Remedial Investigation Report

Lower Fox River and Green Bay, Wisconsin

Prepared for:

Wisconsin Dept. of Natural Resources

Prepared by: The RETEC Group, Inc.
Natural Resource Technology, Inc.

December 2002

RETEC

N R T

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Lower Fox River and Green Bay, Wisconsin

Prepared by:

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RETEC Project No.: WISCN-14414-345

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NRT Project No.: 1300

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Wisconsin Department of Natural Resources
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Table of Contents

Executive Summary xix

1 Introduction 1-1
1.1 Project Overview and Objectives 1-1
1.2 Study Area Overview 1-2
1.2.1 Lower Fox River 1-2
1.2.2 Green Bay 1-3
1.3 Study Area River Reaches and Bay Zones 1-6
1.3.1 Lower Fox River Reaches 1-6
1.3.2 Green Bay 1-7
1.3.2.1 Green Bay Zones 1-7
1.3.2.2 Inner and Outer Bays 1-8
1.3.2.3 Lower Green Bay 1-8
1.4 Background 1-8
1.4.1 Site History 1-8
1.4.2 Historical PCB Use and Discharges 1-12
1.4.3 Regulatory Response 1-14
1.4.3.1 Clean Water Act 1-14
1.4.3.2 Wisconsin Pollution Discharge Elimination System 1-14
1.4.3.3 Great Lakes Areas of Concern 1-14
1.5 Application of NRC Findings and Recommendations 1-15
1.6 Section 1 Figures 1-17

2 Database and Investigation Summaries 2-1
2.1 Data Quality Evaluation 2-2
2.2 Sediment Investigations Included in the FRDB 2-3
2.2.1 1989-1990 Fox River Mass Balance Study Data and 1989-1990 Green Bay Mass Balance Study Data 2-3
2.2.2 1994 Woodward-Clyde Deposit A Sediment Data 2-6
2.2.3 1992/93 BBL Deposit A Sediment Data 2-6
2.2.4 1993 Triad Assessment 2-7
2.2.5 1994 GAS/SAIC Sediment Data 2-8
2.2.6 1995 WDNR Sediment Data 2-8
2.2.7 1996 FRG/BBL Sediment/Tissue Data 2-9
2.2.8 Sediment Remediation Demonstration Projects Data . 2-9
2.2.8.1 Deposit N Demonstration Project 2-11
2.2.8.2 SMU 56/57 Demonstration Project 2-12
2.2.9 1998 FRG/Exponent Data and 1998 FRG/BBL Sediment/Tissue Data 2-15

Table of Contents

2.2.10 1998 RETEC RI/FS Supplemental Data 2-15
2.2.11 Lake Michigan Mass Balance Data 2-17
2.2.12 Fox River Fish Consumption Advisory Data 2-17
2.2.13 USGS National Water Quality Assessment Program (NAWQA) Data 2-17
2.2.14 1997 WDNR Caged Fish Bioaccumulation Study Data 2-17
2.2.15 Minergy Mineralogical Data 2-17
2.3 Ecological Sampling Studies 2-18
2.4 Section 2 Tables 2-19

3 Physical Characteristics 3-1
3.1 Land Use 3-1
3.1.1 Historical Land Use 3-1
3.1.2 Current Land Uses 3-3
3.2 Meteorology 3-5
3.3 Geologic Characteristics 3-6
3.3.1 Regional Geologic Setting 3-7
3.3.1.1 Bedrock Geology 3-7
3.3.1.2 Glacial Geology 3-8
3.3.2 Regional Soils 3-9
3.3.3 Hydrogeology 3-11
3.3.3.1 Regional Hydrogeology 3-11
3.3.3.2 Water Use (1995) 3-15
3.4 Lower Fox River Surface Water Hydrology 3-17
3.4.1 Surface Water Flow Controls 3-17
3.4.1.1 Dams in Wisconsin and on the Lower Fox River 3-17
3.4.1.2 Lower Fox River Dams and Navigational Controls 3-23
3.4.1.3 Neenah-Menasha (Lake Winnebago) 3-24
3.4.2 Lower Fox River Surface Elevation 3-25
3.4.3 Low-Flow and Flood Frequencies 3-26
3.4.4 Measured and Estimated Stream Flow Velocities 3-27
3.4.5 Lower Fox River Bathymetry 3-29
3.4.5.1 LLBdM Reach 3-29
3.4.5.2 Appleton to Little Rapids Reach 3-29
3.4.5.3 Little Rapids to De Pere Reach 3-29
3.4.5.4 De Pere to Green Bay Reach 3-30

Table of Contents

3.5 Green Bay Surface Water Hydrology 3-30
3.5.1 Green Bay Water Level Elevations 3-30
3.5.2 Green Bay Water Circulation, Currents, and Mixing Patterns 3-31
3.5.2.1 Lower Fox River Discharge into Green Bay . . . 3-33
3.5.2.2 Fox River Plume Studies 3-34
3.5.2.3 Inner Bay/Outer Bay Mixing Studies 3-36
3.5.2.4 Green Bay/Lake Michigan Mixing Studies 3-38
3.5.3 Green Bay Bathymetry 3-39
3.5.3.1 Zone 2 Bathymetry 3-41
3.5.3.2 Zone 3 Bathymetry 3-42
3.5.3.3 Zone 4 Bathymetry 3-43
3.5.4 Green Bay Ice Cover 3-45
3.6 Sediment Characteristics 3-46
3.6.1 Sediment Deposition 3-46
3.6.1.1 Lower Fox River Sediment Transport and Deposition 3-46
3.6.1.2 Green Bay Sediment Transport and Deposition 3-49
3.6.1.3 River and Bay Sediment Dredging 3-51
3.6.2 Sediment Grain Size/Lithology 3-52
3.6.3 Estimated Sediment Thickness and Areal Extent 3-53
3.6.3.1 LLBdM Reach 3-55
3.6.3.2 Appleton to Little Rapids Reach 3-55
3.6.3.3 Little Rapids to De Pere Reach 3-55
3.6.3.4 De Pere to Green Bay Reach 3-56
3.6.3.5 Green Bay (Zones 2 through 4) 3-56
3.6.4 Total Organic Carbon 3-56
3.6.5 Other Physical Parameters 3-57
3.7 Section 3 Figures, Tables, and Plates 3-58

4 Ecological Characteristics 4-1
4.1 Overview 4-1
4.1.1 Habitats 4-2
4.1.2 Wildlife Groups 4-3
4.2 Wildlife Habitat 4-5
4.2.1 Open Lands 4-5
4.2.2 Woodlands 4-6
4.2.3 Wetlands 4-8

Table of Contents

4.2.3.1 Wetland Areas and Types 4-8
4.2.3.2 Wetland Losses 4-14
4.2.3.3 Proposed Wetland Restoration Projects 4-18
4.2.4 Riverine Habitat of the Lower Fox River 4-20
4.2.5 Lacustrine Habitat of Green Bay 4-22
4.2.5.1 Overview 4-22
4.2.5.2 Inner Bay Water Quality 4-23
4.2.5.3 Outer Bay Water Quality 4-24
4.3 Benthic Communities 4-25
4.4 Fish 4-27
4.4.1 LLBdM to De Pere Dam Fish Surveys 4-27
4.4.2 De Pere to Green Bay/Duck Creek Fish Surveys 4-28
4.4.3 Green Bay Fishery Observations and Habitat 4-30
4.4.4 Life Histories of Fish Species in the Lower Fox River and Green Bay 4-35
4.4.4.1 Shiners (Minnows) 4-35
4.4.4.2 Gizzard Shad 4-36
4.4.4.3 Rainbow Smelt 4-37
4.4.4.4 Alewife 4-39
4.4.4.5 Yellow Perch 4-41
4.4.4.6 Carp 4-43
4.4.4.7 Walleye 4-45
4.4.4.8 Brown Trout 4-46
4.4.4.9 Sturgeon 4-48
4.5 Birds 4-49
4.5.1 Passerine Birds 4-50
4.5.2 Gulls/Terns 4-51
4.5.3 Diving Birds 4-53
4.5.4 Shorebirds 4-54
4.5.5 Wading Birds 4-55
4.5.6 Waterfowl 4-56
4.5.7 Raptors 4-57
4.6 Mammals 4-59
4.6.1 Mink 4-60
4.6.1.1 Mink Habitat 4-60
4.6.1.2 Domestic Mink Production in Wisconsin 4-61
4.6.1.3 Wild Mink in the Study Area 4-62
4.6.2 Otter 4-62

Table of Contents

4.7 Endangered and Threatened Species 4-63
4.8 Section 4 Figures and Tables 4-64

5 Nature and Extent of Detected Chemicals 5-1
5.1 Detected Compound Sources 5-1
5.1.1 Point Sources 5-1
5.1.1.1 Industrial/Municipal Discharges 5-1
5.1.1.2 Landfills 5-5
5.1.1.3 Spills 5-6
5.1.2 Non-Point Sources 5-7
5.1.2.1 River and Bay Sediments 5-8
5.1.2.2 Stormwater Runoff 5-9
5.1.2.3 Atmospheric Deposition and Volatilization . . . 5-11
5.2 Summary of Detected Chemicals 5-12
5.2.1 Overview 5-12
5.2.2 PCBs 5-14
5.2.3 Dioxin/Furan 5-18
5.2.4 Pesticides 5-19
5.2.5 Inorganic Compounds 5-19
5.2.6 TCLP Results 5-22
5.2.7 Semi-Volatile Organic Compounds (SVOCs) 5-22
5.3 Lake Winnebago (Background) Results 5-23
5.4 Chemical Distribution in Sediments 5-24
5.4.1 Overview 5-24
5.4.2 PCB Distribution 5-25
5.4.2.1 Bed Maps and Sediment Data Interpolation Methods 5-25
5.4.2.2 Lower Fox River and Green Bay PCB Results . . 5-31
5.4.2.3 LLBdM Reach PCB Results 5-32
5.4.2.4 Appleton to Little Rapids Reach PCB Results . 5-36
5.4.2.5 Little Rapids to De Pere Reach PCB Results . . 5-40
5.4.2.6 De Pere to Green Bay Reach PCB Results 5-42
5.4.2.7 Green Bay Zone 2 PCB Results 5-46
5.4.2.8 Green Bay Zone 3 PCB Results 5-48
5.4.2.9 Green Bay Zone 4 PCB Results 5-50
5.4.2.10 General PCB Homolog Distribution 5-52
5.4.3 Dioxin/Furans 5-55
5.4.4 Pesticides 5-56

5.4.4.1 LLBdM Reach Results 5-56
5.4.4.2 Appleton to Little Rapids Reach Results 5-57
5.4.4.3 Little Rapids to De Pere Reach Results 5-57
5.4.4.4 De Pere to Green Bay Reach Results 5-57
5.4.5 Inorganic Compounds 5-58
5.4.5.1 Mercury 5-58
5.4.5.2 Lead 5-59
5.4.5.3 Arsenic 5-61
5.4.6 Other Organic Compounds 5-62
5.4.6.1 LLBdM Reach SVOC Results 5-62
5.4.6.2 Appleton to Little Rapids Reach SVOC Results 5-63
5.4.6.3 Little Rapids to De Pere Reach SVOC Results . 5-63
5.4.6.4 De Pere to Green Bay Reach SVOC Results . . . 5-64
5.4.6.5 Green Bay SVOC Results 5-64
5.4.7 Other Inorganic Compounds 5-64
5.4.7.1 Cadmium/Chromium 5-64
5.4.7.2 Ammonia 5-65
5.5 Surface Water Sampling Results 5-65
5.5.1 Overview 5-65
5.5.2 PCB Distribution 5-66
5.5.2.1 Distribution in the Lower Fox River 5-67
5.5.2.2 PCB Distribution in Green Bay 5-69
5.5.2.3 PCB Distribution in Lake Michigan 5-69
5.5.3 Mercury Distribution 5-70
5.5.4 Pesticide Distribution 5-70
5.6 Chemical Loading to Green Bay 5-71
5.6.1 PCB Loading to Green Bay 5-71
5.6.2 Mercury and DDT Loading to Green Bay 5-71
5.7 Summary of PCBs in Biota 5-72
5.8 Time Trends of Contaminants in Sediment and Fish 5-72
5.8.1 Sediment Methods 5-72
5.8.2 Fish Methods 5-74
5.8.3 Results 5-75
5.8.3.1 Little Lake Butte des Morts 5-76
5.8.3.2 Appleton to Little Rapids 5-78
5.8.3.3 Little Rapids to De Pere 5-78
5.8.3.4 De Pere to Green Bay (Zone 1) 5-79
5.8.3.5 Green Bay Zone 2 5-80

Table of Contents

5.8.4 Conclusion 5-80
5.9 Section 5 Figures, Tables, and Plates 5-82

6 Chemical Transport and Fate 6-1
6.1 Introduction 6-1
6.2 Transport and Fate Processes 6-1
6.2.1 Chemical Transport Interactions 6-1
6.2.2 Physical Transport 6-3
6.2.3 Biological Interactions 6-4
6.3 Compounds of Potential Concern 6-5
6.3.1 Organic Constituents 6-5
6.3.1.1 PCBs 6-5
6.3.1.2 Dioxins and Furans 6-6
6.3.1.3 DDT 6-7
6.3.1.4 Dieldrin 6-8
6.3.2 Inorganic Constituents 6-9
6.3.2.1 Mercury 6-9
6.3.2.2 Lead 6-10
6.3.2.3 Arsenic 6-11
6.4 Lower Fox River/Green Bay Modeling 6-12
6.4.1 GBTOXe Model 6-12
6.4.2 GBFood Model 6-12
6.4.3 Fox River Food (FRFood) Model 6-13
6.4.4 Whole Lower Fox River Model 6-14
6.5 Section 6 Tables 6-15

7 Summary of Findings 7-1
7.1 Introduction 7-1
7.2 Physical and Ecological Characteristics 7-2
7.3 Nature and Extent of Sediment Impacts 7-4
7.3.1 Overview 7-4
7.3.2 Lower Fox River PCB Impacts 7-6
7.3.2.1 Overview 7-6
7.3.2.2 Little Lake Butte des Morts Reach 7-6
7.3.2.3 Appleton to Little Rapids Reach 7-7
7.3.2.4 Little Rapids to De Pere Reach 7-8
7.3.2.5 De Pere to Green Bay Reach 7-8
7.3.3 Green Bay PCB Impacts 7-9

Table of Contents

7.3.3.1 Overview 7-9
7.3.3.2 Green Bay Zone 2 7-10
7.3.3.3 Green Bay Zone 3 7-11
7.3.3.4 Green Bay Zone 4 7-12
7.3.4 Other Chemical Compounds 7-12
7.4 Chemical Transport and Fate 7-15
7.5 Investigative Assumptions/Uncertainties 7-16

8 References 8-1

Table of Contents

Appendix A	Data Management Summary Report (EcoChem, 2000) Addendum 1 to the Data Management Summary Report (EcoChem, 2002)
Appendix B	Time Trends Analysis (Mountain-Whisper-Light, 2001)
Appendix C	A Windrose diagram, developed from the National Oceanic and Atmospheric Administration
Appendix D	Stratigraphic cross-sections and other pertinent information concerning the regional geology of the area (Krohelski and Brown, 1986).
Appendix E	Bathymetry information available from the NOAA recreational charts for Lake Winnebago and the Lower Fox River (NOAA, 1992)
Appendix F	The USGS hydrographs for two storm events in November 1998
Appendix G	Physical parameters tables
Appendix H	PCB Congeners and Homolog Group List (ATSDR, 1997a)
Appendix I	PCB congener results for each reach and zone

List of Figures

Figure 1-1	Lower Fox River Study Area
Figure 1-2	Green Bay Study Area
Figure 1-3	Little Lake Butte des Morts Reach
Figure 1-4	Appleton to Little Rapids Reach
Figure 1-5	Little Rapids to De Pere Reach
Figure 1-6	De Pere to Green Bay Reach
Figure 3-1	Lower Fox River Elevation Profile
Figure 3-2	Green Bay Monthly Mean Surface Circulation - August 1989
Figure 3-3	Green Bay Monthly Bottom Surface Circulation - August 1989
Figure 3-4	Green Bay Zone 2 Bathymetry
Figure 3-5	Green Bay Zone 3 Bathymetry
Figure 3-6	Green Bay Zone 4 Bathymetry
Figure 3-7	Estimated Annual Sediment Transport Rates and Stream Flow Velocities
Figure 4-1	Lower Fox River Wetland, Habitat, and Animal Distribution: Little Lake Butte des Morts Reach
Figure 4-2	Lower Fox River Wetland, Habitat, and Animal Distribution: Appleton to Little Rapids Reach
Figure 4-3	Lower Fox River Wetland, Habitat, and Animal Distribution: Little Rapids to De Pere Reach
Figure 4-4	Lower Fox River Wetland, Habitat, and Animal Distribution: De Pere to Green Bay Reach
Figure 4-5	Wetland Distribution: Green Bay Zones 2 and 3
Figure 4-6	Wetland Distribution: Green Bay Zone 4
Figure 4-7	Wetland Losses in Green Bay: Duck Creek, Cat Island Chain, and Long Tail Point
Figure 4-8	Green Bay Spawning Areas by Fish Types: Salmon/Trout and Benthic Fish
Figure 4-9	Green Bay Spawning Areas by Fish Types: Pelagic and Game Fish
Figure 4-10	Green Bay Spawning Areas by Fish Species: Walleye, Yellow Perch, and Sturgeon
Figure 4-11	Green Bay Spawning Areas by Fish Species: Carp and Alewife
Figure 4-12	Green Bay Spawning Areas by Fish Species: Emerald Shiners and Gizzard Shad
Figure 4-13	Distribution of Birds in Green Bay: Select Species and Groups
Figure 4-14	Lower Fox River Mink Habitat Suitability: Little Lake Butte des Morts Reach
Figure 4-15	Lower Fox River Mink Habitat Suitability: Appleton to Little Rapids Reach
Figure 4-16	Lower Fox River Mink Habitat Suitability: Little Rapids to De Pere Reach
Figure 4-17	Lower Fox River Mink Habitat Suitability: De Pere to Green Bay Reach
Figure 4-18	Green Bay Mink Habitat Suitability: Zone 2
Figure 4-19	Green Bay Mink Habitat Suitability: Zone 3

List of Figures

Figure 5-1 PCB Sampling Frequency Distribution in Lower Fox River and Green Bay Sediments
Figure 5-2 Summary of Total PCB Concentrations in Lower Fox River and Green Bay Sediments
Figure 5-3 PCB Mass Distribution in Sediments for Each River Reach and Bay Zone
Figure 5-4 PCB Mass by Concentration Ranges in Lower Fox River Sediments
Figure 5-5 Contaminated Sediment Volume by Concentration Ranges in the Lower Fox River
Figure 5-6 PCB Mass by Concentration Ranges in Green Bay Sediments
Figure 5-7 Contaminated Sediment Volume by Concentration Ranges in Green Bay
Figure 5-8 PCB Mass Distribution in Lower Fox River and Green Bay Sediments
Figure 5-9 Ratios of PCB Mass/Sediment Volume in the Lower Fox River and Green Bay Sediment
Figure 5-10 Distribution of PCB Mass/Sediment Volume Ratios in Sediments with More Than 50 μg/kg PCBs
Figure 5-11 Aroclors 1242/1254/1260 PCB Homolog Plots
Figure 5-12 PCB Homolog Distribution in Lower Fox River and Green Bay Sediments
Figure 5-13 1994/95 Total PCB & Mercury Concentrations in Lower Fox River Water
Figure 5-14 1998 Total PCB Concentrations in Lower Fox River Water
Figure 5-15 PCB Homolog Distribution in Water: De Pere Dam Through Green Bay
Figure 5-16 Lower Fox River and Green Bay System - Estimated PCB Mass and Major PCB Flux Pathways
Figure 5-17 Time Trends of PCBs in Sediments for Depths from 0 to 10 cm and from 10 to 30 cm
Figure 5-18 Time Trends of PCBs in Sediments for Depths from 30 to 50 cm and from 50 to 100 cm
Figure 5-19 Time Trends of PCBs in Sediments for Depths over 100 cm

List of Tables

Table 2-1 Fox River Database Studies and Data Classification
Table 2-2 Lower Fox River - Supplemental Data Collection Sampling List
Table 3-1 Land Use Classification for Counties Bordering Green Bay
Table 3-2 Temperature and Precipitation Data for the City of Green Bay, Wisconsin
Table 3-3 Temperature and Precipitation Data for the City of Appleton, Wisconsin
Table 3-4 Temperature and Precipitation Data for the City of Marinette, Wisconsin
Table 3-5 Temperature and Precipitation Data for the City of Sturgeon Bay, Wisconsin
Table 3-6 Temperature and Precipitation Data for the City of Fayette, Michigan
Table 3-7 Water Use in the Lower Fox River/Green Bay Watersheds (1995)
Table 3-8 Lower Fox River Dams
Table 3-9 Lower Fox River - U.S. Army Corps of Engineers - Dam Stability and Inspection Information
Table 3-10 Lower Fox River Gradient and Lock/Dam Information
Table 3-11 Lower Fox River Discharge Results - Rapide Croche Gauging Station
Table 3-12 Lower Fox River Stream Velocity Estimates
Table 3-13 Fox River Mouth Gauging Station Results (1989-1999)
Table 3-14 Lower Fox River Total Suspended Solid (TSS) Loads
Table 3-15 USACE Navigation Channel Dredging Records (1957-1999)
Table 4-1 Major Green Bay Wetland Areas/Complexes
Table 4-2 Lower Fox River Habitats
Table 4-3 Lower Fox River Shoreline and Substrate Types
Table 4-4 Lower Fox River Fish Species Composition
Table 4-5 Lower Fox River Fish Populations in the De Pere to Green Bay Reach
Table 4-6 Green Bay Fish Species
Table 4-7 Lower Fox River and Green Bay Bird Species
Table 5-1 Lower Fox River and Green Bay - Sediment Sampling Results: Summary of Detected Compounds
Table 5-2 Lower Fox River and Green Bay - Distribution of Total PCBs in Sediment
Table 5-3 Lower Fox River - Dioxin/Furan (2,3,7,8-TCDD/F) Results
Table 5-4 Lower Fox River and Green Bay - Pesticide Results
Table 5-5 Lower Fox River and Green Bay - Mercury, Lead, and Arsenic Results
Table 5-6 Lower Fox River and Green Bay - Other RCRA Metals, Copper, Nickel, and Zinc
Table 5-7 Lower Fox River and Green Bay - Miscellaneous Inorganic Compounds
Table 5-8 Lower Fox River and Green Bay - Ammonia Results
Table 5-9 Lower Fox River - Toxicity Characteristic Leaching Procedure (TCLP) Results
Table 5-10 Lower Fox River and Green Bay - Semi-Volatile Organic Compound Results (PAHs)
Table 5-11 Lower Fox River and Green Bay - Miscellaneous SVOC Results

List of Tables

Table 5-12 Lake Winnebago Background Sediment Results
Table 5-13 Lower Fox River - PCB Mass and Sediment Volume by Concentration Range
Table 5-14 Lower Fox River - PCB Mass and Sediment Volume by Deposit/SMU Layer
Table 5-15 Green Bay - PCB Mass and Sediment Volume by Concentration Range and Layer
Table 5-16 Lower Fox River and Green Bay - Water Sampling Results: Summary of Detected Compounds
Table 5-17 Lower Fox River - Total PCB Results in Water
Table 5-18 Green Bay - Total PCB Results in Water
Table 5-19 Lower Fox River and Green Bay - Mercury and DDT (DDD/DDE) Water Sampling Results
Table 5-20 PCB Transport within the Lower Fox River and Green Bay System
Table 5-21 Distribution of Resident Tissue Samples over Time in the Lower Fox River - Total PCBs Only
Table 5-22 Distribution of Resident Tissue Samples over Time in Green Bay - Total PCBs Only
Table 5-23 Results of Sediment Time Trends Analysis for the Lower Fox River
Table 5-24 Mass-Weighted Combined Time Trend for 0 to 10 cm Depth by Reach
Table 5-25 Results of Fish Time Trend Analysis on the Lower Fox River
Table 6-1 Lower Fox River - Fate and Transport Chemical Factors

List of Plates

Plate 3-1	Sample Locations and Interpolated Thickness of Sediment with PCBs: Little Lake Butte des Morts Reach
Plate 3-2	Sample Locations and Interpolated Thickness of Sediment with PCBs: Appleton to Little Rapids Reach
Plate 3-3	Sample Locations and Interpolated Thickness of Sediment with PCBs: Little Rapids to De Pere Reach
Plate 3-4	Sample Locations and Interpolated Thickness of Sediment with PCBs: De Pere to Green Bay Reach
Plate 3-5	Sample Locations and Interpolated Thickness of Sediment with PCBs: Green Bay
Plate 5-1	Interpolated PCB Distribution in Sediments: Little Lake Butte des Morts Reach
Plate 5-2	Interpolated PCB Distribution in Sediments: Appleton to Little Rapids Reach
Plate 5-3	Interpolated PCB Distribution in Sediments: Little Rapids to De Pere Reach
Plate 5-4	Interpolated PCB Distribution in Sediments: De Pere to Green Bay Reach
Plate 5-5	Interpolated PCB Distribution in Sediments: Green Bay

List of Acronyms

AOC	Areas of Concern
ATSDR	Agency for Toxic Substances and Disease Registry
AVM	acoustical velocity meter
BCF	bioconcentration factor
BBL	Blasland, Bouck, & Lee
BEHP	bis2-ethylhexylphthalate
°C	degrees Celsius
CDF	confined disposal facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
cfs	cubic feet per second
cm	centimeter(s)
COPC	chemical of potential concern
CWA	Clean Water Act
DDD	p,p'-Dichlorodiphenyldichloroethane
DDE	p.p'-Dichlorodiphenyldichloroethylene
DDT	p.p-Dichlorodiphenyltrichloroethane
DO	dissolved oxygen
ECWRPC	East Central Wisconsin Regional Planning Commission
EIS	Final Environmental Impact Statement
EPA	United States Environmental Protection Agency, Region 5
Exponent	Exponent Environmental Group
°F	degrees Fahrenheit
F&VD	Foth & Van Dyke
FRRAT	Fox River Remediation Advisory Team
FRDB	Fox River Database
FRG	Fox River Group, which is comprised of the following seven companies listed alphabetically: Appleton Papers, Inc., Fort James Corporation; P.H. Glatfelter Company; NCR Corporation; Riverside Paper Corporation; U.S. Paper Mills Corporation; and Wisconsin Tissue Mills, Inc.
FS	Feasibility Study
ft	foot (feet)
ft^2	square feet
ft/s	foot per second
g	gram(s)
g/year	grams per year
GAS	Graef, Anhalt, Schloemer, and Associates, Inc.
GBMBS	Green Bay Mass Balance Study
GBMSD	Green Bay Metropolitan Sewerage District
GBTOXe	Green Bay Toxics Model

List of Acronyms

GIS	Geographic Information System
GLC	Great Lakes Commission
GLNPO	USEPA Great Lakes National Program Office
GLWQA	Great Lakes Water Quality Agreement
gpm	gallons per minute
HDPE	high-density polyethylene
IGLD 1985	International Great Lakes Datum, zero elevation at Rimouski, Quebec, Canada
IJC	International Joint Commission
in	inch(es)
IPS	Integrated Papers Services
kg	kilogram
km	kilometer(s)
km^2	square kilometers
km^3	cubic kilometers
Koc	log water/organic carbon partition coefficient
Kow	log octanol/water partition coefficient
LLBdM	Little Lake Butte des Morts
LTA	long-term average
LUST	leaking underground storage tank
m	meter(s)
m^2	square meters
m/s	meters per second
m^3	cubic meters
m^3/s	cubic meters per second
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MGD	million gallons per day
mi	mile(s)
mi^2	square miles
mi^3	cubic miles
MNFI	Michigan Natural Features Inventory
MSA	Metropolitan Statistical Area
MT	metric tonnes
NWR	national wildlife refuge
NAWQA	USGS National Water Quality Assessment Program
NCP	National Contingency Plan
NCR	National Cash Register
ng/kg	nanograms per kilogram

List of Acronyms

ng/L	nanograms per liter
NOAA	National Oceanic and Atmospheric Administration
NPDES	National Pollution Discharge Elimination System
NPL (Superfund)	National Priority List
NRC	National Research Council
NURE	National Uranium Resources Evaluation project
NWR	National Wildlife Refuge
OZ	ounce
PAH	polynuclear aromatic hydrocarbon
PCB	Polychlorinated Biphenyl
PCP	Pentachlorophenol
pg/m^3	picograms per cubic meter
ppb	parts per billion (μg/kg or μg/L)
ppm	parts per million (mg/kg or mg/L)
ppt	part per trillion (ng/kg or ng/L)
Project Team	The Fox River Project Team
PRP	Principal Responsibility Parties
PSC	Public Service Commission
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
RA	Risk Assessment
RAP	Remedial Action Plan
RCRA	Resource Conservation and Recovery Act
RI	Remedial Investigation
SAIC	Science Application International Corporation
SAV	submerged aquatic vegetation
SCS	Soil Conservation Service
SEF	Sediment enrichment factor
SLRA	Screening Level Risk Assessment
SMU	Sediment Management Unit
SQG	sediment quality guideline
SRD	Sediment Remediation Demonstration
SVOC	semi-volatile organic compound
SWA	State Wildlife Area
SWE	Snow-Water Equivalent
TCLP	Toxicity Characteristic Leaching Procedure
TOC	total organic carbon
TRI	EPA Toxic Release Inventory database
TSCA	Toxic Substance Control Act

List of Acronyms

TSS	total suspended solids
µg/kg	microgram per kilogram
UP	Michigan's Upper Peninsula
USACE	U.S. Army Corps of Engineers
USFWS	U.S. Fish and Wildlife Service
USGS	United States Geological Survey
UST	underground storage tank
UWSGI	University of Wisconsin Sea Grant Institute
VOC	volatile organic compound
W.A.	Wildlife Area
W.A.C.	Wisconsin Administrative Code
WCC	Woodward-Clyde Consultants (formerly EWI Engineering Associates)
WDNR	Wisconsin Department of Natural Resources
WGNHS	Wisconsin Geological and Natural History Survey
WPDES	Wisconsin Pollution Discharge Elimination System
WPSC	Wisconsin Public Service Corporation
WSCO	Wisconsin State Climatology Office
WTM 27	Wisconsin Trans-Mercator Projection, 1927
WWTP	Wastewater Treatment Plant
WY	Water Year
yd^3	cubic yard
YOY	Young-of-year fish

EXECUTIVE SUMMARY

The Remedial Investigation (RI) report summarizes the physical, chemical, and biological characteristics of the Lower Fox River and Green Bay. The purpose of the RI report is to compile and evaluate these data to support development of the Baseline Human Health and Ecological Risk Assessment (RA) and Feasibility Study (FS). The RA identifies the risks posed to human health and the environment by compounds of concern. The FS develops and evaluates a range of remedial alternatives to support the selection of a remedy that will eliminate, reduce and/or control these risks. 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 RI study area includes the Lower Fox River extending 63 km (39 mi) from Lake Winnebago to Green Bay as well as the entire 4,150 km^2 (1,600 mi^2) of the bay. Green Bay is 190 km (119 mi) in length and averages 37 km (23 mi) in width. The Lower Fox River was subdivided into four river reaches. Green Bay is subdivided into zones 2, 3, and 4 (Figure 1). The Green Bay Area of Concern, as designated by the International Joint Commission, is defined as the De Pere to Green Bay Reach and much of Green Bay Zone 2.

The RI evaluated data from numerous investigations conducted within the study area since 1971, which comprise the Fox River Database (FRDB). Sediment, water, and biological samples in the FRDB include analyses for over 200 chemical parameters. Based on these analyses, a Screening Level Risk Assessment identified polychlorinated biphenyls (PCBs), dieldrin, DDT, dioxins/furans, mercury, lead, and arsenic as the compounds present in the study area that represent potential risks to human health and the environment. However, PCBs are the primary compounds of concern.

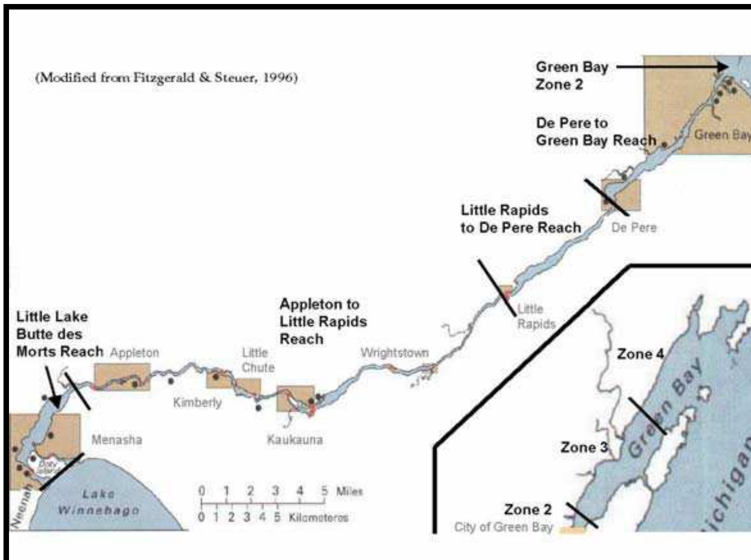

Figure 1. Remedial Investigation Study Areas

Site History and PCB Discharges

In the early 1950s, carbonless copy paper was developed through a process that applied an emulsion containing PCB on paper in a manner that would create document copies. Lower Fox River valley paper mills manufactured and recycled this carbonless paper between 1954 and 1971. About 45 million pounds of PCB were used in the Fox Valley during this time period.

PCBs were released to the environment through manufacturing waste waters and from the de-inking/recycling of waste carbonless copy paper. The Wisconsin Department of Natural Resources (WDNR) estimates the amount of PCB that was discharged to the Lower Fox River from these activities is 313,600 kg (691,370 pounds), with a range from 126,450 kg to 399,450 kg (278,775 to 880,640 pounds). WDNR believes that five facilities contributed over 99 percent of the total PCBs discharged to the Lower Fox River by the end of 1971.

In the late 1970s, commercial production of PCBs in the United States was prohibited due to concerns for human health and the environment. At the present time, some minor unavoidable point source discharges along with atmospheric deposition of PCB continue, but are small compared to the PCB mass present in the river and bay sediments.

Prior to implementation of the federal Clean Water Act in 1972, rough fish were the main species that could live in the Lower Fox River. With implementation of the Clean Water Act and more stringent control over wastewater discharges, water quality in the river improved and game fish began to return to the river. PCBs were detected in trout from Green Bay as early as 1971. Due to continued elevated PCB levels, WDNR issued advisories for public consumption of fish (1976) and waterfowl (1983) derived from Green Bay and the Lower Fox River. The state of Michigan also issued consumption advisories for Green Bay fish in 1977.

PCB Distribution and Sediment Volumes

Considering sediments containing more than 50 μg/kg PCB, about 28,600 kg (63,050 pounds) of PCBs are contained within about 9 million m^3 (11.8 million yd^3) of sediment in the Lower Fox River. In Green Bay, approximately 68,200 kg (150,300 pounds) of PCBs are dispersed in about 465 million m^3 (610 million yd^3) of sediment. The distribution of PCB mass, sediment volume and sediment areal extent are shown on Figure 2. Also shown on Figure 2 is the ratio of PCB mass to sediment volume. The reaches upstream of the De Pere dam are combined on Figure 2 because of their relatively small PCB mass, sediment volume and areal extent.

Much of the PCB discharged into the Lower Fox River has already been transported downstream and is now concentrated in sediments within specific areas:

- The De Pere to Green Bay Reach contains almost 26,000 kg of PCB, which represents about 91 percent of the mass remaining in the river. This reach contains just under 27 percent of the total PCB mass in the system and is concentrated within a relatively small area comprising just over one percent of the total sediment volume. This reach also exhibits the highest mass of PCB per volume of sediment.

- Approximately 70 percent of the total PCB mass in the system has migrated from the river into Green Bay.

- The PCB mass in Green Bay is dispersed over an extraordinarily large area and in an extremely large sediment volume. Almost half of the total PCB mass in Green Bay is found in Zone 2.

Sediment and PCB Transport

Particle size and cohesion along with river/bay conditions, especially current speeds, control the deposition, resuspension, and transportation of sediments (and the PCBs absorbed to them). In the Lower Fox River, sediments have accumulated in 35 separate deposits above

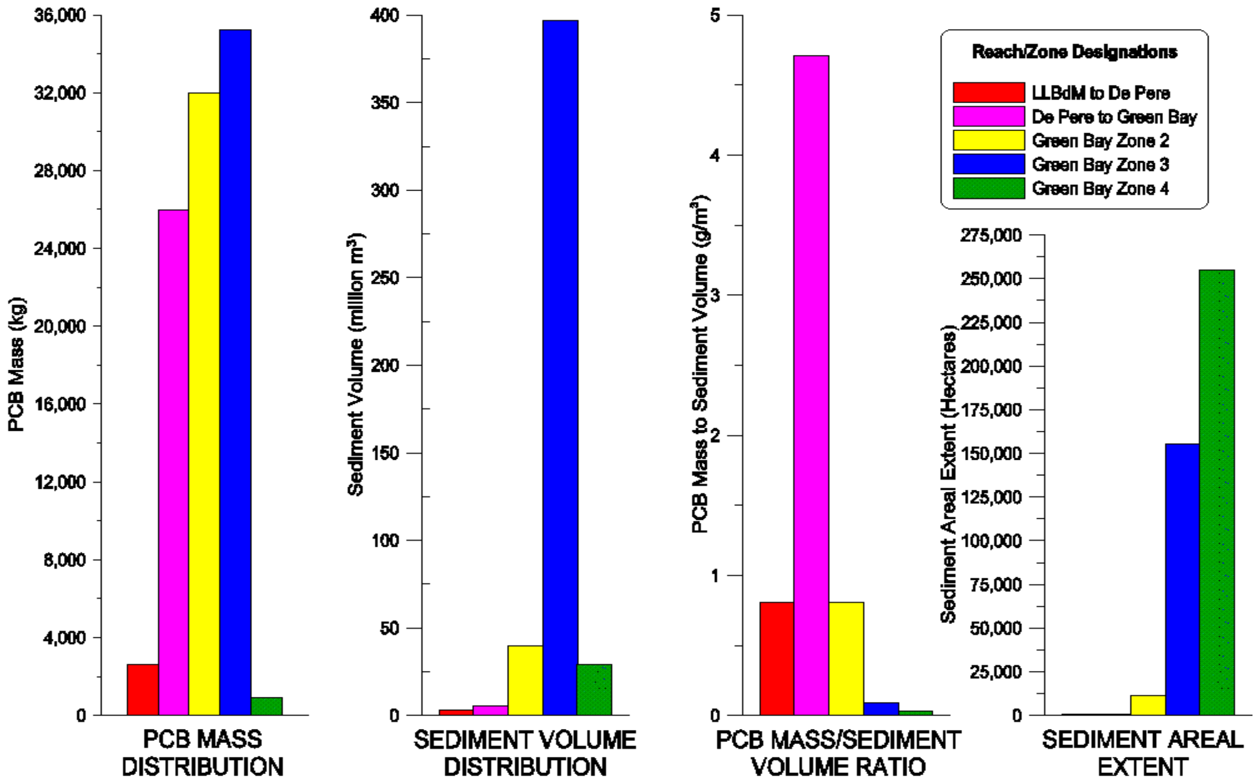

Figure 2. PCB Mass & Sediment Volume/Area Distribution by river reach and bay zone

the De Pere dam. Below the De Pere dam and in Green Bay, where current speeds tend to be lower, sediments cover large areas of the river and bay bottom, except in areas where the sediments are dredged to maintain ship navigation. The highest PCB concentrations have also been observed in the LLBdM and De Pere to Green Bay reaches, in the vicinity of historic discharge points.

The average river discharge was about 122 m^3/s (4,300 cfs) between 1989 and 1998. Due to storm events and spring snowmelt, the river discharge exceeds 272 m^3/s (9,600 cfs) more than 10 percent of the time. These faster currents have the capability to resuspend and transport larger particle sizes and greater volumes of sediment and, therefore, a greater mass of PCB. Field measurements and computer modeling results suggest that these less-frequent, high-discharge events transport much of the PCB mass in the river over the De Pere dam and into Green Bay. In addition to sediment transport, PCB migrates due to dissolution in water and adsorption onto algae and other organic matter. The PCB mass transported from reach to reach increases along the river. Based on sampling data collected as part of the Green Bay Mass Balance study in 1989-90, about 280 kg (610 pounds) of PCB were transported to Green Bay during the study period. Based on work done in 1994-95 as part of the Lake Michigan Mass Balance, it was estimated that 220 kg (485 pounds) of PCB moved from the river into the bay. PCB loads to the bay vary as the river flow varies. This mass represents up to 1 percent of the PCB mass in the river.

Sediment discharged from the Lower Fox River is directed toward the east shore of Green Bay by counterclockwise currents. This sediment-rich water can extend between 20 km to 40 km (12 mi to 24 mi) along the east shore. Fluctuating water levels, wave action and reverses in stream flow in this area facilitate sediment transport and mixing. Consequently, large volumes of sediment containing PCB are present along the southern and eastern portions of Green Bay. At least 68,200 kg (150,300 pounds) of PCBs already reside in the bay. Over 95 percent of the PCB that occurs in Green Bay is derived from the Lower Fox River.

This transport of PCB also extends into Lake Michigan. During 1989/90, it was estimated as part of the Green Bay Mass Balance Study that about 122 kg (270 pounds) of PCBs were transported from Green Bay to Lake Michigan. Other mass transport pathways (such as volatilization) also exist.

Ecological Samples and Characteristics

Exposure of biota to sediments and water containing PCB fosters uptake of PCBs into the food chain. Wetlands, submerged aquatic vegetation, and islands along the Lower Fox River and Green Bay offer nesting/spawning, feeding, and refuge opportunities for fish, birds, and animals. Other lacustrine, riverine, and estuary features also provide habitat for regional wildlife. In addition to birds and fish, the FRDB contains information on PCBs in deer, otter, mink, and various insects and invertebrates. The RA evaluates PCB uptake and accumulation in selected species and the associated human health and environmental risks. Areas with higher PCB concentrations tend to pose a greater risk of exposure.

Effects of Time

The FRDB includes sediment and water results from over a 10 year period while tissue samples were collected between 1971 and 1999. During the 1970s, after PCB discharges into the river ceased, PCB concentrations in fish tissue showed significantly declining concentrations. However, since the mid-1980s, changes in the rate of PCB decline in fish tissue have been observed. Changes in PCB levels in fish tissue have either slowed, remained constant, or is some cases actually increased.

PCB concentration trends in the upper 10 cm (4 in) of sediment are inconsistent, but generally appear to be decreasing over time as more PCB is transported downstream. Soil eroded from the watershed mixes with and may further dilute PCB concentrations in the sediments.

Further Information

The selection of remedies for the Lower Fox River and Green Bay will consider the information within the RI, RA and FS, as well as input by the public and interested parties. For further information, please contact:

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1 Introduction

1.1 Project Overview and Objectives

The RETEC Group, Inc. (RETEC) and was contracted by the Wisconsin Department of Natural Resources (WDNR) in March 1998 to complete a Remedial Investigation (RI), Feasibility Study (FS), and Risk Assessment (RA) for chemically impacted sediments in the Lower Fox River and Green Bay. This project is being conducted under the direction of WDNR, with funding and technical assistance from the United States Environmental Protection Agency, Region 5 (EPA). On July 9, 1998, the EPA proposed adding the Lower Fox River and Lower Green Bay to the National Priority List (NPL) (Superfund). This project has been conducted in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the National Contingency Plan (NCP).

The overall objective of this RI/FS/RA is to develop the necessary supporting information for the selection of a sediment remediation approach for the Lower Fox River and Green Bay that will be protective of human health and the environment. The Lower Fox River study area is defined as the 63 kilometer (km) (39 mile [mi]) portion of the river beginning at the outlet of Lake Winnebago and terminating at the mouth of the river into Green Bay (Figure 1-1). The study area also includes all of Green Bay, which is shown on Figure 1-2.

The RI report, prepared by RETEC and Natural Resource Technology, Inc. (NRT), describes the physical, chemical and biological characteristics of the Lower Fox River and Green Bay. The RA report has been prepared concurrently with this RI report and assesses the potential risks posed to human health and the environment from the compounds found in the Lower Fox River and Green Bay ecosystems. The FS report evaluates applicable remedial alternatives to support the selection of a remedy to eliminate, reduce, and/or control risks identified in the RA. This RI/FS report is consistent with the findings of the National Academy of Science's National Research Council Report entitled *A Risk Management for PCB Contaminated Sediments* (NRC, 2001).

The RI included the following activities:

- Compilation, review, and organization of existing data available for the Lower Fox River and Green Bay.

- Assessment of the quality and usability of the existing data.

- Collection of additional sample data in selected areas of the Lower Fox River during the summer of 1998.

- Description of the physical and ecological characteristics of the Lower Fox River and Green Bay along areas of sediment deposits.

- Evaluation of the occurrence, volume, and mass of chemical parameters of concern in sediment and water.

This RI report describes the magnitude and extent of chemicals of concern in sediments and water only. A substantial amount of chemical data have been collected from a variety of biological organisms. Biological impacts and their implications within the river system are addressed in the RA report.

1.2 Study Area Overview

General descriptions of the Lower Fox River and Green Bay are presented below to provide information about the physical setting of the RI study area and region.

1.2.1 Lower Fox River

The Lower Fox River flows northeast approximately 63 km (39 mi) from Lake Winnebago, the largest inland lake in Wisconsin, to Green Bay (Figure 1-1). The Fox River is the largest tributary to Green Bay, draining approximately 16,395 square kilometers (km^2) (6,330 square mi [mi^2]). The river has a mean discharge into Green Bay of approximately 122 cubic meters per second (m^3/s) (5,000 cubic feet per second [cfs]) (USGS, 1998c; Fitzgerald and Steuer, 1996). The change in river elevation between Lake Winnebago and Green Bay is approximately 51 meters (m) (168 ft) (National Oceanic and Atmospheric Administration [NOAA], 1992).

Historically, the Lower Fox River is impounded by 13 dams and 17 locks, which once made it navigable between Lake Winnebago and Green Bay. Currently, the Rapide Croche Lock is permanently closed to restrict sea lamprey migration and only the last two locks (at Little Rapids and De Pere) are open to recreational boats. The Lower Fox River is bounded upstream by two dams in the cities of Neenah and Menasha that control the pool elevation of Lake Winnebago and discharge to the river. The Neenah and Menasha channels connect Lake Winnebago with Little Lake Butte des Morts (LLBdM). LLBdM is a relatively shallow section of the Lower Fox River, approximately 1,070 m (3,500 ft) wide and extending approximately 4.8 km (3 mi) (Figure 1-3).

Between the outlet of LLBdM and the Little Rapids dam, the Lower Fox River is generally less than 300 m (1,000 ft) wide and the channel meanders more in this stretch of the river than in other downstream reaches (Figure 1-4). 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 LLBdM (Figure 1-5).

From the De Pere dam to the mouth, the Lower Fox River is a large, channelized stream that is stabilized along much of this stretch with either riprap or concrete reinforcement (Figure 1-6). Navigation for ocean bound vessels extends upriver approximately 4.8 km (3 mi) from Green Bay to the Fort James Paper Company (formerly Fort Howard) turning basin via a navigation channel with a maintained water depth of about 7.3 m (24 ft). Flow in this section of the river is sometimes reversed by wind-driven increases in Green Bay water levels, commonly known as seiche events.

1.2.2 Green Bay

The Green Bay of Lake Michigan is a narrow, elongated bay, oriented in a north-northeast -south-southwest (NNE-SSW) direction (Figure 1-2). 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 bay lies on the northeast shore of Wisconsin and the southeast shores of Michigan's Upper Peninsula (UP). The bay is bounded by the city of Green Bay at the south end and by both Big Bay de Noc and Little Bay de Noc on the north end. Big Bay de Noc and Little Bay de Noc are separated by the UP's Stonington Peninsula (Sinclair, 1960). In Wisconsin, the bay is separated from Lake Michigan by the Door Peninsula while the UP's Garden Peninsula separates Big Bay de Noc from Lake Michigan (Figure 1-2). Green Bay is connected with the remainder of Lake Michigan on its northeast side along a line between Washington, Rock, St. Martin's, Poverty, and Summer Islands (Figure 1-2). Rock Island, which lies about 2.4 km (1.5 mi) north of Washington Island, marks the northern tip of Door County. The islands north of Rock Island lie within the state of Michigan.

Green Bay is approximately 190 km (119 mi) long and has an average width of 37 km (23 mi). The 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 mean depth of the bay is approximately 20 m (65 ft). The maximum depth reaches 54 m (176 ft) at a location about 6.4 km (4 mi) west of Washington Island (Bertrand, *et al.,* 1976).

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's UP (Bertrand, *et al.,* 1976). Although there are a number of Green Bay tributaries, the United States Geological Survey (USGS) has measured discharge for 10 tributaries. The measured discharge for these tributaries, along with the drainage area for each, is summarized below. Except for the Lower Fox River, the discharge results listed below are for Water Years 1989 and 1990, which run from October 1, 1998 through September 30, 1990. Data from the Lower Fox River extends from 1898 through 1998.

The Fox River is by far the largest Green Bay tributary based on both discharge and drainage area. The Fox River contributes approximately 42 percent of the total drainage into Green Bay (Bertrand, *et al.,* 1976). Due to its volume, as well as the relatively higher concentration of industrial activity and pollutant load, the Fox River is the tributary of greatest interest with respect to sediment and water quality in Green Bay. Over 95 percent of the polychlorinated biphenyl (PCB) load and 70 percent of the suspended sediments flowing into the bay are derived from the Lower Fox River (WDNR, 1999a; Smith, *et al.,* 1988).

The Menominee River is the only other Green Bay tributary with a mean discharge over 56.6 m^3/sec (2,000 cfs) and a drainage area over 10,000 km^2 (3,861 mi^2). In addition to the ten tributaries that USGS measured, five other Green Bay tributaries have been utilized by LTI Environmental Engineering (LTI, 1999) to model PCB and solids loads into Green Bay. However, stream discharge data were not available for these five tributaries.

Summary of Green Bay Tributaries

Tributary	State	Drainage Area Km^2(mi^2)	Mean Discharge m^3/sec (cfs)
Fox	WI	16,394 (6,330)	149 (5,262)
Duck	WI	394 (152)	1.2 (42.6)
Suamico	WI	157 (60.7)	0.95 (33.4)
Pensaukee	WI	386 (149)	1.7 (59)
Oconto	WI	2,416 (933)	15.9 (560)
Peshtigo	WI	2,991 (1,155)	20 (704)
Menominee	WI/MI	10,748 (4,150)	78 (2,750)
Cedar	MI	917 (354)	N/A
Ford	MI	1,282 (495)	9.3 (327)
Escanaba	MI	2,383 (920)	23 (828)
Tacoosh	MI	75 (29)	N/A
Rapid	MI	352 (136)	N/A
Whitefish	MI	811 (313)	N/A
Sturgeon	MI	523 (202)	5.3 (188)
Fishdam	MI	243 (94)	N/A

Circulation within Green Bay is largely controlled by the prevailing southwesterly winds, which causes a large-scale generally counterclockwise circulation of the bay waters (Miller and Saylor, 1985; Smith, *et al.,* 1988). Localized currents are present throughout the bay and rotate both clockwise and counter-clockwise (HydroQual, 1999). The bay is also subject to seiches, defined as cyclical short-term oscillation of water levels caused by the earth's rotation, wind, and/or abrupt changes in barometric pressure. The seiches typically change water levels by several centimeters in the southern end of Green Bay, resulting in reversed flow in the Lower Fox River. Combined with storm conditions, seiche events have raised water levels at the mouth of the river by over one meter and the seiche effects can extend up to the De Pere dam, 11.3 km (7 mi) upstream from the mouth of the river. Seiche events result in the relatively rapid mixing of sediment-rich tributary waters, and therefore contaminant loads, with the water of Green Bay.

Discharge from the Lower Fox River into Green Bay is directed towards the east by the counterclockwise circulation pattern. Plumes of sediment-rich water can extend up to 20 km along the east shore of the bay (Smith, *et al.,* 1988). Sediment initially deposited in the southern end of the bay can become resuspended due to seiche events and be redeposited further up the east shore. Consequently, the majority of river-related sediment in Green Bay is present along the southern and eastern shores of the bay.

Larger urban areas located along the west shore of Green Bay include the cities of Green Bay, Marinette, Peshtigo, and Oconto, Wisconsin and Escanaba and Menominee, Michigan. The city of Sturgeon Bay, Wisconsin, is the largest urban area located on the east shore of Green Bay (Figure 1-2).

1.3 Study Area River Reaches and Bay Zones

In order to facilitate data presentation and discussion in the RI, the Lower Fox River and Green Bay have been divided into reaches and zones, respectively. These river reach and bay zone designations are used throughout the RI/FS/RA and are described below.

1.3.1 Lower Fox River Reaches

Based on previous investigations, the river has been divided into four reaches and, further, into specific sediment deposits or units within these reaches. Three of these reaches are located upstream of the De Pere dam and the fourth reach extends from the De Pere dam to the mouth of the river. Above the De Pere dam, there are 35 individual sediment deposits (WDNR, 1995). From the De Pere dam to the mouth of the river at Green Bay soft sediment is present over almost the entire river bottom and individual deposits were not established. Rather, the river bottom in this reach was separated into discrete sediment management units (SMUs). The reaches and associated sediment deposits/SMUs discussed in this RI report (as well as in the RA and FS reports) include the following:

- **Little Lake Butte des Morts (LLBdM) Reach** (Figure 1-3) - Extending from the outlet of Lake Winnebago to Appleton for a distance of approximately 10 km (6 mi), this reach includes sediment deposits A through H and POG.

- **Appleton to Little Rapids Reach** (Figure 1-4)- Extending from Appleton to the Little Rapids dam for a distance of approximately 32 km (20 mi), this reach includes deposits I through DD. Sediments in deposits N and O were dredged from the river as part of the sediment remediation demonstration project in the fall of 1998 and the summer through fall of 1999.

- **Little Rapids to De Pere Reach** (Figure 1-5) - Extending from the Little Rapids dam to the De Pere dam for a distance of approximately 9.7 km (6 mi), this reach includes sediment deposits EE through HH. These deposits form a nearly continuous layer of soft sediment that extends for approximately 8.5 km (5 mi) upstream of the De Pere dam.

- **De Pere to Green Bay Reach** (Figure 1-6) - This reach extends about 11.3 km (7 mi) from the De Pere dam to the mouth of the Fox River. Due to the presence of a large and continuous layer of soft sediment between the dam and the river mouth, this area has been divided into 96 SMUs (numbered 20 through 115) and 16 water column segments (6 SMUs to a segment). The SMUs and water column segments were initially established for computer modeling studies. This reach is also referred to as Green Bay Zone 1 for certain modeling activities.

1.3.2 Green Bay

1.3.2.1 Green Bay Zones

Green Bay has been subdivided into four zones by previous investigators (EPA, 1989). Green Bay zones 2, 3, and 4 are shown on Figure 1-2.

- **Zone 1** is identical to, and will be referred to hereinafter as, the De Pere to Green Bay Reach of the Lower Fox River, as discussed above.

- **Zone 2** (Figure 1-2) extends from the river mouth to a line perpendicular with the long axis of the bay (trending northwest-southeast (NW-SE)) about 12.2 km (7.6 mi) from the river mouth. This line crosses the bay near Little Tail Point on the west side of the bay (659,977.31E & 447,330.59N, Wisconsin Trans-Mercator Projection, 1927 [WTM 27]) and near Red Banks/Point Vincent on the east side of the bay (668,804.12E & 441,069.64N, WTM 27) (Velleux, 2000). This is approximately 10 km (6.2 mi) south of Dyckesville, Wisconsin.

- **Zone 3** (Figure 1-2) extends from the east-west line marking the northern boundary of Zone 2 to a line just below Chambers Island. The northern boundary of Zone 3 is located about 87 km (54 mi) north of the mouth of the Fox River. Therefore, Zone 3 extends for a distance of approximately 75 km (47 mi). The boundary line of Zone 3 connects Beattie Point, in the Michigan UP (695,979.10E & 511,652.33N WTM 27) to Fish Creek, Wisconsin (715,892.56E & 500,356.72N WTM 27) on the Door Peninsula (Velleux, 2000).

- **Zone 4** (Figure 1-2) includes the remainder of Green Bay north of Chambers Island, including both Big Bay de Noc and Little Bay de Noc. From the south side of Chambers Island to the northern shores of Big Bay de Noc, the distance is approximately 102 km (63 mi).

Green Bay zones 2 and 3 are further divided into “east” and “west” segments by a line trending northeast-southwest (NE-SW) from the 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 (Figure 1-2).

1.3.2.2 Inner and Outer Bays

Green Bay is also divided into the “inner”and “outer” bay and Chambers Island generally serves as the line of demarcation between these two areas. For the purposes of this RI/FS the "inner bay" includes Green Bay zones 2 and 3 and the "outer bay" is Zone 4, although there may be other uses of these terms in other literature and studies. The inner and outer bay designations are based on the physical environment of Green Bay, since water depths of the inner bay are much shallower than depths of the outer bay. Also, due to these depths, the water temperatures and the commercial and sport fisheries of the inner and outer bay are different.

1.3.2.3 Lower Green Bay

Previous researchers, as well as the efforts described herein, indicate that the majority of the PCB impacted sediments occur within the inner bay and the highest concentrations of PCBs are located in Zone 2, south of Long Tail Point and Point Au Sable. Use of the term “lower Green Bay” refers to this portion of Zone 2, located between the mouth of the Lower Fox River and these two points.

1.4 Background

The following information describes the development of the river and bay region as well as historical conditions and resources. This section also describes how historical development and practices have impacted the river and bay regions.

1.4.1 Site History

Green Bay and the Lower Fox River have long been important transportation corridors within the state of Wisconsin. Abundant and reliable food supplies, as well as other natural resources in the area, fostered development prior to arrival of Europeans to the region. French explorers arrived in the region in 1634 when Jean Nicolet landed on the eastern shore of Green Bay at Red Banks (Burridge, 1997). Following this, the French began colonizing the area, focusing on its vast wealth of furs and game, and exploring for routes further west. In addition to naming Green Bay, the French also referred to the bay as “La Baye de Puans” or the “Stinking Bay” (Burridge, 1997). This name reflected the observations of the

French explorers, likely indicating that lower Green Bay was a characteristically eutrophic water body.

French dominance in the area declined after 1731, as British and Canadian influence in the area increased. British and Canadian interests were dominant in the area until the end of the War of 1812, when the area became a territory of the United States (Burridge, 1997). 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).

An important factor in development of the area was the presence of the Fox and Wisconsin Rivers. Early residents proposed connecting Green Bay and the Mississippi River via the Fox and Wisconsin Rivers. 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 modifications 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. Following many unsuccessful attempts to complete a viable water-way connecting Green Bay with the Mississippi River, the federal government, through the United States Army Corps of Engineers (USACE), assumed authority for maintaining the Lower Fox River and Green Bay navigation channel and system. With this, came the responsibility for maintaining the Lower Fox River dams, locks, and canals. The structures the USACE took control of in 1872 are listed below. The USACE is still listed as owner of eight dams on the Lower Fox River (Table 3-8).

Lower Fox River Dam, Lock, and Canal Summary - 1872 (Burridge, 1997)

Dam	Canal length	Elevation Drop	Power Generation (horsepower)
Menasha Dam	1,317 m (4,320 ft)	2.5 m (8.2 ft)	2,487
Appleton Upper Dam	1.9 km (1.2 mi)	4.3 m (14 ft)	4,238
Appleton Middle Dam		4.3 m (14 ft)	2,225
Appleton Lower Dam		2.6 m (8.5 ft)	2,558
Cedars Dam (at Kimberly)	no listing	no listing	no listing
Little Chute Dam	1,980 m (6,500 ft)	11 m (36.2 ft)	no listing
Combined Locks Dam	no listing	6.6 m (21.8 ft)	no listing
Grand Kaukauna Dam	2,255 m (7,400 ft)	15.3 m (50.3 ft)	no listing
Rapide Croche Dam	536 m (1,760 ft)	2.6 m (8.6 ft)	no listing
Little Rapids Dam	290 m (950 ft)	2.1 m (7 ft)	no listing
De Pere Dam & Lock	no listing	2.7 m (9 ft)	no listing

Development of the Lower Fox River and Green Bay area increased with development of the river and bay navigation channel and system. Along with development came utilization, exploitation, and degradation of the local resources, including the water quality of the river and bay.

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

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

During the late 1800s, the commercial fishing industry had been established in the Green Bay area. However, due to pollution, over fishing, and the introduction of exotic species in Green Bay, several of the bay's most prized fishes disappeared. These included lake sturgeon, herring, and lake trout.

In 1938-39, a Pollution Survey of Green Bay and the Lower Fox River (De Pere to Green Bay Reach) was completed by the Wisconsin State Board of Health -Committee on Water Pollution and the Green Bay Metropolitan Sewerage District (GBMSD). The pollution survey was conducted to investigate the fish die-offs reported by local fishermen in Green Bay and other nuisance concerns.

A similar survey of the Lower Fox River in 1925-26 had found that "intolerable conditions existed for aquatic life during the critical summer months from below Wrightstown to Green Bay" (Wisconsin State Board of Health, 1939). Conclusions of the 1938-39 Pollution Survey (Wisconsin State Board of Health, 1939) included the following:

- Waste sulfite liquors were determined to be the major source of pollution in Green Bay during the winter months, and oxygen depletion occurs along the east side of Green Bay, reflecting the counterclockwise currents of the bay.

- Typical ice coverage in the bay would likely result in oxygen-depleted conditions, especially along the east side of the bay, and near the reported fish die-offs.

- The DO levels at De Pere, the Mason Street bridge in the city of Green Bay, and the mouth of the river were so low that the water could not support fish life during periods of warm temperature and low stream flows (during August and September).

- Although sewage treatment plants had removed large quantities of solids and scum from the river and lowered the bacterial load, the oxygen demand did not decrease significantly because it was calculated that 88 percent of the oxygen demanding materials were associated with the waste sulfite liquors.

The degraded conditions of the Lower Fox River and Green Bay continued into the 1940s and 1950s. Due to high levels of fecal coliform bacteria, resulting from the discharge of untreated municipal sewage, Green Bay's public beach was permanently closed to swimming in 1943. Due to a declining water table and groundwater supplies, as well as the pollution of the Lower Fox River and Green Bay, the city of Green Bay built a water supply pipeline in 1955 to bring Lake Michigan water to the city. The water supply line extends approximately 48 km (30 mi) from Green Bay to Kewaunee and it draws Lake Michigan water through an intake located about 6.4 km (4 mi) offshore.

Yellow perch populations, which had been the mainstay of the local commercial fishing industry, declined significantly during this time period. In 1943, approximately 1.08 million kilograms (kg) (2.4 million pounds) of yellow perch were caught; by 1966 the catch had declined to 73,480 kg (162,000 pounds), a decrease of more than 90 percent (Smith, *et al.*,1988). Further, in 1976, WDNR instituted fish consumption advisories and restricted commercial harvesting due to the presence of PCBs in the fish of the Lower Fox River and Green Bay. Due to the continued presence of PCBs in fish, the WDNR has restricted the commercial yellow perch catch in Green Bay to 90,720 kg (200,000 pounds) annually. The fish consumption advisories, as well as the introduction and migration of exotic species into Green Bay, continue to disrupt and severely limit commercial fishing.

Besides the decline in the commercial fishing catch, the populations of many piscivorous (fish-eating) birds also declined in the 1960s. Bird populations suffered from the eggshell-thinning effects of chlorinated pesticides, such as p.p'-dichlorodiphenyltrichloroethane (DDT) and dieldrin and EPA moved to ban these two pesticides in the early 1970s. The effects associated with chlorinated pesticides lead to concerns about other chlorinated compounds, including PCB, pentachlorophenol (PCP) and dioxins/furans. PCB, DDT and dieldrin were all detected in piscivorous birds in 1987 and 1988, years after the use and discharge of these compounds had been discontinued (Dale and Stromberg, 1993).

