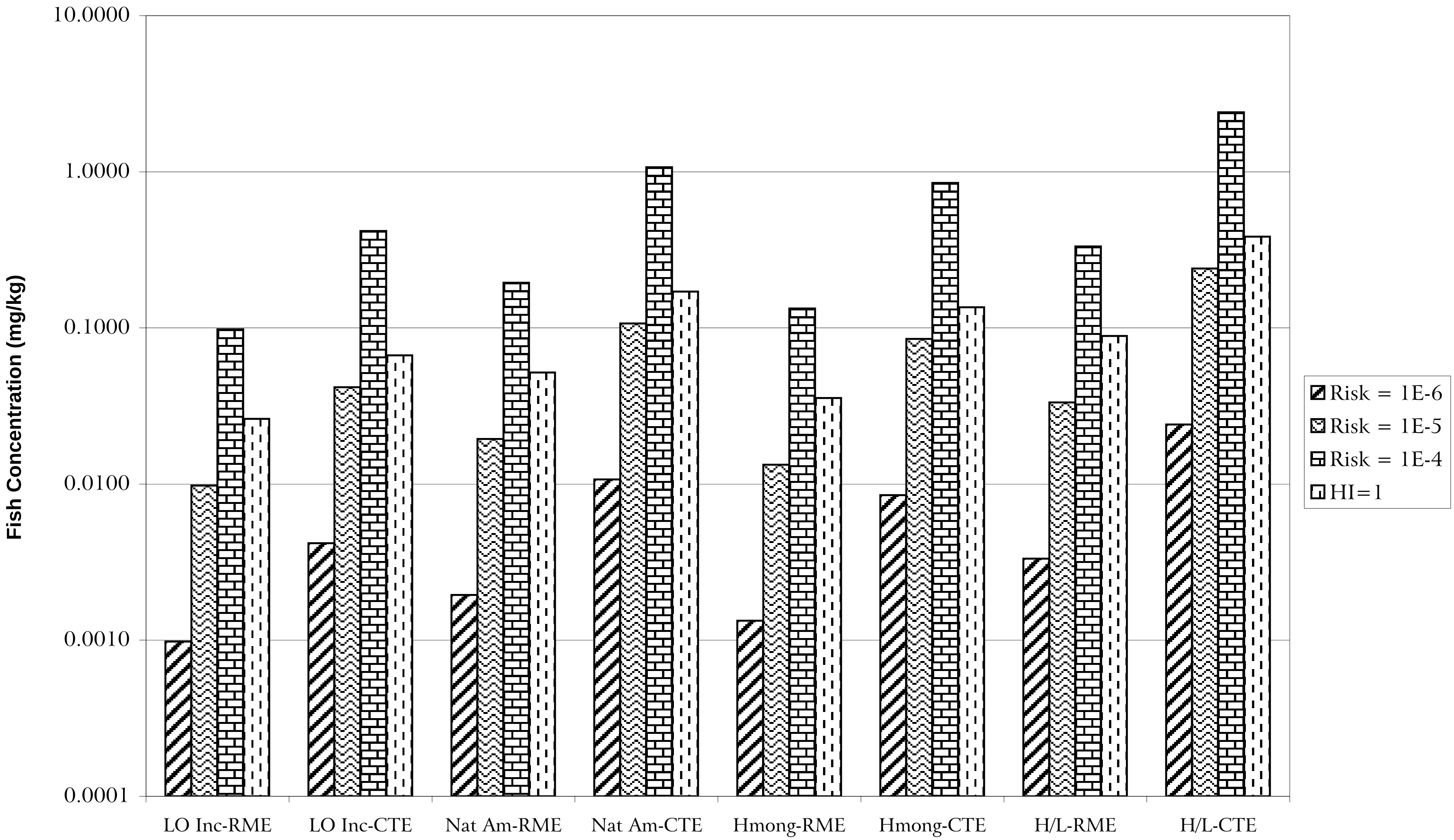
Figure 5-32 Risk-based Fish Concentrations for Recreational Anglers



Key:

89 MI - 1989 Michigan Study
93 MI - 1993 Michigan Study
MI Avg. - Uses average intake from 1989 and 1993 Michigan studies.
89 WI - Wisconsin Study
CTE - Central Tendency Exposure
RME - Reasonable Maximum Exposure

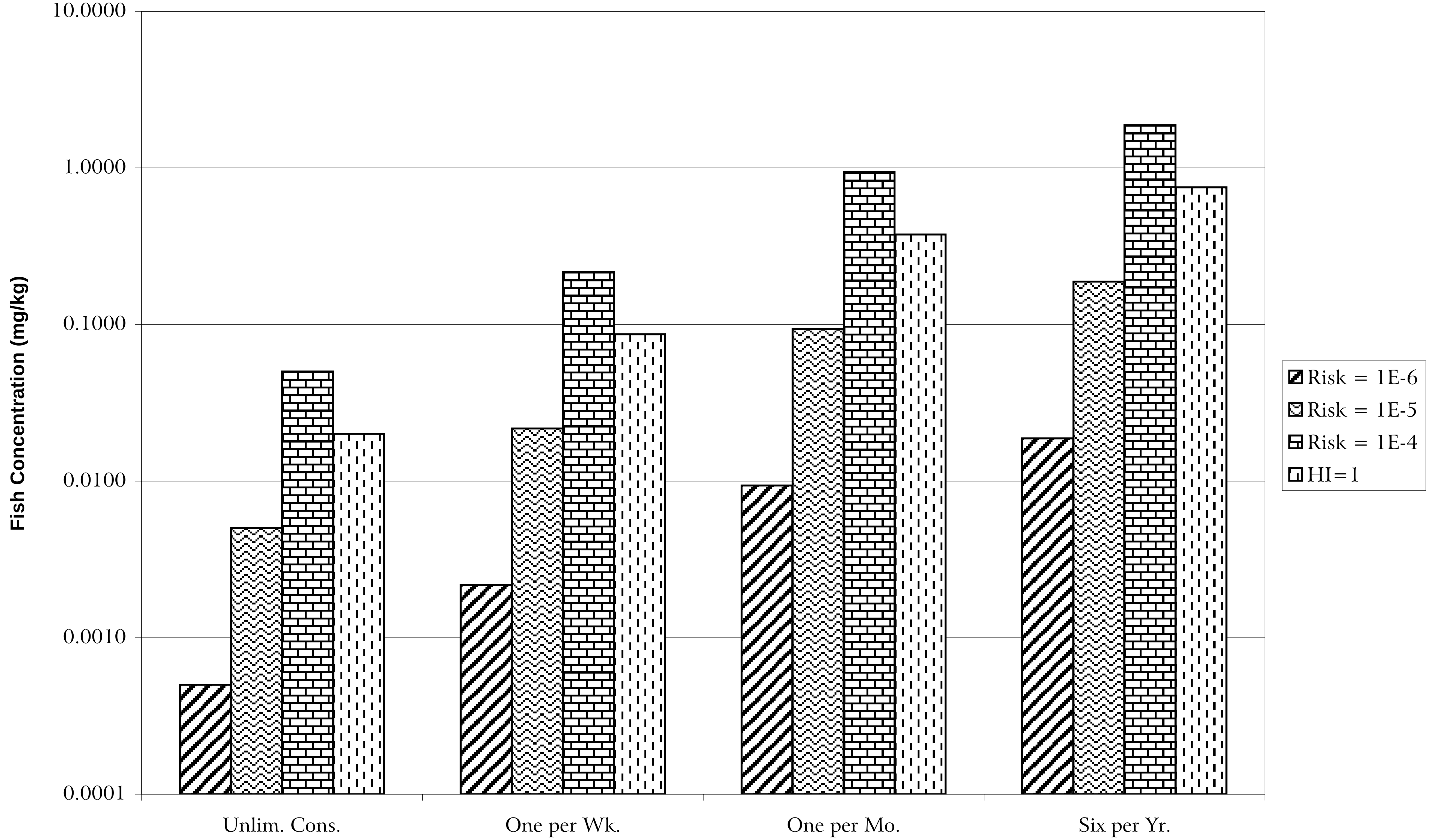
Figure 5-33 Risk-based Fish Concentrations for High-intake Fish Consumers



Key:

CTE - Central Tendency Exposure
LO Inc - Low-income Minotiry Angler
RME - Reasonable Maximum Exposure
H/L - Hmong/Laotian Angler
Nat Am - Native American Angler

Figure 5-34 Risk-based Fish Concentrations Using Assumptions from the Great Lakes Sport Fish Advisory Task Force



Key:

Unlim. Cons. - Unlimited consumption of fish.

One per Wk. - One meal consumed of fish per week.

One per Mo. - One meal consumed of fish per month.

Six per Yr. - Six meals of fish consumed per year.

Table 5-1 Potential Human Receptors and Exposure Pathways for the Lower Fox River and Green Bay

Receptor	Source Medium	Exposure Medium	Exposure Pathway	Comments
Recreational Angler	surface water	outdoor air	inhalation	Pathway potentially complete.
		water	ingestion dermal	Pathways potentially complete, but exposure likely to be intermittent and for short periods.
	surface water and sediment	fish	ingestion	Pathway potentially complete.
High-intake Fish Consumer	surface water	outdoor air	inhalation	Pathway potentially complete.
		water	ingestion dermal	Pathways potentially complete, but exposure likely to be intermittent and for short periods.
	surface water and sediment	fish	ingestion	Pathway potentially complete.
Hunter	surface water	outdoor air	inhalation	Pathway potentially complete.
		water	ingestion dermal	Pathways potentially complete, but exposure likely to be intermittent and for short periods.
	surface water and sediment	waterfowl	ingestion	Pathway potentially complete.
Drinking Water User	surface water	tap water	ingestion dermal	Pathways potentially complete. Water upstream of dam in Appleton and in Green Bay at Marinette is used for drinking. Water is treated before distribution.
		indoor air	inhalation	
Local Resident	surface water	outdoor air	inhalation	Pathway potentially complete.
Recreational Water User	surface water	outdoor air	inhalation	Pathways potentially complete as a result of swimming, wading, water skiing, jet skiing; no beaches in Fox River, beaches in Green Bay.
		water	ingestion dermal	
	sediment	sediment	ingestion dermal	
Marine Construction Worker	surface water	outdoor air	inhalation	Pathways potentially complete.
		water	ingestion dermal	
	sediment	sediment	ingestion dermal	

Table 5-2 Fish Consumption Advisories for Lower Fox River and Green Bay

Water Body/ Fish Species	Eat No More than One Meal/Week or 52 Meals/Year (0.05–0.2 ppm PCBs in fish)	Eat No More than One Meal/Month or 12 Meals/Year (0.2–1.0 ppm PCBs in fish)	Eat No More than One Meal Every 2 Months or 6 Meals/Year (1.0–1.9 ppm PCBs in fish)	Do Not Eat (>1.9 ppm PCBs in fish)
Fox River from Little Lake Butte des Morts to the De Pere Dam				
Walleye		All Sizes		
Northern Pike		All Sizes		
White Bass		All Sizes		
White Perch		All Sizes		
Smallmouth Bass		All Sizes		
Yellow Perch	All Sizes			
Carp				All Sizes
Fox River from the mouth up to the De Pere Dam				
Walleye		Less than 16"	16"–22"	Larger than 22"
Northern Pike		Less than 25"	Larger than 25"	
White Sucker			All Sizes	
White Bass				All Sizes
Black Crappie		Less than 9"	Larger than 9"	
Bluegill		All Sizes		
Rock Bass		All Sizes		
Yellow Perch		All Sizes		
Smallmouth Bass			All Sizes	
Carp				All Sizes
Channel Catfish				All Sizes
Sheepshead		Less than 10"	10"–13"	Larger than 13"

Table 5-2 Fish Consumption Advisories for the Lower Fox River and Green Bay (Continued)

Water Body/ Fish Species	Eat No More than One Meal/Week or 52 Meals/Year (0.05–0.2 ppm PCBs in fish)	Eat No More than One Meal/Month or 12 Meals/Year (0.2–1.0 ppm PCBs in fish)	Eat No More than One Meal Every 2 Months or 6 Meals/Year (1.0–1.9 ppm PCBs in fish)	Do Not Eat (>1.9 ppm PCBs in fish)
Green Bay (south of Marionette and its tributaries, except the Lower Fox River)				
Northern Pike	Less than 22"	Larger than 22"		
Walleye		Less than 17"	17"–26"	Larger than 26"
White Bass				All Sizes
Yellow Perch	All Sizes			
Carp				All Sizes
White Perch			All Sizes	
Smallmouth Bass		All Sizes		
Channel Catfish			All Sizes	
White Sucker		All Sizes		
Rainbow Trout		All Sizes		
Chinook Salmon		Less than 30"	Larger than 30"	
Whitefish			All Sizes	
Splake		Less than 16"	16"–20"	Larger than 20"
Brown Trout		Less than 17"	17"–28"	Larger than 28"
Sturgeon				All Sizes

Table 5-3 Data Summary for 1998 Whole Body Fish Tissue Samples

Constituent	Maximum Detected Concentration (mg/kg)	Average Concentration[1] (mg/kg)	Frequency of Detection
PAHs			
1-Methylnaphthalene	0.027	0.00793	9 / 12
1-Methylphenanthrene	ND	0.004	0 / 12
2,3,5-Trimethylnaphthalene	0.034	0.00683	3 / 12
2,6-Dimethylnaphthalene	0.014	0.0051	3 / 12
2-Methylnaphthalene	0.047	0.01203	10 / 12
Acenaphthene	0.0051	0.00412	2 / 12
Acenaphthylene	ND	0.004	0 / 12
Anthracene	0.0042	0.00402	1 / 12
Benzo(a)anthracene	0.016	0.00583	2 / 12
Benzo(a)pyrene	0.016	0.00583	2 / 12
Benzo(b)fluoranthene	0.016	0.00567	2 / 12
Benzo(e)pyrene	0.0064	0.00438	2 / 12
Benzo(g,h,i)perylene	0.017	0.00617	2 / 12
Benzo(k)fluoranthene	0.02	0.00633	2 / 12
Chrysene	0.018	0.00625	2 / 12
Dibenz(a,h)anthracene	0.017	0.00617	2 / 12
Fluoranthene	0.024	0.00718	5 / 12
Fluorene	0.0064	0.0044	5 / 12
Indeno(1,2,3-cd)pyrene	0.016	0.006	2 / 12
Naphthalene	0.018	0.00788	10 / 12
Perylene	ND	0.004	0 / 12
Phenanthrene	0.01	0.00575	7 / 12
Pyrene	0.022	0.00693	3 / 12
PCBs			
Total PCBs	8.279	2.443	26 / 26
Dioxins			
2,3,7,8-TCDD	0.000002	0.00000076	17 / 17

Notes:

[1] Average concentration includes one-half the detection limit for non-detect samples.

ND - Not Detected.

Table 5-4 Toxicity Criteria and Calculated RBSCs

Constituent	Oral Reference Dose (mg/kg-day)	Oral Cancer Slope Factor $(mg/kg\text{-}day)^{-1}$	Noncancer RBSC (mg/kg)	Cancer RBSC (mg/kg)
PAHs				
1-Methylnaphthalene [1]	0.04	NA	2.0	NA
2,3,5 Trimethylnaphthalene [1]	0.04	NA	2.0	NA
2,6 Dimethylnaphthalene [1]	0.04	NA	2.0	NA
2-Methylnaphthalene	0.04	NA	2.0	NA
Acenaphthene	0.06	NA	3.0	NA
Anthracene	0.3	NA	15	NA
Benzo(a)anthracene	NA	0.73	NA	6.85E-04
Benzo(a)pyrene	NA	7.3	NA	6.85E-05
Benzo(b)fluoranthene	NA	0.73	NA	6.85E-04
Benzo(e)pyrene [2]	0.06	NA	3.0	NA
Benzo(g,h,i)perylene [2]	0.06	NA	3.0	NA
Benzo(k)fluoranthene	NA	0.073	NA	6.85E-03
Chrysene	NA	0.0073	NA	6.85E-02
Dibenz(a,h)anthracene	NA	7.3	NA	6.85E-05
Fluoranthene	0.04	NA	2.0	NA
Fluorene	0.04	NA	2.0	NA
Indeno(1,2,3-cd)pyrene	NA	0.73	NA	6.85E-04
Naphthalene	0.04	NA	2.0	NA
Phenanthrene [3]	0.3	NA	15	NA
Pyrene	0.03	NA	1.5	NA
PCBs				
Total PCBs	2.00E-05	2.0	0.001	2.50E-04
Dioxins				
2,3,7,8-TCDD	NA	150,000	NA	3.33E-09

Notes:

[1] Toxicity criteria for 2-methylnaphthalene were used to evaluate this constituent.

[2] Toxicity criteria for acenaphthene were used to evaluate this constituent.

[3] Toxicity criteria for anthracene were used to evaluate this constituent.

NA - Not available.

Table 5-5 Screening of Constituents Against RBSCs and Calculated Cancer Risks

Constituent	Maximum Detected Concentration (mg/kg)	RBSC for Fish Ingestion (mg/kg)	Does Max. Detect Exceed RBSC?	Calculated Cancer Risk
PAHs				
1-Methylnaphthalene	0.027	2.0	No	
2,3,5 Trimethylnaphthalene	0.034	2.0	No	
2,6 Dimethylnaphthalene	0.014	2.0	No	
2-Methylnaphthalene	0.047	2.0	No	
Acenaphthene	0.0051	3.0	No	
Anthracene	0.0042	15	No	
Benzo(a)anthracene	0.016	6.85E-04	YES	2.3E-05
Benzo(a)pyrene	0.016	6.85E-05	YES	2.3E-04
Benzo(b)fluoranthene	0.016	6.85E-04	YES	2.3E-05
Benzo(e)pyrene	0.0064	3.0	No	
Benzo(g,h,i)perylene	0.017	3.0	No	
Benzo(k)fluoranthene	0.02	6.85E-03	YES	2.9E-06
Chrysene	0.018	6.85E-02	No	
Dibenz(a,h)anthracene	0.017	6.85E-05	YES	2.5E-04
Fluoranthene	0.024	2.0	No	
Fluorene	0.0064	2.0	No	
Indeno(1,2,3-cd)pyrene	0.016	6.85E-04	YES	2.3E-05
Naphthalene	0.018	2.0	No	
Phenanthrene	0.01	15	No	
Pyrene	0.022	1.5	No	
PCBs				
Total PCBs	8.279	0.00025	YES	3.3E-02
Dioxins				
2,3,7,8-TCDD	0.000002	3.33E-09	YES	6.0E-04

Table 5-6 Permeability Coefficients for Chemicals of Potential Concern

Chemical	Kp (cm/hr)	Basis
PCB	0.71	Estimated based on hexachlorobiphenyl
Dioxins/Furans	1.4	Estimated based on 2,3,7,8-TCDD
Dieldrin	0.016	Estimated
DDT	0.43	Estimated
DDE	0.24	Estimated
DDD	0.28	Estimated
Arsenic	0.001	Default value for inorganics
Lead	4×10^{-6}	Measured based on lead acetate
Mercury	1×10^{-3}	Measured based on mercuric chloride

Source:
Dermal Exposure Assessment: Principles and Application (EPA, 1992a).

Table 5-7 Calculated Permeability Coefficients for PCB Aroclors and PCB, Dioxin, and Furan Congeners

Chemical of Potential Concern	Molecular Weight (g/mol)	Log K_{ow}	Estimated Kp (cm/hr)
PCB Aroclors			
Aroclor 1016	257	5.1	2.15E-01
Aroclor 1221	192	4.4	1.71E-01
Aroclor 1232	221	4.85	2.37E-01
Aroclor 1242	261	6.3	2.21E-01
Aroclor 1248	288	6.05	6.59E-01
Aroclor 1254	327	6.45	7.32E-01
Aroclor 1260	372	6.9	8.12E-01
PCB Congeners			
3,3',4,4'-TeCB (PCB-77)	291.99	6.1	6.76E-01
2,3,3',4,4'-PeCB (PCB-105)	326.4	6	3.54E-01
2,3,4,4',5-PeCB (PCB-114)	326.4	6.35	6.27E-01
2,3',4,4',5-PeCB (PCB-118)	326.4	6.35	6.27E-01
2',3,4,4',5-PeCB (PCB-123)	326.4	6.35	6.27E-01
3,3',4,4',5-PeCB (PCB-126)	326.4	6.35	6.27E-01
2,3,3',4,4',5-HxCB (PCB-156)	360.9	7	1.12E+00
2,3,3',4,4',5'-HxCB (PCB-157)	360.9	7	1.12E+00
2,3',4,4',5,5'-HxCB (PCB-167)	360.9	7	1.12E+00
3,3',4,4',5,5'-HxCB (PCB-169)	360.88	7.55	2.75E+00
2,2',3,3',4,4',5-HpCB (PCB-170)	395.32	7.08	7.86E-01
2,2',3,4,4',5,5'-HpCB (PCB-180)	395.32	7.2	9.56E-01
2,3,3',4,4',5,5'-HpCB (PCB-189)	395.3	6.85	5.40E-01
Dioxin Congeners			
1,2,3,7,8-PCDD	356.4	7.4	2.29E+00
1,2,3,4,7,8-HxCDD	391	7.8	2.71E+00
1,2,3,6,7,8-HxCDD	391	7.8	2.71E+00
1,2,3,7,8,9-HxCDD	391	7.8	2.71E+00
1,2,3,4,6,7,8-HpCDD	425.2	8	2.32E+00
OCDD	460	8.2	1.98E+00
Furan Congeners			
2,3,7,8-TCDF	306	6.1	5.55E-01
1,2,3,7,8-PCDF	340.42	6.5	6.58E-01
2,3,4,7,8-PCDF	340.42	6.5	6.58E-01
1,2,3,4,7,8-HxCDF	374.87	7	9.19E-01
1,2,3,6,7,8-HxCDF	374.87	7	9.19E-01
1,2,3,7,8,9-HxCDF	374.87	7	9.19E-01
2,3,4,6,7,8-HxCDF	374.87	7	9.19E-01
1,2,3,4,6,7,8-HpCDF	409.31	7.4	1.09E+00
1,2,3,4,7,8,9-HpCDF	409.31	6.9	4.81E-01
OCDF	443.8	8	1.79E+00

Sources:

Mackay *et al.* (1992a, 1992b) for molecular weight and Log K_{ow}. Kp estimated using equation in *Dermal Exposure Assessment: Principles and Application* (EPA, 1992a).

Table 5-8 Absorption Factors for Chemicals for Ingestion of Sediment

Chemical	Absorption Factor (percent/event)
PCB	100%
Dioxins/Furans	100%
Dieldrin	100%
DDT	100%
DDE	100%
DDD	100%
Arsenic	32%
Lead	100%
Mercury	100%

Source:

Professional judgement except for arsenic, which is based on Freeman *et al*. (1993).

Table 5-9 Absorption Factors for Chemicals for Dermal Contact with Sediment

Chemical	Absorption Factor (percent/event)
PCB	6%
Dioxins/Furans	3%
Dieldrin	10%
DDT	10%
DDE	10%
DDD	10%
Arsenic	3.2%
Lead	1.0%
Mercury	1.0%

Source:
Assessing Dermal Exposure from Soil (EPA, 1995a).

Table 5-10 Fish Ingestion Assumptions for Recreational Angler

Intake Parameter	Recreational Angler RME (West *et al.*, 1989)	Recreational Angler CTE (West *et al.*, 1989)	Recreational Angler RME (West *et al.*, 1993)	Recreational Angler CTE (West *et al.*, 1993)	Recreational Angler RME (Fiore *et al.*, 1989)	Recreational Angler CTE (Fiore *et al.*, 1989)
IR (g/day or g/meal)	39	12	78	17	227	227
EF (days/year or meals/year)	365	365	365	365	59	18
Comparison of Fish Intake Assumptions						
Basis: Annualized IR						
IR (g/day)	39	12	78	17	37	11
EF (days/year)	365	365	365	365	365	365
Basis: Normalized Meals per Year						
IR (g/meal)	227	227	227	227	227	227
EF (meals/year)	63	19	125	27	59	18

Key:

IR is daily consumption of fish (g/day or g/meal).

EF is exposure frequency or number of days per year when sport-caught fish is eaten (days/year), or the number of meals consumed per year (meals/year).

Table 5-11 Fish Ingestion Assumptions for High-intake Fish Consumer

Intake Parameter	Low-income, Minority Angler RME	Low-income, Minority Angler CTE	Native American Angler RME	Native American Angler CTE	Hmong Angler RME	Hmong Angler CTE	Hmong/Laotian Angler RME	Hmong/Laotian Angler CTE
	(West *et al.*, 1993)		(Peterson *et al.*, 1994; Fiore *et al.*, 1989)		(Hutchison and Kraft, 1994)		(Hutchison, 1999)	
IR	110	43	227	227	227	227	227	227
EF	365	365	89	27	130	34	52	12
Comparison of Fish Intake Assumptions								
Basis: Annualized IR								
IR (g/day)	110	43	55	17	81	21	32	8
EF (days/year)	365	365	365	365	365	365	365	365
Basis: Normalized Meals per Year								
IR (g/meal)	227	227	227	227	227	227	227	227
EF (meals/year)	177	69	89	27	130	34	52	12

Key:

IR is daily consumption of fish (g/day or g/meal).

EF is exposure frequency or number of days per year when sport-caught fish is eaten (days/year), or the number of meals consumed per year (meals/year).

Table 5-12 Consumption of Sport Fish by Hmong Anglers

Fish Consumption	Meals/Year	Fraction of Anglers
Never	0	0.08
Once per month	12	0.53
2–3 times per month	30	0.15
Once per week	52	0.09
2–3 times per week	130	0.14
Every day	365	0
Average	34 meals/year	
95th Percentile	130 meals/year	

Source:
Hutchison and Kraft, 1994.

Table 5-13 Consumption of Fish from De Pere to Green Bay Reach of Lower Fox River by Hmong/Laotian Anglers

Fish Consumption	Meals/Year	Fraction of Anglers
Never	0	0.394
Once per month	12	0.515
Once per week	52	0.076
2–3 times per week	130	0.015
Average	12 meals/year	
95th Percentile	52 meals/year	

Source:

Hutchison, 1999.

Table 5-14 Average Size of Meal Consumed by Hmong

Most Likely Meal Size	Bass	Carp	Trout	Salmon	Total	Fraction of Weighed Estimates
1/3 pound	3	2	1	1	7	0.39
1/2 pound	2	4	1	1	8	0.44
1 pound	2	0	1	0	3	0.17
Other	8	3	2	2	15	

Note:

Average quantity: 0.52 lbs.

Source:

Hutchison, 1994 (Sheboygan Study).

Table 5-15 Summary of Intake Parameter Values for Recreational Anglers—RME Assumptions

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
EF (exposure frequency)	=	varies	see individual exposure pathways
ED (exposure duration)	=	50 years	adjusted value for population mobility (see text)
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 50 days	based on exposure period [b]
Fish Intake			
Basis: Annualized Ingestion Rate			
EF (exposure frequency)	=	365 days/yr	assumed
IR (fish ingestion rate)	=	59 g/day	average of 95^{th} percentiles for [c] and [d]
Basis: Normalized Meals per Year			
EF (exposure frequency)	=	94 meals/yr	average of 95^{th} percentiles for [c] and [d]
IR (meal size)	=	227 g/meal	assumed meal size
Other Fish Intake Assumptions			
RF (reduction factor)	=	varies	chemical-specific (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Surface Water:			
EF (exposure frequency)	=	95 days/yr	based on the number of meals per year
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction ingested)	=	10%	professional judgement (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
EF (exposure frequency)	=	95 days/yr	based on the number of meals per year
ET (exposure time)	=	0.25 hr/day	professional judgement
TBS (total body surface area)	=	21,850 cm^2	average upper value for adults [a]
FBE (fraction of body exposed)	=	5.15%	corresponds to hands of adult [a]
SA (exposed skin area = TBS * FBE)	=	1,125 cm^2	SA = TBS * FBE
FC (fraction of dermal exposure at site)	=	100%	conservatively assumed
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
EF (exposure frequency)	=	95 days/yr	based on the number of meals per year
ET (exposure time)	=	6 hrs/day	professional judgement
IR (inhalation rate)	=	1.0 m^3/hr	value for adults, light activity [a]
ABS (absorption factor)	=	100%	conservatively assumed

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .

[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .

[c] West *et al.* , 1989.

[d] West *et al.* , 1993.