1.4.2 Historical PCB Use and Discharges

Based on the historical discharges to the river and bay, numerous compounds can be detected in the sediments and water as well as the aquatic and wildlife species within or frequenting the river and bay. During the early 1980s, more than 100 potentially toxic substances were found in Lower Fox River sediments, water, and fish tissue (Sullivan and Delfino, 1982). Recently, the list of parameters in the river and lower Green Bay have been estimated to include over 360 potentially toxic substances (IJC, 1992), including PCB, mercury, polynuclear aromatic hydrocarbons (PAHs) and ammonia. Other contaminants found in some, but not all deposits/SMU groups include the pesticides DDT, p.p'-dichlorodiphenyldichloroethylene (DDE), and p.p'-dichlorodiphenyl-dichloroethane (DDD), and PCP. Of the potentially toxic substances found, the Baseline Human Health and Ecological Risk Assessment report (RETEC, 2002) concluded that PCBs are the primary chemicals of concern.

During the 1950s, 60s, and 70s, many industries throughout the United States used and/or produced products that contained PCB. PCBs include a class of 209 related chlorinated organic compounds that share similar chemical properties and structure. PCB use was widespread because these compounds are chemically very stable, have a high heat capacity, and do not easily degrade in water. PCBs were historically used in electrical equipment, hydraulic fluids, fire retardants, cutting oil, and a number of other commercial and industrial processes (Merck, 1989).

In the early 1950s, National Cash Register (NCR) developed carbonless copy paper for office and business use. When struck by a typewriter or pressed with a pen, a coating of PCB emulsion on the paper released oils to produce the document copy. In 1954, local paper mills in the Lower Fox River valley began manufacturing carbonless copy paper and PCBs were released to the environment through process waste waters and through the de-inking and recycling of waste carbonless copy paper. Due to rising health concerns about PCBs released to the environment, use of PCBs in the production of carbonless copy paper ceased in 1971. However, recycling of the carbonless copy paper may have continued for a short time thereafter. Monsanto, the primary manufacturer of PCBs in the United States, ceased distribution of PCBs for applications which were uncontained and open to the environment in 1977.

The companies/entities involved in the manufacturing and recycling of carbonless copy papers have been identified as the potentially responsible parties (PRPs) pursuant to CERCLA. These companies formed the Fox River Group (FRG), which collectively have undertaken studies evaluating PCB impacts to the river and bay system. The FRG includes 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.

WDNR completed an evaluation of PCB discharges to the Lower Fox River beginning in the 1950s and coinciding with the production and recycling of carbonless copy paper. WDNR (1999a) estimated that approximately 313,600 kg (691,370 pounds) of PCBs were released to the environment during this time, although the discharge estimates range from 126,450 kg to 399,450 kg (278,775 pounds to 880,640 pounds), based on the percentages of PCBs lost during production or recycling of carbonless copy paper. WDNR (1999a) estimated that 98 percent of the total PCB released into the Lower Fox River had occurred by the end of 1971. Further, 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.

Currently, PCBs are discharged into Green Bay at the mouth of the Lower Fox River through sediment transport and PCB dissolution in the water column. Sediments are the most significant source of PCBs entering the water column (Fitzgerald and Steuer, 1996), and over 95 percent of the PCB load into Green Bay is derived from the Lower Fox River (WDNR, 1999a). Based on the data analyzed as part of this effort, approximately 70,000 kg (154,300 pounds) of PCBs have already escaped from the Lower Fox River into Green Bay.

1.4.3 Regulatory Response

1.4.3.1 Clean Water Act

In response to growing public concern about widespread and serious water pollution, Congress passed the Clean Water Act (CWA) in 1972. The CWA was the first comprehensive national clean water legislation and is the primary federal law protecting our nation's lakes and rivers. The CWA objectives were two-fold: 1) eliminate discharge of pollutants in the water; and 2) achieve water quality levels that support recreational activities, namely fishing and swimming. The objectives were met by allowing the states to set specific water quality criteria, require surface water discharge performance standards and to develop pollution control programs to meet these criteria.

1.4.3.2 Wisconsin Pollution Discharge Elimination System

The implementation of the Wisconsin Pollution Discharge Elimination System (WPDES) program in the mid-1970s greatly reduced the pollutant load to the Lower Fox River. However, low levels of PCBs were still detected in industrial and municipal wastewater discharges associated with the paper mills into 1990, due to the persistence and ubiquitous occurrence of these compounds in the environment (WDNR, 1999a). One of the largest pollutant loads identified within the area of concern (AOC), besides municipal and industrial discharge outfalls, was in-place sediments, especially with respect to PCBs.

1.4.3.3 Great Lakes Areas of Concern

Coinciding with passage of the CWA, the Great Lakes Water Quality Agreement (GLWQA) was signed by the United States and Canada in 1972 and amended in 1978 and 1987. The GLWQA established specific goals and remedial objectives for improving water quality within the Great Lakes Basin. Forty-three AOCs were identified for further assessment and management of Great Lakes water quality. The lower Green Bay and Lower Fox River were designated as an AOC. This AOC includes the Lower Fox River from the De Pere dam to the river mouth (11.3 km [7 mi]) as well as the southern portion of Green Bay.

The lower Green Bay Remedial Action Plan (RAP) (WDNR, 1988) established goals, objectives, and a community frame-work for implementing remedial actions for the lower Green Bay and Fox River AOC. The RAP effort was led by the WDNR with a Citizens Advisory Committee and Technical Advisory Committee, both comprised of representatives of the public and private sectors. Sixteen key actions and 120 associated recommendations were identified to restore the beneficial uses of system. High priority actions included the following:

- Reducing phosphorous and sediment loads to the bay
- Eliminating the toxicity of industrial and municipal discharges and the impacts of contaminated sediment
- Continuing efforts to restore the river's oxygen levels to improve fish habitat

WDNR, the EPA, and U.S. Fish and Wildlife Service (USFWS) have conducted evaluations of PCB contamination in sediment, fish, and wildlife in the Lower Fox River and Green Bay. Due to bio-accumulation of PCBs in fish and fish-eating predators, the WDNR issued the first fish consumption advisory for the area in 1976, while the state of Michigan issued the first Green Bay fish advisory in 1977. Eliminating sediments as a source of PCBs was one of the high priority items established by the RAP. Other significant sources of lake and river water quality degradation include deposition of airborne pollutants, such as PCBs, metals, and PAHs, and polluted runoff, which contributed total suspended solids (TSS) which increase eutrophic conditions within the inner bay (WDNR, 1988).

In addition to the lower Green Bay and Fox River AOC, the Menominee River AOC is located in Green Bay along the shores of the cities of Marinette, Wisconsin and Menominee, Michigan. The Menominee AOC includes the lower 4.8 km (3 mi) of the river from the Upper Scott Paper Company dam (Wisconsin) to the river's mouth and approximately 5 km (3 mi) north and south of the mouth along the adjacent shore of Green Bay. The primary cause of the identified use impairments is arsenic contamination in the turning basin and in sediments along the right bank of the river below the location of the chemical company in Marinette, Wisconsin. Other pollutants, such as mercury, PCBs, and oil and grease have also contributed to use impairments. Although PCBs are present in this AOC, the contribution of PCBs to Green Bay from the Menominee River is far less than from the Lower Fox River. Therefore, the Menominee River AOC is not addressed further in this RI report.

1.5 Application of NRC Findings and Recommendations

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 pose a chronic risk to human health and the environment, and that these risks must be managed. The NRC developed a list of recommendations that captured a need for remedies that 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 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 CERCLA or 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*, which is included 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:

- 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.

- 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.

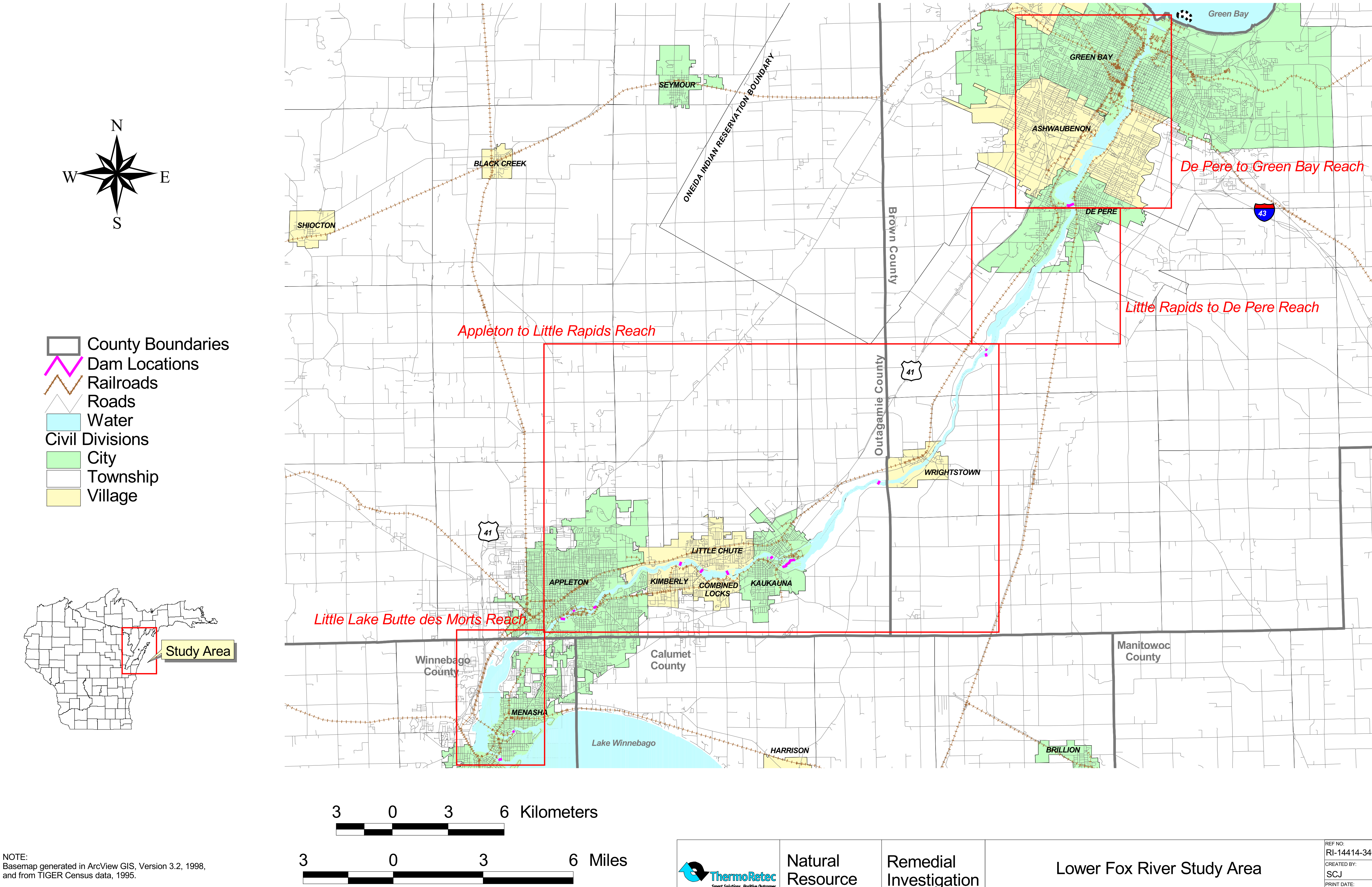
- There are no presumptive remedies. All potential remedial alternatives (including natural attenuation) are evaluated using a range of risk-based sediment clean up values. Local site conditions, feasibility, and estimated long-term risk reduction were defined and estimated for several remedial alternatives (dredging, capping, natural recovery) and carried forward in the FS. Selection of a final remedy will be a management decision defined in the Remedial Action Plan and Record of Decision (ROD),

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.

1.6 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
Figure 1-3 Little Lake Butte des Morts Reach
Figure 1-4 Appleton to Little Rapids Reach
Figure 1-5 Little Rapids to De Pere Reach
Figure 1-6 De Pere to Green Bay Reach



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

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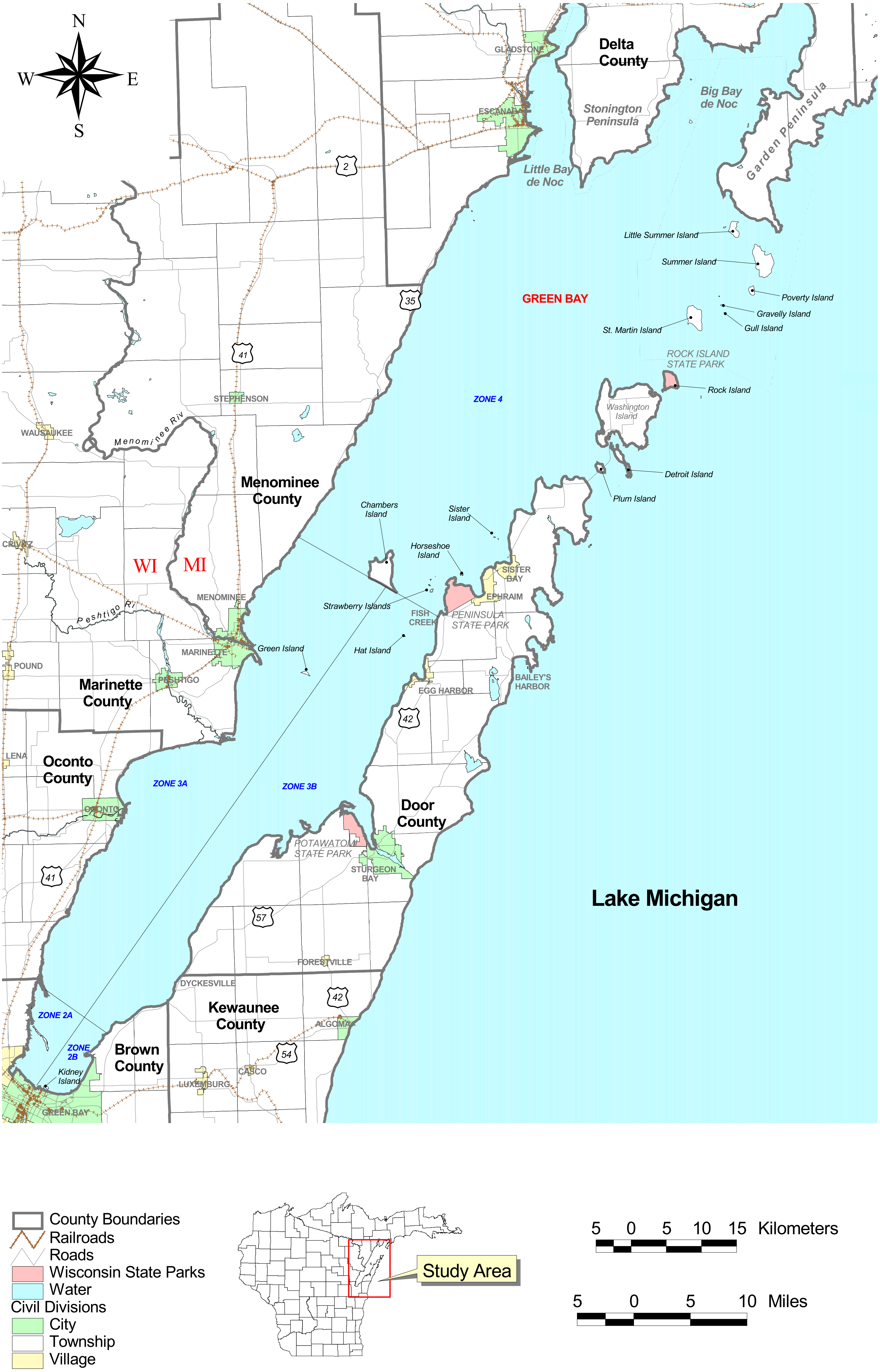
Remedial Investigation Report

Lower Fox River Study Area

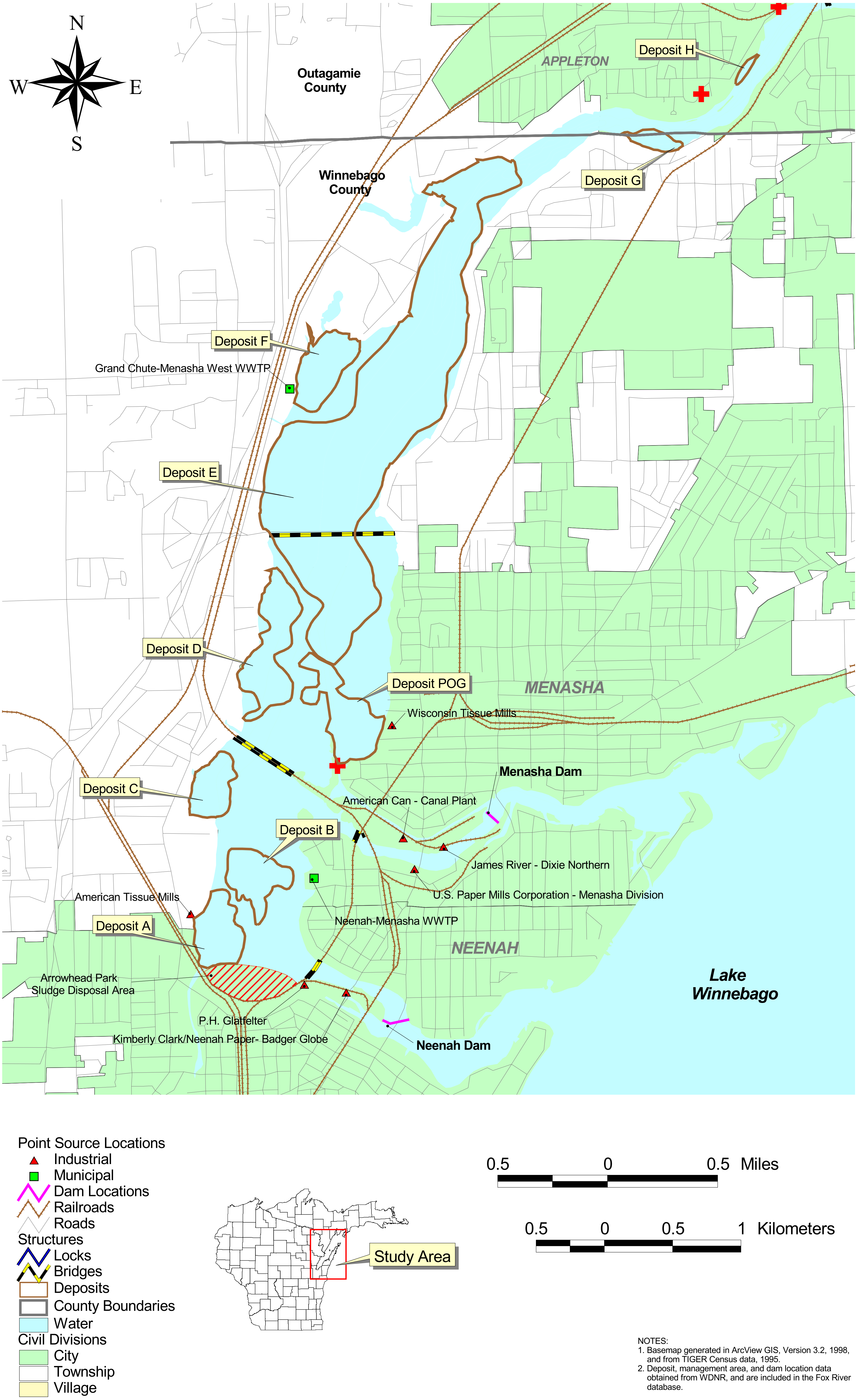
FIGURE 1-1

REF NO: RI-14414-340-1-1
CREATED BY: SCJ
PRINT DATE: 3/14/01
APPROVED: AGF



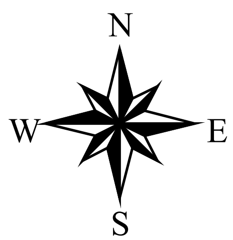
NOTE:
Basemap generated in ArcView GIS, Version 3.2, 1998, and from TIGER Census data, 1995.

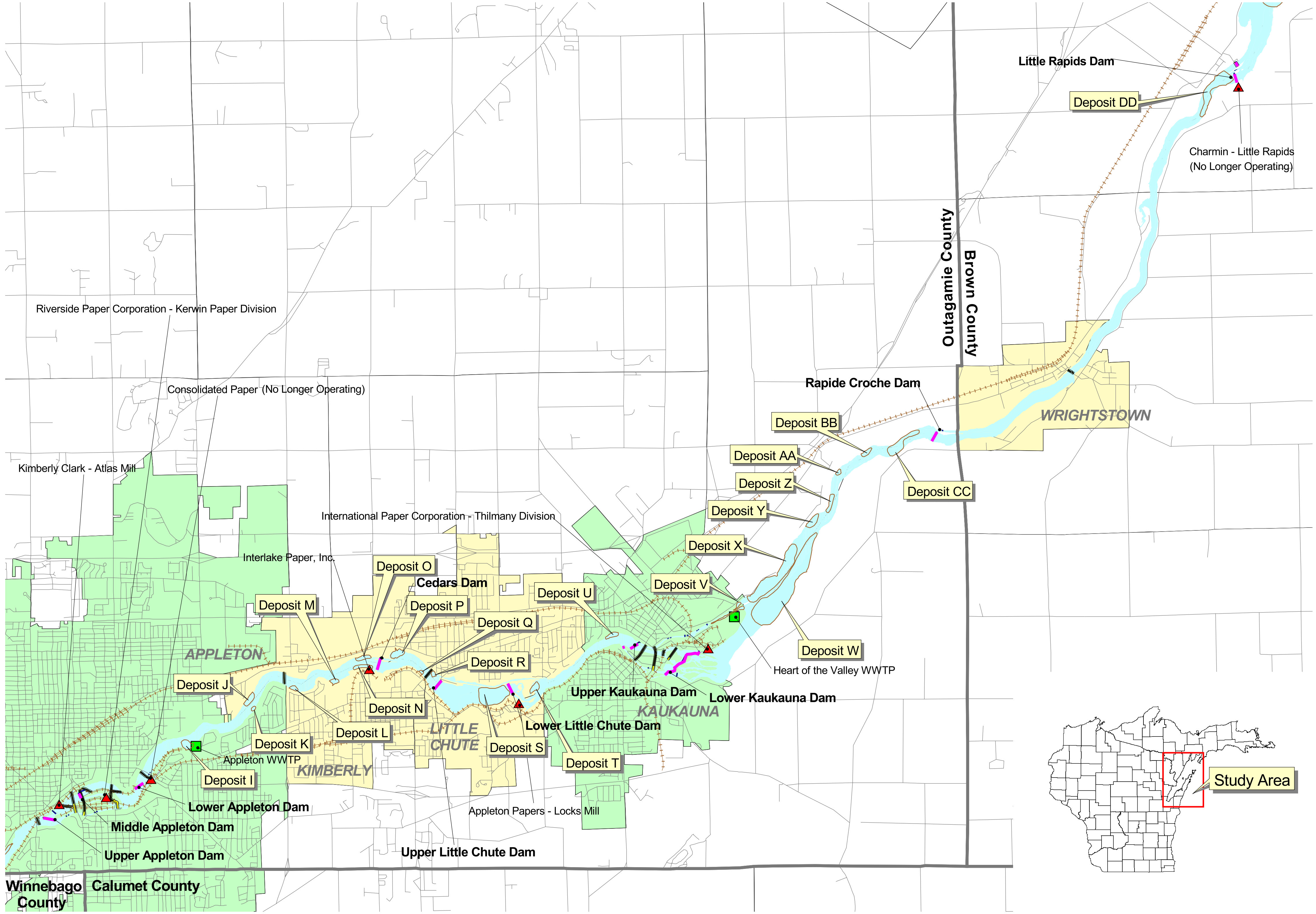
ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Green Bay Study Area	REF NO: RI-14414-340-1-2
				CREATED BY: SCJ
				PRINT DATE: 3/14/01
			FIGURE 1-2	APPROVED: AGF



NOTES:
1. Basemap generated in ArcView GIS, Version 3.2, 1998, and from TIGER Census data, 1995.
2. Deposit, management area, and dam location data obtained from WDNR, and are included in the Fox River database.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Little Lake Butte des Morts Reach	REF NO: RI-14414-340-1-3
			FIGURE 1-3	CREATED BY: SCJ; PRINT DATE: 3/7/01; APPROVED: AGF





Point Source Locations
- Industrial
- Municipal
- Dam Locations
- Railroads
- Roads

Structures
- Locks
- Bridges
- Deposits
- County Boundaries
- Water

Civil Divisions
- City
- Township
- Village

1 0 1 2 3 Kilometers

1 0 1 2 Miles

NOTES:
1. Basemap generated in ArcView GIS, Version 3.2, 1998, and from TIGER Census data, 1995.
2. Deposit, management area, and dam location data obtained from WDNR, and are included in the Fox River database.

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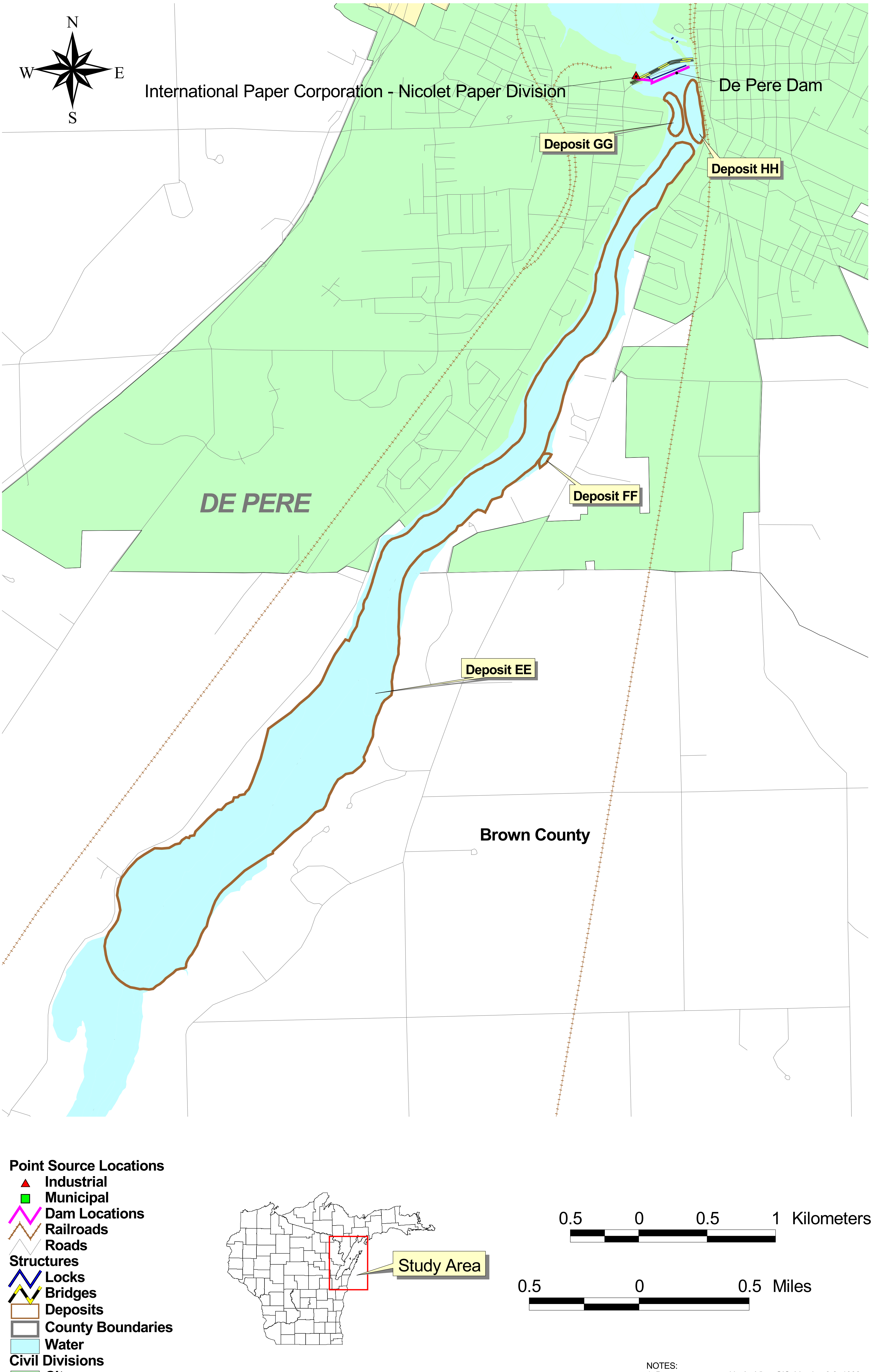
Appleton to Little Rapids Reach

FIGURE 1-4

REF NO:	RI-14414-340-1-4
CREATED BY:	SCJ
PRINT DATE:	3/7/01
APPROVED:	AGF



NOTES:
1. Basemap generated in ArcView GIS, Version 3.2, 1998, and from TIGER Census data, 1995.
2. Deposit, management area, and dam location data obtained from WDNR, and are included in the Fox River database.

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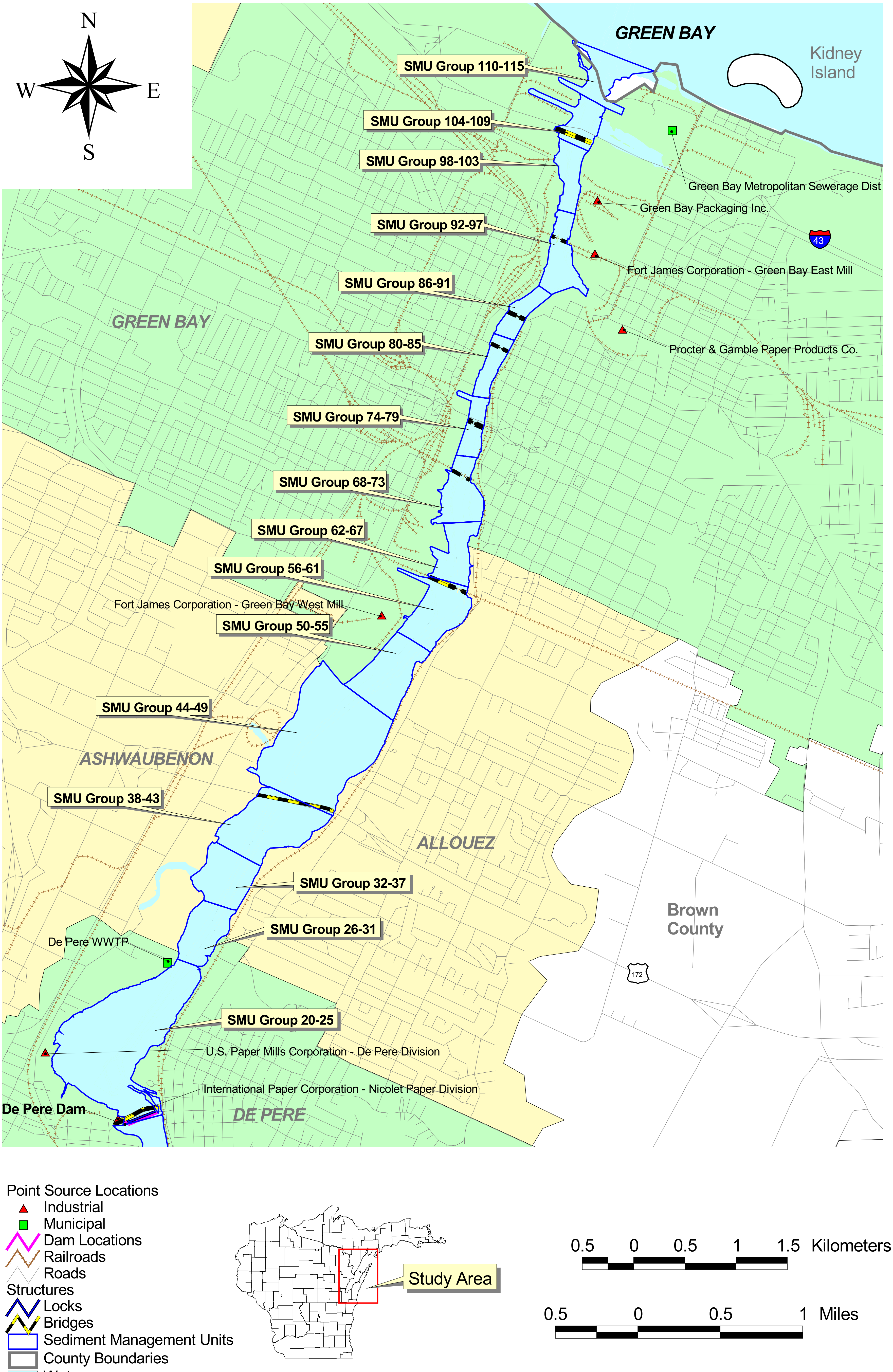
Little Rapids to De Pere Reach

FIGURE 1-5

REF NO: RI-14414-340-1-5
CREATED BY: SCJ
PRINT DATE: 3/7/01
APPROVED: AGF



NOTES:
1. Basemap generated in ArcView GIS, Version 3.2, 1998, and from TIGER Census data, 1995.
2. Deposit, management area, and dam location data obtained from WDNR, and are included in the Fox River database.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	De Pere to Green Bay Reach	REF NO: RI-14414-340-1-6
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE 1-6	APPROVED: AGF

2 Database and Investigation Summaries

Data have been collected from the Lower Fox River and Green Bay during numerous sampling events over a ten-year period. The *Data Management Summary Report* (DM Report) (EcoChem, 2000) presents the 35 studies which comprised the original Fox River Database (FRDB). EcoChem also completed an evaluation of five additional data sets from 2000 and 2001 which were added to the final FRDB. The evaluation is presented in the *Addendum to the Data Management Summary Report* (DMR Addendum) prepared by EcoChem (EcoChem, 2002). The DM Report and DMR Addendum are included as Appendix A. This section briefly summarizes the data contained within the FRDB and presents some of the larger studies that contributed to the database. The general conclusion of the DM Report is that almost all of the data gathered during previous investigations and included in the FRDB is of good quality.

After the draft RI and DM Reports were released in February 1999, the EPA authorized a peer review of these documents by Roy F. Weston, Inc. (Weston). The general conclusions of the peer review included the following:

1) The quantity and quality of data are good enough to support the need for cleanup action;

2) The data are adequate to determine the distribution of contaminants within the system and direct where cleanup actions should focus; and

3) The data are adequate to support identification and selection of possible remedy technologies (Weston, 1999).

Data included in the FRDB were collected during localized and regional studies pertaining to water and sediment quality, biological count and diversity studies, biological tissue sampling efforts, stream flow, and anthropogenic impacts on river quality and bio-diversity in the watershed. The WDNR, USFWS, EPA, academic researchers, and other public and private groups completed these studies. This RI utilizes the sediment and water quality data which meet data quality objectives established for the project in the *June 1998 Work Plan* (RETEC, 1998a) and the *Quality Assurance Project Plan* (QAPP) (RETEC, 1998b). The main sediment studies from which the FRDB has been derived are summarized below.

This RI focuses mainly on sediment and water sampling results within the Lower Fox River and Green Bay. Although there is a significant amount of fish/bird tissue and other biological sampling data in the FRDB, these data are only summarized herein. The detailed analysis of ecological (biological) sampling and trends are presented in the RA and the *Time Trends Analysis*, included as Appendix B. The RI only introduces the studies that collected these data and provides a brief summary of the PCB concentrations in the ecological samples.

2.1 Data Quality Evaluation

The studies composing the FRDB are listed on Table 2-1, along with information pertaining to the type and quantity of data collected. All the data included in the FRDB have been subject to a validation process to evaluate the RI/FS/RA database quality. Additional details regarding the data quality review are described in the DM Report (EcoChem, 2000). The DM Report classifies data sets used for the FRDB as follows:

- **Useable Data** - data have been thoroughly assessed through review of the analytical data itself and associated quality assurance/quality control (QA/QC) documents. The data are of known and verifiable quality.

- **Supporting Data** - supporting data have not been subjected to as rigorous an assessment as the useable data. As such, the precise data quality is not known. This is due to insufficient or incomplete QA/QC information available at the present time. In these cases, QA/QC information may or may not exist. The collection and assessment of this information might render the data fully useable. Until a full data validation is conducted, these data should be used for supporting purposes only.

- **Indeterminate Data** - status of a data set is described as indeterminate if: it is unknown whether the data set has been validated, and/or, QC data to support validation is not available.

Both the "Useable" and "Supporting" data sets are used in this RI. EcoChem has provided these data for use in the RI and the resulting analysis of the data presented in this document (particularly Section 5) uses the data as received, unless otherwise noted.

Although all but one of the data sets listed in Table 2-1 were classified as either usable or supporting, individual data points were rejected due to QA/QC failure. These rejected data points have not been used in the RI/FS/RA. The Ankley and Call data is the only indeterminate set in the FRDB.

2.2 Sediment Investigations Included in the FRDB

2.2.1 1989-1990 Fox River Mass Balance Study Data and 1989-1990 Green Bay Mass Balance Study Data

In 1989-90, EPA and WDNR conducted sediment and water sampling activities in the Lower Fox River and Green Bay as part of the Green Bay Mass Balance Study (GBMBS). The GBMBS was designed to identify the sources, transport paths, and fate of PCBs in the Lower Fox River and Green Bay. Important components of this effort were two PCB transport models that evaluated and modeled the transport pathways and fate of PCBs in the Lower Fox River and Green Bay. The Upper Fox River (UFR) Mass Balance model evaluated the transport and fate of PCBs between LLBdM and the De Pere dam. Similarly, the Lower Fox River (LFR) Mass Balance model evaluated the transport and fate of PCBs from the De Pere dam into Green Bay. A discussion of these modeling efforts is included in Section 6.

The GBMBS evaluated PCBs, lead, cadmium and dieldrin in the De Pere to Green Bay Reach and Green Bay while efforts upstream of the De Pere dam were limited to evaluating and modeling PCBs (including specific PCB congeners). The GBMBS objectives included:

- Mapping soft sediment deposits and quantifying the current PCB mass in the bottom sediments.

- Collecting data over a one-year period for use in calculating PCB fluxes into and out of the river system, including inputs from permitted wastewater dischargers, landfills, groundwater, urban runoff, Lake Winnebago, atmospheric input and resuspension of in-place polluted sediments. Outputs included transport over De Pere dam and volatilization.

- Increasing the understanding of the physical, chemical, and biological processes that affect the above fluxes.

- Developing a model describing the above processes, and calibrating and validating the model using a comprehensive set of physical and chemical data.

- Conducting predictive simulations to assist in the assessment of specific management scenarios and in selection of specific remediation strategies.

In the Lower Fox River, monitoring and quality assurance programs were developed during 1986 and 1987, and sampling began in 1988. Field work occurred from April 1989 to April 1990 along with data set management and model development. From 1990 to 1992, samples were analyzed, data interpreted, and modeling conducted. As part of this effort, areas with accumulated sediments were identified through poling efforts. This effort identified the sediment deposits outlined on Figures 1-3 through 1-5 and the almost continuous presence of sediment below the De Pere dam (Figure 1-6). Based on the presence of soft sediments within a given area/location, a sample was collected for laboratory analysis of PCBs and other parameters.

A similar time-frame was followed for Green Bay, except that sediment sampling in Green Bay occurred between 1987 and 1990 (Manchester-Neesvig, *et al.*, 1996). Also, due to the areal expanse of Green Bay, 169 sediment sampling stations were established using a 5 km x 5 km (3.1 mi x 3.1 mi) grid. The presence or absence of soft river/bay sediments was established using a Ponar Grab sampler. Based on the presence of soft sediments, a core sample was collected for analysis of PCBs. Although 169 sampling stations were established (based in the 5 km grid), a grab or core sample was collected from only 123 stations and of these, cores from only 64 locations were analyzed for PCBs (Manchester-Neesvig, *et al.*, 1996).

Sediment cores collected from both the Lower Fox River and Green Bay were sliced into as many as 28 individual samples. These samples were submitted for laboratory analysis and provided data on the PCB concentrations throughout the sediment profile. In many instances, these sediment slices represented 1 or 2 cm intervals in the profile and the thickness was based on the total length of the recovered sediment core.

The initial 1989-90 Lower Fox River sediment sampling results indicated that approximately 3,900 kg (8,600 pounds) of PCBs are distributed in about 2,100,000 cubic meters (m^3) or 2,745,000 cubic yards (yd^3) of sediment between Lake Winnebago and the De Pere dam. Of this amount, approximately 50 percent of the PCB mass (1,950 kg [4,300 pounds]) was located in LLBdM (WDNR, 1995). Based on the presence of a continuous layer of sediment extending from the De Pere dam to the mouth of the river, the WDNR collected additional samples downstream of the De Pere dam in 1995. Information pertaining to this sampling event is presented in Section 2.2.6.

In Green Bay, the PCB data were evaluated to provide an estimate of the PCB mass and volume of contaminated sediments. Based on the PCB results, Manchester-Neesvig, *et al.*, (1996) estimated that approximately 8,500 kg (18,740 pounds) of PCB are present in the bay. The majority of the PCB within the bay was estimated to be located along the east shore, from the mouth of the river to approximately Little Sturgeon Bay. Manchester-Neesvig, *et al.,* (1996) also estimated that in order to even remove 20 percent (about 1,700 kg) of the PCB in the bay would require dredging approximately 14 million m^3 (18.3 million yd^3). These results reflect the large diffuse nature of PCB contamination within Green Bay.

Other results indicate that significant factors affecting PCB transport appear to be the concentration and composition of suspended particulate matter, the initial PCB concentration in sediments, and river flow. These factors interact in complex ways and the deposition and resuspension of particulate matter largely controls PCB transport. Under typical flow conditions, the average PCB concentrations in water samples ranges from 4 nanograms per liter (ng/L or parts per trillion) flowing out of Lake Winnebago to an average of 47 ng/L in the De Pere to Green Bay Reach. PCBs are suspended and/or dissolved in the water column as flow moves downstream towards Green Bay. During summer, water sample PCB concentrations range between 50 and 90 ng/L at the De Pere dam. However, in winter, the PCB concentrations are approximately 10 percent of the summer values, indicating a strong seasonal variation (Fitzgerald and Steuer, 1996). In addition, when river flow is at its highest due to storm events or spring runoff, the PCB concentrations in water may exceed 100 ng/L. Based on the seasonal variations in PCB concentrations, it is estimated that more than 60 percent of the PCBs transported over the De Pere dam occurs during 20 percent of the year, when discharge is at its greatest (Fitzgerald and Steuer, 1996).

Based on the seasonal variation in water column PCB concentrations, water samples were collected and analyzed for concurrent concentrations of chlorophyll a, the most common algal pigment. Results of these samples indicate that there may be a link between algal productivity and water column PCB concentrations (Fitzgerald and Steuer, 1996). This potential link may suggest that algal production, predation, sinking, and other dynamics may be an important process facilitating the transport and ultimate fate of PCBs in the river. Additionally, bioaccumulation of PCBs by algae may provide a pathway for PCBs into the food chain and other organisms.

The GBMBS modeling efforts identified the location and magnitude of PCB contaminated sediment, evaluated areas contributing to transport and fish consumption advisories, and was used to predict future PCB concentration changes, with and without human intervention, over 25 years (Velleux and

Endicott, 1994; WDNR, 1995). This effort indicated that river sediment is the most significant continued source of PCBs in the river.

2.2.2 1994 Woodward-Clyde Deposit A Sediment Data

WDNR contracted with Woodward-Clyde Consultants (WCC-formerly EWI Engineering Associates) to perform an RI/FS for Deposit A. Based on the results of this effort, WDNR selected dry sediment removal as the remedial alternative for addressing PCB contaminated sediments from Deposit A (Figure 1-3). Dry sediment remediation includes enclosing Deposit A with a temporary cofferdam followed by the dewatering, treatment, and landfilling of the PCB contaminated sediments.

WCC collected additional sediment samples from 14 locations previously containing PCB levels above 50 ppm. Fifteen geotechnical soil borings were completed to further classify sediment and soil in the areas to be remediated, to measure index and engineering properties, to characterize the sediment and underlying soil interface, and to evaluate the presence or absence of more permeable zones within the underlying soil. Results of the geotechnical evaluation indicated that the soil underlying the sediments were softer than indicated by previous data; however, WCC concluded that the cofferdam could be constructed using sheetpile, earth berm, or portable dam alternatives (WCC, 1994 and 1996).

Several bench scale tests were conducted to evaluate the effort involved with preparing the impacted sediments for disposal. The objectives of the sediment handling operations included reducing the sediment weight and volume through drainage and evaporation and to dry and/or solidify the sediments sufficiently for off-site transportation, handling, and landfill disposal. The test results indicated the sediments could be dried relatively quickly, especially when mixed and heated; also, the sediments could be effectively solidified with a bentonite and cement mix at the existing water content.

2.2.3 1992/93 BBL Deposit A Sediment Data

On behalf of the P.H. Glatfelter Company, Blasland, Bouck, & Lee (BBL) performed an RI/FS for LLBdM Sediment Deposit A in 1992/93 (Figure 1-3). BBL conducted additional sediment sampling in Deposit A as well as a baseline human health and ecological risk assessment which evaluated the risks associated with exposures to surface water, sediment, and fish ingestion. BBL used WDNR fish samples collected through 1992 as the basis for this evaluation.

The main findings of the BBL RI/FS included the following: 1) All locations exhibited decreasing PCB concentration with depth with Aroclor 1242 being the primary PCB detected in sediment; and 2) Ingestion of fish posed the greatest risk for exposure.

2.2.4 1993 Triad Assessment

This sediment study sought to characterize soft sediments in the Lower Fox River using the sediment quality triad approach. Using triad and weight of evidence approaches, WDNR applied sediment quality guidelines (SQGs), human health criteria, and wildlife criteria for the protection of benthic life within the Lower Fox River (WDNR, 1992). These three criteria were used to evaluate the degree of sediment contamination. This approach assessed sediments by determining the presence and degree of anthropogenic contamination (bulk chemistry), by assaying the effects of sediments on normal function (growth, reproduction, survival) of standard test organisms, and by assessing in-situ alterations of the benthic community structure (WDNR, 1996).

In 1992 and 1993, sediments were collected from 10 deposits between Lake Winnebago and Green Bay and the following chemical parameters were analyzed: PCBs; chlorinated pesticides; volatile organic compounds (VOCs); semi-volatile organic compounds (SVOCs), including PAHs and PCP; metals; and ammonia. Additionally, physical characteristics of the sediment were recorded, sediment toxicity was analyzed using acute and chronic bioassays, and macroinvertebrate community structure was examined.

Sediment enrichment factors (SEFs) were calculated by dividing the sediment concentrations in a deposit by a reference sediment concentration to compare chemical composition between deposits. All deposits were found to be chemically enriched by certain constituents and PCBs were the primary constituent that resulted in elevated SEF values. Mercury, total PAHs and ammonia were also found to be enriched in all deposits analyzed. Other enriching contaminants were found in some but not all deposits.

Acute and chronic toxicity testing was also completed. The acute toxicity testing results revealed very low mortality to Ceriodaphnia dubia and Daphnia magna as survival exceeded 90 percent and 70 percent, respectively; Hylella azteca was the most sensitive indicator of acute toxicity with significant mortality rates at five of the ten test sites. The chronic toxicity testing results indicated that both Daphnia magna and Chironomous tentans were adversely affected and exhibited reductions in survival, reproduction, and growth rates (WDNR, 1996).

Macroinvertebrate investigations were inconclusive because of deposit abundance variability, unidentified worm taxa dominant in most deposits, and physical substrate differences. Bioassay tests indicated both acute and chronic toxicity for several deposits throughout the length of the river. The deposits with maximum contaminant concentrations were not always the same as deposits with the maximum toxicity or benthic impact. It was reasoned that this could be due to other factors that can influence toxicity that were not measured, including: dissolved oxygen in the pore water and overlying water; pH levels; substrate variation and/or other confounding factors such as sampling season; specific concentrations of contaminants based on vertical profiles; availability of microfauna for food; nutrient fluxes; and algal growth.

2.2.5 1994 GAS/SAIC Sediment Data

In 1994, WDNR and the Fox River Coalition (individuals representing both public and private sector interests), jointly undertook completion of an investigation of the upper three reaches of the Lower Fox River. Graef, Anhalt, Schloemer & Associates Inc. (GAS) and Science Applications International Corporation (SAIC) were contracted to identify the lateral and vertical extent of PCBs and mercury within bottom sediments at selected deposits upstream of the De Pere dam (GAS and SAIC, 1996). The deposits were selected by WDNR based on a ranking system that included transport, bio-availability and PCB mass as well as other considerations. The deposits studied included: 1) Deposit POG, located on the east side of LLBdM; 2) Deposits D and E, located on the west and north ends of LLBdM; 3) Deposit N, located near the city of Kimberly; and 4) Deposits EE, GG, and HH, located just upstream of the De Pere dam. In addition to identifying the extent and magnitude of PCBs and mercury in sediments, a baseline ecological and human health risk assessment and a preliminary assessment of feasible remedial alternatives were completed.

2.2.6 1995 WDNR Sediment Data

This study was funded and carried out by the WDNR, EPA Great Lakes National Program Office (GLNPO), and the Fox River Coalition. During the 1989-90 sediment sampling activities, a large, continuous sediment layer, which extended from the dam to the mouth of the river, was found in the De Pere to Green Bay Reach. Based on the 1989-90 sediment sampling data, it was estimated that this reach contained between 80 percent and 90 percent of the total PCB mass in the Lower Fox River. Due to the significance of sediments as a continuing source of PCBs, WDNR concluded that sediments downstream of the De Pere dam required further characterization in order to adequately model and predict PCB fate and transport from the river into Green Bay. The primary objectives of the 1995 sampling effort (WDNR, 1998) include the following:

- To further define and quantify the PCB sediment distribution downstream of the De Pere dam to Green Bay
- Estimate the mass and volume of PCB containing sediments and develop maps of PCB distribution in the Lower Fox River
- Provide data to enable further refinement of the PCB transport models for the Lower Fox River
- Provide further basis for making sound management decisions throughout the Lower Fox River and into Green Bay
- Support the Fox River Coalition's effort to prioritize contaminated sediment areas and remediate sites in the Lower Fox River
- Implement a Green Bay Remedial Action Plan recommendation for developing a cleanup strategy for the Lower Fox River sediments

WDNR analyzed hundreds of samples for PCBs, total organic carbon (TOC), moisture content, and particle size (plus QA/QC samples). Sediments containing more than 1,000 microgram per kilogram (μg/kg) (1 ppm) of PCB were detected as deep as 200 cm (78.7 inches) below the river bottom and the PCB concentrations above these locations were not significantly lower. WDNR (1998a) estimated that approximately 26,000 kg (57,320 pounds) of PCB was present in this reach.

2.2.7 1996 FRG/BBL Sediment/Tissue Data

In 1996, BBL performed limited sediment sampling in the same deposits investigated by GAS/SAIC on behalf of the FRG. BBL collected eight sediment samples from deposits POG, N, GG and a reference site. These samples were analyzed for PCBs and TOC.

2.2.8 Sediment Remediation Demonstration Projects Data

Two Sediment Remediation Demonstration (SRD) Projects were conducted between 1998 and 1999 at Deposit N and SMU 56/57 to assess the effectiveness of sediment remediation using dredging techniques in the Lower Fox River.

The Deposit N SRD project, located near the town of Kimberly, was funded and completed through an agreement between the WDNR, EPA GLNPO, and the Fox River Coalition. The Deposit N SRD project was successfully completed to design specifications and achieved the target goals for the project. Deposit N sediment data is included in five different sets in the FRDB (Table 2-1). These data sets include the 1997 Demonstration Project Data, 1998 Deposit N Pre- and Post-Dredge Data, the Operational Monitoring Data, and the 1998/1999 Remediation Data.

The SMU 56/57 SRD project located downstream of the De Pere dam, was conducted on behalf of the WDNR and the FRG, with funding provided by the FRG. However, because the targeted design depths were not achieved only part of the designated PCB mass was removed. The SMU 56/57 sediment data is included in the 1997 Demonstration Project Data Set in the FRDB (Table 2-1). Dredging equipment will be remobilized to SMU 56/57 during the summer of 2000 to remove the remaining PCB-contaminated material under administrative order between EPA and the Fort James Corporation (EPA, 2000a). Each of these demonstration projects is discussed briefly below and is detailed in the *Sediment Technology Memorandum* located in Appendix B of the FS.

The SRD projects assessed various phases of sediment remediation including dredging, dewatering, and disposal. The objectives of the SRD projects included the following:

- Assess the implementability, feasibility and cost of a full-scale sediment remediation project for other areas of the Lower Fox River

- Remove the bulk of PCB mass from impacted sediment located within two large hot spots of the Lower Fox River for source control

- Conduct a mass balance study of PCB mass transport during dredging activities to help assess dredging effectiveness

- Assess the extent of sediment resuspension during dredging and the downstream transport of PCB material along with the performance of containment systems and monitoring devices

- Collect technical information which will be useful during the final evaluation and selection of remedial alternatives such as: flow velocity, sediment characteristics, bulk density, extent of debris and obstructions, dewatering and treatment characteristics, and dredging costs.

2.2.8.1 Deposit N Demonstration Project

The former Deposit N is located within the city limits of Kimberly and adjacent to the Interlake Papers facility, on the south side of the river (Figure 1-4). Deposit N sediments were evaluated during both the WDNR 1989-90 and GAS/SAIC 1994 sampling efforts. Deposit N was estimated to be about 1.21 hectares (3 acres) in size and have an average PCB sediment concentration of 45 ppm. Water depths at the location were generally 244 cm (8 ft) deep and the average sediment thickness was about 61 cm (2 ft). Deposit N Sediment samples collected by Foth & Van Dyke (F&VD) indicated that total PCB results ranged from 550 to 130,000 μg/kg prior to remediation. F&VD estimated that approximately 142 kg (312 pounds) of PCBs were present in Deposit N (F&VD, 2000).

Remedial Action. Sediment removal was conducted using an 8-inch Moray/Utra hydraulic cutterhead dredge with a swinging ladder configuration, a rotating variable-speed cutter, and an intake/suction line. A special containment system was installed around the deposit to ensure that sediments resuspended during construction would remain within the dredged area and be removed in the cleanup process. The containment system consisted of a 80-mil high density polyethylene (HDPE) curtain anchored to the river bed and buoyed by flotation devices. The curtain acted as a flexible wall effectively preventing suspended sediments from flowing downstream with the current. The chronological summary of site activities at Deposit N is listed below.

Hydraulically dredged material was pumped through double-walled piping to the on-shore treatment system. Sediment slurry was screened to remove gravel and sand (>#200 sieve), conditioned with a polymer to increase the percent solids, then pumped into 200 pounds per square inch (psi) filter presses for compression. The compressed solid material was stockpiled and tested for PCBs, mercury, and percent solids. Water separated during pressing was treated through solid filtration and carbon adsorption prior to discharge back to the Lower Fox River.

Based on PCB concentrations relative to Toxic Substances Control Act (TSCA) standards, dried sediment was transported to either the Winnebago County Landfill (PCB concentration less than 50 ppm) or the Wayne Disposal landfill in Belleview, Michigan (PCB greater than 50 ppm) in 1998. During 1999, all dredged sediments were transported to the Winnebago County Landfill (Fitzpatrick, 2000).

Monitoring. The environmental monitoring program focused primarily on bathymetry surveys, sediment sampling, water quality monitoring during dredging, and post-verification surface sediment sampling. WDNR collected water samples during remediation activities to evaluate whether significant concentrations of PCBs were released from the sediment into the water column.

The Fox River Remediation Advisory Team (FRRAT) determined that the best method for assessing the effectiveness of dredging was a mass balance approach. The mass balance approach included three essential components: deposit mass balance, river transport, and process mass balance. Twenty surface sediment samples were used to assess residual concentrations and daily surface water samples collected from upstream and downstream transects at two depths were used to determine river transport (along with estimated flow measurements provided by USGS). Chemical analyses of the byproducts of the treatment products were used to determine PCB fate during the dredging process.

Results. Due to the presence of a hard bedrock substrate located beneath the soft sediments, the target goal of the demonstration project was to remove contaminated sediment down to a design depth of 7.5 to 15 cm (3 to 6 in [inches]) above bedrock. Approximately 5,475 m^3 (7,160 yd^3) of sediment and 50.3 kg (112 pounds) of PCBs were removed from Deposit N during 1998/1999 (F&VD, 2000). Overall, 82 percent of the PCB mass was removed from Deposit N and approximately 31 kg (68 pounds) of PCB remained in the sediments that were not accessible to dredging activities (F&VD, 2000).

The PCB mass balance study conducted during dredging activities (FRRAT, 2000), estimated that the resulting press cake material contained 96 percent of the PCBs removed from the deposit and that less than 0.01 percent of PCBs from the slurry concentration was discharged back to the river. The mass balance model did not measure an overall increase in mass of particles transported downstream during dredging (TSS), however, the PCBs transported on the particles did increase (increased net load of 2.2 kg PCB during the active dredging period).

Currently, there are no further plans for additional work at Deposit N. Data collected from Deposit N prior to completion of the SRD has been flagged in the FRDB and only post-remediation data was evaluated as part of the RI/FS and RA. According to WDNR, the remedial activities completed at Deposit N have essentially removed this deposit from the river (Fitzpatrick, 2000).

2.2.8.2 SMU 56/57 Demonstration Project

SMU 56/57 is located within the Green Bay city limits and adjacent to the Fort James Corporation facility, on the west bank of the Lower Fox River (Figure 1-6).

Based on the WDNR 1995 sediment sampling results, SMU 56/57 contained the highest PCB concentrations detected anywhere in the Lower Fox River and Green Bay. An estimated 3,000 kg (6,600 pounds) of PCBs were present within a total sediment volume of approximately 69,800 m^3 (91,300 yd^3) encompassing an area of approximately 3.7 hectares (9.3 acres) (Montgomery Watson, 1998). These sediments were estimated to contain approximately 10 percent of the total PCBs downstream of the De Pere dam, although the volume only represented about 1 percent of the estimated sediment volume downstream of the De Pere dam.

Results of the baseline sediment sampling collected by Montgomery Watson in 1998 indicated that most sediment cores contained PCBs throughout their entire length extending to almost 5 m (16 ft) in some areas. The laboratory results indicated that the highest PCB concentrations were generally located between a depth of 61 to 153 cm (2 to 5 ft) below the sediment surface. Total PCB concentrations ranged as high as 710,000 μg/kg. Approximately one third of the cores reached undetectable PCB concentrations at the deepest interval tested. Similarly, mercury concentrations increased with depth across the site. Concentrations averaged approximately 1 mg/kg in the 0 to 10 cm (0 to 4 in) interval and increased to approximately 7 mg/kg in the 274 to 305 cm (9 to 10 ft) interval.

Remedial Action. The SMU 56/57 dredging demonstration project began on September 1, 1999, with the objective of removing about 61,160 m^3 (80,000 yd^3) of impacted sediment. The target area was isolated from the rest of the river through the installation of an anchored silt curtain. Material was extracted from the riverbed using a hydraulic cutterhead and horizontal auger dredges and dewatered on-shore. Sediment was dewatered through equalization basins and filter presses then transported to an engineered landfill cell owned by the Fort James Corporation for disposal. Process water was treated with polymer, run through sand/carbon filters and discharged back to the river. The chronological summary of site activities at SMU 56/57 is provided below.

Equipment difficulties and the presence of large debris significantly slowed the pilot test progress. During early stages of the project, coal ships docking at the Fort James facility disturbed the silt curtain, ripping it from its moorings on at least one occasion. Also, the liner of one of the two settling ponds was damaged during October 1999 requiring use of that pond to be discontinued until the liner could be repaired. The initial goal of removing 61,160 m^3 (80,000 yd^3) was reduced by nearly half, due to increased costs caused by these and other delays. Dredging was suspended on December 15, 1999, due to ice on river and icing of the wastewater treatment system.

Monitoring. The environmental monitoring program focused primarily on bathymetry surveys, sediment chemistry sampling, and surface water quality monitoring. Post-dredging sampling activities were initiated on December 20, 1999 and continued through early January 2000. An acoustical bathymetry survey completed after suspension of the dredging activities indicated that approximately 22,940 to 23,700 m^3 (30,000 to 31,000 yd^3) of sediment were removed from the target area. A PCB mass balance study was conducted during dredging to compute the mass of PCBs discharged to the river during dredging. Samples were collected from the dredge slurry, dewatered solids, supernatant, and process water effluent.

Results. The target goal of the project was to dredge to a design elevation of 565 feet, mean sea level. Dredging to this design elevation was expected to remove sediments with PCB concentrations greater than 1 ppm. However, the target elevation was not achieved in any of the subunits within the dredge prism. Due to the difficulties encountered during dredging and the on-set of winter, the expected elevation was raised 2 to 3 feet in most areas. A final "cleanup pass" initially intended for all areas was only completed in four of the 59 subareas (WDNR, 2000a). In these areas, the final PCB concentrations in the newly exposed surface sediments showed a general decline compared with pre-dredging concentrations, and in some locations the final PCB concentrations were as low as 0.25 ppm. However, in other areas where no "final pass" was completed down to the targeted sediment elevations, the final PCB concentrations were higher (32 to 280 ppm) than baseline surface concentrations (2 to 5 ppm) (Montgomery Watson, 2000). In these areas, the final sediment elevations achieved were 30 to 230 cm (1 ft to 7.5 ft) above the targeted elevations.

Under an EPA Administrative Order by Consent (AOC No. V-W-00-C-596), the Fort James Corporation continued sediment remediation activities at SMU 56/57 during the summer, 2000. The dredging activities conducted in two phases:

- Phase 1 - removal of contaminated sediment from subunits that were previously disturbed (dredged) during the SRD project to SRD target elevations (estimated 15,290 m^3 [20,000 yd^3]).

- Phase 2 - removal of additional sediment from different subunits that were not disturbed during the SRD project.

The total in-situ dredge volume of the two phases will not exceed 38,225 m^3 (50,000 yd^3), given the need to preserve stable side slopes, not exceed the capacity of the landfill, and avoid leaving residual elevated PCB concentrations. Surficial sediments will be tested to determine if cleanup objectives (1 ppm PCBs) have been met. However, dredging activities will cease after the removal of 38,225 m^3 (50,000 yd^3) regardless of residual PCB concentrations.

Conclusions. Conclusions drawn from both SRD dredging projects indicate the following:

- Pre-dredging data provided sufficient resolution to define the lateral and vertical extent of contamination;
- Contaminated sediment can be removed within the river without increasing surface concentrations; and
- Partial cleanup left significantly higher PCB concentration in some surface sediments where the target elevation was not achieved.

The estimated PCB mass and sediment volume removed during the SMU 56/57 SRD project have been subtracted from the mass and volume estimates for the De Pere to Green Bay Reach in this RI (Section 5.4.2.6).

2.2.9 1998 FRG/Exponent Data and 1998 FRG/BBL Sediment/Tissue Data

During 1998, the FRG hired both BBL and Exponent Environmental Group (Exponent) to evaluate various aspects of the Lower Fox River and Green Bay. BBL collected at least 363 sediment samples for PCBs, with 116 of these samples being collected within Green Bay to supplement the 1989-90 GBMBS data. At least 520 water samples were collected and analyzed for PCBs present in unfiltered or filtered water or present on particulate in the water column. In addition, both BBL and Exponent collected just over 300 tissue samples. This tissue data is included in the FRDB and is discussed further in the RA.

Exponent also completed a Habitat Characterization Assessment of the Lower Fox River and southern half of Green Bay. The habitat characterization data and results are discussed further in Section 4.

2.2.10 1998 RETEC RI/FS Supplemental Data

Based on review of data from the above investigations, the Project Team and WDNR collected supplemental sediment samples in selected areas of the Lower Fox River and Lake Winnebago in June 1998. These data were collected for the following:

- Evaluate upstream background concentrations in sediments for selected chemical parameters

- Collect additional information for use in the RA

- Evaluate the physical properties of the sediments for use in the FS

- Provide additional chemical information from sediment deposits containing PCBs for comparison with other data sets used in the RI

The focus of this evaluation included 12 deposits upstream of the De Pere dam that were estimated to contain over 97 percent of the PCB mass within this stretch of the river (WDNR, 1995).

The supplemental sediment sampling activities were conducted between June 1 and 8, 1998. The sample collection procedures and laboratory analytical methods are listed in the *Quality Assurance Project Plan for Supplemental Data Collection, Lower Fox River RI/FS* (RETEC, 1998b). The sediment samples were collected and analyzed for the parameters listed on Table 2-2.

The 1989-90 WDNR sediment sampling results were used as the basis for further study of a number of the deposits. Five supplemental sediment samples were collected from deposits C, E, W, X, and EE. Deposits E and EE cover such long portions of the river bottom that additional sampling in each deposit was performed to supplement existing data. Samples were collected from the sediment surface to a depth of approximately 45 cm.

Five samples were also collected from the SMUs in the De Pere to Green Bay Reach that exhibited the highest PCB concentrations in 1995. Surface sediment samples were collected and analyzed for use in the RA and to compare the Aroclor concentrations with levels of other chemicals of potential concern (COPC).

Samples were also collected from Lake Winnebago as background data. The background samples from Lake Winnebago were collected in areas where significant deposits of soft sediment were found.

These data have also been utilized in the *Time Trends Analysis* (Mountain-Whisper-Light, 2001). The time trends analysis evaluates whether PCB concentrations in sediment, fish tissue, and bird tissue samples have changed over time compared to previously collected data.

2.2.11 Lake Michigan Mass Balance Data

The Lake Michigan Mass Balance samples were collected in 1994 and 1995. Sediment, water, tissue, and air samples were collected and were analyzed for PCB congeners, volatiles, pesticides/herbicides, metals and other inorganic parameters. Although this data set contains 6,987 samples, much of the data was collected outside of the Lower Fox River and Green Bay region.

2.2.12 Fox River Fish Consumption Advisory Data

This data set is primarily tissue data with a small number of sediment samples. The tissue samples were collected by WDNR in the Fox River and Green Bay between 1971 and 1996. The 1,766 samples in this set were analyzed for PCB congeners and Aroclors, metals, chlorinated pesticides, and dioxins.

2.2.13 USGS National Water Quality Assessment Program (NAWQA) Data

The NAWQA data represent 441 sediment, water, and tissue samples collected by the USGS between 1992 and 1997. These samples were analyzed for an extensive list of chlorinated pesticides and herbicides, organophosphorus pesticides, SVOCs, and metals. Approximately 90 percent of the samples in this set were collected from waterways other than the Fox River and these samples are noted as "reference."

2.2.14 1997 WDNR Caged Fish Bioaccumulation Study Data

WDNR placed caged fish near Deposit N and SMU 56/57 prior to the start of the SRD projects. The fish and co-located sediment samples were collected and analyzed for PCB congeners. This data set consists of 25 fish tissue and sediment samples.

2.2.15 Minergy Mineralogical Data

The Minergy data are comprised of results from the analysis of 15 sediment samples for 11 different mineral oxides, sulfur, chloride, and other physical tests. None of these samples were analyzed for PCBs, dioxin, pesticide or SVOCs. Therefore, these data are of limited value in analysis of sediment impacts in the river or bay.

2.3 Ecological Sampling Studies

As indicated in Table 2-1, a number of studies that involved analysis of ecological (biological) samples for PCBs and other chemical compounds have been completed. The studies that included ecological sampling are listed below and have been divided into those studies in which only biological samples were collected and those studies that included biological sampling in addition to sediment and water sampling. The studies are listed by the total number of samples included in the FRDB (Table 2-1) and include the following:

Biological Sampling Studies

- State of Michigan Fish Consumption Advisory Data
- 1996 WDNR Fish Tissue Data
- 1998 WDNR Fish Consumption Data
- 1996-1999 USFWS NRDA Fish Tissue Data
- 1998 FRG/Exponent Data
- 1993 USFWS Tree Swallow Data
- 1994-1995 Cormorant Data
- WDNR Wildlife Tissue Data
- 1997 USFWS NRDA Waterfowl Tissue Data
- Stromberg Eagle Data Collection

Studies That Included Biological Sampling

- Lake Michigan Mass Balance Data
- 1989-90 Green Bay Mass Balance Study (GLNPO)
- Fox River Fish Consumption Advisory Data
- 1998 FRG/BBL Sediment/Tissue Data
- USGS NAWQA Data
- 1998 RETEC RI/FS Supplemental Data
- 1998/1999 Deposit N Sediment Remediation Data
- Ankley and Call (Indeterminate)
- 1996 FRG/BBL Sediment/Tissue Data
- 1997 WDNR Caged Fish Bioaccumulation Study Data

Biological sampling often included fish and bird tissue analysis. However, some studies also included analysis of bird eggshells and other biological specimens. Detailed analysis of ecological sampling and trends is presented in the *Time Trends Analysis* (Mountain-Whisper-Light, 2001) and the RA. Again, it should be noted that the Ankley and Call data are classified as indeterminate by the DM Report (EcoChem, 2000). Use of these data are discussed further in the RA.

2.4 Section 2 Tables

Tables for Section 2 follow this page, and include:

Table 2-1 Fox River Database Studies and Data Classification
Table 2-2 Lower Fox River - Supplemental Data Collection Sampling List

Table 2-1. Fox River Database Studies and Data Classification

Data Source	Number of Samples	Matrices[1]	Analyses Conducted[2]	Number of Records	Data Quality Classification
Lake Michigan Mass Balance Data	6,987	A,S,T,W	M, P/H,PCB-C, V, W	91,621	Supporting
1989/90 Green Bay Mass Balance Study (GLNPO)	2,069	S,T,W	B, PCB-C, W	201,701	Supporting
1989/90 Fox River Mass Balance Study	1,967	S,W	PCB-A, PCB-C, W	25,457	Supporting
Fox River Fish Consumption Advisory Data	1,766	S,T	B, DXN, M, P/H, PCB-A, PCB-C, SVOA, V, W	11,620	Supporting
1998 FRG/BBL Sediment/Tissue Data	1,315	S,T,W	B, M, P/H, PCB-A, PCB-C, RAD, SVOA, W	18,824	Useable
1995 WDNR Sediment Data	488	S	M, PCB-A, W	6,433	Useable
USGS NAWQA Data	441	S,T,W	B, M, P/H, PCB, SVOA, V, W	11,879	Supporting
State of Michigan Fish Consumption Advisory Data	434	T	B, DXN, M, P/H, PCB-A, W	6,979	Useable
WDNR Wildlife Tissue Data	417	T	B, M, P/H, PCB-A	2,532	Supporting
1996-1999 USFWS NRDA Fish Tissue Data	376	T	DXN, P/H, PCB-A, PCB-C, W	16,017	Useable
1997-1998 Demonstration Project Data - SMU 56/57	295	S,W	DXN, M, P/H, PCB-A, SVOA, V, W	3,114	Useable
1994 GAS/SAIC Sediment Data	253	S	DXN, M, P/H, PCB-A, SVOA, V, W	5,654	Useable
1998 RETEC RI/FS Supplemental Data	252	S,T	B, DXN, M, P/H, PCB-A, PCB-C, SVOA, V, W	10,781	Useable
1998 FRG/Exponent Data	225	T	B, M, P/H, PCB-A, PCB-C, W	17,708	Useable
1993 USFWS Tree Swallow Data	200	T	B, DXN, P/H, V, W	5,429	Supporting
1996 WDNR Fish Tissue Data	200	T	B, PCB-A, W	1,673	Useable
1998/1999 Deposit N Sediment Remediation Data	197	T,W	PCB-C, W	10,264	Useable
1994-1995 Cormorant Data	193	T	B, DXN, P/H, PCB-C, W	6,178	Supporting
1998 WDNR Fish Consumption Data	130	T	B,M, PCB-A, W	777	Useable
1992/93 BBL Deposit A Data	117	S,W	M, P/H, PCB-A, SVOA, V, W	1,094	Useable
Lake Michigan Tributary Monitoring Data	88	W	M, P/H, PCB-C, V	5,722	Useable
1997 USFWS NRDA Waterfowl Tissue Data	70	T	B, P/H, PCB, V, W	1,680	Supporting
1994 Woodward-Clyde Deposit A Sediment Data	66	S	PCB-A, W	585	Useable
Ankley and Call	62	PW,S,T,W	DXN, M, P/H, PCB, SVOA, W	1,607	Indetereminate
1998 Deposit N Pre-Dredge	53	S	PCB-A, PCB-C, W	1,437	Useable
1998 Deposit N Post-Dredge	43	S	PCB-A, PCB-C, W	690	Useable
Stromberg Eagle Data	31	T	B, DXN, P/H, PCB-A, PCB-C, SVOA, V, W	954	Supporting
1993 Triad Assessment	27	S	B, M, P/H, PCB-A, SVOA, W	631	Supporting
1996 FRG/BBL Sediment/Tissue Data	25	S,T	B, PCB-C, W	2,771	Useable
1997 WDNR Caged Fish Bioaccumulation Study Data	25	S,T	B, PCB-C, W	1,672	Supporting
Minergy Mineralogical Data	15	S	W	219	Supporting
Lower Fox River Background Metals Assessment	14	W	M	78	Supporting
Deposit N Operational Monitoring Data	12	S	M, PCB-A, W	123	Useable
1997 Demonstration Project Data - Deposit N	10	S	M, PCB, W	83	Useable
WPDES Permit Influent Data	8	W	B, DXN, M, P/H, PCB-A, RAD, SVOA, V, W	847	Supporting

Reference - EcoChem, 2000.

1) Matrices
S = Sediment
T = Tissue
W = Water
PW = Sediment Pore Water
A = Ambiant Air

2) Analyses
PCB-A = PCB Aroclor
PCB-C = PCB Congener
PCB = Total PCB only
B = Biological
DXN = Dioxins

M = Metals
P/H = Pesticides/Herbicides
SVOA = Semi-volatiles
V = Volatiles
W = Wet Chemistry (including all Physical and Conventional data)

Table 2-2. Lower Fox River - Supplemental Data Collection Sampling List

Specific Deposit/General Area of Sampling (# of Core/Ponar Grab Sample Locations)	Sampling Parameters (both Chemical & Physical)												
	Core Samples							Surface Samples (Ponar™ Grab Samples)					
	Aroclors[1]	Atterberg limits[2]	Shear strength[2]	Specific gravity[2]	Grain size[2]	Dry density[2]	Consolidation[2]	PCB Congeners	SVOCs	Chlorinated Pesticides	Metals	TOC	Moisture content
C (5)	15	2	1	2	2	2	1	2	2	2	2	5	5
E (6)	18	2	1	2	2	2	1	2	2	2	2	6	6
W (5)	15	2	1	2	2	2	1	2	2	2	2	5	5
X (5)	15	2	1	2	2	2	1	2	2	2	2	5	5
EE/22 (4)	12	2	1	2	2	2	1	2	2	2	2	4	4
EE/23 (5)	15	2	1	2	2	2	1	2	2	2	2	5	5
EE/24 (5)	15	2	1	2	2	2	1	2	2	2	2	5	5
EE/25 (5)	15	2	1	2	2	2	1	2	2	2	2	5	5
EE/26 (5)	15	2	1	2	2	2	1	2	2	2	2	5	5
EE/27 (2)	0	0	0	0	0	0	0	2	0	0	0	2	2
Lake Winnebago	3	0	0	0	3	0	0	3	3	3	3	3	3
Below De Pere Dam	5	2	1	2	5	2	1	5	5	5	5	5	5
Total Number of Field Samples[3]	176	20	10	20	26	20	10	41	34	34	39	65	65

Notes:

1) Samples were collected from select intervals of each core for submittal to the laboratory for analysis.
2) Indicates that an intact core (approximately 30 cm long) was submitted for analysis of the physical parameters.
3) Total includes QA/QC samples collected as equipment rinsate or field duplicate samples.

3 Physical Characteristics

This chapter provides a historical description of the anthropogenic impacts to the river and bay system and a description of the current physical and ecological characteristics of the Lower Fox River valley and Green Bay. Specifically, this chapter describes the Lower Fox River and Green Bay land use, meteorological, geological, and hydrological characteristics. Hydrologic characteristics include flow and currents within both the river and bay, as well as information pertaining to sediment deposition and transport, which are important factors in the movement of chemicals that have been detected in the river system.

3.1 Land Use

The abundance of natural resources in the region has had a significant impact on the current environmental conditions and land use. This section describes the historical and current land use as well as the important role which wood pulping and paper manufacturing has played in the region. In addition, other commercial activities have been impacted by historical and current environmental degradation conditions within the region.

3.1.1 Historical Land Use

The Lower Fox River valley has long been home to many different Native Americans (Menominee, Winnebago, Fox, and other tribes) before European settlers arrived in the area. In the late 1600s, Europeans had entered the region and used the river system for fur trading and as a route for exploration and transportation. Early settlements in the area included Fort Howard, which eventually became the city of Green Bay. By the early 1800s, timber, agriculture, fishing, fur trading, and other commercial activities were either well established or beginning to be developed based on the availability of the local resources. The historical settlement of the Lower Fox River valley has resulted in numerous present-day cultural and historic landmarks.

This region has long been used by humans for transportation, commerce, energy, food (fish and waterfowl), and recreation, and by wildlife for habitat and migration. Industries developed rapidly in the Lower Fox River valley due to the availability of water from Lake Winnebago, the Lower Fox River, and Green Bay. Beginning in about 1820, lumber and flour industries came to the Lower Fox River valley. The year 1850 marked the peak of the flour industry, which was followed by flour mill conversion to saw mills and/or pulp and paper mills. The earliest paper mill in Outagamie County was established in Appleton in 1853.

Fourteen hydropower sites were also located along the river from Lake Winnebago to Green Bay.

By the mid-1800s, saw mills were using dam-generated power. As these facilities developed and economic changes occurred, some of these mills converted to paper production and wood pulping. Today, industries and municipalities use the river for waste assimilation, industrial processing, cooling water, and power generation, while individuals use the river for recreation and as a food source (WDNR, 1995).

Green Bay is the largest city in the region, with a population of approximately 185,000 people (Brown County Planning Department, 1999). Historical development of the Green Bay region has been similar to that of the Lower Fox River valley. The city was originally founded as a fort and center of trade and transport at the mouth of the Lower Fox River. First under French control, the area later was commanded by the British, and finally by the Americans following the War of 1812. In 1816, Fort Howard was erected just west of the mouth of the Lower Fox River to consolidate American power and deter British and Canadian interests in the region, which had been predominant since the 1730s. The city of Green Bay developed around fishing, commerce, manufacturing, transportation, and as a general cargo port. It continues to be an important port, exporting paper, lumber, and wood products, and importing general bulk cargo. The Port of Green Bay operates from April 1 through December 31 and typically handles about 1.8 million tons of bulk cargo annually (Haen, 2000).

The cities of Oconto, Peshtigo, and Marinette, Wisconsin and Menominee, Michigan developed around the timber industry in the 1820s and 1830s. Timber and lumber mills in these cities helped supply the burgeoning cities of Milwaukee and Chicago, both of which were rapidly building and growing during this time. Whereas mills in the Lower Fox River valley were able to switch from flour and lumber processes to paper manufacturing, most of the mills located north of the city of Green Bay eventually closed as the need for these mills could not be sustained and the source of timber moved further west.

The city of Sturgeon Bay, Wisconsin, developed as a center for ship building, fishing, and agriculture. The first permanent residents arrived in the area during the 1850s and the city took its name from the huge sturgeon that once populated the waters of the bay. The Sturgeon Bay canal connects the waters of Sturgeon Bay (Green Bay) with Lake Michigan, thus shortening the trip for vessels carrying cargo between the city of Green Bay and the cities of southern Lake Michigan, including Milwaukee and Chicago. The canal was completed in 1882.

The city of Escanaba, Michigan, developed along with the iron mining industry in Michigan's Upper Peninsula (UP) and served as an important export and transportation center. Similar to the decline of the timber industry in the other cities along Green Bay, the city of Escanaba eventually experienced a decline in port activities as the iron mining industry in the UP declined. Today, approximately 7 to 8 million long tons of iron ore and taconite pellets are shipped out of Escanaba annually, compared with 12 to 14 million long tons annually in the early 1980s (Rodgers, 2000).

Tourism has also become an important commercial activity in the cities located along Green Bay in recent years. As each of the major manufacturing/commercial industries discussed above has declined, the percentage of income generated through tourism has increased. Therefore, tourism remains an important economic activity for the region, due in large part to the natural harbors, scenic views, and wildlife areas located in and around the shores of Green Bay.

3.1.2 Current Land Uses

The Green Bay and Lower Fox River areas support a population of approximately 595,300. The Lower Fox River valley is the second largest urbanized region in the state of Wisconsin and supports a population of approximately 412,900, about 8.1 percent of the state population. The Lower Fox River valley includes the Fox Cities, which include all the cities from Neenah/Menasha through Kaukauna, as well as the Green Bay Metropolitan Statistical Area (MSA), which includes much of Brown County. The population of the other counties surrounding Green Bay is approximately 119,100 in Wisconsin and about 63,300 in Michigan.

The Lower Fox River valley, from the Fox Cities to Green Bay, may still contain the largest concentration of pulp and paper industries in the world (20 mills in approximately 59.5 km [37 mi]). The paper industry remains active within the valley and plays a vital role in the local and state economy. The paper industry employs approximately 26,000 in the Lower Fox River valley and over 53,000 people at pulp, paper, and allied firms throughout the state (Wisconsin Paper Council, 2000). 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.

Regional land use along the Lower Fox River was compiled by planning commissions in both the Fox Cities and Brown County. The Fox Cities Area Existing Land Use Map (East Central Wisconsin Regional Planning Commission

[ECWRPC], 1996) extends from the outlet of Lake Winnebago to a point about 5 km (3 mi) downstream of Kaukauna. The Fox River Corridor Land Use Map (Brown County Planning Commission, 1990) covers the entire length of the Lower Fox River within Brown County. There is stretch of river about 1.5 km (1 mi) not covered by these two maps; however, land-use details on these maps provide a general description of development in the river vicinity. The approximated land use percentages for areas within about 0.4 km (0.25 mi) of the bank of the Lower Fox River are summarized below.

Land Use Summary - Lower Fox River Valley

Land Use	Fox Cities (1996)	Brown County (1990)	Entire River
Residential	32.9%	25.5%	29.2%
Industrial/Commercial	26.2%	25.3%	25.8%
Woodlands	14.6%	17.9%	16.2%
Parks	11.6%	6.8%	9.3%
Agricultural	0.5%	11.4%	5.8%
Public	7.2%	1.3%	4.3%
Wetlands	5.1%	1.6%	3.4%
Vacant	2.0%	10.2%	6.0%

Notes: Percentages are approximate and are intended to provide a general indication of land use along the Lower Fox River. The Fox Cities includes all communities between Neenah/Menasha and Kaukauna. Public land includes school properties.

The largest category of land use along the Lower Fox River is residential. In addition, about 40 percent of land use along the river not classified as residential or industrial/commercial represents potential wildlife habitat.

Land use in the vicinity of Green Bay was collected from available county records for Brown, Door, Kewaunee, Marinette, and Oconto counties in Wisconsin and for Delta and Menominee counties in Michigan. Except for Kewaunee County, a large percentage, if not all of the land within these counties, lies in the Green Bay watershed. Much of Kewaunee County, as well as portions of Door County, Wisconsin and Delta County, Michigan, lie in the Lake Michigan watershed. Additionally, land use further inland may have as significant impact on water quality in Green Bay as do near- or on-shore land uses. A summary of the land use in the counties bordering Green Bay is presented on Table 3-1.

Counties located along Green Bay are largely undeveloped (Table 3-1). Brown County, Wisconsin, is the only county where more than 5 percent of the total land is used for residential or industrial/commercial purposes. Between 65 percent and 85 percent of all land in these counties is classified as either agricultural or forested lands, reflecting the overall rural nature of this area. Wetlands comprise 3 percent to 20 percent of the land in these counties (Table 3-1). The largest wetland areas are located in Brown, Oconto, and Marinette counties, all located along the western side of Green Bay. Door and Kewaunee counties on the eastern side of the bay have less than 3.3 percent wetlands.

3.2 Meteorology

Meteorological data for the region provide background on weather patterns that are considered in the evaluation and design of possible sediment remedy technologies. Temperature and precipitation extremes influence long-term planning and remedial management considerations.

Northeastern Wisconsin and the applicable portions of the Michigan UP are characteristic of continental climate with distinct changes in weather over the region. Summers are warm and occasionally hot and humid while the winters are cold and snowy. Spring and autumn are transitional seasons, with gradual to abrupt changes in weather. Weather fronts, moving from west to east and southwest to northeast, account for the abrupt changes in weather and usually occur every two to four days. Lake Michigan and Green Bay provide a modifying influence on local weather, creating the "lake effect" of cooler temperatures near the lakes during the summer and slightly warmer temperatures during the winter (Wisconsin State Climatology Office [WSCO], 2000).

The average monthly and annual temperature and precipitation data for the cities of Green Bay, Appleton, Marinette, and Sturgeon Bay, Wisconsin, along with information for Fayette, Michigan (located on Big Bay de Noc) from 1961 through 1990 are summarized on Tables 3-2 through 3-6, respectively. Between the late spring and summer months of May through September, the average monthly temperature ranges from a low of 10°C to a high of 21°C (50°F to 70°F). Temperatures are highest during July, with an average of approximately 21°C (70°F). Both Sturgeon Bay, Wisconsin and Fayette, Michigan (located on the Door and Garden Peninsulas, respectively), are the coolest locations. These two locations are cooler than cities on the south or west sides of Green Bay due to the lake effect, the prevailing southwest winds, and their proximity to Lake Michigan. From June through August, Green Bay, Appleton, and Marinette typically have about five to seven days per year with temperatures exceeding 32°C (90°F). However, during this same period, Sturgeon Bay only has one to two days annually and Fayette, Michigan, has only one day every 10 years where temperatures exceed 32°C (90°F). Conversely, during the winter months of December through February, the average temperature ranges from -10°C to -4°C (14°F to 24°F). January temperatures are coldest with an average of approximately -8°C (16°F). It is also typical to have between 15 and 23 days in January where the average temperature is below 0°C (32°F). Frost usually occurs from mid-October through very early May (WSCO, 2000) and soils in the region are seasonally frozen.

The average annual precipitation in the study area ranged from 0.73 to 0.82 meters (28.8 to 32.2 inches). Most of the precipitation occurs as rain and snow with occasional episodes of sleet and hail. Over half the annual precipitation (from about 53 percent to 57 percent) falls from May through September. August is typically the wettest month with at least 8.1 centimeters (3.2 inches) of rain and significant precipitation also occurs during both June and September (Tables 3-2 through 3-6). February is typically the driest month with just over 2.5 centimeters (1 inch) of precipitation. Snowfall is extremely variable year to year; the mean annual snowfall is approximately 1.2 meters (44 to 48 inches) at Green Bay, Appleton, and Sturgeon Bay, while both Marinette and Fayette, Michigan, typically receive about 1.34 meters (53 inches) of snowfall. The highest snowfall amounts recorded range from 2.3 to 3.3 meters (90 to 130 inches), with snowfall generally increasing to the north, reflecting lake effect snows (WSCO, 2000). Most of the streams and lakes are ice-covered from late November to late March and flooding is most frequent and serious during the month of April, when melting snow and spring run-off are greatest (WSCO, 2000).

Prevailing winds are from the northwest in winter and from the southwest in summer. However, wind from the northeast is common in the vicinity of Green Bay. A windrose diagram, developed from the NOAA weather station at the city of Green Bay, is included in Appendix C. The wind rose diagram and accompanying table indicate that prevalent winds are out of the west and south-southwest directions. The table indicates that winds are out of this west to south-southwesterly direction 37 percent of the time and range between 10 and 30 km/hr (6 to 19 mph) 27 percent of the time. The wind rose diagram also indicates that winds from the northeast and northwest are about evenly distributed while easterly and southeasterly winds are the least common. As previously discussed, the winds from the northeasterly direction are significant due to the seiche effect on currents and water levels in Green Bay and the Lower Fox River.

3.3 Geologic Characteristics

This section discusses the regional geology, soils, hydrogeologic characteristics, and water use in the region. These factors affect the physical characteristics of sediments, migration of chemicals of concern, possible sediment remedies, and on-land disposal options of PCB impacted material.

3.3.1 Regional Geologic Setting

The Lower Fox River and Green Bay basins lie in the ridges and lowlands province of eastern Wisconsin and western Michigan. The eastern ridges and lowlands generally trend north-south across Wisconsin from northeastern Illinois to the Michigan shores of Lake Superior. This province is a southwest-northeast trending area underlain by Paleozoic Rocks. The bedrock does not entirely control surface geomorphology, as the glacial advances and retreats planed off the bedrock highs and filled in bedrock valleys with till and outwash deposits (Krohelski and Brown, 1986). Stratigraphic cross-sections and other pertinent information concerning the regional geology of the area are included in Appendix D.

3.3.1.1 Bedrock Geology

The Lower Fox River valley and Green Bay is underlain by a sequence of Precambrian undifferentiated granite overlain by Paleozoic sandstones dolomite, and shale (Appendix D). The Paleozoic bedrock units, from oldest to youngest, are Cambrian sandstones, Ordovician dolomite, sandstone, and shale units and undifferentiated Silurian dolomites. The Paleozoic rocks range from 61 to 488 m (200 ft to 1,600 ft) thick on the western and eastern sides of Brown County, respectively. The bedrock surface slopes east approximately 5.7 to 7.6 m/km (30 to 40 ft/mi), toward and beneath Lake Michigan (Krohelski and Brown, 1986). This regional dip has resulted in the most prominent surface expression of the bedrock, the Silurian Niagara Escarpment. The escarpment lies east of and parallel to the Lower Fox River lowlands. In addition, the Ordovician Maquoketa Shale has also been eroded in the western part of the study area due to the regional dip of the bedrock strata. Where present, the Maquoketa Shale serves as an aquitard that hydraulically separates the shallow Niagara dolomite from the deeper sandstone and dolomite aquifers.

In the Lower Fox River valley, the Silurian Niagara Dolomite is only present in the eastern portion of Brown County; it is entirely absent in Outagamie and Winnebago counties. Around Green Bay, the Niagara dolomite comprises the surface bedrock in both the Door and Garden Peninsulas (Bosley, 1976; Sinclair, 1960).

Similar to the Niagara Dolomite, the Maquoketa Shale has also been eroded east of (and parallel to) the Lower Fox River. In Wisconsin, the Maquoketa Shale is only present in the very southeastern corner of Outagamie County (Krohelski and Brown, 1986) and as thin outcroppings along the very western edge of Door County (USGS, 1992). In Michigan, the contemporaneous Ordovician Shale unit is the Richmond Group/Collingwood Formation, which comprises the surface bedrock of the Stonington Peninsula. The contact between Silurian age units and Ordovician age units within Michigan is just east of Stonington Peninsula, at the north end of Big Bay de Noc.

Due to the erosion of the dolomite and shale bedrock units, the uppermost bedrock in the Lower Fox River valley (from the city of Green Bay to Little Bay de Noc) are Ordovician age limestone/dolomite units. Within Wisconsin, these are the Sinnipee Group, composed of the Galena and Platteville formation dolomites, and the Decorah Formation shale. The Sinnipee Group subcrops just east and west of the Lower Fox River, along the axis of the river valley. Additionally, bedrock units of the western shore of Green Bay are comprised of the Galena and Platteville formations (Krohelski and Brown, 1986). Within Michigan, these are the Trenton and Black River formation, and they are contemporaneous with the Galena and Platteville units (Sinclair, 1960; Vanlier, 1963).

3.3.1.2 Glacial Geology

Unconsolidated Quaternary glacial deposits cover the bedrock and consist of silty clay to clay loam tills with associated sand and gravel outwash and lacustrine units. In the Lower Fox River valley the glacial deposits range in thickness from approximately 15 m (50 ft) over much of the area to over 61 m (200 ft) in the area around Wrightstown. The surficial units were deposited by the Green Bay and Lake Michigan lobes of the Wisconsinan glaciation, approximately 10,000 to 13,000 years ago (Attig, *et al.,* 1988). The associated till and outwash units are of the Kewaunee and Horicon formations (Appendix D). Superimposed on the glacial deposits are modern fluvial and alluvial sediments associated with slopewash, river, and floodplain deposits (Krohelski and Brown, 1986).

At least 10 separate tills of the Kewaunee Formation (Mickelson, *et al.,* 1984) have been described in the Lower Fox River valley, Green Bay, and the surrounding region (Appendix D). In addition to the Kewaunee Formation till units, there are silty and clayey lacustrine sediments of several ages, as well as sand and gravel proglacial outwash sediments of several ages. According to Mickelson, *et al.* (1984), an arbitrary vertical cut-off at the Lower Fox River (and hence on each side of the bay) has been used because the correlative units differ significantly on both sides of the river. In general, the Kewaunee Formation is comprised of fine grained units usually having a predominance of silt rather than clay with approximately one-third sand. The Kewaunee Formation tills were deposited by both the Green Bay and Lake Michigan lobes.

Glenmore Member (Kewaunee Formation) deposits underlie the stream bed and overbanks from Lake Winnebago to the tip of Door County on the east side of the Lower Fox River valley and Green Bay. Along the west side, deposits of the Middle Inlet and Kirby Lake Members (Kewaunee Formation) underlie the stream bed and overbank of both the river and bay. The Kirby Lake Member extends from south of Lake Winnebago to just upstream of Wrightstown and the Middle Inlet Member extends from this point well into Michigan (Mickelson, *et al.,* 1984). The Kewaunee unconsolidated deposits are overlain by undifferentiated alluvium, lacustrine sediments, and peat or muck.

Following deposition of the till units above, the Lower Fox River valley and Green Bay basin were modified by proglacial lakes. The southern Fox River valley was occupied by proglacial Lake Oshkosh while areas of Lake Michigan and the Lower Fox River valley were occupied by proglacial Nipissing Lake. These lakes deposited significant volumes of largely fine-grained materials, consisting of very fine sand, silt, and clay and differing from modern river sediments by a lack of organic material (Need, 1983). These lakes also affected the western shore of Green Bay but only flooded the southern portion of Door County. The northern portion of the Door Peninsula and the Garden Peninsula do not exhibit proglacial lake sediments.

Due to the glacial events which occurred in the Lower Fox River valley and Green Bay basins, soils and river sediments in the region are predominantly silt and clay units with varying amounts of sand and gravel. Soils in the vicinity of the Lower Fox River are generally described as silty clay loam and silty clay. In the northern portion of Green Bay, especially along the west side, the outwash and glacial lake plains are typically dominated by sands while clay till deposits are predominant on the Door and Garden Peninsulas (Soil Conservation Service [SCS], 1972; 1978; 1988; 1989; 1991; 1994). Due to the easterly dip of the bedrock, the thickness of the glacial deposits is as great as 15 m (50 ft) on the west side of Green Bay. However, these deposits are generally less than 3 m (10 ft) thick on the Door and Garden Peninsulas, and thinner along the eastern shore of Green Bay.

3.3.2 Regional Soils

Soils in the Lower Fox River valley are largely comprised of tills and lacustrine unconsolidated sediments which range in age from approximately 10,000 to 13,000 years old (Mickelson, *et al.,* 1984). These soils are the Hortonville, Kewaunee, and Manawa soils, which were formed in till, and the Winneconne and Oshkosh soils, which were formed in proglacial lake sediments (SCS, 1972).

Soils in Winnebago County belong to the Kewaunee-Manawa-Hortonville soil association. These soils are generally well to somewhat poorly drained silt loam with loamy or clayey subsoil underlain by loamy or clayey glacial till (SCS, 1972). Soils between the Winnebago County line and Wrightstown, within Outagamie County, are classified in the Winneconne-Manawa Soil Association. These soils are well to somewhat poorly drained, medium to fine textured, slowly permeable soils underlain by silty clay glacial till or lacustrine sediments (SCS, 1972). These soils were deposited in glacial Lake Oshkosh.

Soils along the lowest reaches of the Lower Fox River lowlands from Wrightstown north to Green Bay belong to the Oshkosh-Manawa Soil Association (SCS, 1972). Oshkosh soils are well drained to somewhat poorly drained with a clayey subsoil; these soils formed in glacial lake plains (SCS, 1972). Along the Green Bay shoreline at the mouth of the Lower Fox River is an extensive area of Carbondale-Cathro-Marsh soils, which are very poorly drained organic soils and marsh approximately 1.2 m (4 ft) thick (SCS, 1972). Other areas along the shoreline are described as filled land, indicating that soils were placed in their present locations through construction or other activities.

Soils along the west side of Green Bay are generally more sandy than soils along the east side of the bay. Soils immediately inland of the southwest side of the bay belong to the Tedrow-Roscommon Soil Association and are comprised of deep, nearly level, somewhat poorly to poorly drained sandy soils of lacustrine origin. These sands were likely derived from Upper Cambrian sandstones and transported by upland streams and re-worked by longshore currents (SCS, 1972). Soils located immediately adjacent to the bay are the organic Carbondale-Cathro-Marsh soils, described above.

Shoreline soils in Oconto and Marinette counties, Wisconsin and in Menominee County, Michigan are dominated by nearly level to gently sloping, somewhat poorly to very poorly drained, sandy soil on flats and in depressions of outwash and glacial lake plains (SCS, 1988; 1989; 1991). In Oconto and Marinette counties, these soil are of the Wainola-Cormant and Wainola-Deford Associations; in Menominee County they are of the Deford-Wainola-Rousseau Association. In the upland areas of Oconto and Marinette counties, the soils are loamy, nearly level to very steep, and well drained to somewhat poorly drained soils; these belong to the Onaway-Solona and Emmet-Charlevoix Associations, respectively.

In Michigan, loamy soil of the Charlevoix-Ensley-Cathro Association and organic soils of the Roscommo-Tawas Association are present along the west shore of the bay in Menominee and Delta counties (SCS, 1989 and 1994). Soils along the west and east shores of Little Bay de Noc are dominantly sandy soils of outwash and lake plains origin of the Rubicon Soil Association. The predominant soils of the Stonington Peninsula are loamy, nearly level, poorly drained loamy and organic soils of the Nahma-Ensley-Cathro Association. The Garden Peninsula is comprised of loamy soils of the Summerville-Limestone rock Landongrie Association. These soils are loamy and organic soils poorly to very poorly drained (SCS, 1994).

Along the east shore of Green Bay in Wisconsin, the dominant soils of southern Door County are deep, well to somewhat poorly drained, nearly level to somewhat steep silty clay soils of the Kewaunee-Kolberg-Manawa Association over silty clay till or dolomite bedrock (SCS, 1978). Soils of the Summerville-Longrie-Omena association extend from just north of Little Sturgeon Bay through the Garden Peninsula. These soils are shallow to deep, well drained, nearly level to moderately steep soils that have sandy loam to loam subsoil over sandy loam, till or dolomite bedrock (SCS, 1978).

3.3.3 Hydrogeology

3.3.3.1 Regional Hydrogeology

Three aquifer systems are present in the Lower Fox River (LFR) valley and Green Bay watershed. These aquifer systems generally consist of more than one geologic unit conducive to the movement and migration of water and they generally extend from the southern part of Wisconsin north into the UP (Krohelski and Brown, 1986; USGS, 1992). These aquifer systems include the following:

1. The Upper Aquifer of unconsolidated Quaternary deposits, Galena/Platteville Formations, and, where present, the Niagara dolomite

2. The St. Peter aquifer in the Ordovician age sandstones

3. The Elk Mound aquifer in the deeper Cambrian age sandstones

In addition, there are two general confining units (aquitards), which separate the aquifers and limit vertical groundwater movement. These units are the Maquoketa Shale/Sinnipee Dolomite and the St. Lawrence, a silty dolomite. The Precambrian basement granite also forms an aquitard at the base of the Elk Mound aquifer (Krohelski and Brown, 1986). As stated above, these geologic units continue north into the UP.

The upper aquifer in the region includes the Silurian Niagara dolomite above the Maquoketa Shale on the east side of the area and the upper Ordovician sandstone formations on the west side of the area. The Niagara dolomite is the upper bedrock unit in both the Door and Garden Peninsulas. Although the aquifer is not extensive, it can supply up to 50 gallons per minute (gpm) in areas where it is present and where secondary porosity has increased water movement (USGS, 1992). West of the Niagara Escarpment in Wisconsin, the Galena/Platteville Formations form the upper bedrock units. In the UP, the Trenton/Black River Formations comprise the upper bedrock units. The Galena/Platteville/Trenton/Black River formations typically yield only enough water to be used for domestic supply wells (USGS, 1992). These bedrock units are generally hydraulically connected to the overlying Quaternary deposits wherever present. The aquitards beneath the Upper Aquifer are either the Maquoketa or Glenwood shale or Sinnipee dolomite, depending on the region of the state and the surface bedrock units (USGS, 1992).

The St. Peter aquifer includes the St. Peter Formation, the Prairie du Chien Group, and the Jordan Formation (Au Train Formation in the UP). It is underlain by the St. Lawrence aquitard (Krohelski and Brown, 1986; USGS, 1992). Most of the St. Peter aquifer units are sandstones which readily yield water, but significant amounts of dissolved minerals within this and underlying aquifers may make the water aesthetically unpleasing (USGS, 1992). The St. Lawrence confining unit consists of the St. Lawrence Formation and Tunnel City Group, and is composed of silty, shaly dolomites.

The underlying Elk Mound aquifer consists of sandstone units of the Elk Mound Group, and is hydraulically similar to the St. Peter aquifer. In Wisconsin, the Elk Mound Group consists of the Wonowoc, Eau Claire, and Mount Simon Formations (Krohelski and Brown, 1986). The Eau Claire and Mount Simon Formations extend, with the Mount Simon formation being the more productive of the two units in the UP (USGS, 1992). The basement complex is Precambrian, composed of igneous, crystalline rock that limits the vertical movement of groundwater. Primary water production is from the St. Peter aquifer, and the Elk Mound aquifer, both are bedrock aquifers and located at depth.

Prior to development in the Fox River Valley in the 1900s, the St. Peter aquifer was confined and existed under artesian conditions throughout most of the area. However, significant demands placed upon the aquifer have caused a well-known and studied drop in the potentiometric surface of the St. Peter aquifer. The cone of depression was centered on the city of Green Bay until 1950s when the city built a pipeline to Lake Michigan to supply the city's water needs. The St. Peter aquifer rebounded somewhat in the city of Green Bay, however, additional deep water wells were built along the Lower Fox River from De Pere to Lake Winnebago to supply growing population and industry needs and the cone of depression migrated south along the Lower Fox River, and is currently most dramatic in the De Pere area (Conlon, 1998; Axness, et. al., 2002). The potentiometric surface in the St. Peters has fallen between 100 and 400 feet from pre-development levels.

Hydrogeologic Setting Lower Fox River

The Lower Fox River occupies a lowland area approximately 10 miles wide, commonly described as the Fox River Valley. The Lower Fox River generally flows across relatively low permeability Quaternary deposits of lacusterine clay and silts and glacial till (Krohelski and Brown, 1986). These low permeability units underlie operable units OU1, OU3 & OU4 and sections of OU2. The clay, silt and till vary in thickness from less than 50 feet to over 100 feet (Need, 1985).

Under sections of OU2 in the Lower Fox River, the Sinnipee dolomite sub crops in the riverbed. Evidence of bedrock sub crop includes the rapids that exist along OU2, and limited soft sediment deposits. The river is classically narrow due to the bedrock riverbed. Rocks of this formation form the first major confining unit in the area and are considered to be relatively impermeable - or of low permeability (Krohelski and Brown, 1986; Conlon, 1998). The primary water supply aquifers for the Lower Fox River Valley are located beneath this confining unit.

Because shallow groundwater flow generally follows the ground surface topographic contours, groundwater flow in the Upper Aquifer is toward the Lower Fox River from the northwest and southeast (Plate 1, Krohelski and Brown, 1986).

Prior to development in the 1900s and significant pumping from the St. Peter aquifer, many springs and seeps existed in the Fox Valley as a result of the artesian conditions of the St. Peter aquifer. It is thought that the St. Peter aquifer also likely discharged to the Upper Aquifer and the Lower Fox River (Krohelski and Brown, 1986). Since water levels have been drawn down as much as 400 feet in the St. Peter aquifer, it no longer discharges to the Lower Fox River (Conlon, 1998). The significant cone of depression in the St. Peter aquifer induces vertical flow from the Upper Aquifer to the St. Peter aquifer reducing the amount of discharge to local streams including the Lower Fox River (USGS, 1998).

If water use in the valley changes, and the St. Peter aquifer rebounds to predevelopment levels, it may once again discharge to the Lower Fox River along certain reaches (Batten and Bradbury, 1996; Krohelski, 2002).

Lower Fox River/Groundwater Interaction

The Upper Aquifer in the area is composed of Silurian dolomites east of the Lower Fox River, and the unconsolidated glacial tills and lake sediments that cover the entire area. Groundwater movement in the Upper Aquifer is part of the local flow system and controlled by local topographic features. Because the Lower Fox River lies in a wide low valley, trending southwest to northeast, groundwater movement is toward the river (Krohelski and Brown, 1986; USGS, 1998). There have been no detailed studies of the Upper Aquifer to quantify the amount of ground water discharging to the Lower Fox River. Draw down in the St. Peter aquifer since development in 1900s has caused an increase in discharge from the Upper Aquifer downward to the St. Peter, reducing the volume of ground water discharging to the Lower Fox River (Conlon, 2002). However, it is likely that groundwater from the Upper Aquifer discharges to the Lower Fox River during periods of low or base flow. Discharge to the river is limited due to the following factors:

- Relatively impermeable tills and lake bed deposits, 50 - 100 feet thick, in which the river bed flows

- Relatively impermeable dolomite which sub crops in stretches of the river bed in OU2 (Conlin, 2002; Krohelski, 2002)

- Moderate to low head conditions between the Lower Fox River and the Upper Aquifer

- High surface run-off after storm events, reducing recharge to the Upper Aquifer

- Increased pumping rates for municipal and industrial use, and consequential drawdown

In a water supply modeling study (USGS, 1998), the volume of water in the Lower Fox River was measured at several points along the river from LLBdM to river mouth at Green Bay in order to estimate the contribution of groundwater to the river. For rivers with significant groundwater contributions, the expectation is that flow volume will increase downstream even after taking into account tributaries and other sources. In the case of the Lower Fox River, there was relatively minor unaccounted for change in volume over the 39 miles, supporting the case of limited groundwater discharge. For the same study, an inspection of a dolomite quarry in Kaukauna, approximately 100 feet from the Lower Fox River, revealed limited groundwater discharge into the quarry several hundred feet below the water level of the river, further supporting the case of limited ground water movement through this formation to the river (Conlin, 2002; Krohelski, 2002). In addition, caliper logs in the Sinnipee show no borehole enlargement, indicating relatively dense, and impermeable material. Due to the lack of detailed local studies of the Upper Aquifer, the discharge volumes to the Lower Fox River have not been quantified.

Although the majority of the Upper Aquifer is less impermeable material, lens of sand and gravel are present (Krohelski and Brown, 1986), and may produce locally significant discharge to the Lower Fox River where the sand and gravel lens intersect the river bed. Individual lens have not been specifically identified in the study area.

3.3.3.2 Water Use (1995)

Water use data (USGS, 1995a and 1995b) for the Lower Fox River watershed and the other significant Green Bay tributaries are summarized on Table 3-7. Approximately 595,300 people live in the Lower Fox River and Green Bay watersheds. Over 381,000 people are served by public water supply systems, which provide over 62.8 million gallons per day (MGD) (USGS, 1995a and 1995b). The source of water supplied by public systems is about equal between groundwater and surface water sources. Private wells and well systems supply about 11.1 MGD to the remaining population in the watersheds listed (Table 3-7).

The Lower Fox River watershed (Fox Cities MSA through Green Bay MSA) uses about 46.5 MGD, or 74 percent of the water consumed in the region daily. About 92 percent of this 46.5 MGD is supplied via public water supply systems. Further, only about 17.8 MGD of groundwater is pumped from the regional aquifers in the Lower Fox River area. According to water supply well records, the wells which supply the 17.8 MGD range in depth from 500 to over 1,000 ft below land surface (WDNR, 1985). Based on these well depths, it is unlikely that contaminated sediments would impact the groundwater sources that supply these municipal water wells. The remaining 28.7 MGD of water provided by public water supply systems are obtained from surface water sources. Many of the larger municipalities in the region, including Neenah, Menasha, Appleton, and Green Bay, use surface water for municipal water supply. Neenah, Menasha and Appleton pump water from Lake Winnebago while the city of Green Bay pumps water from Lake Michigan through a 42-mile pipeline that is located approximately four miles offshore of the city of Kewaunee.

Based on the fine-grained glacial deposits which underlie the Lower Fox River and the absence of regional groundwater extraction, there is little groundwater recharge from the Lower Fox River into the upper aquifer. Therefore, it is unlikely that contaminated river sediments are adversely impacting groundwater quality beneath the Lower Fox River. According to Krohelski and Brown (1986), only two streams within Brown County (Duck Creek and Suamico River) were identified as losing streams. These Green Bay tributaries recharge the upper aquifer in different reaches due to the absence of glacial material beneath the riverbed.

Water use in the other watersheds are significantly lower than that in the Lower Fox River watershed and is much more dependent on private water supplies (Table 3-7). Of the remaining 16.33 MGD of water consumed in the region, only the Menominee (Marinette/Menominee area) and Door/Kewaunee watersheds consume more than 1.57 MGD (Table 3-7). Approximately 6.7 MGD are consumed in the Menominee watershed while about 3.13 MGD are consumed in the Door/Kewaunee watershed. Within the Menominee watershed about 38.5 percent of the population is supplied by private wells/systems. Between 42 percent and 75 percent of the population is served by private wells/systems in the remaining watersheds. This breakdown of the population served by public versus private water supply systems reflects the rural nature of the remaining watersheds, especially when compared with the urban centers located throughout the Lower Fox River valley and at Marinette/Menominee.

The generation of electrical power uses the greatest volume of water in the Lower Fox River and Green Bay area. Over 398 MGD is used for thermoelectric power generation at the Wisconsin Public Service Corporation (WPSC) Pulliam power plant, which is located at the mouth of the Fox River. In addition, hydroelectric power (from dams on the river) uses almost 11.5 billion gallons per day. However, this water use is not included in the Total Water Use column (Table 3-7) because this water only represents river flow. No pumping or other efforts are required to obtain this water. In addition, water use for the Point Beach Nuclear power plant in Kewaunee County is not included in Table 3-7 because this water is obtained from Lake Michigan.

Over 146 MGD are used for industrial/commercial purposes, with about 80 percent of the total consumed in the Lower Fox River and Menominee watersheds. Additionally, over 93 percent of the water used for industrial/commercial purposes is obtained from surface water sources. Mining, irrigation, and livestock consume about 18.7 MGD (Table 3-7). Therefore, of the 625 MGD of water consumed in the region, about 92 percent of the water (574 MGD) is obtained from surface water sources. Due to the historic problems with water pollution in the Lower Fox River and Green Bay, the main surface water sources for human consumption are Lakes Winnebago and Michigan.

3.4 Lower Fox River Surface Water Hydrology

This section discusses the factors that influence or control flow in the Lower Fox River. Current velocities, high, low, and average flow characteristics, and river bathymetry all influence the movement of impacted sediments and consideration of possible remedial alternatives.

The slope of the bedrock and the pre-glacial bedrock valleys control the topography and drainage of the Lower Fox River valley. A pre-glacial bedrock valley lies along the axis of the Lower Fox River and was filled with glacial sediments from glacial Lake Oshkosh (around Lake Winnebago) and Nipissing Lake (from De Pere to Green Bay). The Lower Fox River and its tributaries have flowed over and cut through these relatively flat glacial lake plain sediments (Olcott, 1968).

3.4.1 Surface Water Flow Controls

3.4.1.1 Dams in Wisconsin and on the Lower Fox River

Dams in Wisconsin and on the Lower Fox River are subject to state and federal regulations and most of the dams are regulated for energy production. Most existing dams are not primarily flood control structures and there are no plans to remove any of the existing dams on the Lower Fox River. However, there are concerns about the release of upstream contaminated sediment in the event of a dam removal or failure. Inspection and dam stability information on the dams owned and operated by the USACE reveals that the dams are regularly inspected, have post inspection maintenance conducted and have no significant stability concerns.

Regulatory History of Wisconsin Dams. The first dam built in Wisconsin was built in 1809 to provide power for a sawmill on the Fox River at De Pere. Black River saw it's first sawmill in 1819, and in 1831 one was built on the Wisconsin River. These early dams aided people in providing flowages for transporting goods, and for powering lumber and grain mills. The first state regulation of dams began with the Milldam Act, a part of the Wisconsin Territorial Laws of 1840, No. 48. The purpose of this act was to encourage the construction of mill-powering dams, by permitting the flooding of the land of others without acquiring easements for millponds. These early dams provided for and encouraged settlement in Wisconsin.

In 1841, dams on navigable streams were required to obtain legislative permission, as a part of the Wisconsin Territorial Laws of 1841, No. 9. This helped encourage economic development, as well as protect the public interest in waterways. The Milldam Act was repealed in 1849 (ch. 157), as the constitutionality of preventing compensation by flooded landowners was challenged at the Wisconsin Supreme Court. The impoundments created by dams were viewed as a public resource, and therefore it was argued that private land, such as the land being flooded by these dams, could not be taken from its landowners for public use without compensation being given to the landowner. In 1857 the Milldam Act was revived under Chapter 62, Laws of 1857, but was repealed and recreated in 1858. In a court case in 1860, it was stated by the court that the Milldam Act would be overruled if it were not for precedent and economic benefits, and therefore the Milldam Act was constitutional.

In 1863, it was declared that navigable waterways are public highways. In the following years, the "sawlog" test was developed to determine navigability. In 1909, the legislature decided they no longer had the time or expertise to issue permits for dams, and that responsibility was given to state agencies.

For much of the early 1900s, the Rail Road Commission and then the Public Service Commission (PSC) had jurisdiction over dams. Laws changed over the years, to address issues such as the rights of upstream and downstream landowners, the debate over navigable and non-navigable rivers, and public safety rights. In 1967, the Wisconsin Department of Natural Resources was created, and jurisdiction over dams was handed over from the PSC to the WDNR. In the early 1980s, the WDNR developed standards for design, construction and reconstruction of large dams, enacted Warning Sign and Portages for Dams rules for public safety. In 1991, procedures for implementation of dam maintenance, repair, modification or abandonment grant program were put into place.

The WDNR currently deals with permitting for new dam construction, repairs, reconstruction, ownership transfers, and abandonment. Many dams in the state have been in place since the late 1800s, and a great deal of time must be invested in inspecting aging dams and making sure they comply with public safety requirements, and environmental regulations.

Wisconsin Dams. There are approximately 3,700 dams inventoried in the state of Wisconsin. An additional 700 dams have been built and washed out or removed since the late 19th century. The federal government has jurisdiction over large dams that produce hydroelectricity - approximately 5 percent of the dams in Wisconsin. The WDNR regulates most of the rest of the dams. Approximately 50 percent of the dams in Wisconsin are owned by private individuals, 19 percent by the state of Wisconsin, 16 percent by municipalities such as townships or county governments, and 15 percent by other ownership types.

A dam with a structural height of over 6 feet and impounding 50 acre-feet or more, or having a structural height of 25 feet or more and impounding more than 15 acre-feet is classified as a large dam. There are approximately 1,200 large dams in the state of Wisconsin. Dams are classified as High Hazard when their failure would put lives at risk. The "hazard" rating is not based on the physical attributes, quality or strength of the dam itself, but rather the possibility of loss of life and property should the dam fail.

The Public Trust Doctrine emanates from Article IX, Section 1 of the Wisconsin Constitution. It states that all rivers, lakes and navigable waterways are under the jurisdiction of the state of Wisconsin. Any structure which is built on a waterway impacts the public rights to that waterway, and needs to be monitored by the state of Wisconsin to assure safety, water quality, public access and monitor its impact on Wisconsin wildlife.

Dam Safety Program. Chapter 31, created in 1917 under the Water Power Law, was developed to ensure that dams are safely built, operated and maintained. NR 333 provides design and construction standards for large dams and NR 335 covers the administration of the Municipal Dam Repair and Removal Grant Program. WDNR is responsible for administration of these regulations. Chapter 31 covers:
- Dam permitting
- Dam construction
- Dam safety, operation and maintenance
- Alteration or repair of dams
- Dam transfer and dam removal
- Water level and flow control

In regards to dam safety inspections, Chapter 31.19 requires the department to inspect all of the large dams on navigable waterways once every 10 years. However, WDNR does not typically inspect dams that are regulated by a federal agency.

Dam Removal. Dams have been built and removed in Wisconsin for almost 200 years. In the early years, when a dam no longer provided and functional or economic purpose it was removed from the stream. Many of the dams in the state today have been in place for years. While many of these no longer provide their original function they have become a part of the communities identity. This can make decisions about whether to perform costly upgrades to dams or remove them very difficult.

The WDNR is required to review and approve all applications for dam abandonment and removal. Consideration of abandonment/removal has usually come about because of a failure incident or as the result of a WDNR inspection that found significant defects that requires major repairs to correct. Economic, social, and environmental factors all play a significant role in the decision to remove dams.

In recent decades, Wisconsin has seen a large number of its historic dams aging and falling into disrepair. In most cases the Department has remained neutral in the decision making process, only seeking to correct safety deficiencies at dams. As dam removals have been accomplished over the last 20 years, significant improvements have been noted in water quality, habitat and bio-diversity at many of these sites. In light of this, in recent years, the WDNR has advocated for the removal of certain dams for the purpose of stream and habitat restoration.

In all cases, the Department's activities related to dam removal included assuring that the project meets the statutory requirements of Chapter 31 and is completed in a manner that protects the public rights in navigable waters and public safety. In cases where WDNR advocated dam removal, they participated in public information meetings to explain the benefits of dam removal to the surrounding ecosystem, and assisted with funding to accomplish removal and restoration activities. In the future these types of efforts will probably continue on a selective basis, driven by watershed plans that identify dams which are most detrimental to the ecosystem. Without willing dam owners, dams cannot be removed or property operated and maintained.

Almost 100 dams have been removed from Wisconsin streams since 1967. The dam inventory lists over 900 dams that have been built and removed since the 1800s. Removed dams have ranged in size from small dams on trout streams, such as the Cartwright Dam on Shell Creek, medium size dams such as the Ontario Dam on the Kickapoo River and fairly large dams on warm water streams such as the North Avenue Dam on the Milwaukee River.

The three major reasons for dam removals in Wisconsin are:

- Removal of an unsafe structure under Chapter 31.19 of our state statutes. Under Chapter 31.19 the WDNR is required to inspect "large" dams at least once every 10 years to ensure their safety.

- Chapter 31.187 charges the WDNR with removing "abandoned" dams when either no owner is found or the owner or owners are not able to fund repairs.

- In a few cases, WDNR has removed or proposed to remove dams that have a significant environmental impact. Many of those are on WDNR properties.

The normal process in which a removal might be considered would involve a dam that has been identified as deficient through a failure or an inspection. If the dam owner can be identified, the owner would then be notified of the problems and given a timeline to correct all deficiencies. An official order may be given, ordering the dam owner to either perform the needed repairs or remove the structure - repair or removal is their choice. If the dam owner is considering removal, or if it is not economically feasible for the dam owner to repair the dam (dam removal generally costs one-third of estimated reconstruction costs), the owner submits an application to abandon the permit of the dam and a plan for removal of the structure. At this point, a public information meeting is often held, in which the WDNR explains the situation and gains public input. If the owner chooses to pursue dam removal, an Environmental Assessment may then be prepared, followed by public notice, which provides the opportunity for a contested case hearing. Once these steps are complete, a permit to abandon the dam will be issued with conditions for removal.

With regard to resource management, the most significant benefits of dam removal include:

- Re-connection of important seasonal fish habitat
- Normalized temperature regimes
- Improved water clarity (in most cases)
- Improved dissolved oxygen concentrations
- Normalized sediment and energy transport
- Improved biological diversity

In general, carp prefer the warm waters of an impoundment, yet when a dam is removed the cool water species such as trout and bass, generally preferred by anglers, can move back into the river and re-populate.

Dams on the Lower Fox River. Table 3-8 presents a summary of the location and pertinent information on the dams for the lower Fox River from Lake Winnebago to Green Bay. In that stretch of the river there are 13 existing dams and one dam that was abandoned. Of the existing dams, all are classified as large. Nine of these dams have a high hazard potential while four have a significant hazard rating. A majority of these dams (11) are licensed by the Federal Energy Regulatory Commission, suggesting that the dams primary purpose is energy related, not flood control. While all of the dams have some potential for the release of contaminated sediments from upstream sediment deposits, the database maintained by the WDNR's Dam Safety program specifically lists the releases of contaminated sediments as a concern relative to dam failure scenarios or immediate need for draw downs for six of these dams.

Joint dam ownership is quite common for the dams along the Fox River. Eight dams have at least partial ownership by the U.S. Army Corps of Engineers. Sections of some of these dams are also under private ownership. Negotiations are continuing on the transfer of the "transportation locks" portion from the USACE to the state. The USACE (and co-owners) will retain the ownership of the dams. At this time, the WDNR is not aware of any plans to remove any of these dams. Of the Lower Fox River dams, WDNR Dam Safety staff has indicated that the De Pere dam may be in need of repairs, however, they do not believe that there is a concern of a catastrophic failure.

Eight of the dams on the lower Fox River from Lake Winnebago to the mouth of the Fox River at Green Bay are either fully or partially owned by the U.S. Army Corps of Engineers. The WDNR reviewed past periodic inspection and the conclusions of stability analysis for each of these dams. The results of this review are presented in Table 3-9. The USACE is not identified as a co-owner of Kaukauna dam.

In general, the stability analysis indicated that the spillway and sluiceway sections of the dams have adequate compression to resist overturning and the have adequate bearing capacity to support the maximum base pressure. While inspections did reveal various potential problems, such as the need for concrete repairs, the overall conclusion of the reports were that dams were found to be in good condition overall and no structural deficiencies were found which would affect the operation of the dam. Many of the inspection reports recommended development of a plan to prioritize repairs for the dams on the Fox River over a subsequent five-year period. The USACE has stated that maintenance recommended by the routine inspection is conducted. This information is from WDNR's Dam Safety, Floodplain, Shoreland program's webpage (http://www.dnr.state.wi.us/org/water/wm/dsfm/dams/index.html) concerning dam safety. In addition, the web page provides more information such as frequently asked questions about the dams in Wisconsin.

3.4.1.2 Lower Fox River Dams and Navigational Controls

There are 17 locks and 13 existing dams and one abandoned dam located along the Lower Fox River between Lake Winnebago and the De Pere dam. There is one abandoned dam. The locks are an important aspect of navigation on the Lower Fox River. The Neenah and Menasha dams control discharge from Lake Winnebago. Similarly, the other dams located between LLBdM and De Pere control flow in the lower portion of the river. These dams are used to control water levels throughout the river to provide a continued source of power for the hydroelectric plants located along the river and to allow navigation.

The locks serve approximately 7,400 boats and barges annually and, according to the ECWRPC, boaters generate between $5 million to $6 million in revenues to the area annually. Additionally, the locks save many area property owners thousands of dollars annually on maintenance costs because marine contractors that utilize the locks can move equipment to project sites much more cheaply by water than by land.

In 1984, the navigation portion of the Lower Fox River project was placed in "caretaker status" by the USACE. Under this status, the USACE performs minimal maintenance, and only three of the 17 navigation locks are in operational condition: the De Pere, Little Rapids, and Menasha locks. With the exception of the Rapide Croche Lock (which is permanently closed to restrict the movement of sea lampreys), all the other locks would require maintenance and renovation before operational status could be restored.

In June 1998, the United States House of Representatives passed a bill which would allow control and maintenance of the Lower Fox River locks to pass from the federal government to state and local governments in Wisconsin. The state of Wisconsin and the USACE signed a memorandum of agreement in September 2000 for the transfer of the Fox River locks (WDNR, 2000d). This agreement does not actually transfer the control or property yet, but it establishes the framework for the transfer to occur in the future. A number of general provisions of the agreement include the following:

- The Rapide Croche Lock will be maintained as a sea lamprey barrier

- The federal government will provide funding for the repair and rehabilitation of the land, locks, and appurtenant features prior to transfer

- The locks and dams will be inspected to evaluate which features require immediate attention

- The state of Wisconsin will be responsible for the operation, maintenance, repair, replacement, and rehabilitation of the locks and appurtenant features after the transfer is complete

3.4.1.3 Neenah-Menasha (Lake Winnebago)

Lake Winnebago is a controlled waterway with specific water level targets, depending on the season of the year. The USACE oversees and maintains discharge from Lake Winnebago to the Lower Fox River. The information contained within this section was obtained from the Lake Winnebago Facts Book (USACE, 1998a).

In the early 1980s, water level targets were established to provide water usage for hydropower and navigation while preserving or enhancing fish, wildlife, and wetland habitat, as well as water quality in the Lower Fox River and the Lake Winnebago pool. The Lake Winnebago pool consists of the other large water bodies upstream of Lake Winnebago. The local water level datum for Lake Winnebago is the Oshkosh datum. The water level in Lake Winnebago has been established at or above the crest of the Menasha Dam (51 centimeters or 1.68 ft Oshkosh datum) during the navigation season.

Lake Winnebago seasonal water level targets have a range of less than 107 cm (3.5 ft) between the allowable low (5.5 cm or 0.18 ft Oshkosh) and high (105 cm or 3.45 ft Oshkosh) water levels. The water level targets are divided into five segments based on seasonal water level objectives. The regulation periods and objectives are briefly described below (USACE, 1998a).

Winter Drawdown: Following formation of solid ice cover in the Lake Winnebago pool, the water level in Lake Winnebago is slowly lowered to the winter drawdown level of 21 cm (0.68 ft) Oshkosh. This drawdown level of 21 cm (0.68 ft) Oshkosh provides capacity needed to contain spring runoff. If the capacity is insufficient, flooding in the Lower Fox River is likely during snow melt. However, if the lake level is drawn down too low, spring outflows from Lake Winnebago may have to be restricted in order to achieve the required navigation stage when the pool is refilled.

Typically, drawdown commences at a rate designed to achieve a target level by about March 1.

Between Drawdown and Ice-out: Once the target drawdown level has been achieved, the stage is held constant until ice cover in the Lake Winnebago pool breaks up and starts moving out, which usually occurs in late March or early April. Maintenance of these water levels is important because water level increases can cause ice damage to wetlands and the Lake Winnebago shoreline.

After Ice-out: Following breakup of the ice, the Lake Winnebago pool is refilled. The target navigation stage, 91 cm (3.0 ft) Oshkosh, is to be achieved by the beginning of May, typically the start of the navigation season. To achieve this, the pool is allowed to fill in early April.

Navigation Season: During the navigation season, the Lake Winnebago water level is held as close as possible to the target stage. However, since the year's lowest inflows occur during this time, it is not always possible to maintain the target level throughout the navigation season. The navigation season extends through approximately mid-October.

Between Navigation Season and Freeze-up: When the navigation season ends, the water level in Lake Winnebago is decreased to approximately 61 to 76 cm (2.0 to 2.5 ft) Oshkosh by December 1. The only outflow constraint is to observe a maximum safe discharge of about 510 m^3/s (18,000 cfs), while allowing only gradual changes in stage to minimize impacts on wildlife. Following this, the winter drawdown water levels are implemented in accordance with the plan.

3.4.2 Lower Fox River Surface Elevation

The Lower Fox River decreases about 48.2 m (158 ft) between the Menasha and De Pere dams and approximately 3.3 m (11 ft) between the De Pere dam and the mouth of the river. The overall gradient for the Lower Fox River is 51.5 m (169 ft) over 63 km (39 miles) or 8.2×10^{-4} m/m. Gradient information obtained from the NOAA Recreational Chart (1992) is summarized on Table 3-10 and the river profile is shown on Figure 3-1.

Three areas exist where the water level elevation decline approaches or exceeds 9.1 m (30 ft). These three sections are located within the Appleton to Little Rapids Reach, between the outlet of LLBdM and the Rapide Croche dam (Figure 3-1 and Table 3-10). The first section is located between the Upper and Lower Appleton dams, where the river elevation declines about 8.5 m (28 ft) in just 1.9 km (1.2 miles). The other two sections are located adjacent to one another. These extend from the Little Chute dam to the Kaukauna dam and from the Kaukauna dam to the Rapide Croche dam. The gradients for each of these river sections is approximately an order of magnitude higher than the gradients for the remaining sections of the river (Table 3-10). These three sections of the river contain limited soft sediment deposits because of increased flow velocities. The only two locations with a large areal extent of sediment in these sections are deposits W and X. Deposits W and X are located between the Kaukauna and Rapide Croche dams, in an area where the river width increases to approximately 640 m (2,100 ft), and flow velocities decrease. Additionally, the elevation decline in the Appleton to Little Rapids Reach exceeds 42.8 m (140 ft), whereas the elevation decreases in the other three reaches are all approximately 3 m (10 ft) or less.