Table 5-16 Summary of Intake Parameter Values for Recreational Anglers—CTE Assumptions

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
EF (exposure frequency)	=	varies	see individual exposure pathways
ED (exposure duration)	=	30 years	adjusted value for population mobility (see text)
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 30 days	based on exposure period [b]
Ingestion of Fish:			
<u>Basis: Annualized Ingestion Rate</u>			
EF (exposure frequency)	=	365 days/yr	assumed
IR (fish ingestion rate)	=	15 g/day	average of mean values for [c] and [d]
<u>Basis: Normalized Meals per Year</u>			
EF (exposure frequency)	=	23 meals/yr	average of mean values for [c] and [d]
IR (meal size)	=	227 g/meal	assumed meal size
<u>Other Fish Intake Assumptions</u>			
RF (reduction factor)	=	varies	chemical-specific (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Surface Water:			
EF (exposure frequency)	=	24 days/yr	based on the number of meals per year
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction ingested)	=	10%	professional judgement (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
EF (exposure frequency)	=	24 days/yr	based on the number of meals per year
ET (exposure time)	=	0.25 hr/day	professional judgement
TBS (total body surface area)	=	18,150 cm^2	average mean value for adults [a]
FBE (fraction of body exposed)	=	5.15%	corresponds to hands of adult [a]
SA (exposed skin area = TBS * FBE)	=	935 cm^2	SA = TBS * FBE
FC (fraction of dermal exposure at site)	=	100%	conservatively assumed
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
EF (exposure frequency)	=	24 days/yr	based on the number of meals per year
ET (exposure time)	=	6 hrs/day	professional judgement
IR (inhalation rate)	=	1.0 m^3/hr	value for adults, light activity [a]
ABS (absorption factor)	=	100%	conservatively assumed

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .
[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .
[c] West *et al.* , 1989.
[d] West *et al.* , 1993.

Table 5-17 Summary of Intake Parameter Values for High-intake Fish Consumers—RME Assumptions

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
EF (exposure frequency)	=	varies	see individual exposure pathways
ED (exposure duration)	=	50 years	adjusted value for population mobility (see text)
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 50 days	based on exposure period [b]
Ingestion of Fish:			
Basis: Annualized Ingestion Rate			
EF (exposure frequency)	=	365 days/yr	assumed
IR (fish ingestion rate)	=	81 g/day	95th percentile for [c]
Basis: Normalized Meals per Year			
EF (exposure frequency)	=	130 meals/yr	95th percentile for [c]
IR (fish ingestion rate)	=	227 g/day	assumed meal size
Other Fish Intake Assumptions			
RF (reduction factor)	=	varies	chemical-specific (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Surface Water:			
EF (exposure frequency)	=	130 days/yr	based on the number of meals per year [c]
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction ingested)	=	10%	professional judgement (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
EF (exposure frequency)	=	130 days/yr	based on the number of meals per year [c]
ET (exposure time)	=	0.25 hr/day	professional judgement
TBS (total body surface area)	=	21,850 cm^2	average upper value for adults [a]
FBE (fraction of body exposed)	=	5.15%	corresponds to hands of adult [a]
SA (exposed skin area = TBS * FBE)	=	1,125 cm^2	SA = TBS * FBE
FC (fraction of dermal exposure at site)	=	100%	conservatively assumed
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
EF (exposure frequency)	=	130 days/yr	based on the number of meals per year [c]
ET (exposure time)	=	4 hrs/day	professional judgement
IR (inhalation rate)	=	1.0 m^3/hr	value for adults, light activity [a]
ABS (absorption factor)	=	100%	conservatively assumed

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .

[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .

[c] Hutchison and Kraft, 1994.

Table 5-18 Summary of Intake Parameter Values for High-intake Fish Consumers—CTE Assumptions

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
EF (exposure frequency)	=	varies	see individual exposure pathways
ED (exposure duration)	=	30 years	adjusted value for population mobility (see text)
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 30 days	based on exposure period [b]
Ingestion of Fish:			
Basis: Annualized Ingestion Rate			
EF (exposure frequency)	=	365 days/yr	assumed
IR (fish ingestion rate)	=	21 g/day	mean value in [c]
Basis: Normalized Meals per Year			
EF (exposure frequency)	=	34 meals/yr	mean value in [c]
IR (fish ingestion rate)	=	227 g/day	assumed meal size
Other Fish Intake Assumptions			
RF (reduction factor)	=	varies	chemical-specific (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Surface Water:			
EF (exposure frequency)	=	34 days/yr	based on the number of meals per year [c]
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction ingested)	=	10%	professional judgement (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
EF (exposure frequency)	=	34 days/yr	based on the number of meals per year [c]
ET (exposure time)	=	0.25 hr/day	professional judgement
TBS (total body surface area)	=	18,150 cm^2	average mean value for adults [a]
FBE (fraction of body exposed)	=	5.15%	corresponds to hands of adult [a]
SA (exposed skin area = TBS * FBE)	=	935 cm^2	SA = TBS * FBE
FC (fraction of dermal exposure at site)	=	100%	conservatively assumed
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
EF (exposure frequency)	=	34 days/yr	based on the number of meals per year [c]
ET (exposure time)	=	4 hrs/day	professional judgement
IR (inhalation rate)	=	1.0 m^3/hr	value for adults, light activity [a]
ABS (absorption factor)	=	100%	conservatively assumed

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .

[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .

[c] Hutchison and Kraft, 1994.

Table 5-19 Summary of Intake Parameter Values for Hunters—RME Assumptions

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
EF (exposure frequency)	=	varies	see individual exposure pathways
ED (exposure duration)	=	50 years	adjusted value for population mobility (see text)
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 50 days	based on exposure period [b]
Ingestion of Waterfowl:			
EF (exposure frequency)	=	12 meals/yr	based on data from Amundson study [c]
IR (waterfowl ingestion rate)	=	110 g/meal	reasonable maximum meal size presented in [d]
RF (reduction factor)	=	100%	based on data from Amundson study [c]
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Surface Water:			
EF (exposure frequency)	=	12 days/yr	based on the number of meals per year [c]
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction ingested)	=	10%	professional judgement (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
EF (exposure frequency)	=	12 days/yr	based on the number of meals per year [c]
ET (exposure time)	=	0.25 hr/day	professional judgement
TBS (total body surface area)	=	21,850 cm^2	average upper value for adults [a]
FBE (fraction of body exposed)	=	5.15%	corresponds to hands of adult [a]
SA (exposed skin area = TBS * FBE)	=	1,125 cm^2	SA = TBS * FBE
FC (fraction of dermal exposure at site)	=	100%	conservatively assumed
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
EF (exposure frequency)	=	12 days/yr	based on the number of meals per year [c]
ET (exposure time)	=	8 hrs/day	professional judgement
IR (inhalation rate)	=	1.0 m^3/hr	value for adults, light activity [a]
ABS (absorption factor)	=	100%	conservatively assumed

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .

[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .

[c] Amundson, 1984. Organochlorine pesticides and PCBs in edible tissues of giant Canada geese from the Chicago area.

[d] Pao *et al.* , 1982.

Table 5-20 Summary of Intake Parameter Values for Hunters—CTE Assumptions

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
EF (exposure frequency)	=	varies	see individual exposure pathways
ED (exposure duration)	=	30 years	adjusted value for population mobility (see text)
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 30 days	based on exposure period [b]
Ingestion of Waterfowl:			
EF (exposure frequency)	=	6 meals/yr	based on data from Amundson study [c]
IR (waterfowl ingestion rate)	=	110 g/meal	reasonable maximum meal size presented in [d]
RF (reduction factor)	=	100%	based on data from Amundson study [c]
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Surface Water:			
EF (exposure frequency)	=	6 days/yr	based on the number of meals per year [c]
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction ingested)	=	10%	professional judgement (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
EF (exposure frequency)	=	6 days/yr	based on the number of meals per year [c]
ET (exposure time)	=	0.25 hr/day	professional judgement
TBS (total body surface area)	=	18,150 cm^2	average mean value for adults [a]
FBE (fraction of body exposed)	=	5.15%	corresponds to hands of adult [a]
SA (exposed skin area = TBS * FBE)	=	935 cm^2	SA = TBS * FBE
FC (fraction of dermal exposure at site)	=	100%	conservatively assumed
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
EF (exposure frequency)	=	6 days/yr	based on the number of meals per year [c]
ET (exposure time)	=	8 hrs/day	professional judgement
IR (inhalation rate)	=	1.0 m^3/hr	value for adults, light activity [a]
ABS (absorption factor)	=	100%	conservatively assumed

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .

[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .

[c] Amundson, 1984. Organochlorine pesticides and PCBs in edible tissues of giant Canada geese from the Chicago area.

[d] Pao *et al.* , 1982

Table 5-21 Summary of Intake Parameter Values for Drinking Water Users

Assumptions			Comments and References
General Assumptions:			
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 30 days	based on exposure period [b]
EF (exposure frequency)	=	350 days/year	default for a residential receptor [c]
Young Child (1 to 6 years)			
ED (exposure duration)	=	6 years	value for ages 1–6 [c]
BW (body weight)	=	16.6 kg	average body weight for boys and girls age 1–6 [a]
Ingestion of Water:			
IR (incidental ingestion rate)	=	1.5 L/day	upper-percentile for a child age 3–5 [a]
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Water:			
FBE (fraction of body exposed)	=	100%	whole body while bathing
TBS (total body surface area)	=	8,105 cm^2	average value for a young child [a]
SA (exposed skin area = TBS * FBE)	=	8,105 cm^2	SA = TBS * FBE
ET (exposure time)	=	0.33 hr/day	average time spent in bath [a]
FC (fraction of dermal exposure from site)	=	100%	conservatively assumed
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Water:			
IR (inhalation rate)	=	1.0 m^3/hr	value for child engaged in light activities [a]
ET (exposure time)	=	0.33 hr/day	average time spent in bath [a]
ABS (absorption factor)	=	100%	conservatively assumed
Older Child to Adult (7 to 31 years)			
ED (exposure duration)	=	24 years	value for ages 7–31 [c]
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
Ingestion of Water:			
IR (incidental ingestion rate)	=	2.3 L/day	upper-percentile for an adult [a]
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Water:			
FBE (fraction of body exposed)	=	100%	whole body while bathing/showering
TBS (total body surface area)	=	21,850 cm^2	average upper value for adults [a]
SA (exposed skin area = TBS * FBE)	=	21,850 cm^2	SA = TBS * FBE
ET (exposure time)	=	0.25 hr/day	average time spent in bath/shower [a]
FC (fraction of dermal exposure from site)	=	100%	conservatively assumed
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Water:			
IR (inhalation rate)	=	1.0 m^3/hr	value for adult engaged in light activities [a]
ET (exposure time)	=	0.25 hr/day	average time spent in bath/shower [a]
ABS (absorption factor)	=	100%	conservatively assumed

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .

[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .

[c] EPA, 1991. *Standard Default Exposure Factors* .

Table 5-22 Summary of Intake Parameter Values for Local Residents

Assumptions			Comments and References
General Assumptions:			
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 30 days	based on exposure period [b]
EF (exposure frequency)	=	350 days/year	default for a residential receptor [c]
Young Child (1 to 6 years)			
Inhalation of Volatiles from Surface Water:			
ED (exposure duration)	=	6 years	value for ages 1–6 [c]
BW (body weight)	=	16.6 kg	average body weight for boys and girls age 1–6 [a]
IR (inhalation rate)	=	0.42 m^3/hr	daily IR of 10 m^3/day for child 6–8 yrs divided by ET
ET (exposure time)	=	24 hrs/day	total hours in a day
ABS (absorption factor)	=	100%	conservatively assumed
Older Child to Adult (7 to 31 years)			
Inhalation of Volatiles from Surface Water:			
ED (exposure duration)	=	24 years	value for ages 7–31 [b]
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
IR (inhalation rate)	=	0.55 m^3/hr	daily IR of 13.3 m^3/day for adult divided by ET
ET (exposure time)	=	24 hrs/day	total hours in a day
ABS (absorption factor)	=	100%	conservatively assumed

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .

[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .

[c] EPA, 1991. *Standard Default Exposure Factors* .

Table 5-23 Summary of Intake Parameter Values for Swimmers

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
EF (exposure frequency)	=	18 days/yr	1 time per week for 4 warmest months of the year
ED (exposure duration)	=	30 years	default exposure duration for a resident [b]
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 30 days	based on exposure period [c]
Incidental Ingestion of Surface Water:			
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction ingested)	=	100%	conservatively assumed
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
ET (exposure time)	=	1 hour/day	average time for swimming per event [a]
TBS (total body surface area)	=	21,850 cm^2	average upper value for adults [a]
FBE (fraction of body exposed)	=	100.0%	entire body exposed while swimming
SA (exposed skin area = TBS * FBE)	=	21,850 cm^2	SA = TBS * FBE
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
ET (exposure time)	=	1 hour/day	average time for swimming per event [a]
IR (inhalation rate)	=	3.2 m^3/hr	value for adults, heavy activity [a]
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Sediments:			
IR (incidental ingestion rate)	=	5 mg/day	one-tenth daily soil rate for an adult (see text)
FI (fraction ingested)	=	100%	conservatively assumed
ABS (absorption factor)	=	varies	chemical-specific (see text)
Dermal Contact with Sediments:			
FBE (fraction of body exposed)	=	6.75%	corresponds to feet of an adult [a]
SA (exposed skin area = TBS * FBE)	=	1,475 cm^2	SA = TBS * FBE
AF (soil adherence factor)	=	1.0 mg/cm^2	upper value for soil contact [d]
FC (fraction of daily contact occurring at the site)	=	5%	professional judgement (see text)
ABS (skin absorption factor)	=	varies	chemical-specific (see text)
Dermal Contact with Sediment Pore Water:			
ET (exposure time)	=	0.25 hour/day	exposure might occur for 15 minutes
TBS (total body surface area)	=	21,850 cm^2	average upper value for adults [a]
FBE (fraction of body exposed)	=	6.75%	corresponds to feet of an adult [a]
SA (exposed skin area = TBS * FBE)	=	1,475 cm^2	SA = TBS * FBE
PC (permeability constant)	=	varies	chemical-specific (see text)

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .
[b] EPA, 1991. *Standard Default Exposure Factors* .
[c] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .

[d] EPA, 1992a. *Dermal Exposure Assessment: Principles and Applications* .

Table 5-24 Summary of Intake Parameter Values for Waders

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	51 kg	average body weight of an older child, age 9–18 [a]
EF (exposure frequency)	=	18 days/yr	1 time per week for 4 warmest months of the year
ED (exposure duration)	=	10 years	duration of time from age 9 to age 18
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 10 days	based on exposure period [b]
Incidental Ingestion of Surface Water:			
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction of time ingestion occurs)	=	10%	professional judgement (see text)
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
ET (exposure time)	=	0.5 hour/day	assumed time spent wading
TBS (total body surface area)	=	14,400 cm^2	average 50^{th} percentile value for children age 9–18 [a]
FBE (fraction of body exposed)	=	22.9%	feet and lower legs exposed while wading
SA (exposed skin area = TBS * FBE)	=	3,298 cm^2	SA = TBS * FBE
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
ET (exposure time)	=	0.5 hour/day	assumed time spent wading
IR (inhalation rate)	=	1.2 m^3/hr	value for children, moderate activity [a]
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Sediments:			
IR (incidental ingestion rate)	=	5 mg/day	one-tenth daily soil rate for an older child (see text)
FI (fraction ingested)	=	100%	conservatively assumed
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Sediments:			
FBE (fraction of body exposed)	=	7.37%	corresponds to feet of an older child [a]
SA (exposed skin area = TBS * FBE)	=	1,061 cm^2	SA = TBS * FBE
AF (soil adherence factor)	=	1.0 mg/cm^2	upper value for soil contact [c]
FC (fraction of daily contact occurring at the site)	=	10%	professional judgement (see text)
ABS (skin absorption factor)	=	varies	chemical-specific (see text)
Dermal Contact with Sediment Pore Water:			
ET (exposure time)	=	0.5 hour/day	exposure might occur for 30 minutes
TBS (total body surface area)	=	14,400 cm^2	average 50^{th} percentile value for children age 9–18 [a]
FBE (fraction of body exposed)	=	7.37%	corresponds to feet of an older child [a]
SA (exposed skin area = TBS * FBE)	=	1,061 cm^2	SA = TBS * FBE
PC (permeability constant)	=	varies	chemical-specific (see text)

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .

[b] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .

[c] EPA, 1992a. *Dermal Exposure Assessment: Principles and Applications* .

Table 5-25 Summary of Intake Parameter Values for Marine Construction Workers

Assumptions			Comments and References
General Assumptions:			
BW (body weight)	=	71.8 kg	default body weight of an adult [a]
EF (exposure frequency)	=	24 days/yr	twice per month (professional judgement)
ED (exposure duration)	=	25 years	value specified for workers [b]
AT (averaging times)			
Carcinogenic Effects	=	365 * 75 days	value specified in [a]
Noncarcinogenic Effects	=	365 * 25 days	based on exposure period [c]
Incidental Ingestion of Surface Water:			
IR (incidental ingestion rate)	=	20 ml/day	professional judgement (1 mouthfull of water)
FI (fraction ingested)	=	100%	conservatively assumed
ABS (absorption factor)	=	100%	conservatively assumed
Dermal Contact with Surface Water:			
ET (exposure time)	=	0.5 hrs/day	exposure might occur for one-half hour during the workday
TBS (total body surface area)	=	21,850 cm^2	average upper value for adults [a]
FBE (fraction of body exposed)	=	11.6%	corresponds to hands and forearms of adult [a]
SA (exposed skin area = TBS * FBE)	=	2,535 cm^2	SA = TBS * FBE
PC (permeability constant)	=	varies	chemical-specific (see text)
Inhalation of Volatiles from Surface Water:			
ET (exposure time)	=	8 hrs/day	hours in a work day
IR (inhalation rate)	=	1.5 m^3/hr	value for outdoor worker, moderate activity [a]
ABS (absorption factor)	=	100%	conservatively assumed
Incidental Ingestion of Sediments:			
IR (incidental ingestion rate)	=	25 mg/day	half the daily soil rate for an adult (see text)
FI (fraction ingested)	=	100%	conservatively assumed
ABS (absorption factor)	=	varies	chemical-specific (see text)
Dermal Contact with Sediments:			
FBE (fraction of body exposed)	=	5.15%	corresponds to hands of an adult [a]
SA (exposed skin area = TBS * FBE)	=	1,125 cm^2	SA = TBS * FBE
AF (soil adherence factor)	=	1.0 mg/cm^2	upper value for soil contact [c]
FC (fraction of dermal exposure at site)	=	100%	conservatively assumed
ABS (skin absorption factor)	=	varies	chemical-specific (see text)

Notes:

[a] EPA, 1997b. *Exposure Factors Handbook* .
[b] EPA, 1991. *Standard Default Exposure Factors* .
[c] EPA, 1989c. *Risk Assessment Guidance for Superfund, Volume 1: Human Health Evaluation Manual (Part A: Baseline Risk Assessment)* .
[d] EPA, 1992a. *Dermal Exposure Assessment: Principles and Applications* .

Table 5-26 Upper-bound Measured Concentrations for the Little Lake Butte des Morts Reach

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	3.6	0.66	ND	1.530E-05	3.749
Aroclor 1016	ND		ND	ND	ND
Aroclor 1221	ND		ND	ND	ND
Aroclor 1232	ND		ND	ND	ND
Aroclor 1242	1.32		ND	1.900E-05	21.1
Aroclor 1248	0.156		ND	ND	3.43
Aroclor 1254	1.01		ND	ND	2.93
Aroclor 1260	0.216		ND	ND	1.400
Total PCB Aroclors (less 1016/1254)	2.59	0.66	0	1.530E-05	0.819
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)	0.0031			2.390E-07	0.0264
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)	0.013				0.0106
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)					0.0106
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)	0.052			8.380E-08	0.596
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)	0.0057				0.0012
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)	ND				3.2E-04
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)	0.0029				0.00743
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)	0.00079				0.0025
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)					0.00471
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)	ND				ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)	0.0034				0.0103
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)	0.023			3.230E-08	0.228
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)					8.5E-04
Total PCB Congeners (less dioxin-like)	3.49611	0.66	0	1.494E-05	2.85009
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)	ND				4.31E-06
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)	0.0000018				7.129E-05
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	ND	0.0143			0.0059
4,4'-DDD	ND	ND			0.019
4,4'-DDE	0.0769	0.68			ND
4,4'-DDT	ND	ND			0.050
Inorganics					
Arsenic	ND	ND			5.09
Lead	ND	ND	1.45E-03	1.17E-04	522
Mercury (total)	0.133	ND	7.14E-03	ND	1.45
Mercury (inorganic)					
Mercury (organic)					

Table 5-27 Upper-bound Measured Concentrations for the Appleton to Little Rapids Reach

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	5.06	0.774	ND	9.450E-06	1.479
Aroclor 1016	ND		ND	ND	ND
Aroclor 1221	ND		ND	ND	ND
Aroclor 1232	ND		ND	ND	ND
Aroclor 1242	0.512		ND	8.060E-06	8.89
Aroclor 1248	ND		ND	ND	ND
Aroclor 1254	0.555		ND	ND	0.340
Aroclor 1260	0.155		ND	ND	2.07
Total PCB Aroclors (less 1016/1254)	4.505	0.774	0	9.450E-06	1.139
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)				1.925E-07	0.035
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)					0.138
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)					3.5E-04
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)				1.31E-07	0.181
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)				3.200E-08	ND
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)					5.2E-05
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)					0.0015
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)					2.0E-04
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)				ND	0.0021
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)					ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)				ND	0.0061
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)				5.000E-08	0.0716
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)					1.3E-04
Total PCB Congeners (less dioxin-like)				9.045E-06	1.043
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)					
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)			ND		
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	ND	ND	ND		ND
4,4'-DDD	ND	ND	ND		0.0017
4,4'-DDE	0.070	0.121	ND		ND
4,4'-DDT	ND	ND	ND		0.0034
Inorganics					
Arsenic			ND		6.4
Lead			0.0018		88.9
Mercury (total)	0.381	0.0415	9.0E-05	9.000E-05	1.740
Mercury (inorganic)					
Mercury (organic)					

Table 5-28 Upper-bound Measured Concentrations for the Little Rapids to De Pere Reach

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	0.751	1.23		1.230E-05	2.112
Aroclor 1016	ND			ND	ND
Aroclor 1221	ND			ND	ND
Aroclor 1232	ND			ND	ND
Aroclor 1242	0.517			1.420E-05	11.3
Aroclor 1248	0.653			ND	ND
Aroclor 1254	0.563			ND	0.806
Aroclor 1260	0.204			ND	0.266
Total PCB Aroclors (less 1016/1254)	0.188	1.23		1.230E-05	1.306
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)				1.610E-07	0.0579
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)					0.0214
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)					0.00647
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)				6.990E-08	0.584
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)					0.0059
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)					0.00079
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)					0.00569
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)					0.0016
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)					0.0029
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)					ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)					0.0106
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)				4.730E-08	0.0223
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)					0.00074
Total PCB Congeners (less dioxin-like)				1.202E-05	1.39171
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)					6.820E-06
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)					1.170E-04
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	ND				ND
4,4'-DDD	0.0104				0.0028
4,4'-DDE	0.0744				0.022
4,4'-DDT	ND				0.020
Inorganics					
Arsenic					5.11
Lead			7.07E-04	1.24E-04	274
Mercury (total)	0.287		7.12E-03	2.52E-03	4.04
Mercury (inorganic)					
Mercury (organic)					

Table 5-29 Upper-bound Measured Concentrations for the De Pere to Green Bay Reach

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	2.76	0.8		1.770E-05	2.984
Aroclor 1016	ND		ND	ND	ND
Aroclor 1221	ND		ND	ND	ND
Aroclor 1232	ND		ND	ND	ND
Aroclor 1242	0.783		ND	1.400E-05	5.72
Aroclor 1248	0.367		ND	ND	ND
Aroclor 1254	0.931		ND	ND	0.630
Aroclor 1260	0.258		ND	ND	0.400
Total PCB Aroclors (less 1016/1254)	1.829	0.8	0	1.770E-05	2.354
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)	0.0038			1.740E-07	0.027
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)	0.0217				0.0106
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)	0.00423			2.170E-08	0.00438
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)	0.0546			5.500E-08	0.0241
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)	0.0059			3.820E-08	9.34E-04
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)	0.0012				2.7E-04
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)	0.0064			7.110E-09	0.00199
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)	0.0025			1.0E-09	8.0E-05
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)	0.0068			3.030E-09	9.1E-04
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)	0.0006				ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)	0.0355			2.120E-08	0.00235
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)	0.0246			2.030E-08	0.00672
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)	0.000943			1.380E-09	2.6E-04
Total PCB Congeners (less dioxin-like)	2.591227			1.736E-05	2.904406
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)	1.6E-06		ND		
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)	5.5E-05		ND		
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	0.0133	ND	ND		ND
4,4'-DDD	0.0230	ND	ND	5.900E-08	0.0045
4,4'-DDE	0.119	0.103	ND	4.410E-08	0.0019
4,4'-DDT	ND	ND	ND		ND
Inorganics					
Arsenic	ND	ND	1.5E-03		16.9
Lead	ND	ND	5.2E-03		91.2
Mercury (total)	0.286	0.05	4.03E-05	7.57E-06	1.37
Mercury (inorganic)					
Mercury (organic)					

Table 5-30 Upper-bound Measured Concentrations for Green Bay

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	2.51	0.755		2.410E-06	0.213
Aroclor 1016	ND				ND
Aroclor 1221	ND				ND
Aroclor 1232	ND				ND
Aroclor 1242	0.526				0.279
Aroclor 1248	1.070				ND
Aroclor 1254	1.450				ND
Aroclor 1260	0.050				ND
Total PCB Aroclors (less 1016/1254)	1.06	0.755		0.00000241	0.213
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)				4.240E-08	0.0092
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)					0.0052
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)				5.370E-09	1.57E-04
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)				1.280E-08	0.0193
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)					ND
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)					5.2E-05
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)				2.320E-09	2.16E-04
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)				9.040E-10	5.62E-05
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)				1.700E-09	4.02E-04
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)					ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)				9.300E-09	7.27E-04
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)				1.100E-08	0.00373
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)				4.090E-10	9.21E-05
Total PCB Congeners (less dioxin-like)				2.324E-06	0.1738681
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)	3.8E-06				
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)	3.5E-05				
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	0.0603	0.0168			ND
4,4'-DDD	0.367	0.0111			ND
4,4'-DDE	0.422	0.145			ND
4,4'-DDT	0.027	ND			ND
Inorganics					
Arsenic		ND			6.39
Lead		ND	2.64E-04	4.42E-05	43.5
Mercury (total)	0.27	0.33	3.82E-04	2.27E-04	0.767
Mercury (inorganic)					
Mercury (organic)					

Table 5-31 Average Measured Concentrations for the Little Lake Butte des Morts Reach

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	2.83	0.361	ND	1.110E-05	3.699
Aroclor 1016	ND		ND	ND	ND
Aroclor 1221	ND		ND	ND	ND
Aroclor 1232	ND		ND	ND	ND
Aroclor 1242	0.711		ND	1.400E-05	9.63
Aroclor 1248	0.119		ND	ND	0.732
Aroclor 1254	0.668		ND	ND	2.120
Aroclor 1260	0.171		ND	ND	0.711
Total PCB Aroclors (less 1016/1254)	2.162	0.361	0	1.110E-05	1.579
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)	0.00146			1.980E-07	0.0113
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)	0.0061				0.00663
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)					1.93E-03
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)	0.0235			7.460E-08	0.257
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)	0.00252				0.0012
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)	ND				3.20E-04
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)	0.00143				2.39E-03
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)	3.97E-04				6.45E-04
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)					2.27E-03
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)	ND				ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)	0.0034				0.0044
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)	0.0103			2.810E-08	0.0662
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)					8.50E-04
Total PCB Congeners (less dioxin-like)	2.780893			1.080E-05	3.343865
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)	ND				2.46E-06
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)	1.8E-06				6.40E-05
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	ND	0.0114			0.0059
4,4'-DDD	ND	ND			0.0178
4,4'-DDE	0.023	0.164			ND
4,4'-DDT	ND	ND			0.05
Inorganics					
Arsenic	ND	ND			4.65
Lead	ND	ND	1.450E-03	1.170E-04	172
Mercury (total)	0.107	ND	2.240E-03	ND	0.955
Mercury (inorganic)					
Mercury (organic)					

Table 5-32 Average Measured Concentrations for the Appleton to Little Rapids Reach

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	3.98	0.515	ND	4.840E-06	1.398
Aroclor 1016	ND		ND	ND	ND
Aroclor 1221	ND		ND	ND	ND
Aroclor 1232	ND		ND	ND	ND
Aroclor 1242	0.315		ND	7.210E-06	4.7
Aroclor 1248	ND		ND	ND	ND
Aroclor 1254	0.34		ND	ND	0.340
Aroclor 1260	0.102		ND	ND	0.572
Total PCB Aroclors (less 1016/1254)	3.64	0.515	0	4.840E-06	1.058
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)				1.250E-07	0.00646
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)					0.0152
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)					3.50E-04
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)				8.080E-08	0.0542
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)				0.000000032	ND
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)					5.20E-04
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)					1.50E-03
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)					1.19E-04
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)				ND	2.10E-03
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)					ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)				ND	0.0061
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)				4.760E-08	0.0157
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)					1.30E-04
Total PCB Congeners (less dioxin-like)				4.555E-06	1.295621
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)					
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)			ND		
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	ND	ND	ND		ND
4,4'-DDD	ND	ND	ND		0.0017
4,4'-DDE	0.0284	0.0807	ND		ND
4,4'-DDT	ND	ND	ND		0.0034
Inorganics					
Arsenic			ND		4.44
Lead			1.400E-03		75.6
Mercury (total)	0.27	0.0294	6.640E-05	0.000065	0.766
Mercury (inorganic)					
Mercury (organic)					

Table 5-33 Average Measured Concentrations for the Little Rapids to De Pere Reach

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	0.615	0.838		1.130E-05	2.078
Aroclor 1016	ND			ND	ND
Aroclor 1221	ND			ND	ND
Aroclor 1232	ND			ND	ND
Aroclor 1242	0.243			1.200E-05	4.43
Aroclor 1248	0.316			ND	ND
Aroclor 1254	0.289			ND	0.421
Aroclor 1260	0.128			ND	0.164
Total PCB Aroclors (less 1016/1254)	0.326	0.838		1.130E-05	1.657
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)				1.470E-07	0.0147
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)					0.0108
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)					2.80E-03
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)				5.540E-08	0.0334
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)					0.00261
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)					6.27E-04
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)					2.57E-03
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)					1.55E-03
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)					1.85E-03
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)					ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)					0.0055
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)				3.020E-08	0.0129
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)					7.40E-04
Total PCB Congeners (less dioxin-like)				1.107E-05	1.987973
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)					5.26E-06
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)					8.14E-05
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	ND				ND
4,4'-DDD	0.00494				0.0028
4,4'-DDE	0.0426				0.0125
4,4'-DDT	ND				0.0165
Inorganics					
Arsenic					4.6
Lead			6.170E-04	1.210E-04	159
Mercury (total)	0.235		3.880E-03	0.00127	3.5
Mercury (inorganic)					
Mercury (organic)					

Table 5-34 Average Measured Concentrations for the De Pere to Green Bay Reach

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	2.44	0.225		1.660E-05	2.959
Aroclor 1016	ND		ND	ND	ND
Aroclor 1221	ND		ND	ND	ND
Aroclor 1232	ND		ND	ND	ND
Aroclor 1242	0.631		ND	1.220E-05	4.39
Aroclor 1248	0.285		ND	ND	ND
Aroclor 1254	0.743		ND	ND	0.356
Aroclor 1260	0.226		ND	ND	0.331
Total PCB Aroclors (less 1016/1254)	1.697	0.225	0	1.660E-05	2.603
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)	0.000511			1.610E-07	0.013
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)	0.0115				0.00565
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)	0.000799			1.60E-08	1.38E-03
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)	0.0314			4.940E-08	0.0127
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)	0.000742			3.22E-08	0.000409
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)	0.000154				2.38E-04
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)	0.00241			6.1E-09	1.03E-03
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)	5.83E-04			8.18E-10	8.00E-05
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)	0.00104			2.0E-09	8.50E-04
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)	0.000194				ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)	0.00766			1.25E-08	0.0016
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)	0.0158			1.610E-07	0.00391
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)	0.000139			8.31E-10	2.60E-04
Total PCB Congeners (less dioxin-like)	2.367068			1.616E-05	2.917893
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)	0.0000016		ND		
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)	1.5E-05		ND		
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	0.0102	ND	ND		ND
4,4'-DDD	0.0167	ND	ND	4.74E-08	0.0045
4,4'-DDE	0.0791	0.0421	ND	4.07E-08	0.0019
4,4'-DDT	ND	ND	ND		ND
Inorganics					
Arsenic	ND	ND	0.0015		10.1
Lead	ND	ND	3.110E-03		75.7
Mercury (total)	0.237	0.05	2.750E-05	0.00000487	1.03
Mercury (inorganic)					
Mercury (organic)					

Table 5-35 Average Measured Concentrations for Green Bay

Chemical of Potential Concern	Concentration in Fish (mg/kg)	Concentration in Waterfowl (mg/kg)	Total Concentration in Water (mg/L)	Dissolved Concentration in Water (mg/L)	Concentration in Sediment (mg/kg)
PCBs					
Total PCBs	2.11	0.328		2.180E-06	0.212
Aroclor 1016	ND				ND
Aroclor 1221	ND				ND
Aroclor 1232	ND				ND
Aroclor 1242	0.0341				0.164
Aroclor 1248	0.48				ND
Aroclor 1254	0.904				ND
Aroclor 1260	0.0327				ND
Total PCB Aroclors (less 1016/1254)	1.206	0.328			0.212
3,3',4,4'-Tetrachlorobiphenyl (PCB-77)				3.620E-08	0.00182
2,3,3',4,4'-Pentachlorobiphenyl (PCB-105)					0.00118
2,3,4,4',5-Pentachlorobiphenyl (PCB-114)				4.21E-09	1.01E-04
2,3',4,4',5-Pentachlorobiphenyl (PCB-118)				1.150E-08	0.00709
2',3,4,4',5-Pentachlorobiphenyl (PCB-123)					ND
3,3',4,4',5-Pentachlorobiphenyl (PCB-126)					4.13E-05
2,3,3',4,4',5-Hexachlorobiphenyl (PCB-156)				2.1E-09	1.17E-04
2,3,3',4,4',5'-Hexachlorobiphenyl (PCB-157)				7.41E-10	4.72E-05
2,3',4,4',5,5'-Hexachlorobiphenyl (PCB-167)				9.4E-10	2.79E-04
3,3',4,4',5,5'-Hexachlorobiphenyl (PCB-169)					ND
2,2',3,3',4,4',5-Heptachlorobiphenyl (PCB-170)				5.75E-09	0.0003
2,2',3,4,4',5,5'-Heptachlorobiphenyl (PCB-180)				8.970E-09	0.00187
2,3,3',4,4',5,5'-Heptachlorobiphenyl (PCB-189)				3.31E-10	7.26E-05
Total PCB Congeners (less dioxin-like)				2.109E-06	0.1990959
Chlorinated Dioxins					
2,3,7,8-Tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD)	0.00000372				
1,2,3,7,8-Pentachlorodibenzo-p-dioxin (1,2,3,7,8-PCDD)					
1,2,3,4,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,4,7,8-HxCDD)					
1,2,3,6,7,8-Hexachlorodibenzo-p-dioxin (1,2,3,6,7,8-HxCDD)					
1,2,3,7,8,9-Hexachlorodibenzo-p-dioxin (1,2,3,7,8,9-HxCDD)					
1,2,3,4,6,7,8-Heptachlorodibenzo-p-dioxin (1,2,3,4,6,7,8-HpCDD)					
Octachlorodibenzo-p-dioxin (OCDD)					
Chlorinated Furans					
2,3,7,8-Tetrachlorodibenzofuran (2,3,7,8-TCDF)	1.7E-05				
1,2,3,7,8-Pentachlorodibenzofuran (1,2,3,7,8-PCDF)					
2,3,4,7,8-Pentachlorodibenzofuran (2,3,4,7,8-PCDF)					
1,2,3,4,7,8-Hexachlorodibenzofuran (1,2,3,4,7,8-HxCDF)					
1,2,3,6,7,8-Hexachlorodibenzofuran (1,2,3,6,7,8-HxCDF)					
1,2,3,7,8,9-Hexachlorodibenzofuran (1,2,3,7,8,9-HxCDF)					
2,3,4,6,7,8-Hexachlorodibenzofuran (2,3,4,6,7,8-HxCDF)					
1,2,3,4,6,7,8-Heptachlorodibenzofuran (1,2,3,4,6,7,8-HpCDF)					
1,2,3,4,7,8,9-Heptachlorodibenzofuran (1,2,3,4,7,8,9-HpCDF)					
Octachlorodibenzofuran (OCDF)					
Organochlorine Pesticides					
Dieldrin	0.0447	0.0125			ND
4,4'-DDD	0.0283	0.00933			ND
4,4'-DDE	0.301	0.0934			ND
4,4'-DDT	0.0215	ND			ND
Inorganics					
Arsenic		ND			3.81
Lead		ND	1.690E-04	4.410E-05	16.8
Mercury (total)	0.222	0.0895	1.900E-04	0.000131	0.29
Mercury (inorganic)					
Mercury (organic)					

Table 5-36 Cancer Evidence for Exposure to Commercial PCB Mixtures

Type of Study	Result	Mixture Composition
Lifetime Dietary Exposure	liver tumors in rats (Kimbrough *et al.*, 1975; Norback and Weltman, 1985; Schaeffer *et al.*, 1984)	60% chlorine
	promotion of benign tumors to malignant tumors (Norback and Weltman, 1985)	60% chlorine
	gastrointestinal tumors (NCI, 1978; Morgan *et al.*, 1981; Ward, 1985)	54% chlorine
Less-than-lifetime Dietary Exposure	precancerous liver lesions (Kimbrough and Linder, 1974; Ito *et al.*, 1973, 1974; Rao and Banerji, 1988)	42%–60% chlorine
Epidemiological	capacitor manufacturing workers had increased mortality from malignant melanoma and liver, gall bladder, gastrointestinal tract, and biliary tract cancer (Brown, 1987; Sinks *et al.*, 1992; Gustavsson *et al.*, 1986)	41%–54% chlorine
	petrochemical refinery workers had increased mortality from malignant melanoma (Bahn *et al.*, 1976)	54% chlorine
	electric utility workers had increased mortality from malignant melanoma and brain cancer (Loomis, *et al.*, 1997)	PCBs
Case-control	non-Hodgkin lymphoma (Hardell *et al.*, 1996; Rotham *et al.*, 1997)	PCBs in adipose tissue and serum
	mortality from liver and lung cancer in general population following consumption of PCB- and dibenzofuran-contaminated rice oil (Masuda, 1994)	heated PCBs above 270 ˚C

Table 5-37 PCB Cancer Slope Factors by Persistence and Route of Exposure

PCB Mixture Characteristic	Ingestion of Fish/Waterfowl	Ingestion of Sediment	Dermal Contact with Sediment	Ingestion of Water	Dermal Contact with Water	Inhalation of Volatilized Compounds
Highest Risk and Persistence						
Central Tendency Slope	1	1	1	0.3	0.3	0.3
Upper-bound Slope	2	2	2	0.4	0.4	0.4
Lowest Risk and Persistence						
Central Tendency Slope	0.04	0.04	0.04	0.04	0.04	0.04
Upper-bound Slope	0.07	0.07	0.07	0.07	0.07	0.07

Note:

All values have units of $(mg/kg\text{-}day)^{-1}$.

Table 5-38 Toxicity Equivalency Factors for Dioxin-like PCBs

PCBs	U.S. EPA TEF Value (a)	WHO TEF Value (b)
Non-ortho Congeners		
3,3',4,4'-TeCB (PCB 77)	0.0005	0.0001
3,4,4',5-TeCB (PCB 81)	NA	0.0001
3,3',4,4',5-PeCB (PCB 126)	0.1	0.1
3,3',4,4',5,5'-HxCB (PCB 169)	0.01	0.01
Mono-ortho Congeners		
2,3,3',4,4'-PeCB (PCB 105)	0.0001	0.0001
2,3,4,4',5-PeCB (PCB 114)	0.0005	0.0005
2,3',4,4',5-PeCB (PCB 118)	0.0001	0.0001
2',3,4,4',5-PeCB (PCB 123)	0.0001	0.0001
2,3,3',4,4',5-HxCB (PCB 156)	0.0005	0.0005
2,3,3',4,4',5'-HxCB (PCB 157)	0.0005	0.0005
2,3',4,4',5,5'-HxCB (PCB 167)	0.00001	0.00001
2,3,3',4,4',5,5'-HpCB (PCB 189)	0.0001	0.0001
Di-ortho Congeners		
2,2',3,3',4,4',5-HpCB (PCB 170)	0.0001	NA
2,2',3,4,4',5,5'-HpCB (PCB 180)	0.00001	NA

Note:

NA indicates a TEF is not available.

Sources:

a. EPA, 1996a.

b. WHO, 1997.

Table 5-39 Summary of Dioxin and Furan Toxicity Equivalency Factors

Congeners	U.S. EPA TEF Value (a)	WHO TEF Value (b)
Dioxins		
2,3,7,8-TCDD	1	1
2,3,7,8-PCDD	0.5	1
2,3,7,8-HxCDD	0.1	0.1
2,3,7,8,-HpCDD	0.01	0.01
OCDD	0.001	0.0001
Furans		
2,3,7,8-TCDF	0.1	0.1
1,2,3,7,8-PCDF	0.05	0.05
2,3,4,7,8-PCDF	0.5	0.5
2,3,7,8-HxCDF	0.1	0.1
2,3,7,8-HpCDF	0.01	0.01
OCDF	0.001	0.0001

Sources:

a. EPA, 1989.
b. WHO, 1997.

Table 5-40 Summary of Cancer Slope Factors by Route of Exposure

Chemical of Potential Concern	Oral Soil/Sed CSFslo (mg/kg-day)$^{-1}$	Oral Water CSFwo (mg/kg-day)$^{-1}$	Oral Fish/Food CSFfo (mg/kg-day)$^{-1}$	Dermal Soil/Sed CSFsld (mg/kg-day)$^{-1}$	Dermal Water CSFwd (mg/kg-day)$^{-1}$	Inhalation Vapor CSFavi (mg/kg-day)$^{-1}$	Inhalation Particulate CSFapi (mg/kg-day)$^{-1}$
PCBs							
Total PCBs	2.00E+00	4.00E-01	2.00E+00	2.00E+00	4.00E-01	4.00E-01	2.00E+00
Aroclor 1016	7.00E-02	7.00E-02	7.00E-02	7.00E-02	7.00E-02	7.00E-02	7.00E-02
Aroclor 1221	2.00E+00	4.00E-01	2.00E+00	2.00E+00	4.00E-01	4.00E-01	2.00E+00
Aroclor 1232	2.00E+00	4.00E-01	2.00E+00	2.00E+00	4.00E-01	4.00E-01	2.00E+00
Aroclor 1242	2.00E+00	4.00E-01	2.00E+00	2.00E+00	4.00E-01	4.00E-01	2.00E+00
Aroclor 1248	2.00E+00	4.00E-01	2.00E+00	2.00E+00	4.00E-01	4.00E-01	2.00E+00
Aroclor 1254	2.00E+00	4.00E-01	2.00E+00	2.00E+00	4.00E-01	4.00E-01	2.00E+00
Aroclor 1260	2.00E+00	4.00E-01	2.00E+00	2.00E+00	4.00E-01	4.00E-01	2.00E+00
3,3',4,4'-TeCB (PCB-77)	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01
2,3,3',4,4'-PeCB (PCB-105)	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01
2,3,4,4',5-PeCB (PCB-114)	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01
2,3',4,4',5-PeCB (PCB-118)	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01
2',3,4,4',5-PeCB (PCB-123)	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01
3,3',4,4',5-PeCB (PCB-126)	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
2,3,3',4,4',5-HxCB (PCB-156)	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01
2,3,3',4,4',5'-HxCB (PCB-157)	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01	7.50E+01
2,3',4,4',5,5'-HxCB (PCB-167)	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.50E+00
3,3',4,4',5,5'-HxCB (PCB-169)	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03
2,2',3,3',4,4',5-HpCB (PCB-170)	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01
2,2',3,4,4',5,5'-HpCB (PCB-180)	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.50E+00	1.50E+00
2,3,3',4,4',5,5'-HpCB (PCB-189)	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01	1.50E+01
Chlorinated Dioxins							
2,3,7,8-TCDD	1.50E+05	1.50E+05	1.50E+05	1.50E+05	1.50E+05	1.50E+05	1.50E+05
1,2,3,7,8-PCDD	7.50E+04	7.50E+04	7.50E+04	7.50E+04	7.50E+04	7.50E+04	7.50E+04
1,2,3,4,7,8-HxCDD	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
1,2,3,6,7,8-HxCDD	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
1,2,3,7,8,9-HxCDD	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
1,2,3,4,6,7,8-HpCDD	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03
OCDD	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02
Chlorinated Furans							
2,3,7,8-TCDF	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
1,2,3,7,8-PCDF	7.50E+03	7.50E+03	7.50E+03	7.50E+03	7.50E+03	7.50E+03	7.50E+03
2,3,4,7,8-PCDF	7.50E+04	7.50E+04	7.50E+04	7.50E+04	7.50E+04	7.50E+04	7.50E+04
1,2,3,4,7,8-HxCDF	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
1,2,3,6,7,8-HxCDF	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
1,2,3,7,8,9-HxCDF	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
2,3,4,6,7,8-HxCDF	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04	1.50E+04
1,2,3,4,6,7,8-HpCDF	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03
1,2,3,4,7,8,9-HpCDF	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03	1.50E+03
OCDF	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02	1.50E+02
Organochlorine Pesticides							
Dieldrin	1.60E+01	1.60E+01	1.60E+01	1.60E+01	1.60E+01	1.61E+01	1.61E+01
4,4'-DDD	2.40E-01	2.40E-01	2.40E-01	2.40E-01	2.40E-01	NA	NA
4,4'-DDE	3.40E-01	3.40E-01	3.40E-01	3.40E-01	3.40E-01	NA	NA
4,4'-DDT	3.40E-01	3.40E-01	3.40E-01	3.40E-01	3.40E-01	3.40E-01	3.40E-01
Inorganics							
Arsenic	1.50E+00	1.50E+00	1.50E+00	1.58E+00	1.58E+00	1.51E+01	1.51E+01
Lead	NA	NA	NA	NA	NA	NA	NA
Mercury (total)	NA	NA	NA	NA	NA	NA	NA
Mercury (inorganic)	NA	NA	NA	NA	NA	NA	NA
Mercury (organic)	NA	NA	NA	NA	NA	NA	NA

Table 5-41 Summary of Reference Doses by Route of Exposure

Chemical of Potential Concern	Oral Soil/Sed RfDcslo (mg/kg-day)	Oral Water RfDcwo (mg/kg-day)	Oral Fish/Food RfDcfo (mg/kg-day)	Dermal Soil/Sed RfDcsd (mg/kg-day)	Dermal Water RfDcwd (mg/kg-day)	Inhalation Vapor RfDcavi (mg/kg-day)	Inhalation Particulate RfDcapi (mg/kg-day)
PCBs							
Total PCBs	2.00E-05	2.00E-05	2.00E-05	1.80E-05	1.80E-05	NA	NA
Aroclor 1016	7.00E-05	7.00E-05	7.00E-05	7.00E-05	7.00E-05	NA	NA
Aroclor 1221	2.00E-05	2.00E-05	2.00E-05	1.80E-05	1.80E-05	NA	NA
Aroclor 1232	2.00E-05	2.00E-05	2.00E-05	1.80E-05	1.80E-05	NA	NA
Aroclor 1242	2.00E-05	2.00E-05	2.00E-05	1.80E-05	1.80E-05	NA	NA
Aroclor 1248	2.00E-05	2.00E-05	2.00E-05	1.80E-05	1.80E-05	NA	NA
Aroclor 1254	2.00E-05	2.00E-05	2.00E-05	1.80E-05	1.80E-05	NA	NA
Aroclor 1260	2.00E-05	2.00E-05	2.00E-05	1.80E-05	1.80E-05	NA	NA
3,3',4,4'-TeCB (PCB-77)	NA	NA	NA	NA	NA	NA	NA
2,3,3',4,4'-PeCB (PCB-105)	NA	NA	NA	NA	NA	NA	NA
2,3,4,4',5-PeCB (PCB-114)	NA	NA	NA	NA	NA	NA	NA
2,3',4,4',5-PeCB (PCB-118)	NA	NA	NA	NA	NA	NA	NA
2',3,4,4',5-PeCB (PCB-123)	NA	NA	NA	NA	NA	NA	NA
3,3',4,4',5-PeCB (PCB-126)	NA	NA	NA	NA	NA	NA	NA
2,3,3',4,4',5-HxCB (PCB-156)	NA	NA	NA	NA	NA	NA	NA
2,3,3',4,4',5'-HxCB (PCB-157)	NA	NA	NA	NA	NA	NA	NA
2,3',4,4',5,5'-HxCB (PCB-167)	NA	NA	NA	NA	NA	NA	NA
3,3',4,4',5,5'-HxCB (PCB-169)	NA	NA	NA	NA	NA	NA	NA
2,2',3,3',4,4',5-HpCB (PCB-170)	NA	NA	NA	NA	NA	NA	NA
2,2',3,4,4',5,5'-HpCB (PCB-180)	NA	NA	NA	NA	NA	NA	NA
2,3,3',4,4',5,5'-HpCB (PCB-189)	NA	NA	NA	NA	NA	NA	NA
Chlorinated Dioxins							
2,3,7,8-TCDD	1.00E-09	1.00E-09	1.00E-09	1.00E-09	1.00E-09	NA	NA
1,2,3,7,8-PCDD	NA	NA	NA	NA	NA	NA	NA
1,2,3,4,7,8-HxCDD	NA	NA	NA	NA	NA	NA	NA
1,2,3,6,7,8-HxCDD	NA	NA	NA	NA	NA	NA	NA
1,2,3,7,8,9-HxCDD	NA	NA	NA	NA	NA	NA	NA
1,2,3,4,6,7,8-HpCDD	NA	NA	NA	NA	NA	NA	NA
OCDD	NA	NA	NA	NA	NA	NA	NA
Chlorinated Furans							
2,3,7,8-TCDF	NA	NA	NA	NA	NA	NA	NA
1,2,3,7,8-PCDF	NA	NA	NA	NA	NA	NA	NA
2,3,4,7,8-PCDF	NA	NA	NA	NA	NA	NA	NA
1,2,3,4,7,8-HxCDF	NA	NA	NA	NA	NA	NA	NA
1,2,3,6,7,8-HxCDF	NA	NA	NA	NA	NA	NA	NA
1,2,3,7,8,9-HxCDF	NA	NA	NA	NA	NA	NA	NA
2,3,4,6,7,8-HxCDF	NA	NA	NA	NA	NA	NA	NA
1,2,3,4,6,7,8-HpCDF	NA	NA	NA	NA	NA	NA	NA
1,2,3,4,7,8,9-HpCDF	NA	NA	NA	NA	NA	NA	NA
OCDF	NA	NA	NA	NA	NA	NA	NA
Organochlorine Pesticides							
Dieldrin	5.00E-05	5.00E-05	5.00E-05	5.00E-05	5.00E-05	NA	NA
4,4'-DDD	NA	NA	NA	NA	NA	NA	NA
4,4'-DDE	NA	NA	NA	NA	NA	NA	NA
4,4'-DDT	5.00E-04	5.00E-04	5.00E-04	5.00E-04	5.00E-04	NA	NA
Inorganics							
Arsenic	3.00E-04	3.00E-04	3.00E-04	2.85E-04	2.85E-04	NA	NA
Lead	NA	NA	NA	NA	NA	NA	NA
Mercury (total)	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	8.60E-05	8.60E-05
Mercury (inorganic)	3.00E-04	3.00E-04	3.00E-04	3.00E-04	3.00E-04	8.60E-05	8.60E-05
Mercury (organic)	1.00E-04	1.00E-04	1.00E-04	1.00E-04	1.00E-04	NA	NA

Table 5-42 Total Cancer Risks for the Recreational Angler (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	2.0E-03	2.8E-03	4.1E-04	1.5E-03	1.4E-03
Total Dioxins/Furans	7.4E-06	0.0E+00	0.0E+00	2.9E-04	3.0E-04
Total Pesticides	7.2E-06	6.5E-06	7.6E-06	7.1E-05	3.3E-04
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	1.1E-07	0.0E+00
Total	**2.0E-03**	**2.8E-03**	**4.2E-04**	**1.9E-03**	**2.0E-03**
Risks by Pathway					
Ingestion of Fish	2.0E-03	2.8E-03	4.2E-04	1.9E-03	2.0E-03
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	3.2E-09	2.0E-09	2.6E-09	1.1E-07	5.1E-10
Inhalation of Indoor and Outdoor Air	1.7E-08	9.5E-09	1.2E-08	1.8E-08	5.3E-09
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**2.0E-03**	**2.8E-03**	**4.2E-04**	**1.9E-03**	**2.0E-03**
Percent of Total for Chemical Group					
Total PCBs	99.27%	99.76%	98.18%	80.65%	68.57%
Total Dioxins/Furans	0.37%	0.00%	0.00%	15.56%	14.96%
Total Pesticides	0.36%	0.24%	1.82%	3.78%	16.47%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.01%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	100.00%	100.00%	100.00%	99.99%	100.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.01%	0.00%
Inhalation of Indoor and Outdoor Air	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	2.0E-03	2.8E-03	4.1E-04	1.5E-03	1.4E-03
Total PCBs using Aroclor Data	1.5E-03	6.7E-04	1.1E-03	1.3E-03	1.7E-03
Total PCBs using Congener Data	4.5E-04	3.6E-08	2.7E-08	6.0E-03	1.8E-08
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	75.0%	24.2%	257.9%	84.7%	123.4%
Total PCBs using Congener Data	23.0%	0.0%	0.0%	398.5%	0.0%

Table 5-43 Total Hazard Indices for the Recreational Angler (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	73.936	103.949	15.428	56.700	51.563
Total Dioxins/Furans	0.000	0.000	0.000	0.657	1.561
Total Pesticides	0.000	0.000	0.000	0.109	0.518
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	2.300	3.134	2.464	2.350	2.239
Total	**76.236**	**107.083**	**17.893**	**59.817**	**55.881**
Hazard Indices by Pathway					
Ingestion of Fish	75.907	107.079	17.786	59.816	55.861
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.006	0.000	0.006	0.001	0.000
Inhalation of Indoor and Outdoor Air	0.323	0.004	0.101	0.000	0.020
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**76.236**	**107.083**	**17.893**	**59.817**	**55.881**
Percent of Total for Chemical Group					
Total PCBs	96.98%	97.07%	86.23%	94.79%	92.27%
Total Dioxins/Furans	0.00%	0.00%	0.00%	1.10%	2.79%
Total Pesticides	0.00%	0.00%	0.00%	0.18%	0.93%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	3.02%	2.93%	13.77%	3.93%	4.01%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	99.57%	100.00%	99.40%	100.00%	99.96%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.01%	0.00%	0.03%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	0.42%	0.00%	0.56%	0.00%	0.04%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	73.936	103.949	15.428	56.700	51.563
Total PCBs using Aroclor Data	55.467	25.104	39.792	48.051	63.604
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	75.0%	24.2%	257.9%	84.7%	123.4%

Table 5-44 Total Cancer Risks for the Recreational Angler (RME with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	1.5E-03	2.2E-03	3.4E-04	1.3E-03	1.3E-03
Total Dioxins/Furans	7.4E-06	0.0E+00	0.0E+00	1.3E-04	2.2E-04
Total Pesticides	2.1E-06	2.6E-06	4.3E-06	5.3E-05	2.3E-04
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	1.1E-07	0.0E+00
Total	**1.6E-03**	**2.2E-03**	**3.4E-04**	**1.5E-03**	**1.8E-03**
Risks by Pathway					
Ingestion of Fish	1.6E-03	2.2E-03	3.4E-04	1.5E-03	1.8E-03
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	2.3E-09	1.0E-09	2.4E-09	1.2E-07	4.6E-10
Inhalation of Indoor and Outdoor Air	1.3E-08	4.9E-09	1.1E-08	3.2E-08	4.8E-09
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**1.6E-03**	**2.2E-03**	**3.4E-04**	**1.5E-03**	**1.8E-03**
Percent of Total for Chemical Group					
Total PCBs	99.39%	99.88%	98.74%	88.07%	74.47%
Total Dioxins/Furans	0.47%	0.00%	0.00%	8.42%	12.68%
Total Pesticides	0.14%	0.12%	1.26%	3.50%	12.85%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.01%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	100.00%	100.00%	100.00%	99.99%	100.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.01%	0.00%
Inhalation of Indoor and Outdoor Air	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	1.5E-03	2.2E-03	3.4E-04	1.3E-03	1.3E-03
Total PCBs using Aroclor Data	9.1E-04	4.1E-04	5.3E-04	1.0E-03	1.0E-03
Total PCBs using Congener Data	2.2E-04	2.4E-08	2.4E-08	1.0E-03	1.8E-08
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	59.0%	19.0%	158.7%	77.3%	79.1%
Total PCBs using Congener Data	14.1%	0.0%	0.0%	76.2%	0.0%

Table 5-45 Total Hazard Indices for the Recreational Angler (RME with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	58.076	81.659	12.635	50.127	49.057
Total Dioxins/Furans	0.000	0.000	0.000	0.657	1.528
Total Pesticides	0.000	0.000	0.000	0.084	0.402
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	0.982	2.224	1.985	1.948	2.165
Total	**59.058**	**83.883**	**14.619**	**52.816**	**53.152**
Hazard Indices by Pathway					
Ingestion of Fish	58.955	83.880	14.565	52.814	53.140
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.002	0.000	0.003	0.002	0.000
Inhalation of Indoor and Outdoor Air	0.101	0.003	0.051	0.000	0.012
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**59.058**	**83.883**	**14.619**	**52.816**	**53.152**
Percent of Total for Chemical Group					
Total PCBs	98.34%	97.35%	86.42%	94.91%	92.30%
Total Dioxins/Furans	0.00%	0.00%	0.00%	1.24%	2.88%
Total Pesticides	0.00%	0.00%	0.00%	0.16%	0.76%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	1.66%	2.65%	13.58%	3.69%	4.07%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	99.83%	100.00%	99.63%	100.00%	99.98%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.02%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	0.17%	0.00%	0.35%	0.00%	0.02%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	58.076	81.659	12.635	50.127	49.057
Total PCBs using Aroclor Data	34.287	15.551	20.050	38.724	38.786
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	59.0%	19.0%	158.7%	77.3%	79.1%