3.4.3 Low-Flow and Flood Frequencies

The flow of the Lower Fox River, from Lake Winnebago to the mouth at Green Bay, has been historically monitored by as many as six stream gauging stations operated by the USGS. Most recently, the USGS operated two automated acoustical velocity meter (AVM) stream gauging stations on the Lower Fox River. The first AVM gauge was located at the south end of Lutz Park, approximately 0.8 km (0.5 mile) upstream of Memorial Drive bridge in Appleton (Hydrologic Station # 04084445). The other AVM gauge was located about 1.3 km (0.8 mile) upstream from the mouth in Green Bay, or about 0.8 km (0.5 mile) upstream of Interstate 43 bridge (Hydrologic Station # 040851385). The former gauging stations and the years for which data are available from each are listed below.

The historical river discharge information from the Rapide Croche Dam station (#04084500) is presented on Table 3-11. This gauging station has been recording discharge and stream flow since October 1917. The Water Year (WY) extends from October 1 through September 30 of the following year. The summarized Rapide Croche results (Table 3-11) show that daily discharge volumes ranged from a low of 4 m^3/s (138 cfs) to a maximum of 680 m^3/s (24,000 cfs). The month of April typically exhibits the highest discharge volumes, due to winter snow melt and spring rains. Four months, March through June, have average daily discharge volumes exceeding the annual average of 122 m^3/s (4,300 cfs). Conversely, the late summer months of August and September generally have the lowest flows. These results are similar to the shorter records of other Lower Fox River gauges.

Fox River Gauging Stations and Years of Available Data

Station Location	Hydrologic Station #	Drainage Area km^2 (mi^2)	Years of Data Available
Fox River at Appleton	04084445	15,410 (5,950)	7/1/86 to 9/30/97
Fox River at State Highway 55 at Kaukauna	04084475	15,488 (5,980)	10/1/88 to 9/30/90
Fox River at Rapide Croche Dam near Wrightstown	04084500	15,565 (6,010)	10/1/17 to 9/30/97
Fox River at Little Rapids	04085054	15,800 (6,100)	10/1/88 to 9/30/90
Fox River at De Pere	04085059	15,825 (6,110)	10/1/88 to 9/30/90
Fox River at Oil Tank Depot, Green Bay	040851385	16,395 (6,330)	10/1/88 to 9/30/99

Note: The historical stream flow data for each of the gauges listed is available through the Internet from the USGS (http://waterdata.usgs.gov/nwis-w/WI/) and are USGS, 1998a, 1998b, 1998c, 1998d, 1998e and 2000, respectively.

In 1980, the WDNR developed a waste load allocation for the Lower Fox River, based on the seven-day average low stream flow with a ten-year frequency ($Q_{7,10}$) of 26.9 m^3/s (950 cfs). Discharge records by the Appleton water department used in this study indicated that stream discharge volumes exceeding 96 m^3/s (3,400 cfs) were far more frequent than were any of the other volumes evaluated (WDNR, 1980). Based on the stream gauge records for the Rapide Croche gauge, the average discharge volume in the upper portion of the river (between LLBdM and the De Pere dam) is approximately 122 m^3/s (4,300 cfs) (USGS, 1998c).

A similar flood frequency evaluation at the Rapide Croche gauging station was completed by USGS (Krug, *et al.,* 1992). The 10-year flood discharge is 544 m^3/s (19,200 cfs) while the 100-year flood flow is over 685 m^3/s (24,200 cfs). These volumes are 5 to 6 times greater than the average discharge of 122 m^3/s (4,300 cfs).

3.4.4 Measured and Estimated Stream Flow Velocities

Stream flow velocity is an important factor in evaluating areas where sediment deposition or erosion is likely to occur. The average stream flow velocity in each river reach was estimated using discharge measurements collected from USGS gauges along the river (Table 3-12). These estimates were completed using the river cross-sections determined for the GBMBS modeling efforts (WDNR, 1995).

The cross-sections listed on Table 3-12 are the area estimated at the boundary between each water column segment in the transport models (Velleux and Endicott, 1994; WDNR, 1995). The cross-sectional areas listed are for the boundary of each model segment and the deposits within each segment are listed

(Table 3-12). Some deposits lie in more than one model segment and these have been listed accordingly. Water column segments 4 and 5 lie adjacent to each other and are only separated by the Menasha Channel; therefore, these two segments share the boundary with water column segment 6, which Table 3-12 reflects. Also, because the De Pere dam separates water column segments 27 and 28, there was no listing for this boundary, so deposits GG and HH have been listed as though they fall in segment 26. In general, stream flow velocities in the river average approximately 0.14 meter per second (m/s) (0.45 feet per second [ft/s]).

The average stream flow velocity in the LLBdM Reach is 0.15 m/s (0.51 ft/s) and velocities range from 0.08 to 0.35 m/s (0.26 to 1.15 ft/s). However, in LLBdM itself (water column segments 2 through 9), the average steam flow velocity is just under 0.13 m/s (0.42 ft/s) and overall velocities range from 0.08 to 0.20 m/s (0.26 to 0.65 ft/s) (Table 3-12). This lower average for LLBdM is due to the fact that LLBdM is a wide, generally shallow lake in comparison with the rest of the river. This is evident by the increased stream flow velocity (exceeding 0.30 m/s) in water column segments 10 and 11. These segments (10 and 11) are located at the outlet of LLBdM and the cross-sectional area decreases significantly compared to the other portions of LLBdM (Table 3-12).

The average stream flow velocity in the Appleton to Little Rapids Reach is 0.24 m/s (0.78 ft/s), approximately 65 percent higher than the LLBdM Reach and almost double the velocity found in LLBdM proper. This reach had the highest estimated stream flow velocities in the river, ranging from 0.15 m/s (0.48 ft/s) to 0.37 m/s (1.23 ft/s) (Table 3-12). Two of the three highest stream flow velocities in this reach are found in water column segments 19 through 21, a part of the river where no sediment deposits were found.

The average stream flow velocity in the Little Rapids to De Pere Reach is 0.12 m/s (0.40 ft/s), approximately half of the average velocity for the Appleton to Little Rapids Reach (Table 3-12). Flow velocities in this reach range from 0.11 m/s (0.37 ft/s) to 0.13 m/s (0.42 ft/s), the smallest variation in flow velocities noted in any reach (Table 3-12). The largest sediment deposit located upstream of the De Pere dam, Deposit EE, is located in this reach.

The De Pere to Green Bay Reach has an average stream flow velocity of 0.08 m/s (0.25 ft/s), the lowest found in the river (Table 3-12). Due to these overall low stream flow velocities, the largest volume of deposited sediment occurs in this reach.

3.4.5 Lower Fox River Bathymetry

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

3.4.5.1 LLBdM Reach

Water depths in the LLBdM Reach are generally less than 1.8 m (6 ft) (NOAA, 1992). Water depths on the south end of the lake, near sediment deposits A and B, are less than 1.2 m (4 ft). The main flow channel, which starts near the edge of sediment Deposit C, is approximately 2.4 m (8 ft) deep on the south end and increases to approximately 5.8 m (19 ft) near the lake outlet. Downstream of Deposit E, the water depth in the main channel ranges between 1.8 and 3.4 (6 and 11 ft) with depths between 0.6 and 1.2 m (2 and 4 ft) along the banks of the river.

3.4.5.2 Appleton to Little Rapids Reach

This reach of the river meanders more than any other reach and is comprised of a series of large contiguous pools. Similar to the LLBdM Reach, water depth in the main channel ranges between 1.8 and 3 m (6 and 10 ft) throughout much of the reach. This reach is marked by sections of the river with varied widths and, as such, the river depth decreases to as little as 0.3 m (1 ft) just downstream of Kaukauna. Near the Rapide Croche dam, the river depth increases to as great as 16 ft in the main channel. Between the Rapide Croche and Little Rapids dams, the river is generally narrow and main channel water depths are usually between 1.4 to 3.7 m (8 to 12 ft).

3.4.5.3 Little Rapids to De Pere Reach

The width is greatest at the upstream end and decreases downstream. The main channel depth is usually greater than 2.7 m (9 ft) and increases to 5.5 m (18 ft) approaching the De Pere dam. Along the banks of the river the depth is generally less than 1.8 m (6 ft) deep throughout this reach.

3.4.5.4 De Pere to Green Bay Reach

Water depths in this reach range between 1.8 and 7.3 m (6 and 24 ft) deep in the main channel. The lower 4.8 km (3 mil) of the reach are dredged by the USACE in order to maintain the navigation channel. Prior to 1982, the navigation channel was maintained from the mouth of the river to the De Pere dam, but since 1982 this upper portion of the channel has been maintained to a depth of 1.8 m (6 ft). Between De Pere and the Fort James-West turning basin (formerly Fort Howard), the depth of water is generally less than 1.8 m (6 ft) outside of the navigation channel. Downstream of the Fort James-West turning basin, the river narrows so that the navigation channel almost encompasses the entire width of the river. Dredging of sediments from the navigation channel is discussed in more detail in Section 3.6.1.3 below.

3.5 Green Bay Surface Water Hydrology

This section discusses the factors that influence water currents, bathymetry, and mixing in Green Bay. These factors control the migration of impacted sediments from the Lower Fox River in the bay. The occurrence and movement of ice in the bay will also influence the feasibility and costs of removing and treating or storing impacted sediments. A number of studies concerning Green Bay water circulation, currents, and mixing patterns were recently summarized by the USFWS (Stratus, 1999a). Portions of the information included in this section were derived from the USFWS document.

3.5.1 Green Bay Water Level Elevations

Water level elevations within Green Bay reflect the water level within the Lake Michigan-Huron basin. These two lakes are connected through the Straits of Mackinac and are a single lake basin.

Water levels within the Great Lakes are measured according to the International Great Lakes Datum 1985 (IGLD 1985), which has its zero reference elevation point located at Rimouski, Quebec, Canada (USACE, 1996). The bench mark elevation for Lake Michigan is 178.065 m (584.203 ft) IGLD 1985 at Calumet Harbor, at the south end of the lake. The overall annual long-term average (LTA) elevation for the Lake Michigan-Huron basin is 176.485 m (579.02 ft) IGLD 1985 (USACE, 1998b). The monthly LTA elevation ranges from a low of 176.34 m (578.54 ft) IGLD 1985 in February to a high of 176.64 m (579.53 ft) IGLD 1985 in July (USACE, 1998b).

Historically, the lowest and highest monthly water elevation levels were recorded in March 1964 and October 1986, respectively. In March 1964, the Lake

Michigan-Huron basin had a water level elevation of 175.58 m (576.05 ft) IGLD 1985. In October 1986, the measured water level elevation was 177.50 m (582.35 ft) IGLD 1985. The basin has an overall range of approximately 1.92 m (6.3 ft) (USACE, 1998b).

Water levels within the Great Lakes are currently decreasing. During 1996 and 1997, water levels were significantly above average, and the winters of 1995-96 and 1996-97 experienced snowfall accumulations which provided recharge for the Great Lakes. However, staring in late 1998, water levels within the lakes begin to decline, falling to near average or below average water levels. The Lake Michigan-Huron basin began 1999 at 176.281 m (578.35 ft), about 7.6 cm (3 in) below the January LTA and the 1999 elevations peaked in mid-July at 176.41 m (578.77 ft), which is about 22.9 cm (9 in) below the July LTA (USACE, 2000a). During the rest of 1999 water level elevations declined even further to about 175.96 m (577.30 ft), or about 43.2 cm (17 in) below the December LTA (USACE, 2000a).

Data collected between March 1999 and February 2000 indicate that only 68 percent of the normal annual precipitation fell in the Lake Michigan-Huron basin during this time frame. Snowmelt runoff is responsible for about 40 percent of the annual water supply into the Great Lakes (USACE, 2000b). Snow cover in the Lake Michigan-Huron basin in March 2000 was drastically lower compared to March 1997 USACE (2000b). In March 1997, large portions of the UP had snow pack with a snow-water equivalent (SWE) exceeding 30 cm (12 in) and the lower peninsula of Michigan had a SWE of >0 to 20 cm (>0 to 8 in) (USACE, 2000b). However, in March 2000, the snow cover SWE was less than 10 cm (4 in) throughout in Michigan and in Wisconsin (USACE, 2000b). In addition to less snow fall, the warmer winters of 1998, 1999, and 2000 have reduced ice cover over the lakes and increased evaporation (USACE, 2000b). Combined, these factors have contributed to lakes levels which are approaching the record low for the Lake Michigan-Huron basin (USACE, 2000b).

3.5.2 Green Bay Water Circulation, Currents, and Mixing Patterns

PCBs and other contaminants in the Lower Fox River are either adsorbed onto suspended sediment particles or dissolved within the water column. Therefore, current patterns in Green Bay are important for evaluating the spatial distribution of PCBs and other contaminants in both the sediments and water column derived from the river.

Complex water currents and circulation patterns are present in Green Bay. However, there is an overall general counterclockwise movement of water in the bay. Water from Lake Michigan moves into the bay and flows south along the west shore (Smith, *et al.,* 1988). Water from the Lower Fox River is generally transported north along the east shore of the bay, carrying suspended sediment as well as contaminants in dissolved and particulate phases. In addition, the inner bay and outer bay each have their own general counterclockwise currents (or gyres), which are effected by the presence of spits and shoals on the west side of the bay. Based on modeling results, it was estimated that monthly average residual currents exceeding 5.0 cm/s were common in most of the bay during August 1989 (Blumberg, 2000).

Water circulation in Green Bay is controlled by a number of different factors:

- Wind speed and direction
- Surface water elevation changes induced by wind and barometric pressure
- River discharge
- Upwelling of the thermocline in Lake Michigan
- Thermal and density gradients between the bay and Lake Michigan
- Ice cover
- The Coriolis effect (Gottlieb, *et al.,* 1990)

HydroQual, Inc. (HydroQual) completed a modeling analysis of current patterns in Green Bay based on data collected during the 1989-90 GBMBS. The monthly mean surface and bottom circulation patterns as calculated by a three dimensional circulation model (HydroQual, 1999) for August 1989 are shown in Figures 3-2 and 3-3, respectively. The USFWS also recently completed a summary of previous flow studies in the Lower Fox River and Green Bay system. Portions of the following sections concerning water circulation in Green Bay have been derived from this summary (Stratus, 1999a).

Shallow bays and lakes, especially like the inner bay of Green Bay, respond rapidly to the transient forces listed above, which tend to dominate over steady, low-frequency forces for short time intervals. Long term averaging of currents reveals steady, residual circulation patterns responsible for the net mass transport (Blumberg, 2000). Miller and Saylor (1985) noted that the monthly averaging of currents shows a relatively consistent circulation pattern, with the magnitude of the currents varying from month to month. Figures 3-2 and 3-3 show the formation of several gyres in the bay, resulting in a complex residual circulation pattern in Green Bay. This circulation pattern affects mixing, flushing, and mass transport.

The formation of small-scale gyres, in both the inner and outer bays, causes localized entrapment of water masses and associated constituents. Due to the localized gyres, the flushing time for Green Bay is estimated to be on the order of 1,000 days (Blumberg, 2000). Estimated flushing times for the inner portion of Green Bay (HydroQual, 1999) are much lower than for the entire bay. The areas within 10 km and 25 km of the mouth of the Fox River flush in about 25 days and about 100 days, respectively (Blumberg, 2000).

3.5.2.1 Lower Fox River Discharge into Green Bay

As mentioned above, the USGS has an AVM gauge located at the mouth of the Fox River to record discharge into Green Bay. The Fox River is the largest tributary to Green Bay, with an average discharge of 122 m^3/s (4,300 cfs) (USGS, 1998c). A summary of observed flow measurements at the mouth of the river are listed in Table 3-13. Discharge during WY 1999 was about 106 m^3/s (3,753 cfs) while the average discharge over the past 11 years (WY 1989-1999) was 141 m^3/s (4,999 cfs) (USGS, 2000) (Table 3-13). In addition, data from WY 1989-99 indicate that river discharge exceeds 272 m^3/s (9,605 cfs) 10 percent of the time and 114 m^3/s (4,040 cfs) 50 percent of the time (Table 3-13).

Negative discharge values result from seiche events, when flow in the Lower Fox River is reversed and water moves from Green Bay into the river. The seiche is produced when northeast winds push water in Green Bay to the south end of the bay (Smith, *et al.,* 1988). The seiche occurs daily and, as evidenced by the AVM data, results in reversed stream flows in the lower reach of the river. Water levels in the south end of the bay often fluctuate between 0.15 and 0.3 m (0.5 and 1 ft), although water levels have increased more due to storm events. The seiche also results in the general counterclockwise flow in Green Bay, which facilitates mixing of the river and bay water. The flow reversal can be significant, with recorded reversed discharge volumes of 92 m^3/s (3,250 cfs), which is 75 percent of the Lower Fox River average discharge of 122 m^3/s (4,300 cfs).

Even greater flow reversals have been recorded for individual storm events. The USGS hydrographs for two storm events in November 1998 are included in Appendix F. On November 10, 1998, the gauging station hydrograph recorded a significant reversal of flow in the Lower Fox River. Over an approximate 6- to 12-hour period the, following conditions were observed at the mouth of the Lower Fox River:

- Streamflow volume reversed from a high of about 710 m^3/s (25,000 cfs) to about -1,840 m^3/s (-64,900 cfs)

- Water levels dropped from approximately 176.63 m (579.5 ft) IGLD 1985 prior to the storm to 175.01 m (574.2 ft) IGLD 1985 immediately following the storm

- The stream flow velocities decreased from about 0.15 m/s (0.5 ft/sec) to -1.52 m/s (-5 ft/s).

A similar storm on November 23, 1998, produced a stream flow volume reversal of -566 m^3/s (-20,000 cfs) with a drop in water levels of approximately 0.37 m (1.2 ft), and a decrease from a positive stream flow velocity to about -0.49 m/s (-1.6 ft/s) (Appendix F). The records for these two storm events indicate that significant changes in water level and flow are possible at the southern end of Green Bay.

An intense storm event in April 1973 was responsible for severe flooding near the mouth of the river. This storm lifted a 1,000,000-gallon oil tank off of its foundation and removed the last small remnants of the Cat Island Chain which were present above the surface water at that time (Erdman, 1999a). The Cat Island Chain, which had been experiencing continued erosion following the development and rip-rapping activities associated with construction of the Bay Port confined disposal facility (CDF) in the former Atkinson Marsh, disappeared following this storm event. However, at the time of this RI, small portions of the chain were visible in the bay due to low water levels. Development of the Bay Port CDF and loss of large areas of wetlands in the southern end and west shore of the bay are discussed further (Section 4.2.3.2).

3.5.2.2 Fox River Plume Studies

The Fox River is the dominant tributary to Green Bay and, based on USGS gauging station data for the eight largest tributaries (the Fox, Pensaukee, Oconto, Peshtigo, Menominee, Ford, Escanaba, Fishdam-Sturgeon basins) its accounts for over 40 percent of the total tributary inflows into the bay (Bertrand, *et al.,* 1976). Historical analysis of water movement in Green Bay was initiated by Harrington in 1895 (Bertrand, *et al.,* 1976). Fisherman and sailors around Green Bay noted that Fox River water moved from the mouth of the river along the southeastern and eastern shore of the bay on a general line from the mouth of the river towards Point Au Sable (Erdman, 1999a). On the 1845 chart of Green Bay, water depths between the mouth of the river and Point Au Sable, east of Grassy Island, generally range from 3 to 4.9 m (10 to 16 ft) (Bosley, 1976). Water levels west of the river mouth and Grassy Island range from 1.2 to 3 m (4 to 10 ft), indicating that the main channel from the river into the bay was located east of Grassy Island. Originally, navigators had to tack around Point Au Sable and Grassy Island in order to sail into the Fox River. The navigation channel opened in 1867 cut through Grassy Island and the sand bar located near the mouth of the Lower Fox River (University of Wisconsin Sea Grant Institute [UWSGI], 1979). Dredging of the navigation channel thus diverted some of the Fox River discharge from the southeast corner of Green Bay straight into the bay from the river mouth.

Historically, low DO concentrations detected along the east shore of the inner bay were blamed for massive fish die-offs. Studies were conducted by the Wisconsin State Board of Health - Committee on Water Pollution in 1938-39, 1948, and 1956, the Sulphite Pulp Manufacturer's Committee on Waste Disposal in 1944 (Wiley, 1944), and the WDNR in 1966-67 (WDNR, 1968). These four studies indicated that low DO conditions were present on the east side of Green Bay just downstream from the mouth of the Lower Fox River, especially during winter months when ice-cover was greatest.

In 1966, Schraufnagel presented a general summary of the counterclockwise water currents in the bay (Bertrand, *et al.,* 1976). Although Schraufnagel's summary of water currents within the bay was fairly accurate, it was not based on actual plume delineation studies. Rather, this evaluation of Fox River water movement through the bay was based more on empirical observations, like those described above and the fish die-offs noted on the east side of the bay during winter.

Water entering Green Bay from the Fox River is typically warmer and more sediment laden than the rest of the bay water, thus, allowing the river plume to be tracked within the bay. Studies conducted since the late 1960s of the Fox River plume in Green Bay show that river water moves up the east shore of the bay. The plume has been observed and detected up to 40 km (25 mi) from the mouth of the river (Gottlieb, *et al.,* 1990).

In July 1968 and August 1969, Modlin and Beeton (1970) used specific conductance measurements to trace the Fox River plume in Green Bay. They traced the Fox River plume for distances of 14 to 34 km (8.7 to 21.1 mi) from the river mouth and they noted that the plume moved north along the eastern shore of the bay. Additionally, they detected a plume of lower conductivity water along the western shore of the inner bay and ascertained that this was either outer bay or Lake Michigan water moving south along the western shore. Similarly, in late 1969, Ahrnsbrak and Ragotzie (1970) used conductivity and light transmissivity measurements to observe the distribution of Fox River water in the bay and their conclusions were similar to those of Modlin and Beeton (1970). Ahrnsbrak and Ragotzie (1970) tracked the Lower Fox River plume up to 20 km (12.4 mi) from the river mouth along the eastern shore during the prevailing southerly winds. Their results also suggested that Long Tail Point limited the mixing of water in the southernmost portion of the bay. Long Tail Point is located along the west shore of Green Bay and it extends approximately 5.5 km (3.4 mi) into the bay. Both studies concluded that movement of the Fox River plume north along the east side of the bay is part of an overall counterclockwise circulation pattern in the bay.

More recently, Lathrop, *et al.* (1990) used remote sensing techniques to observe and track the Fox River plume along the east shore of Green Bay. Lathrop, *et al.* (1990) observed that the Fox River plume moved along the east shore from 20 to 40 km (12.4 to 25 mi) north of the river mouth. These findings were based on satellite and other remote sensing data collected on July 18, 1984, July 24, 1986, and June 9 and July 27, 1987. These study results supported the conclusion by Ahrnsbrak and Ragotzkie (1970) that Long Tail Point forms a mixing barrier in the southernmost portion of Green Bay, allowing Lower Fox River water to move farther north into the bay before becoming thoroughly mixed with other water.

Similarly, the Fox River plume was discernible in the water column chloride data collected as part of the GBMBS in 1989 (HydroQual, 1999). A plume of higher chloride concentrations extended from the mouth of the river along the east shore of the bay for a distance of approximately 42 km (26 miles), which is consistent with other observations of the plume. The surface and bottom water currents in August 1989 (Figures 3-2 and 3-3) indicate that northward flow occurs immediately adjacent to the east shore of the bay, from the mouth of the river to about the location of Little Sturgeon Bay. North of Little Sturgeon Bay, the flow patterns become much more varied and complicated.

3.5.2.3 Inner Bay/Outer Bay Mixing Studies

Chambers Island is the boundary between inner and outer Green Bay and several studies have examined the circulation pattern and exchange of water between the inner and outer bay around the island. Flow around Chambers Island is an important aspect of circulation in Green Bay and the USFWS recently summarized a number of studies documenting these patterns (Stratus, 1999a). Generally, these studies have found that net flow is from the inner to the outer bay. As shown on Figures 3-2 through 3-3, flow around Chambers is complex. The prevailing winds are from the south-southwest in Green Bay (Appendix C) and during such events, circulation patterns in the bay are generally counterclockwise and flow from the inner to outer bay occurs along the east side of the island (Miller and Saylor, 1985). However, when the wind shifts from south-southwest (SSW) to north-northeast (NNE), the currents in Green Bay also change, with flow from the inner to outer bay occurring along the west shore of Green Bay (Miller and Saylor, 1985). Using modeling results, Heaps *et al.* (1982) determined that the circulation patterns in the bay became steady within about 12 hours of the onset of wind from any particular direction. Based on the wind induced current patterns, PCB transport from the inner to outer bay generally occurs on the east side of Chambers Island. However, this current and PCB transport pattern is disrupted and reversed during strong northeasterly winds (Miller and Saylor, 1985).

Surface water investigations found that DO concentrations were much higher along the west side of Chambers Island than the east side in 1982 (Stratus, 1999a). These results suggested that the higher DO water of the outer bay and/or Lake Michigan was moving along the west side of the bay while lower DO water of the inner bay was moving along the east side. Similarly, in 1985, Miller and Saylor measured current and temperature on the west and east sides of Chambers Island. They observed that at a depth of approximately 12 m (39 ft), cold water from the outer bay generally flows southward along the west shore while warm water from the inner bay flows northward along the east shore. The remote sensing studies completed by Lathrop, *et al.* (1990) showed a thermal difference between the surface waters on the west and east sides of Chambers Island, with colder water extending farther south on the west side, and warmer water farther north on the east side.

In 1993, Miller and Saylor showed that water flow around Chambers Island is more complex than a simple counterclockwise motion. During the summer months, the colder and deeper water tends to flow south into the inner bay to the west of Chambers Island, and the shallow, warmer water layer flows north out of the inner bay on both the west and east sides (Miller and Saylor, 1993). These results are shown on Figures 3-2 and 3-3 (HydroQual, 1999). During the summer, surface currents are stronger east of the Oconto River, with two clockwise gyres between the Oconto and Menominee Rivers. These gyres merge along the northern shore, downstream of the Peshtigo River. Around Chambers Island, surface currents are clockwise northwest of the island and counterclockwise southeast of the island (Figure 3-2) (Blumberg, 2000). The combined surface currents are then directed northeast towards Washington Island (Blumberg, 2000). In addition, the formation of many small-scale gyres causes localized entrapment of water masses and their constituents, implying that the mass crossing the Chambers Island transect is not directly transported to the mouth of Green Bay and into Lake Michigan (Blumberg, 2000). During the winter, water tends to flow north out of the inner bay on the east side of the island and the eastern half of the western passage. These flow patterns result in a lesser, separate counterclockwise flow pattern in both the inner and outer bay (HydroQual, 1999).

In addition to the current evaluation, Miller and Saylor (1993) estimated water exchange between the inner and outer portions of Green Bay. They concluded that net flow for the study period was from the inner to the outer bay at approximately 130 m^3/s (4,591 cfs). Additionally, Gottlieb, *et al.* (1990) measured current velocities around Chambers Island, in the inner bay, and in the passages connecting Green Bay with Lake Michigan. Current velocities were greatest on the east of Chambers Island, sometimes ranging as high as 0.35 m/s (1.1 ft/s). West of Chambers Island the velocities typically ranged from 0.12 m/s to 0.24 m/s (0.4 ft/s to 0.8 ft/s). Current velocities in the inner bay typically ranged up to 0.12 m/s (0.4 ft/s) (Gottlieb, *et al.,* 1990).

In addition to the current and volume measurements, Hawley and Niester (1993) used water transparency data and information collected at the same time as Miller and Saylor's data to estimate sediment transport. Hawley and Niester (1993) concluded that approximately 17,500 metric tonnes (MT) (19,290 tons) of sediment were transported from the inner bay to the outer bay, generally along the east side of Chambers Island, during May through October 1989. However, they also found that approximately 19,900 MT (21,940 tons) of sediment were transported from the outer bay to the inner bay along the west side of Chambers Island. Therefore, there was a net increase of approximately 2,400 MT (2,650 tons) of sediment transported into the inner bay. However, as bay sediments are often subjected to a repeating cycling of suspension-transport-deposition, movement of sediment between the inner and outer bays may occur a number of times before sediment is ultimately transported further north into the bay and Lake Michigan.

3.5.2.4 Green Bay/Lake Michigan Mixing Studies

Similar to current flow within Green Bay, USFWS also summarized the exchange of water between Green Bay and Lake Michigan (Stratus, 1999a). Miller and Saylor (1985) and HydroQual (Blumberg, 2000) evaluated the water exchange between Lake Michigan and Green Bay, which is highly complex, variable, and difficult to measure accurately. There are four main channels through which Green Bay and Lake Michigan are connected. Moving north from the Door Peninsula to Point Detour (on the tip of the Garden Peninsula), these channels are: 1) Porte Des Morts Passage; 2) Rock Island Passage; 3) St. Martin Island Passage; and 4) Poverty Island Passage. These passages are oriented roughly northwest-southeast, range from 2 to 7 km (1.2 to 4.3 miles) wide, and all but Poverty Passage are deeper than 30 m (98 ft) (Miller and Saylor, 1985). These passages also have a cross-sectional area of approximately 52 km^2 (20 mi^2) (Gottlieb, *et al.,* 1990).

Measurements showed that large volumes of water consistently transfer through the Porte des Morts and Rock Island Passages. Warm water was found to be leaving the bay in the upper portion of the water column while cold water enters the bay in the lower part of the water column (Figures 3-2 and 3-3). Currents measured in the passages connecting Green Bay with Lake Michigan typically ranged from 0.12 m/s to 0.30 m/s (0.4 ft/s to 1.0 ft/s) (Gottlieb, *et al.,* 1990). Miller and Saylor (1985) estimated flow into the bay to be approximately 3,300 m^3/s (116,540 cfs) while investigations in 1992 suggested the estimated water volume exchange between Green Bay and Lake Michigan was 3,500 m^3/s (123,600 cfs) (Stratus, 1999a). Modeling results for August 1989 suggest that surface water (epilimnetic) flow from Green Bay to Lake Michigan was about 3,000 m^3/s (105,940 cfs) while bottom water (hypolimnetic) flow to the bay was about 2,870 m^3/s (101,350 cfs) (Blumberg, 2000). This resulted in a net outflow of about 130 m^3/s (4,590 cfs) from the bay to the lake. However, during this period net flow across the Chambers Island transect was about 130 m^3/s (4,590 cfs) towards the upper bay (Blumberg, 2000). Thus in August 1989, the outer bay was in steady state with little change in water surface elevation. The circulation patterns obtained for the August 1989 modeling results show that a large volume of water can enter Green Bay from Lake Michigan (Blumberg, 2000).

The exchange of water between Green Bay and Lake Michigan is much greater than any other source of water into or out of the bay. According to Mortimer (1978), estimated precipitation input to the bay is 105 m^3/s (3,700 cfs), tributary input is 336 m^3/s (11,865 cfs), and evaporation loss is 87 m^3/s (3,070 cfs). These values are all at least an order of magnitude less than the estimated exchange between Green Bay and Lake Michigan.

Water exchange between Green Bay and Lake Michigan at the Sturgeon Bay Ship Canal is limited due to the size of the canal. The east end of the canal, which opens into Lake Michigan is only approximately 49 m (160 ft) wide and about 6.1 m (20 ft) deep. This is a cross-sectional area of about 300 m^2 (3,200 ft^2), compared with a cross-sectional area of 52 km^2 (20 mi^2) between the tips of the Door and Garden Peninsulas.

3.5.3 Green Bay Bathymetry

The bathymetry for each of the Green Bay zones differs from that of the other zones. 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 generally represent a large, relatively deep body of water which only have areas with depths less than 9 m (30 ft) located along the shoreline. The bathymetry for Green Bay zones 2, 3, and 4 are shown on Figures 3-4, 3-5, and 3-6, respectively. These figures were developed using NOAA nautical charts 14902 (1996), 14908 (1991), 14909 (1998a), 14910 (1998b), 14917 (1997a), 14918 (1998c), and 14919 (1997b).

The Green Bay bathymetry is controlled by the bedrock geology. Due to the eastern dip of the bedrock units and the glacial scouring of the basin, the bay gradually deepens to mid-bay moving from west to east. Eastward of this mid-bay point, the bottom is a relatively flat, sediment plain that rises abruptly near the east shore. The bottom contour of the bay also affects the development and distribution of wetland habitat. Numerous wetland areas developed along the west side of the bay due to the gentle and gradual deepening of water while the deeper shores/cliffs of the east side of the bay generally inhibited wetland development (Bosley, 1978).

Bathymetric changes in Green Bay are affected by the currents and water mixing discussed above and physical environment of the bay. In 1968, Moore and Meyer completed an evaluation of the bathymetry of Green Bay (Bertrand, *et al.,* 1976). After completing sounding surveys of the majority of the bay, Moore and Meyer compared their bathymetry results with surveys of the southern and northern portions of the bay which were completed in 1943 and 1950, respectively. Moore and Meyer found significant decreases in depth in the southern portion of the bay. In the central part of the southern bay, depths had decreased by up to 1.2 m (4 ft) while larger areas of the bay had decrease in depth approximately 0.6 m (2 ft); this indicates that significant sedimentation occurred in the southern bay between 1950 and 1968.

In addition to the decreased depths, Moore and Meyer estimated that the Lower Fox River contributed about 226,800 MT (250,000 tons) of sediment annually, or about 36.3 MT (40 tons) of sediment for each square mile of the Fox Wolf drainage basin (Bertrand, *et al.,* 1976). Similarly, the Oconto, Peshtigo, and Menominee Rivers were also estimated to have contributed about 780,200 MT (860,000 tons) of sediment, or about 18.2 MT (20 tons) of sediment for each square mile of the drainage basins for these three watersheds. By comparison, Harris (1994) estimated sediment load from the Lower Fox River into Green Bay in 1993 was approximately 136,100 MT (150,000 tons) annually.

3.5.3.1 Zone 2 Bathymetry

The bathymetry of Zone 2 is generally shallow, with all water depths less than 8 m (26.5 feet) as shown on Figure 3-4. From the mouth of the Fox River to a line connecting Long Tail Point and Point Au Sable (the lower Green Bay AOC), water depths range from 0.3 to 3.4 m (1 to 11 ft), excluding the navigation channel (Figure 3-4).

Water depths west of a line between Long Tail Point and Kidney Island CDF are less than 1.5 m (5 ft). Along the west shore of Green Bay is Peats Lake (also sometimes historically referred to as "Peaks Lake"), a shallow submerged and emergent wetland complex located at the mouth of Duck Creek. Water depths in the Peats Lake area and the Duck Creek delta range from 0.6 to 1.2 m (2 to 4 ft) (Figure 3-4). This area is bounded on the north by the former Cat Island Chain and Grassy Island, which lies at the east end of the chain. The former Cat Island Chain is a series of small islands which, up until 1973, were always above water. Dead Horse Bay is a shallow basin located along the west shore south of Long Tail Point. Water depths in Dead Horse Bay generally range from 0.6 to 2.7 m (2 to 9 ft), with the shallowest waters located immediately adjacent to the west shore of Green Bay, the former Cat Island Chain, or Long Tail Point. In the central part of Dead Horse Bay lies a shallow basin where water depths range from 1.8 to 2.7 m (6 to 9 ft).

East of the line between Long Tail Point and Renard Island, the water depths are greater, generally ranging from 2.1 to 3.7 m (7 to 12 ft). However, Frying Pan Shoal extends from Frying Pan Island to Point Au Sable and water depths on the shoal range from 0.3 to 1.2 m (1 to 4 ft) (Figure 3-4).

North of Long Tail Point and Point Au Sable, only areas located immediately adjacent to the shores of Green Bay have water depths less than 1.8 m (6 ft). Along the east shore of Green Bay in this area, water depths of less than 6 ft (1.8 m) extend from approximately 250 to 760 m (830 to 2,500 ft) from the shore. Additionally, the 3.7-m (12-ft) depth contour is 570 to 1,520 m (1,875 to 5,000 ft) from the shore. On the west side, water depths less than 1.8 m (6 ft) extend much further into the bay, from about 1,120 to 2,130 m (3,670 to 7,000 ft) from shore. Water depth increases more rapidly along the east shore than along the west shore of the bay, and this is consistent throughout the bay.

The navigation channel lies almost entirely within Zone 2. The navigation channel extends approximately 18.8 km (11.7 miles) from the mouth of the Fox River (Figure 3-4). The depth of the navigation channel is maintained between 6.25 and 7.16 m (20.5 and 23.5 ft). The general width of the navigation channel is about 45.7 m (150 ft). From the mouth of the Lower Fox River, the channel extends approximately 5 km (3.1 miles), passing Grassy Island about halfway. The channel turns slightly to the east for a distance of approximately 2.5 km (1.6 miles), then resumes the approximate original course, (north) for a distance of 11.4 km (7.1 miles) until it reaches an area where water depths consistently exceed 7.6 m (25 ft) (Figure 3-4).

There are a number of spits, shoals, and other shallows located in Green Bay that are prominent physical features of the bathymetry. Many of the shoals and shallows are associated with the tributaries, predominantly located along the west side of the bay. In Zone 2 these shallow areas are expressed as the island chains and points extending from the west shore out into the bay. Long Tail and Little Tail Points are two examples of spits/shallows associated with Green Bay tributaries. Long Tail Point is located just south of the Suamico River mouth while Little Tail Point is located just south the Little Suamico River (Figure 3-4). Both these spits/shallow areas are replenished from sediment loads contributed by these two rivers as well as sediments transported from other areas. Long Tail Point and Little Tail Point extend for a distance of approximately 5.1 km (3.2 miles) and 3.5 km (2.2 miles) into the bay, respectively. Similarly, Frying Pan Shoal (extending from Frying Pan Island to Point Au Sable) and the shallow wetlands of Peats Lake are both associated with sediment loads from the Lower Fox River and Duck Creek, respectively (Figure 3-4).

3.5.3.2 Zone 3 Bathymetry

The bathymetry of Zone 3 is less complex than that of Zone 2. The depth of water in this zone is generally greater than 9.1 m (30 ft) deep, and the water depths reveal the general west-to-east cross-section of the bay. Water depths increase gradually along the west shore whereas along the east shore the water depths increase more rapidly (Figure 3-5). Comparison of the 9.1-m (30-ft) depth contour indicates that along the west side of the bay this depth is found approximately 6.5 to 7.0 km (4 to 4.3 miles) from the shore. This is a gradient of approximately 0.0013 to 0.0014. On the east side of the bay, the 9.1-m (30-ft) depth contour is about 1.8 to 3.4 km (1.1 to 2.1 miles) from the shore, which is a gradient of approximately 0.0027 to 0.005.

Water depths in Zone 3 range from about 12.5 m (41 ft) at the zones 2 and 3 boundary to 33.5 m (110 ft), just west of Chambers Island near the zones 3 and 4 boundary. The deepest part of Zone 3 is located just southeast of Green Island where water depths of 34.4 m (113 ft) have been measured.

Within Zone 3, four shallow shoals are located along the west side of the bay, and two shallow water areas extend into the east side of the bay (Figure 3-5). The Menekaunee shoal is associated with the Menominee River on the west side of the bay and extends for a distance of approximately 2.4 km (1.5 mi). The Peshtigo Reef is located near the mouth of the Peshtigo River and extends for a distance of approximately 5 km (3.1 mi). Finally, both the Oconto and Pensaukee shoal are located near the mouth of the Oconto and Pensaukee Rivers, respectively. These two shoals extend for a distance of 6.4 km and 5.6 km (4 and 3.5 mi), respectively. The water depth associated with all these shoals and reef are less than 1.8 m (6 ft) for the distances cited above. On the east side of the bay, Monument Shoal and Sherwood Point Shoal extend for distances of 1.8 and 6.1 km (1.1 and 3.8 mi), respectively. Unlike the shallow areas on the west side of the bay, water depths within these two shoals range as deep as 7.3 to 9.1 m (24 to 30 ft) in the deepest portions (Figure 3-5).

3.5.3.3 Zone 4 Bathymetry

Large portions of Zone 4, from Chambers Island to just south of Big and Little Bay de Noc have water depths exceeding 9.1 m (30 ft). However, in the vicinity of Big and Little Bay de Noc, the water depths decrease and shallow areas with water depths less than 9.1 m (30 ft) are predominant (Figure 3-6). Additionally, a number of shoals are located within this zone.

Bathymetry measurements on the west side of the bay in Zone 4 indicate that the 9.1-m (30-ft) depth contour is generally located between 1.3 to 1.8 km (0.8 to 1.1 mi) from the shore. However, in the vicinity of the Ford River the 9.1-m (30-ft) depth contour is found about 9.1 km (5.7 mi) from shore. The general gradient for the west side of the bay in Zone 4 is 0.005 to 0.0069; however, in the shallow water area near the Ford River, the gradient decreases to 0.001.

The Door Peninsula extends for a distance of about 24.4 km (15.2 mi) along the east side of the bay within Zone 4. Bathymetry measurements on the east side of Zone 4 indicate that the 9.1-m (30-ft) depth contour is located between 0.2 to 2 km (0.12 to 1.2 mi) from the shore. This is a general gradient of 0.0045 to 0.045. Similar to the results for Zone 3, the gradient on the east side of the bay is up to one order of magnitude greater than the gradient on the west side of the bay. The deepest point in the bay is 53 m (176 ft) deep, located about 6.4 km (4 mi) west of Washington Island (Bertrand, *et al.,* 1976).

As noted previously, the four main passages connecting Green Bay with Lake Michigan are: 1) Porte des Morts Passage; 2) Rock Island Passage; 3) St. Martin Island Passage; and 4) Poverty Island Passage. The Porte des Morts Passage is approximately 2.3 km (1.4 mi) wide and water depths in the passage range as deep as 39.3 m (129 ft). The Rock Island Passage is approximately 3.9 km (2.4 mi) wide. The passage is narrow due to the presence of the St. Martin Island Shoal, which extends approximately 3.6 km (2.2 mi) south of St. Martin Island. Water depths in this passage range as deep as 46.6 m (153 ft). The St. Martin Island Passage is located between St. Martin Island and a number of small islands and shallows, including Gull, Little Gull, and Gravelly Islands, as well as the Gravelly Island Shoals (Gull/Gravelly Island complex). This passage is only approximately 2 km (1.2 mil) wide and water depths range as deep as 36.3 m (119 ft). Finally, the Poverty Island Passage is located between the Gull/Gravelly Island complex and Poverty Island. This passage is approximately 3.4 km (2.1 mi) wide and water depths range as deep as 26.5 m (87 ft). No significant waterway passage is located north of Poverty Island. Water depths between Poverty, Summer, and Little Summer Islands and Point Detour at the very tip of the Garden Peninsula, are less than 9.1 m (30 ft). Significant shallow water is present between Summer and Little Summer Islands, with large areas where water depths are less than 1.8 m (6 ft) (Figure 3-6).

Water levels in Big Bay de Noc and Little Bay de Noc are generally much shallower than other water levels in Zone 4. Besides the Escanaba River, six small streams/rivers flow into Little Bay de Noc. The water depth in the north end of Little Bay de Noc is generally less than 9.1 m (30 ft) deep except in the central portion of the channel. The shallowest waters are located along the east shore of Little Bay de Noc, where water depths less than 3.7 m (12 ft) extend for a distance of approximately 3.1 km (1.9 mi) into the bay. Water depths in the north portion of Little Bay de Noc range as deep as 15.5 m (51 ft). South of Escanaba water depths increase significantly in the main channel of the bay, exceeding, 24.4 m (80 ft) just 1 km (0.6 mile) south of the city and ranging as deep as 33.5 m (110 ft) near the beginning of the bay.

Water levels in Big Bay de Noc are also generally much shallower than the other portions of Zone 4. Ten small streams/rivers flow into Big Bay de Noc; Sturgeon River, at the north end of the bay, is the largest. Water depths in the northern portion of Big Bay de Noc are generally less than 9.1 m (30 ft), although two small channels extend through the central part of each arm of the bay, where water levels range as deep as 15.5 m (51 ft). This north end of Big Bay de Noc is generally defined by the presence of Round Island, Big Bay de Noc Shoal, and Ripley Shoal, which extend approximately 12.0 to 14.7 km (7.5 to 9.1 mi) from the northern shore of the bay. Water depths increase gradually in the southern part of Big Bay de Noc, generally ranging from 12.2 to 18.3 m (40 to 60 ft).

Within Zone 4 there are five other significant shoals/reefs besides those already mentioned. These include the Strawberry Islands, Horseshoe Reef, Whaleback Shoal and the Drisco and Corona shoal complexes. The Strawberry Islands are a chain of small islands located between the Door Peninsula and Chambers Island. The shallows associated with these islands extend approximately 3.4 km (2.1 mi) from the shore and water depths of less than 9.1 m (30 ft) extend for a distance of approximately 7.1 km (4.4 mi). Horseshoe Reef is located approximately 9.1 km (5.7 mi) east-northeast (E-NE) of Chambers Island. Water depths of less than 9.1 m (30 ft) extend over a distance of 4.6 km (2.9 mi) and are approximately 1.5 km (0.9 mi) wide. Whaleback Shoal is located approximately 22.3 km (13.9 mi) northeast (NE) of Chambers Island. This shoal has water depths ranging from 1.2 to 9.1 m (4 to 30 ft) over an area 11.2 km^2 (4.3 mi^2). The Drisco Shoal complex is an area actually comprised of the Drisco, North Drisco, and Minneapolis shoals. This shoal complex is located approximately 11.7 km (7.3 mi) south of Peninsula Point at the tip of the Stonington Peninsula. The three shoals that form this complex extend over an area of approximately 8.3 km^2 (3.2 mi^2) with water depths ranging from 2.7 to 9.1 m (9 to 30 ft). Similar to the Drisco Shoal complex, the Corona Shoal complex is comprised of three shoals located near one another. These three shoals are the Peninsula Point, Eleven Foot, and Corona Shoals. These three shoals extend south approximately 6.6 km (4.1 mi) from Peninsula Point. Water depth less than 9.1 m (30 ft) extend about 9.1 km (5.7 mi) going west to east from the edge of Little Bay de Noc to Big Bay de Noc.

3.5.4 Green Bay Ice Cover

The Port of Green Bay is annually closed to shipping from January 1 through March 31 due to ice cover (Haen, 2000). Although the port is officially closed for this three month period, ice cover in the bay is usually present from early to mid-December through mid- to late April (Leshkevich, 1977; Assel, *et al.,* 1979; Assel, *et al.,* 1984; and Gottlieb, *et al.,* 1990).

Ice cover in Green Bay initially occurs over the shallowest water areas of the inner bay as well as both Bays de Noc. Ice typically begins forming loose open pack of ice floes in these areas in early to mid-December, as temperatures usually range from -10°C to -4°C (14°F to 24°F). During December, the ice slowly consolidates from loose pack to a solid ice sheet covering the shallowest areas and slowly expanding. During January, which has the coldest average temperatures, ice cover within the bay usually ranges from 95 percent to 100 percent. Depending upon seasonal conditions, open water areas usually form in the outer bay in late January and February. This occurs first in and around the passages connecting Green Bay with Lake Michigan and along the east side of the outer bay (due to the counter-clockwise currents) because Lake Michigan water is generally about 1°C to 2°C (about 2°F to 4°F) warmer than water within Green Bay. Additionally, water from the Green Bay tributaries is generally the coldest water within the bay, due to the fact that the formation of frazil ice within the river can cool water temperatures below 0°C (32°F).

Frazil ice is comprised of small ice crystals that form in turbulent water. Due to the water movement, the ice crystals flow within the water and act to super-cool the water to temperatures below 0°C (32°F). The ice does not solidify until the water movement slows or until the water comes in contact with solid objects that slow the current velocity. When present, frazil ice can cause difficulties with water intakes and piers/docks located along the rivers or bay. As the water flows from the rivers into the bay, current velocities decrease and ice forms rapidly.

3.6 Sediment Characteristics

Chemical compounds entering the waters of the Lower Fox River and Green Bay move through the water column as either a solid or dissolved phase. Chemicals present as solids (particulates) generally move along with or attached to sediment particles. This is especially true for hydrophobic organic compounds, such as PCBs, dioxin/furan compounds, organochlorine pesticides, and PAHs, which have a strong chemical affinity for organic material. Therefore, the location of accumulated sediment, as well as their chemical and physical properties, is important to understanding the distribution of chemical compounds with these river and bay sediments.

Sediment deposition and resuspension processes are primarily a function of particle size and water velocity. Sediment transport occurs as particles are suspended (or re-suspended) in the water column 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), bathymetry (e.g., shoreline erosion) and other factors.

3.6.1 Sediment Deposition

3.6.1.1 Lower Fox River Sediment Transport and Deposition

Previous investigations have identified distinct deposits of accumulated sediment throughout the Lower Fox River (WDNR, 1989/90; WDNR, 1995; and GAS/SAIC, 1996). Upstream of the De Pere dam, areas which have experienced a net depositional gain of sediment are located in environments where stream flow velocities decrease. These areas are typically located immediately upstream of the locks and dams or areas where the width of the river increases. Downstream of the De Pere dam, sediments have been deposited over much of the river bottom, likely due to such factors as low river gradient and flow reversals (seiches) that occur in this reach.

Detailed modeling efforts have been completed for Deposit A (EWI, 1991) and the De Pere to Green Bay Reach (Gailani, *et al.,* 1991) to evaluate movement of river sediments. Modeling at Deposit A indicated that the critical river flow velocity was 0.09 m/s (0.3 ft/s) (EWI, 1991). Areas where the flow velocity was less than 0.09 m/s (0.3 ft/s) experienced net depositional gain while areas where the flow velocity was greater experienced net erosional loss. Also evaluated were stress ratios on sediment particles, which is the ratio of the bottom shear stress to the "critical" shear stress for resuspension of particles. Sediments accumulated in areas where the stress ratios were below 3 to 5 (EWI, 1991).

Gailani, *et al.* (1991) applied the numerical model SEDZL to evaluate sediment movement (both re-suspension and deposition) in the De Pere to Green Bay reach. The upper layer of soft sediment (described as "less than 3 hours old" rather than a predetermined thickness) is often re-suspended and moves along the river bottom in accordance with the flow rate and shear stress applied to the particle.

TSS data collected by WDNR (1995) and BBL (1998) have been evaluated to estimate movement of sediment through the river and bay system (Table 3-14). A conceptual flow diagram for the TSS load from Lake Winnebago into Green Bay, and thus the movement of PCB contaminated sediment through the system, is shown on Figure 3-7. However, estimates of net deposition or net erosion only reflect an average accumulation or loss of sediment over time for a reach and do not explain finer-scale deposition/erosion events occurring within a reach. Net deposition does not imply a purely depositional environment or vice-versa.

Using the 1989/90 TSS data, WDNR (1995) indicate that over 75,000 MT (82,700 tons) of sediment entered LLBdM from Lake Winnebago (Table 3-14). However, the TSS load at the Appleton gauging station decreased by approximately 8,000 MT (8,800 tons), suggesting this material was deposited within LLBdM, as evidenced by extensive sediment deposits A through F and POG. Stream flow velocities in this reach are below 0.2 m/s (Table 3-12).

The TSS results (WDNR, 1995) also suggest the Appleton to Little Rapids Reach experiences a net loss (erosion) of sediments (Table 3-14 and Figure 3-7). Between Appleton and Kaukauna, the TSS load shows a marginal increase of about 2,500 MT (2,750 tons) (Table 3-14). However, between Kaukauna and Little Rapids, the TSS load doubles from approximately 70,000 MT (77,000 tons) to approximately 142,000 MT (154,000 tons), indicating sediment erosion

(Table 3-14). Sediment deposits V through CC are located between Kaukauna and the Rapide Croche dam. The lack of soft sediment between the Rapide Croche and Little Rapids dams suggest that sediments suspended upstream of the Rapide Croche dam are likely transported to Little Rapids (Deposit DD) or beyond, into the Little Rapids to De Pere Reach. Kankapot, Plum, and Apple Creeks are also located in this stretch of the river. WDNR (1995) estimated that these three creeks contribute about 16,500 MT (18,200 tons) annually, which is only 23 percent of the increased TSS load (Table 3-14). Stream flow velocities in this reach generally exceed 0.2 m/s and range as high as 0.3 m/s (Table 3-12), which likely inhibits overall sediment accumulation.

The TSS data (WDNR, 1995) suggest that the Little Rapids to De Pere Reach experiences overall sediment deposition and accumulation. The TSS load declines by about 61,500 MT (68,000 tons), or by about 43 percent, in this reach (Table 3-14). The De Pere dam slows stream flow velocities to an average of 0.12 m/s (Table 3-12), allowing a significant portion of the TSS load to settle out of the water column. Deposit EE, the largest sediment deposit upstream of the De Pere dam, extends approximately 8.5 km (5.3 mi) upstream of the dam.

TSS data collected in 1998 (BBL, 1998) has been used to evaluate the De Pere to Green Bay Reach. These data, and the resultant calculations, support the finding by Gailani, *et al.* (1991) that more sediment is transported over the De Pere dam than is discharged into the bay and that, overall, sediments continue to accumulate in this reach. The TSS load coming over the De Pere dam is estimated to be about 155,600 MT (171,100 tons) annually but this load declines to about 153,600 MT (167,900 tons) at the mouth (Table 3-14). Using data collected in 1989/90, Gailani, *et al.* (1991) also found that the TSS load declined between the De Pere dam and the river mouth. The average streamflow velocity in this reach was less than 0.08 m/s (Table 3-12), which is the lowest value for any of the river reaches. Thus, the two reaches from Little Rapids to the mouth of the river both experience net sediment deposition.

The effects of high discharge events and sediment resuspension were modeled by Gailani, *et al.* (1991). Stream discharge and TSS measurements were collected at the De Pere dam and the river mouth in 1989/90 as part of the GBMBS. The table below shows how the TSS load increases with increased river discharge. At a typical discharge rate of 105 m^3/s (3,700 cfs), approximately 272 MT (300 tons) of TSS flow over the De Pere dam daily; however, only about 54 MT (60 tons) are discharged at the mouth daily.

TSS Loads in the Lower Fox River, De Pere to Green Bay Reach

Sampling Point	River Discharge		Total Suspended Solids	
	M^3/s	cfs	mg/L	MT/day
1989-80 Results (Gailani, *et al.*, 1991)				
De Pere dam	105	3,700	30	270
	280	9,880	75	1,800
	432	15,250	190	7,100
River Mouth	105	3,700	6	54
	280	9,880	57	1,400
	432	15,250	130	4,900

During increased discharge events (e.g., storms), the TSS load both over the De Pere dam and out into Green Bay increase significantly. Discharge at the Lower Fox River mouth exceeds 272 m^3/s (9,600 cfs) for more than 36 days annually (10 percent of the time) (Table 3-13). The TSS load over the De Pere dam increases by about 1,800 MT (2,000 tons) for storm events with a discharge of 280 m^3/s (9,900 cfs). When discharge is about 430 m^3/s (15,250 cfs), the TSS increases by about 7,100 MT (7,850 tons) daily (Gailani, *et al.,* 1991). Therefore, quadrupling the stream flow rate increases the TSS load by approximately 26 times.

Net deposition in the De Pere to Green Bay Reach is evident by the TSS load discharged to Green Bay at the higher discharge volumes. At typical flows, the TSS load to Green Bay decreases by approximately 80 percent relative to the load over the De Pere dam. At increased flows, the TSS load in this reach still declined by 24 percent to 32 percent between the De Pere dam and the mouth of the river. In addition, Velleux and Endicott (1994) found that even though the TSS load may decrease between the De Pere dam and the mouth of the river, the overall PCB load in the river (and thus entering Green Bay) increases in this reach by up to 50 percent. These results are discussed further in Section 5.5.

3.6.1.2 Green Bay Sediment Transport and Deposition

As noted previously, Moore and Meyer found that water depths in the southern end of Green Bay decreased between 0.6 to 1.2 m (2 to 4 ft) between 1950 and 1968 due to significant sediment accumulation (Bertrand, *et al.,* 1976). The USGS estimated that the average annual sediment load from the Fox River into Green Bay is approximately 136,000 MT (150,000 tons) (Harris, 1994). Chroneer (1996) indicated previous investigators had found annual sediment deposition rates as great as 150 mg/cm^2 in the AOC, for a mass sedimentation rate of 82,500 MT (90,940 tons) annually. The TSS data above suggests that about 154,000 MT (168,800 tons) of sediment were discharged into the bay during

1998 (BBL, 1998). Based on these studies, the annual sediment mass transported into Green Bay likely ranges from about 82,500 MT to a high of about 154,000 MT (90,940 to 169,800 tons).

Along with bay mixing studies, USFWS also evaluated sediment movement through Green Bay and the following summary was adapted from this discussion (Stratus, 1999a). 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. Manchester-Neesvig, *et al.* (1996) determined the primary depositional zone in Green Bay extends along the east shore of Green Bay for a distance of approximately 25 km (15.5 miles) north of the Fox River mouth. The northern end of this zone is a line between Sturgeon Bay and the mouth of the Peshtigo River. A large portion of the sediment (and adsorbed PCBs or other hydrophobic chemical compounds) discharged from the Lower Fox River settle in this depositional zone within the inner bay.

Most Lower Fox River sediments discharged into the bay initially settle within the inner bay (Hawley and Niester, 1993). Also, Lathrop, *et al.* (1990) observed that the Lower Fox River water mass is still distinguishable by temperature, but not by transmissivity, by the time the Lower Fox River plume reaches Chambers Island. Most of the Lower Fox River sediment matter settled out before the water reached Chambers Island (Lathrop, *et al.,* 1990). In addition to the Lower Fox River sediments, Hawley and Niester (1993) estimated a net gain of about 2.4 million kg (5.3 million pounds) of sediment that were transported from the outer bay to the inner bay along the west side of Chambers Island.

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 (Chroneer, 1996). Also, erosion of shore and near-shore sediments was found to be directly related to wind factors (magnitude, direction, and duration) within the bay that affect currents and wave action (Chroneer, 1996). Lick, *et al.* (1995) found that sediment deposits in the bay are located in areas where the stress ratios were less than about 5 to 9, in comparison with the Lower Fox River Deposit A ratios of 3 to 5 (EWI, 1991). Sediments within the bay settle in a far less turbulent environment than those of the Lower Fox River, therefore, the upper most layer of sediment was found to have consolidated in 7 to 14 days, rather than less than 3 hours (Lick, *et al.,* 1995). Moderate to strong winds are the most important factor for bay sediment resuspension and occur, on average, every seven days on the Great Lakes (Lick, *et al.,* 1995).

In addition to the net sediment gain of the inner bay, Hawley and Niester (1993) documented suspended sediment transport from the inner to the outer bay. Sediment transport from the inner to outer bay primarily occurs along the east side of Chambers Island (Hawley and Niester, 1993). They also documented a large volume of sediment transported from the inner bay to the outer bay as a result of a September 1989 storm. Hawley and Niester (1993) estimated that about 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. These studies demonstrate that some inner bay sediments are resuspended and transported to the outer bay. However, circulation patterns around Chambers Island are complex (Figures 3-2 and 3-3, HydroQual, 1999), and there is a net mass of sediment moving from the outer to inner bay. Therefore, sediments resuspended from the inner bay may be transported to the outer bay, where they may either settle out, be transported further into the bay (or Lake Michigan), or be transported back into the inner bay. Currently, no studies have evaluated the extent to which sediments originating in the Lower Fox River are also transported into Lake Michigan.

In addition to these studies, the USFWS summarized a number of Green Bay sediment transport and deposition modeling results developed as part of the GBMBS, which included sediment resuspension throughout the bay (Stratus, 1999a). Eadie, *et al.* (1991) concluded from their measurements of high sediment settling velocities in the bay that the pool of suspended particulate matter in the Green Bay water column must be recharged at a high rate, either from sediment resuspension or horizontal movement (Stratus, 1999a).

3.6.1.3 River and Bay Sediment Dredging

The rapids on the river and the extensive areas of accumulated sediment historically impeded navigation of the Lower Fox River and lower Green Bay. Completion of the lock and dam system facilitated navigation but has resulted in numerous sediment deposits upstream of the De Pere dam. In 1872, the USACE was given authority to maintain a navigation channel. The USACE periodically dredged the channel, which extends from Lake Winnebago out into Green Bay approximately 18.8 km (11.7 miles). The channel was maintained at a depth of approximately 1.8 m (6 ft) between Lake Winnebago and the De Pere dam. Downstream of the dam and into the bay the navigation channel depth ranges from 6 to 7.4 m (20 to 24 ft). The USACE currently only dredges and maintains the navigation channel in Green Bay and as far upstream as the Fort Howard turning basin, located approximately 5.5 km (3.4 miles) upstream of the mouth of the river. The remaining portions of the navigation channel, along with the lock and dam system, have been placed in “caretaker” status. The available

USACE dredging records, from 1957 through 1999, are summarized on Table 3-13.

Dredging records for the Lower Fox River are scarce. The only information available since 1957 indicates that approximately 9,900 m^3 (12,950 yd^3) were dredged from the Menasha Channel and Neenah Harbor in 1965 and 1968, respectively (Table 3-15). Historic information indicates that over $3.3 million were expended on maintaining the Lower Fox River navigation channel between 1872 ands 1914, although no information is available concerning the volume of dredged sediments (Burridge, 1997).

Expansive areas of sediments have accumulated downstream of the De Pere dam and out into the southern end of Green Bay. USACE (1999) records for the De Pere to Green Bay Reach, as well as Green Bay, indicate that over 12.1 million m^3 (15.9 million yd^3) have been dredged from the navigation channel since 1957 (Table 3-15). Prior to 1965, most dredged sediments were disposed of in open water locations without any containment. Approximately 2.8 million m^3 (3.7 million yd^3) of sediment were disposed of at open-water locations since 1957 (Table 3-15). The primary open-water sediment disposal areas were located in the vicinity of the former Cat Island Chain and on the north side of the shoal extending from Point Au Sable to Frying Pan Island (Wisconsin State Commission on Water Pollution, 1939, Figure 3-4). The Bay Port CDF was opened in 1965 and has served as the primary disposal facility for navigation channel sediments (Table 3-15). Almost 7.3 million m^3 (9.4 million yd^3) have been placed in the Bay Port CDF (Table 3-15) and, according to Haen (2000), the facility has capacity for another 1.5 million m^3 (2 million yd^3) of sediment. The Kidney (Renard) Island CDF opened in 1979 and received over 2 million m^3 (2.7 million yd^3) of sediment. According to the dredging records, an average of approximately 282,350 m^3 (369,300 yd^3) of sediment is removed from the channel annually (Table 3-15).

3.6.2 Sediment Grain Size/Lithology

Over 1,300 sediment samples collected from the Lower Fox River during previous site investigations were analyzed for grain size. Only 21 samples were collected in Green Bay during BBL sampling activities in 1998. The results of these analyses, along with the results for other physical parameters, are summarized on tables in Appendix G.

The Lower Fox River sediment grain size distribution reflects the mixture of sand, silt and clay comprising the native silty clay glacial till deposits of the area. Sand and silt are the dominant grain sizes in Lower Fox River sediments, typically accounting for 75 to 90 percent of the particle sizes present. A minority of the sediments contain trace (<1 percent) gravel, while clay normally comprise 10 to 25 percent of the samples.

The grain size data have been listed for each deposit or SMU regardless of sampling depth (Appendix G). In LLBdM, the Appleton to Little Rapids Reach, and the De Pere to Green Bay Reach, silt comprises about 40 percent of the sediments encountered while the sand content ranges between 41 and 46 percent. However, in the Little Rapids to De Pere Reach, where extensive sediment accumulations have been observed at Deposit EE, the silt content increases to 54 percent while sand comprises only about 23 percent of the sediments. These results suggest that the De Pere dam is a significant trap for finer grained sediments migrating down the Lower Fox River.

Sediments within Green Bay have a higher percentage of sand than the river. The 11 samples collected in Zone 2 (2A/2B) indicate that the sand content ranges between about 52 and 93 percent, with an average of 73 percent sand in this zone. In Zone 3A, along the west side of Green Bay, sand content is greater than 97 percent. However, in Zone 3B, on the east side of the bay, the sand content generally ranges between 60 and 80 percent, with one of the four samples having a sand content of 27 percent. The results for Zone 3B reflect the influence of Lower Fox River sediments, with a slightly higher silt/clay content in this area than in the other three areas of Green Bay. In Zone 4, the sand content averages 96 percent, which is similar to Zone 3A. Overall, the average sand content of the bay is 78 percent.

Atterberg Limits data were collected during the 1993 Deposit A investigation by BBL, as well as during both the WDNR and FRG 1998 sampling activities. Those sediments tested are characterized by high liquid and plastic limits (Appendix G). Under the Unified Soil Classification System, the majority of the sediments were classified as high compressibility silts (MH) while a small percentage were classified as highly plastic clays (CH). Classification results were not available for all samples.