Table 5-46 Total Cancer Risks for the Recreational Angler (CTE with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	2.4E-04	3.3E-04	5.1E-05	2.0E-04	2.0E-04
Total Dioxins/Furans	1.1E-06	0.0E+00	0.0E+00	1.9E-05	3.4E-05
Total Pesticides	3.3E-07	4.0E-07	6.5E-07	8.1E-06	3.4E-05
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	1.7E-08	0.0E+00
Total	**2.4E-04**	**3.3E-04**	**5.2E-05**	**2.3E-04**	**2.7E-04**
Risks by Pathway					
Ingestion of Fish	2.4E-04	3.3E-04	5.2E-05	2.3E-04	2.7E-04
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	3.0E-10	1.3E-10	3.1E-10	1.8E-08	6.0E-11
Inhalation of Indoor and Outdoor Air	1.9E-09	7.5E-10	1.7E-09	4.8E-09	7.3E-10
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**2.4E-04**	**3.3E-04**	**5.2E-05**	**2.3E-04**	**2.7E-04**
Percent of Total for Chemical Group					
Total PCBs	99.39%	99.88%	98.74%	88.07%	74.47%
Total Dioxins/Furans	0.47%	0.00%	0.00%	8.42%	12.68%
Total Pesticides	0.14%	0.12%	1.26%	3.50%	12.85%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.01%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	100.00%	100.00%	100.00%	99.99%	100.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.01%	0.00%
Inhalation of Indoor and Outdoor Air	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	2.4E-04	3.3E-04	5.1E-05	2.0E-04	2.0E-04
Total PCBs using Aroclor Data	1.4E-04	6.3E-05	8.2E-05	1.6E-04	1.6E-04
Total PCBs using Congener Data	3.3E-05	3.5E-09	3.6E-09	1.6E-04	2.7E-09
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	59.0%	19.0%	158.7%	77.3%	79.1%
Total PCBs using Congener Data	14.1%	0.0%	0.0%	76.2%	0.0%

Table 5-47 Total Hazard Indices for the Recreational Angler (CTE with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	14.765	20.761	3.212	12.744	12.472
Total Dioxins/Furans	0.000	0.000	0.000	0.167	0.389
Total Pesticides	0.000	0.000	0.000	0.021	0.102
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	0.250	0.565	0.505	0.495	0.550
Total	**15.015**	**21.326**	**3.717**	**13.428**	**13.513**
Hazard Indices by Pathway					
Ingestion of Fish	14.989	21.325	3.703	13.427	13.510
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.001	0.000	0.001	0.000	0.000
Inhalation of Indoor and Outdoor Air	0.026	0.001	0.013	0.000	0.003
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**15.015**	**21.326**	**3.717**	**13.428**	**13.513**
Percent of Total for Chemical Group					
Total PCBs	98.34%	97.35%	86.43%	94.91%	92.30%
Total Dioxins/Furans	0.00%	0.00%	0.00%	1.24%	2.88%
Total Pesticides	0.00%	0.00%	0.00%	0.16%	0.76%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	1.66%	2.65%	13.57%	3.69%	4.07%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	99.83%	100.00%	99.63%	100.00%	99.98%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.02%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	0.17%	0.00%	0.35%	0.00%	0.02%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	14.765	20.761	3.212	12.744	12.472
Total PCBs using Aroclor Data	8.717	3.954	5.098	9.845	9.861
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	59.0%	19.0%	158.7%	77.3%	79.1%

Table 5-48 Total Cancer Risks for the High-intake Fish Consumer (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	2.7E-03	3.8E-03	5.6E-04	2.1E-03	2.0E-03
Total Dioxins/Furans	1.0E-05	0.0E+00	0.0E+00	4.0E-04	4.1E-04
Total Pesticides	9.8E-06	8.9E-06	1.1E-05	9.8E-05	4.5E-04
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	1.5E-07	0.0E+00
Total	**2.7E-03**	**3.8E-03**	**5.7E-04**	**2.6E-03**	**2.9E-03**
Risks by Pathway					
Ingestion of Fish	2.7E-03	3.8E-03	5.7E-04	2.6E-03	2.9E-03
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	4.4E-09	2.7E-09	3.7E-09	1.6E-07	7.1E-10
Inhalation of Indoor and Outdoor Air	1.6E-08	8.6E-09	1.2E-08	3.3E-08	4.9E-09
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**2.7E-03**	**3.8E-03**	**5.7E-04**	**2.6E-03**	**2.9E-03**
Percent of Total for Chemical Group					
Total PCBs	99.27%	99.77%	98.17%	80.64%	70.34%
Total Dioxins/Furans	0.37%	0.00%	0.00%	15.55%	14.14%
Total Pesticides	0.36%	0.23%	1.83%	3.80%	15.52%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.01%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	100.00%	100.00%	100.00%	99.99%	100.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.01%	0.00%
Inhalation of Indoor and Outdoor Air	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	2.7E-03	3.8E-03	5.6E-04	2.1E-03	2.0E-03
Total PCBs using Aroclor Data	2.0E-03	9.2E-04	1.5E-03	1.8E-03	5.1E-03
Total PCBs using Congener Data	6.2E-04	3.7E-08	2.8E-08	8.3E-03	2.0E-08
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	75.0%	24.1%	258.1%	84.9%	247.4%
Total PCBs using Congener Data	23.0%	0.0%	0.0%	398.3%	0.0%

Table 5-49 Total Hazard Indices for the High-intake Fish Consumer (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	101.316	142.472	21.142	77.727	76.683
Total Dioxins/Furans	0.000	0.000	0.000	0.901	2.139
Total Pesticides	0.000	0.000	0.000	0.151	0.816
Arsenic	0.000	0.000	0.000	0.001	0.000
Mercury	3.004	4.294	3.331	3.222	6.997
Total	**104.320**	**146.766**	**24.473**	**82.001**	**86.635**
Hazard Indices by Pathway					
Ingestion of Fish	104.017	146.762	24.373	81.997	86.616
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.008	0.001	0.008	0.003	0.001
Inhalation of Indoor and Outdoor Air	0.295	0.003	0.092	0.002	0.018
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**104.320**	**146.766**	**24.473**	**82.001**	**86.635**
Percent of Total for Chemical Group					
Total PCBs	97.12%	97.07%	86.39%	94.79%	88.51%
Total Dioxins/Furans	0.00%	0.00%	0.00%	1.10%	2.47%
Total Pesticides	0.00%	0.00%	0.00%	0.18%	0.94%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	2.88%	2.93%	13.61%	3.93%	8.08%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	99.71%	100.00%	99.59%	99.99%	99.98%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.01%	0.00%	0.03%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	0.28%	0.00%	0.38%	0.00%	0.02%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	101.316	142.472	21.142	77.727	76.683
Total PCBs using Aroclor Data	76.008	34.401	54.557	65.958	189.737
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	75.0%	24.1%	258.0%	84.9%	247.4%

Table 5-50 Total Cancer Risks for the High-intake Fish Consumer (RME with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	2.1E-03	3.0E-03	4.6E-04	1.8E-03	1.8E-03
Total Dioxins/Furans	1.0E-05	0.0E+00	0.0E+00	1.8E-04	3.1E-04
Total Pesticides	2.9E-06	3.6E-06	5.9E-06	7.3E-05	3.1E-04
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	1.5E-07	0.0E+00
Total	**2.1E-03**	**3.0E-03**	**4.7E-04**	**2.1E-03**	**2.4E-03**
Risks by Pathway					
Ingestion of Fish	2.1E-03	3.0E-03	4.7E-04	2.1E-03	2.4E-03
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	3.2E-09	1.4E-09	3.3E-09	1.6E-07	6.4E-10
Inhalation of Indoor and Outdoor Air	1.1E-08	4.5E-09	1.0E-08	2.9E-08	4.4E-09
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**2.1E-03**	**3.0E-03**	**4.7E-04**	**2.1E-03**	**2.4E-03**
Percent of Total for Chemical Group					
Total PCBs	99.39%	99.88%	98.74%	88.07%	74.47%
Total Dioxins/Furans	0.47%	0.00%	0.00%	8.42%	12.68%
Total Pesticides	0.14%	0.12%	1.26%	3.50%	12.85%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.01%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	100.00%	100.00%	100.00%	99.99%	100.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.01%	0.00%
Inhalation of Indoor and Outdoor Air	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	2.1E-03	3.0E-03	4.6E-04	1.8E-03	1.8E-03
Total PCBs using Aroclor Data	1.3E-03	5.7E-04	7.3E-04	1.4E-03	1.4E-03
Total PCBs using Congener Data	3.0E-04	2.4E-08	2.5E-08	1.4E-03	1.7E-08
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	59.0%	19.0%	158.7%	77.3%	79.1%
Total PCBs using Congener Data	14.1%	0.0%	0.0%	76.2%	0.0%

Table 5-51 Total Hazard Indices for the High-intake Fish Consumer (RME with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	79.583	111.900	17.313	68.690	67.224
Total Dioxins/Furans	0.000	0.000	0.000	0.901	2.094
Total Pesticides	0.000	0.000	0.000	0.115	0.550
Arsenic	0.000	0.000	0.000	0.001	0.000
Mercury	1.299	3.046	2.697	2.669	2.961
Total	**80.883**	**114.946**	**20.010**	**72.375**	**72.830**
Hazard Indices by Pathway					
Ingestion of Fish	80.787	114.943	19.959	72.373	72.819
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.003	0.000	0.005	0.002	0.000
Inhalation of Indoor and Outdoor Air	0.092	0.002	0.046	0.000	0.011
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**80.883**	**114.946**	**20.010**	**72.375**	**72.830**
Percent of Total for Chemical Group					
Total PCBs	98.39%	97.35%	86.52%	94.91%	92.30%
Total Dioxins/Furans	0.00%	0.00%	0.00%	1.24%	2.88%
Total Pesticides	0.00%	0.00%	0.00%	0.16%	0.76%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	1.61%	2.65%	13.48%	3.69%	4.07%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	99.88%	100.00%	99.74%	100.00%	99.99%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.02%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	0.11%	0.00%	0.23%	0.00%	0.01%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	79.583	111.900	17.313	68.690	67.224
Total PCBs using Aroclor Data	46.984	21.310	27.476	53.065	53.149
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	59.0%	19.0%	158.7%	77.3%	79.1%

Table 5-52 Total Cancer Risks for the High-intake Fish Consumer (CTE with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	3.3E-04	4.7E-04	7.2E-05	2.9E-04	2.8E-04
Total Dioxins/Furans	1.6E-06	0.0E+00	0.0E+00	2.7E-05	4.8E-05
Total Pesticides	4.6E-07	5.7E-07	9.2E-07	1.1E-05	4.9E-05
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	2.4E-08	0.0E+00
Total	**3.4E-04**	**4.7E-04**	**7.3E-05**	**3.3E-04**	**3.8E-04**
Risks by Pathway					
Ingestion of Fish	3.4E-04	4.7E-04	7.3E-05	3.3E-04	3.8E-04
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	4.3E-10	1.9E-10	4.4E-10	2.5E-08	8.4E-11
Inhalation of Indoor and Outdoor Air	1.8E-09	7.0E-10	1.6E-09	4.6E-09	6.9E-10
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**3.4E-04**	**4.7E-04**	**7.3E-05**	**3.3E-04**	**3.8E-04**
Percent of Total for Chemical Group					
Total PCBs	99.39%	99.88%	98.74%	88.07%	74.47%
Total Dioxins/Furans	0.47%	0.00%	0.00%	8.42%	12.68%
Total Pesticides	0.14%	0.12%	1.26%	3.50%	12.85%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.01%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	100.00%	100.00%	100.00%	99.99%	100.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.01%	0.00%
Inhalation of Indoor and Outdoor Air	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	3.3E-04	4.7E-04	7.2E-05	2.9E-04	2.8E-04
Total PCBs using Aroclor Data	2.0E-04	8.9E-05	1.1E-04	2.2E-04	2.2E-04
Total PCBs using Congener Data	4.7E-05	3.6E-09	3.7E-09	2.2E-04	2.6E-09
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	59.0%	19.0%	158.7%	77.3%	79.1%
Total PCBs using Congener Data	14.1%	0.0%	0.0%	76.2%	0.0%

Table 5-53 Total Hazard Indices for the High-intake Fish Consumer (CTE with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	20.814	29.266	4.528	17.965	17.582
Total Dioxins/Furans	0.000	0.000	0.000	0.236	0.548
Total Pesticides	0.000	0.000	0.000	0.030	0.144
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	0.340	0.797	0.705	0.698	0.774
Total	**21.154**	**30.063**	**5.233**	**18.929**	**19.048**
Hazard Indices by Pathway					
Ingestion of Fish	21.129	30.062	5.220	18.928	19.045
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.001	0.000	0.001	0.001	0.000
Inhalation of Indoor and Outdoor Air	0.024	0.001	0.012	0.000	0.003
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**21.154**	**30.063**	**5.233**	**18.929**	**19.048**
Percent of Total for Chemical Group					
Total PCBs	98.39%	97.35%	86.52%	94.91%	92.30%
Total Dioxins/Furans	0.00%	0.00%	0.00%	1.24%	2.88%
Total Pesticides	0.00%	0.00%	0.00%	0.16%	0.76%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	1.61%	2.65%	13.48%	3.69%	4.07%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	99.88%	100.00%	99.75%	100.00%	99.99%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.02%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	0.11%	0.00%	0.23%	0.00%	0.01%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	20.814	29.266	4.528	17.965	17.582
Total PCBs using Aroclor Data	12.288	5.573	7.186	13.878	13.900
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	59.0%	19.0%	158.7%	77.3%	79.1%

Table 5-54 Total Cancer Risks for the Hunter (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	4.4E-05	5.2E-05	8.3E-05	5.4E-05	5.1E-05
Total Dioxins/Furans	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total Pesticides	1.6E-05	1.4E-06	0.0E+00	1.2E-06	1.1E-05
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	1.4E-08	0.0E+00
Total	**6.1E-05**	**5.3E-05**	**8.3E-05**	**5.5E-05**	**6.1E-05**
Risks by Pathway					
Ingestion of Fish	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion of Waterfowl	6.1E-05	5.3E-05	8.3E-05	5.5E-05	6.1E-05
Ingestion/Dermal Contact with Water	4.1E-10	2.5E-10	3.3E-10	1.4E-08	6.5E-11
Inhalation of Indoor and Outdoor Air	2.9E-09	1.6E-09	2.1E-09	3.1E-09	9.0E-10
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**6.1E-05**	**5.3E-05**	**8.3E-05**	**5.5E-05**	**6.1E-05**
Percent of Total for Chemical Group					
Total PCBs	73.24%	97.41%	100.00%	97.83%	82.48%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	26.76%	2.59%	0.00%	2.14%	17.52%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.03%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	99.99%	100.00%	100.00%	99.97%	100.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.03%	0.00%
Inhalation of Indoor and Outdoor Air	0.00%	0.00%	0.00%	0.01%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	4.4E-05	5.2E-05	8.3E-05	5.4E-05	5.1E-05
Total PCBs using Aroclor Data	4.0E-09	1.5E-09	2.7E-09	2.7E-09	0.0E+00
Total PCBs using Congener Data	6.9E-09	5.7E-09	4.3E-09	6.3E-09	3.0E-09
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	0.0%	0.0%	0.0%	0.0%	0.0%
Total PCBs using Congener Data	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5-55 Total Hazard Indices for the Hunter (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	1.662	1.949	3.098	2.015	1.901
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.016	0.000	0.000	0.000	0.017
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	0.055	0.022	0.018	0.025	0.170
Total	**1.733**	**1.971**	**3.115**	**2.040**	**2.088**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	1.678	1.970	3.098	2.040	2.085
Ingestion/Dermal Contact with Water	0.001	0.000	0.001	0.000	0.000
Inhalation of Indoor and Outdoor Air	0.054	0.001	0.017	0.000	0.003
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**1.733**	**1.971**	**3.115**	**2.040**	**2.088**
Percent of Total for Chemical Group					
Total PCBs	95.91%	98.91%	99.43%	98.76%	91.07%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	0.91%	0.00%	0.00%	0.00%	0.81%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	3.18%	1.09%	0.57%	1.24%	8.12%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	96.82%	99.97%	99.43%	99.99%	99.84%
Ingestion/Dermal Contact with Water	0.04%	0.00%	0.02%	0.01%	0.00%
Inhalation of Indoor and Outdoor Air	3.14%	0.03%	0.55%	0.00%	0.16%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	1.662	1.949	3.098	2.015	1.901
Total PCBs using Aroclor Data	0.000	0.000	0.000	0.000	0.000
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5-56 Total Cancer Risks for the Hunter (RME with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	2.4E-05	3.5E-05	3.0E-05	1.5E-05	2.2E-05
Total Dioxins/Furans	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total Pesticides	8.0E-06	9.2E-07	0.0E+00	4.8E-07	7.6E-06
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	1.4E-08	0.0E+00
Total	**3.2E-05**	**3.6E-05**	**3.0E-05**	**1.6E-05**	**3.0E-05**
Risks by Pathway					
Ingestion of Fish	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion of Waterfowl	3.2E-05	3.6E-05	3.0E-05	1.6E-05	3.0E-05
Ingestion/Dermal Contact with Water	3.0E-10	1.3E-10	3.1E-10	1.5E-08	5.9E-11
Inhalation of Indoor and Outdoor Air	2.1E-09	8.3E-10	1.9E-09	5.4E-09	8.2E-10
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**3.2E-05**	**3.6E-05**	**3.0E-05**	**1.6E-05**	**3.0E-05**
Percent of Total for Chemical Group					
Total PCBs	75.16%	97.41%	100.00%	96.84%	74.38%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	24.84%	2.59%	0.00%	3.07%	25.62%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.09%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	99.99%	100.00%	99.99%	99.87%	100.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.09%	0.00%
Inhalation of Indoor and Outdoor Air	0.01%	0.00%	0.01%	0.03%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	2.4E-05	3.5E-05	3.0E-05	1.5E-05	2.2E-05
Total PCBs using Aroclor Data	2.9E-09	1.4E-09	2.2E-09	2.4E-09	0.0E+00
Total PCBs using Congener Data	5.7E-09	3.8E-09	3.9E-09	6.0E-09	2.9E-09
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	0.0%	0.0%	0.0%	0.0%	0.0%
Total PCBs using Congener Data	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5-57 Total Hazard Indices for the Hunter (RME with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.909	1.297	1.137	0.567	0.826
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.012	0.000	0.000	0.000	0.012
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	0.017	0.015	0.009	0.025	0.002
Total	**0.938**	**1.312**	**1.146**	**0.593**	**0.840**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.921	1.312	1.137	0.592	0.838
Ingestion/Dermal Contact with Water	0.000	0.000	0.000	0.000	0.000
Inhalation of Indoor and Outdoor Air	0.017	0.000	0.009	0.000	0.002
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**0.938**	**1.312**	**1.146**	**0.593**	**0.840**
Percent of Total for Chemical Group					
Total PCBs	96.93%	98.84%	99.22%	95.74%	98.32%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	1.23%	0.00%	0.00%	0.00%	1.44%
Arsenic	0.00%	0.00%	0.00%	0.01%	0.00%
Mercury	1.84%	1.16%	0.78%	4.26%	0.24%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	98.15%	99.96%	99.21%	99.96%	99.76%
Ingestion/Dermal Contact with Water	0.03%	0.00%	0.04%	0.04%	0.00%
Inhalation of Indoor and Outdoor Air	1.82%	0.03%	0.75%	0.01%	0.23%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.909	1.297	1.137	0.567	0.826
Total PCBs using Aroclor Data	0.000	0.000	0.000	0.000	0.000
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5-58 Total Cancer Risks for the Hunter (CTE with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	7.3E-06	1.0E-05	9.1E-06	4.5E-06	6.6E-06
Total Dioxins/Furans	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total Pesticides	2.4E-06	2.8E-07	0.0E+00	1.4E-07	2.3E-06
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	4.2E-09	0.0E+00
Total	**9.7E-06**	**1.1E-05**	**9.1E-06**	**4.7E-06**	**8.9E-06**
Risks by Pathway					
Ingestion of Fish	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion of Waterfowl	9.7E-06	1.1E-05	9.1E-06	4.7E-06	8.9E-06
Ingestion/Dermal Contact with Water	7.5E-11	3.3E-11	7.8E-11	4.4E-09	1.5E-11
Inhalation of Indoor and Outdoor Air	6.4E-10	2.5E-10	5.8E-10	1.6E-09	2.4E-10
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**9.7E-06**	**1.1E-05**	**9.1E-06**	**4.7E-06**	**8.9E-06**
Percent of Total for Chemical Group					
Total PCBs	75.16%	97.41%	100.00%	96.84%	74.38%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	24.84%	2.59%	0.00%	3.07%	25.62%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.09%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	99.99%	100.00%	99.99%	99.87%	100.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.09%	0.00%
Inhalation of Indoor and Outdoor Air	0.01%	0.00%	0.01%	0.03%	0.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	7.3E-06	1.0E-05	9.1E-06	4.5E-06	6.6E-06
Total PCBs using Aroclor Data	8.8E-10	4.0E-10	6.7E-10	7.0E-10	0.0E+00
Total PCBs using Congener Data	1.7E-09	1.1E-09	1.1E-09	1.8E-09	8.7E-10
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	0.0%	0.0%	0.0%	0.0%	0.0%
Total PCBs using Congener Data	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5-59 Total Hazard Indices for the Hunter (CTE with Average Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.455	0.649	0.568	0.284	0.413
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.006	0.000	0.000	0.000	0.006
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	0.009	0.008	0.004	0.013	0.001
Total	**0.469**	**0.656**	**0.573**	**0.296**	**0.420**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.460	0.656	0.568	0.296	0.419
Ingestion/Dermal Contact with Water	0.000	0.000	0.000	0.000	0.000
Inhalation of Indoor and Outdoor Air	0.009	0.000	0.004	0.000	0.001
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**0.469**	**0.656**	**0.573**	**0.296**	**0.420**
Percent of Total for Chemical Group					
Total PCBs	96.93%	98.84%	99.22%	95.74%	98.32%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	1.23%	0.00%	0.00%	0.00%	1.44%
Arsenic	0.00%	0.00%	0.00%	0.01%	0.00%
Mercury	1.84%	1.16%	0.78%	4.26%	0.24%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	98.16%	99.96%	99.22%	99.96%	99.76%
Ingestion/Dermal Contact with Water	0.03%	0.00%	0.04%	0.03%	0.00%
Inhalation of Indoor and Outdoor Air	1.82%	0.03%	0.75%	0.01%	0.23%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.455	0.649	0.568	0.284	0.413
Total PCBs using Aroclor Data	0.000	0.000	0.000	0.000	0.000
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	0.0%	0.0%	0.0%	0.0%	0.0%

Table 5-60 Total Cancer Risks for the Drinking Water User (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	2.6E-07	1.6E-07	2.1E-07	3.1E-07	4.2E-08
Total Dioxins/Furans	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total Pesticides	0.0E+00	0.0E+00	0.0E+00	7.6E-10	0.0E+00
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	3.8E-05	0.0E+00
Total	**2.6E-07**	**1.6E-07**	**2.1E-07**	**3.8E-05**	**4.2E-08**
Risks by Pathway					
Ingestion of Fish	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	2.6E-07	1.6E-07	2.1E-07	3.8E-05	4.1E-08
Inhalation of Indoor and Outdoor Air	7.2E-09	4.4E-09	5.8E-09	8.3E-09	1.1E-09
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**2.6E-07**	**1.6E-07**	**2.1E-07**	**3.8E-05**	**4.2E-08**
Percent of Total for Chemical Group					
Total PCBs	100.00%	100.00%	100.00%	0.80%	100.00%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	0.00%	0.00%	0.00%	0.00%	0.00%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	99.19%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	97.28%	97.28%	97.28%	99.98%	97.28%
Inhalation of Indoor and Outdoor Air	2.72%	2.72%	2.72%	0.02%	2.72%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	2.6E-07	1.6E-07	2.1E-07	3.1E-07	4.2E-08
Total PCBs using Aroclor Data	2.0E-07	8.5E-08	1.5E-07	1.5E-07	0.0E+00
Total PCBs using Congener Data	7.9E-07	7.0E-07	5.4E-07	7.1E-07	1.8E-07
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	75.5%	51.9%	70.2%	48.1%	0.0%
Total PCBs using Congener Data	299.3%	426.8%	255.4%	232.9%	424.1%

Table 5-61 Total Hazard Indices for the Drinking Water User (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.086	0.053	0.069	0.099	0.014
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.000	0.000	0.000	0.000	0.000
Arsenic	0.000	0.000	0.000	0.210	0.000
Mercury	3.476	0.044	3.154	0.017	0.175
Total	**3.562**	**0.097**	**3.223**	**0.327**	**0.189**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	3.084	0.091	3.055	0.326	0.174
Inhalation of Indoor and Outdoor Air	0.478	0.006	0.169	0.001	0.015
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**3.562**	**0.097**	**3.223**	**0.327**	**0.189**
Percent of Total for Chemical Group					
Total PCBs	2.41%	54.78%	2.14%	30.42%	7.16%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	0.00%	0.00%	0.00%	0.00%	0.00%
Arsenic	0.00%	0.00%	0.00%	64.26%	0.00%
Mercury	97.59%	45.22%	97.86%	5.32%	92.84%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	86.59%	93.79%	94.77%	99.85%	91.96%
Inhalation of Indoor and Outdoor Air	13.41%	6.21%	5.23%	0.15%	8.04%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.086	0.053	0.069	0.099	0.014
Total PCBs using Aroclor Data	0.061	0.026	0.045	0.045	0.000
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	70.6%	48.5%	65.6%	44.9%	0.0%

Table 5-62 Total Hazard Indices for the Drinking Water User (RME with Upper-bound Concentrations and Recent Mercury Data)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.086	0.053	0.069	0.099	0.014
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.000	0.000	0.000	0.000	0.000
Arsenic	0.000	0.000	0.000	0.210	0.000
Mercury	0.089	0.044	0.089	0.017	0.175
Total	**0.175**	**0.097**	**0.158**	**0.327**	**0.189**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.162	0.091	0.146	0.326	0.174
Inhalation of Indoor and Outdoor Air	0.012	0.006	0.012	0.001	0.015
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**0.175**	**0.097**	**0.158**	**0.327**	**0.189**
Percent of Total for Chemical Group					
Total PCBs	49.23%	54.78%	43.81%	30.42%	7.16%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	0.00%	0.00%	0.00%	0.00%	0.00%
Arsenic	0.00%	0.00%	0.00%	64.26%	0.00%
Mercury	50.77%	45.22%	56.19%	5.32%	92.84%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	93.02%	93.79%	92.28%	99.85%	91.96%
Inhalation of Indoor and Outdoor Air	6.98%	6.21%	7.72%	0.15%	8.04%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.086	0.053	0.069	0.099	0.014
Total PCBs using Aroclor Data	0.061	0.026	0.045	0.045	0.000
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	70.6%	48.5%	65.6%	44.9%	0.0%

Table 5-63 Total Cancer Risks for the Local Resident (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	1.2E-07	6.8E-08	8.8E-08	1.3E-07	3.8E-08
Total Dioxins/Furans	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total Pesticides	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total Inorganics (Arsenic)	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**1.2E-07**	**6.8E-08**	**8.8E-08**	**1.3E-07**	**3.8E-08**
Risks by Pathway					
Ingestion of Fish	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Inhalation of Indoor and Outdoor Air	1.2E-07	6.8E-08	8.8E-08	1.3E-07	3.8E-08
Ingestion/Dermal Contact with Sediment	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Total	**1.2E-07**	**6.8E-08**	**8.8E-08**	**1.3E-07**	**3.8E-08**
Percent of Total for Chemical Group					
Total PCBs	100.00%	100.00%	100.00%	100.00%	100.00%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	0.00%	0.00%	0.00%	0.00%	0.00%
Total Inorganics (Arsenic)	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	100.00%	100.00%	100.00%	100.00%	100.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	1.2E-07	6.8E-08	8.8E-08	1.3E-07	3.8E-08
Total PCBs using Aroclor Data	1.6E-07	6.0E-08	1.1E-07	1.1E-07	0.0E+00
Total PCBs using Congener Data	2.4E-07	2.0E-07	1.5E-07	2.2E-07	1.1E-07
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	130.0%	89.3%	120.8%	82.8%	0.0%
Total PCBs using Congener Data	192.4%	291.2%	166.0%	165.7%	298.6%