3.6.3 Estimated Sediment Thickness and Areal Extent

The sampling points and associated sediment thickness measured during previous sampling activities are plotted on Plates 3-1 through 3-5. The methods used to develop the sediment thickness and areal extent on Plates 3-1 through 3-5 are discussed in Section 5.4.1, where the PCB distribution plots are presented. Plates 3-1 through 3-5 present only the sediments in which PCB was detected. The estimated areal extent of each deposit is listed on the table in Appendix G.

Areas where sediment is absent only indicate that no PCBs were detected/sampled in these locations.

During the early portion of the 1989-90 sampling efforts, sediment thickness was measured to a maximum depth of 1.06 m (3.5 ft). Greater sediment thicknesses were subsequently noted in some deposits and these results are included in the database. However, not all of these results are reflected on Plates 3-1 through 3-4 because accurate coordinates were not available. The maximum depth from which PCB samples were collected in each deposit/SMU group, as well as in each bay zone, is included on the table in Appendix G. The maximum sample depths in each reach or zone are listed below.

Maximum Sediment Sampling Depth

Lower Fox River Reach	Maximum Sampling Depth	Green Bay Zones	Maximum Sampling Depth
LLBdM	1.89 m (6.2 ft)	Zone 2 (2A & 2B)	0.91 m (3 ft)
Appleton to Little Rapids	1.83 m (6 ft)	Zone 3A	0.30 m (1 ft)
Little Rapids to De Pere	2.13 m (7 ft)	Zone 3B	0.62 m (2 ft)
De Pere to Green Bay	3.96 m (13 ft)	Zone 4	0.30 m (1 ft)

During the supplemental data collection activities conducted as part of the RI/FS effort, gravity core and push-core samples were collected. In general, these samples ranged up to approximately 0.6 m (2 ft) in length.

In general, there are three layers observed in sediment cores, and these consist of the following:

Layer 1 The surface layer is primarily fine-grained, unconsolidated sediment with a high organic content. As suggested by previous investigators and modeling results, sediments in this layer are fairly recent in age and are susceptible to re-suspension based on flow velocities and shear stress effects.

Layer 2 Consists of fine grained sediments with slightly more sand and gravel along with shell and wood debris. Based on field observations, these sediments are usually more compact, with less water content than the surface layer and would likely require high flow velocities/shear stresses to achieve resuspension.

Layer 3 This layer is the native glacial material which underlies the river. This material typically consists of red-orange, stiff, damp to dry, silty clay, similar to the glacial till in the region.

Sediment thickness is generally greatest in the central portion of the deposit and thins towards the edges. A discussion of each river reach and deposits of significant areal extent are discussed below.

3.6.3.1 LLBdM Reach

Areas of deposits A, C, D, E, F, and POG exhibit sediment thickness approaching or exceeding 1 m (3.28 ft) (Plate 3-1). Overall, LLBdM has conditions that promote deposition and sediments cover about 313.5 hectares (775 acres) in the lake. The areal extent of these deposits ranges from 12.4 hectares (30.6 acres) for Deposit C to 202.5 hectares (500 acres) for Deposit E. Plate 3-1 indicates that sediments thicker than 1 m (3.28 ft) cover much of the width of the river in Deposit E, which is also the largest deposit in this reach. Downstream of the outlet of LLBdM, deposits G and H have surface areas of 4.1 hectares (10 acres) or less.

3.6.3.2 Appleton to Little Rapids Reach

Sediments cover approximately 153 hectares (378 acres) in this reach. Deposits W and X are the largest deposits in this reach, covering a combined area exceeding 82 hectares (202 acres). The sediment thickness in these deposits ranges as high as 1.52 m (5 ft) and 1.83 m (6 ft), respectively (Plate 3-2). The other two deposits in this reach which exceed 10 hectares (24.7 acres) are deposits S and DD. The sediment thickness in these two deposits, as well as the other remaining deposits is less than 1 m (3.28 ft). These thickness and areal extent results suggest that deposits S, W, X, and DD are located in areas which have conditions favorable for sediment deposition. The areal extent of all the remaining deposits in this reach is less than 10 hectares (24.7 acres).

3.6.3.3 Little Rapids to De Pere Reach

Deposits FF, GG, and HH are contiguous with Deposit EE and these four deposits encompass one continuous depositional area (Plate 3-3), covering approximately 266 hectares (658 acres). Deposit EE, the largest of all deposits upstream of the De Pere dam, extends for a distance of approximately 8.6 km (5.4 miles) and has a surface area of 258 hectares (640 acres) (Appendix G). Sediments with PCB range up to 2.3 m (7.5 ft) thick in this reach. In addition, sediments thicker than 1 m (3.287 ft) are located throughout much of this reach (Plate 3-3). Sediment thicknesses exceed 2.3 m (7.5 ft) in these deposits.

3.6.3.4 De Pere to Green Bay Reach

A large, almost continuous deposit of sediment extends from the De Pere dam to the Fort James-West turning basin (Plate 3-4). Downstream of the turning basin, most of the sediment is routinely removed by dredging operations conducted to maintain the navigation channel, and only isolated areas of sediment are present. Sediment thickness is typically up to 1 m (3.28 ft) between the dam and SMU group 38-43. Downstream of SMU group 38-43 (3.28 ft), large areas of the river bottom are covered by sediment thicker than 1 meter. In the vicinity of the turning basin, sediment thickness is 3.65 m (12 ft). Montgomery Watson (1998) reported sediment thickness up to 5.8 meters (19 ft) near the turning basin itself. The areal extent of sediment is approximately 524 hectares (1,290 acres) (Appendix G). The two largest SMU groups based on areal extent are SUMs 20-25 and 44-49, which cover 113.4 hectares (280 acres) and 107.2 hectares (265 acres), respectively.

3.6.3.5 Green Bay (Zones 2 through 4)

Sediment thickness in Green Bay is shown on Plate 3-5. PCB samples were collected from depths as great as 0.9 m (3 ft) in Zone 2 (2A and 2B), near the mouth of the Fox River. A sediment thickness of 0.62 m (2 ft) was also noted along the east shore of Green Bay in Zone 3B (Appendix G). Due to the number of samples collected in Green Bay, the interpolated sediment thickness results only range as high as 0.30 m (1 ft) on plate 3-5. Sediments containing PCBs cover almost 421,300 hectares (1,041,050 acres). Green Bay zones 2A and 2 B cover a combined 11,080 hectares (27,380 acres) while zones 3A and 3 B cover 155,230 hectares (383,580 acres). Zone 4 sediments cover almost 255,000 hectares (630,116 acres).

In Green Bay, sediment cores were only collected where a Ponar Grab sample indicated that sediments with a high organic carbon content were likely present. Therefore, no core was collected in areas where no sediment was retrieved by the grab sampler or where native clay till was present.

3.6.4 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 collected from the Lower Fox River, Green Bay, and select tributaries to assist in the interpretation of the sediment organics data. These results allow for TOC-normalization of the data for comparisons with sediment reference material or with WDNR calculated SQGs. The average TOC result for each deposit, SMU group, or bay zone is listed in Appendix G and the average TOC results (by percent) for each reach and zone are listed below.

Average Reach/Zone TOC Content

Lower Fox River Reach	Average TOC Content	Green Bay Zones	Average TOC Content
LLBdM	6.47%	Zone 2 (2A & 2b)	1.48%
Appleton to Little Rapids	3.68%	Zone 3A	0.19%
Little Rapids to De Pere	4.98%	Zone 3B	2.33%
De Pere to Green Bay	4.54%	Zone 4	0.14%

The average TOC content in Lake Winnebago is 7.8 percent (78,000 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 Lake Michigan TOC average is 0.35 percent and the USGS reference site samples, which have been collected at various sediment sites throughout the country, is 5.68 percent (Appendix G).

It is likely that high concentrations of organic contaminants within the sediments account for some of the TOC detected, as seen in data for Deposit A. Deposit A had an average TOC concentration of 9.04 percent while the LLBdM Reach as a whole had an average TOC concentration of 6.47 percent. Similarly, the average TOC concentrations in SMU 56/57 ranged from 5.42 to 7.56 percent while the average for the De Pere to Green Bay Reach was 4.54 percent.

3.6.5 Other Physical Parameters

Samples were also collected and submitted for percent solids and bulk density and these data are summarized on tables in Appendix G. Solids generally comprise approximately 40 percent of the sediment samples analyzed (Appendix G). The average values for all three of the reaches upstream of the De Pere dam range from 37 to 42 percent. However, individual values have a much greater range, between 18.1 and 88.2 percent, and may reflect varying sample depths as well as the degree of sediment consolidation. The average result in Green Bay is 44 percent, similar to the river. However, in Green Bay Zone 4, the average percent solids result is approximately 70 percent, indicating that sediments in this portion of the bay are more likely to consist of coarse grained sands rather than fine-grained silt/clay.

The average bulk density results (wet and dry bulk density) for each deposit/SMU group is listed in Appendix G. The average dry bulk density results range from 0.31 to 1.18 grams per cubic centimeter (g/cm^3). The average results for each reach range between 0.51 g/cm^3 and 0.66 g/cm^3, while the river-wide average is 0.55 g/cm^3.

Wet bulk density and specific gravity results are available for only a few deposits/SMUs. Wet bulk density results give an indication of how much the mass of the material will change once sediments are removed from the river (e.g., during remedial efforts). The wet bulk density results ranged from 1.15 g/cm^3 to 1.23 g/cm^3 with an average of 1.17 g/cm^3. The moisture content was also calculated as part of the bulk density determinations and the water content (mass) generally comprises approximately 50 to 75 percent of the sediment sample mass. Specific gravity results ranged from 2.32 to 2.59 with an average value of 2.46.

3.7 Section 3 Figures, Tables, and Plates

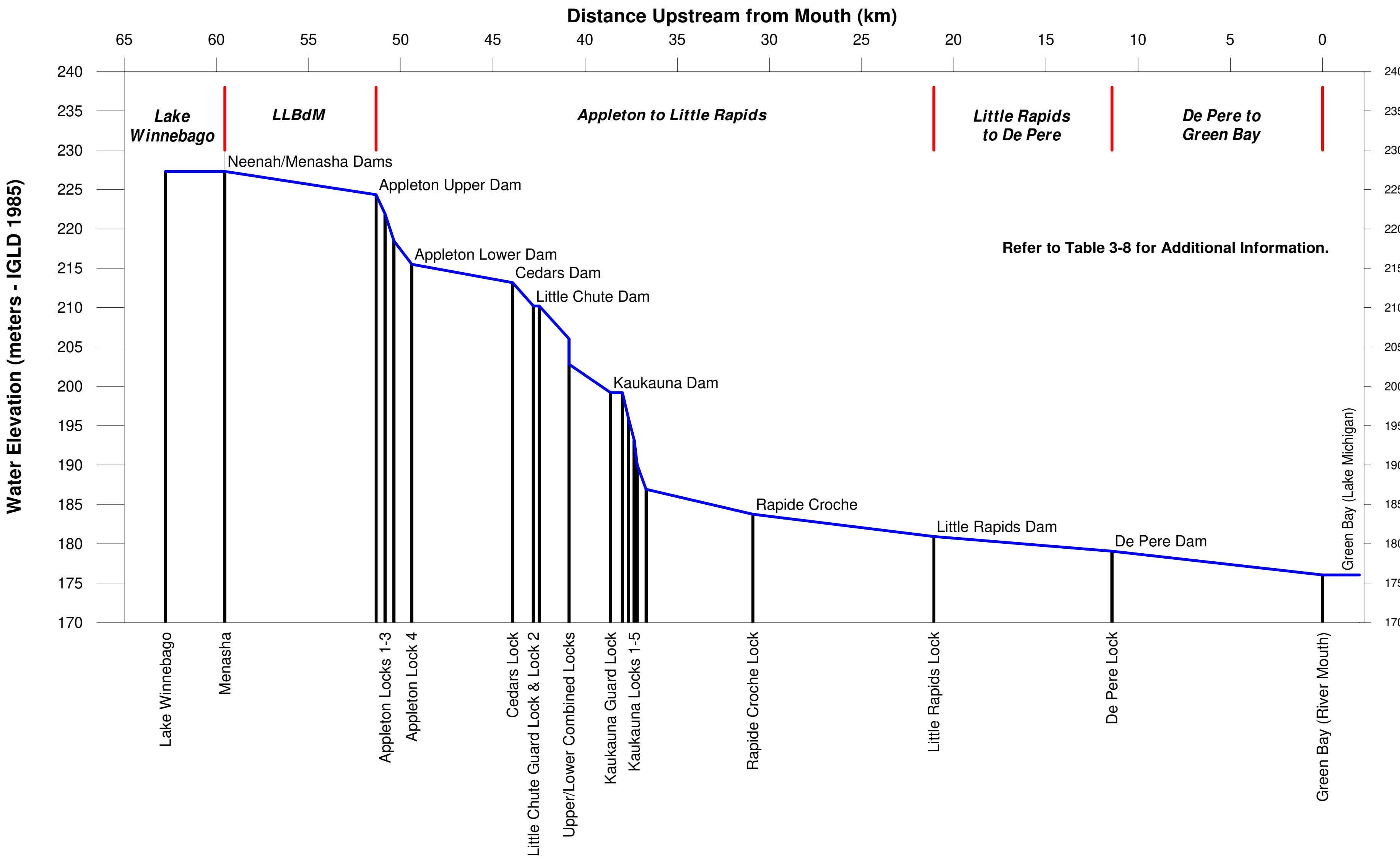
Figures, tables, and plates for Section 3 follow this page, and include:

Figure 3-1 Lower Fox River Elevation Profile
Figure 3-2 Green Bay Monthly Mean Surface Circulation - August 1989
Figure 3-3 Green Bay Monthly Bottom Surface Circulation - August 1989
Figure 3-4 Green Bay Zone 2 Bathymetry
Figure 3-5 Green Bay Zone 3 Bathymetry
Figure 3-6 Green Bay Zone 4 Bathymetry
Figure 3-7 Estimated Annual Sediment Transport Rates and Stream Flow Velocities

Table 3-1 Land Use Classification for Counties Bordering Green Bay
Table 3-2 Temperature and Precipitation Data for the City of Green Bay, Wisconsin
Table 3-3 Temperature and Precipitation Data for the City of Appleton, Wisconsin
Table 3-4 Temperature and Precipitation Data for the City of Marinette, Wisconsin
Table 3-5 Temperature and Precipitation Data for the City of Sturgeon Bay, Wisconsin

Table 3-6 Temperature and Precipitation Data for the City of Fayette, Michigan
Table 3-7 Water Use in the Lower Fox River/Green Bay Watersheds (1995)
Table 3-8 Lower Fox River Dams
Table 3-9 Lower Fox River - U.S. Army Corps of Engineers - Dam Stability and Inspection Information
Table 3-10 Lower Fox River Gradient and Lock/Dam Information
Table 3-11 Lower Fox River Discharge Results - Rapide Croche Gauging Station
Table 3-12 Lower Fox River Stream Velocity Estimates
Table 3-13 Fox River Mouth Gauging Station Results (1989-1999)
Table 3-14 Lower Fox River Total Suspended Solid (TSS) Loads
Table 3-15 USACE Navigation Channel Dredging Records (1957-1999)

Plate 3-1 Sample Locations and Interpolated Thickness of Sediment with PCBs: Little Lake Butte des Morts Reach
Plate 3-2 Sample Locations and Interpolated Thickness of Sediment with PCBs: Appleton to Little Rapids Reach
Plate 3-3 Sample Locations and Interpolated Thickness of Sediment with PCBs: Little Rapids to De Pere Reach
Plate 3-4 Sample Locations and Interpolated Thickness of Sediment with PCBs: De Pere to Green Bay Reach
Plate 3-5 Sample Locations and Interpolated Thickness of Sediment with PCBs: Green Bay



ThermoRetec
Smart Solutions Positive Outcomes

Natural Resource Technology

Remedial Investigation Report

Lower Fox River Elevation Profile

FIGURE: 3-1

REF NO:
CREATED BY:
PRINT DATE:
APPROVED:

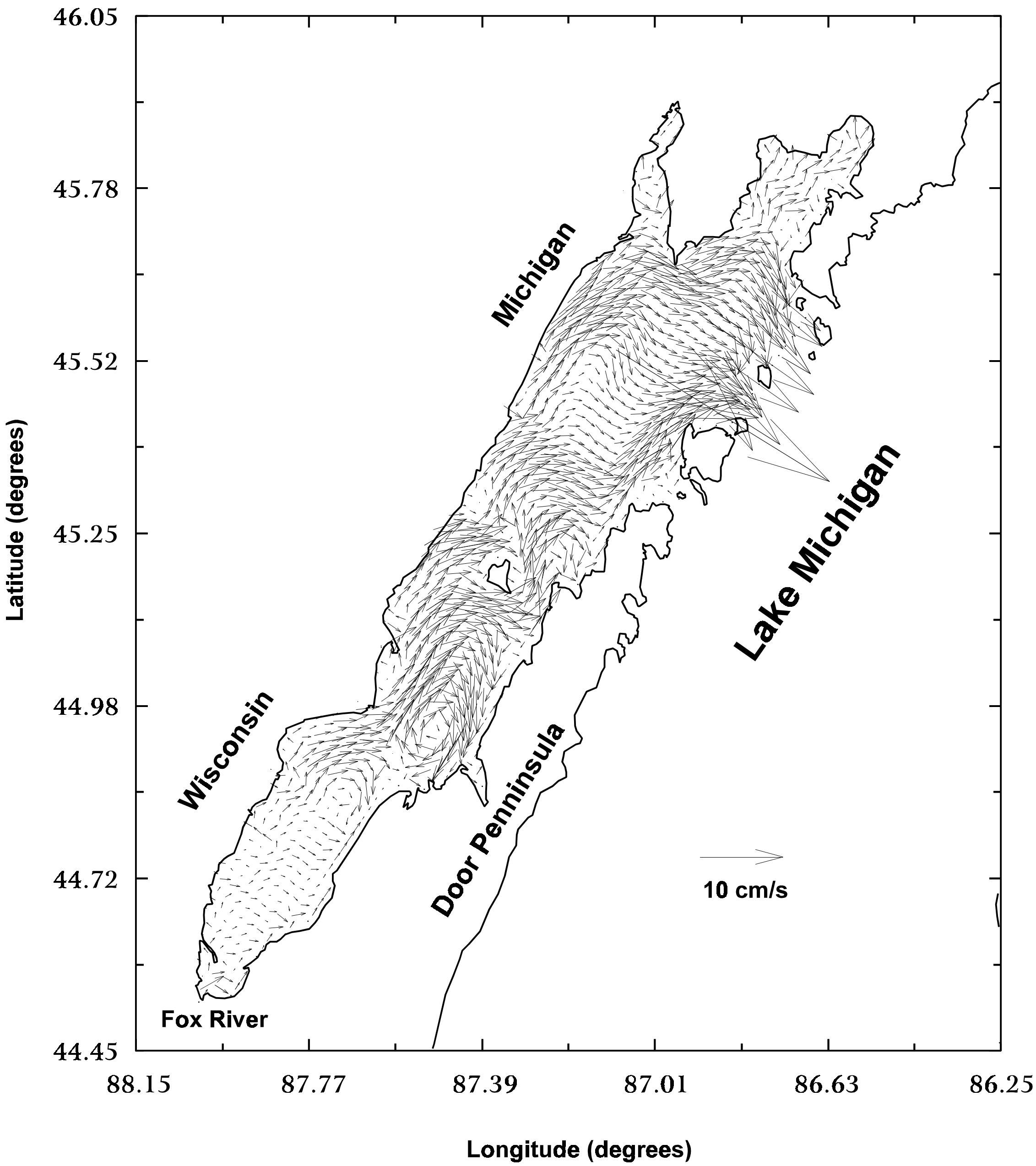


Figure 3-2 Green Bay Monthly Mean Surface Circulation - August 1989

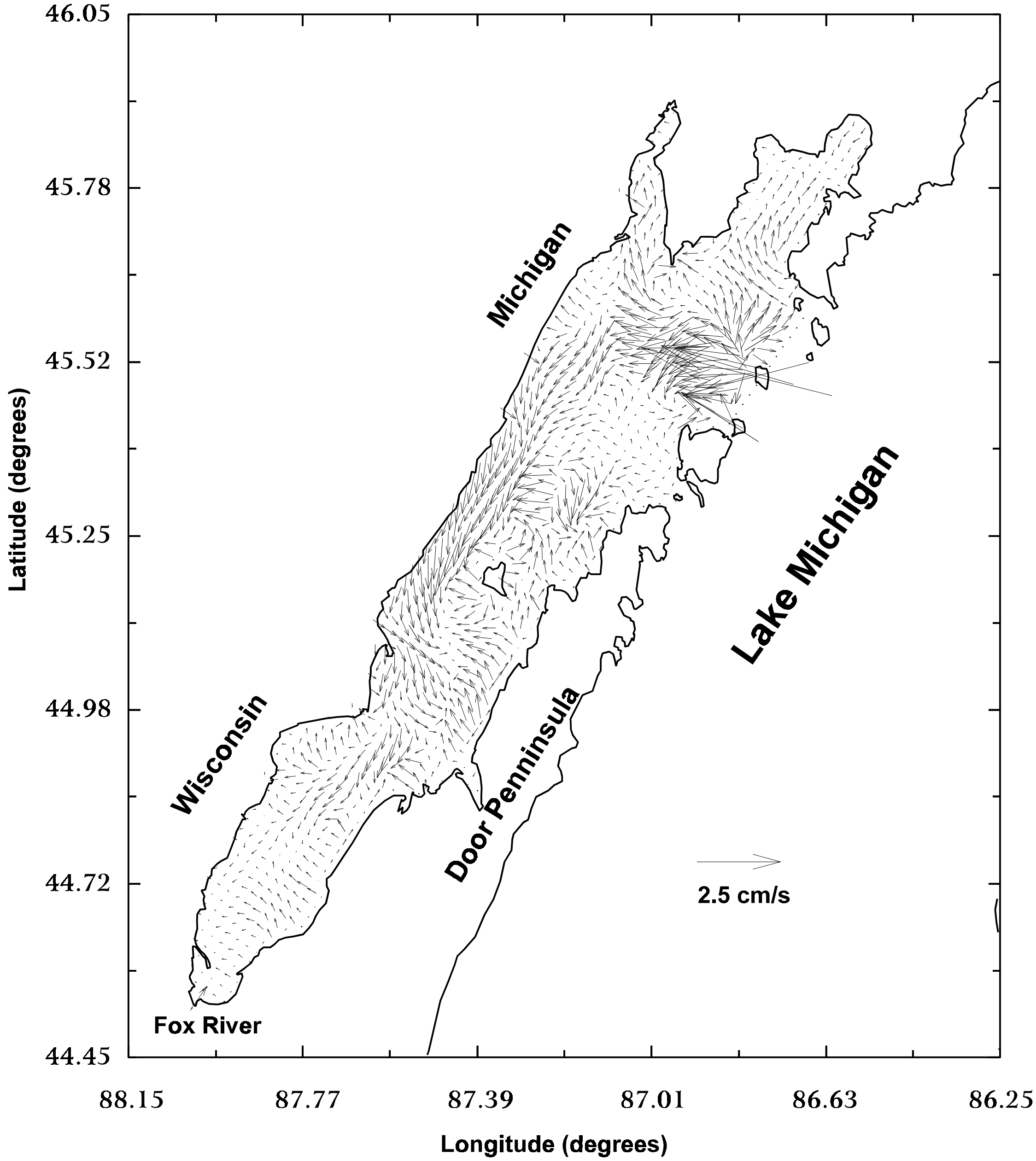
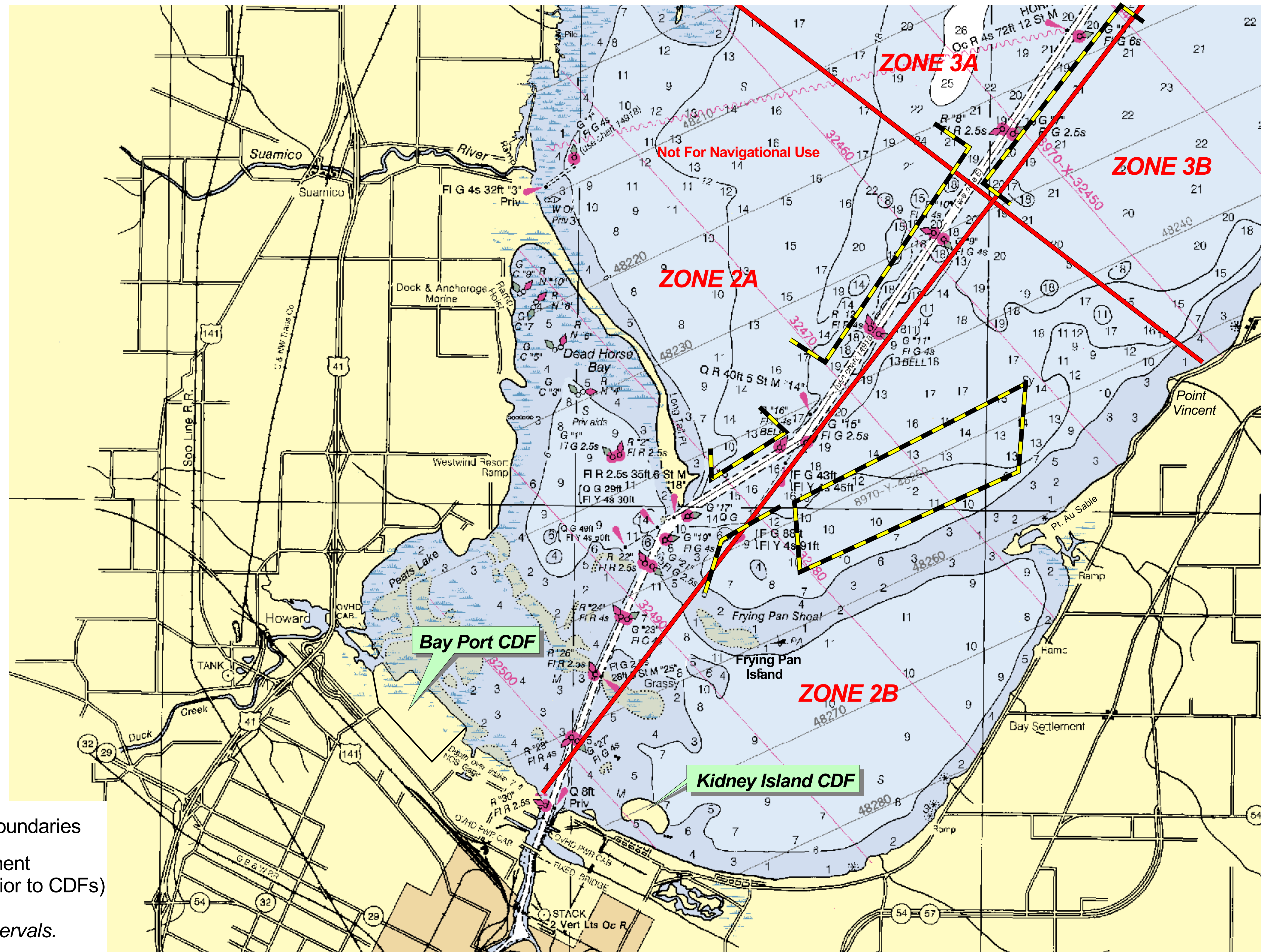


Figure 3-3 Green Bay Monthly Mean Bottom Circulation - August 1989



N
W E
S

Green Bay Zone Boundaries

Open Water Sediment Disposal Areas (Prior to CDFs)

Bathymetry contours in 6-foot intervals.

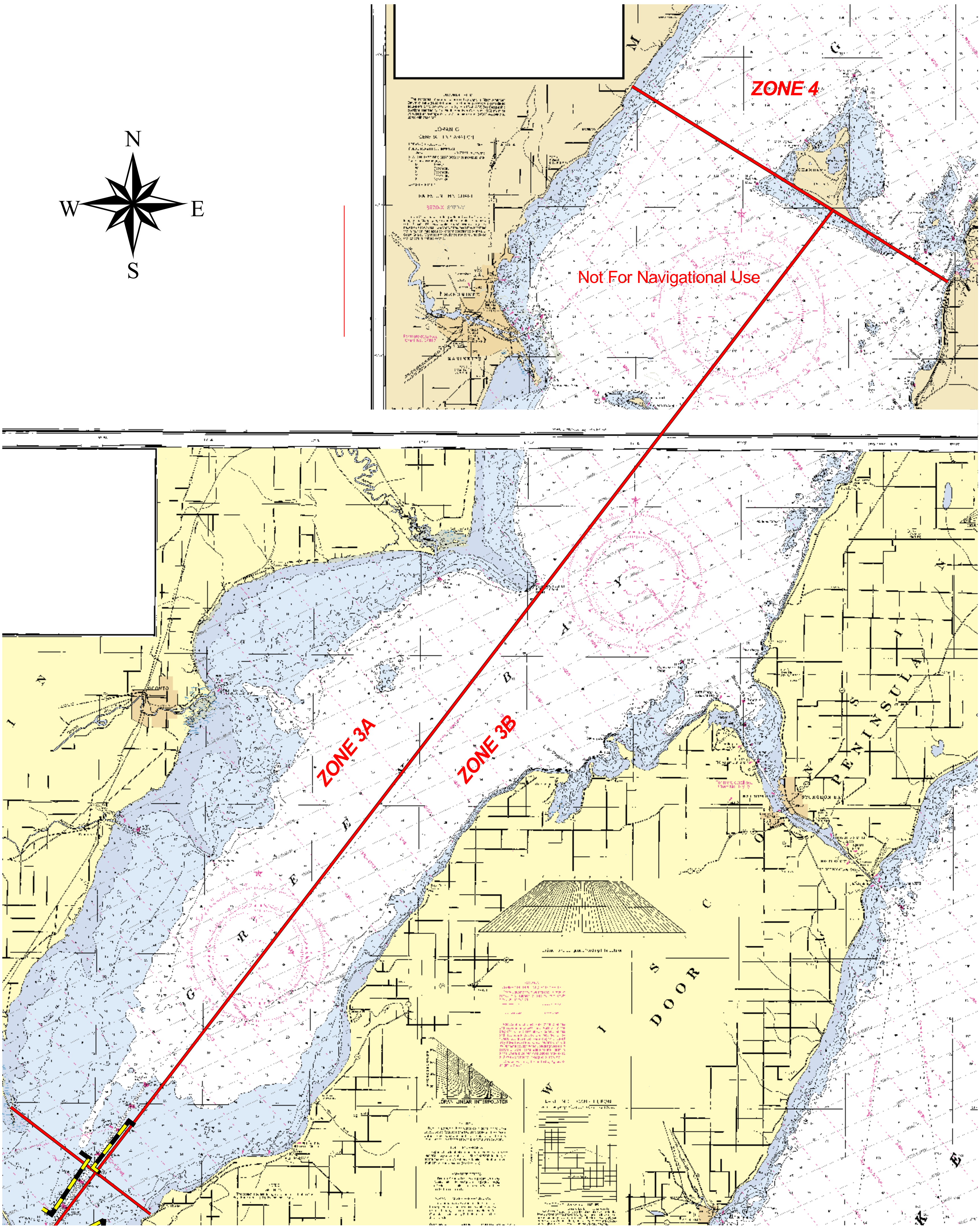
Confined Disposal Facilites (Existing)

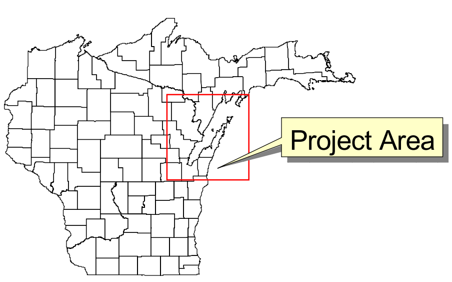
1 0 1 2 3 Kilometers

1 0 1 2 Miles

Source: NOAA Chart 14918 (1998)

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Green Bay Zone 2 Bathymetry	FIGURE NO: RI-14414-340-3-4
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE: 3-4	APPROVED: AGF





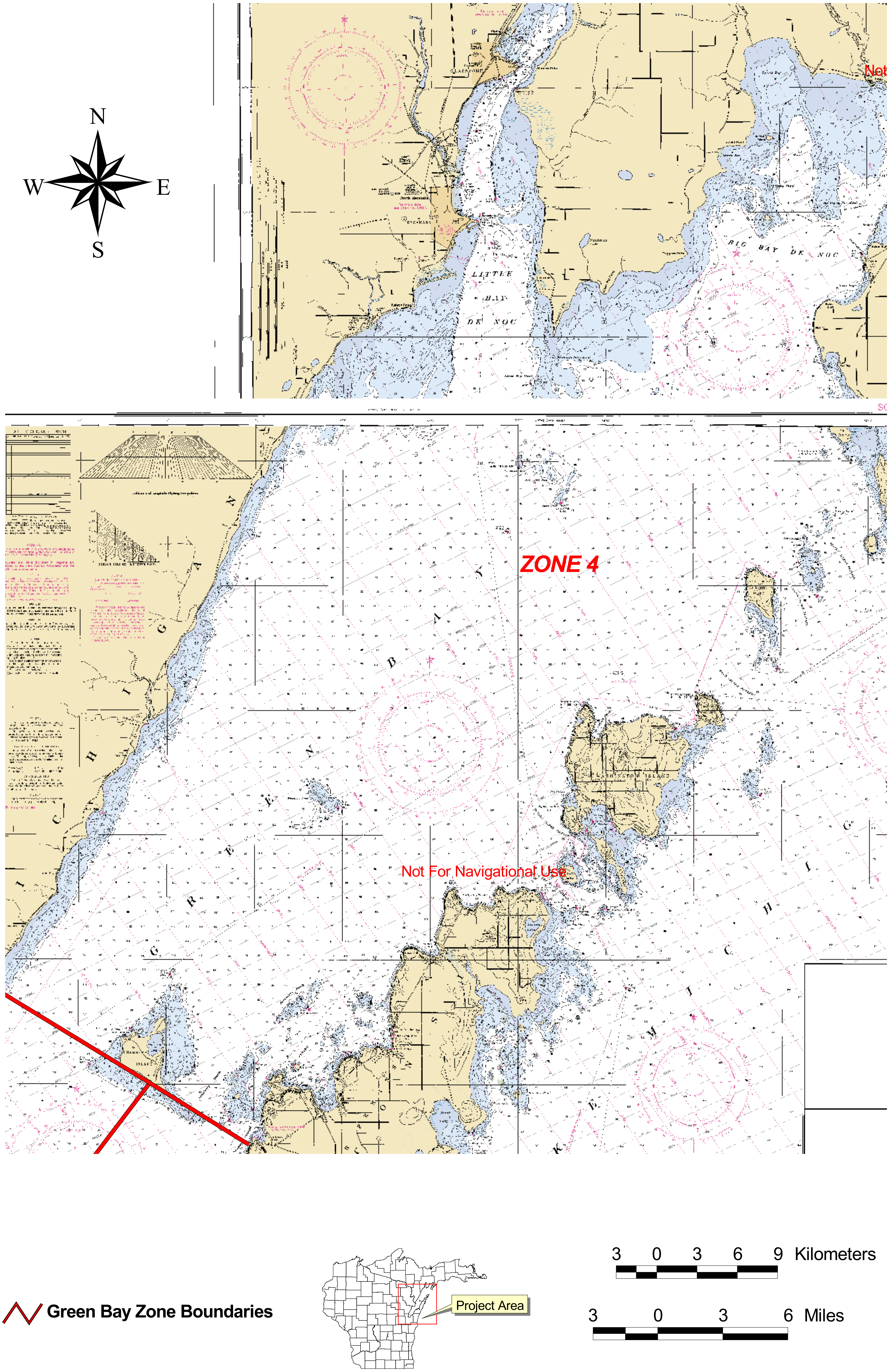
5 0 5 10 15 Kilometers

5 0 5 10 Miles

Green Bay Zone Boundaries
Open Water Sediment Disposal Areas (Prior to CDF's)

SOURCE: NOAA Chart 14909 (1998) and 14910 (1991)
Bathymetry contours in 6-foot intervals.

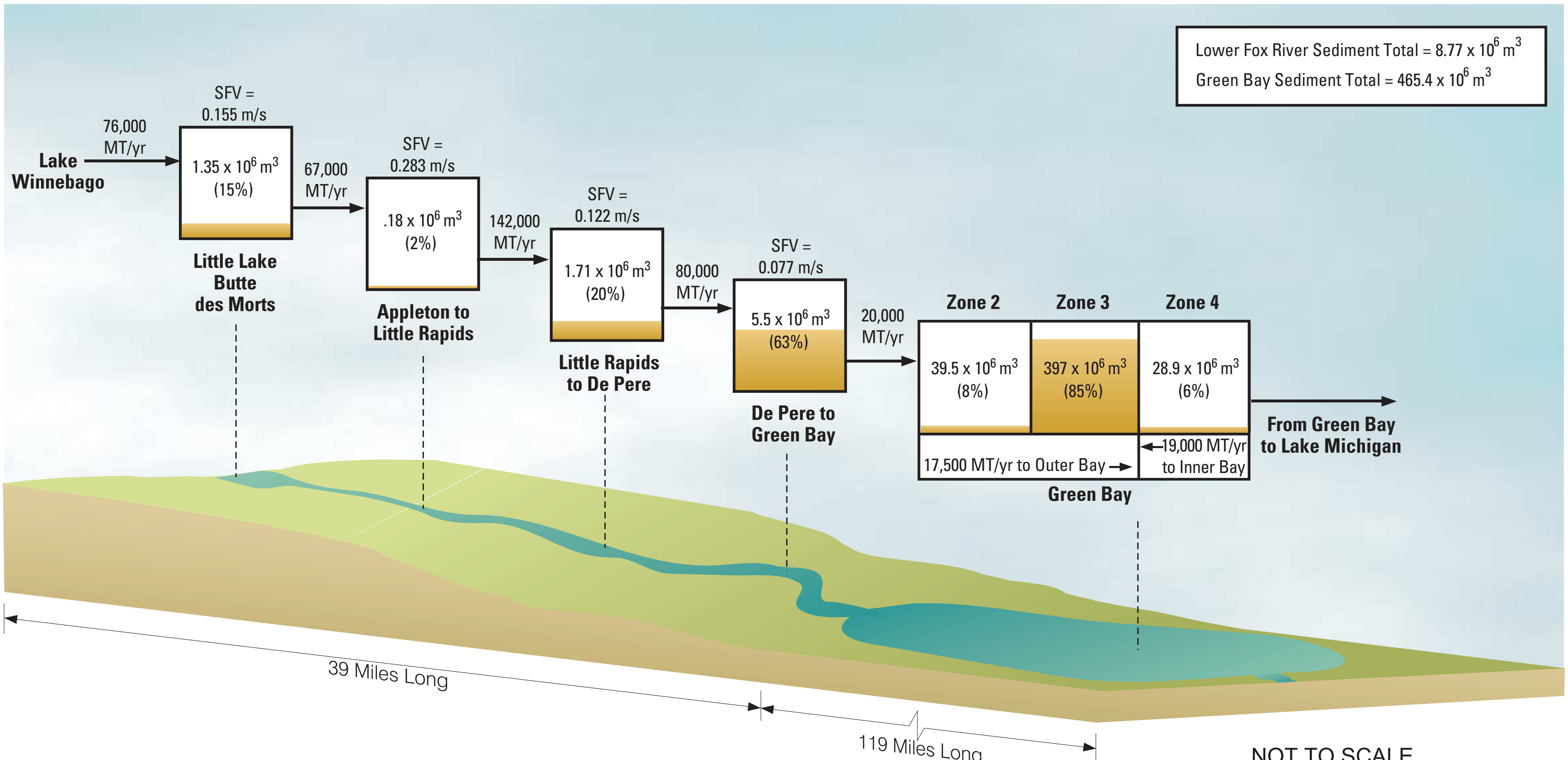
ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Green Bay Zone 3 Bathymetry	DRAWING NO: RI-4414-340-3-5
				PRINT DATE: 3/7/01
				CREATED BY: SCJ
			FIGURE 3-5	APPROVED: AGF



SOURCE: NOAA Chart 14909 (1998) and 14908 (1991)
Bathymetry contours in 6-foot intervals.

ThermoRetec	Natural Resource Technology	Remedial Investigation Report	Green Bay Zone 4 Bathymetry	DRAWING NO: RI-4414-340-3-6
				PRINT DATE: 3/7/01
				CREATED BY: SCJ
			FIGURE 3-6	APPROVED: AGF

Figure 3-7. 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

Table 3-1. Land Use Classification for Counties Bordering Green Bay

Land Use Class	Wisconsin Counties										Michigan Counties				Total Land Usage [F]	
	Brown [A]		Door [B]		Kewaunee [C]		Oconto [D]		Marinette [E]		Menominee		Delta			
	Percent	Hectares	Percent	Hectares	Percent	Hectares	Percent	Hectares	Percent	Hectares	Percent	Hectares	Percent	Hectares	Percent	Hectares
Residential	7.8%	10,687	4.0%	5,092	1.9%	172	3.1%	1,904	0.4%	1,483	1.0%	2,726	1.2%	3,661	1.9%	24,984
Ind./Com.	9.3%	12,742	0.9%	1,146	3.3%	297	0.7%	426			0.7%	1,908	0.9%	2,746	1.5%	19,882
Agriculture	58.6%	80,275	49.3%	62,758	69.1%	6,187	37.3%	23,307	12.2%	45,227	14.4%	39,251	8.7%	26,543	22.1%	283,547
Forested			34.1%	43,409	21.7%	1,947	51.6%	32,210	53.1%	196,849	71.9%	195,954	76.2%	232,419	55.0%	705,816
Open	6.7%	9,180	3.3%	4,201	0.4%	38	5.5%	3,454	8.6%	31,881	4.4%	11,993	3.9%	11,899	5.2%	66,477
Vacant			0.1%	127			0.0%	22	0.6%	2,187	0.01%	27	0.01%	31	0.4%	5,443
Public	7.8%	10,687	6.5%	8,274	0.1%	7	0.6%	358	0.01%	37	0.1%	273	0.01%	31	1.5%	19,666
Wetlands	9.8%	13,427	0.6%	764	3.3%	295	0.1%	40	23.0%	85,264	6.8%	18,535	8.3%	25,323	11.2%	143,648
Water	0.01%	14	1.2%	1,528	0.1%	7	1.1%	686	2.1%	7,785	0.7%	1,908	0.8%	2,441	1.1%	14,368
TOTAL	100.0%	137,011	100.0%	127,298	100.0%	8,951	100.0%	62,408	100.00%	370,714	100.0%	272,574	100.00%	305,091	100.0%	1,283,831

Notes: Ind./Com. is Industrial/Commercial - this category also includes lands designated for transportation/utility use.

Open land is non-forested land not currently under cultivation.

A) There was no distinction between forested, open, and vacant land use.

B) Wetlands, beaches, marshes, grasslands, and meadows are combined and equal about 0.6% of land designated as wetlands.

C) Land use information only available for Town of Red River (which borders Green Bay and includes Dyckesville). Total county area is 85,420 hectares and open/vacant land are not distinguished.

D) Land use information only available for the eastern 1/4 of county. Total county area is 263,442 hectares.

E) There was no distinction of urban land use between residential and industrial/commercial.

F) Combined classifications were divided equally when calculating total land usage values.

Table 3-2. Temperature and Precipitation Data for the City of Green Bay, Wisconsin

Temperature Data (Averages: 1961-1990 and Extremes: 1896-1996)

Time	Averages			Daily Extremes				Mean Extremes				Day	Max	Day	Min
Period	Max	Min	Mean	High	Date	Low	Date	High	Year	Low	Year	=>90	<=32	<=32	<=0
January	22.8	5.8	14.3	56	1/26/44	-31	1/30/51	27.6	33	-1.1	12	0	22	30	9.6
February	27.1	9.5	18.3	60	2/21/30	-33	2/10/1899	29	31	4.6	36	0	19	27	6.9
March	38.5	21.4	30	82	3/29/10	-29	3/1/62	41.4	10	19.5	60	0	9.1	26	1.2
April	54	33.9	44	89	4/22/80	7	4/3/54	52.3	15	35.1	7	0	0.6	13	0
May	67.2	43.7	55.5	99	5/31/34	21	5/9/66	63.4	77	47.5	7	0.1	0	1.9	0
June	75.5	53.5	64.5	101	6/1/34	32	6/6/58	72.9	33	57.2	69	1.6	0	0	0
July	80.5	58.9	69.7	104	7/13/36	40	7/6/65	77.4	21	64.9	92	3.2	0	0	0
August	77.5	56.8	67.1	100	8/24/48	38	8/30/15	75.1	47	61.7	50	2	0	0	0
September	69.1	48.8	59	97	9/10/31	24	9/29/49	67.3	31	54.2	74	0.7	0	0.5	0
October	57.4	38.5	48	88	10/6/63	12	10/30/25	58.9	47	39	25	0	0.1	6.7	0
November	42	26.8	34.4	74	11/1/33	-9	11/28/76	43.2	31	25.4	51	0	5.5	21	0.3
December	27.7	12.5	20.2	62	12/1/70	-27	12/19/83	32.1	31	9.1	76	0	19	29	5
Annual	53.3	34.2	43.8	104	7/13/36	-33	02/10/99'	49.5	31	40.4	17	7.7	75	156	23
Winter	25.9	9.3	17.6	62	12/1/70	-33	02/10/99'	27.1	32	10.1	4	0	60	86	21
Spring	53.2	33	43.2	99	5/31/34	-29	3/1/62	49.6	77	37.6	50	0.1	9.7	41	1.2
Summer	77.8	56.4	67.1	104	7/13/36	32	6/6/58	72.6	95	63.1	15	6.8	0	0	0
Fall	56.2	38	47.1	97	9/10/31	-9	11/28/76	54.7	31	42.4	76	0.7	5.6	28	0.3

Precipitation Data (Averages: 1961-1990 and Extremes: 1896-1996)

	Total Precipitation							Snow			# Days Precipitation		
	Mean	High	Year	Low	Year	1 - Day Max		Mean	High	Year	0.01	0.5	1
January	1.15	2.64	50	0.12	81	1.2	13904	11.7	31.5	96	10	0.4	0
February	1.03	4.54	22	0.04	69	2.03	2/22/22	8	20.6	62	8.4	0.4	0.1
March	2.05	4.68	77	0.19	10	1.87	3/19/03	9.2	24.2	89	10.3	1.1	0.1
April	2.4	6.47	29	0.49	89	1.86	4/25/94	2.1	11.8	77	10.8	1.7	0.3
May	2.82	9.7	18	0.06	88	2.6	5/29/42	0.1	4.3	90	11.3	1.8	0.5
June	3.39	10.29	90	0.31	76	4.9	6/22/90	0	0	49	10.8	2.2	0.9
July	3.1	7.46	12	0.7	46	4.39	7/23/12	0	0	48	10	2.1	0.7
August	3.5	9.04	75	0.36	'99	3.83	8/28/75	0	0	48	9.8	2.1	0.6
September	3.47	7.8	65	0.28	76	2.99	9/3/64	0	0	48	10.1	2.2	0.8
October	2.23	5	54	0	52	3.44	10/2/54	0.2	1.7	59	9.1	1.2	0.4
November	2.16	6.19	34	0.16	76	2.23	11/1/85	4.6	17.1	95	9.5	1.1	0.3
December	1.53	3.65	21	0.03	43	1.57	12/27/04	12.5	27	77	10	0.5	0.1
Annual	28.83	38.36	85	16.31	30	4.9	33046	48.5	92	85	120.7	16.9	4.7
Winter	3.71	9.07	22	1.34	61	2.03	2/22/22	31.4	53.2	62	28.3	1.3	0.2
Spring	7.27	14.12	18	3.42	31	2.6	5/29/42	11.5	25.5	77	32.5	4.6	1
Summer	9.99	18.89	14	4.42	76	4.9	6/22/90	0	0	48	30.8	6.4	2.1
Fall	7.86	13.21	31	1.26	76	3.44	10/2/54	4.8	17.1	95	28.9	4.6	1.5

Notes:

1) Information from the Green Bay Airport Station 473269 (GREEN_BAY_WSO_AIRPORT)

2) Temperatures are in degrees Fahrenheit and precipitation is in inches.

Table 3-3. Temperature and Precipitation Data for the City of Appleton, Wisconsin

Temperature Data (Averages 1961-1990 and Extremes 1901-1996)

Time	Averages			Daily Extremes				Mean Extremes				Day	Max	Day	Min
Period	Max	Min	Mean	High	Date	Low	Date	High	Year	Low	Year	=>90	<=32	<=32	<=0
January	23.8	7.2	15.5	55	1/27/44	-30	1/30/51	26.9	90	0.1	12	0	19	27	8.6
February	28.5	11.2	19.9	59	2/23/30	-32	2/20/29	29.6	54	3.9	36	0	16	25	5.9
March	39.6	22.6	31.1	80	3/29/10	-21	3/1/62	42.1	10	22.3	60	0	7.4	24	0.9
April	54.6	35	44.8	89	4/22/80	7	4/6/79	53.1	15	36.6	7	0	0.4	12	0
May	68	46.3	57.2	94	5/31/88	23	5/4/05	69.2	11	49.3	7	0.1	0	1.5	0
June	77.1	56.2	66.6	101	6/20/88	34	6/8/13	72.7	11	59.5	69	1.7	0	0	0
July	81.9	62	71.9	107	7/14/36	41	7/31/03	78.3	16	66.8	92	3.5	0	0	0
August	79	59.7	69.4	103	8/16/88	35	8/27/15	77.5	47	63.7	27	2.2	0	0	0
September	70.3	51.5	60.9	101	9/2/13	25	9/30/93	67.4	8	54.4	93	0.7	0	0.4	0
October	58.1	40.7	49.4	89	10/6/63	15	10/19/92	60	47	38.7	17	0	0	5.2	0
November	42.7	28.2	35.5	73	11/1/35	-7	11/29/29	43	31	26.1	95	0	4.6	19	0.2
December	28.6	13.8	21.2	59	12/8/46	-23	12/21/89	31.4	39	9.9	85	0	17	27	4
Annual	54.4	36.2	45.3	107	7/14/36	-32	2/20/29	50.3	38	40.6	17	8.2	65	142	20
Winter	27	10.7	18.9	59	2/23/30	-32	2/20/29	26.2	32	11.5	18	0	52	79	18
Spring	54.1	34.6	44.4	94	5/31/88	-21	3/1/62	50.7	77	38.5	96	0.1	7.8	38	0.9
Summer	79.3	59.3	69.3	107	7/14/36	34	6/8/13	74.3	88	64.1	15	7.4	0	0	0
Fall	57	40.1	48.6	101	9/2/13	-7	11/29/29	54.8	31	44	76	0.7	4.6	24	0.2

Precipitation Data (Averages 1961-1990 and Extremes 1901-1996)

	Total Precipitation							Snow			# Days Precipitation		
	Mean	High	Year	Low	Year	1 - Day Max		Mean	High	Year	0.01	0.5	1
January	1.12	4.35	29	0.04	81	1.23	1/16/80	10.9	29.9	94	8.8	0.5	0
February	1.08	3.66	81	0.04	69	1.87	2/8/66	7.9	26.1	62	7.2	0.5	0.1
March	2.17	5.36	13	0.16	78	3.12	3/14/13	8.2	28.2	56	9	1.2	0.2
April	2.78	6.64	29	0.2	1	2.3	4/3/81	2	11	85	10.2	1.9	0.4
May	3.19	8.79	42	0.22	88	2.96	5/31/54	0.2	5.3	90	10.8	2.2	0.6
June	3.64	9.07	90	0.17	12	4.18	6/23/90	0	0	48	10	2.4	0.9
July	3.21	8.76	12	0.4	16	3.29	7/2/52	0	0	48	9.3	2.3	0.9
August	3.74	10.3	95	0.5	76	3.7	8/28/75	0	0	48	9.2	2.2	0.7
September	3.66	9.15	86	0.32	67	2.67	9/11/86	0	0	48	9.7	2.5	0.8
October	2.45	6.41	67	0.09	52	2.85	10/24/67	0.2	2	76	8.7	1.3	0.3
November	2.17	5.93	34	0.02	4	2.15	11/22/34	3.8	16.8	59	8.5	1.3	0.3
December	1.54	3.33	68	0.15	94	1.55	12/27/59	11.7	28.1	68	8.5	0.6	0.1
Annual	30.75	40.98	61	19.21	1	4.18	6/23/90	44.5	98.2	59	109.7	18.9	5.4
Winter	3.74	7.27	29	1.26	95	1.87	2/8/66	29.7	57.1	62	24.6	1.6	0.2
Spring	8.14	15.47	13	3.5	39	3.12	3/14/13	10.5	34.5	56	30.6	5.4	1.2
Summer	10.59	19.19	61	4.92	37	4.18	6/23/90	0	0	48	29.3	7.2	2.6
Fall	8.28	15.23	11	1.38	76	2.85	10/24/67	4	17.6	59	27.2	5.1	1.5

Notes:
1) Information from the Appleton Weather Station 470265.
2) Temperatures are in degrees Fahrenheit and precipitation is in inches.

Table 3-4. Temperature and Precipitation Data for the City of Marinette, Wisconsin

Temperature Data (Averages: 1961-1990 and Extremes: 1948-1996)

Time Period	Averages			Daily Extremes				Mean Extremes				Day	Max	Day	Min
	Max	Min	Mean	High	Date	Low	Date	High	Year	Low	Year	=>90	<=32	<=32	<=0
January	24.8	6.1	15.5	50	1/26/73	-30	1/17/82	25.3	64	8.5	77	0	20	30	8.1
February	28.1	8	18.1	57	2/29/64	-30	2/3/96	30.7	54	12.5	63	0	15	27	5.2
March	39.3	19.7	29.5	75	3/30/63	-20	3/1/62	39.3	73	24.3	96	0	5.2	26	1
April	53.3	32.2	42.8	90	4/27/52	5	4/9/89	49.9	87	35.2	50	0	0.2	14	0
May	66.4	43.4	54.9	97	5/30/88	22	3/10/66	64.2	77	47.8	83	0.5	0	2.8	0
June	76.8	53.2	65	100	6/14/87	34	6/8/49	71.4	88	58.2	82	2.7	0	0	0
July	82.8	59	70.9	102	7/6/88	40	7/6/65	76.3	55	64	92	4.9	0	0	0
August	78.9	56.6	67.8	101	8/21/55	34	8/28/86	75.3	55	64.2	50	2.7	0	0	0
September	70	49.2	59.6	96	9/1/53	23	9/23/74	64.9	61	53.7	74	0.6	0	0.8	0
October	57.7	38.4	48.1	89	10/6/63	16	10/18/48	59.2	63	41.7	88	0	0	6.7	0
November	42.9	26.3	34.6	75	11/18/53	-8	11/24/50	41.8	53	28.5	95	0	3.2	21	0.2
December	29.4	13.2	21.4	60	12/1/62	-22	12/23/83	31.3	65	10.9	89	0	16	29	3.9
Annual	54.2	33.8	44	102	7/6/88	-30	1/17/82	48.7	87	41.7	90	12	60	158	18
Winter	27.4	9.1	18.3	60	12/1/62	-30	1/17/82	26.6	87	14.6	79	0	51	86	17
Spring	53	31.8	42.4	97	5/30/88	-20	3/1/62	48.9	77	37.6	50	0.6	5.4	43	1
Summer	79.5	56.3	67.9	102	7/6/88	34	6/8/49	72.9	55	63.9	92	10	0	0	0
Fall	56.9	38	47.4	96	9/1/53	-8	11/24/50	54.1	63	44.6	93	0.6	3.2	28	0.2

Precipitation Data (Averages: 1961-1990 and Extremes: 1919-1996)

Time Period	Total Precipitation							Snow			# Days Precipitation		
	Mean	High	Year	Low	Year	1 - Day Max		Mean	High	Year	=>.01	=>.50	=>1
January	1.62	8.49	96	0	90	2.35	1/27/96	14.5	36	71	8.4	0.8	0.2
February	1.34	4.2	22	0	90	2.16	2/21/37	10.8	29	85	6.6	0.6	0.1
March	2.28	7.03	77	0.16	37	1.65	3/20/21	9.6	26.5	56	7.7	1.2	0.2
April	2.82	6.68	68	0.36	46	1.97	4/17/68	2.5	13	77	8.8	2	0.6
May	3.49	8.81	65	0.77	88	5.17	5/16/65	0.1	3.5	90	10.2	2.1	0.6
June	3.64	11.07	96	0.56	21	3.31	6/22/90	0	0	48	10.3	2.2	1
July	3.27	7.52	91	0.87	81	3.96	7/28/91	0	0	48	10	2.3	0.6
August	3.24	9.97	60	0.53	70	5.05	8/3/60	0	0	48	9.2	2.2	0.8
September	3.62	8.38	65	0.31	67	2.78	9/1/79	0	0	48	10.3	2.4	0.8
October	2.36	6.04	67	0.06	52	2.13	10/7/95	0.1	2.3	76	8.7	1.5	0.5
November	2.58	8.2	85	0.1	76	3.36	11/1/85	2.7	17	51	8.8	1.5	0.5
December	1.9	5.74	59	0	89	3.1	12/28/59	14.7	37.2	68	8.6	0.7	0.2
Annual	32.16	45.27	96	16.65	89	5.17	5/16/65	53.7	115.3	85	106.8	19.4	5.8
Winter	4.86	11.21	96	0	90	3.1	12/28/59	39.6	70.5	79	23.5	2.1	0.5
Spring	8.59	15.64	65	3.83	88	5.17	5/16/65	12.3	32.5	56	27.4	5.4	1.3
Summer	10.15	17.68	96	4.58	37	5.05	8/3/60	0	0	48	29.7	6.7	2.4
Fall	8.56	14.87	34	1.92	76	3.36	11/1/85	2.9	17	51	27.8	5.5	1.7

Notes:
1) Information from the Marinette Weather Station 475091.
2) Temperatures are in degrees Fahrenheit and precipitation is in inches.

Table 3-5. Temperature and Precipitation Data for the City of Sturgeon Bay, Wisconsin

Temperature Data (Averages: 1961-1990 and Extremes: 1905-1996)

Time Period	Averages			Daily Extremes				Mean Extremes				Day	Max	Day	Min
	Max	Min	Mean	High	Date	Low	Date	High	Year	Low	Year	=>90	<=32	<=32	<=0
January	24.8	8.7	16.8	55	1/26/44	-29	1/17/82	27	90	0	12	0	21	30	8.2
February	28.4	11.3	19.8	58	2/23/06	-29	2/10/12	28.8	54	4	36	0	18	27	6.7
March	38.2	21.8	30	76	3/28/46	-23	3/2/62	39.7	46	20.5	23	0	8.3	27	1.5
April	51.6	32.8	42.2	85	4/26/62	2	4/4/23	48.1	55	33.4	7	0	0.6	16	0
May	64.5	41.9	53.2	91	5/31/25	20	4/4/07	59.9	77	43.7	7	0	0	3.6	0
June	74.2	51.4	62.8	100	6/30/10	29	6/9/13	69	21	54.9	15	1	0	0.2	0
July	79.6	57.9	68.8	105	7/13/36	36	7/18/12	77.8	21	62.7	15	1.8	0	0	0
August	77.4	56.8	67.2	102	8/21/55	32	8/30/34	73.6	55	61.5	12	1.2	0	0	0
September	69.1	50	59.6	96	9/9/31	26	9/25/47	66.2	21	54.4	24	0.2	0	0.6	0
October	57.1	40.4	48.8	86	10/6/63	12	10/30/25	57.6	63	40.2	25	0	0	5.9	0
November	42.8	29.9	36.4	71	11/2/90	-6	11/24/50	42.1	31	28.7	95	0	3.9	20	0.1
December	30	16.7	23.4	58	12/9/46	-22	12/27/33	33.9	23	12.8	89	0	17	29	3
Annual	53.1	35	44.1	105	7/13/36	-29	2/10/12	50	5	39.6	17	4.4	69	159	19
Winter	27.7	12.2	20	58	2/23/06	-29	2/10/12	27.6	83	12.7	17	0	56	86	18
Spring	51.4	32.2	41.8	91	5/31/25	-23	3/2/62	46.9	77	36.3	23	0	8.9	46	1.5
Summer	77.1	55.4	66.3	105	7/13/36	29	6/9/13	71.7	21	59.8	15	4.1	0	0.2	0
Fall	56.3	40.1	48.3	96	9/9/31	-6	11/24/50	52.9	31	43.9	32	0.2	4	27	0.1

Precipitation Data (Averages: 1961-1990 and Extremes: 1905-1996)

Time Period	Total Precipitation							Snow			# Days Precipitation		
	Mean	High	Year	Low	Year	1 - Day Max		Mean	High	Year	=>.01	=>.50	=>1
January	1.53	3.78	6	0.2	57	1.32	1/16/80	12.5	41	29	8.8	0.5	0.1
February	1.13	4.1	22	0.02	69	1.57	2/21/37	7.8	39	8	7.3	0.6	0.1
March	2.09	7.18	6	0.19	10	2.17	3/2/06	7.5	29	9	8.1	1.2	0.3
April	2.65	6.18	9	0.5	46	1.97	4/29/09	2	13.5	9	9.6	1.7	0.5
May	3.12	10.54	18	0.15	88	3.85	5/28/73	0.1	9	11	10.4	1.9	0.6
June	3.31	8.26	90	0.61	88	3.07	6/19/13	0	0	5	10.1	2.2	0.8
July	3.36	8.9	5	0.72	36	3.96	7/6/93	0	0	5	10	2.2	0.8
August	3.42	8.68	85	0.29	25	4.57	8/25/10	0	0	5	9.3	2.1	0.7
September	3.88	10.38	65	0.68	76	3.71	9/1/79	0	0	5	10.7	2.2	0.8
October	2.66	6.1	95	0.11	52	2.61	10/19/84	0	6	17	9.4	1.6	0.4
November	2.45	6.72	6	0.22	76	1.98	11/22/34	2.4	19	16	9.2	1.4	0.4
December	1.89	5	59	0.08	43	3.6	12/28/59	11.7	32	9	8.6	0.8	0.1
Annual	31.49	47.36	85	16.99	25	4.57	8/25/10	44.1	129.8	9	111.4	18.4	5.7
Winter	4.55	9.01	22	1.48	57	3.6	12/28/59	31.5	77	8	24.6	1.9	0.3
Spring	7.86	14.5	73	3.79	35	3.85	5/28/73	9.6	45.5	9	28.1	4.8	1.4
Summer	10.09	16.34	85	4.39	30	4.57	8/25/10	0	0	5	29.5	6.4	2.3
Fall	8.99	16.69	12	2.03	76	3.71	9/1/79	2.5	19	16	29.3	5.3	1.7

Notes:
1) Information from the Sturgeon Bay Weather Station 478267.
2) Temperatures are in degrees Fahrenheit and precipitation is in inches.