Table 5-64 Total Hazard Indices for the Local Resident (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.000	0.000	0.000	0.000	0.000
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.000	0.000	0.000	0.000	0.000
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	3.823	0.043	1.194	0.004	0.237
Total	**3.823**	**0.043**	**1.194**	**0.004**	**0.237**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.000	0.000	0.000	0.000	0.000
Inhalation of Indoor and Outdoor Air	3.823	0.043	1.194	0.004	0.237
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**3.823**	**0.043**	**1.194**	**0.004**	**0.237**
Percent of Total for Chemical Group					
Total PCBs	0.00%	0.00%	0.00%	0.00%	0.00%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	0.00%	0.00%	0.00%	0.00%	0.00%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	100.00%	100.00%	100.00%	100.00%	100.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	100.00%	100.00%	100.00%	100.00%	100.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.000	0.000	0.000	0.000	0.000
Total PCBs using Aroclor Data	0.000	0.000	0.000	0.000	0.000
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	NA	NA	NA	NA	NA

Table 5-65 Total Hazard Indices for the Local Resident (RME with Upper-bound Concentrations and Recent Mercury Data)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.000	0.000	0.000	0.000	0.000
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.000	0.000	0.000	0.000	0.000
Arsenic	0.000	0.000	0.000	0.000	0.000
Mercury	0.097	0.043	0.086	0.004	0.237
Total	**0.097**	**0.043**	**0.086**	**0.004**	**0.237**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.000	0.000	0.000	0.000	0.000
Inhalation of Indoor and Outdoor Air	0.097	0.043	0.086	0.004	0.237
Ingestion/Dermal Contact with Sediment	0.000	0.000	0.000	0.000	0.000
Total	**0.097**	**0.043**	**0.086**	**0.004**	**0.237**
Percent of Total for Chemical Group					
Total PCBs	0.00%	0.00%	0.00%	0.00%	0.00%
Total Dioxins/Furans	0.00%	0.00%	0.00%	0.00%	0.00%
Total Pesticides	0.00%	0.00%	0.00%	0.00%	0.00%
Arsenic	0.00%	0.00%	0.00%	0.00%	0.00%
Mercury	100.00%	100.00%	100.00%	100.00%	100.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.00%	0.00%	0.00%	0.00%	0.00%
Inhalation of Indoor and Outdoor Air	100.00%	100.00%	100.00%	100.00%	100.00%
Ingestion/Dermal Contact with Sediment	0.00%	0.00%	0.00%	0.00%	0.00%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.000	0.000	0.000	0.000	0.000
Total PCBs using Aroclor Data	0.000	0.000	0.000	0.000	0.000
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	NA	NA	NA	NA	NA

Table 5-66 Total Cancer Risks for the Recreational Water User: Swimmer (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	1.7E-07	2.7E-08	3.9E-08	5.5E-08	6.2E-09
Total Dioxins/Furans	3.9E-09	0.0E+00	6.0E-09	0.0E+00	0.0E+00
Total Pesticides	4.4E-10	5.7E-12	5.4E-11	5.2E-11	0.0E+00
Total Inorganics (Arsenic)	4.7E-08	4.6E-08	3.7E-08	1.5E-07	4.6E-08
Total	**2.2E-07**	**7.3E-08**	**8.1E-08**	**2.0E-07**	**5.2E-08**
Risks by Pathway					
Ingestion of Fish	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	2.6E-08	1.6E-08	2.1E-08	5.7E-08	4.1E-09
Inhalation of Indoor and Outdoor Air	1.1E-09	5.8E-10	7.5E-10	1.1E-09	3.2E-10
Ingestion/Dermal Contact with Sediment	1.9E-07	5.7E-08	6.0E-08	1.5E-07	4.8E-08
Total	**2.2E-07**	**7.3E-08**	**8.1E-08**	**2.0E-07**	**5.2E-08**
Percent of Total for Chemical Group					
Total PCBs	76.52%	37.29%	47.41%	27.17%	11.85%
Total Dioxins/Furans	1.78%	0.00%	7.35%	0.00%	0.00%
Total Pesticides	0.20%	0.01%	0.07%	0.03%	0.00%
Total Inorganics (Arsenic)	21.50%	62.71%	45.17%	72.81%	88.15%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	12.05%	21.96%	25.78%	27.92%	7.88%
Inhalation of Indoor and Outdoor Air	0.49%	0.79%	0.92%	0.55%	0.62%
Ingestion/Dermal Contact with Sediment	87.46%	77.26%	73.29%	71.53%	91.50%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	1.7E-07	2.7E-08	3.9E-08	5.5E-08	6.2E-09
Total PCBs using Aroclor Data	2.6E-07	1.4E-07	2.1E-07	1.1E-07	4.9E-09
Total PCBs using Congener Data	1.2E-07	1.0E-07	1.8E-07	1.1E-07	2.8E-08
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	154.0%	517.8%	535.0%	205.6%	79.7%
Total PCBs using Congener Data	72.3%	378.5%	462.0%	191.1%	446.9%

Table 5-67 Total Hazard Indices for the Recreational Water User: Swimmer (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.024	0.007	0.010	0.014	0.002
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.000	0.000	0.000	0.000	0.000
Arsenic	0.000	0.000	0.000	0.001	0.000
Mercury	0.035	0.001	0.012	0.000	0.002
Total	**0.059**	**0.008**	**0.022**	**0.015**	**0.004**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.011	0.006	0.009	0.011	0.002
Inhalation of Indoor and Outdoor Air	0.033	0.000	0.010	0.000	0.002
Ingestion/Dermal Contact with Sediment	0.015	0.002	0.003	0.005	0.001
Total	**0.059**	**0.008**	**0.022**	**0.015**	**0.004**
Percent of Total for Chemical Group					
Total PCBs	40.41%	89.95%	45.31%	93.64%	41.51%
Total Dioxins/Furans	0.05%	0.00%	0.18%	0.00%	0.00%
Total Pesticides	0.00%	0.00%	0.00%	0.00%	0.00%
Arsenic	0.44%	3.22%	0.92%	5.33%	6.15%
Mercury	59.10%	6.83%	53.59%	1.03%	52.34%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	18.79%	70.73%	38.92%	68.90%	36.46%
Inhalation of Indoor and Outdoor Air	55.14%	4.58%	45.88%	0.21%	48.63%
Ingestion/Dermal Contact with Sediment	26.07%	24.69%	15.20%	30.89%	14.91%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.024	0.007	0.010	0.014	0.002
Total PCBs using Aroclor Data	0.045	0.033	0.053	0.029	0.001
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	189.1%	455.7%	530.2%	202.7%	75.6%

Table 5-68 Total Cancer Risks for the Recreational Water User: Wader (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	4.2E-07	2.9E-08	4.2E-08	6.0E-08	4.4E-09
Total Dioxins/Furans	9.0E-09	0.0E+00	1.4E-08	0.0E+00	0.0E+00
Total Pesticides	1.7E-09	2.3E-11	2.2E-10	2.7E-11	0.0E+00
Total Inorganics (Arsenic)	7.1E-08	7.0E-08	5.6E-08	1.9E-07	7.0E-08
Total	**5.0E-07**	**9.9E-08**	**1.1E-07**	**2.5E-07**	**7.4E-08**
Risks by Pathway					
Ingestion of Fish	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	9.4E-10	5.8E-10	7.6E-10	7.4E-09	1.5E-10
Inhalation of Indoor and Outdoor Air	9.3E-11	5.1E-11	6.6E-11	9.9E-11	2.8E-11
Ingestion/Dermal Contact with Sediment	5.0E-07	9.8E-08	1.1E-07	2.4E-07	7.4E-08
Total	**5.0E-07**	**9.9E-08**	**1.1E-07**	**2.5E-07**	**7.4E-08**
Percent of Total for Chemical Group					
Total PCBs	83.71%	29.17%	37.73%	23.81%	5.90%
Total Dioxins/Furans	1.80%	0.00%	12.08%	0.00%	0.00%
Total Pesticides	0.34%	0.02%	0.19%	0.01%	0.00%
Total Inorganics (Arsenic)	14.15%	70.81%	49.99%	76.18%	94.10%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.19%	0.59%	0.67%	2.94%	0.20%
Inhalation of Indoor and Outdoor Air	0.02%	0.05%	0.06%	0.04%	0.04%
Ingestion/Dermal Contact with Sediment	99.79%	99.36%	99.27%	97.02%	99.76%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	4.2E-07	2.9E-08	4.2E-08	6.0E-08	4.4E-09
Total PCBs using Aroclor Data	5.8E-07	2.5E-07	3.1E-07	1.7E-07	7.3E-09
Total PCBs using Congener Data	1.2E-07	8.6E-08	2.7E-07	7.6E-08	2.0E-08
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	139.4%	877.7%	734.1%	280.0%	166.4%
Total PCBs using Congener Data	28.2%	298.3%	650.4%	127.3%	461.6%

Table 5-69 Total Hazard Indices for the Recreational Water User: Wader (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.099	0.008	0.013	0.018	0.001
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.000	0.000	0.000	0.000	0.000
Arsenic	0.001	0.001	0.001	0.003	0.001
Mercury	0.011	0.001	0.005	0.000	0.001
Total	**0.111**	**0.010**	**0.019**	**0.022**	**0.003**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.002	0.001	0.002	0.001	0.000
Inhalation of Indoor and Outdoor Air	0.009	0.000	0.003	0.000	0.001
Ingestion/Dermal Contact with Sediment	0.100	0.009	0.014	0.020	0.003
Total	**0.111**	**0.010**	**0.019**	**0.022**	**0.003**
Percent of Total for Chemical Group					
Total PCBs	88.92%	82.59%	66.78%	83.58%	41.35%
Total Dioxins/Furans	0.18%	0.00%	1.35%	0.00%	0.00%
Total Pesticides	0.02%	0.01%	0.02%	0.00%	0.00%
Arsenic	1.06%	11.84%	4.91%	14.76%	34.74%
Mercury	9.82%	5.57%	26.93%	1.66%	23.91%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	2.22%	6.31%	11.59%	5.75%	6.89%
Inhalation of Indoor and Outdoor Air	7.74%	0.97%	14.16%	0.04%	15.89%
Ingestion/Dermal Contact with Sediment	90.04%	92.72%	74.24%	94.21%	77.21%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.099	0.008	0.013	0.018	0.001
Total PCBs using Aroclor Data	0.173	0.097	0.140	0.075	0.003
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	174.4%	1187.8%	1102.5%	412.7%	250.2%

Table 5-70 Total Cancer Risks for the Marine Construction Worker (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Risk for All Chemicals					
Risks by Chemical Group					
Total PCBs	1.3E-06	8.7E-08	1.2E-07	1.8E-07	1.4E-08
Total Dioxins/Furans	3.4E-08	0.0E+00	5.0E-08	0.0E+00	0.0E+00
Total Pesticides	4.9E-09	6.6E-11	6.3E-10	7.6E-11	0.0E+00
Total Inorganics (Arsenic)	1.4E-07	1.3E-07	1.1E-07	3.7E-07	1.3E-07
Total	**1.5E-06**	**2.2E-07**	**2.8E-07**	**5.5E-07**	**1.5E-07**
Risks by Pathway					
Ingestion of Fish	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion of Waterfowl	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Ingestion/Dermal Contact with Water	1.7E-09	1.1E-09	1.4E-09	1.7E-08	2.7E-10
Inhalation of Indoor and Outdoor Air	4.4E-09	2.4E-09	3.1E-09	4.7E-09	1.3E-09
Ingestion/Dermal Contact with Sediment	1.5E-06	2.2E-07	2.8E-07	5.2E-07	1.5E-07
Total	**1.5E-06**	**2.2E-07**	**2.8E-07**	**5.5E-07**	**1.5E-07**
Percent of Total for Chemical Group					
Total PCBs	88.12%	39.26%	43.95%	32.14%	9.23%
Total Dioxins/Furans	2.30%	0.00%	17.69%	0.00%	0.00%
Total Pesticides	0.33%	0.03%	0.22%	0.01%	0.00%
Total Inorganics (Arsenic)	9.25%	60.71%	38.13%	67.85%	90.77%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.12%	0.48%	0.49%	3.05%	0.18%
Inhalation of Indoor and Outdoor Air	0.30%	1.08%	1.11%	0.86%	0.91%
Ingestion/Dermal Contact with Sediment	99.58%	98.44%	98.40%	96.09%	98.91%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Risks					
Total PCBs	1.3E-06	8.7E-08	1.2E-07	1.8E-07	1.4E-08
Total PCBs using Aroclor Data	1.7E-06	6.4E-07	7.0E-07	3.9E-07	1.6E-08
Total PCBs using Congener Data	3.6E-07	2.5E-07	7.6E-07	2.1E-07	5.8E-08
Ratio to Risk for Total PCBs					
Total PCBs using Aroclor Data	129.0%	736.4%	567.9%	220.1%	115.4%
Total PCBs using Congener Data	28.1%	290.7%	613.9%	122.2%	427.4%

Table 5-71 Total Hazard Indices for the Marine Construction Worker (RME with Upper-bound Concentrations)

Chemical of Potential Concern	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Green Bay
Part 1: Hazard Indices for All Chemicals					
Hazard Indices by Chemical Group					
Total PCBs	0.105	0.007	0.010	0.014	0.001
Total Dioxins/Furans	0.000	0.000	0.000	0.000	0.000
Total Pesticides	0.000	0.000	0.000	0.000	0.000
Arsenic	0.001	0.001	0.001	0.002	0.001
Mercury	0.166	0.002	0.054	0.001	0.010
Total	**0.272**	**0.011**	**0.065**	**0.018**	**0.012**
Hazard Indices by Pathway					
Ingestion of Fish	0.000	0.000	0.000	0.000	0.000
Ingestion of Waterfowl	0.000	0.000	0.000	0.000	0.000
Ingestion/Dermal Contact with Water	0.002	0.000	0.002	0.001	0.000
Inhalation of Indoor and Outdoor Air	0.163	0.002	0.051	0.000	0.010
Ingestion/Dermal Contact with Sediment	0.107	0.008	0.012	0.016	0.002
Total	**0.272**	**0.011**	**0.065**	**0.018**	**0.012**
Percent of Total for Chemical Group					
Total PCBs	38.70%	68.53%	15.77%	82.44%	8.76%
Total Dioxins/Furans	0.11%	0.00%	0.56%	0.00%	0.00%
Total Pesticides	0.01%	0.01%	0.01%	0.00%	0.00%
Arsenic	0.33%	8.52%	1.10%	14.03%	7.21%
Mercury	60.85%	22.94%	82.55%	3.53%	84.02%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Percent of Total for Pathway					
Ingestion of Fish	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion of Waterfowl	0.00%	0.00%	0.00%	0.00%	0.00%
Ingestion/Dermal Contact with Water	0.77%	4.36%	2.94%	5.30%	1.49%
Inhalation of Indoor and Outdoor Air	59.94%	17.29%	78.44%	0.90%	81.39%
Ingestion/Dermal Contact with Sediment	39.29%	78.35%	18.63%	93.80%	17.12%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
Part 2: Focused PCB Evaluation					
Hazard Indices					
Total PCBs	0.105	0.007	0.010	0.014	0.001
Total PCBs using Aroclor Data	0.135	0.052	0.057	0.031	0.001
Ratio to Hazard Index for Total PCBs					
Total PCBs using Aroclor Data	128.5%	719.0%	555.1%	214.8%	117.4%

Table 5-72 Cancer Risks for the Lower Fox River and Green Bay

Receptor/Scenario	Little Lake Butte des Morts Reach	Appleton to Little Rapids Reach	Little Rapids to De Pere Reach	De Pere to Green Bay Reach	Green Bay
Recreational Angler					
RME with Upper-bound Concentrations	2.0E-03	2.8E-03	4.2E-04	1.9E-03	2.0E-03
RME with Average Concentrations	1.6E-03	2.2E-03	3.4E-04	1.5E-03	1.8E-03
CTE with Average Concentrations	2.4E-04	3.3E-04	5.2E-05	2.3E-04	2.7E-04
High-intake Fish Consumer					
RME with Upper-bound Concentrations	2.7E-03	3.8E-03	5.7E-04	2.6E-03	2.9E-03
RME with Average Concentrations	2.1E-03	3.0E-03	4.7E-04	2.1E-03	2.4E-03
CTE with Average Concentrations	3.4E-04	4.7E-04	7.3E-05	3.3E-04	3.8E-04
Hunter					
RME with Upper-bound Concentrations	6.1E-05	5.3E-05	8.3E-05	5.5E-05	6.1E-05
RME with Average Concentrations	3.2E-05	3.6E-05	3.0E-05	1.6E-05	3.0E-05
CTE with Average Concentrations	9.7E-06	1.1E-05	9.1E-06	4.7E-06	8.9E-06
Drinking Water User					
RME with Upper-bound Concentrations	2.6E-07	1.6E-07	2.1E-07	3.8E-05	4.2E-08
Local Resident					
RME with Upper-bound Concentrations	1.2E-07	6.8E-08	8.8E-08	1.3E-07	3.8E-08
Recreational Water User—Swimmer					
RME with Upper-bound Concentrations	2.2E-07	7.3E-08	8.1E-08	2.0E-07	5.2E-08
Recreational Water User—Wader					
RME with Upper-bound Concentrations	5.0E-07	9.9E-08	1.1E-07	2.5E-07	7.4E-08
Marine Construction Worker					
RME with Upper-bound Concentrations	1.5E-06	2.2E-07	2.8E-07	5.5E-07	1.5E-07

Table 5-73 Hazard Indices for the Lower Fox River and Green Bay

Receptor/Scenario	Little Lake Butte des Morts Reach	Appleton to Little Rapids Reach	Little Rapids to DePere Reach	DePere to Green Bay Reach	Green Bay
Recreational Angler					
RME with Upper-bound Concentrations	76.2	107.1	17.9	59.8	55.9
RME with Average Concentrations	59.1	83.9	14.6	52.8	53.2
CTE with Average Concentrations	15.0	21.3	3.7	13.4	13.5
High-intake Fish Consumer					
RME with Upper-bound Concentrations	104.3	146.8	24.5	82.0	86.6
RME with Average Concentrations	80.9	114.9	20.0	72.4	72.8
CTE with Average Concentrations	21.2	30.1	5.2	18.9	19.0
Hunter					
RME with Upper-bound Concentrations	1.7	2.0	3.1	2.0	2.1
RME with Average Concentrations	0.9	1.3	1.1	0.6	0.8
CTE with Average Concentrations	0.5	0.7	0.6	0.3	0.4
Drinking Water User					
RME with Upper-bound Concentrations	3.56	0.10	3.22	0.33	0.19
RME with Upper-bound Concentrations and Recent Mercury Data	0.17	0.10	0.16	0.33	0.19
Local Resident					
RME with Upper-bound Concentrations	3.823	0.043	1.194	0.004	0.237
RME with Upper-bound Concentrations and Recent Mercury Data	0.097	0.043	0.086	0.004	0.237
Recreational Water User—Swimmer					
RME with Upper-bound Concentrations	0.059	0.008	0.022	0.015	0.004
Recreational Water User—Wader					
RME with Upper-bound Concentrations	0.111	0.010	0.019	0.022	0.003
Marine Construction Worker					
RME with Upper-bound Concentrations	0.272	0.011	0.065	0.018	0.012

Table 5-74 Summary of Lead Data in Surface Sediment Samples

Reach of Lower Fox River	Frequency of Detection	Range of Detected Concentrations (mg/kg)
Little Lake Butte des Morts	27/27	3.8–522
Appleton to Little Rapids	15/15	5.17–280
Little Rapids to De Pere	20/20	6.15–1,400
De Pere to Green Bay	95/95	4.44–350
Reference/Background	10/10	14–39

Table 5-75 Fish Species with Fillet and Skin Tissue Samples for Total PCBs

Black Bullhead
Black Crappie
Bluegill
Brook Trout
Brown Bullhead
Brown Trout
Burbot
Carp
Chinook Salmon
Cisco/Lake Herring
Freshwater Drum
Lake Trout
Lake Whitefish
Largemouth Bass
Northern Pike
Pumpkinseed
Rainbow Smelt
Rock Bass
Sauger
Smallmouth Bass
Splake
Walleye
White Bass
White Perch
White Sucker
Yellow Perch

Table 5-76 Summary of Total PCB Concentrations in Fish Tissue Samples from the Lower Fox River

Sample Type	Number of Samples	Number of Detects	Minimum Detected Concentration (µg/kg)	Median (µg/kg)	Average (µg/kg)	95th Percentile (µg/kg)	Maximum Detected Concentration (µg/kg)	Standard Deviation (µg/kg)
Little Lake Butte des Morts Reach								
All Fish Samples	286	265	46	650	2,817	13,900	39,000	5,881
All Fish Samples in 1990s	126	126	46	310	960	4,550	9,300	1,630
All Carp Samples	76	76	140	4,200	8,074	30,000	39,000	9,321
All Carp Samples in 1990s	30	30	354	3,185	3,173	6,941	9,300	2,158
All Perch Samples	34	24	75	240	406	989	1,400	364
All Perch Samples in 1990s	6	6	75	104	152	295	320	98
All Walleye Samples	71	62	55	380	649	2,100	5,200	846
All Walleye Samples in 1990s	39	34	55	270	272	523	940	190
All White Bass Samples	26	25	70	205	291	633	2,200	411
All White Bass Samples in 1990s	20	20	70	185	206	303	740	144
Appleton to Little Rapids Reach								
All Fish Samples	113	111	69	1,400	3,979	16,400	57,000	7,683
All Fish Samples in 1990s	22	22	69	670	910	2,260	4,000	863
All Carp Samples	24	24	750	6,850	12,035	36,200	57,000	13,522
All Carp Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA
All Perch Samples	2	1	440	270	270	423	440	240
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples	30	30	69	1,095	2,197	6,785	14,000	2,902
All Walleye Samples in 1990s	5	5	69	140	300	632	660	271
All White Bass Samples	8	8	530	880	1,335	3,275	3,800	1,149
All White Bass Samples in 1990s	7	7	530	760	983	1,940	2,300	620
Little Rapids to De Pere Reach								
All Fish Samples	101	92	46	410	603	1,300	4,000	708
All Fish Samples in 1990s	101	92	46	410	603	1,300	4,000	708
All Carp Samples	2	2	720	1,010	1,010	1,271	1,300	410
All Carp Samples in 1990s	2	2	720	1,010	1,010	1,271	1,300	410
All Perch Samples	6	6	46	565	528	905	920	347
All Perch Samples in 1990s	6	6	46	565	528	905	920	347
All Walleye Samples	48	47	110	370	541	1,165	2,800	457
All Walleye Samples in 1990s	48	47	110	370	541	1,165	2,800	457
All White Bass Samples	14	14	180	670	852	2,170	3,600	886
All White Bass Samples in 1990s	14	14	180	670	852	2,170	3,600	886
De Pere to Green Bay Reach								
All Fish Samples	520	512	45	1,420	2,440	8,805	50,000	3,681
All Fish Samples in 1990s	292	287	45	1,100	1,344	3,529	4,800	1,020
All Carp Samples	40	40	1,200	7,000	9,044	17,754	50,000	8,895
All Carp Samples in 1990s	3	3	2,300	3,000	3,023	3,691	3,768	734
All Perch Samples	43	40	45	730	1,116	2,970	5,300	1,199
All Perch Samples in 1990s	31	28	45	220	1,052	2,850	3,100	1,149
All Walleye Samples	155	154	110	1,380	1,533	3,490	8,100	1,131
All Walleye Samples in 1990s	125	124	110	1,285	1,347	2,868	4,600	833
All White Bass Samples	64	64	370	2,400	2,823	6,395	8,400	1,688
All White Bass Samples in 1990s	46	46	370	2,300	2,295	4,200	4,800	1,085

Notes:

Perch data include white perch and yellow perch samples.

The average is used in the risk calculations. Other statistics are provided to supply information on the data sets.

Table 5-77 Calculation of PCB Concentration in Carp Fillet Using Fillet-to-Whole Body Ratio

Reach/Zone	Measured Total PCB Data				Calculated Fillet Concentration [3] (mg/kg)
	Fillet Samples [1]		Whole Body Samples [2]		
	No. of Samples	Mean (mg/kg)	No. of Samples	Mean (mg/kg)	
Little Lake Butte des Morts	30	3.173	30	1.992	1.056
Appleton to Little Rapids	NA	NA	12	2.581	1.368
Little Rapids to De Pere	2	1.010	20	3.919	2.077
De Pere to Green Bay	3	3.023	115	6.637	3.518
Green Bay Zone 3A	1	0.126	NA	NA	NA
Green Bay Zone 3B	NA	NA	NA	NA	NA
Green Bay Zone 4	1	2.840	NA	NA	NA

Ratio of Fillet to Whole Body PCB Concentrations = 0.53

Notes:

[1] Includes samples from 1990 on.

[2] Includes samples from 1989 on.

[3] Applies the calculated ratio to the measured whole body concentration.

NA - Not Available

Table 5-78 Summary of Total PCB Concentrations in Fish Tissue Samples from Green Bay

Sample Type	Number of Samples	Number of Detects	Minimum Detected Concentration (μg/kg)	Median (μg/kg)	Average (μg/kg)	95th Percentile (μg/kg)	Maximum Detected Concentration (μg/kg)	Standard Deviation (μg/kg)
Green Bay Zone 3A								
All Fish Samples	295	292	88	1,800	2,057	4,800	11,697	1,513
All Fish Samples in 1990s	101	100	126	950	1,357	3,600	5,500	1,146
All Carp Samples	16	16	88	3,755	3,918	8,774	11,697	2,983
All Carp Samples in 1990s	1	1	126	126	126	126	126	NA
All Perch Samples	20	20	220	1,250	1,869	4,835	5,500	1,511
All Perch Samples in 1990s	19	19	370	1,300	1,955	4,870	5,500	1,501
All Walleye Samples	15	15	157	1,020	1,671	4,897	5,520	1,583
All Walleye Samples from 1989 on	5	5	560	1,072	1,134	1,741	1,820	502
All White Bass Samples	NA	NA	NA	NA	NA	NA	NA	NA
All White Bass Samples In 1990s	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 3B								
All Fish Samples	103	102	240	2,200	3,551	12,120	24,000	4,012
All Fish Samples in 1990s	9	9	800	970	1,039	1,344	1,370	213
All Carp Samples	16	16	2,100	7,800	8,569	19,275	24,000	6,013
All Carp Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA
All Perch Samples	12	12	240	825	817	1,335	1,500	366
All Perch Samples in 1990s	5	5	800	970	1,000	1,180	1,200	155
All Walleye Samples	23	23	500	2,300	2,510	5,060	8,100	1,958
All Walleye Samples from 1989 on	4	4	822	1,080	1,088	1,360	1,370	289
All White Bass Samples	NA	NA	NA	NA	NA	NA	NA	NA
All White Bass Samples In 1990s	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 4								
All Fish Samples	188	185	26	835	1,452	3,637	38,000	3,059
All Fish Samples in 1990s	115	115	34	622	951	2,870	3,900	859
All Carp Samples	11	11	65	1,240	2,390	8,151	8,640	2,988
All Carp Samples in 1990s	1	1	2,840	2,840	2,840	2,840	2,840	NA
All Perch Samples	NA	NA	NA	NA	NA	NA	NA	NA
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples	30	30	132	456	678	1,486	3,520	690
All Walleye Samples from 1989 on	30	30	132	456	678	1,486	3,520	690
All White Bass Samples	NA	NA	NA	NA	NA	NA	NA	NA
All White Bass Samples In 1990s	NA	NA	NA	NA	NA	NA	NA	NA

Notes:

All fish samples includes walleye data from 1989.
Perch data include white perch and yellow perch samples.
The average is used in the risk calculations. Other statistics are provided to supply information on the data sets.

Table 5-79 PCB Concentrations in Skin-on Fillet Fish Samples from Lake Winnebago

Fish Specie	Sample Date	Concentration (µg/kg)
White Bass	07/31/92	< 40
Walleye	07/31/92	< 40
Walleye	07/31/92	< 40
Walleye	07/31/92	42
White Bass	08/04/92	130
White Bass	08/04/92	140
Northern Pike	08/11/92	71
Average		**63.3**

Table 5-80 Intake Assumptions and Toxicological Parameters for the Recreational Angler

Parameter	1989 Michigan Study (West *et al.*, 1989) RME	CTE	1993 Michigan Study (West *et al.*, 1993) RME	CTE	Average of Michigan Studies (West *et al.*, 1989, 1993) RME	CTE	1989 Wisconsin Study (Fiore *et al.*, 1989) RME	CTE
Intake Parameters								
IR and EF Basis: Original Study								
IR (g/day or g/meal)	39	12	78	17	59	15	227	227
EF (days/year or meals/year)	365	365	365	365	365	365	59	18
Basis: Annualized IR								
IR (g/day)	39	12	78	17	59	15	37	11
EF (days/year)	365	365	365	365	365	365	365	365
Basis: Normalized Meals per Year								
IR (g/meal)	227	227	227	227	227	227	227	227
EF (meals/year)	63	19	125	27	94	23	59	18
Other Intake Parameters								
RF (mg/mg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
ABS (mg/mg)	1	1	1	1	1	1	1	1
CF (kg/g)	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
ED (years)	50	30	50	30	50	30	50	30
BW (kg)	71.8	71.8	71.8	71.8	71.8	71.8	71.8	71.8
ATc (days)	27,375	27,375	27,375	27,375	27,375	27,375	27,375	27,375
ATnc (days)	18,250	10,950	18,250	10,950	18,250	10,950	18,250	10,950
Cancer Slope Factor								
CSF $(mg/kg\text{-}day)^{-1}$	2	2	2	2	2	2	2	2
Reference Dose								
RfD (mg/kg-day)	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05
Cancer Intake Factor								
IntFacC (kg-fish/kg-BW-day)	1.8E-04	3.3E-05	3.6E-04	4.7E-05	2.7E-04	4.0E-05	1.7E-04	3.1E-05
Noncancer Intake Factor								
IntFacNc (kg-fish/kg-BW-day)	2.7E-04	8.4E-05	5.4E-04	1.2E-04	4.1E-04	1.0E-04	2.6E-04	7.8E-05

Table 5-81 Intake Assumptions and Toxicological Parameters for the High-intake Fish Consumer

Parameter	Low-income Minority RME (West *et al.*, 1993)	Low-income Minority CTE (West *et al.*, 1993)	Native American RME (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Native American CTE (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Hmong RME (Hutchison and Kraft, 1994)	Hmong CTE (Hutchison and Kraft, 1994)	Hmong/Laotian RME (Hutchison, 1999)	Hmong/Laotian CTE (Hutchison, 1999)
Intake Parameters								
IR and EF Basis: Original Study								
IR (g/day or g/meal)	110	43	227	227	227	227	227	227
EF (days/year or meals/year)	365	365	89	27	130	34	52	12
Basis: Annualized IR								
IR (g/day)	110	43	55	17	81	21	32	7
EF (days/year)	365	365	365	365	365	365	365	365
Basis: Normalized Meals per Year								
IR (g/meal)	227	227	227	227	227	227	227	227
EF (meals/year)	177	69	89	27	130	34	52	12
Other Intake Parameters								
RF (mg/mg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
ABS (mg/mg)	1	1	1	1	1	1	1	1
CF (kg/g)	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
ED (years)	50	30	50	30	50	30	50	30
BW (kg)	71.8	71.8	71.8	71.8	71.8	71.8	71.8	71.8
ATc (days)	27,375	27,375	27,375	27,375	27,375	27,375	27,375	27,375
ATnc (days)	18,250	10,950	18,250	10,950	18,250	10,950	18,250	10,950
Cancer Slope Factor								
CSF (mg/kg-day)$^{-1}$	2	2	2	2	2	2	2	2
Reference Dose								
RfD (mg/kg-day)	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05
Cancer Intake Factor								
IntFacC (kg-fish/kg-BW-day)	5.1E-04	1.2E-04	2.6E-04	4.7E-05	3.8E-04	5.9E-05	1.5E-04	2.1E-05
Noncancer Intake Factor								
IntFacNc (kg-fish/kg-BW-day)	7.7E-04	3.0E-04	3.9E-04	1.2E-04	5.6E-04	1.5E-04	2.3E-04	5.2E-05

Table 5-82 Cancer Risks by Lower Fox River Reach for the Recreational Angler

Location	Average Fish Concentration (mg/kg)	1989 Michigan Study RME (West *et al.*, 1989)	1989 Michigan Study CTE (West *et al.*, 1989)	1993 Michigan Study RME (West *et al.*, 1993)	1993 Michigan Study CTE (West *et al.*, 1993)	Average of Michigan Studies RME (West *et al.*, 1989, 1993)	Average of Michigan Studies CTE (West *et al.*, 1989, 1993)	1989 Wisconsin Study RME (Fiore *et al.*, 1989)	1989 Wisconsin Study CTE (Fiore *et al.*, 1989)
Little Lake Butte des Morts									
All Fish Samples in 1990s	*0.960*	*3.5E-04*	*6.4E-05*	*7.0E-04*	*9.1E-05*	*5.2E-04*	*7.8E-05*	*3.3E-04*	*6.0E-05*
All Carp Samples in 1990s	3.173	1.1E-03	2.1E-04	2.3E-03	3.0E-04	1.7E-03	2.6E-04	1.1E-03	2.0E-04
All Perch Samples in 1990s	0.152	5.5E-05	1.0E-05	1.1E-04	1.4E-05	8.2E-05	1.2E-05	5.2E-05	9.5E-06
All Walleye Samples in 1990s	0.272	9.9E-05	1.8E-05	2.0E-04	2.6E-05	1.5E-04	2.2E-05	9.3E-05	1.7E-05
All White Bass Samples in 1990s	0.206	7.4E-05	1.4E-05	1.5E-04	1.9E-05	1.1E-04	1.7E-05	7.0E-05	1.3E-05
Appleton to Little Rapids									
All Fish Samples in 1990s	*0.910*	*3.3E-04*	*6.1E-05*	*6.6E-04*	*8.6E-05*	*4.9E-04*	*7.4E-05*	*3.1E-04*	*5.7E-05*
All Carp Samples in 1990s	1.368	5.0E-04	9.1E-05	9.9E-04	1.3E-04	7.4E-04	1.1E-04	4.7E-04	8.5E-05
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples in 1990s	0.300	1.1E-04	2.0E-05	2.2E-04	2.8E-05	1.6E-04	2.4E-05	1.0E-04	1.9E-05
All White Bass Samples in 1990s	0.983	3.6E-04	6.6E-05	7.1E-04	9.3E-05	5.3E-04	7.9E-05	3.3E-04	6.1E-05
Little Rapids to De Pere									
All Fish Samples in 1990s	*0.603*	*2.2E-04*	*4.0E-05*	*4.4E-04*	*5.7E-05*	*3.3E-04*	*4.9E-05*	*2.1E-04*	*3.8E-05*
All Carp Samples in 1990s	1.010	3.7E-04	6.8E-05	7.3E-04	9.6E-05	5.5E-04	8.2E-05	3.4E-04	6.3E-05
All Perch Samples in 1990s	0.528	1.9E-04	3.5E-05	3.8E-04	5.0E-05	2.9E-04	4.3E-05	1.8E-04	3.3E-05
All Walleye Samples in 1990s	0.541	2.0E-04	3.6E-05	3.9E-04	5.1E-05	2.9E-04	4.4E-05	1.8E-04	3.4E-05
All White Bass Samples in 1990s	0.852	3.1E-04	5.7E-05	6.2E-04	8.1E-05	4.6E-04	6.9E-05	2.9E-04	5.3E-05
De Pere to Green Bay									
All Fish Samples in 1990s	*1.344*	*4.9E-04*	*9.0E-05*	*9.7E-04*	*1.3E-04*	*7.3E-04*	*1.1E-04*	*4.6E-04*	*8.4E-05*
All Carp Samples in 1990s	3.023	1.1E-03	2.0E-04	2.2E-03	2.9E-04	1.6E-03	2.4E-04	1.0E-03	1.9E-04
All Perch Samples in 1990s	1.052	3.8E-04	7.0E-05	7.6E-04	1.0E-04	5.7E-04	8.5E-05	3.6E-04	6.6E-05
All Walleye Samples in 1990s	1.347	4.9E-04	9.0E-05	9.8E-04	1.3E-04	7.3E-04	1.1E-04	4.6E-04	8.4E-05
All White Bass Samples in 1990s	2.295	8.3E-04	1.5E-04	1.7E-03	2.2E-04	1.2E-03	1.9E-04	7.8E-04	1.4E-04
Lake Winnebago									
All Fish Samples in the 1990s	0.063	2.3E-05	4.2E-06	4.6E-05	6.0E-06	3.4E-05	5.1E-06	2.1E-05	3.9E-06

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.
The risks for Lake Winnebago represent risks calculated using background fish samples.
The carp concentration for the Appleton to Little Rapids Reach was calculated using a whole body concentration multiplied by a fillet-to-whole body ratio

Table 5-83 Cancer Risks by Green Bay Zone for the Recreational Angler

Location	Average Fish Concentration (mg/kg)	1989 Michigan Study (West *et al.*, 1989) RME	CTE	1993 Michigan Study (West *et al.*, 1993) RME	CTE	Average of Michigan Studies (West *et al.*, 1989, 1993) RME	CTE	1989 Wisconsin Study (Fiore *et al.*, 1989) RME	CTE
Green Bay Zone 3A									
All Fish Samples in 1990s	*1.357*	*4.9E-04*	*9.1E-05*	*9.8E-04*	*1.3E-04*	*7.4E-04*	*1.1E-04*	*4.6E-04*	*8.5E-05*
All Carp Samples in 1990s	0.126	4.6E-05	8.4E-06	9.1E-05	1.2E-05	6.8E-05	1.0E-05	4.3E-05	7.9E-06
All Perch Samples in 1990s	1.955	7.1E-04	1.3E-04	1.4E-03	1.9E-04	1.1E-03	1.6E-04	6.7E-04	1.2E-04
All Walleye Samples from 1989 on	1.134	4.1E-04	7.6E-05	8.2E-04	1.1E-04	6.2E-04	9.2E-05	3.9E-04	7.1E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 3B									
All Fish Samples in 1990s	*1.039*	*3.8E-04*	*6.9E-05*	*7.5E-04*	*9.8E-05*	*5.6E-04*	*8.4E-05*	*3.5E-04*	*6.5E-05*
All Carp Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Perch Samples in 1990s	1.000	3.6E-04	6.7E-05	7.2E-04	9.5E-05	5.4E-04	8.1E-05	3.4E-04	6.2E-05
All Walleye Samples from 1989 on	1.088	3.9E-04	7.3E-05	7.9E-04	1.0E-04	5.9E-04	8.8E-05	3.7E-04	6.8E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 4									
All Fish Samples in 1990s	*0.951*	*3.4E-04*	*6.4E-05*	*6.9E-04*	*9.0E-05*	*5.2E-04*	*7.7E-05*	*3.2E-04*	*5.9E-05*
All Carp Samples in 1990s	2.840	1.0E-03	1.9E-04	2.1E-03	2.7E-04	1.5E-03	2.3E-04	9.7E-04	1.8E-04
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples from 1989 on	0.678	2.5E-04	4.5E-05	4.9E-04	6.4E-05	3.7E-04	5.5E-05	2.3E-04	4.2E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lake Winnebago									
All Fish Samples in 1990s	0.063	2.3E-05	4.2E-06	4.6E-05	6.0E-06	3.4E-05	5.1E-06	2.1E-05	3.9E-06

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

Table 5-84 Hazard Indices by Lower Fox River Reach for the Recreational Angler

Location	Average Fish Concentration (mg/kg)	1989 Michigan Study (West *et al.*, 1989) RME	CTE	1993 Michigan Study (West *et al.*, 1993) RME	CTE	Average of Michigan Studies (West *et al.*, 1989, 1993) RME	CTE	1989 Wisconsin Study (Fiore *et al.*, 1989) RME	CTE
Little Lake Butte des Morts									
All Fish Samples in 1990s	*0.960*	*13.0*	*4.0*	*26.1*	*5.7*	*19.6*	*4.8*	*12.3*	*3.7*
All Carp Samples in 1990s	3.173	43.1	13.3	86.2	18.8	64.6	16.0	40.5	12.4
All Perch Samples in 1990s	0.152	2.1	0.6	4.1	0.9	3.1	0.8	1.9	0.6
All Walleye Samples in 1990s	0.272	3.7	1.1	7.4	1.6	5.5	1.4	3.5	1.1
All White Bass Samples in 1990s	0.206	2.8	0.9	5.6	1.2	4.2	1.0	2.6	0.8
Appleton to Little Rapids									
All Fish Samples in 1990s	*0.910*	*12.4*	*3.8*	*24.7*	*5.4*	*18.5*	*4.6*	*11.6*	*3.5*
All Carp Samples in 1990s	1.368	18.6	5.7	37.2	8.1	27.9	6.9	17.5	5.3
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples in 1990s	0.300	4.1	1.3	8.1	1.8	6.1	1.5	3.8	1.2
All White Bass Samples in 1990s	0.983	13.3	4.1	26.7	5.8	20.0	5.0	12.6	3.8
Little Rapids to De Pere									
All Fish Samples in 1990s	*0.603*	*8.2*	*2.5*	*16.4*	*3.6*	*12.3*	*3.0*	*7.7*	*2.4*
All Carp Samples in 1990s	1.010	13.7	4.2	27.4	6.0	20.6	5.1	12.9	3.9
All Perch Samples in 1990s	0.528	7.2	2.2	14.3	3.1	10.7	2.7	6.7	2.1
All Walleye Samples in 1990s	0.541	7.3	2.3	14.7	3.2	11.0	2.7	6.9	2.1
All White Bass Samples in 1990s	0.852	11.6	3.6	23.1	5.0	17.4	4.3	10.9	3.3
De Pere to Green Bay									
All Fish Samples in 1990s	*1.344*	*18.3*	*5.6*	*36.5*	*8.0*	*27.4*	*6.8*	*17.2*	*5.2*
All Carp Samples in 1990s	3.023	41.0	12.6	82.1	17.9	61.6	15.3	38.6	11.8
All Perch Samples in 1990s	1.052	14.3	4.4	28.6	6.2	21.4	5.3	13.4	4.1
All Walleye Samples in 1990s	1.347	18.3	5.6	36.6	8.0	27.4	6.8	17.2	5.3
All White Bass Samples in 1990s	2.295	31.2	9.6	62.3	13.6	46.7	11.6	29.3	8.9
Lake Winnebago									
All Fish Samples in the 1990s	0.063	0.9	0.3	1.7	0.4	1.3	0.3	0.8	0.2

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.
The risks for Lake Winnebago represent risks calculated using background fish samples.
The carp concentration for the Appleton to Little Rapids Reach was calculated using a whole body concentration multiplied by a fillet-to-whole body ratio.

Table 5-85 Hazard Indices by Green Bay Zone for the Recreational Angler

Location	Average Fish Concentration (mg/kg)	1989 Michigan Study (West *et al.*, 1989) RME	1989 Michigan Study CTE	1993 Michigan Study (West *et al.*, 1993) RME	1993 Michigan Study CTE	Average of Michigan Studies (West *et al.*, 1989, 1993) RME	Average of Michigan Studies CTE	1989 Wisconsin Study (Fiore *et al.*, 1989) RME	1989 Wisconsin Study CTE
Green Bay Zone 3A									
All Fish Samples in 1990s	*1.357*	*18.4*	*5.7*	*36.9*	*8.0*	*27.7*	*6.9*	*17.3*	*5.3*
All Carp Samples in 1990s	0.126	1.7	0.5	3.4	0.7	2.6	0.6	1.6	0.5
All Perch Samples in 1990s	1.955	26.6	8.2	53.1	11.6	39.8	9.9	25.0	7.6
All Walleye Samples from 1989 on	1.134	15.4	4.7	30.8	6.7	23.1	5.7	14.5	4.4
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 3B									
All Fish Samples in 1990s	*1.039*	*14.1*	*4.3*	*28.2*	*6.2*	*21.2*	*5.2*	*13.3*	*4.1*
All Carp Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Perch Samples in 1990s	1.000	13.6	4.2	27.2	5.9	20.4	5.0	12.8	3.9
All Walleye Samples from 1989 on	1.088	14.8	4.5	29.5	6.4	22.2	5.5	13.9	4.2
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 4									
All Fish Samples in 1990s	*0.951*	*12.9*	*4.0*	*25.8*	*5.6*	*19.4*	*4.8*	*12.1*	*3.7*
All Carp Samples in 1990s	2.840	38.6	11.9	77.1	16.8	57.8	14.3	36.3	11.1
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples from 1989 on	0.678	9.2	2.8	18.4	4.0	13.8	3.4	8.7	2.6
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lake Winnebago									
All Fish Samples in the 1990s	0.063	0.9	0.3	1.7	0.4	1.3	0.3	0.8	0.2

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

Table 5-86 Cancer Risks by Lower Fox River Reach for the High-intake Fish Consumer

Location	Average Fish Concentration (mg/kg)	Low-income Minority (West *et al.*, 1993)		Native American (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)		Hmong (Hutchison and Kraft, 1994)		Hmong/Laotian (Hutchison, 1999)	
		RME	CTE	RME	CTE	RME	CTE	RME	CTE
Little Lake Butte des Morts									
All Fish Samples in 1990s	*0.960*	*9.8E-04*	*2.3E-04*	*4.9E-04*	*9.0E-05*	*7.2E-04*	*1.1E-04*	*2.9E-04*	*4.0E-05*
All Carp Samples in 1990s	3.173	3.2E-03	7.6E-04	1.6E-03	3.0E-04	2.4E-03	3.7E-04	9.5E-04	1.3E-04
All Perch Samples in 1990s	0.152	1.5E-04	3.6E-05	7.8E-05	1.4E-05	1.1E-04	1.8E-05	4.6E-05	6.3E-06
All Walleye Samples in 1990s	0.272	2.8E-04	6.5E-05	1.4E-04	2.5E-05	2.0E-04	3.2E-05	8.2E-05	1.1E-05
All White Bass Samples in 1990s	0.206	2.1E-04	4.9E-05	1.1E-04	1.9E-05	1.5E-04	2.4E-05	6.2E-05	8.6E-06
Appleton to Little Rapids									
All Fish Samples in 1990s	*0.910*	*9.3E-04*	*2.2E-04*	*4.7E-04*	*8.5E-05*	*6.8E-04*	*1.1E-04*	*2.7E-04*	*3.8E-05*
All Carp Samples in 1990s	1.368	1.4E-03	3.3E-04	7.0E-04	1.3E-04	1.0E-03	1.6E-04	4.1E-04	5.7E-05
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples in 1990s	0.300	3.1E-04	7.2E-05	1.5E-04	2.8E-05	2.3E-04	3.5E-05	9.0E-05	1.2E-05
All White Bass Samples in 1990s	0.983	1.0E-03	2.4E-04	5.1E-04	9.2E-05	7.4E-04	1.2E-04	3.0E-04	4.1E-05
Little Rapids to De Pere									
All Fish Samples in 1990s	*0.603*	*6.2E-04*	*1.4E-04*	*3.1E-04*	*5.6E-05*	*4.5E-04*	*7.1E-05*	*1.8E-04*	*2.5E-05*
All Carp Samples in 1990s	1.010	1.0E-03	2.4E-04	5.2E-04	9.4E-05	7.6E-04	1.2E-04	3.0E-04	4.2E-05
All Perch Samples in 1990s	0.528	5.4E-04	1.3E-04	2.7E-04	4.9E-05	4.0E-04	6.2E-05	1.6E-04	2.2E-05
All Walleye Samples in 1990s	0.541	5.5E-04	1.3E-04	2.8E-04	5.1E-05	4.1E-04	6.4E-05	1.6E-04	2.2E-05
All White Bass Samples in 1990s	0.852	8.7E-04	2.0E-04	4.4E-04	8.0E-05	6.4E-04	1.0E-04	2.6E-04	3.5E-05
De Pere to Green Bay									
All Fish Samples in 1990s	*1.344*	*1.4E-03*	*3.2E-04*	*6.9E-04*	*1.3E-04*	*1.0E-03*	*1.6E-04*	*4.0E-04*	*5.6E-05*
All Carp Samples in 1990s	3.023	3.1E-03	7.2E-04	1.6E-03	2.8E-04	2.3E-03	3.6E-04	9.1E-04	1.3E-04
All Perch Samples in 1990s	1.052	1.1E-03	2.5E-04	5.4E-04	9.8E-05	7.9E-04	1.2E-04	3.2E-04	4.4E-05
All Walleye Samples in 1990s	1.347	1.4E-03	3.2E-04	6.9E-04	1.3E-04	1.0E-03	1.6E-04	4.0E-04	5.6E-05
All White Bass Samples in 1990s	2.295	2.3E-03	5.5E-04	1.2E-03	2.1E-04	1.7E-03	2.7E-04	6.9E-04	9.5E-05
Lake Winnebago									
All Fish Samples in the 1990s	0.063	6.4E-05	1.5E-05	3.2E-05	5.9E-06	4.7E-05	7.4E-06	1.9E-05	2.6E-06

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.
The risks for Lake Winnebago represent risks calculated using background fish samples.
The carp concentration for the Appleton to Little Rapids Reach was calculated using a whole body concentration multiplied by a fillet-to-whole body ratio.

Table 5-87 Cancer Risks by Green Bay Zone for the High-intake Fish Consumer

Location	Average Fish Concentration (mg/kg)	Low-income Minority RME (West *et al.*, 1993)	Low-income Minority CTE (West *et al.*, 1993)	Native American RME (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Native American CTE (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Hmong RME (Hutchison and Kraft, 1994)	Hmong CTE (Hutchison and Kraft, 1994)	Hmong/Laotian RME (Hutchison, 1999)	Hmong/Laotian CTE (Hutchison, 1999)
Green Bay Zone 3A									
All Fish Samples in 1990s	*1.357*	*1.4E-03*	*3.3E-04*	*7.0E-04*	*1.3E-04*	*1.0E-03*	*1.6E-04*	*4.1E-04*	*5.6E-05*
All Carp Samples in 1990s	0.126	1.3E-04	3.0E-05	6.5E-05	1.2E-05	9.5E-05	1.5E-05	3.8E-05	5.2E-06
All Perch Samples in 1990s	1.955	2.0E-03	4.7E-04	1.0E-03	1.8E-04	1.5E-03	2.3E-04	5.9E-04	8.1E-05
All Walleye Samples from 1989 on	1.134	1.2E-03	2.7E-04	5.8E-04	1.1E-04	8.5E-04	1.3E-04	3.4E-04	4.7E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 3B									
All Fish Samples in 1990s	*1.039*	*1.1E-03*	*2.5E-04*	*5.3E-04*	*9.7E-05*	*7.8E-04*	*1.2E-04*	*3.1E-04*	*4.3E-05*
All Carp Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Perch Samples in 1990s	1.000	1.0E-03	2.4E-04	5.1E-04	9.4E-05	7.5E-04	1.2E-04	3.0E-04	4.2E-05
All Walleye Samples from 1989 on	1.088	1.1E-03	2.6E-04	5.6E-04	1.0E-04	8.2E-04	1.3E-04	3.3E-04	4.5E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 4									
All Fish Samples in 1990s	*0.951*	*9.7E-04*	*2.3E-04*	*4.9E-04*	*8.9E-05*	*7.1E-04*	*1.1E-04*	*2.9E-04*	*4.0E-05*
All Carp Samples in 1990s	2.840	2.9E-03	6.8E-04	1.5E-03	2.7E-04	2.1E-03	3.3E-04	8.5E-04	1.2E-04
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples from 1989 on	0.678	6.9E-04	1.6E-04	3.5E-04	6.3E-05	5.1E-04	8.0E-05	2.0E-04	2.8E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lake Winnebago									
All Fish Samples in the 1990s	0.063	6.4E-05	1.5E-05	3.2E-05	5.9E-06	4.7E-05	7.4E-06	1.9E-05	2.6E-06

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

Table 5-88 Hazard Indices by Lower Fox River Reach for the High-intake Fish Consumer

Location	Average Fish Concentration (mg/kg)	Low-income Minority RME (West *et al.*, 1993)	Low-income Minority CTE	Native American RME (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Native American CTE	Hmong RME (Hutchison and Kraft, 1994)	Hmong CTE	Hmong/Laotian RME (Hutchison, 1999)	Hmong/Laotian CTE
Little Lake Butte des Morts									
All Fish Samples in 1990s	*0.960*	*36.8*	*14.4*	*18.5*	*5.6*	*27.0*	*7.1*	*10.8*	*2.5*
All Carp Samples in 1990s	3.173	121.5	47.5	61.2	18.6	89.3	23.4	35.7	8.2
All Perch Samples in 1990s	0.152	5.8	2.3	2.9	0.9	4.3	1.1	1.7	0.4
All Walleye Samples in 1990s	0.272	10.4	4.1	5.2	1.6	7.7	2.0	3.1	0.7
All White Bass Samples in 1990s	0.206	7.9	3.1	4.0	1.2	5.8	1.5	2.3	0.5
Appleton to Little Rapids									
All Fish Samples in 1990s	*0.910*	*34.9*	*13.6*	*17.5*	*5.3*	*25.6*	*6.7*	*10.3*	*2.4*
All Carp Samples in 1990s	1.368	52.4	20.5	26.4	8.0	38.5	10.1	15.4	3.6
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples in 1990s	0.300	11.5	4.5	5.8	1.8	8.4	2.2	3.4	0.8
All White Bass Samples in 1990s	0.983	37.6	14.7	18.9	5.7	27.7	7.2	11.1	2.6
Little Rapids to De Pere									
All Fish Samples in 1990s	*0.603*	*23.1*	*9.0*	*11.6*	*3.5*	*17.0*	*4.4*	*6.8*	*1.6*
All Carp Samples in 1990s	1.010	38.7	15.1	19.5	5.9	28.4	7.4	11.4	2.6
All Perch Samples in 1990s	0.528	20.2	7.9	10.2	3.1	14.9	3.9	5.9	1.4
All Walleye Samples in 1990s	0.541	20.7	8.1	10.4	3.2	15.2	4.0	6.1	1.4
All White Bass Samples in 1990s	0.852	32.6	12.8	16.4	5.0	24.0	6.3	9.6	2.2
De Pere to Green Bay									
All Fish Samples in 1990s	*1.344*	*51.5*	*20.1*	*25.9*	*7.9*	*37.8*	*9.9*	*15.1*	*3.5*
All Carp Samples in 1990s	3.023	115.8	45.3	58.3	17.7	85.1	22.3	34.0	7.9
All Perch Samples in 1990s	1.052	40.3	15.8	20.3	6.2	29.6	7.7	11.8	2.7
All Walleye Samples in 1990s	1.347	51.6	20.2	26.0	7.9	37.9	9.9	15.2	3.5
All White Bass Samples in 1990s	2.295	87.9	34.4	44.2	13.4	64.6	16.9	25.8	6.0
Lake Winnebago									
All Fish Samples in the 1990s	0.063	2.4	0.9	1.2	0.4	1.8	0.5	0.7	0.2

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

The carp concentration for the Appleton to Little Rapids Reach was calculated using a whole body concentration multiplied by a fillet-to-whole body ratio

Table 5-89 Hazard Indices by Green Bay Zone for the High-intake Fish Consumer

Location	Average Fish Concentration (mg/kg)	Low-income Minority RME (West *et al.*, 1993)	Low-income Minority CTE (West *et al.*, 1993)	Native American RME (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Native American CTE (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Hmong RME (Hutchison and Kraft, 1994)	Hmong CTE (Hutchison and Kraft, 1994)	Hmong/Laotian RME (Hutchison, 1999)	Hmong/Laotian CTE (Hutchison, 1999)
Green Bay Zone 3A									
All Fish Samples in 1990s	*1.357*	*5.2E+01*	*2.0E+01*	*2.6E+01*	*7.9E+00*	*3.8E+01*	*1.0E+01*	*1.5E+01*	*3.5E+00*
All Carp Samples in 1990s	0.126	4.8E+00	1.9E+00	2.4E+00	7.4E-01	3.5E+00	9.3E-01	1.4E+00	3.3E-01
All Perch Samples in 1990s	1.955	7.5E+01	2.9E+01	3.8E+01	1.1E+01	5.5E+01	1.4E+01	2.2E+01	5.1E+00
All Walleye Samples from 1989 on	1.134	4.3E+01	1.7E+01	2.2E+01	6.6E+00	3.2E+01	8.3E+00	1.3E+01	2.9E+00
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 3B									
All Fish Samples in 1990s	*1.039*	*4.0E+01*	*1.6E+01*	*2.0E+01*	*6.1E+00*	*2.9E+01*	*7.7E+00*	*1.2E+01*	*2.7E+00*
All Carp Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Perch Samples in 1990s	1.000	3.8E+01	1.5E+01	1.9E+01	5.8E+00	2.8E+01	7.4E+00	1.1E+01	2.6E+00
All Walleye Samples from 1989 on	1.088	4.2E+01	1.6E+01	2.1E+01	6.4E+00	3.1E+01	8.0E+00	1.2E+01	2.8E+00
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Green Bay Zone 4									
All Fish Samples in 1990s	*0.951*	*3.6E+01*	*1.4E+01*	*1.8E+01*	*5.6E+00*	*2.7E+01*	*7.0E+00*	*1.1E+01*	*2.5E+00*
All Carp Samples in 1990s	2.840	1.1E+02	4.3E+01	5.5E+01	1.7E+01	8.0E+01	2.1E+01	3.2E+01	7.4E+00
All Perch Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
All Walleye Samples from 1989 on	0.678	2.6E+01	1.0E+01	1.3E+01	4.0E+00	1.9E+01	5.0E+00	7.6E+00	1.8E+00
All White Bass Samples in 1990s	NA	NA	NA	NA	NA	NA	NA	NA	NA
Lake Winnebago									
All Fish Samples in the 1990s	0.063	2.4E+00	9.4E-01	1.2E+00	3.7E-01	1.8E+00	4.6E-01	7.1E-01	1.6E-01

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.
The risks for Lake Winnebago represent risks calculated using background fish samples.