Table 3-6. Temperature and Precipitation Data for the City of Fayette, Michigan

Temperature Data (Averages: 1961-1990 and Extremes: 1931-1996)

Time Period	Averages			Daily Extremes				Mean Extremes				Day	Max	Day	Min
	Max	Min	Mean	High	Date	Low	Date	High	Year	Low	Year	=>90	<=32	<=32	<=0
January	24.5	10.3	17.4	52	1/22/32	-24	1/23/63	29.1	32	7.8	94	0	23	31	6
February	26.9	11.2	19.1	49	2/19/81	-25	2/1/38	28.5	54	6.8	36	0	19	27	5.3
March	36.1	20.4	28.2	63	3/15/90	-18	3/11/48	36	46	20.9	60	0	9.6	28	1.3
April	48.1	31.3	39.7	78	4/21/73	5	4/7/72	44.6	55	32.7	50	0	0.8	17	0
May	60.5	41.2	50.9	89	5/23/72	20	5/6/54	55.9	82	44	47	0	0	3.2	0
June	69.1	50	59.6	90	6/26/64	29	6/8/49	66.1	95	54	58	0	0	0	0
July	75.6	57.4	66.5	96	7/12/36	39	7/1/60	71.7	83	61.2	92	0.1	0	0	0
August	73.8	57.1	65.4	93	8/19/83	36	8/22/50	71.2	55	59.1	50	0	0	0	0
September	65.8	50.8	58.3	85	9/1/37	26	9/25/47	62.9	31	53.9	74	0	0	0.4	0
October	55	41.2	48.1	77	10/6/63	18	10/27/36	56	47	43.7	36	0	0	4.3	0
November	41.9	30.4	36.2	67	11/16/53	0	11/28/76	42.3	31	29.1	59	0	4	18	0
December	29.6	17.5	23.6	57	12/2/82	-19	12/29/76	31.8	31	13.4	89	0	18	29	1.6
Annual	50.6	34.9	42.8	96	7/12/36	-25	2/1/38	46.5	87	40.2	50	0.2	74	158	14
Winter	27	13	20	57	12/2/82	-25	2/1/38	28	32	14.3	77	0	59	86	13
Spring	48.2	31	39.6	89	5/23/72	-18	3/11/48	43.6	87	34.8	50	0	10	49	1.3
Summer	72.8	54.8	63.8	96	7/12/36	29	6/8/49	68	55	59.3	50	0.2	0	0	0
Fall	54.2	40.8	47.5	85	9/1/37	0	11/28/76	52.6	31	43.5	76	0	4	23	0

Precipitation Data (Averages: 1961-1990 and Extremes: 1931-1996)

Time Period	Total Precipitation							Snow			# Days Precipitation		
	Mean	High	Year	Low	Year	1 - Day Max		Mean	High	Year	=>.01	=>.50	=>1
January	1.49	4.27	50	0.12	86	1.71	1/18/96	14.1	39	50	9.5	0.7	0.1
February	1.1	4.18	53	0.03	93	1.54	2/21/37	10.3	42	45	7.7	0.6	0.1
March	1.9	5.96	82	0.11	93	4.5	3/30/82	9.9	34	72	7.9	1.2	0.2
April	2.33	6.03	54	0.57	71	2.15	4/27/54	2.2	18	50	8.2	1.6	0.4
May	2.86	7.41	60	0.88	88	3.23	5/28/41	0	8.5	54	9.1	2	0.5
June	2.88	7.33	53	0.36	95	2.9	6/30/53	0	0	31	9.7	2	0.5
July	2.61	8.9	52	0.51	39	2.99	7/6/93	0	0	31	9.3	1.9	0.6
August	3.53	6.61	62	0.18	91	2.75	8/16/74	0	0	31	9.2	2.2	0.8
September	3.43	8.1	31	0.8	52	3.45	9/2/37	0	0.5	42	9.8	2.4	0.7
October	2.53	5.27	82	0.18	56	2.8	10/20/82	0.2	3.5	33	8.5	1.5	0.4
November	2.19	6.82	48	0.47	76	2.24	11/2/85	3.5	24.5	51	9.2	1.7	0.4
December	1.96	4.3	68	0.11	94	1.2	12/14/75	13.8	38	68	9.2	0.9	0.1
Annual	28.81	39.96	38	20.42	76	4.5	3/30/82	53	125.8	50	107.7	18.8	4.9
Winter	4.55	9.45	71	1.58	61	1.71	1/18/96	37.9	89	45	26.5	2.3	0.3
Spring	7.09	12.07	54	3.91	80	4.5	3/30/82	12	40.5	43	25.2	4.7	1.2
Summer	9.02	15.76	52	3.33	55	2.99	7/6/93	0	0	31	28.2	6.2	1.9
Fall	8.15	14.44	31	3.3	76	3.45	9/2/37	3.8	26.5	51	27.8	5.6	1.5

Notes:

1) Information from the Fayette Weather Station 202737.

2) Temperatures are in degrees Fahrenheit and precipitation is in inches.

Table 3-7. Water Use in the Lower Fox River/Green Bay Watersheds (1995)

Watershed Name	USGS Hydrologic Unit Code	State	Population			Withdrawals [A]				Domestic Water Use [A]		
			Total [B]	Served by GW Public Supply	Served by SW Public Supply	GW	SW	Total	Per Capita Use	Self-supplied Population	Total Withdrawals	Per Capita Use
Lower Fox	4030204	WI	306,360	75,640	206,430	17.77	28.7	46.47	164.75	24,290	1.45	59.7
Duck-Pensaukee	4030103	WI	66,890	16,770	0	1.44	0	1.44	85.87	50,120	3.01	60.06
Oconto	4030104	WI	25,650	7,280	0	1.35	0	1.35	185.44	18,370	1.1	59.88
Peshtigo	4030105	WI	30,770	7,690	0	0.98	0	0.98	127.44	23,080	1.38	59.79
Menominee	4030108	WI/MI	57,320	21,490	13,740	4.01	2.73	6.74	393.17	22,090	1.48	130.28
Door-Kewaunee	4030102	WI	47,410	17,820	0	3.13	0	3.13	175.65	29,590	1.78	60.16
Cedar-Ford	4030109	MI	18,250	1,410	9,160	0.44	1.13	1.57	148.53	7,680	0.53	69.01
Escanaba	4030110	MI	7,570	3,960	0	1.04	0	1.04	262.63	3,610	0.26	72.02
Fishdam-Sturgeon	4030112	MI	2,170	670	0	0.08	0	0.08	119.4	1,500	0.11	73.33
Totals			**562,390**	**152,730**	**229,330**	**30.24**	**32.56**	**62.80**	**184.76**	**180,330**	**11.10**	**71.58**

Notes:

A) All water units expressed as a million gallons per day (MGD).

B) The population figures cited herein are 1995 estimates for select watersheds only. The overall population of the Lower Fox River and Green Bay system is 595,300.

C) 723.23 MGD of water used for Thermoelectric Power Generation in the Door-Kewaunee watershed is not included because this facility draws water from Lake Michigan.

Total per capita use values are the average value for the column.

GW - Indicates groundwater is source.

SW - Indicates surface water is source.

Table 3-7. Water Use in the Lower Fox River/Green Bay Watersheds (1995) (Continued)

Watershed Name	USGS Hydrologic Unit Code	State	Commercial Water Use [A]				Industrial Water Use [A]			Thermoelectric Power Generation [A]			
			GW	SW	Total	Consumptive Use	GW	SW	Total	GW	SW	Total	Gigawatt Hours
Lower Fox	4030204	WI	0.43	0	0.43	1.78	2.4	101.32	103.72	2	396.6	398.6	1680.14
Duck-Pensaukee	4030103	WI	0	0	0	0.08	0	0	0	0	0	0	0
Oconto	4030104	WI	0	0	0	0.04	0.21	1.18	1.39	0	0	0	0
Peshtigo	4030105	WI	0	0	0	0.04	2.37	7.24	9.61	0	0	0	0
Menominee	4030108	WI/MI	0.14	0.14	0.28	0.17	2.62	9.36	11.98	0	0	0	0
Door-Kewaunee	4030102	WI	1.49	0	1.49	0.39	0.17	0	0.17	C	C	C	C
Cedar-Ford	4030109	MI	0.09	0.09	0.18	0.03	0.1	7.77	7.87	0	0	0	0
Escanaba	4030110	MI	0.06	0.06	0.12	0.07	0.07	5.99	6.06	0	0	0	0
Fishdam-Sturgeon	4030112	MI	0.17	0.17	0.34	0.04	0.03	3.3	3.33	0	0	0	0
Totals			**2.38**	**0.46**	**2.84**	**2.64**	**7.97**	**136.16**	**144.13**	**2**	**396.6**	**398.6**	**1,680.14**

Notes:

A) All water units expressed as a million gallons per day (MGD).

B) The population figures cited herein are 1995 estimates for select watersheds only.
The overall population of the Lower Fox River and Green Bay system is 595,300.

C) 723.23 MGD of water used for Thermoelectric Power Generation in the Door-Kewaunee watershed is not included because this facility draws water from Lake Michigan.

Total per capita use values are the average value for the column.

GW - Indicates groundwater is source.

SW - Indicates surface water is source.

Table 3-7. Water Use in the Lower Fox River/Green Bay Watersheds (1995) (Continued)

Watershed Name	USGS Hydrologic Unit Code	State	Mining Water Use [A]			Livestock Water Use [A]				Irrigation Water Use [A]			
			GW	SW	Total	GW	SW	Total	Consumptive Use	GW	SW	Total	Consumptive Use
Lower Fox	4030204	WI	0	0	0	1.01	0.11	1.12	0.9	0.04	0	0.04	0.24
Duck-Pensaukee	4030103	WI	0	0	0	0	0	0	0	0	0	0	0
Oconto	4030104	WI	0	0	0	0.58	0.07	0.65	0.52	1.31	0	1.31	0.82
Peshtigo	4030105	WI	0	0	0	0.72	2.19	2.91	0.51	1.03	0	1.03	0.91
Menominee	4030108	WI/MI	0.01	0.11	0.12	0.33	0.03	0.36	0.29	0.91	0.04	0.95	1.32
Door-Kewaunee	4030102	WI	0	0	0	1.06	0.12	1.18	0.94	0.22	0	0.22	1.32
Cedar-Ford	4030109	MI	0.12	0.54	0.66	0.12	0.01	0.13	0.12	0.02	0.02	0.04	0.23
Escanaba	4030110	MI	1.27	5.01	6.28	0.02	0	0.02	0.02	0.01	0.01	0.02	0.12
Fishdam-Sturgeon	4030112	MI	0	0.08	0.08	0.03	0	0.03	0.03	0.02	0.02	0.04	0.19
Totals			**1.40**	**5.74**	**7.14**	**3.87**	**2.53**	**6.40**	**3.33**	**3.56**	**0.09**	**3.65**	**5.15**

Notes:
A) All water units expressed as a million gallons per day (MGD).
B) The population figures cited herein are 1995 estimates for select watersheds only. The overall population of the Lower Fox River and Green Bay system is 595,300.
C) 723.23 MGD of water used for Thermoelectric Power Generation in the Door-Kewaunee watershed is not included because this facility draws water from Lake Michigan.
Total per capita use values are the average value for the column.
GW - Indicates groundwater is source.
SW - Indicates surface water is source.

Table 3-7. Water Use in the Lower Fox River/Green Bay Watersheds (1995) (Continued)

Watershed Name	USGS Hydrologic Unit Code	State	Hydroelectric Power Generation [A]			Total Water Use [A]			
			SW	Gigawatt Hours	# Of Facilities	GW	SW	Total	Consumptive Use
Lower Fox	4030204	WI	571.48	63.4	4	23.65	526.73	550.38	28.39
Duck-Pensaukee	4030103	WI	0	0	0	1.44	0	1.44	0.86
Oconto	4030104	WI	321.57	7.2	1	3.45	1.25	4.7	2.42
Peshtigo	4030105	WI	2261.92	67.7	7	5.1	9.43	14.53	2.34
Menominee	4030108	WI/MI	8120.08	403.94	14	8.02	12.41	20.43	4.66
Door-Kewaunee	4030102	WI	0	0	0	6.07	0.12	6.19	9.49
Cedar-Ford	4030109	MI	0	0	0	0.89	9.56	10.45	0.86
Escanaba	4030110	MI	192.22	3.07	1	2.47	11.07	13.54	1.07
Fishdam-Sturgeon	4030112	MI	0	0	0	0.33	3.57	3.9	0.41
Totals			**11,467.27**	**545.31**	**27.00**	**51.42**	**574.14**	**625.56**	**50.50**

Notes:
A) All water units expressed as a million gallons per day (MGD).
B) The population figures cited herein are 1995 estimates for select watersheds only.
The overall population of the Lower Fox River and Green Bay system is 595,300.
C) 723.23 MGD of water used for Thermoelectric Power Generation in the Door-Kewaunee
watershed is not included because this facility draws water from Lake Michigan.
Total per capita use values are the average value for the column.
GW - Indicates groundwater is source.
SW - Indicates surface water is source.

Table 3-8. Lower Fox River Gradient and Lock/Dam Information

Lock	Lock Water Elevation		Dam	Dam Water Elevation		Distance Upstream		Gradient**
	(meters*)	(feet*)		(meters*)	(feet*)	Km	Miles	
Lake Winnebago	227.32	745.80		227.32	745.80	62.8	39.0	---
Menasha	227.32	745.80	Menasha Dam	227.32	745.80	59.5	37.0	0.0E+00
Appleton Lock 1	224.36	736.10	Appleton Upper Dam	224.36	736.10	51.3	31.9	3.6E-04
Appleton Lock 2	221.92	728.10				50.9	31.6	
Appleton Lock 3	218.48	716.80				50.4	31.3	
Appleton Lock 4	215.49	707.00	Appleton Lower Dam	215.49	707.00	49.4	30.7	4.6E-03
Cedars Lock	213.18	699.40	Cedars Dam	213.18	699.40	43.9	27.3	4.2E-04
Little Chute Guard Lock	210.19	689.60	Little Chute Dam	210.19	689.60	42.8	26.6	2.7E-03
Little Chute Lock 2	210.19	689.60				42.5	26.4	
Upper Combined Lock	206.04	676.00				40.9	25.4	
Lower Combined Lock	202.81	665.40				40.9	25.4	
Kaukauna Guard Lock	199.19	653.50	Kaukauna Dam	199.19	653.50	38.6	24.0	2.6E-03
Kaukauna Lock 1	199.19	653.50				38.0	23.6	
Kaukauna Lock 2	196.05	643.20				37.7	23.4	
Kaukauna Lock 3	193.12	633.60				37.3	23.2	
Kaukauna Lock 4	190.01	623.40				37.2	23.1	
Kaukauna Lock 5	186.90	613.20				36.7	22.8	
Rapide Croche Lock	183.73	602.80	Rapide Croche	183.73	602.80	30.9	19.2	2.0E-03
Little Rapids Lock	180.90	593.50	Little Rapids Dam	180.90	593.50	21.1	13.1	2.9E-04
De Pere Lock	179.04	587.40	De Pere Dam	179.04	587.40	11.4	7.1	1.9E-04
Green Bay (River Mouth)	176.02	577.50	Green Bay (River Mouth)	176.02	577.50	0.0	0.0	2.6E-04
Entire River	---	---	---	---	---	---	---	**8.2E-04**

Notes: Information obtained from the USACE and from the NOAA Recreational Atlas 14916 (1992).

* IGLD - International Great Lakes Datum, 1985

** Gradient values from upstream dam to this dam

Table 3-9. Lower Fox River Discharge Results Rapide Croche Gauging Station

Summary of Flow Conditions for Water Years 1918 to 1997	Discharge (m^3/s)	Discharge (cfs)	Date	
Daily Average	122	4,314	--	
Highest Daily Mean	680	24,000	04/18/52	
Lowest Daily Mean	4	138	08/02/36	
Monthly Mean Max.	206	7,286	April	
Monthly Mean Min.	74	2,609	August	
Monthly Discharge Results				
Month	**Average**		**Minimum**	**Maximum**
	(m^3/s)	**(cfs)**	**(m^3/s)**	**(m^3/s)**
January	116	4,082	31	269
February	117	4,126	30	340
March	146	5,156	25	603
April	206	7,286	22	680
May	171	6,048	23	669
June	137	4,821	17	603
July	96	3,372	18	530
August	74	2,609	4	419
September	81	2,872	8	510
October	94	3,315	6	516
November	116	4,084	15	445
December	115	4,043	32	363

Note: A Water Year runs from October 1 through September 30.

Table 3-10. Lower Fox River Stream Velocity Estimates

Model Segments	Deposits Within Lower # Segment	Cross Sectional Area (m^2)	Flow Velocities (m/s)				
			Average Flow ($122m^3/s$)	10 Year Peak ($544m^3/s$)	10 Year Low ($27m^3/s$)	100 Year Peak ($680m^3/s$)	100 Year Low ($4m^3/s$)
Little Lake Butte des Morts Reach							
2/3	A	634.8	0.19	0.86	0.04	1.07	0.006
3/4	B	802.7	0.15	0.68	0.03	0.85	0.005
4/6	C,POG	1,371.5	0.09	0.40	0.02	0.50	0.003
6/7	D,E	1,549.4	0.08	0.35	0.02	0.44	0.003
7/8	D,E	1,495.5	0.08	0.36	0.02	0.45	0.003
8/9	E,F	1,225.6	0.10	0.44	0.02	0.55	0.003
9/10	E	616.8	0.20	0.88	0.04	1.10	0.006
10/11	G,H	348.9	0.35	1.56	0.08	1.95	0.011
Reach Average			**0.15**	**0.69**	**0.03**	**0.86**	**0.005**
Appleton to Little Rapids Reach							
11/12	I,J,K	405.9	0.30	1.34	0.07	1.67	0.010
12/14	L Through R	578.8	0.21	0.94	0.05	1.17	0.007
14/15	S	537.8	0.23	1.01	0.05	1.26	0.007
15/16	T,U	577.8	0.21	0.94	0.05	1.18	0.007
16/17	V,W,X	831.7	0.15	0.65	0.03	0.82	0.005
17/18	W,X,Y,Z	730.7	0.17	0.74	0.04	0.93	0.005
18/19	AA,BB,CC	456.8	0.27	1.19	0.06	1.49	0.009
19/20	--	324.9	0.37	1.67	0.08	2.09	0.012
20/21	--	424.8	0.29	1.28	0.06	1.60	0.009
21/22	DD	652.8	0.19	0.83	0.04	1.04	0.006
Reach Average			**0.24**	**1.06**	**0.05**	**1.33**	**0.008**
Little Rapids to De Pere Reach							
22/23	EE	947.7	0.13	0.57	0.03	0.72	0.004
23/24	EE	1,081.6	0.11	0.50	0.02	0.63	0.004
24/25	EE	1,016.6	0.12	0.53	0.03	0.67	0.004
25/26	EE	985.6	0.12	0.55	0.03	0.69	0.004
26/27	EE through HH	988.6	0.12	0.55	0.03	0.69	0.004
Reach Average			**0.12**	**0.54**	**0.03**	**0.68**	**0.004**
De Pere to Green Bay Reach							
28/29	SMU 20-25	1,727.4	0.07	0.31	0.02	0.39	0.002
29/30	SMU 25-31	1,122.6	0.11	0.48	0.02	0.61	0.004
30/31	SMU 32-37	1,277.5	0.10	0.43	0.02	0.53	0.003
31/32	SMU 38-43	1,574.4	0.08	0.35	0.02	0.43	0.003
32/33	SMU 44-49	1,858.3	0.07	0.29	0.01	0.37	0.002
33/34	SMU 50-55	1,458.5	0.08	0.37	0.02	0.47	0.003
34/35	SMU 56-61	1,906.3	0.06	0.29	0.01	0.36	0.002
35/36	SMU 62-67	1,863.3	0.07	0.29	0.01	0.36	0.002
36/37	SMU 68-73	1,909.3	0.06	0.28	0.01	0.36	0.002
37/38	SMU 73-79	1,801.3	0.07	0.30	0.01	0.38	0.002
38/39	SMU 80-85	1,383.5	0.09	0.39	0.02	0.49	0.003
39/40	SMU 86-91	1,522.4	0.08	0.36	0.02	0.45	0.003
Reach Average			**0.08**	**0.35**	**0.02**	**0.43**	**0.003**
Entire River Averages			**0.14**	**0.61**	**0.03**	**0.77**	**0.004**

Note: 1) The average, peak, and low flow velocities listed are from USGS records for the Rapide Croche gauging station, #04084500.
2) Cross Sectional areas obtained from Velleux & Endicott, 1994 and WDNR, 1995.

Table 3-11. Fox River Mouth Gauging Station Results (1989-1999)

Summary of Flow Conditions	Discharge		Date
	m^3/s	cfs	
Water Year 1999			
Daily Average	106	3,753	---
Maximum Daily	326	11,500	July 23/24, 1999
Minimum Daily	-35	-1230	Aug. 25, 1999
Maximum Monthly Mean	175	6,176	July (1999)
Minimum Monthly Mean	36.6	1,294	October (1998)
Annual Runoff	20.45 cm	8.05 in.	---
Water Years 1989 through 1999			
Daily Average	141	4,999	---
Maximum Daily	957	33,800	Jun. 23, 1990
Minimum Daily	-92	-3,260	Nov. 4,1990
Maximum Monthly Mean	215	7,580	April
Minimum Monthly Mean	92.2	3,256	September
Annual Runoff	27.25 cm	10.73 in.	---
10% of Flow Exceeds	272	9610	---
50% of Flow Exceeds	114	4040	---
90% of Flow Exceeds	54	1920	---

Note: Data from USGS, 2000. Fox River at Oil Tank Depot, Green Bay, Wisconsin.
http://h20.usgs.gov/swr/WI/?statnum=040851385.

Table 3-12. Lower Fox River Total Suspended Solid (TSS) Loads

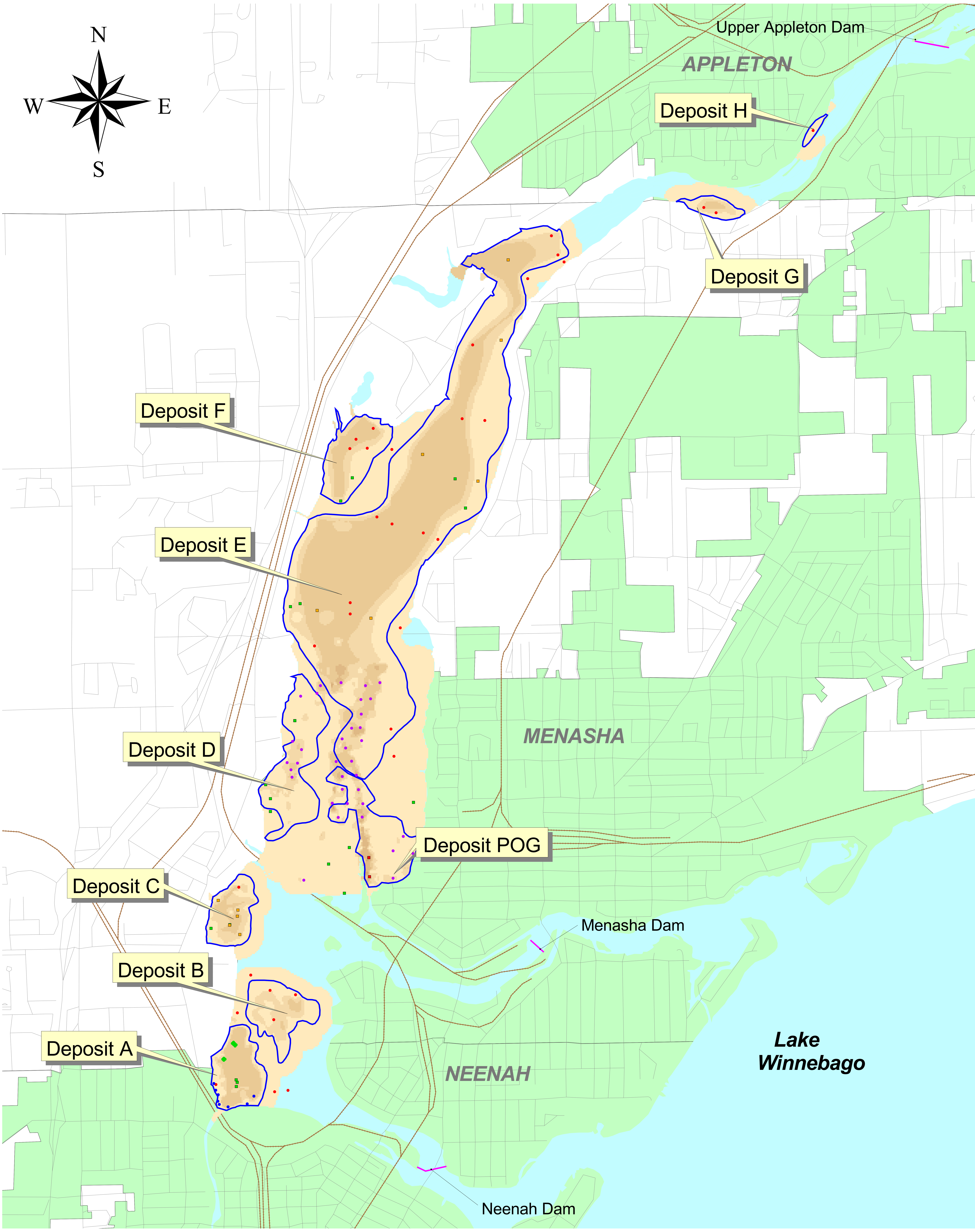
Sampling Point	River Discharge		Total Suspended Solids (TSS)		
	(m^3/s)	(cfs)	(mg/L)	(MT/year)	(Ton/year)
1995 - Mean Values from WDNR, 1995					
Menasha Gauge*	140	4,938	7.7	33,968	37,365
Neenah Gauge*	80	2,809	17	42,661	46,927
Appleton Gauge	93	3,279	23	67,375	74,113
Kaukauna Gauge*	85	3,009	26	69,892	76,881
Little Rapids Gauge**	87	3,058	52	142,060	156,266
De Pere Gauge	85	3,003	30	80,484	88,532
1998 - TSS Values from BBL, 1998 and Discharge Data from USGS, 2000					
De Pere Dam***	106	3,753	46.4	155,571	171,128
River Mouth	106	3,753	45.8	153,559	168,915

Notes: * the stream flow result for this station is actually the flow at the Appleton station.
** the stream flow result for this station is actually the flow at the De Pere station.
*** the stream flow result for this station is actually the average 1998 flow at the mouth.
MT = metric tons.

Table 3-13. USACE Navigation Channel Dredging Records (1957-1999)

Green Bay Dredging Totals and Disposal Locations								
Year	Open Water		Bay Port CDF		Kidney Island CDF		Total	
	m^3	(yd^3)	m^3	(yd^3)	m^3	(yd^3)	m^3	(yd^3)
1957	38,075	49,800	-	-	-	-	38,075	49,800
1958	120,987	158,245	-	-	-	-	120,987	158,245
1959	45,408	59,391	-	-	-	-	45,408	59,391
1960	27,401	35,839	-	-	-	-	27,401	35,839
1961	127,759	167,103	-	-	-	-	127,759	167,103
1962	13,903	18,185	-	-	-	-	13,903	18,185
1963	90,289	118,093	-	-	-	-	90,289	118,093
1964	137,767	180,192	-	-	-	-	137,767	180,192
1965	503,052	657,967	-	-	-	-	503,052	657,967
1966	-	-	115,456	151,011	-	-	115,456	151,011
1967	-	-	335,159	438,371	-	-	335,159	438,371
1968	-	-	57,800	75,600	-	-	57,800	75,600
1969	507,836	664,225	-	-	-	-	507,836	664,225
1970	1,083,137	1,416,690	-	-	-	-	1,083,137	1,416,690
1971	-	-	718,682	940,000	-	-	718,682	940,000
1972	-	-	917,466	1,200,000	-	-	917,466	1,200,000
1973	76,455	100,000	1,131,541	1,480,000	-	-	1,207,997	1,580,000
1974	43,580	57,000	1,021,417	1,335,963	-	-	1,064,997	1,392,963
1975	-	-	691,794	904,832	-	-	691,794	904,832
1976	-	-	-	-	-	-	-	-
1977	-	-	229,366	300,000	-	-	229,366	300,000
1978	-	-	260,288	340,444	-	-	260,288	340,444
1979	-	-	620,213	811,208	19,687	25,750	639,900	836,958
1980	-	-	-	-	-	-	-	-
1981	-	-	-	-	453,964	593,762	453,964	593,762
1982	-	-	-	-	296,214	387,433	296,214	387,433
1983	-	-	-	-	209,187	273,606	209,187	273,606
1984	-	-	-	-	141,150	184,617	141,150	184,617
1985	-	-	91,856	120,143	78,094	102,143	169,950	222,286
1986	-	-	-	-	51,026	66,740	51,026	66,740
1987	-	-	87,256	114,127	120,020	156,980	207,276	271,107
1988	-	-	127,672	166,989	-	-	127,672	166,989
1989	-	-	37,785	49,421	-	-	37,785	49,421
1990	-	-	35,485	46,413	123,208	161,150	158,693	207,563
1991	-	-	-	-	128,600	168,202	128,600	168,202
1992	-	-	111,615	145,987	125,448	164,080	237,063	310,067
1993	-	-	97,712	127,802	145,313	190,062	243,024	317,864
1994	-	-	111,292	145,564	-	-	111,292	145,564
1995	-	-	-	-	141,211	184,697	141,211	184,697
1996	-	-	53,914	70,517	53,914	70,517	107,828	141,034
1997	-	-	128,149	167,612	-	-	128,149	167,612
1998	-	-	178,647	233,661	-	-	178,647	233,661
1999	-	-	78,202	102,284	-	-	78,202	102,284
Totals	**2,815,649**	**3,682,730**	**7,238,767**	**9,467,949**	**2,087,035**	**2,729,739**	**12,141,451**	**15,880,418**

Lower Fox River Records	1965	8,463 m3 (11,069 yd^3)	Menasha Channel
	1968	1,437 m3 (1,880 yd^3)	Neenah Harbor
	Totals	**9,900 m3 (12,949 yd^3)**	



Sample Points
- 1989/90 Mass Balance Sediment Data
- 1992/93 LLBdM RI/FS Deposit A Sediment Data
- 1994 Woodward Clyde Deposit A Sediment Data
- 1994 SAIC and GAS Sediment Data
- 1995 WDNR Sediment Data
- 1996 BBL Sediment Data
- 1997 Segment 56/57 Demonstration
- 1998 BBL Sediment/Tissue Data
- 1998 Deposit N Post-Dredge Sediment Data
- 1998 RI/FS Supplemental Data

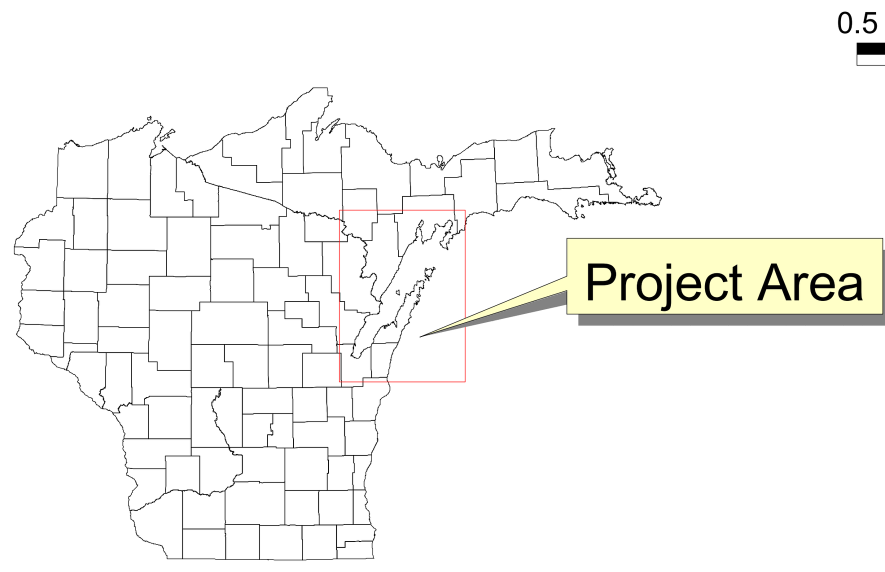
Soft Sediment Thickness (m)
- 0-0.5
- 0.5-1
- 1-1.5
- 1.5-2
- 2-2.5

Deposits
Dam Locations
Railroads
Roads
Water

Civil Divisions
- City
- Township
- Village

0.5 0 0.5 1 Kilometers

0.5 0 0.5 1 Miles



Notes:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, Version 3.2, WTM projection.
2. Blue areas within the river or bay implies areas with no soft sediment.

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Remedial Investigation Report

Sample Locations and Interpolated Thickness of Sediment with PCBs: Little Lake Butte des Morts Reach

PLATE 3-1

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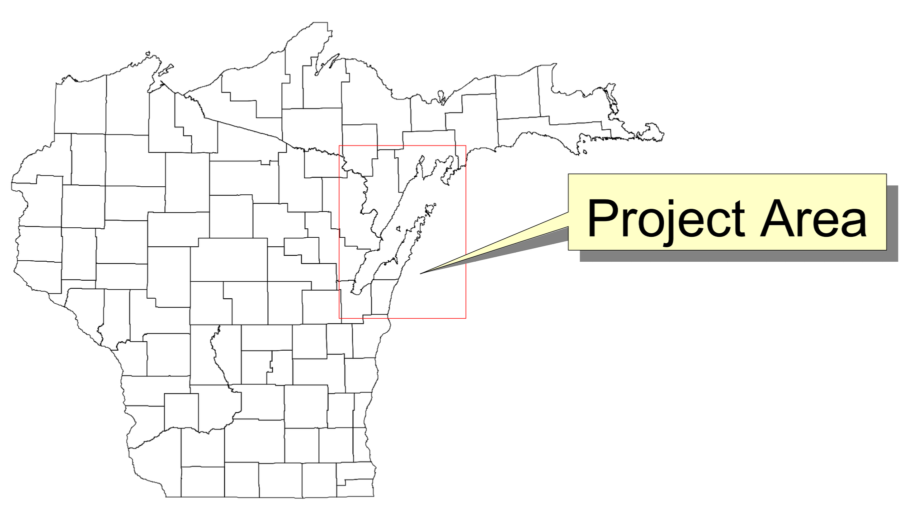
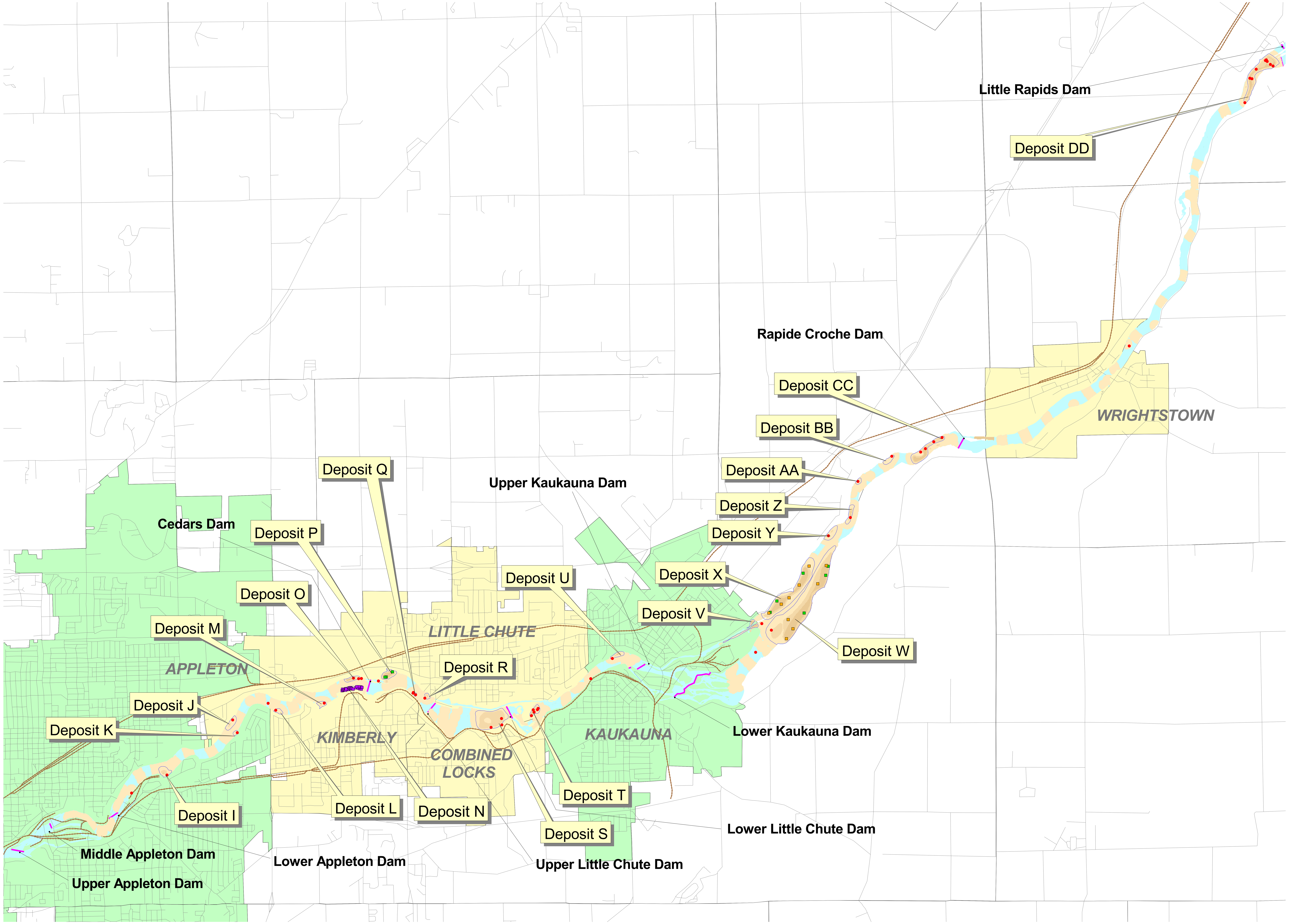
PRINT DATE: 6/18/01
CREATED BY: SCJ
APPROVED: AGF





Sample Points
- 1989/90 Mass Balance Sediment Data
- 1992/93 LLBdM RI/FS Deposit A Sediment Data
- 1994 Woodward Clyde Deposit A Sediment Data
- 1994 SAIC and GAS Sediment Data
- 1995 WDNR Sediment Data
- 1996 BBL Sediment Data
- 1997 Segment 56/57 Demonstration
- 1998 BBL Sediment/Tissue Data
- 1998 Deposit N Post-Dredge Sediment Data
- 1998 RI/FS Supplemental Data

Soft Sediment Thickness (m)
- 0-0.5
- 0.5-1
- 1-1.5
- 1.5-2
- 2-2.5

- Deposits
- Dam Locations
- Railroads
- Roads
- Water

Civil Divisions
- City
- Township
- Village

2 0 2 Kilometers

1 0 1 2 Miles

Notes:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, Version 3.2, WTM projection.
2. Blue areas within the river or bay implies areas with no soft sediment.

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Remedial Investigation Report

Sample Locations and Interpolated Thickness of Sediment with PCBs: Appleton to Little Rapids Reach

PLATE 3-2

DRAWING NO: RI-14414-340-3-2
PRINT DATE: 6/18/01
CREATED BY: SCJ
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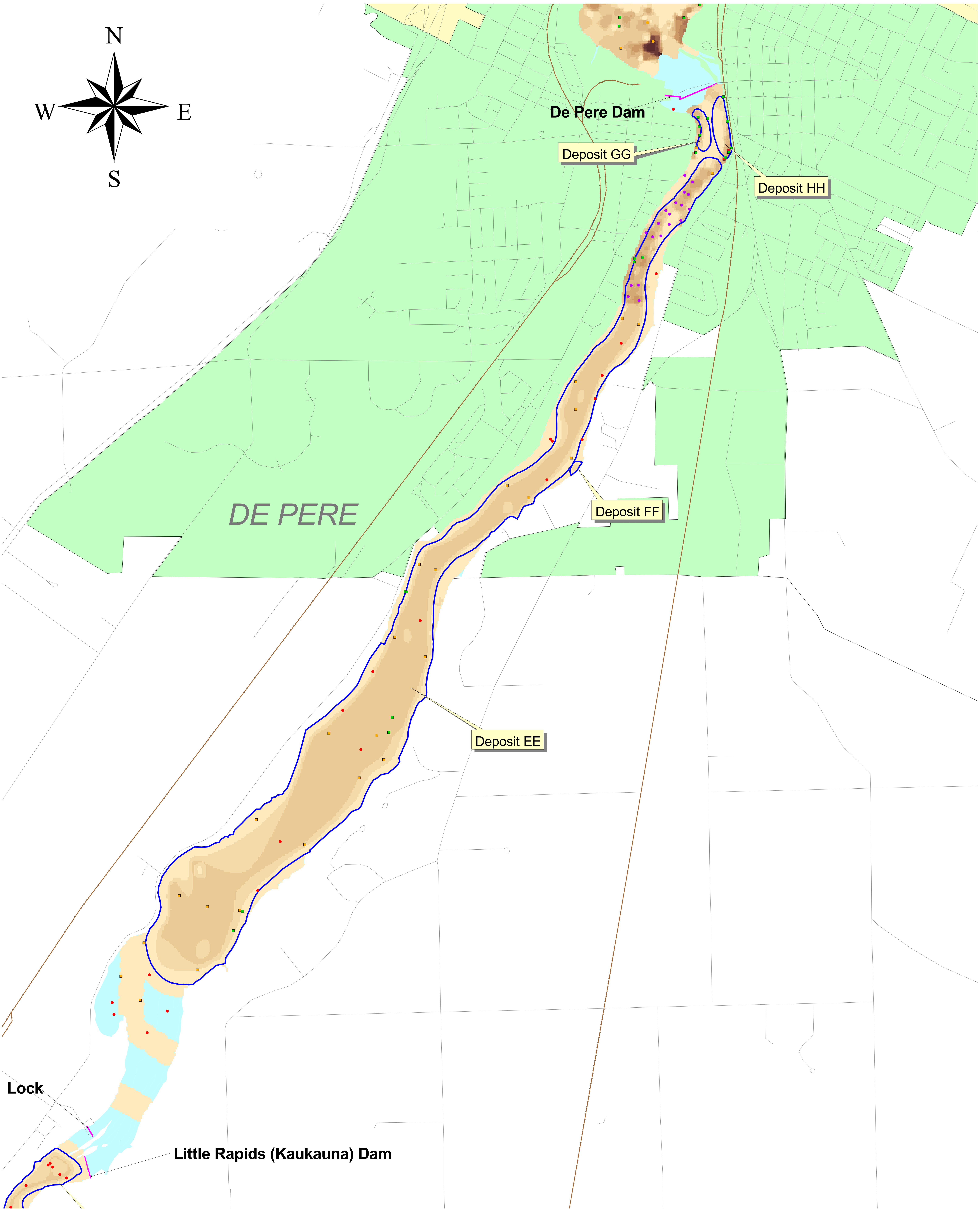
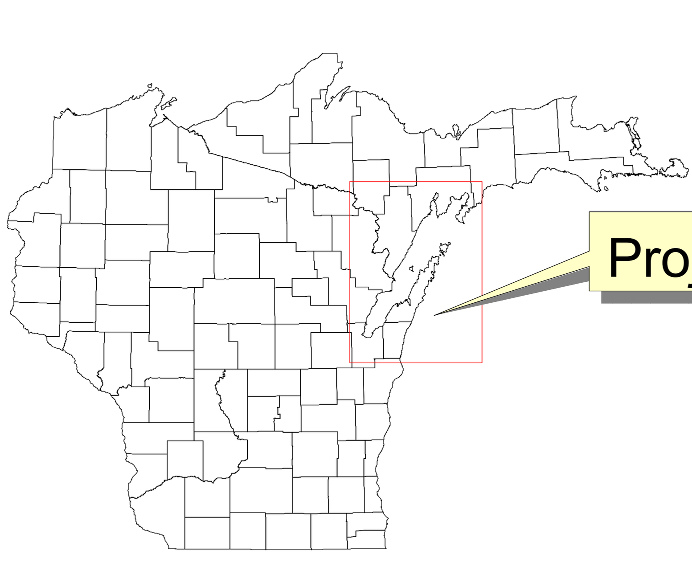


Sample Points
- 1989/90 Mass Balance Sediment Data
- 1992/93 LLBdM RI/FS Deposit A Sediment Data
- 1994 Woodward Clyde Deposit A Sediment Data
- 1994 SAIC and GAS Sediment Data
- 1995 WDNR Sediment Data
- 1996 BBL Sediment Data
- 1997 Segment 56/57 Demonstration
- 1998 BBL Sediment/Tissue Data
- 1998 Deposit N Post-Dredge Sediment Data
- 1998 RI/FS Supplemental Data

Soft Sediment Thickness (m)
- 0-0.5
- 0.5-1
- 1-1.5
- 1.5-2
- 2-2.5
- 2.5-3
- 3-3.5
- 3.5-4
- 4-4.5
- 4.5-5
- 5-5.5
- 5.5-6

- Deposits
- Dam Locations
- Railroads
- Roads
- Water

Civil Divisions
- City
- Township
- Village



0.5 0 0.5 1 Kilometers

0.5 0 0.5 1 Miles

Notes:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, Version 3.2, WTM projection.
2. Blue areas within the river or bay implies areas with no soft sediment.

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Lower Fox River & Green Bay Remedial Investigation Report

Sample Locations and Interpolated Thickness of Sediment with PCBs: Little Rapids to De Pere Reach

PLATE 3-3

DRAWING NO: RI-14414-340-3-3
PRINT DATE: 6/18/01
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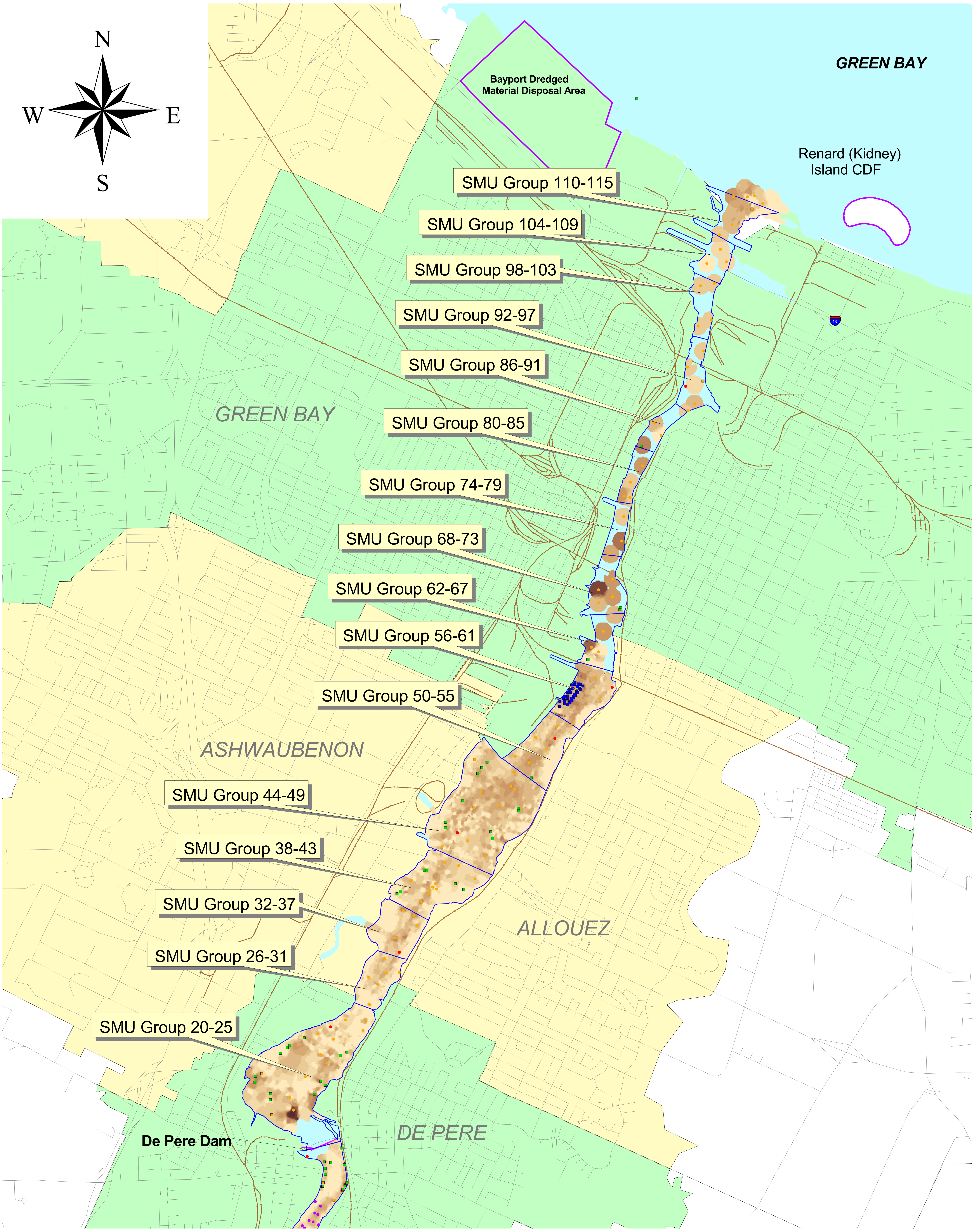
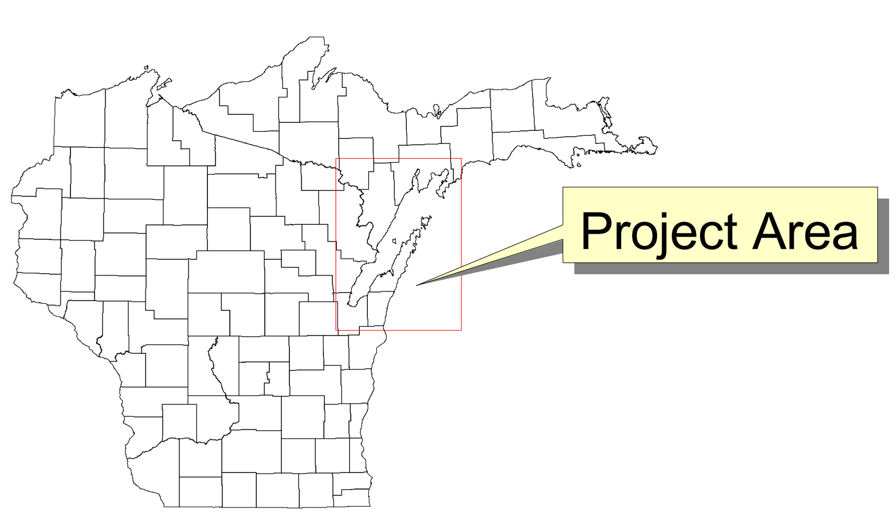


Sample Points
- 1989/90 Mass Balance Sediment Data
- 1992/93 LLBdM RI/FS Deposit A Sediment Data
- 1994 Woodward Clyde Deposit A Sediment Data
- 1994 SAIC and GAS Sediment Data
- 1995 WDNR Sediment Data
- 1996 BBL Sediment Data
- 1997 Segment 56/57 Demonstration
- 1998 BBL Sediment/Tissue Data
- 1998 Deposit N Post-Dredge Sediment Data
- 1998 RI/FS Supplemental Data

Soft Sediment Thickness (m)
- 0-0.5
- 0.5-1
- 1-1.5
- 1.5-2
- 2-2.5
- 2.5-3
- 3-3.5
- 3.5-4
- 4-4.5
- 4.5-5
- 5-5.5
- 5.5-6

- Sediment Management Units
- Dam Locations
- Railroads
- Roads
- Water

Civil Divisions
- City
- Township
- Village



1 0 1 Kilometers

0.5 0 0.5 1 Miles

Notes:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, Version 3.2, WTM projection.
2. Blue areas within the river or bay implies areas with no soft sediment.

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Lower Fox River & Green Bay Remedial Investigation Report

Sample Locations and Interpolated Thickness of Sediment with PCBs: De Pere to Green Bay Reach

PLATE 3-4

DRAWING NO: RI-14414-340-3-4
PRINT DATE: 6/18/01
CREATED BY: SCJ
APPROVED: AGF

Notes:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, Version 3.2, WTM projection.
2. Blue areas within the river or bay implies areas with no soft sediment.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Sample Locations and Interpolated Thickness of Sediment with PCBs: Green Bay	DRAWING NO: RI-14414-340-3-5
			PLATE 3-5	PRINT DATE: 6/18/01
				CREATED BY: SCJ
				APPROVED: AGF

4 Ecological Characteristics

4.1 Overview

This chapter provides a description of the historical and current ecological characteristics of the Lower Fox River valley and Green Bay, with an emphasis on habitat and specific animals that are present in the area, as well as how they have been affected by both area development and environmental degradation. This information is used in the RA and the assessment of risks posed by historical discharge of PCBs and other pollutants into this system.

In September 1998, Exponent completed the *Habitat Characterization for the Lower Fox River and Green Bay Assessment Area* (Exponent, 1998) on behalf of the FRG. The assessment area began at the outlet of Lake Winnebago and extended to just north of the Oconto Marsh, on the west side of the bay, and Little Sturgeon Bay, on the east side (Exponent, 1998). Much of the information referenced in this section for the Lower Fox River was obtained from this document.

In addition to the Exponent (1998) report, a number of other data sources were utilized for this section. These sources largely consisted of electronic data files compiled by the ESRI ArcView™ (version 3.2) geographic information system (GIS), which was used to develop the maps for this section. Other sources included the USFWS fish and bird injury reports (Stratus, 1999b and 1999c), discussions with USFWS personnel, USGS reports, and specific texts concerning select species.

These data, and the resulting maps, have been used to develop an understanding of the Lower Fox River and Green Bay system. The data sources are listed below and included on the appropriate figures, which will also be used in the RA.

Lower Fox River GIS Data Sources

Habitat Data	Description	Source
Physical and habitat features (bridge, riffles)	in-water polygon shapes	OSI/Exponent, 1999
Shoreline (bulkhead, riprap)	linear colors only along the shoreline	OSI/Exponent, 1999
Wetlands	Green areas along shore and upland	WDNR, 1999d. USFWS, 1993
Bald eagle nesting sites	yellow triangles, discrete points	Stratus, 1999c. Stubenvoll, 1998.
Threatened or endangered resources	TRS1/4S polygons	Natural Heritage Inventory (NHI), 2000
Basemap generated from TIGER census data and ESRI data and maps in ARCVIEW GIS version 3.2, WTM projection.		

Green Bay GIS Data Sources

Habitat Data	Description	Source
Physical and habitat features (bridge, riffles)	in-water polygon shapes	OSI/Exponent, 1999
Wetlands	Green areas along shore and upland	WDNR, 1999d. Minc and Albert, 1998. USFWS, 1981 and 1993.
Bald eagle nesting sites	yellow triangles, discrete points	Stratus, 1999c. Stubenvoll, 1998.
Threatened or endangered resources	Colored Squares by nearest Township, Range, and Section	NHI, 2000 Natural heritage Inventory (NHI), 2000
Fish Distribution	in-water polygons	NOAA, 1997c.
Bird Distribution	in-water polygons	NOAA, 1997c.
Fish Locations	discrete points in Michigan	Great Lakes Commission, 2000.
Bird Locations	discrete points in Michigan	Great Lakes Commission, 2000.
Fish Spawning grounds	in-water polygons	UWSGI, 1980
Basemap generated from TIGER census data and ESRI data and maps in ARCVIEW GIS version 3.2, WTM projection.		

4.1.1Habitats

The abundance and type of wildlife populating an area depends on the presence of suitable habitat, including the availability and distribution of food and water, protective cover, and appropriate breeding and nesting grounds. The Lower Fox River and Green Bay system varies considerably in its potential to provide and support different kinds of habitat and this variability affects the wildlife diversity and populations.

The two major types of habitat present are 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 include wetland, riverine, and lacustrine. 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, and sparrows, robins, blackbirds, etc.,) and scavengers (i.e., raccoons, squirrels, vermin, etc.).

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 MSA and Green Bay MSA, much of the river shoreline and associated former wildlife habitat has been developed (Figures 1-3 through 1-6). Natural habitats have retreated from the river and exist only in less developed areas such as lands cultivated for agriculture, open meadows, or small, localized woodlands. The aquatic habitat is wetland and riverine, and it is comprised of and confined to the Lower Fox River and its tributaries.

Green Bay represents a lacustrine habitat and the other habitats, listed above, are found in the area surrounding the bay. The land surrounding Green Bay is much less developed than the Lower Fox River valley, as detailed in Section 3.1.2. Open, agricultural land and forests/woodlands comprise between 65 percent 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 3-1). 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 (as well as the Lower Fox River watershed), approximately 289,000 people inhabit the Green Bay area (Table 3-7). 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.

4.1.2 Wildlife Groups

The significant groups of wildlife found within the Lower Fox River and Green Bay habitats are summarized below.

- Both pelagic and benthic aquatic invertebrates 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 the river and bay (Szymanski, 2000). Due to their aggressive nature, the presence of zebra mussels in the system will present problems for the native macroinvertebrates that cannot adequately compete with these mussels for food or habitat.

- Fish of the region include salmon, trout, game fish such as walleye, yellow perch, and northern pike, and pelagic and benthic non-game fish. Fish species included within uptake modeling and analysis are discussed in detail in this section.

- Birds of the region include raptors, gulls, terns, diving birds, migratory waterfowl, passerines, shorebirds, and wading birds. 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. 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 are discussed in detail within this document. Mink are the principal species that are discussed in the RA report.

- Reptiles and amphibians, including snakes, turtles, frogs, and toads are present in the region (Exponent, 1998). Frogs and toads that dwell in wetlands or nearshore areas are fed upon by wading birds of the region. These include the leopard frog, wood frog, green frog, chorus frog, and Eastern grey-tree frog as well as the American toad (Nikolai, 2000a). Typically, the frogs and turtles confine themselves to the wetland and near shore areas while snakes of many different species and toads are found in association with both terrestrial and aquatic habitats. Salamanders confine themselves to forested wetlands and the Blandings turtle is listed as a threatened species in Wisconsin (Nikolai, 2000a). Many egg laying sites have been eliminated due to development along the Lower Fox River (Nikolai, 2000a).

4.2 Wildlife Habitat

4.2.1 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) and the habitat characterization report (Exponent, 1998) indicate that this is the largest habitat present within 0.8 km (0.5 mi) of the Lower Fox River.

Along the east side of Green Bay, from the Fox River mouth to Little Sturgeon Bay, open land is the predominant habitat (Exponent, 1998). Use of the land for agricultural purposes is responsible for the presence of this habitat along the east shore of Green Bay. Although the Exponent habitat characterization ended at Little Sturgeon Bay, review of Door County SCS (1978) soil survey maps and land use information (Section 3.1.2) indicates that open land habitat is prevalent throughout the Door Peninsula. Approximately 50 percent and 70 percent of the land use in Door and Kewaunee Counties, respectively, is classified as agricultural.

Extensive tracts of agricultural and open land are also present in Brown and Oconto counties. More than 60 percent and 42 percent of the land in Brown and Oconto counties, respectively, is classified as agricultural or open (Section 3.1.2). However, the percentage of agricultural and open land decreases moving north. Agricultural and open land in Marinette, Menominee, and Delta counties ranges between approximately 13 percent and 21 percent, with forested land comprising the majority of the remaining land use (Table 3-1).

Typical open land vegetative cover includes grasses and legumes such as fescue, bromegrass, vetch, and birdsfoot trefoil. Native vegetation consisting of wild herbaceous plants such as goldenrod, asters, beggar-ticks, violets, and various other spring herbs occur on open landscapes. Grasses and prairie grasses such as wheatgrass, big and little bluestem, indiangrass, switchgrass, and sideoats grama exist in limited areas along the bluffs and open areas with prairie forbs consisting of round-headed bush-cover, New England aster, rigid goldenrod, and prairie blazingstar. Cultivated vegetation in the area includes clover, oats, sorghum, soybeans, alfalfa, and hay. This vegetation, both wild and cultivated, provides food and protective cover for wildlife that populates this habitat.

Animals which are frequently observed 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.

Although open lands are prevalent along the Lower Fox River and east side of Green Bay, pressure from individuals and developers to convert farmland and other open areas into residential housing or urban uses may reduce the acreage of this habitat. The Brown County Year 2020 Land Use and Transportation Plan (HNTB, 1996) expects the county population to increase by about 32 percent, from 194,500 in 1990 to around 257,700 in 2020. The recommended land use plan map indicates that residential housing is intended for large areas along the east shore of Green Bay. Due to the presence of the wetlands and the large tracts of state-owned land along the west side of the bay, residential housing developments in this area will be more limited. However, development of these areas is still expected to impact the nearby habitats.

Increases in housing and population are also expected in Door County. The Door County Development Plan expects that the year-around population will increase by about 5.4 percent (1,380 people) between 1990 and 2015 (Olejniczak and Florence, 1995). Again, much of this growth is expected to decrease open land areas as well as other habitats.

4.2.2 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 UP. Due to development and growth of urban areas and agricultural activities in the Lower Fox River valley, few significant tracts (40 acres or more) of woodland habitat are present within a mile of either bank of the Lower Fox River. Those areas that are present are usually thin, elongated areas which border roads or farm fields.

Agricultural activities have dominated the historical development of northeastern Wisconsin and significant losses of woodlands have occurred in this area. However, large tracts of woodlands and forests remain in the UP. Moving north along the shores of the bay, the acreage of wooded land increases. This is especially true where the growth of agricultural areas has slowed and replanted forests have matured since the trees were logged during the 1800s and early 1900s. Review of the aerial photos used for the SCS soil maps for the counties surrounding Green Bay (1972, 1978, 1988, 1989, 1991, and 1994) indicates that the size of the tracts of woodlands increases moving north. Less than 6.7 percent of the land within Brown County was described as forested compared to 51 percent to 76 percent in Oconto, Marinette, Menominee, and Delta counties (Table 3-1). Over 625,000 hectares (1.54 million acres) of forests are present in Marinette, Menominee, and Delta counties (Table 3-1). Forested land comprises between 22 percent and 34 percent of land use in Door and Kewaunee counties (Table 3-1).

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 use the vegetation for nesting sites and 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.

Historical development in northeast Wisconsin and Michigan's Upper Peninsula (UP) have reduced the forests, which were originally the dominant habitat in the region. Logging activities, for lumber and to supply raw material to the paper mills in the Fox Valley greatly reduced the woodland acreage. Following logging, these areas were typically cultivated, especially within the Lower Fox River valley and along the southern half of Green Bay. With this lost forested land, the animal populations utilizing this habitat also decreased and changed.

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 mi). 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 mi). 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. All together, the Escanaba River State Forest comprises 168,350 hectares (416,000 acres) of land. The Hiawatha National Forest 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 and comprises 348,000 hectares (860,000 acres). 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 along the east shore of Green Bay on the Door Peninsula. The largest of these is Peninsula State Park, which comprises about 1,520 hectares (3,760 acres) of forest and includes about 32 km (20 mi) 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).

4.2.3Wetlands

4.2.3.1 Wetland Areas and Types

Wetlands are critical habitat for many wildlife groups within the Lower Fox River and Green Bay area. 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, golden eye, 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 (Exponent, 1998). Small game and fur-bearing mammals, including muskrat, mink, otter, and bats 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 the 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). Moving from deeper water to the shore, these wetland types include the following:

1) Submergent marsh: contains submerged aquatic vegetation (SAV) and/or floating vegetation.

2) Emergent marsh: characterized by shallow water or saturated soils with rushes, cattails, and other emergent species

3) Shoreline (or strand) zone: located at or just above the water line and are typically thin zones, usually dominated by herbs

4) Wet meadow (herbaceous): characterized by saturated or periodically flooded soils dominated by sedges, grasses, and other herbs

5) Shrub swamp & 6) 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, riverine, palustrine, and lacustrine/freshwater estuaries. 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 LLBdM and the Lower Fox River. These wetland areas are a combination of the emergent, shoreline, and wet meadow types defined by MNFI (above). Typical emergent vegetation in these wetlands include cattails, bulrush, arrowhead, assorted rushes, sedges and reeds. 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. Typical vegetation in these wetlands include shrub willows, small cottonwoods, dogwoods, and small ash, as well as elderberry and buttonbush. 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 herons species (Exponent, 1998).

- **Forested wetlands:** These wetlands occur along the banks of the Lower Fox River and the shorelines of Green Bay throughout the area that Exponent characterized (1998). These wetlands are forested with numerous deciduous species, including elm, cottonwood, willow, ash, maples, box elder, dogwood, and sumac. 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).

Areas identified and mapped as wetlands by the WDNR along the Lower Fox River are shown on Figures 4-1 through 4-4. Wetland areas along Green Bay, which were identified and mapped by USFWS (1981 and 1993) are shown on Figures 4-5 and 4-6.

Emergent/wet meadow wetland complexes account for 43 percent of all wetlands observed in the Lower Fox River and southern Green Bay assessment area. Shrub/scrub wetlands comprise approximately 27 percent of the wetlands and are located mainly along the west shore of Green Bay. Forested wetlands account for 25 percent of the area and are predominantly located in the northern portion of this assessment area. Open water within designated wetland areas account for 2 percent of the total area and aquatic beds, excavated ponds, and wetlands smaller than 0.8 hectares (2 acres) in size comprise the remaining 3 percent of the assessed area (Exponent, 1998).

Only 135 hectares (334 acres) of wetlands within 0.4 km (0.25 mi) of the shore were identified within the Lower Fox River valley (Exponent, 1998). Of these identified wetlands, 119 hectares (294 acres) or 88 percent were located between LLBdM and the De Pere dam (Figures 4-1 through 4-3). 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) (Exponent, 1998). The largest wetland areas are associated with the Stroebe Island Marsh and backwater areas in LLBdM, the Thousand 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, 1998). Only 16 hectares (40 acres) of wetlands were identified in the De Pere to Green Bay Reach (Green Bay Zone 1), and these were predominantly emergent/wet meadow and forested wetlands (Figure 4-4). Approximately 60 percent of these wetlands (9.5 hectares or 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. However, it appears that Exponent (1998) did not classify these areas as wetlands. Approximately 350 hectares (865 acres) of SAV are present in the Lower Fox, with only about 8 hectares (20 acres) located downstream of the De Pere dam. Approximately 260 hectares (642 acres) of SAV are present within LLBdM and are likely associated with the Stroebe Island Marsh and the other backwater wetlands of LLBdM; however, SAV is also associated with smaller wetlands, both within LLBdM and other areas of the river. Another 62 hectares (153 acres) of SAV are present in the same part of the river as the Thousand 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 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 (1978) or the establishment of SAV. In addition, water clarity and depth are also other limiting factors which effect the presence or absence of SAV in a given location (Szymanski, 2000).