Table 5-90 Intake Assumptions from the Great Lakes Sport Fish Advisory Task Force

Parameter	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Intake Parameters				
IR and EF Basis: Original Study				
IR (g/day or g/meal)	227	227	227	227
EF (days/year or meals/year)	225	52	12	6
Basis: Annualized IR				
IR (g/day)	140	32	7	4
EF (days/year)	365	365	365	365
Basis: Normalized Meals per Year				
IR (g/meal)	227	227	227	227
EF (meals/year)	225	52	12	6
Other Intake Parameters				
RF (mg/mg)	0.5	0.5	0.5	0.5
ABS (mg/mg)	1	1	1	1
CF (kg/g)	1.00E-03	1.00E-03	1.00E-03	1.00E-03
ED (years)	75	75	75	75
BW (kg)	70	70	70	70
ATc (days)	27,375	27,375	27,375	27,375
ATnc (days)	27,375	27,375	27,375	27,375
Cancer Slope Factor				
CSF $(mg/kg\text{-}day)^{-1}$	2	2	2	2
Reference Dose				
RfD (mg/kg-day)	2.0E-05	2.0E-05	2.0E-05	2.0E-05
Cancer Intake Factor				
IntFacC (kg-fish/kg-BW-day)	1.0E-03	2.3E-04	5.3E-05	2.7E-05
Noncancer Intake Factor				
IntFacNc (kg-fish/kg-BW-day)	1.0E-03	2.3E-04	5.3E-05	2.7E-05

Table 5-91 Cancer Risks by Lower Fox River Reach Using Intake Assumptions from the Great Lakes Sport Fish Advisory Task Force

Location	Concentration (mg/kg)	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Little Lake Butte des Morts					
All Fish Samples in 1990s	*0.960*	*1.9E-03*	*4.4E-04*	*1.0E-04*	*5.1E-05*
All Carp Samples in 1990s	3.173	6.3E-03	1.5E-03	3.4E-04	1.7E-04
All Perch Samples in 1990s	0.152	3.0E-04	7.0E-05	1.6E-05	8.1E-06
All Walleye Samples in 1990s	0.272	5.4E-04	1.3E-04	2.9E-05	1.5E-05
All White Bass Samples in 1990s	0.206	4.1E-04	9.5E-05	2.2E-05	1.1E-05
Appleton to Little Rapids					
All Fish Samples in 1990s	*0.910*	*1.8E-03*	*4.2E-04*	*9.7E-05*	*4.9E-05*
All Carp Samples in 1990s	1.368	2.7E-03	6.3E-04	1.5E-04	7.3E-05
All Perch Samples in 1990s	NA	NA	NA	NA	NA
All Walleye Samples in 1990s	0.300	6.0E-04	1.4E-04	3.2E-05	1.6E-05
All White Bass Samples in 1990s	0.983	2.0E-03	4.5E-04	1.0E-04	5.2E-05
Little Rapids to De Pere					
All Fish Samples in 1990s	*0.603*	*1.2E-03*	*2.8E-04*	*6.4E-05*	*3.2E-05*
All Carp Samples in 1990s	1.010	2.0E-03	4.7E-04	1.1E-04	5.4E-05
All Perch Samples in 1990s	0.528	1.1E-03	2.4E-04	5.6E-05	2.8E-05
All Walleye Samples in 1990s	0.541	1.1E-03	2.5E-04	5.8E-05	2.9E-05
All White Bass Samples in 1990s	0.852	1.7E-03	3.9E-04	9.1E-05	4.5E-05
De Pere to Green Bay					
All Fish Samples in 1990s	*1.344*	*2.7E-03*	*6.2E-04*	*1.4E-04*	*7.2E-05*
All Carp Samples in 1990s	3.023	6.0E-03	1.4E-03	3.2E-04	1.6E-04
All Perch Samples in 1990s	1.052	2.1E-03	4.9E-04	1.1E-04	5.6E-05
All Walleye Samples in 1990s	1.347	2.7E-03	6.2E-04	1.4E-04	7.2E-05
All White Bass Samples in 1990s	2.295	4.6E-03	1.1E-03	2.4E-04	1.2E-04
Lake Winnebago					
All Fish Samples in the 1990s	0.063	1.3E-04	2.9E-05	6.7E-06	3.4E-06

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

The carp concentration for the Appleton to Little Rapids Reach was calculated using a whole body concentration multiplied by a fillet-to-whole body ratio.

Table 5-92 Cancer Risks by Green Bay Zone Using Intake Assumptions from the Great Lakes Sport Fish Advisory Task Force

Location	Concentration (mg/kg)	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Green Bay Zone 3A					
All Fish Samples in 1990s	*1.357*	*2.7E-03*	*6.3E-04*	*1.4E-04*	*7.2E-05*
All Carp Samples in 1990s	0.126	2.5E-04	5.8E-05	1.3E-05	6.7E-06
All Perch Samples in 1990s	1.955	3.9E-03	9.0E-04	2.1E-04	1.0E-04
All Walleye Samples from 1989 on	1.134	2.3E-03	5.2E-04	1.2E-04	6.0E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA
Green Bay Zone 3B					
All Fish Samples in 1990s	*1.039*	*2.1E-03*	*4.8E-04*	*1.1E-04*	*5.5E-05*
All Carp Samples in 1990s	NA	NA	NA	NA	NA
All Perch Samples in 1990s	1.000	2.0E-03	4.6E-04	1.1E-04	5.3E-05
All Walleye Samples from 1989 on	1.088	2.2E-03	5.0E-04	1.2E-04	5.8E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA
Green Bay Zone 4					
All Fish Samples in 1990s	*0.951*	*1.9E-03*	*4.4E-04*	*1.0E-04*	*5.1E-05*
All Carp Samples in 1990s	2.840	5.7E-03	1.3E-03	3.0E-04	1.5E-04
All Perch Samples in 1990s	NA	NA	NA	NA	NA
All Walleye Samples from 1989 on	0.678	1.4E-03	3.1E-04	7.2E-05	3.6E-05
All White Bass Samples in 1990s	NA	NA	NA	NA	NA
Lake Winnebago					
All Fish Samples in the 1990s	0.063	1.3E-04	2.9E-05	6.7E-06	3.4E-06

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.
The risks for Lake Winnebago represent risks calculated using background fish samples.

Table 5-93 Hazard Indices by Lower Fox River Reach Using Intake Assumptions from the Great Lakes Sport Fish Advisory Task Force

Location	Concentration (mg/kg)	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Little Lake Butte des Morts					
All Fish Samples in 1990s	*0.960*	*48.0*	*11.1*	*2.6*	*1.3*
All Carp Samples in 1990s	3.173	158.6	36.7	8.5	4.2
All Perch Samples in 1990s	0.152	7.6	1.8	0.4	0.2
All Walleye Samples in 1990s	0.272	13.6	3.1	0.7	0.4
All White Bass Samples in 1990s	0.206	10.3	2.4	0.5	0.3
Appleton to Little Rapids					
All Fish Samples in 1990s	*0.910*	*45.5*	*10.5*	*2.4*	*1.2*
All Carp Samples in 1990s	1.368	68.4	15.8	3.6	1.8
All Perch Samples in 1990s	NA	NA	NA	NA	NA
All Walleye Samples in 1990s	0.300	15.0	3.5	0.8	0.4
All White Bass Samples in 1990s	0.983	49.1	11.4	2.6	1.3
Little Rapids to De Pere					
All Fish Samples in 1990s	*0.603*	*30.1*	*7.0*	*1.6*	*0.8*
All Carp Samples in 1990s	1.010	50.5	11.7	2.7	1.3
All Perch Samples in 1990s	0.528	26.4	6.1	1.4	0.7
All Walleye Samples in 1990s	0.541	27.0	6.2	1.4	0.7
All White Bass Samples in 1990s	0.852	42.6	9.8	2.3	1.1
De Pere to Green Bay					
All Fish Samples in 1990s	*1.344*	*67.2*	*15.5*	*3.6*	*1.8*
All Carp Samples in 1990s	3.023	151.1	34.9	8.1	4.0
All Perch Samples in 1990s	1.052	52.6	12.2	2.8	1.4
All Walleye Samples in 1990s	1.347	67.3	15.6	3.6	1.8
All White Bass Samples in 1990s	2.295	114.7	26.5	6.1	3.1
Lake Winnebago					
All Fish Samples in the 1990s	0.063	3.1	0.7	0.2	0.1

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

The carp concentration for the Appleton to Little Rapids Reach was calculated using a whole body concentration multiplied by a fillet-to-whole body ratio.

Table 5-94 Hazard Indices by Green Bay Zone Using Intake Assumptions from the Great Lakes Sport Fish Advisory Task Force

Location	Concentration (mg/kg)	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Green Bay Zone 3A					
All Fish Samples in 1990s	*1.357*	*67.8*	*15.7*	*3.6*	*1.8*
All Carp Samples in 1990s	0.126	6.3	1.5	0.3	0.2
All Perch Samples in 1990s	1.955	97.7	22.6	5.2	2.6
All Walleye Samples from 1989 on	1.134	56.7	13.1	3.0	1.5
All White Bass Samples in 1990s	NA	NA	NA	NA	NA
Green Bay Zone 3B					
All Fish Samples in 1990s	*1.039*	*51.9*	*12.0*	*2.8*	*1.4*
All Carp Samples in 1990s	NA	NA	NA	NA	NA
All Perch Samples in 1990s	1.000	50.0	11.5	2.7	1.3
All Walleye Samples from 1989 on	1.088	54.4	12.6	2.9	1.4
All White Bass Samples in 1990s	NA	NA	NA	NA	NA
Green Bay Zone 4					
All Fish Samples in 1990s	*0.951*	*47.5*	*11.0*	*2.5*	*1.3*
All Carp Samples in 1990s	2.840	141.9	32.8	7.6	3.8
All Perch Samples in 1990s	NA	NA	NA	NA	NA
All Walleye Samples from 1989 on	0.678	33.9	7.8	1.8	0.9
All White Bass Samples in 1990s	NA	NA	NA	NA	NA
Lake Winnebago					
All Fish Samples in the 1990s	0.063	3.1	0.7	0.2	0.1

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

Table 5-95 Results of Probabilistic Analysis for Recreational Anglers Using Little Lake Butte des Morts Fish Concentrations

	Recreational Angler							
	(West *et al.*, 1989)		(West *et al.*, 1993)		(Fiore *et al.*, 1989)		(Exponent, 2000)	
	Risk	Haz Index	Risk	Haz Index	Risk	Haz Index	Risk	Haz Index
Percentiles								
0.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	5.6E-09	3.9E-03
5.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	3.0E-07	9.5E-02
10.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	9.3E-08	2.7E-02	5.6E-07	1.5E-01
15.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.0E-06	2.0E-01	9.0E-07	2.2E-01
20.0%	8.5E-07	1.9E-01	0.0E+00	0.0E+00	2.4E-06	3.8E-01	1.3E-06	2.9E-01
25.0%	2.8E-06	4.7E-01	0.0E+00	0.0E+00	4.2E-06	5.6E-01	1.7E-06	3.5E-01
30.0%	5.6E-06	8.3E-01	0.0E+00	0.0E+00	6.5E-06	7.6E-01	2.1E-06	4.3E-01
35.0%	9.4E-06	1.2E+00	0.0E+00	0.0E+00	9.1E-06	1.0E+00	2.7E-06	5.1E-01
40.0%	1.4E-05	1.7E+00	0.0E+00	0.0E+00	1.2E-05	1.3E+00	3.3E-06	6.1E-01
45.0%	2.0E-05	2.2E+00	0.0E+00	0.0E+00	1.6E-05	1.5E+00	4.1E-06	7.1E-01
50.0%	2.7E-05	2.8E+00	0.0E+00	0.0E+00	2.1E-05	1.8E+00	5.0E-06	8.3E-01
55.0%	3.5E-05	3.3E+00	0.0E+00	0.0E+00	2.7E-05	2.2E+00	6.2E-06	9.7E-01
60.0%	4.5E-05	4.0E+00	0.0E+00	0.0E+00	3.4E-05	2.8E+00	7.7E-06	1.1E+00
65.0%	5.8E-05	4.9E+00	0.0E+00	0.0E+00	4.3E-05	3.4E+00	9.4E-06	1.3E+00
70.0%	7.5E-05	5.7E+00	1.6E-05	7.0E+00	5.6E-05	4.2E+00	1.2E-05	1.6E+00
75.0%	9.7E-05	6.7E+00	6.7E-05	8.3E+00	7.2E-05	5.0E+00	1.5E-05	1.9E+00
80.0%	1.2E-04	7.8E+00	1.3E-04	1.0E+01	9.4E-05	6.3E+00	1.8E-05	2.3E+00
85.0%	1.6E-04	9.2E+00	2.2E-04	1.7E+01	1.3E-04	8.1E+00	2.5E-05	2.9E+00
90.0%	2.2E-04	1.1E+01	3.4E-04	2.0E+01	1.8E-04	1.0E+01	3.5E-05	3.9E+00
95.0%	**3.1E-04**	**1.3E+01**	**6.1E-04**	**2.7E+01**	**3.0E-04**	**1.3E+01**	**6.0E-05**	**5.8E+00**
98.0%	4.3E-04	1.6E+01	9.3E-04	4.1E+01	4.4E-04	2.1E+01	1.1E-04	9.2E+00
99.0%	5.1E-04	1.7E+01	1.2E-03	5.3E+01	5.8E-04	2.5E+01	1.4E-04	1.2E+01
99.9%	6.8E-04	2.1E+01	2.7E-03	1.4E+02	1.1E-03	3.4E+01	3.5E-04	2.7E+01
100.0%	8.2E-04	2.8E+01	5.5E-03	1.8E+02	1.3E-03	4.6E+01	1.5E-03	4.8E+01
Statistics								
Mean	7.3E-05	4.2E+00	1.0E-04	5.9E+00	6.6E-05	3.8E+00	1.5E-05	1.6E+00
Standard Deviation	1.1E-04	4.4E+00	2.7E-04	1.2E+01	1.2E-04	5.1E+00	3.6E-05	2.6E+00
Point Estimates								
CTE	6.4E-05	4.0E+00	9.1E-05	5.7E+00	5.9E-05	3.7E+00	1.4E-05	1.6E+00
RME	3.5E-04	1.3E+01	7.0E-04	2.6E+01	3.3E-04	1.2E+01	1.5E-04	5.7E+00
Variance	1.2E-08	1.9E+01	7.4E-08	1.5E+02	1.4E-08	2.6E+01	1.3E-09	6.7E+00
Kurtosis	2.4E+00	1.2E+00	5.6E+00	4.4E+00	3.8E+00	2.5E+00	1.4E+01	5.7E+00
Skewness	9.6E+00	3.8E+00	5.8E+01	3.8E+01	2.3E+01	1.1E+01	4.4E+02	6.2E+01
Errors Calculated	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table 5-96 Results of Probabilistic Analysis for High-intake Fish Consumers Using Little Lake Butte des Morts Fish Concentrations

	High-intake Fish Consumers					
	Low-income Minority (West *et al.*, 1993)		Hmong (Hutchison & Kraft, 1994)		Hmong/Laotian (Hutchison, 1999)	
	Risk	Haz Index	Risk	Haz Index	Risk	Haz Index
Percentiles						
0.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
5.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
10.0%	0.0E+00	0.0E+00	1.2E-06	1.3E+00	0.0E+00	0.0E+00
15.0%	0.0E+00	0.0E+00	5.7E-06	1.5E+00	0.0E+00	0.0E+00
20.0%	0.0E+00	0.0E+00	9.5E-06	1.7E+00	0.0E+00	0.0E+00
25.0%	0.0E+00	0.0E+00	1.4E-05	1.9E+00	0.0E+00	0.0E+00
30.0%	0.0E+00	0.0E+00	1.9E-05	2.1E+00	0.0E+00	0.0E+00
35.0%	0.0E+00	0.0E+00	2.5E-05	2.3E+00	0.0E+00	0.0E+00
40.0%	0.0E+00	0.0E+00	3.2E-05	2.5E+00	5.1E-07	1.3E+00
45.0%	0.0E+00	0.0E+00	3.9E-05	2.7E+00	6.1E-06	2.0E+00
50.0%	0.0E+00	0.0E+00	4.8E-05	3.1E+00	1.1E-05	2.1E+00
55.0%	2.8E-05	6.1E+00	5.7E-05	3.9E+00	1.6E-05	2.3E+00
60.0%	6.6E-05	7.1E+00	6.8E-05	4.6E+00	2.4E-05	2.4E+00
65.0%	1.0E-04	9.5E+00	8.1E-05	5.3E+00	3.3E-05	2.5E+00
70.0%	1.6E-04	1.6E+01	9.8E-05	6.2E+00	4.2E-05	2.6E+00
75.0%	2.3E-04	1.9E+01	1.2E-04	7.4E+00	5.4E-05	2.7E+00
80.0%	3.1E-04	2.2E+01	1.6E-04	1.0E+01	6.9E-05	2.9E+00
85.0%	4.6E-04	2.5E+01	2.2E-04	1.6E+01	8.5E-05	3.1E+00
90.0%	6.7E-04	2.8E+01	3.2E-04	2.1E+01	1.0E-04	4.0E+00
95.0%	**1.0E-03**	**3.9E+01**	**6.0E-04**	**2.8E+01**	**1.5E-04**	**1.1E+01**
98.0%	2.3E-03	1.6E+02	1.0E-03	4.9E+01	3.7E-04	1.4E+01
99.0%	4.1E-03	1.8E+02	1.3E-03	5.6E+01	4.6E-04	2.6E+01
99.9%	7.2E-03	2.2E+02	2.5E-03	7.4E+01	1.2E-03	3.5E+01
100.0%	8.4E-03	2.6E+02	3.0E-03	8.7E+01	1.4E-03	4.1E+01
Statistics						
Mean	2.5E-04	1.5E+01	1.3E-04	7.5E+00	4.4E-05	2.6E+00
Standard Deviation	7.0E-04	3.2E+01	2.7E-04	1.1E+01	9.8E-05	4.3E+00
Point Estimates						
CTE	2.3E-04	1.4E+01	1.1E-04	7.1E+00	4.0E-05	2.5E+00
RME	9.8E-04	3.7E+01	7.2E-04	2.7E+01	2.9E-04	1.1E+01
Variance	4.9E-07	1.0E+03	7.1E-08	1.2E+02	9.6E-09	1.8E+01
Kurtosis	6.0E+00	4.0E+00	4.6E+00	2.9E+00	6.0E+00	4.0E+00
Skewness	4.8E+01	2.0E+01	3.1E+01	1.3E+01	5.4E+01	2.3E+01
Errors Calculated	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table 5-97 Results of Probabilistic Analysis for Recreational Anglers Using De Pere to Green Bay Fish Concentrations

	Recreational Angler							
	(West *et al.*, 1989)		(West *et al.*, 1993)		(Fiore *et al.*, 1989)		(Exponent, 2000)	
	Risk	Haz Index	Risk	Haz Index	Risk	Haz Index	Risk	Haz Index
Percentiles								
0.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	6.4E-09	6.4E-03
5.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	4.8E-07	1.6E-01
10.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.3E-07	3.8E-02	9.3E-07	2.4E-01
15.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	1.5E-06	2.9E-01	1.4E-06	3.3E-01
20.0%	1.3E-06	2.8E-01	0.0E+00	0.0E+00	3.5E-06	5.4E-01	1.9E-06	4.2E-01
25.0%	3.8E-06	6.4E-01	0.0E+00	0.0E+00	5.9E-06	8.1E-01	2.4E-06	5.1E-01
30.0%	7.9E-06	1.1E+00	0.0E+00	0.0E+00	9.1E-06	1.1E+00	3.0E-06	6.2E-01
35.0%	1.3E-05	1.6E+00	0.0E+00	0.0E+00	1.3E-05	1.4E+00	3.8E-06	7.3E-01
40.0%	1.9E-05	2.2E+00	0.0E+00	0.0E+00	1.7E-05	1.8E+00	4.8E-06	8.7E-01
45.0%	2.7E-05	3.0E+00	0.0E+00	0.0E+00	2.3E-05	2.2E+00	5.9E-06	1.0E+00
50.0%	3.6E-05	3.8E+00	0.0E+00	0.0E+00	3.0E-05	2.5E+00	7.2E-06	1.2E+00
55.0%	4.9E-05	4.6E+00	0.0E+00	0.0E+00	3.8E-05	3.1E+00	8.8E-06	1.4E+00
60.0%	6.3E-05	5.6E+00	0.0E+00	0.0E+00	4.9E-05	3.9E+00	1.1E-05	1.6E+00
65.0%	8.1E-05	6.6E+00	0.0E+00	0.0E+00	6.2E-05	4.9E+00	1.3E-05	1.9E+00
70.0%	1.1E-04	7.8E+00	2.0E-05	1.0E+01	7.9E-05	5.9E+00	1.6E-05	2.2E+00
75.0%	1.3E-04	9.2E+00	8.9E-05	1.2E+01	9.9E-05	7.0E+00	2.0E-05	2.6E+00
80.0%	1.7E-04	1.1E+01	1.9E-04	1.4E+01	1.3E-04	8.7E+00	2.6E-05	3.2E+00
85.0%	2.2E-04	1.3E+01	3.1E-04	2.3E+01	1.8E-04	1.1E+01	3.3E-05	4.0E+00
90.0%	3.0E-04	1.5E+01	4.7E-04	2.8E+01	2.6E-04	1.4E+01	4.8E-05	5.2E+00
95.0%	**4.4E-04**	**1.8E+01**	**8.5E-04**	**3.8E+01**	**4.2E-04**	**1.8E+01**	**7.9E-05**	**7.7E+00**
98.0%	6.1E-04	2.1E+01	1.3E-03	5.7E+01	6.4E-04	2.9E+01	1.4E-04	1.2E+01
99.0%	7.2E-04	2.3E+01	1.7E-03	7.4E+01	8.3E-04	3.4E+01	1.9E-04	1.7E+01
99.9%	9.2E-04	2.8E+01	3.9E-03	1.8E+02	1.4E-03	4.5E+01	5.3E-04	3.3E+01
100.0%	1.2E-03	3.1E+01	1.0E-02	2.6E+02	1.7E-03	7.1E+01	1.3E-03	5.6E+01
Statistics								
Mean	1.0E-04	5.8E+00	1.5E-04	8.3E+00	9.3E-05	5.3E+00	2.0E-05	2.3E+00
Standard Deviation	1.5E-04	6.0E+00	4.0E-04	1.7E+01	1.7E-04	7.0E+00	4.2E-05	3.4E+00
Point Estimates								
CTE	9.0E-05	5.6E+00	1.3E-04	8.0E+00	8.3E-05	5.2E+00	2.0E-05	2.3E+00
RME	4.9E-04	1.8E+01	9.7E-04	3.7E+01	4.6E-04	1.7E+01	2.1E-04	8.0E+00
Variance	2.4E-08	3.6E+01	1.6E-07	2.9E+02	2.8E-08	4.9E+01	1.8E-09	1.1E+01
Kurtosis	2.4E+00	1.1E+00	7.1E+00	4.2E+00	3.7E+00	2.4E+00	8.7E+00	4.9E+00
Skewness	9.4E+00	3.5E+00	9.9E+01	3.6E+01	2.2E+01	1.1E+01	1.4E+02	4.2E+01
Errors Calculated	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table 5-98 Results of Probabilistic Analysis for High-intake Fish Consumers Using De Pere to Green Bay Fish Concentrations

	High-intake Fish Consumers					
	Low-income Minority (West *et al.*, 1993)		Hmong (Hutchison & Kraft, 1994)		Hmong/Laotian (Hutchison & Kraft, 1994)	
	Risk	Haz Index	Risk	Haz Index	Risk	Haz Index
Percentiles						
0.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
5.0%	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
10.0%	0.0E+00	0.0E+00	2.1E-06	1.9E+00	0.0E+00	0.0E+00
15.0%	0.0E+00	0.0E+00	8.0E-06	2.2E+00	0.0E+00	0.0E+00
20.0%	0.0E+00	0.0E+00	1.3E-05	2.4E+00	0.0E+00	0.0E+00
25.0%	0.0E+00	0.0E+00	2.0E-05	2.6E+00	0.0E+00	0.0E+00
30.0%	0.0E+00	0.0E+00	2.7E-05	2.9E+00	0.0E+00	0.0E+00
35.0%	0.0E+00	0.0E+00	3.5E-05	3.2E+00	0.0E+00	0.0E+00
40.0%	0.0E+00	0.0E+00	4.5E-05	3.5E+00	7.3E-07	2.4E+00
45.0%	0.0E+00	0.0E+00	5.5E-05	3.8E+00	9.2E-06	2.9E+00
50.0%	0.0E+00	0.0E+00	6.7E-05	4.2E+00	1.5E-05	3.1E+00
55.0%	3.6E-05	8.8E+00	8.1E-05	5.5E+00	2.4E-05	3.2E+00
60.0%	8.8E-05	9.9E+00	9.4E-05	6.4E+00	3.4E-05	3.3E+00
65.0%	1.5E-04	1.3E+01	1.1E-04	7.4E+00	4.7E-05	3.5E+00
70.0%	2.1E-04	2.2E+01	1.3E-04	8.5E+00	6.1E-05	3.6E+00
75.0%	3.1E-04	2.6E+01	1.7E-04	1.0E+01	7.7E-05	3.8E+00
80.0%	4.1E-04	3.1E+01	2.3E-04	1.5E+01	9.8E-05	4.0E+00
85.0%	6.2E-04	3.5E+01	3.1E-04	2.2E+01	1.2E-04	4.2E+00
90.0%	9.3E-04	3.9E+01	4.8E-04	3.0E+01	1.4E-04	5.0E+00
95.0%	**1.4E-03**	**5.5E+01**	**8.6E-04**	**4.0E+01**	**2.0E-04**	**1.5E+01**
98.0%	3.5E-03	2.2E+02	1.4E-03	6.7E+01	5.2E-04	1.9E+01
99.0%	6.1E-03	2.4E+02	1.7E-03	7.9E+01	6.8E-04	3.6E+01
99.9%	9.8E-03	2.9E+02	3.2E-03	1.0E+02	1.6E-03	4.6E+01
100.0%	1.1E-02	3.4E+02	4.1E-03	1.2E+02	2.0E-03	5.1E+01
Statistics						
Mean	3.6E-04	2.0E+01	1.9E-04	1.1E+01	6.3E-05	3.6E+00
Standard Deviation	1.0E-03	4.4E+01	3.6E-04	1.5E+01	1.4E-04	5.9E+00
Point Estimates						
CTE	3.2E-04	2.0E+01	1.6E-04	9.9E+00	5.6E-05	3.5E+00
RME	1.4E-03	5.1E+01	1.0E-03	3.8E+01	4.0E-04	1.5E+01
Variance	1.0E-06	2.0E+03	1.3E-07	2.2E+02	1.9E-08	3.4E+01
Kurtosis	5.9E+00	3.9E+00	4.3E+00	2.9E+00	5.9E+00	3.9E+00
Skewness	4.4E+01	1.9E+01	2.7E+01	1.3E+01	5.2E+01	2.2E+01
Errors Calculated	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00

Table 5-99 Summary of Uncertainty Evaluation—Little Lake Butte des Morts Reach

		Recreational Angler				High-intake Fish Consumer			
		Mean	Range Minimum		Range Maximum	Mean	Range Minimum		Range Maximum
Risk	**Mean**	**6.5E-05**	**1.5E-05**	**to**	**1.0E-04**	**1.4E-04**	**4.4E-05**	**to**	**2.5E-04**
	5th percentile	7.5E-08	1.0E-08	to	3.0E-07	0.0E+00	1.0E-08	to	1.0E-08
	25th percentile	2.2E-06	1.0E-08	to	4.2E-06	4.8E-06	1.0E-08	to	1.4E-05
	50th percentile	1.3E-05	1.0E-08	to	2.7E-05	2.0E-05	1.0E-08	to	4.8E-05
	75th percentile	6.3E-05	1.5E-05	to	9.7E-05	1.4E-04	5.4E-05	to	2.3E-04
	90th percentile	1.9E-04	3.5E-05	to	3.4E-04	3.6E-04	1.0E-04	to	6.7E-04
	95th percentile	**3.2E-04**	**6.0E-05**	**to**	**6.1E-04**	**5.9E-04**	**1.5E-04**	**to**	**1.0E-03**
Hazard Index	**Mean**	**3.9E+00**	**1.6E+00**	**to**	**5.9E+00**	**8.2E+00**	**2.6E+00**	**to**	**1.5E+01**
	5th percentile	2.4E-02	0.0E+00	to	9.5E-02	0.0E+00	0.0E+00	to	0.0E+00
	25th percentile	3.5E-01	0.0E+00	to	5.6E-01	6.2E-01	0.0E+00	to	1.9E+00
	50th percentile	1.4E+00	0.0E+00	to	2.8E+00	1.7E+00	0.0E+00	to	3.1E+00
	75th percentile	5.5E+00	1.9E+00	to	8.3E+00	9.6E+00	2.7E+00	to	1.9E+01
	90th percentile	1.1E+01	3.9E+00	to	2.0E+01	1.8E+01	4.0E+00	to	2.8E+01
	95th percentile	**1.5E+01**	**5.8E+00**	**to**	**2.7E+01**	**2.6E+01**	**1.1E+01**	**to**	**3.9E+01**

Table 5-100 Summary of Uncertainty Evaluation—De Pere to Green Bay Reach

		Recreational Angler				High-intake Fish Consumer			
		Mean	Range Minimum		Range Maximum	Mean	Range Minimum		Range Maximum
Risk	**Mean**	**9.0E-05**	**2.0E-05**	**to**	**1.5E-04**	**2.0E-04**	**6.3E-05**	**to**	**3.6E-04**
	5th percentile	1.2E-07	1.0E-08	to	4.8E-07	0.0E+00	1.0E-08	to	1.0E-08
	25th percentile	3.0E-06	1.0E-08	to	5.9E-06	6.7E-06	1.0E-08	to	2.0E-05
	50th percentile	1.8E-05	1.0E-08	to	3.6E-05	2.8E-05	1.0E-08	to	6.7E-05
	75th percentile	8.5E-05	2.0E-05	to	1.3E-04	1.9E-04	7.7E-05	to	3.1E-04
	90th percentile	2.7E-04	4.8E-05	to	4.7E-04	5.1E-04	1.4E-04	to	9.3E-04
	95th percentile	**4.5E-04**	**7.9E-05**	**to**	**8.5E-04**	**8.3E-04**	**2.0E-04**	**to**	**1.4E-03**
Hazard Index	**Mean**	**5.4E+00**	**2.3E+00**	**to**	**8.3E+00**	**1.1E+01**	**3.6E+00**	**to**	**2.0E+01**
	5th percentile	3.9E-02	0.0E+00	to	1.6E-01	0.0E+00	0.0E+00	to	0.0E+00
	25th percentile	4.9E-01	0.0E+00	to	8.1E-01	8.7E-01	0.0E+00	to	2.6E+00
	50th percentile	1.9E+00	0.0E+00	to	3.8E+00	2.4E+00	0.0E+00	to	4.2E+00
	75th percentile	7.6E+00	2.6E+00	to	1.2E+01	1.3E+01	3.8E+00	to	2.6E+01
	90th percentile	1.6E+01	5.2E+00	to	2.8E+01	2.5E+01	5.0E+00	to	3.9E+01
	95th percentile	**2.0E+01**	**7.7E+00**	**to**	**3.8E+01**	**3.7E+01**	**1.5E+01**	**to**	**5.5E+01**

Table 5-101 Child-to-Adult Fish Ingestion Rate Ratios

Study	Fish Type	Age Group	Mean Ingestion Rate (g/day)	Child-to-Adult Ratio
EPA, 1996f [1]	Freshwater/Estuarine	14 & under 15–44	2.35 6.64	0.35
	Marine	14 & under 15–44	9.02 14.88	0.61
	All Fish	14 & under 15–44	11.36 21.51	0.53
EPA, 1996f [1]	Freshwater/Estuarine	14 & under 15–44	56.95 91.66	0.62
	Marine	14 & under 15–44	95.56 115.41	0.83
	All Fish	14 & under 15–44	96.07 136.12	0.71
West *et al.* , 1989 [3]	Recreational Fish	1–5 6–10 Adult	5.63 7.94 12	0.47 0.66
Average for All Ratios				0.60

Notes:

[1] Per capita distribution of fish intake, uncooked fish weight.

[2] Consumers only distribution of fish intake, uncooked fish weight.

[3] Households that participate in recreational fishing; uncooked fish weight.

Table 5-102 Intake Assumptions and Toxicological Parameters for the Recreational Angler Child

Parameter	1989 Michigan Study RME (West *et al.*, 1989)	1989 Michigan Study CTE (West *et al.*, 1989)	1993 Michigan Study RME (West *et al.*, 1993)	1993 Michigan Study CTE (West *et al.*, 1993)	Average of Michigan Studies RME (West *et al.*, 1989, 1993)	Average of Michigan Studies CTE (West *et al.*, 1989, 1993)	1989 Wisconsin Study RME (Fiore *et al.*, 1989)	1989 Wisconsin Study CTE (Fiore *et al.*, 1989)
Intake Parameters								
IR and EF Basis: Original Study								
IR (g/day or g/meal)	39	12	78	17	59	15	227	227
EF (days/year or meals/year)	365	365	365	365	365	365	59	18
Basis: Annualized IR								
IR (g/day)	39	12	78	17	59	15	37	11
EF (days/year)	365	365	365	365	365	365	365	365
Basis: Normalized Meals per Year								
IR (g/meal)	227	227	227	227	227	227	227	227
EF (meals/year)	63	19	125	27	94	23	59	18
Other Intake Parameters								
Child to Adult Fish Ingestion Ratio	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
RF (mg/mg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
ABS (mg/mg)	1	1	1	1	1	1	1	1
CF (kg/g)	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
ED (years)	7	7	7	7	7	7	7	7
BW (kg)	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8
ATnc (days)	2,555	2,555	2,555	2,555	2,555	2,555	2,555	2,555
Reference Dose								
RfD (mg/kg-day)	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05
Noncancer Intake Factor								
IntFacNc (kg-fish/kg-BW-day)	6.6E-04	2.0E-04	1.3E-03	2.9E-04	9.9E-04	2.4E-04	6.2E-04	1.9E-04

Table 5-103 Intake Assumptions and Toxicological Parameters for the High-intake Fish Consumer Child

Parameter	Low-income Minority		Native American		Hmong		Hmong/Laotian	
	RME	CTE	RME	CTE	RME	CTE	RME	CTE
	(West *et al.*, 1993)		(Peterson *et al.*, 1994 and Fiore *et al.*, 1989)		(Hutchison and Kraft, 1994)		(Hutchison, 1999)	
Intake Parameters								
IR and EF Basis: Original Study								
IR (g/day or g/meal)	110	43	227	227	227	227	227	227
EF (days/year or meals/year)	365	365	89	27	130	34	52	12
Basis: Annualized IR								
IR (g/day)	110	43	55	17	81	21	32	7
EF (days/year)	365	365	365	365	365	365	365	365
Basis: Normalized Meals per Year								
IR (g/meal)	227	227	227	227	227	227	227	227
EF (meals/year)	177	69	89	27	130	34	52	12
Other Intake Parameters								
Child to Adult Fish Ingestion Ratio	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
RF (mg/mg)	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
ABS (mg/mg)	1	1	1	1	1	1	1	1
CF (kg/g)	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03	1.00E-03
ED (years)	7	7	7	7	7	7	7	7
BW (kg)	17.8	17.8	17.8	17.8	17.8	17.8	17.8	17.8
ATnc (days)	2,555	2,555	2,555	2,555	2,555	2,555	2,555	2,555
Reference Dose								
RfD (mg/kg-day)	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05	2.0E-05
Noncancer Intake Factor								
IntFacNc (kg-fish/kg-BW-day)	1.9E-03	7.2E-04	9.3E-04	2.8E-04	1.4E-03	3.6E-04	5.5E-04	1.3E-04

Table 5-104 Hazard Indices by Lower Fox River Reach for the Recreational Angler Child

Location	Average Fish Concentration (mg/kg)	1989 Michigan Study (West *et al.*, 1989) RME	CTE	1993 Michigan Study (West *et al.*, 1993) RME	CTE	Average of Michigan Studies (West *et al.*, 1989, 1993) RME	CTE	1989 Wisconsin Study (Fiore *et al.*, 1989) RME	CTE
Little Lake Butte des Morts									
All Fish Samples in 1990s	*0.960*	*31.6*	*9.7*	*63.1*	*13.8*	*47.3*	*11.7*	*29.7*	*9.1*
All Carp Samples in 1990s	3.173	104.3	32.1	208.6	45.5	156.4	38.8	98.1	29.9
All Perch Samples in 1990s	0.152	5.0	1.5	10.0	2.2	7.5	1.9	4.7	1.4
All Walleye Samples in 1990s	0.272	8.9	2.8	17.9	3.9	13.4	3.3	8.4	2.6
All White Bass Samples in 1990s	0.206	6.8	2.1	13.5	2.9	10.1	2.5	6.4	1.9
De Pere to Green Bay									
All Fish Samples in 1990s	*1.344*	*44.2*	*13.6*	*88.4*	*19.3*	*66.3*	*16.4*	*41.6*	*12.7*
All Carp Samples in 1990s	3.023	99.3	30.6	198.7	43.3	149.0	36.9	93.5	28.5
All Perch Samples in 1990s	1.052	34.6	10.6	69.2	15.1	51.9	12.9	32.5	9.9
All Walleye Samples in 1990s	1.347	44.3	13.6	88.5	19.3	66.4	16.5	41.7	12.7
All White Bass Samples in 1990s	2.295	75.4	23.2	150.8	32.9	113.1	28.0	71.0	21.6
Lake Winnebago									
All Fish Samples in the 1990s	0.063	2.1	0.6	4.1	0.9	3.1	0.8	1.9	0.6

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

Table 5-105 Hazard Indices by Lower Fox River Reach for the High-intake Fish Consumer Child

Location	Average Fish Concentration (mg/kg)	Low-income Minority RME (West *et al.*, 1993)	Low-income Minority CTE	Native American RME (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Native American CTE	Hmong RME (Hutchison and Kraft, 1994)	Hmong CTE	Hmong/Laotian RME (Hutchison, 1999)	Hmong/Laotian CTE
Little Lake Butte des Morts									
All Fish Samples in 1990s	*0.960*	*89.0*	*34.8*	*44.8*	*13.6*	*65.4*	*17.1*	*26.2*	*6.0*
All Carp Samples in 1990s	3.173	294.2	115.0	148.0	44.9	216.2	56.5	86.5	20.0
All Perch Samples in 1990s	0.152	14.1	5.5	7.1	2.1	10.3	2.7	4.1	1.0
All Walleye Samples in 1990s	0.272	25.2	9.9	12.7	3.9	18.5	4.9	7.4	1.7
All White Bass Samples in 1990s	0.206	19.1	7.5	9.6	2.9	14.0	3.7	5.6	1.3
De Pere to Green Bay									
All Fish Samples in 1990s	*1.344*	*124.6*	*48.7*	*62.7*	*19.0*	*91.6*	*24.0*	*36.6*	*8.5*
All Carp Samples in 1990s	3.023	280.2	109.5	141.0	42.8	205.9	53.9	82.4	19.0
All Perch Samples in 1990s	1.052	97.5	38.1	49.1	14.9	71.7	18.8	28.7	6.6
All Walleye Samples in 1990s	1.347	124.9	48.8	62.8	19.1	91.8	24.0	36.7	8.5
All White Bass Samples in 1990s	2.295	212.7	83.2	107.0	32.5	156.3	40.9	62.5	14.4
Lake Winnebago									
All Fish Samples in the 1990s	0.063	5.8	2.3	2.9	0.9	4.3	1.1	1.7	0.4

Notes:

The most relevant risk calculations are for the *All Fish Samples in 1990s* data set, which have been italicized.

The risks for Lake Winnebago represent risks calculated using background fish samples.

Table 5-106 Risk-based Fish Concentrations for the Recreational Angler

Risk or Hazard Index Level	1989 Michigan Study (West *et al.*, 1989) RME	CTE	1993 Michigan Study (West *et al.*, 1993) RME	CTE	Average of Michigan Studies (West *et al.*, 1989, 1993) RME	CTE	1989 Wisconsin Study (Fiore *et al.*, 1989) RME	CTE
Risk:								
1E-06	2.8E-03	1.5E-02	1.4E-03	1.1E-02	1.8E-03	1.2E-02	2.9E-03	1.6E-02
1E-05	2.8E-02	1.5E-01	1.4E-02	1.1E-01	1.8E-02	1.2E-01	2.9E-02	1.6E-01
1E-04	2.8E-01	1.5E+00	1.4E-01	1.1E+00	1.8E-01	1.2E+00	2.9E-01	1.6E+00
Hazard Index:								
1	7.4E-02	2.4E-01	3.7E-02	1.7E-01	4.9E-02	2.0E-01	7.8E-02	2.6E-01

Note:

Fish concentrations are in mg PCB/kg fish.

Table 5-107 Risk-based Fish Concentrations for the High-intake Fish Consumer

Risk or Hazard Index Level	Low-income Minority (West *et al.*, 1993) RME	CTE	Native American (Peterson *et al.*, 1994 and Fiore *et al.*, 1989) RME	CTE	Hmong (Hutchison and Kraft, 1994) RME	CTE	Hmong/Laotian (Hutchison, 1999) RME	CTE
Risk:								
1E-06	9.8E-04	4.2E-03	1.9E-03	1.1E-02	1.3E-03	8.5E-03	3.3E-03	2.4E-02
1E-05	9.8E-03	4.2E-02	1.9E-02	1.1E-01	1.3E-02	8.5E-02	3.3E-02	2.4E-01
1E-04	9.8E-02	4.2E-01	1.9E-01	1.1E+00	1.3E-01	8.5E-01	3.3E-01	2.4E+00
Hazard Index:								
1	2.6E-02	6.7E-02	5.2E-02	1.7E-01	3.6E-02	1.4E-01	8.9E-02	3.8E-01

Note:

Fish concentrations are in mg PCB/kg fish.

Table 5-108 Risk-based Fish Concentrations Using Intake Assumptions from the Great Lakes Sport Fish Advisory Task Force

Risk or Hazard Index Level	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Risk:				
1E-06	5.0E-04	2.2E-03	9.4E-03	1.9E-02
1E-05	5.0E-03	2.2E-02	9.4E-02	1.9E-01
1E-04	5.0E-02	2.2E-01	9.4E-01	1.9E+00
Hazard Index:				
1	2.0E-02	8.7E-02	3.8E-01	7.5E-01

Note:

Fish concentrations are in mg PCB/kg fish.

Table 5-109 Cancer Risks for the Lower Fox River and Green Bay

Receptor/Scenario	Little Lake Butte des Morts Reach	Appleton to Little Rapids Reach	Little Rapids to De Pere Reach	De Pere to Green Bay Reach	Green Bay
Recreational Angler					
RME with Upper-bound Concentrations	2.0E-03	2.8E-03	4.2E-04	1.9E-03	2.0E-03
RME with Average Concentrations	1.6E-03	2.2E-03	3.4E-04	1.5E-03	1.8E-03
CTE with Average Concentrations	2.4E-04	3.3E-04	5.2E-05	2.3E-04	2.7E-04
Subsistence Angler					
RME with Upper-bound Concentrations	2.7E-03	3.8E-03	5.7E-04	2.6E-03	2.9E-03
RME with Average Concentrations	2.1E-03	3.0E-03	4.7E-04	2.1E-03	2.4E-03
CTE with Average Concentrations	3.4E-04	4.7E-04	7.3E-05	3.3E-04	3.8E-04
Hunter					
RME with Upper-bound Concentrations	6.1E-05	5.3E-05	8.3E-05	5.5E-05	6.1E-05
RME with Average Concentrations	3.2E-05	3.6E-05	3.0E-05	1.6E-05	3.0E-05
CTE with Average Concentrations	9.7E-06	1.1E-05	9.1E-06	4.7E-06	8.9E-06
Drinking Water User					
RME with Upper-bound Concentrations	2.6E-07	1.6E-07	2.1E-07	3.8E-05	4.2E-08
Local Resident					
RME with Upper-bound Concentrations	1.2E-07	6.8E-08	8.8E-08	1.3E-07	3.8E-08
Recreational Water User—Swimmer					
RME with Upper-bound Concentrations	2.2E-07	7.3E-08	8.1E-08	2.0E-07	5.2E-08
Recreational Water User—Wader					
RME with Upper-bound Concentrations	5.0E-07	9.9E-08	1.1E-07	2.5E-07	7.4E-08
Marine Construction Worker					
RME with Upper-bound Concentrations	1.5E-06	2.2E-07	2.8E-07	5.5E-07	1.5E-07

Notes:

Wisconsin uses a risk level of 10^{-5} for evaluating cancer risks under Chapter NR 700.

EPA uses a risk level of 10^{-6} as the point at which risk management decisions may be made under Superfund.

Table 5-110 Noncancer Hazard Indices for the Lower Fox River and Green Bay

Receptor/Scenario	Little Lake Butte des Morts Reach	Appleton to Little Rapids Reach	Little Rapids to De Pere Reach	De Pere to Green Bay Reach	Green Bay
Recreational Angler					
RME with Upper-bound Concentrations	76.2	107.1	17.9	59.8	55.9
RME with Average Concentrations	59.1	83.9	14.6	52.8	53.2
CTE with Average Concentrations	15.0	21.3	3.7	13.4	13.5
Subsistence Angler					
RME with Upper-bound Concentrations	104.3	146.8	24.5	82.0	86.6
RME with Average Concentrations	80.9	114.9	20.0	72.4	72.8
CTE with Average Concentrations	21.2	30.1	5.2	18.9	19.0
Hunter					
RME with Upper-bound Concentrations	1.7	2.0	3.1	2.0	2.1
RME with Average Concentrations	0.9	1.3	1.1	0.6	0.8
CTE with Average Concentrations	0.5	0.7	0.6	0.3	0.4
Drinking Water User					
RME with Upper-bound Concentrations	3.56	0.10	3.22	0.33	0.19
RME with Upper-bound Concentrations and Recent Mercury Data	0.17	0.10	0.16	0.33	0.19
Local Resident					
RME with Upper-bound Concentrations	3.823	0.043	1.194	0.004	0.237
RME with Upper-bound Concentrations and Recent Mercury Data	0.097	0.043	0.086	0.004	0.237
Recreational Water User—Swimmer					
RME with Upper-bound Concentrations	0.059	0.008	0.022	0.015	0.004
Recreational Water User—Wader					
RME with Upper-bound Concentrations	0.111	0.010	0.019	0.022	0.003
Marine Construction Worker					
RME with Upper-bound Concentrations	0.272	0.011	0.065	0.018	0.012

Note:

Wisconsin under Chapter NR 700 and EPA under Superfund use a hazard index of 1.0 as the point at which risk management decisions may be made.

Table 5-111 Summary of Cancer Risks and Noncancer Hazard Indices for Anglers Exposed to PCBs from Ingestion of Fish

Location	Recreational Anglers			High-intake Fish Consumer		
	Lowest	Median	Highest	Lowest	Median	Highest
Cancer Risks						
Lower Fox River						
All Fish Samples						
RME Scenario	*2.1E-04*	*4.5E-04*	*9.7E-04*	*1.8E-04*	*5.5E-04*	*1.4E-03*
CTE Scenario	*3.8E-05*	*6.9E-05*	*1.3E-04*	*2.5E-05*	*9.9E-05*	*3.2E-04*
All Carp Samples						
RME Scenario	1.1E-03	1.4E-03	2.3E-03	3.0E-04	1.0E-03	3.2E-03
CTE Scenario	2.0E-04	2.3E-04	3.0E-04	4.2E-05	2.0E-04	7.6E-04
All Per., Wal. and Wh. B. Smpl.						
RME Scenario	7.0E-05	3.2E-04	1.7E-03	4.6E-05	3.1E-04	2.3E-03
CTE Scenario	1.3E-05	5.2E-05	2.2E-04	6.3E-06	5.9E-05	5.5E-04
Green Bay						
All Fish Samples						
RME Scenario	*3.2E-04*	*5.0E-04*	*9.8E-04*	*2.9E-04*	*7.1E-04*	*1.4E-03*
CTE Scenario	*5.9E-05*	*8.4E-05*	*1.3E-04*	*4.0E-05*	*1.2E-04*	*3.3E-04*
All Carp Samples						
RME Scenario	NA	NA	NA	NA	NA	NA
CTE Scenario	NA	NA	NA	NA	NA	NA
All Per., Wal. and Wh. B. Smpl.						
RME Scenario	2.3E-04	5.2E-04	1.4E-03	2.0E-04	6.4E-04	2.0E-03
CTE Scenario	4.2E-05	7.8E-05	1.9E-04	2.8E-05	1.1E-04	4.7E-04
Lake Winnebago						
RME Scenario	2.1E-05	2.9E-05	4.6E-05	1.9E-05	4.0E-05	6.4E-05
CTE Scenario	3.9E-06	4.7E-06	6.0E-06	2.6E-06	6.7E-06	1.5E-05
Hazard Indices						
Lower Fox River						
All Fish Samples						
RME Scenario	*7.7*	*16.8*	*36.5*	*6.8*	*20.8*	*51.5*
CTE Scenario	*2.4*	*4.3*	*8.0*	*1.6*	*6.2*	*20.1*
All Carp Samples						
RME Scenario	40.5	53.9	86.2	11.4	38.6	121.5
CTE Scenario	12.4	14.6	18.8	2.6	12.6	47.5
All Per., Wal. and Wh. B. Smpl.						
RME Scenario	2.6	12.1	62.3	1.7	11.7	87.9
CTE Scenario	0.8	3.3	13.6	0.4	3.7	34.4
Green Bay						
All Fish Samples						
RME Scenario	*12.1*	*18.9*	*36.9*	*10.7*	*26.5*	*52.0*
CTE Scenario	*3.7*	*5.3*	*8.0*	*2.5*	*7.3*	*20.3*
All Carp Samples						
RME Scenario	NA	NA	NA	NA	NA	NA
CTE Scenario	NA	NA	NA	NA	NA	NA
All Per., Wal. and Wh. B. Smpl.						
RME Scenario	8.7	19.4	53.1	7.6	24.0	74.9
CTE Scenario	2.6	4.9	11.6	1.8	7.0	29.3
Lake Winnebago						
RME Scenario	0.8	1.1	1.7	0.7	1.5	2.4
CTE Scenario	0.2	0.3	0.4	0.2	0.4	0.9

Notes:

All Per., Wal. and Wh. B. Smpl. - All perch, walleye and white bass samples.

Risks and hazard indices were calculated from fish concentrations using samples from the 1990s plus walleye samples in Green Bay from 1989.

The most relevant risk calculations are for the *All Fish Samples* data set, which have been italicized.

Risks and hazard indices calculated for Lake Winnebago fish samples represent background.

Wisconsin uses a risk level of 10^{-5} for evaluating cancer risks under Chapter NR 700.

EPA uses a risk level of 10^{-6} as the point at which risk management decisions may be made under Superfund.

Wisconsin under Chapter NR 700 and EPA under Superfund use a hazard index of 1.0 as the point at which risk management decisions may be made.

Table 5-112 Summary of Maximum Cancer Risks and Noncancer Hazard Indices for Anglers Exposed to PCBs from Ingestion of Fish

A. Lower Fox River

Receptor/Scenario	Little Lake Butte des Morts	Appleton to Little Rapids	Little Rapids to De Pere	De Pere to Green Bay	Lake Winnebago
Cancer Risks					
Recreational Angler					
RME Scenario	7.0E-04	6.6E-04	4.4E-04	9.7E-04	4.6E-05
CTE Scenario	9.1E-05	8.6E-05	5.7E-05	1.3E-04	6.0E-06
High-intake Fish Consumer					
RME Scenario	9.8E-04	9.3E-04	6.2E-04	1.4E-03	6.4E-05
CTE Scenario	2.3E-04	2.2E-04	1.4E-04	3.2E-04	1.5E-05
Hazard Indices					
Recreational Angler					
RME Scenario	26.1	24.7	16.4	36.5	1.7
CTE Scenario	5.7	5.4	3.6	8.0	0.4
High-intake Fish Consumer					
RME Scenario	36.8	34.9	23.1	51.5	2.4
CTE Scenario	14.4	13.6	9.0	20.1	0.9

Notes:

Risks and hazard indices were calculated using fish concentrations based on samples from the 1990s.
Risks and hazard indices calculated for Lake Winnebago fish samples represent background.
Wisconsin uses a risk level of 10^{-5} for evaluating cancer risks under Chapter NR 700.
EPA uses a risk level of 10^{-6} as the point at which risk management decisions may be made under Superfund.
Wisconsin under Chapter NR 700 and EPA under Superfund use a hazard index of 1.0 as the point at which risk management decisions may be made.

B. Green Bay

Receptor/Scenario	Zone 3A	Zone 3B	Zone 4	Lake Winnebago
Cancer Risks				
Recreational Angler				
RME Scenario	9.8E-04	7.5E-04	6.9E-04	4.6E-05
CTE Scenario	1.3E-04	9.8E-05	9.0E-05	6.0E-06
High-intake Fish Consumer				
RME Scenario	1.4E-03	1.1E-03	9.7E-04	6.4E-05
CTE Scenario	3.3E-04	2.5E-04	2.3E-04	1.5E-05
Hazard Indices				
Recreational Angler				
RME Scenario	36.9	28.2	25.8	1.7
CTE Scenario	8.0	6.2	5.6	0.4
High-intake Fish Consumer				
RME Scenario	52.0	39.8	36.4	2.4
CTE Scenario	20.3	15.6	14.2	0.9

Notes:

Risks and hazard indices were calculated using fish concentrations based on samples from the 1990s plus walleye samples in 1989.
Risks and hazard indices calculated for Lake Winnebago fish samples represent background.
Wisconsin uses a risk level of 10^{-5} for evaluating cancer risks under Chapter NR 700.
EPA uses a risk level of 10^{-6} as the point at which risk management decisions may be made under Superfund.
Wisconsin under Chapter NR 700 and EPA under Superfund use a hazard index of 1.0 as the point at which risk management decisions may be made.

Table 5-113 Risk-based Fish Concentrations

A. Recreational Anglers

Risk or Noncancer Hazard Index Level	1989 Michigan Study RME (West *et al.*, 1989)	1989 Michigan Study CTE (West *et al.*, 1989)	1993 Michigan Study RME (West *et al.*, 1993)	1993 Michigan Study CTE (West *et al.*, 1993)	Average of Michigan Studies RME (West *et al.*, 1989, 1993)	Average of Michigan Studies CTE (West *et al.*, 1989, 1993)	1989 Wisconsin Study RME (Fiore *et al.*, 1989)	1989 Wisconsin Study CTE (Fiore *et al.*, 1989)
Risk Level:								
1E-06	2.8E-03	1.5E-02	1.4E-03	1.1E-02	1.8E-03	1.2E-02	2.9E-03	1.6E-02
1E-05	2.8E-02	1.5E-01	1.4E-02	1.1E-01	1.8E-02	1.2E-01	2.9E-02	1.6E-01
1E-04	2.8E-01	1.5E+00	1.4E-01	1.1E+00	1.8E-01	1.2E+00	2.9E-01	1.6E+00
Hazard Index Level:								
1.0	7.4E-02	2.4E-01	3.7E-02	1.7E-01	4.9E-02	2.0E-01	7.8E-02	2.6E-01

B. High-intake Fish Consumers

Risk or Noncancer Hazard Index Level	Low-income Minority RME (West *et al.*, 1993)	Low-income Minority CTE (West *et al.*, 1993)	Native American RME (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Native American CTE (Peterson *et al.*, 1994 and Fiore *et al.*, 1989)	Hmong RME (Hutchison and Kraft, 1994)	Hmong CTE (Hutchison and Kraft, 1994)	Hmong/Laotian RME (Hutchison, 1999)	Hmong/Laotian CTE (Hutchison, 1999)
Risk Level:								
1E-06	9.8E-04	4.2E-03	1.9E-03	1.1E-02	1.3E-03	8.5E-03	3.3E-03	2.4E-02
1E-05	9.8E-03	4.2E-02	1.9E-02	1.1E-01	1.3E-02	8.5E-02	3.3E-02	2.4E-01
1E-04	9.8E-02	4.2E-01	1.9E-01	1.1E+00	1.3E-01	8.5E-01	3.3E-01	2.4E+00
Hazard Index Level:								
1.0	2.6E-02	6.7E-02	5.2E-02	1.7E-01	3.6E-02	1.4E-01	8.9E-02	3.8E-01

C. Great Lakes Sport Fish Advisory Task Force

Risk or Noncancer Hazard Index Level	Unlimited Consumption	One Meal per Week	One Meal per Month	Six Meals per Year
Risk Level:				
1E-06	5.0E-04	2.2E-03	9.4E-03	1.9E-02
1E-05	5.0E-03	2.2E-02	9.4E-02	1.9E-01
1E-04	5.0E-02	2.2E-01	9.4E-01	1.9E+00
Hazard Index Level:				
1.0	2.0E-02	8.7E-02	3.8E-01	7.5E-01

Notes:

All fish concentrations are in mg/kg.

Wisconsin uses a risk level of 10^{-5} for evaluating cancer risks under Chapter NR 700.

EPA uses a risk level of 10^{-6} as the point at which risk management decisions may be made under Superfund.

Wisconsin under Chapter NR 700 and EPA under Superfund use a hazard index of 1.0 as the point at which risk management decisions may be made.