The USFWS completed a study of the fish and wildlife resources of the Great Lakes coastal wetlands in 1981. This study found that there are at least 17,098 hectares (42,250 acres) of wetlands located along the shores of Green Bay (Table 4-1). The wetland/wetland complexes identified on Table 4-1 include those over 40.5 hectares (100 acres) in size, which is the MNFI study size criterion (Albert, 2000). Although there are a number of fully functioning wetlands under 20.2 hectares (50 acres) along the shores of Green Bay, physical constraints generally inhibit these wetland areas from expanding (Albert, 2000). Therefore, controlling losses in larger wetland complexes is important for maintaining the overall wetland habitat of the region (Albert, 2000). However, the functional value or benefit of smaller wetland areas cannot be discounted. The 40.5 hectare (100 acre) size criteria is only used to focus the discussion below.

Approximately 42 percent of wetland areas larger than 40.5 hectares are located in Wisconsin while about 58 percent are located in Michigan. Both the 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 Bay de Noc and Little Bay de Noc (Table 4-1; Figures 4-5 and 4-6).

Almost 570 hectares (1,400 acres) of wetlands are located along the east shore of Green Bay. This represents just over 3 percent of all the wetlands larger than 40.5 hectares (100 acres) in the bay (Table 4-1). 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 m (6 feet) deep. Based on the Exponent (1998) and USFWS (1981) descriptions, many of the wetlands along the east shore of Green Bay are emergent/wet meadow wetlands.

About 8,000 hectares (19,770 acres) of wetlands are present along the west shore of Green Bay, from the Fox River mouth to the city of Escanaba, Michigan, (Table 4-1). This is approximately 47 percent of the Green Bay wetlands greater than 40.5 hectares. Between the Fox River mouth and 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 (Table 4-1). The USFWS (1981) primarily classified all the west shore wetlands as lacustrine systems (Table 4-1), although smaller palustrine systems were typically associated with these wetlands. The west shore wetlands are affected by littoral currents, storm driven wave action, wind action, and ice scour, which 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 are associated with the Green Bay tributary spits or deltas. Only wetlands associated with river deltas are classified as riverine systems (Table 4-1). 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 (Table 4-1). Other riverine wetlands are associated with the other tributaries; however, these wetlands are usually very small and are not included on Table 4-1.

Wetlands found in both Little Bay de Noc and Big Bay 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 just under 50 percent of the Green Bay wetlands larger than 40.5 hectares (Table 4-1). These wetlands have extensive emergent vegetation development (Minc and Albert, 1998). Also, the wet meadow complexes, shrub swamp, swamp forest wetlands in the UP are typically larger and more a readily extensive than further south in Green Bay. This is primarily due to less development in this region of the bay compared with areas further south.

Due to the fact that the west and north shore wetlands developed on gently sloping lake or outwash plains, these wetlands are considered to be "pulse stable" systems (USFWS, 1981; MDNR, 1998). Periodic, short-term and long-term water level fluctuations are very important to the maintenance and productivity of pulse stable wetlands. High water levels in the mid-1970s and mid-1990s reduced the areal extent of these wetlands, flooded areas of emergent vegetation, and may adversely effect wet meadow or shrub/scrub plant species that may not be able to tolerate flooded conditions for extended periods of time. Conversely, periods of low water levels allow expansion of wetland areas, decomposition of accumulated organic material, and new wetland plants to germinate (MDNR, 1998). Emergent plant species will colonize shallow water areas as the area of wet meadow and shrub/scrub plant species increases lakeward.

The state of Wisconsin has a number of designated wetlands/wildlife areas located in the Green Bay area. The largest of these is the Green Bay West Shores State Wildlife Area (SWA), which comprises 11 separate wetland units. The 11 units are listed below, starting near the Fox River mouth and moving north along the west shore. The status of an area as either a designated SWA or national wildlife refuge (NWR) is also indicated.

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 NWR.	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)**

Currently, just over 3,015 hectares (7,450 acres) are designated as part of the Green Bay West Shores SWA. However, the WDNR desires to expand this area to a total of 5,639 hectares (13,933 acres) in the future (WDNR, 2000b).

Along the east side of the bay, the Gardener Swamp SWA covers 478 hectares (1,181 acres) in Door County (WDNR, 2000b). Gardener Swamp SWA is located just south of Little Sturgeon Bay, approximately 2.4 km (1.5 mi) from the bay. The WDNR is also currently planning to establish the Red Banks Glades

SWA in Brown County. This planned SWA would cover approximately 204 hectares (503 acres) and be located just inland from the bay, similar to the Gardener Swamp SWA (WDNR, 2000b).

The city of Green Bay owns and operates the Bay Beach Wildlife Sanctuary, which is located approximately 1.9 km (1.2 mi) east of the Fox River mouth. 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 in the sanctuary (Baumann, 2000).

4.2.3.2 Wetland Losses

Wetlands, similar to woodlands, were historically more prevalent than they are today. While wetland losses can be attributed to both human and natural processes, those associated with human activities are generally more permanent. Filling of lowland and marshy areas was historically considered advantageous, as these areas were of little recognized use or importance and the resulting land could be developed for numerous purposes. This was probably more predominant along the banks of the Lower Fox River than along the shores of Green Bay, but it has occurred throughout the region (Burridge, 1997; Exponent, 1998). Due to the cities and large areas of developed land located along the banks of Lower Fox River, it is likely that wetland losses along the river resulting from human activities have been more significant than along the shores of the bay. Additionally, water level fluctuations within the bay play an important role in the amount of wetland present immediately adjacent to the shore and extending into the bay during any given time period.

In the Lower Fox River, the only wetland exceeding 8.1 hectares (20 acres) is associated with the Thousand Islands Nature Preserve (Exponent, 1998). Wetland losses in the Lower Fox River were generally associated with filling and development activities, including construction of the locks and dams. Although not directly documented, it is likely that construction of the locks and dams of the Lower Fox River, along with the dredging activities which occurred up through the 1960s (as listed on Table 3-13) likely had long-term detrimental impacts on the riverine wetlands. Exponent (1998) documented development of the Lower Fox River shoreline and these results are discussed below in riverine habitat section.

Green Bay shoreline development has also resulted in wetland habitat loss, some of which has been documented. The Bay Port Industrial Park and CDF is a 243 hectare (600 acre) facility located along the west shore of Green Bay about 3.2 km (2 mi) from the Fox River mouth. This facility was constructed between Interstate 43 and the bay, largely over Atkinson Marsh. In the early 1960s, the

Bay Port Industrial Park was envisioned as a facility to enlarge, enhance, and modernize the Port of Green Bay. In order to fill the incorporated wetlands of Atkinson Marsh and the other low areas, the city of Green Bay offered the site to the USACE as a CDF for placement of sediments dredged from the navigation channel and other harbor work. The USACE began disposing of dredge spoils at Bay Port in 1966 and approximately 7.24 million m^3 (9.47 million yd^3) have been placed in the CDF through the end of 1999 (Table 3-13).

Wetland losses along the west shore of Green Bay from the Fox River mouth to the city of Marinette, Wisconsin were studied in the mid-1970s (Bosley, 1976 and 1978). Using land survey information from 1834 through 1844, it was estimated that at least 223 km^2 (86 mi^2) of coastal wetlands were present along the west shore of Green Bay (Bosley, 1976). In the mid-1970s, Bosley (1978) estimated that the west shore wetland areas had decreased to approximately 63 km^2 (24.3 mi^2) at low water levels and about 45.3 km^2 (17.5 mi^2) at high water levels. This represents a loss of 72 percent to 80 percent of the west shore wetlands. In 1981, the USFWS estimated that there were approximately 63.5 km^2 (25.5 mi^2) between the mouths of the Fox and Menominee Rivers, similar to Bosley's (1978) estimate.

Schideler (1994a) documented the loss of wetland areas between 1951 and 1986 resulting from natural processes, specifically water level fluctuations and storm effects. Schideler (1994a) analyzed the size and extent of Long and Little Tail Points and their associated wetlands. The Long Tail Point area included the point and all wetlands from just east of the Fox River mouth to the location where Long Tail Point joins the shore. This area included the Duck Creek delta, Peats Lake, Atkinson Marsh, Peters Marsh, Dead Horse Bay, and the other bayhead islands between Long Tail Point and the mouth of the river, including the Cat Island Chain and Grassy Island. Much of this area is shown on Figure 4-7. The Little Tail Point area included the point and all wetlands from just south of the Suamico River to just north of the Little Suamico River.

Estimated net wetland losses in the Long and Little Tail Point areas between 1951 and 1986 were approximately 420 hectares (1,040 acres) and 200 hectares (500 acres), respectively (Schideler, 1994a). The net loss (or gain) of wetland is the total difference between total wetland losses and total wetland gains. Typically, there is some amount of loss in one area with wetland gains occurring in other areas. The most significant periods of high water levels found during this time frame were in 1952-53, 1973-74, and 1985-86. As mentioned above, although the wetlands of Green Bay are pulse-stable systems, extended periods of high water reduce overall wetland areas. Additionally, if significant wind action, wave action or storms occur during these periods of high water, significant sediment volumes may be displaced, thereby disturbing, reducing, or destroying the wetland. Schideler (1994a) observed such results in the Long Tail Point area and the specific areas of wetland losses are listed below and shown as blackened areas on Figure 4-7.

Wetland Losses in Select Areas of Lower Green Bay, 1951-1986.

Location	1951-1982 Hectares (Acres)	1982-1986 Hectares (Acres)	Total losses Hectares (Acres)
Long Tail Point	57.6 (142.3)	50 (123.6)	107.6 (265.9)
Duck Creek Delta	136 (336.2)	82.8 (204.5)	218.8 (540.7)
Duck Creek (Upstream)	12.2 (30.1)	18.9 (46.6)	31.1 (76.7)
Peters Marsh/Peats Lake	40.9 (101.1)	11.1 (27.4)	52 (128.5)
Dead Horse Bay	2.4 (6)	10.5 (26)	12.9 (32)
Cat Island Chain	16.7 (41.3)	2.1 (5.3)	18.8 (46.6)
Other Bayhead Islands	5.0 (12.3)	0 (0)	5.0 (12.3)
Bay Port	12.4 (30.7)	13.1 (32.3)	25.5 (63.0)
TOTALS	**283.3 (700)**	**188.5 (465.7)**	**471.8 (1,165.7)**

Most of the wetlands within this area are exposed to bay waters; therefore, the day-to-day wind/wave actions, storms, and water level fluctuations all impact these wetlands. The greatest wetland losses were associated with Long Tail Point and the Duck Creek delta, where over 324 hectares (800 acres) of wetlands were lost (Figure 4-7). Conversely, the wetland losses for Dead Horse Bay, which is largely protected from bay wave/wind action and storms by Long Tail Point, were only about 2.4 hectares (6 acres) during this time period. The most significant event affecting wetland losses between 1951 and 1982 was the April 1973 storm described in Section 3.5.2.1.

Water levels were high during 1973-74 and in April 1973 a strong storm blowing out of the northeast struck Green Bay. Significant wetland losses resulted from this storm. It is estimated that most of the wetland loss listed for the Duck Creek delta occurred during this storm, as flood waters washed into Duck Creek and destroyed wetlands upstream of the mouth (Erdman, 1999a). Long Tail Point was also severely eroded during this storm; so much so, that a large lighthouse that had been located just off the tip of the point since the 1800s was completely destroyed (Erdman, 1999a).

The Cat Island Chain was also virtually destroyed following the April 1973 storm, as all portions of the chain that had previously been above water were eroded below the water surface. The Cat Island Chain was a group of three large islands and approximately eight to ten smaller islands (Schideler, 1994a) (Figure 4-7) that had been a stable and constant feature in Green Bay since the first navigational charts were drawn in 1845 (Neville Public Museum). This chain acted as barrier islands, protecting the other shoreline wetlands in this area (Smith, 1999a). Review of the 1905 Green Bay Lake Survey Chart 725 (USACE, 1905) indicates that emergent vegetation was present over much of the area south and west of the Cat Island Chain, except in the immediate area of Peats (Peaks) Lake. It is speculated that loss of the Cat Island Chain resulted from the armoring of the shoreline in the vicinity of the Bay Port CDF (Smith, 1999a). Wetlands located on the bay side of the reinforced shoreline were completely eroded during the storm (Schideler, 1994a). The armored shore provided no dampening effect to absorb wave energy in the south end of the bay; therefore, the wave energy was simply reflected back into the bay (Smith, 1999a). Consequently, the bayhead islands, including those of the Cat Island Chain, were affected by severe wave action from both the bay and shore side, thereby facilitating erosion. Based on the high water level, the sediments composing these islands were removed and dispersed throughout the lower bay. Due to the recent low water level conditions, only about 37.2 m^2 (400 ft^2) remains of the chain today (USACE, 1998c).

Although there was an overall net loss of wetlands in the Long Tail Point area during this time frame, there were some wetland gains (Schideler, 1994a). The most important of these gains, in Schideler's opinion, was the construction of the Kidney (Renard) Island CDF. This facility and its construction are discussed in more detail in Section 4.2.3.3. Other small increases in wetland areas were noted in Dead Horse Bay, Peats Lake, Peters Marsh, and along the shoreline of the Bay Port facility.

Wetland losses were also documented for the Little Tail Point area (Schideler, 1994a). Between 1951 and 1974, this area experienced a net loss of just 2 hectares (5 acres). However, between 1974 and 1986, the net wetland loss was approximately 200 hectares (495 acres) (Schideler, 1994a). The majority of these losses were associated with Little Tail Point and the nearby mainland (85 hectares or 210 acres), the Sensiba SWA (44 hectares or 109 acres), and the mouths of the Suamico and Little Suamico Rivers (29.5 hectares or 73 acres and 43 hectares or 106 acres, respectively).

Schideler (1994b) completed a similar review of the Oconto, Pensaukee, and Peshtigo wetland areas over the same period of time. Between the early 1950s and 1974, the Oconto and Peshtigo areas actually had a net gain of about 15.8 hectares (39 acres) and 1.8 hectares (4.5 acres), respectively, while the Pensaukee area had a net loss of about 3.4 hectares (8.4 acres) (Schideler, 1994b). However, from 1974 through about 1987, all these wetlands decreased in size. The Pensaukee wetlands lost approximately 74 hectares (183.1 acres) while the Oconto and Peshtigo wetlands decreased by about 170 hectares (419 acres) and 145 hectares (358 acres), respectively. The wetland losses observed for all of the west shore wetlands likely resulted from increased water levels. The west shore wetland areas are likely re-establishing themselves based on the low water levels Green Bay is currently experiencing (USACE, 2000b).

4.2.3.3 Proposed Wetland Restoration Projects

Wetland redevelopment has been identified as a priority for restoration of the Green Bay area and ecosystem (RAP Biota & Habitat Work Group, 1994 & 1996). Three of the top four priorities identified by the Green Bay RAP Committee in 1994 included the following: 1) restoration of the Cat Island Chain; 2) protection, enhancement, and restoration of the river and bay wetlands; and 3) enhancement or creation of near-shore and in-lake habitat. In addition, establishment of the Kidney (Renard) Island CDF has facilitated wetland restoration east of the Fox River mouth. However, because sediments placed within this CDF are contaminated with PCBs, the overall impacts, both positive and negative, are still debated.

The USACE, along with the USFWS and other governmental and private agencies, are currently reviewing plans to re-establish the Cat Island Chain. The Cat Island Chain restoration proposal plans to use sediments from the northern most end of the navigation channel or further north in the bay, which are less likely to contain significant concentrations of PCBs or other chemical compounds (Smith, 1999b). The restored Cat Island Chain would provide additional bird and fish habitat in this area. The islands would also protect and facilitate recovery of the other west shore wetlands in lower Green Bay (Smith, 1999b). These wetland areas include Peats Lake, Peters Marsh, the Duck Creek delta, and the remaining portions of Atkinsons Marsh. The current plans include constructing three man-made islands of dredged material along the previous landforms. The USACE believes the work could commence in 2002 and would begin with the western most island, located closest to the western shore of Green Bay (Campbell, 1999). The three islands would be approximately 62.7 hectares (155 acres), 21.5 hectares (53 acres), and 15.6 hectares (38.6 acres), respectively (USACE, 1998c). Based on the fact that Kidney Island, which is about 21 hectares (52 acres), has already received more than 2.1 million m^3 (2.7 million yd^3) of sediment, it is possible that these three islands could receive well over 9.2 million m^3 (12 million yd^3) of sediment. Revegetation activities must also be undertaken in conjunction with island restoration to prevent exotic species from overtaking these areas (Nikolai, 2000a).

In addition to the Cat Island Chain restoration project, other activities would be undertaken to facilitate wetland and habitat recovery. Reintroduction of SAV in the area of the Duck Creek delta and Peats Lake would provide habitat for fish fry, as well as facilitate wetland recovery. Additionally, the riprapped areas of shoreline in the southern bay would be softened by promoting the growth of emergent vegetation and through creation of nearby sandbars. Softening this shoreline would reduce wave energy in the south end of the bay, thereby allowing further establishment of more SAV and emergent vegetation along the shore.

Kidney Island CDF has received over 2.1 million m^3 (2.7 million yd^3) of sediment since 1979 and has been a controversial project in the Green Bay area. Some consider the CDF an unsuitable habitat restoration alternative, due to the fact that PCBs and other chemical compounds contaminate the sediments contained therein. Also, the location of the CDF immediately offshore of Green Bay's historic Bay Beach has been a concern to some local residents. Concerns for the Kidney Island CDF were included in the Final Environmental Impact Statement (EIS), completed when expansion of the CDF was proposed (USACE, 1985). However, the presence of the CDF has fostered re-establishment of emergent vegetation around the perimeter of the island, especially in the quiet water between the CDF and the shoreline to the south. Some colonial nesting birds (e.g., terns) use the island as nesting grounds (Erdman, 1999b).

Neither the Bay Port nor Kidney Island CDFs have achieved their original project objectives. The Bay Port Industrial Park has not yet become the port facility originally intended and Kidney Island has not evolved into the wetland habitat and possible marina that was envisioned. Consequently, future island restoration projects like that proposed for the Cat Island Chain, and further use of CDF sediments contaminated by significant levels of PCBs or other chemical compounds may be of concern to some Green Bay area stakeholders (Erdman, 1999b).

The MDNR (1998) released a restoration and management plan for Portage Marsh. This marsh is located along the west shore of Green Bay south of the city of Escanaba (Figure 4-6). A dike system was established to facilitate access to the marsh in 1984; however, the dikes have impeded water exchange between the bay and marsh and limited water level fluctuations. Therefore, areas that were once wetlands are becoming uplands. Also, continued use of the area by off-road vehicles has contributed to further degradation. Therefore, the restoration and management plan called for prohibition of off-road vehicle use within the marsh and removal or opening of some dikes in order to allow water exchange between the bay and marsh as well as facilitate water level fluctuations (MDNR, 1998). Also, because wet meadow areas of the marsh were beginning to see the establishment of various trees (marking transition to a shrub swamp or swamp forest type wetland), the MDNR proposed controlled burning of select areas. This burning would facilitate growth of wet meadow plant species and, in select areas, provide more open water spaces for increased use by wildlife (especially migratory waterfowl).

4.2.4 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 Fox River are also influenced by the amount of the development immediately adjacent to the riverbanks or within the drainage basin.

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 LLBdM, Appleton to Kaukauna, and Kaukauna 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 and the percentage of each type within the river are listed on Table 4-2 and shown for each reach on Figures 4-1 through 4-4.

The largest category described by Exponent (1998) was the Island/Peninsula habitat (Table 4-2). Most 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 habitat type are Stroebe and James Islands in LLBdM (Figure 4-1), the Thousand Islands Nature Conservancy near Kaukauna (Figure 4-2), and the unnamed islands associated with the Cedar, Combined, Rapide Croche, and Little Rapids Locks (Exponent, 1998).

Backwater, cuts, and coves are the second largest habitat category observed within the river (Table 4-2) (Exponent, 1998). These areas are relatively undisturbed by human activities and, thus, they are very desirable for wildlife and fish (Exponent, 1998). These habitat areas are also 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 4-1 through 4-4.

Two other important habitat types are the dam riffles and submerged rock, piling, or ruin environments. Although these two habitats constitute just over 12 percent of the Lower Fox River, game fish are often associated with these areas. Fish such as walleye prefer rocky substrates with fast running water for spawning purposes. Walleye are an important game fish of the Lower Fox River. Although, sandbars and silt deposits are rare along the Lower Fox River, they are important for turtle nesting and shorebird feeding activities (Nikolai, 2000b).

In addition to reviewing the aquatic habitat, Exponent (1998) evaluated the riverbanks and substrate characteristics. The shoreline classifications are shown on Figures 4-1 through 4-4 (Exponent, 1998). The river shoreline was divided into both developed and natural riverbank, with subcategories of each (Table 4-3). About 44.6 percent of the river shoreline is developed and protected with either riprap or bulkheads while the remaining 55.4 percent is natural bank (Table 4-3).

Slightly more than 22.4 km (13.9 mi) of the 28 km (17.4 mi) of developed shoreline is protected with riprap (Table 4-3) and, according to Exponent (1998), riprap is preferable to bulkheads. Riprap tends to offer some habitat possibilities as some fish will find protection and feeding opportunities and some birds will nest in the crevices and gaps of the 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 mi) of natural shoreline (Table 4-3). Almost 44 percent of the entire river shoreline is classified as riparian canopy, which includes tree-lined and forested banks of the river (Exponent, 1998). About 15.9 km (9.9 mi) of riparian canopy shoreline is situated between the Cedars and Little Rapids locks (Figure 4-2). 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 comprise almost 6.8 km (4.2 mi) while sand and gravel beaches comprise less than 1 percent of the shore (Table 4-3).

The river substrate summary is included on Table 4-3 (Exponent, 1998). The areal extent of the river is about 21.8 km^2 (8.4 mi^2). Soft silty sediment (Type 1) comprises about 11.7 km^2 (4.5 mi^2) or about 53 percent of the river bottom. Compact sand and gravel (Type 3) accounts for about 6.3 km^2 (2.4 mi^2), or about 29 percent of the river bottom (Table 4-3). The river bottom downstream of LLBdM is essentially made up of either Type 1 or Type 3 sediments. Half of the bottom material in LLBdM is Type 2, semi-compact sand/clay, sediments. The most prevalent areas of Type 3 sediment (compact sand/gravel) are located between the Appleton and Little Rapids dams (Table 4-3), suggesting the increased current velocities associated with the generally narrow river width, transport silt and other fine-grained sediments further downstream of these areas. Between Appleton and Little Rapids, the only significant accumulation of soft silty Type 1 sediment is in the part of the river where the Thousand Island Nature Conservancy and wetlands are located.

Downstream of the Little Rapids dam, the majority of the river bottom is Type 1 soft, silty sediments. The areal extent of the river from Little Rapids to the mouth of the Lower Fox River is almost 9.1 km^2 (3.5 mi^2), but only 0.3 km^2 (0.12 mi^2) of Type 3 river bottoms were noted in this stretch (Table 4-3). These results confirm the sediment sampling results of previous investigations, which found long, continuous deposits of soft sediment between Little Rapids and the river mouth (WDNR, 1995 and 1998; GAS/SAIC, 1996; Exponent, 1998).

4.2.5Lacustrine Habitat of Green Bay

4.2.5.1 Overview

The lacustrine habitat of Green Bay is very different than the riverine habitats of the Lower Fox River. Lacustrine systems have deeper water, allowing a temperature stratification (thermocline) to develop. 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 have a particular temperature preference. Numerous fish species can be found within different areas and at various depths of lacustrine habitat based on the water depth, temperature, and currents. 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 normally have a unidirectional current (gravitational), lacustrine currents are more complex, variable, and weaker (Maitland and Morgan, 1997). Sediments transported from the Lower Fox River and other tributaries into Green Bay are deposited down current from the mouth as the river and bay waters mix and the water velocities decrease. Together with littoral transport, which moves sediments along a lake shore, these factors result in sediment accumulations (like the Duck Creek delta) and the spits, shoals, and shallows located near the tributary mouths on the west side of the bay (refer to Figures 3-4 through 3-6). Because wind, wave action, and currents are the primary causes for erosion and redeposition within the Great Lakes (USACE, 1998d), sediment erosion within Green Bay is largely confined to shore and near-shore areas where water depths are shallower. These actions may resuspend deposited sediment and move it through the bay. Lacustrine environments typically develop larger wetlands than riverine systems, especially in areas of extensive shallow water and low current velocities.

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 hypereutrophic (extreme eutrophic conditions) while the northern portion of the bay is generally oligotrophic. The general characteristics of eutrophic and oligotrophic conditions are listed below (Maitland and Morgan, 1997). In addition, Green Bay is also mesotrophic in areas; the mesotrophic condition is an intermediate classification between the eutrophic and oligotrophic conditions.

General Trophic Classifications Which Apply to Green Bay

Character	Eutrophic	Oligotrophic
Basin shape	Broad and shallow	Narrow and deep
Substrate	Organic silt	Stones or inorganic silt
Shoreline	Weedy	Stony
Water transparency	Low	High
Water color	Green or Yellow	Blue or Green
Dissolved solids	High (much N/Ca)	Low (poor in N)
Suspended solids	High	Low
Oxygen	Low (especially under ice or thermocline)	High
Phytoplankton	Few species/high numbers	Many species/low numbers
Zooplankton	Few species/high numbers	Many species/low numbers
Macrophytes	Many species/some abundant	Few species/rarely abundant
Zoobenthos	Many species/high numbers	Many species/low numbers
Fish	Many species	Few species

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).

4.2.5.2 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 the AOC are generally less than 1.8 m (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 tend to become silty. Potential nutrients within bottom sediments are 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 20th century. 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, 1994).

Fish dies-offs on the east side of the bay in 1938-39 (Wisconsin State Board of Health, 1939) indicated the impacts of poor water quality and the lack of DO within the inner bay. Water quality and benthic community studies throughout the mid-1900s showed low DO. and degraded water quality. Recent waste treatment practices have greatly reduced the loads of organic material in the river and bay since the 1960s and 1970s and resulting in DO concentrations generally remaining above the standard of 5 mg/L (Harris, 1994). Since at least 1975 there have not been any large fish die-offs related to low DO levels (Lychwick, 2000c). However, DO concentrations have dropped below 5 mg/L during summer months when algal blooms occur (Harris, 1994). 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 re-establishment of wild celery in some west shore wetland areas (Harris, 1991; McAllister, 1991).

4.2.5.3 Outer Bay Water Quality

Sager and Richman (1991) documented that the northern half of Green Bay (the outer bay) is generally oligotrophic to mesotrophic. 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 Big Bay de Noc and Little Bay 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 through the central portion of the bay and along the western shore. 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 quality conditions.

4.3 Benthic Communities

The benthic macroinvertebrates of the Lower Fox River and Green Bay environment include adult and larval insects, mollusks, crustaceans, and worms that predominantly burrow directly into the fine-grained 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. These creatures are also an important food resource for the benthic and pelagic fish communities, and semi-aquatic organisms such as birds and mammals feed on them occasionally as well.

Many of the benthic community surveys have focused on oligochaetes, chironomids, and the burrowing mayfly (*Hexagenia*). The oligochaetes and chironomids are thought to be tolerant of organic enrichment and/or degraded habitats, like that of the Lower Fox River and lower Green Bay, whereas other species are less tolerant of enriched/degraded habitats. *Hexagenia* are considered to be pollution sensitive or intolerant taxa.

Historical macroinvertebrates surveys completed between 1938 and 1978 examined populations and taxa richness near the mouth of the Lower Fox River and in lower Green Bay (Markert, 1978). The 1938-39 pollution survey found that oligochaetes and chironomids dominated the benthic communities. *Hexagenia* were also detected at 16 of 51 stations sampled in 1938-39 (Markert, 1978), suggesting that water quality conditions had not reached their worst in the bay. In addition, very low numbers of leeches, sowbugs, scuds, clams, and snails were all observed at various locations in 1938-39 (Markert, 1978).

Water quality deteriorated significantly between 1938-39 and 1952 as measured by the benthic community populations. Comparison of the 1938-39 and 1952 sampling data indicated that both the oligochaete and chironomid populations had increased. During 1938-39 oligochaetes and chironomids were completely absent in a few locations in the southern bay (Surber and Cooley, 1952). However, in 1952 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 deteriorating water quality results were noted in 1978 (Markert, 1978). In 1978, the density of oligochaetes and midges was greater than in 1938-39, while *Hexagenia* were not observed at all in 1978, indicating further degradation of water quality was continuing. 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 (Integrated Paper Services [IPS], 1993a, 1993b, 1994, and 1995; and WDNR, 1996). 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 round worms, flat worms, scuds, caddisflies, leeches, and sow bugs completing the inventory (IPS, 1993a and 1993b). 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, 1996 [*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 1992-93 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 LLBdM 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 LLBdM (IPS, 1995). Downstream of LLBdM, in deposits N and EE/FF, the 1992-1994 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 sow bugs, 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 Green Bay due to the ability of this exotic species to out-compete the local benthic species for food and habitat (IPS, 1995).

4.4 Fish

The WDNR has completed a number of fish surveys in the Lower Fox River and inner Green Bay. However, due to the numerous factors that may effect fish populations, simple review and comparison of the survey results from various years is not valid. Year to year fish populations do not necessarily indicate whether conditions within the river and bay are degraded or improving because other environmental, physical, or biological factors may be impacting select species at any given time. Surveys reviewed for the Lower Fox River and Green Bay zones 1 and 2 provide data on the fish present within the system. In addition, the personal observations from WDNR and MDNR personnel familiar with both the commercial and sport fisheries of Green Bay are included. The RA addresses the possible population impacts that result from anthropogenic and natural stresses.

Fish samples collected for PCB analysis are included in the FRDB and the fish surveys summarized herein are population counts only and include those species evaluated in the RA or RA food web model. Therefore, this discussion is not intended to be a comprehensive evaluation of all species in the system. Rather, this summary provides insight into the role that fish have in PCB uptake into the food chain. Further analysis of PCB uptake are included in the RA.

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 reasons. Fish have historically been a staple part of the diet of the Oneida and Menominee people as a major source of protein because fish can be dried, canned, salted, or smoked for use throughout the year (Stratus, 1999b).

4.4.1LLBdM to De Pere Dam Fish Surveys

The WDNR has conducted a number of fish population surveys of the Lower Fox River in association with water quality studies. The surveys listed below consist of tabulated data only and are unpublished. They were completed during several time periods with a variety of survey equipment and for different purposes. Therefore, is not appropriate to analyze whether particular data indicates an increasing or decreasing population because the factors affecting fish populations are much more complex than the survey numbers may suggest.

WDNR Lower Fox River Fish Surveys

Survey Area	Year(s)	WDNR Investigators	Purpose
LLBdM 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
LLBdM to Wrightstown	1977	Meyers	Community and populations
LLBdM	1983	Meyers	Evaluate northern pike populations and spawning areas
LLBdM to Wrightstown	1993/1994	Bruch & Lychwick	Fisheries and habitat status
Little Rapids to De Pere	1994/1995	Lychwick	Population surveys

The fish population results from these studies are summarized on Table 4-4. At least 43 different fish species were identified in the river upstream of the De Pere dam (Table 4-4). Twenty-four species were game fish and nineteen species were non-game fish (as defined by state statute). The 1983 LLBdM fish survey indicates that approximately 60 percent of the species captured were game fish, and that black bullhead and black crappie were the predominant type (Table 4-4).

Population results for the LLBdM to the De Pere dam indicate that game fish typically comprise about 30 percent to 40 percent of the fish captured (Table 4-4). Yellow perch, walleye, white bass, and bullheads have all been the dominant game fish species at one point or another. The 1994-95 walleye results for the Little Rapids to De Pere Reach suggests that improved water quality due to decreases in the suspended solid load have facilitated an increase in the walleye populations. (Lychwick, 2000b). Carp was the most prevalent fish observed upstream of the De Pere dam. Carp typically accounted for 50 percent to 90 percent of non-game fish and approximately 50 percent to 60 percent of the all fish captured in the surveys.

4.4.2 De Pere to Green Bay/Duck Creek Fish Surveys

WDNR has conducted surveys in Green Bay zones 1 (the De Pere to Green Bay Reach) and 2 and in Duck Creek. These surveys are discussed together because these areas are interconnected and fish found within any of these waters may also inhabit other areas.

The Oneida Indians came to Wisconsin from New York in the 1800s. Duck Creek lies within the Oneida Reservation and became an important resource for the tribe because of the abundant waterfowl and fish associated with it. Because PCBs have been found within fish caught in Duck Creek, the results of the 1998 Duck Creek fish assessment are summarized here. The assessment was completed cooperatively by the USFWS, WDNR, and Oneida Nation. Although the Duck Creek assessment is published (Cogswell and Bougie, 1998), the 1987 through 1998 survey data for the De Pere to Green Bay Reach are only tabulated and unpublished. The two surveys summarized in this section are listed below.

WDNR Green Bay Zones 1 and 2 Fish Surveys

Survey Area	Year(s)	WDNR Investigators	Purpose
De Pere to Green Bay	1987/1998	Lychwick	Evaluate early spring spawning populations
Duck Creek Assessment	1995/1996	Cogswell/Bougie	Populations survey spring through fall

The fish population results from these studies are summarized on Table 4-5. Annual fyke net surveys were completed by WDNR for the De Pere to Green Bay Reach between 1987 and 1998 (Table 4-5). Only the data from April of each year is listed on Table 4-5 due to the different length of time each survey was conducted.

Game fish account for 70 percent to 90 percent of the total captured fish population. The dominant game fish typically include yellow perch, which is also 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 4-5). This may reflect the success of the historic WDNR walleye stocking programs, as there is now a sustainable natural reproducing population (Lychwick, 2000b). Non-game fish below the De Pere dam are predominantly carp, white sucker, drum, and quillback.

In Duck Creek, 21 species (7 non-game and 14 game fish) were observed that were also present in the De Pere to Green Bay Reach (Cogswell and Bougie, 1998). In addition to the species listed on Table 4-5, 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 DO, 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).

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 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), indicating fish migration between Green Bay and its tributaries. Similarly, Lychwick (2000a) 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. These results suggest that the fish move to locations where food and habitat characteristics are favorable.

4.4.3 Green Bay Fishery Observations and Habitat

To facilitate analysis of PCB uptake in the RA, the Project Team has categorized fish of Green Bay into four groups (Table 4-6). These groups include salmon/trout, benthic, pelagic, and game fish. 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 near the water surface. The game fish listed on Table 4-6 are those typically sought by sport or commercial fisherman.

The general spawning areas in Green Bay for each of these fish groups is shown on Figures 4-8 and 4-9 (NOAA, 1997c). The NOAA (1997c) spawning data only extended to a line just north of Door County, Wisconsin. Therefore, additional spawning observation data for the remaining portion of Zone 4 were obtained from the Great Lakes Commission (GLC) (2000). Whereas the NOAA (1997c) data identified the spawning locations by select fish group and species, the GLC (2000) data did not include such distinctions. Rather, GLC (2000) data is simply shown as points on Figures 4-8 through 4-12 indicating locations where fish spawn.

Spawning areas for the salmon/trout are in the vicinity of the tributaries and the central portion of the bay, where water temperatures are generally colder (Figure 4-8). The spawning areas for the pelagic and benthic fish are similar (Figures 4-8 and 4-9) and concentrated mainly in the areas of significant wetlands (Figures 4-5 and 4-6). Game fish spawning areas are also similar but include additional areas on the east side of the bay, likely due to the fact that some species, like walleye, prefer gravel beds to the SAV associated with the wetlands.

Most of the species discussed herein are pelagic fish (shiners, gizzard shad, smelt, and alewife) as indicated on Table 4-6. Yellow perch and walleye are game fish, carp and sturgeon are benthic species, and brown trout represent the salmon/trout group. Identified spawning areas for most of these fish in the southern half of Green Bay are shown on Figures 4-10 through 4-12. In the northern portion of the bay, walleye spawn in the river tributaries, and along the reefs, shorelines, and islands of both Big Bay de Noc and Little Bay de Noc while yellow perch spawn in the shallow waters of these bays (Schneeberger, 1999). Alewife, gizzard shad and shiners all spawn in the nearshore waters of both bays while carp are concentrated in the northern end of Little Bay de Noc and along the shoreline of Big Bay de Noc (Schneeberger, 1999). Smelt historically ran in most of the rivers and streams in the area but have recently been spawning in more offshore waters as well (Schneeberger, 1999).

The Green Bay fishery habitat varies based on the water characteristics and bay bathymetry. Green Bay zones 2 and 4 are quite different in terms of their physical characteristics and this 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 are lower population densities of fish, less trophic complexity, clearer water, and less human development 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 localized currents between the Peshtigo Reef and Sturgeon Bay (Figures 3-2 and 3-3) and differing trophic conditions in this area (Lychwick, 2000b). 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, 2000).

Heavily pursued sport fish south of the Sturgeon Bay-Peshtigo line include walleye, yellow perch, northern pike, and spotted muskellunge (muskie). Small mouth bass, brown trout and salmonids are also pursued north of Sturgeon

Bay-Peshtigo (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, whitefish migrate south in pursuit of food when water temperatures decrease in the southern end of the bay (Toneys, 1999; Belonger, 2000). Tagging studies of yellow perch and small mouth bass indicate that these fish tend to stay within the area where they were caught. For example, yellow perch caught in the warm waters of the southern bay do not typically migrate to the cold water fishery in the northern bay (Toneys, 1999). Similarly, the Sturgeon Bay Canal is prone to seiche effects and water temperature changes of 5.5°C to 11°C (10°F to 20°F) in a single day, which tend to limit the movement of fish through this channel (Toneys, 1999). Therefore, fish within Green Bay may move into Lake Michigan and vice-versa, but this canal is not a significant migration route (Toneys, 1999).

A thermocline has been observed in the Sturgeon Bay-Peshtigo area, and this also influences fish movement in the bay. The thermocline tends to form and stay near a depth of 3 to 12 m (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 m (60 feet) (Belonger, 2000).

In northern Green Bay, walleye, yellow perch, northern pike, splake, chinook salmon, small mouth 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, 2000). Lake whitefish and rainbow smelt are the main commercial species. 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, 2000).

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, 2000). In the northern half of Green Bay, the walleye fishery ha; also increased in the number of fish caught for each hour of fishing and the total numbers of walleye taken (Schneeberger, 2000).

The overall patterns of fish abundance, species distribution, and habitat use 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 each zone). All of these stations were along the western side of Green Bay except for one station near Point Au Sable on the eastern side of Zone 2. The two habitats targeted for sampling were wetlands (12 stations) and sandy beaches (12 stations). Half of the stations for both of these habitats were located in developed areas while the other half were located in undeveloped areas.

The stations were sampled in the summer and fall of 1990 and 1991, and in the spring of 1991. Almost 42,000 fish were caught and analyzed over these sampling periods and these fish represented 54 species and 20 families. 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.

These data collected by Brazner and colleagues were analyzed to determine to what degree fish preferentially used different regions of the bay, the 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.

Brazner and Magnuson (1994) found that more fish preferred the near shore wetland habitats to beaches, which have fewer plants and stronger wave action. Brazner (1997) 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 fish 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).

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). Brazner and Beals (1997) estimated that 70 percent of the water contained within Zone 2 (Long Tail Point to Point Sable) originates from the Lower Fox River.

In terms of 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 the Zone 2 catch data, spottail shiners were still one of the top five most abundant species caught. The remaining top five species caught 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 zone-biased 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). Although rainbow smelt, trout, perch, and banded killfish were predominantly caught only in Zone 3, none of these were the most abundant fish taken in this zone.

The bay zone and habitat of the specific fish species that have been selected for risk evaluation of the Lower Fox River and Green Bay are summarized below (Brazner, 1997).

Fish Species	Dominant Zone Occurrence	Dominant Habitat
Yellow Perch	Green Bay Zone 2 (74 percent)	wetland habitat (74 percent)
Spottail Shiner	Green Bay Zone 2	beach habitat
Alewife	Throughout bay	beach habitat
Gizzard Shad	Green Bay Zone 2	various habitat
Emerald Shiner	Green Bay Zone 2	various habitat
Common Shiner	Throughout bay	wetland habitat
Golden Shiner	Green Bay Zone 4	undeveloped wetland habitat
Common Carp	Green Bay Zone 2	undeveloped wetland habitat
Rainbow Smelt	Green Bay Zone 3	beach habitat
Trends for brown trout and walleye were not evaluated because an insufficient number of individuals were collected. Only two brown trout and nine walleye were caught as part of these efforts		

4.4.4Life Histories of Fish Species in the Lower Fox River and Green Bay

The section describes the important receptor species identified in the RA. The discussion also illustrates the interactions of fish within the Lower Fox River and Green Bay system and the uptake of PCB into the food chain. The fish discussed herein represent only a small segment of the fish community in the system.

4.4.4.1 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*). The shiners, as well as carp, are in the family Cyprinidae.

All shiner species are relatively small forage fish that average 5 to 10 cm (2 to 4 in) 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 are rarely 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; 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). 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, 1983b), and typically 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, 1983b). They are known to feed at the bottom of streams or lakes, in the wet column and near the surface. Males typically grow faster and larger than females, and they range in lengths from about 9 to 20 cm (3.5 to 8 inches), depending on the age, sex, and species of shiner observed (USFWS, 1983b; 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).

4.4.4.2 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 in) 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 typically travel in schools close to the surface. Spawning typically occurs between late April/early May through August (Becker, 1983), and may extend over a period of 2 weeks for any given female. Gizzard shad typically spawn in shallow rivers and streams. 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 two, the gizzard shad's egg production generally declines, sometimes rapidly.

Gizzard shad typically live less than 6 years, reaching lengths of 28 to 41 cm (11 to 16 in) and weighing around 0.91 kg (2 pounds). However, specimens ranging up to 52.1 cm (20.5 in) 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 their 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).

Being an essentially an open water species, living at or near the water surface (Becker, 1983, USFWS, 1985), they are preyed on by numerous species. Young-of-year (YOY) shad are important to sport fish and water fowl 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).

4.4.4.3 Rainbow Smelt

Rainbow smelt (*Osmerus mordax*) are widespread and abundant non-indigenous pelagic planktivores in the Great Lakes (Jones, *et al.,* 1995). Smelt are common and are an important prey in Green Bay but are not found above the De Pere dam in the upper Fox River. These fish average 15 to 20 cm (6 to 8 in) in length, but despite their small size, they have comparatively large mouths. Rainbow smelt are olive colored on top, and sliver 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. 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, and once hatched, smelt fry are transparent and about 5.5 to 6 mm (0.22 to 0.24 in) long (Becker, 1983).

While YOY fish are pelagic, they move towards a bottom existence as they age. The fish often school offshore, prefer cool clear water, and are most abundant in water depths of 18 to 26 m (59 to 85 ft), although they can be found in water depths of 14 to 64 m (46 to 210 ft) (Becker, 1983). Optimum temperatures range from 6.1˚C to 13.3˚C (43˚F to 56˚F), and feeding temperatures peak at 10˚C (50˚F). Rainbow smelt reach sexual maturity in approximately 2 years (at that time they are about 170 mm [6.7 in] in length) and can live up to 8 years (Becker, 1983). Males live approximately 5 years, reaching a length of about 21.8 cm (8.6 in), while females typically live about 7 years and reach a length around 31 cm (12.2 in) (Becker, 1983).

Full-grown smelt subsist principally on larger crustaceans (like opossum shrimp). However, in the inshore waters they may consume a large number 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 on 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. 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, 2000a). 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 and the cities of Oconto and Marinette, Wisconsin attracted 20,000 to 30,000 people to festivities scheduled to coincide with these runs (UWSGI, 2000a; 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 one night, when previously, these runs might have lasted anywhere from seven to ten 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).

4.4.4.4 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 [6.3 in] in length) of the marine alewife (approximately 36 cm [14.2 in] in length) (Scott and Crossman, 1973). Alewife are blue-green colored on top and sliver on the sides, with thin dark stripes on their top and upper sides.

The alewife is abundant in Lake Michigan and Green Bay, and Becker (1983) indicated that alewives constituted 70 to 90 percent of the fish biomass in Lake Michigan. Alewives 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). Alewives swim in dense schools and are the major prey of the trout, salmon, and other fish in the lake (UWSGI, 2000b). 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 populations 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 its primary predators (Flath and Diana, 1985); walleye and perch 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 and in Lake Michigan; peak spawning occurs in the first 2 weeks of July (Becker, 1983). Preferred temperatures for spawning have been estimated at 13˚C to 16˚C (55˚F to 61˚F) in Lake Ontario, although temperatures can also vary widely from 5˚C to 22˚C (41˚F to 72˚F).

Spawning typically occurs from June through August, 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 (g) (4 to 8 ounces [oz]) (UWSGI, 2000b; 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 alewives captured in the littoral zone, indicating the alewives 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, *et al.,* (1980) found that the distribution of juvenile and adult alewives differs with temperature. YOY alewives reach maximum abundance when daytime water temperatures exceed 17˚C (62.5˚F) while adult alewives prefer water temperatures of 11˚C to 14˚C (52˚F 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 Lake 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. Alewives 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 compose the diet of these fish (UWSGI, 2000b). 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).

4.4.4.5 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. The yellow perch, along with the walleye, is a member of the perch family Percidae. Yellow perch average 15 to 25 cm (6 to 10 in) in length. They are green colored on top, whitish on the underside, and they have distinct green-brown vertical bands extending down yellow sides.

Preferred habitat for yellow perch is shoreline areas with sand, gravel or muddy sediments, modest to moderate amount of aquatic vegetation, and water depths of less than 10 m (30 ft) in clear lakes with temperatures of 18˚C to 21˚C (64˚F to 70˚F) (Becker, 1983; Scott and Crossman, 1973; USFWS 1983a). A study examining the frequency of littoral 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 parts ppm killed numerous yellow perch, but many also 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˚C and 11.1˚C (45˚F and 52˚F), and may continue for 8 to 19 days (Becker, 1983). During spawning, the eggs are usually deposited in sheltered areas and they are frequently draped over emergent and submergent vegetation or submerged brush in water depths of 0.6 to 3 m (2 to 10 ft). Rocks, sand or gravel may be used when submergent vegetation is not available (USFWS, 1983a). The fish may travel long distances during the migration. Lake Winnebago perch may swim from 48 to 81 km (30 to 50 mi) up the Fox River before they reach suitable spawning habitat (Becker, 1983). Egg production in the female yellow perch is extremely variable and depends 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 m (7 ft) in length and up to 10 cm (4 in) 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˚C to 12˚C (47˚F to 53˚F) water (Becker, 1983). Larvae are approximately 0.5 cm (0.2 in) upon hatching and they swim to the surface, where they remain in the upper 0.9 to 1.2 m (3 to 4 ft) 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). YOY 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 in) or more, sometime between the age of 3 and 4 years (Becker, 1983).

Mature yellow perch generally range in length from 15 to 25 cm (6 to 10 in) and from 170 to 454 g (6 to 16 oz) (UWSGI, 2000c). 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, 1983a). Brandt, *et al.,* (1980) found that the distribution of juvenile and adult perch differs with temperature. Juvenile perch catches are highest in waters 15˚C to 20˚C (59˚F to 68˚F) while catches of adult perch are greatest in waters that are 7˚C to 8˚C (44.5˚F 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 has been inversely related to abundance of alewife (Brandt *et al.,* 1987; Mason and Brandt, 1996). Between 1889 and 1970, average catch rates were 2.4 million pounds per year from Green Bay. However, because of the dramatic decline in perch since 1990 (a loss of 80 percent of the population), Wisconsin banned commercial fishing and reduced daily recreational limits to five individuals per day. These restriction became effective in January 1997. 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.

- 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).

4.4.4.6 Carp

Carp (*Cyprinus carpio*) is an abundant bottom-dwelling species found in southern Green Bay. Along with shiners, the carp are within the minnow and carp family Cyprinidae. Adult carp have been found to range in length from 41 to 58 cm (16 to 23 in) and weigh from 1 to 10 kg (2.2 to 22 pounds) (Weber and Otis, 1984). Carp have two distinct barbles on each side of the upper jaw. These fish are grey/grey-green colored on top, have a dark edge on the upper side, white to yellow on the underside.

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

Carp have the ability to range widely; some tagged fish have traveled 1,090 km (680 mi), and a carp tagged in Lake Winnebago was recaptured 148 km (92 mi) 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˚C to 28˚C (64˚F to 82˚F) (Becker, 1983; Scott and Crossman, 1973). An investigation of spawning carp in Lake Winnebago and nearby lakes, determined that carp preferred to spawn in areas of shallow vegetated waters (0.15 to 1.2 m [.49 to 3.9 ft] 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). Young move off vegetation 4 to 5 days after hatching, 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 in) of water (Weber and Otis, 1984). Young carp leave this shallow weedy habitat when they are 76 to 102 mm (3 to 4 in) and generally too large for predators to consume (Becker, 1983). After the first season of growth, carp are generally 13 to 19 cm (5 to 8 in) 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, and 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 in) in length and weigh up to 3.2 kg (7 pounds) (UWSGI, 2000d). 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 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).

4.4.4.7 Walleye

Walleye (*Stizostedion vitreum*) is a popular, year-round game and commercial fish found in Lake Michigan, generally in areas less than 7 m (23 ft) 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. Walleye have strong canine teeth and very large mouths that extend past the eye (Becker, 1983). Walleye are yellow-olive/brown colored on top and brassy yellow-blue along sides. They have five to twelve 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 due to low DO conditions 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). YOY fish can be found near the sediments in 6 to 10 m (19.7 to 32.8 ft) of water (Scott and Crossman, 1973), but can be caught in surface waters up to lengths of approximately 35 mm (1.5 in) (WDNR, 1970). Larger fish are generally in depths of 14 m (45.9 ft) or less and form loose schools (Scott and Crossman, 1973). Schooling is common during feeding and spawning.

Walleye generally spawn between mid-April and early May, and they have specific spawning habitat requirements (Becker, 1983; USFWS, 1984). Preferred spawning habitat 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 to spawn. Lake Winnebago walleye, for instance, may swim 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 one night. Summer territories and spawning grounds are distinct areas. The range of summer area is generally limited to 3 to 8 km (1.9 to 5 mi), but the recorded range has varied from 0.8 to 110 km (0.5 to 68.4 mi). A study of walleye in Lake Poygan found that walleye traveled an average distance 47 km (29.2 mi) (Becker, 1983).

Walleye spawn soon after the ice melts and temperatures reach 3˚C to 7˚C (37˚F to 45˚F), and spawning peaks when temperatures are 6˚C to 10˚C (43˚F 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 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.

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 (1.25 in) and then return to shore around June (Becker, 1983). By the end of July, walleye in Lake Winnebago are about 75 mm (3 in) or larger. At this size, walleye shift from a zooplankton-only diet to also include fish and invertebrates. By fall they are generally 130 mm (5 in) (Becker, 1983).

Female walleye grow faster and become larger than males; however, growth of the walleye is dependent upon the food supply, temperature, and population density (USFWS, 1984). Female walleye reach maturity in 3 to 6 years and males reach maturity in 2 to 4 years (Scott and Crossman, 1973). In Wisconsin waters walleye generally live about 7 to 10 years (UWSGI, 2000e), but walleye can live more than 20 years (Lychwick, 2000a) in Green Bay.

4.4.4.8 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 in) and weigh from 0.9 to 3.6 kg (2 to 8 pounds). These fish are light brown to brown-black in color with red and black spots, but on the lower sides and stomach, they are generally silver in color. 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 contain deeper and colder waters. Preferred temperatures are 10˚C to 18˚C (50˚F to 64˚F) (Becker, 1983). In addition, brown trout tagging studies indicate that these fish move between the waters of northern Green Bay and Lake Michigan (Toneys, 1999).

Brown trout are most often found along the shore in waters no deeper than 15 m (50 ft) (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 mi) in 1 year. Hatchery-reared trout released in Wisconsin waters generally remained within 24 km (15 mi) of the release point, but some tagged fish after 1 year were found to range up to 323 km (200 mi) (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; crowding and schooling are not tolerated when these fish are not spawning (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, mollusks, frogs, shrimp, salamanders, and other fish. Zooplankton are an important food source for small brown trout (Becker, 1983). Up to about 229 mm (9 in) they are insect feeders and past this length they dominantly (70 percent of the diet) consume 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).

4.4.4.9 Sturgeon

The Menominee Indians have lived in Wisconsin longer than any other tribe. The lake sturgeon is included in this section because it was the most important fish to the Menominee Indians for both cultural and religious reasons. 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). Return of the sturgeon in spring was a cause for religious celebration because of its importance as a food source after the winter, when the supply was typically lowest (Beck, 1995).

Prior to the 1800s, lake sturgeon (*Acipenser fulvescens*) were common and abundant in the Lake Michigan, Lake Superior, and Mississippi River drainage basins (Becker, 1983). Lake sturgeon were also abundant in Green Bay and the larger tributaries, including the Fox-Wolf, Menominee, Peshtigo, and Oconto rivers (USFWS, 1998). Native American populations, especially the Menominee Nation, utilized the sturgeon for various cultural and spiritual purposes and annually celebrated the return of the sturgeon to its ancestral spawning grounds within the Lake Winnebago-Wolf-Upper Fox River system (USFWS, 1995). Areas where sturgeon either spawn or have been observed within the Lower Fox River or Green Bay are shown on Figures 4-1 through 4-4 and 4-10. Because the sturgeon are a threatened species, spawning locations are approximate and are shown as a block representing the nearest township, range and section (Natural Heritage Inventory, 2000).

Following the establishment of the commercial fishing industry, sturgeon were viewed as a nuisance fish because they became entangled in and ripped fishing nets. During this period, they were simply thrown onto the shore and left to rot (Becker, 1983; Beck, 1985). After 1870, a large commercial fishing industry subsequently evolved for sturgeon. The roe was prized for caviar, the flesh was delicious either smoked or fresh, and the high-quality gelatin material isinglass was obtained from the swim bladder.

Due to the aggressive fishing and length of time required for sturgeon to mature and reproduce, the abundance of lake sturgeon had declined so much that by the 1880s and 1890s it was no longer worth pursuing (USFWS, 1998). Along with the loss of suitable spawning habitat and the construction of dams along many of the significant tributaries, especially on the Lower Fox River, sturgeon populations declined to levels from which they have never fully recovered. Becker (1983) recounts that the Lake Michigan sturgeon catch in 1880 was 1,741,600 kg (38,839,600 pounds); in 1966 only 907 kg (2,000 pounds) of sturgeon were taken from the lake. The state of Michigan has listed the lake sturgeon as a threatened species (Table 4-6).

Sturgeon were also valued by Native American populations due to its large size and longevity. Lake sturgeon typically live 50 and 80 years, growing to lengths up to 2.4 meters (8 feet) long and maturing slowly (Becker, 1983; USFWS, 1998). Historical records from the 1800s indicate that lake sturgeon weighing over 45.4 kg (100 pounds) and measuring over 2 meters (6.5 feet) were captured near Milwaukee (USFWS, 1998). Previous researchers found that over 97 percent of sturgeon captured which were more than 30 years old were female (Becker, 1983).

The slow growth and maturity rate of sturgeon may be one reason that significant decreases in sturgeon populations over a very short period have had such a crucial impact on the current and future populations. Males typically mature in about 15 years and are usually about 114 cm (45 inches) at this age. Additionally, most males spawn every 1 to 2 years. However, female sturgeons mature more slowly and spawn less frequently. Females typically mature when they are about 24 to 26 years old and about 140 cm (55 inches) long. Unlike the males, female sturgeon only spawn once every 4 to 6 years and typically produce and release anywhere between 50,000 and 700,000 eggs (Becker, 1983).

Without teeth, sturgeons rely on suction to feed, much like suckers and other bottom-feeding fish. Sturgeon feed on small organisms including insect larvae, snail, leeches, small clams, and other invertebrates. Although not typically preyed upon by other fish, Becker (1983) notes that otter have been noted to drag sturgeon from the water onto the ice of Lake Winnebago in the winter and that suckers, carp, crayfish, and other sturgeon may prey upon the sturgeon eggs.

4.5 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
- Raptors

Some of the most common birds in the region are shown on Table 4-7. The species list (Table 4-7) was developed by the Project Team for use in the RA, based on the species' importance with respect to uptake of PCBs into the food chain within each group and its status as a threatened or endangered species. A brief description of each bird group is presented below.

Information about the probability of sighting a specific bird was taken from Temple, *et al.* (1997), which is a summary of data collected by WDNR, the University of Wisconsin, and the Wisconsin Society for Ornithology. Sightings have been collected by professional and amateur bird watchers using a standardized format since 1982. Figure 4-13 shows the general distribution of the birds within these groups throughout Green Bay (NOAA, 1997c). As with the fish data in Zone 4, bird data obtained from the GLC (2000) did not differentiate specific species. Therefore, locations where birds of concern either nest or have been observed in Green Bay Zone 4 are simply shown as points on Figures 4-13.

4.5.1 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 4-7). These birds typically feed on insects, seeds, and small invertebrates found through foraging along the ground. The passerines listed on Table 4-7 for the Green Bay area include six species of blackbirds, wrens, and sparrows. 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 habitats for these birds are 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, and dependent on local winter weather conditions and food supply (Harrison and Greensmith, 1993). None of the passerines are listed on state or federal endangered/threatened species list (Table 4-7).

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 are typically found in Wisconsin from late February through late November (Temple, *et al.,* 1997). The likelihood of sighting the other birds in this group (Table 4-7) 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). The annual probability of sighting this bird is about 80 percent and they are typically found in Wisconsin from April through September (Temple, *et al.,* 1997).

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

4.5.2 Gulls/Terns

The gulls/terns group for the Green Bay area includes two species of gulls and four species of terns (Table 4-7). All six of these species feed on fish, insects, and eggs, 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 percent 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 migrate to other areas. The terns are typically present in Green Bay from April through October (Temple, *et al.,* 1997).

The Forster's, Common (*Sterna hirundo*), and Caspian (*Sterna caspia*) terns are migratory species of colonial waterbirds that breed in the Great Lakes and generally winter in more southern coastal areas. In Wisconsin, the Caspian, Common, and Forster's terns are endangered species while Caspian and Common terns as threatened species in Michigan (Table 4-7). All three of these terns are protected under the Migratory Bird Treaty Act (Exponent, 1998). Due to the tern's endangered status within Wisconsin, the locations of tern nests in the

Lower Fox River and Green Bay area are presented as blocks on Figures 4-1 through 4-4 and 4-13.

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. The primary nesting locations for Forster's terns are the Bay Port and Kidney Island CDFs, Long Tail Point, and the Oconto Marsh. Common terns primarily nest on Kidney Island and the Pensaukee Dredge Spoil Island while the Caspian tern nesting colonies are on Gravelly and Gull Islands, located just south of Summer Island between Green Bay and Lake Michigan (Stratus, 1999c).

Tern populations have generally been increasing over the past 20 years. From 1978 and 1987 the nesting pairs of Forster's terns 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, 1999c). Although the tern populations continue to increase, the impacts of PCB uptake are evident and well documented (Stratus, 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 were placed at several locations in the state, including Green Bay. The six monitored island platforms in Green Bay indicated feeding, but not nesting activity. For the common tern, fencing and ring-billed gull control have been used to enhance breeding success. However, due to the difficulty in maintaining them, these platforms are no longer placed in these areas (Nikolai, 2000b).

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. 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 CDF (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). Six common tern colony sites are present in Wisconsin and two are in Green Bay: Kidney Island CDF and the Pensaukee Dredge Spoil Island, with an estimated number of breeding pairs of 16 and 75, respectively. Similarly, nine Forster's tern colony sites are located in Wisconsin, and Long Tail Point and the South Oconto Marsh have about 70 and 45 breeding pairs, respectively.

As with the Forster's tern, both inland and coastal populations of Common terns have faced recent historical population declines during 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).

4.5.3 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 percent 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 list.

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 25 percent of their body weight each day and on average weigh 1.9 kg (4.2 pounds). Their primary food is small fish, such as rainbow smelt, alewife and even perch, when available.

Similar to the terns described above, 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. Beginning in the 1950s and continuing through the 1970s, the double-crested cormorant population in the Great Lakes region experienced large population declines, largely from the presence of contaminants. More recently, populations of double-crested cormorants in the Great Lakes region have greatly increased (Weseloh, *et al.,* 1994).

In 1972, the double-crested cormorant was listed as a Wisconsin state endangered species due to the lack of nesting pairs of birds in the state. 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. By 1986, populations in the state increased such that the double-crested cormorant was removed from the Wisconsin state endangered species list.

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 (Matteson, *et al.,* 1998). The largest colonies for double-crested cormorants in Green Bay are Cat, Jack, Hat, and Snake islands (Stratus, 1999c). 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. Cormorant nesting locations along the Lower Fox River and Green Bay are shown on Figures 4-1 through 4-4 and Figure 4-13.

4.5.4Shorebirds

The shorebirds group for the Green Bay area includes eight species of plovers, sandpipers, and snipe (Table 4-7). 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 percent to 25 percent as these species generally migrate further north. Therefore, these birds are generally 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 on Michigan, Wisconsin, and federal endangered species lists (Table 4-7).

4.5.5 Wading Birds

The wading birds group for the Green Bay area includes 13 species of heron, woodcock, rail, egret, bittern, and crane (Table 4-7). As indicated by the name, birds within this group typically feed in shallow, near-shore 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, if necessary, will nest in marshes and lowlands if suitable habitat is not available (Harrison and Greensmith, 1993). Rookeries for both the great blue and black-crowned night herons are located in the Thousand Islands Nature Conservancy as well as in Green Bay (Nikolai, 1998). The herons, woodcock, and crane, 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, and 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 each included on one of the state or federal threatened or endangered species lists (Table 4-7). 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).

4.5.6Waterfowl

The waterfowl of the Green Bay area includes 21 different species (Table 4-7). 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; Harrison and Greensmith, 1993). 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 throughout the year and the annual probability of sighting for these species ranges from 50 percent 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 percent 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 which 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 percent to 60 percent (Temple, *et al.,* 1997). Species which pass through the region, typically found anywhere between March and May and again in October and November, include the canvasback, redhead, and ring-necked ducks, as well as the lesser scaup, northern shoveler, and whistling swan. These species are also fairly common, with sighting probabilities ranging from 35 percent to 55 percent (Temple, et *al.,* 1997). Being migratory in nature, waterfowl are generally protected under the Migratory Bird Treaty Act (Exponent, 1998). 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 water fowl 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 piscivorous birds, like the goldeneye and the mergansers, suggests that the populations are increasing from survey lows observed in the 1960s and 1970s (Nikolai, 1998).

4.5.7 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 piscivorous, 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). Bald eagle and osprey nesting locations (both active and inactive nests) in the Lower Fox River are shown on Figure 4-1 through 4-4 while nesting locations within Green Bay are shown on Figure 4-13. The two falcon species typically hunt other birds or small mammals. Preferring open land, they 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). Of the four species listed on Table 4-7, the eagle and osprey are more common in Wisconsin than the peregrine falcon or merlin. The annual probability of sighting the eagle and osprey is around 55 percent and 45 percent, respectively (Temple, *et al.,* 1997). The likelihood of sighting the two falcons is less than 25 percent, as both are less common in the area. The eagle winters 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 4-7). 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 4-7). These birds are also protected under the Migratory Bird Treaty Act (Exponent, 1998).

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. However, 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 throughout the year, while others are transient and winter in more southern locations (Palmer, 1988). The Green Bay region contains one 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; Meyer, *et al.,* 1997), and includes surveys along the Lower Fox River and Green Bay. These studies have been summarized by the USFWS (Stratus, 1999c). The following section summarizes the Stratus (1999c) analysis of the information taken principally from those reports.

Bald eagle populations have generally been increasing throughout the Great Lakes (Stratus, 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 (Dykstra and Meyer, 1996 citing 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 were 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 (Stratus, 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, 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.

Eagle nesting locations within the Lower Fox River and Green Bay are shown on Figure 4-1 through 4-4 and 4-13, respectively. There are two active nests within the Lower Fox River; one within the Little Lake Butte des Morts Reach (Figure 4-1), and one at Kaukauna in the Appleton to Little Rapids Reach (Figure 4-2).

Within the bay (Figure 4-13), 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 (Dykstra and Meyer, 1996). Mean annual production rates for the inland nests has been at, or exceeded one young per nest annually; this rate is 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, 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. These eagle data are analyzed further in the RA.

4.6 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 a 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 LLBdM 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 was analyzed is included in the RA.

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, 2000a).

4.6.1 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 research which 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.

4.6.1.1 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 m (660 ft) 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 provides 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 WISCNLAND GIS maps of the project area and are shown for the Lower Fox River on Figures 4-14 through 4-17. 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

- **Unsuitable**: aquatic beds/flats, open water, barren, 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 LLBdM Reach and between Appleton and Kaukauna is characterized by Exponent as either "poor" or "unsuitable" on Figures 4-14 and 4-15, 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 4-15 and 4-16, respectively). Mink habitat suitability in the De Pere to Green Bay Reach is largely characterized as "unsuitable" (Figure 4-17), which is similar to the LLBdM Reach.

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, (Figures 4-18 and 4-19). The shoreline in Green Bay zones 2A and 3A, on the west side, are generally characterized as "marginal to good" (Figures 4-18 and 4-19, 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 4-18). 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 4-19).

4.6.1.2 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 effect both wild and domesticated mink populations.

4.6.1.3 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 1998-99 (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.

4.6.2Otter

WDNR harvest records for 1998-99 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 1998-99. 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 1998-99 harvest records suggest that this trend continues (WDNR, 1999b).

4.7 Endangered and Threatened Species

A number of different animals have been or are currently on the Wisconsin, Michigan, or Federal Endangered and Threatened Species List. According to the 1973 Endangered Species Act, the term endangered species means “any species which is in danger of extinction throughout all or a significant portion of its range” while a threatened species is “any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.”

Listed endangered or threatened animals which have historically been found in the vicinity of the Lower Fox River or Green Bay include: ospreys, Common terns, Forster's terns, Caspian terns, and great egret (Matteson, *et al.,* 1998). The ospreys, Common terns, and Forster's terns have nested along the Lower Fox River as well as at upstream locations in Lake Winnebago, Lake Butte des Morts, and Lake Poygan. The osprey have been sighted near Kaukauna and have attempted to nest in the vicinity of Combined Locks, while the terns have been observed farther upstream. Additionally, Common, Caspian, and Forster's terns as well as great egrets 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).

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, but are not currently listed by state or federal agencies. WDNR also reported a bed of clams or mussels which may be threatened. The sediment bed which these clams/mussels inhabit is approximately 20 feet wide and 100 feet long and it is located near the mouth of Mud Creek in the Lower Fox River (Szymanski, 1998).

The endangered and threatened mammals, fish, and birds of the region are listed below.

Endangered/Threatened Species in Wisconsin & Michigan

List	Endangered	Threatened
Mammals		
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
Fish		
Wisconsin	None	None
Michigan	None	Lake Sturgeon, Sauger
Federal	None	None
Birds		
Wisconsin	Peregrine Falcon, Caspian Tern, Common Tern, Foster' Tern, Piping Plover, and Snowy Egret	Osprey and Yellow Rail
Michigan	Peregrine Falcon, Piping Plover, and King Rail	Bald Eagle, Merlin, Osprey, Caspian Tern, Common Tern, Least Brittern, and Yellow Rail
Federal	Peregrine Falcon, Piping Plover, and King Rail	Bald Eagle and Piping Plover

4.8 Section 4 Figures and Tables

Figures and tables for Section 4 follow this page, and include:

Figure 4-1 Lower Fox River Wetland, Habitat, and Animal Distribution: Little Lake Butte des Morts Reach

Figure 4-2 Lower Fox River Wetland, Habitat, and Animal Distribution: Appleton to Little Rapids Reach

Figure 4-3 Lower Fox River Wetland, Habitat, and Animal Distribution: Little Rapids to De Pere Reach

Figure 4-4 Lower Fox River Wetland, Habitat, and Animal Distribution: De Pere to Green Bay Reach

Figure 4-5 Wetland Distribution: Green Bay Zones 2 and 3

Figure 4-6 Wetland Distribution: Green Bay Zone 4

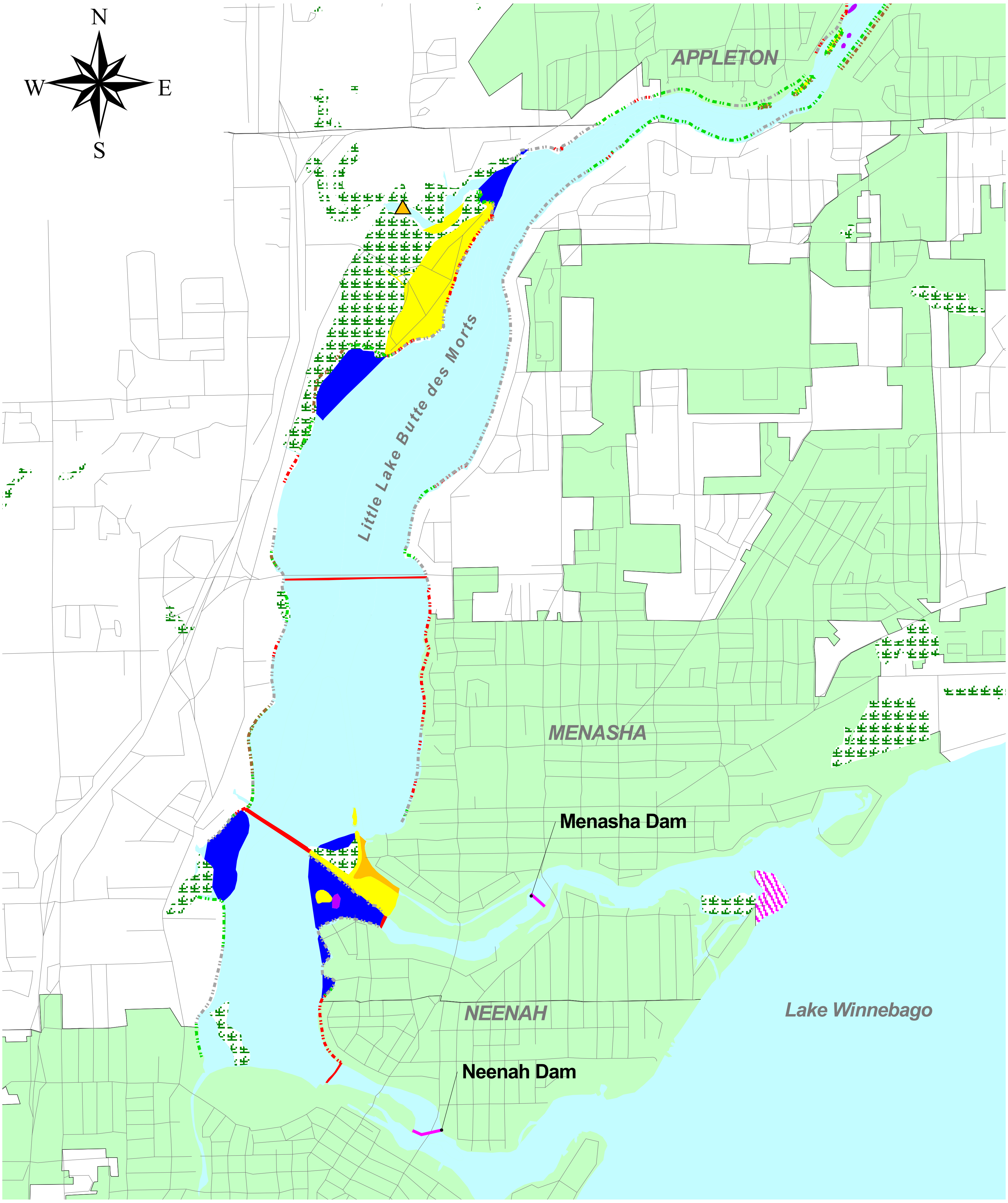
Figure 4-7 Wetland Losses in Green Bay: Duck Creek, Cat Island Chain, and Long Tail Point

Figure 4-8 Green Bay Spawning Areas by Fish Types: Salmon/Trout and Benthic Fish

Figure 4-9 Green Bay Spawning Areas by Fish Types: Pelagic and Game Fish

Figure 4-10	Green Bay Spawning Areas by Fish Species: Walleye, Yellow Perch, and Sturgeon
Figure 4-11	Green Bay Spawning Areas by Fish Species: Carp and Alewife
Figure 4-12	Green Bay Spawning Areas by Fish Species: Emerald Shiners and Gizzard Shad
Figure 4-13	Distribution of Birds in Green Bay: Select Species and Groups
Figure 4-14	Lower Fox River Mink Habitat Suitability: Little Lake Butte des Morts Reach
Figure 4-15	Lower Fox River Mink Habitat Suitability: Appleton to Little Rapids Reach
Figure 4-16	Lower Fox River Mink Habitat Suitability: Little Rapids to De Pere Reach
Figure 4-17	Lower Fox River Mink Habitat Suitability: De Pere to Green Bay Reach
Figure 4-18	Green Bay Mink Habitat Suitability: Zone 2
Figure 4-19	Green Bay Mink Habitat Suitability: Zone 3

Table 4-1	Major Green Bay Wetland Areas/Complexes
Table 4-2	Lower Fox River Habitats
Table 4-3	Lower Fox River Shoreline and Substrate Types
Table 4-4	Lower Fox River Fish Species Composition
Table 4-5	Lower Fox River Fish Populations in the De Pere to Green Bay Reach
Table 4-6	Green Bay Fish Species
Table 4-7	Lower Fox River and Green Bay Bird Species



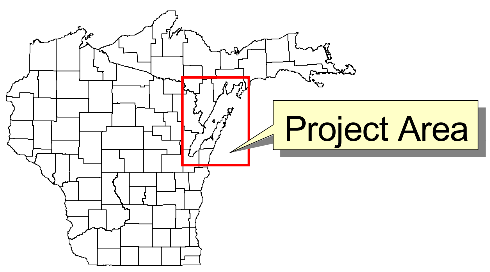
Physical Habitat Features
- Bridge
- Cuts, Coves, Backwaters
- Dam Riffles
- Island
- Lock Channel
- Submerged piling, ruin, rock
- Tributary

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

- Wetlands
- Bald Eagle Nesting Sites

Threatened or Endangered Resources
- Lake Sturgeon
- Dam Locations
- Roads
- Water

Civil Divisions
- City
- Township
- Village

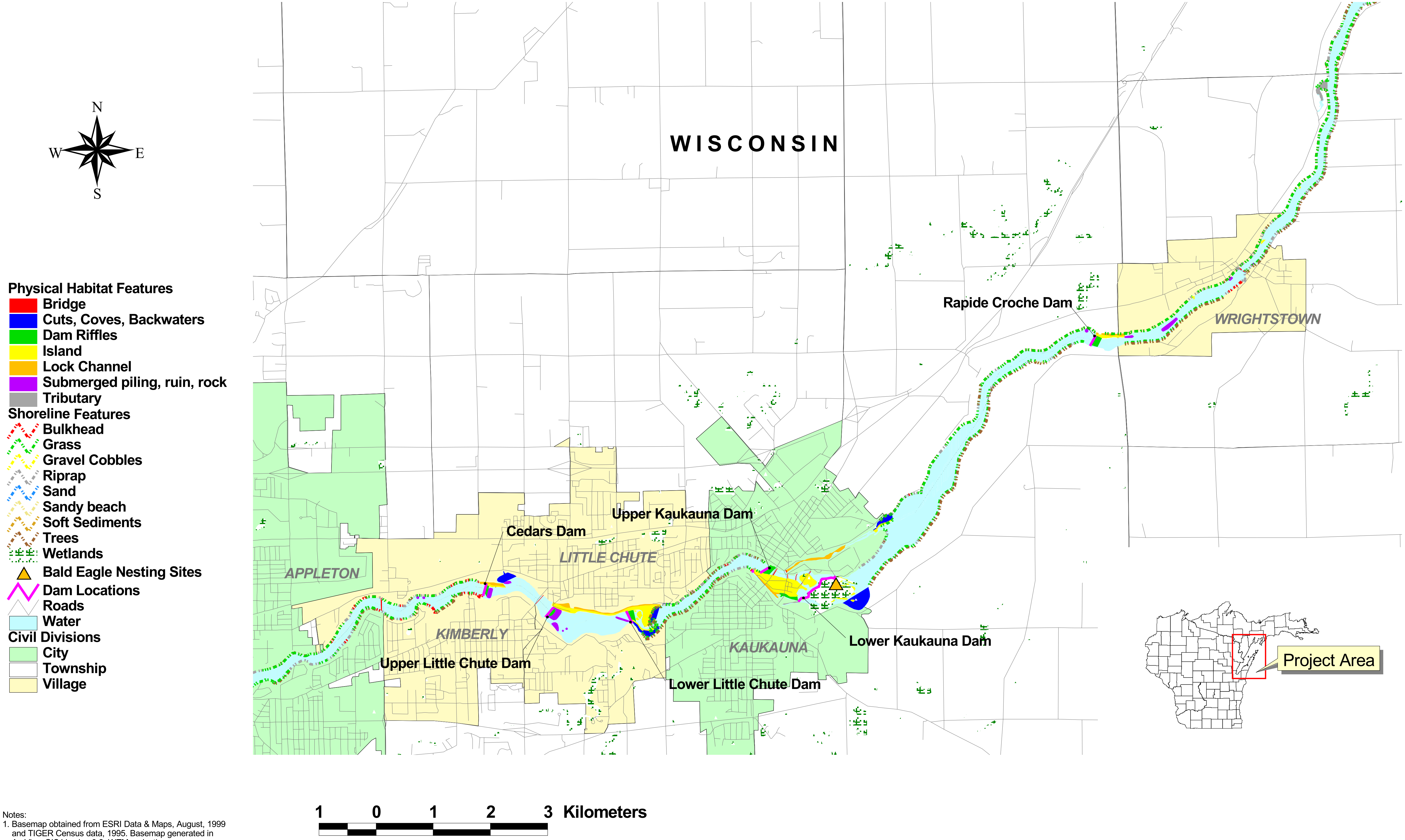


0.5 0 0.5 1 Kilometers

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	Remedial Investigation Report	Lower Fox River Wetland, Habitat, and Animal Distribution: Little Lake Butte des Morts Reach	REFERENCE NO: RI-14414-340-4-1
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE 4-1	APPROVED: AGF



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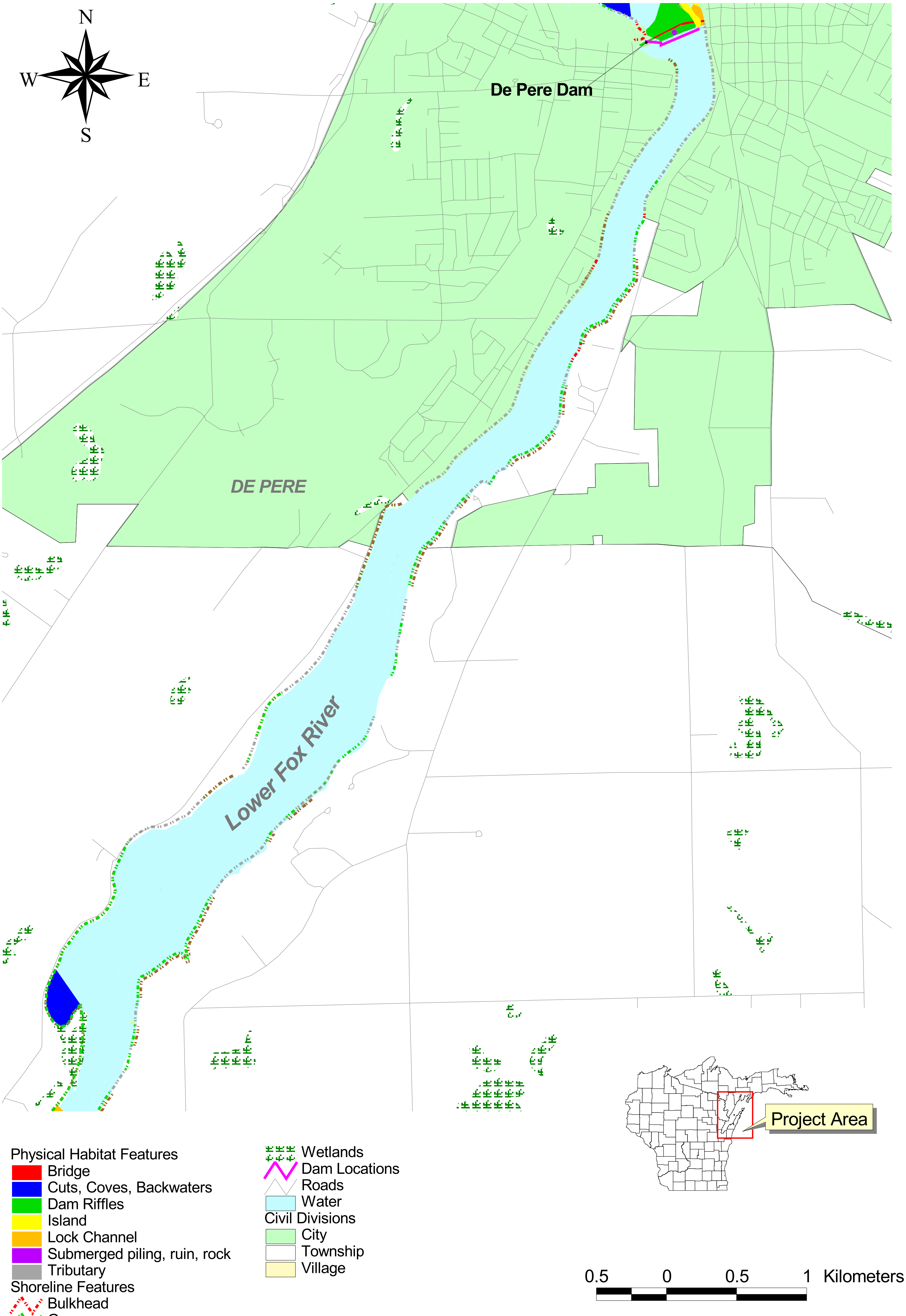
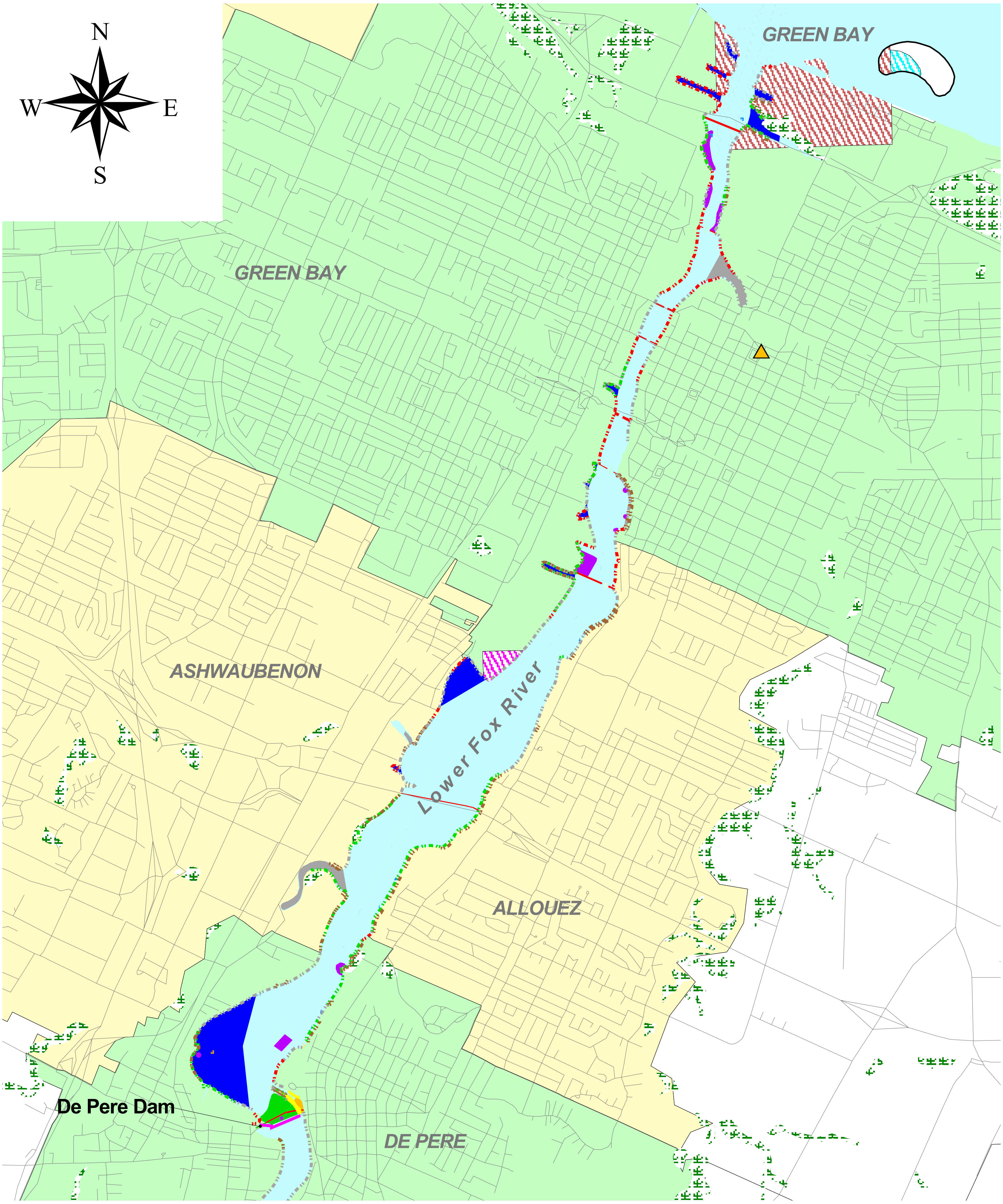
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Threatened and endangered resources data obtained from Natural Heritage Inventory, WDNR Endangered Resources Program, 1999.
3. Wetlands data obtained from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

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Lower Fox River Wetland, Habitat, and Animal Distribution: Appleton to Little Rapids Reach FIGURE 4-2	REFERENCE NO: RI-14414-340-4-2 CREATED BY: SCJ PRINT DATE: 3/7/01 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. 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	Remedial Investigation Report	Lower Fox River Wetland, Habitat, and Animal Distribution: Little Rapids to De Pere Reach	REFERENCE NO: RI-14414-340-4-3
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE 4-3	APPROVED: AGF



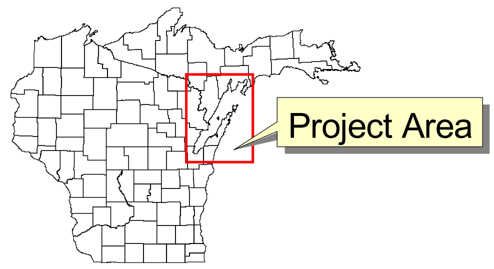
Physical Habitat Features
- Bridge
- Cuts, Coves, Backwaters
- Dam Riffles
- Island
- Lock Channel
- Submerged piling, ruin, rock
- Tributary

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



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.

1 0 1 Kilometers

0.5 0 0.5 1 Miles

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Natural Resource Technology

Remedial Investigation Report

Lower Fox River Wetland, Habitat, and Animal Distribution: De Pere to Green Bay Reach

FIGURE 4-4

REFERENCE NO: RI-14414-340-4-4
CREATED BY: SCJ
PRINT DATE: 3/7/01
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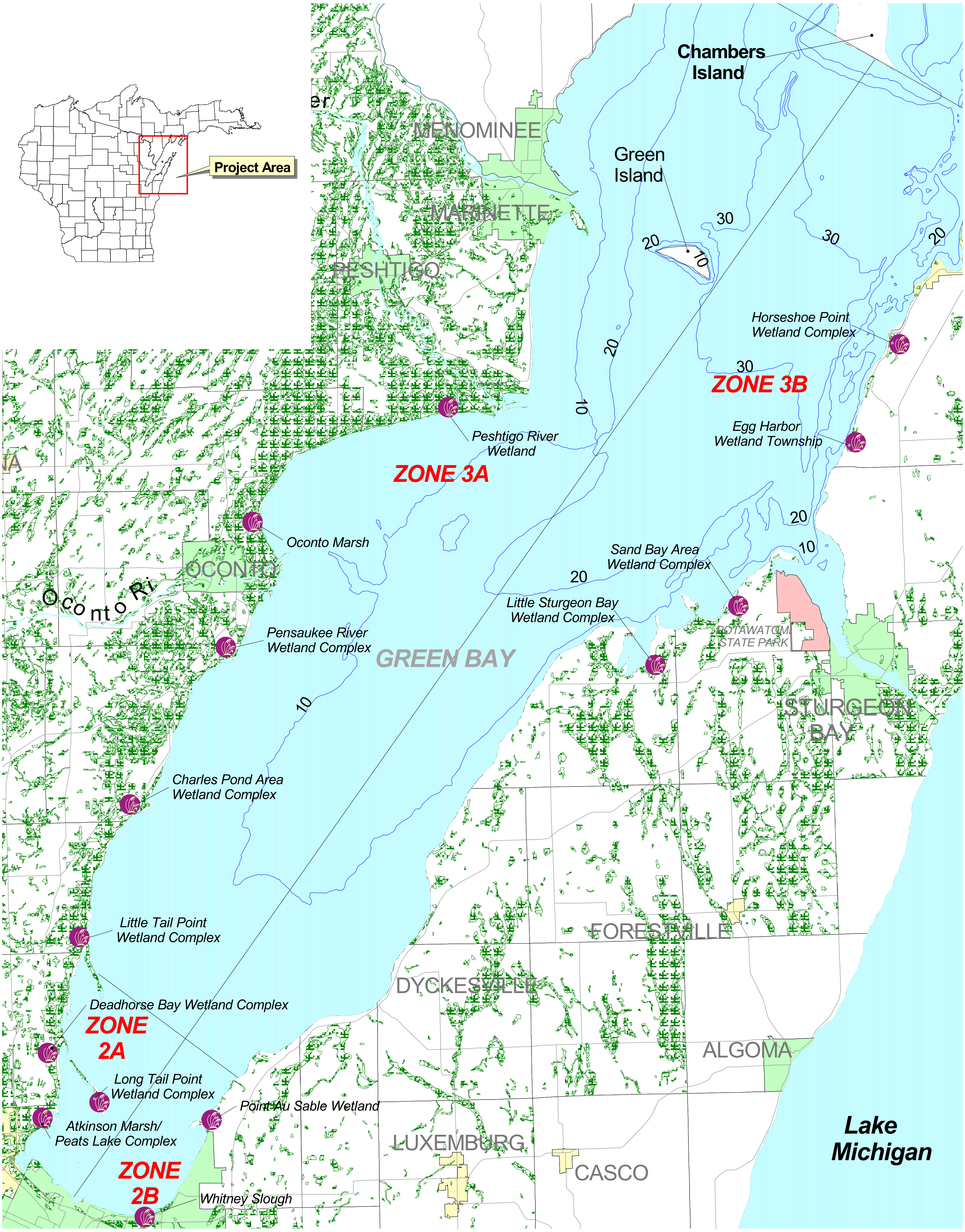


Wetland Areas > 40 Hectares (100 acres)
Bathymetry Contours (10 m)
Roads
Wetlands
Wisconsin State Parks
Water
Civil Divisions
City
Township
Village

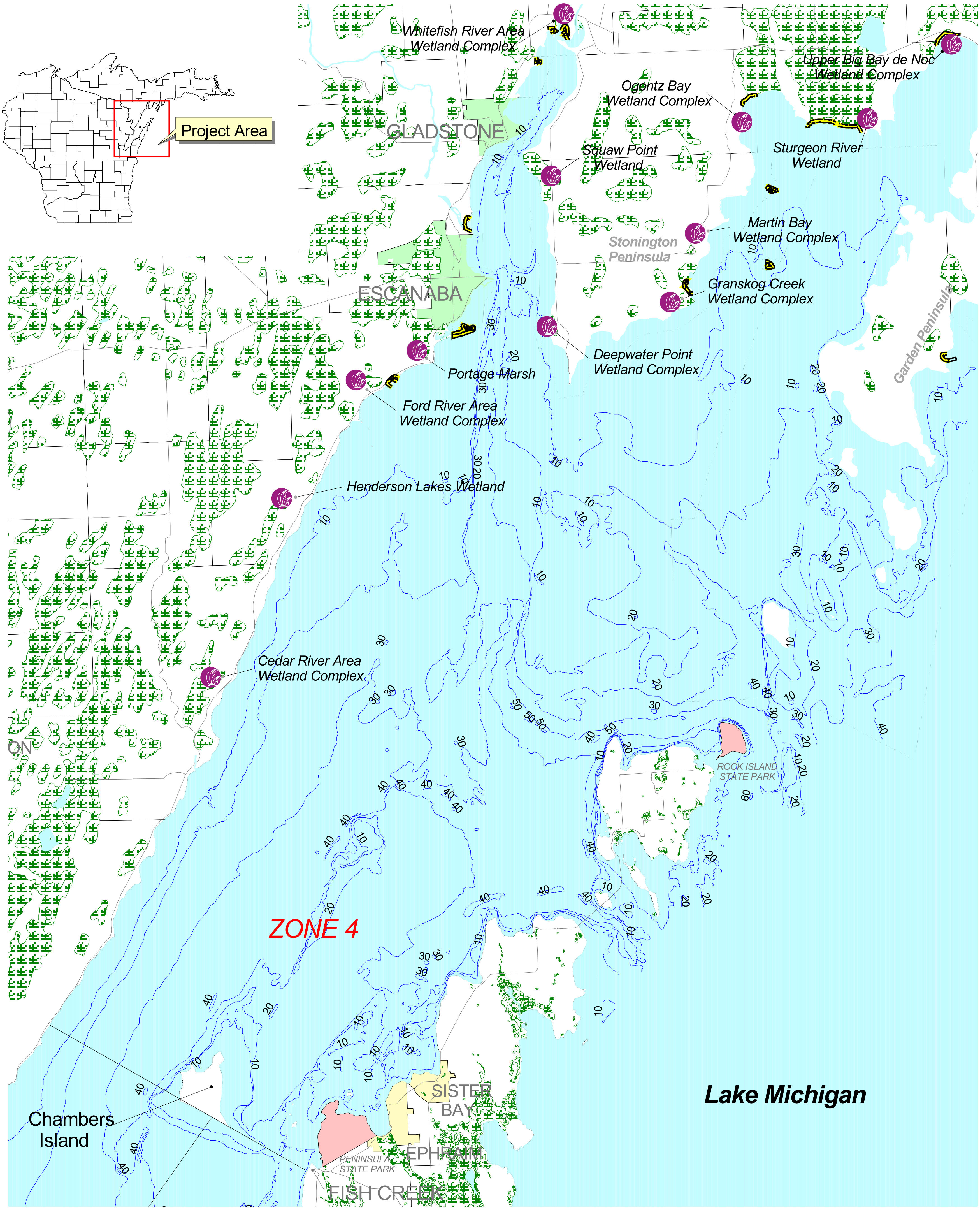
5 0 5 10 Kilometers

5 0 5 Miles

N E S W

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	Natural Resource Technology	Remedial Investigation Report	Wetland Distribution: Green Bay Zones 2 & 3	DRAWING NO: RI-14414-340-4-5
			FIGURE 4-5	PRINT DATE: 1/23/01
				CREATED BY: SCJ
				APPROVED: AGF



Wetland Areas > 40 Hectares (100 acres)
Bathymetry Contours (10 m)
Roads
Delta County Environmental Areas
Water
Wetlands
Area Parks
Civil Divisions
City
Township
Village

5 0 5 10 15 Kilometers

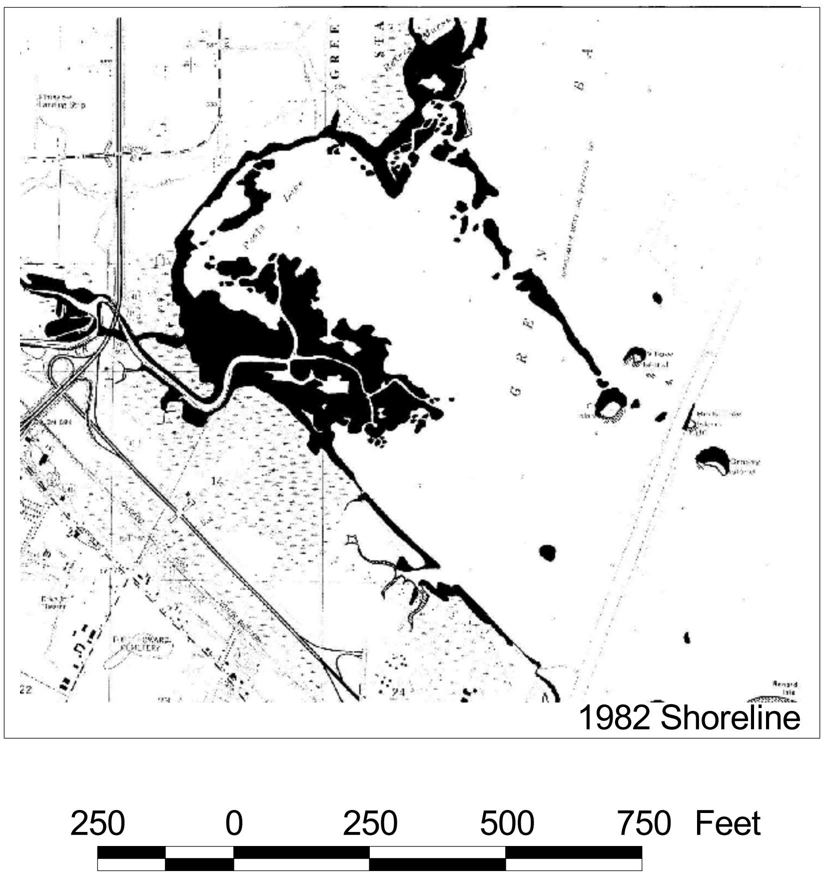
5 0 5 10 Miles

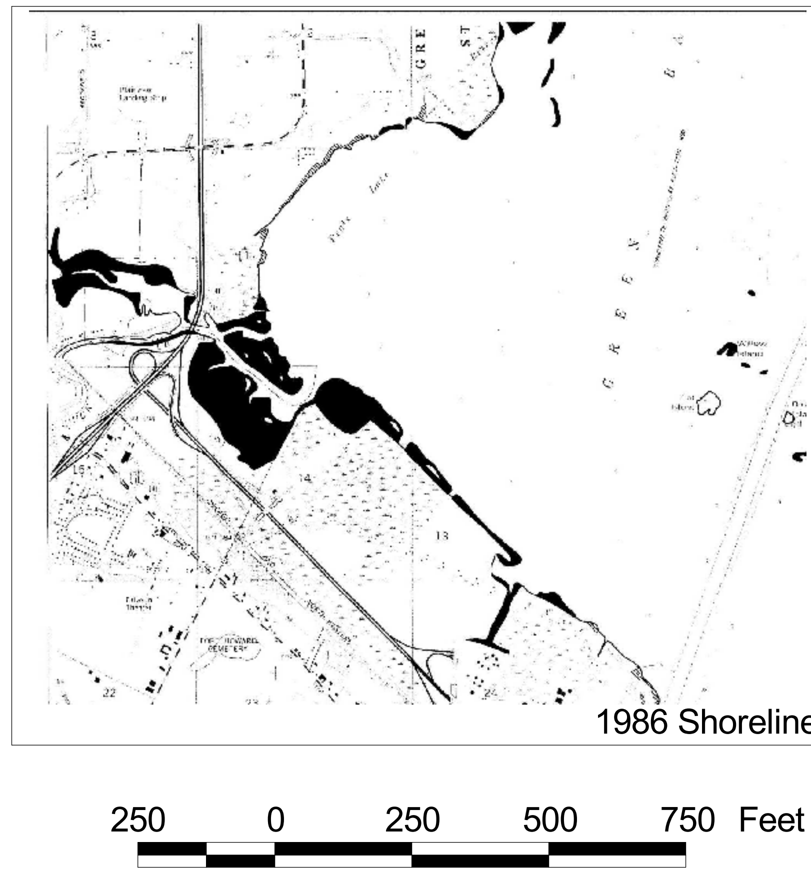
N
W E
S

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.

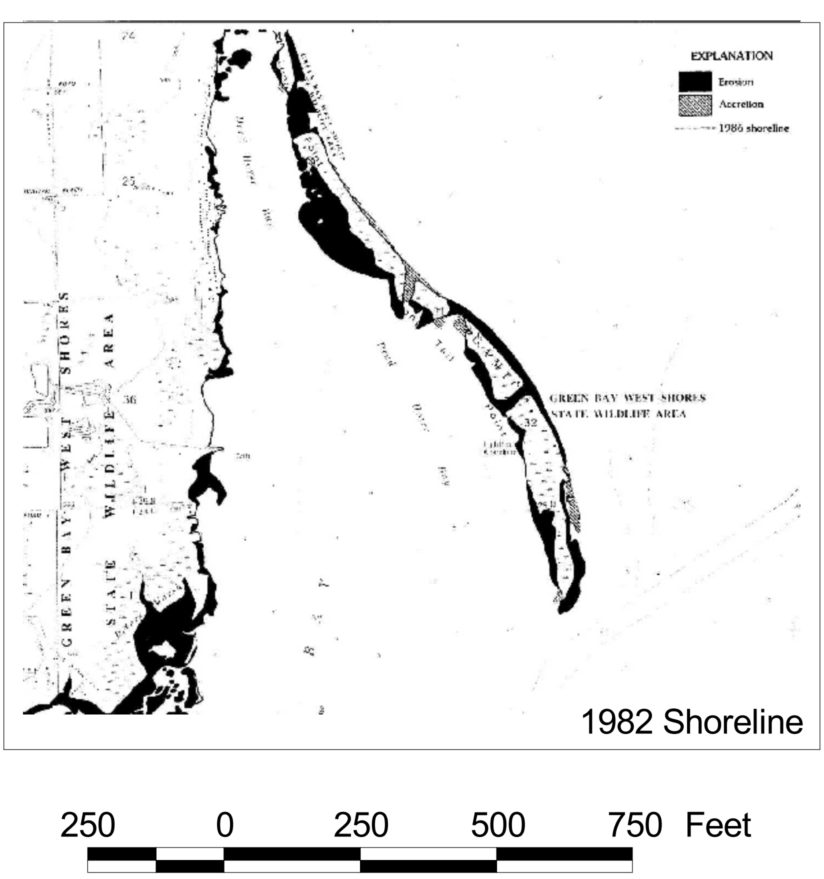
ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Wetland Distribution: Green Bay Zone 4	DRAWING NO: RI-14414-340-4-6
				PRINT DATE: 1/23/01
				CREATED BY: SCJ
			FIGURE 4-6	APPROVED: AGF

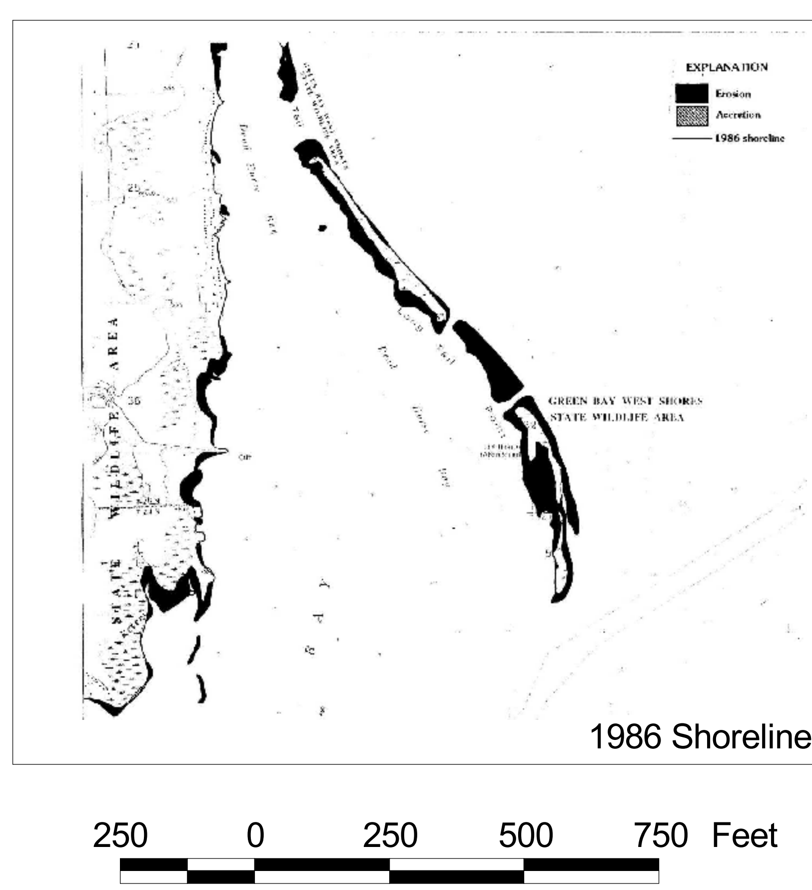
Duck Creek and Cat Island Chain Area





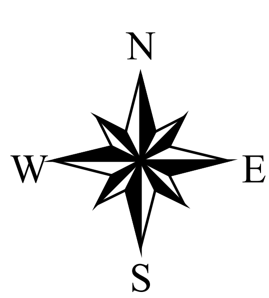
Long Tail Point Area

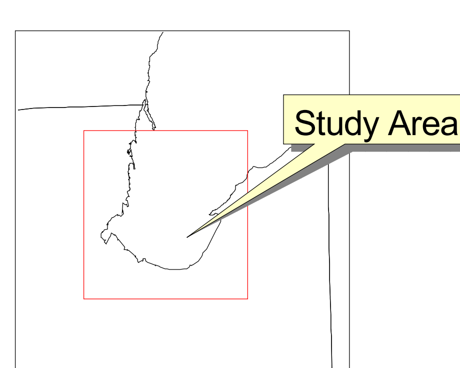




Wetland Losses

Wetland Gains





Reference: G.L. Schideler, USGS 1994
Map MF - 2254

ThermoRetec
Smart Solutions. Positive Outcomes.

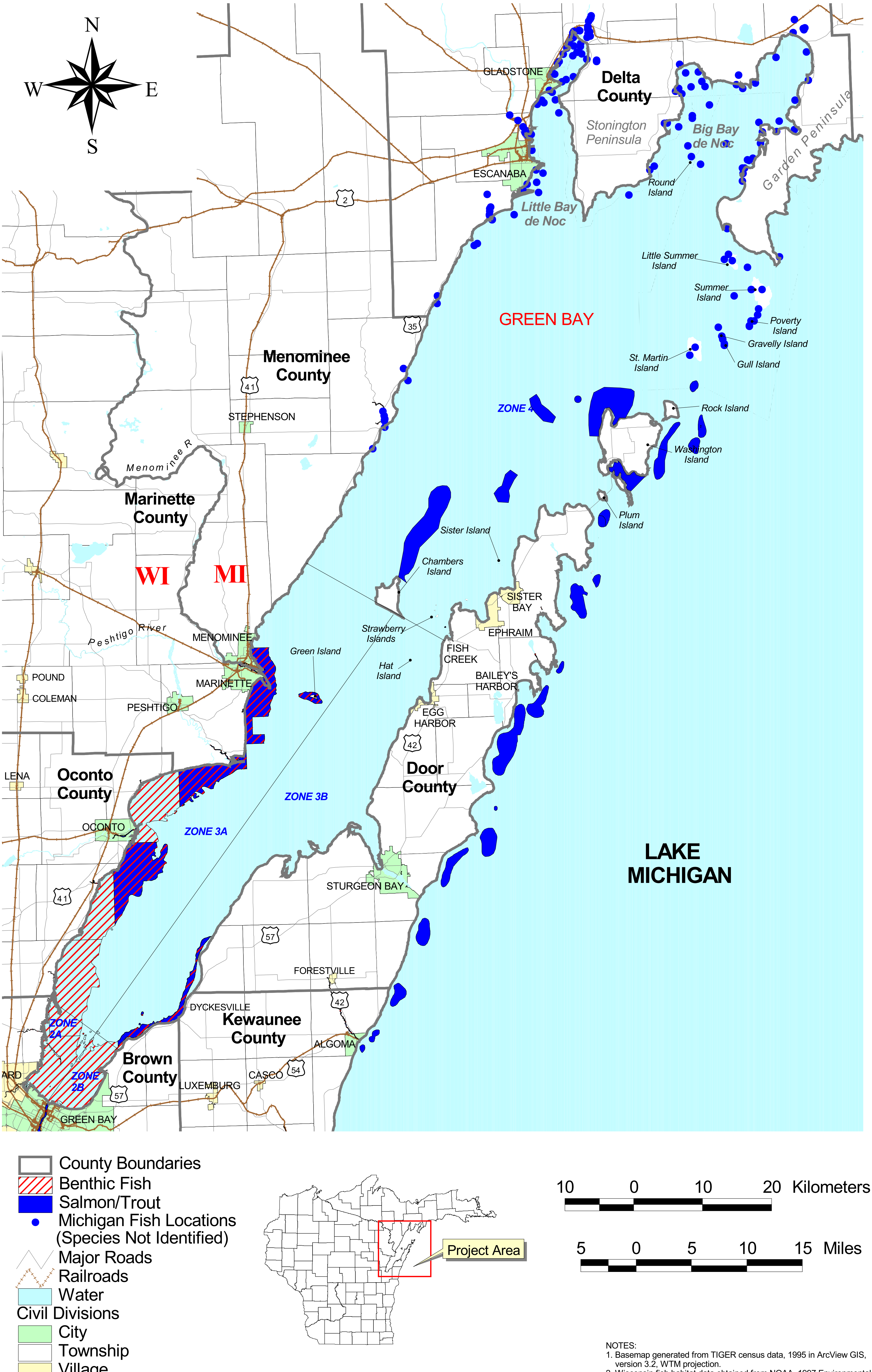
Natural Resource Technology

Remedial Investigation Report

Wetland Losses in Green Bay:
Duck Creek, Cat Island Chain,
& Long Tail Point

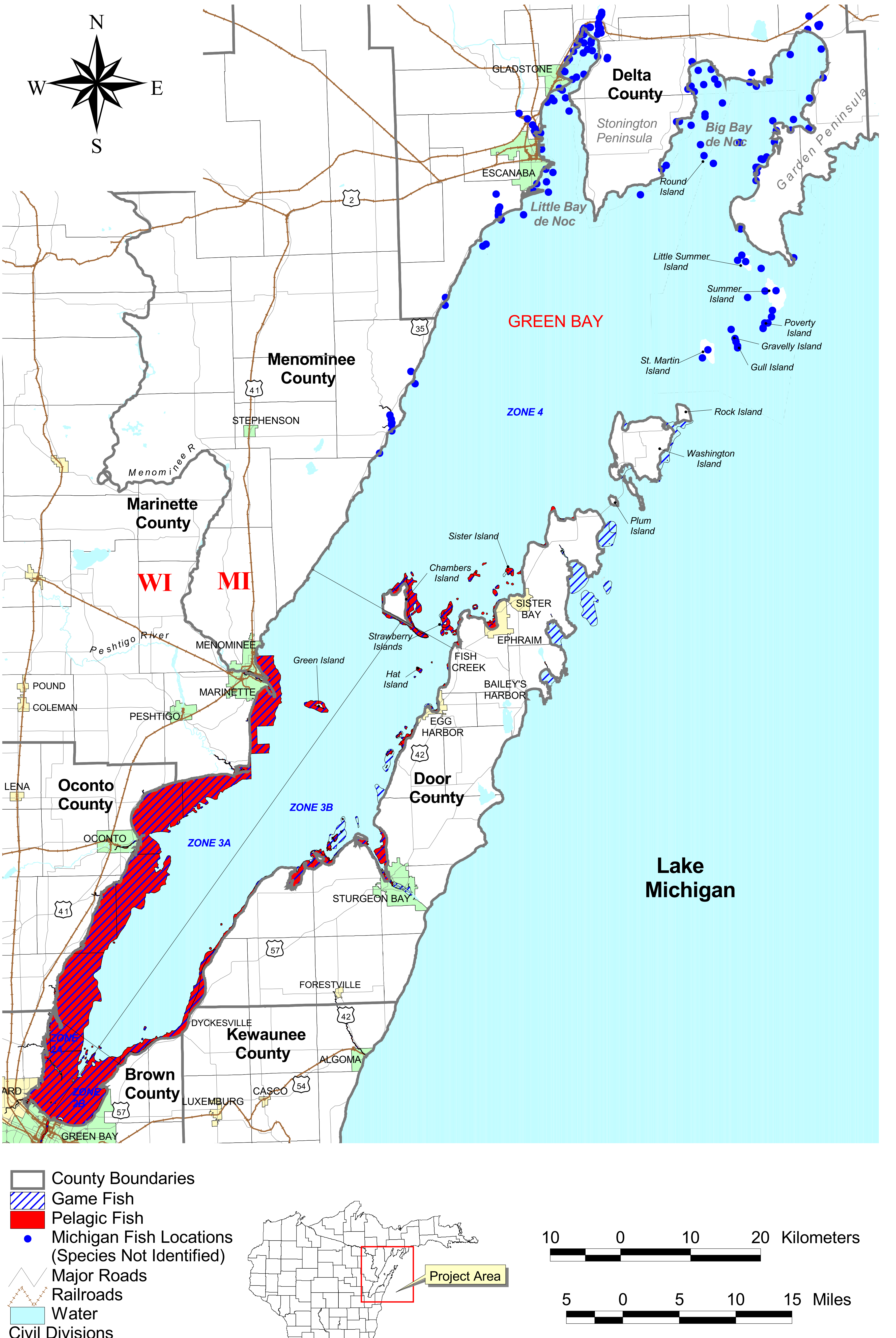
FIGURE 4-7

DRAWING NO: RI-4414-340-4-7
PRINT DATE: 3/7/01
CREATED BY: SCJ
APPROVED: AGF



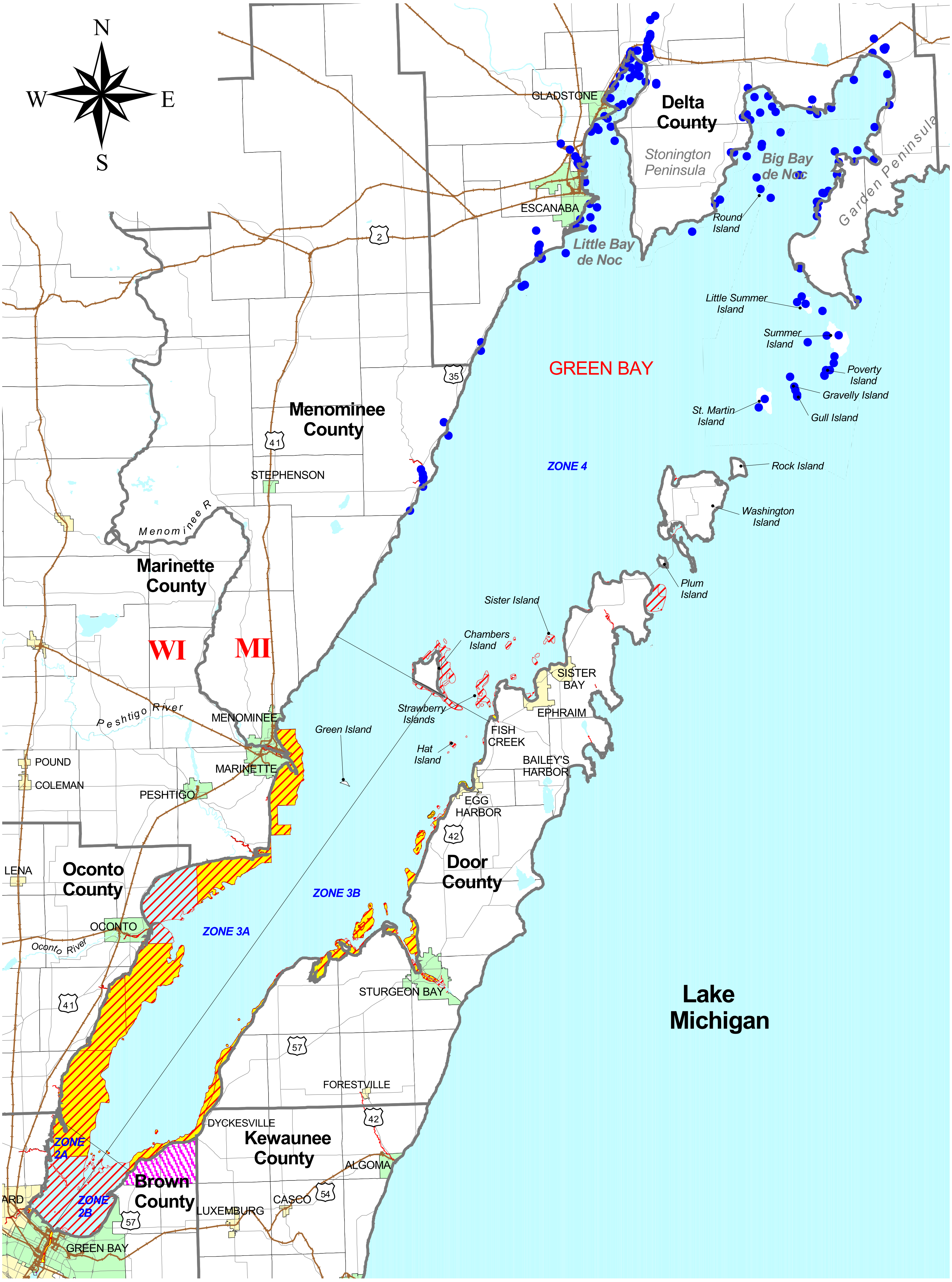
NOTES:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, version 3.2, WTM projection.
2. Wisconsin fish habitat data obtained from NOAA, 1997 Environmental Sensitivty Index Metadata, and lake trout data obtained from U. of Wisconsin Sea Grant Institute, 1980.
3. Michigan fish locations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

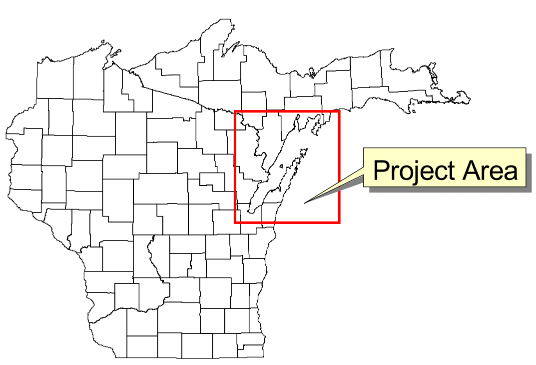
ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Green Bay Spawning Areas by Fish Types: Salmon/Trout and Benthic Fish	DRAWING NO: RI-4414-340-4-8
				PRINT DATE: 3/7/01
				CREATED BY: SCJ
			FIGURE 4-8	APPROVED: AGF



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.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Green Bay Spawning Areas by Fish Types: Pelagic and Game Fish	DRAWING NO: RI-4414-340-4-9
				PRINT DATE: 1/23/01
				CREATED BY: SCJ
			FIGURE 4-9	APPROVED: AGF

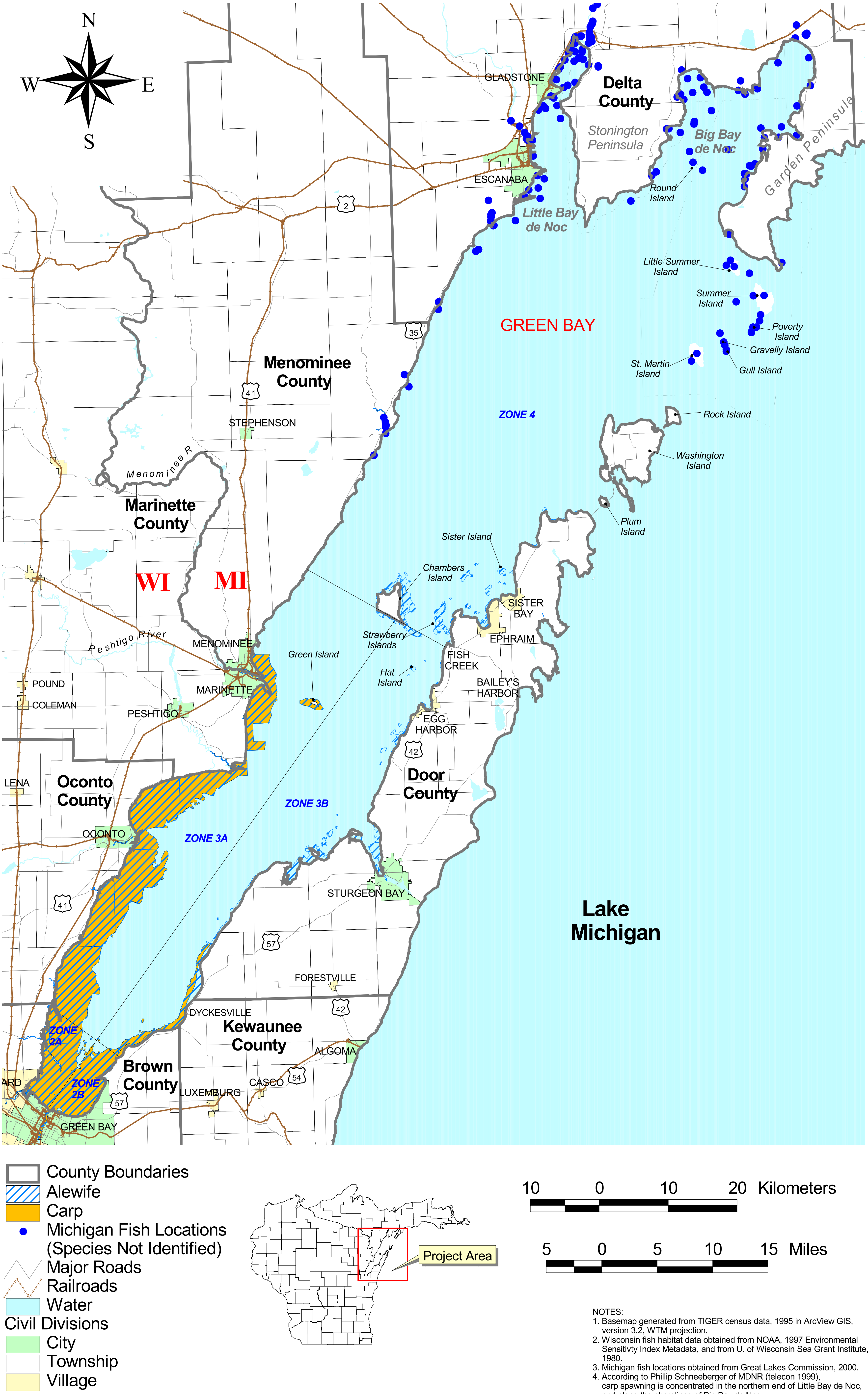




NOTES:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, version 3.2, WTM projection.
2. Wisconsin fish habitat data obtained from NOAA, 1997 Environmental Sensitivty Index Metadata, and lake trout data obtained from U. of Wisconsin Sea Grant Institute, 1980.
3. Michigan fish locations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

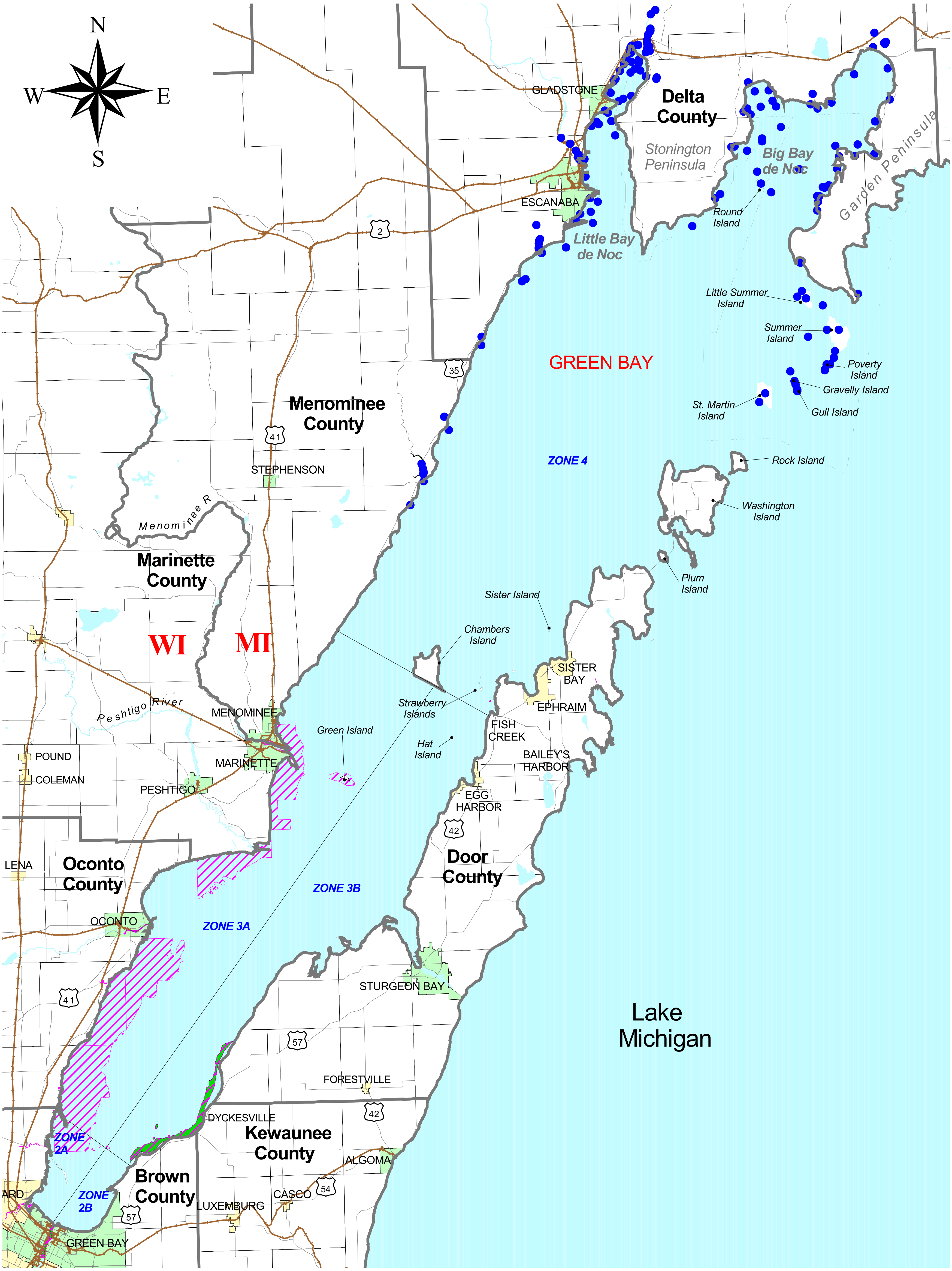
ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Green Bay Spawning Areas by Fish Species: Walleye, Yellow Perch, and Sturgeon	DRAWING NO: RI-4414-340-4-10 PRINT DATE: 3/7/01 CREATED BY: SCJ APPROVED: AGF

FIGURE 4-10

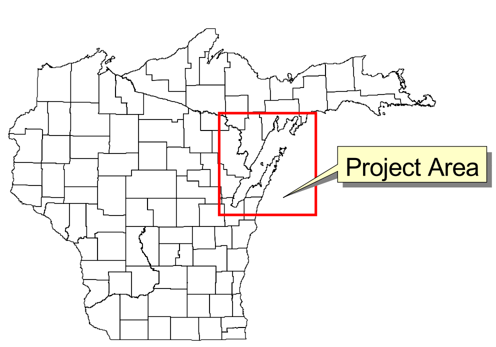


NOTES:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, version 3.2, WTM projection.
2. Wisconsin fish habitat data obtained from NOAA, 1997 Environmental Sensitivty Index Metadata, and from U. of Wisconsin Sea Grant Institute, 1980.
3. Michigan fish locations obtained from Great Lakes 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	Remedial Investigation Report	Green Bay Spawning Areas by Fish Species: Carp and Alewife	DRAWING NO: RI-4414-340-4-11
				PRINT DATE: 3/7/01
				CREATED BY: SCJ
			FIGURE 4-11	APPROVED: AGF



County Boundaries
Gizzard Shad
Emerald Shiner
Michigan Fish Locations (Species Not Identified)
Major Roads
Railroads
Water
Civil Divisions
City
Township
Village

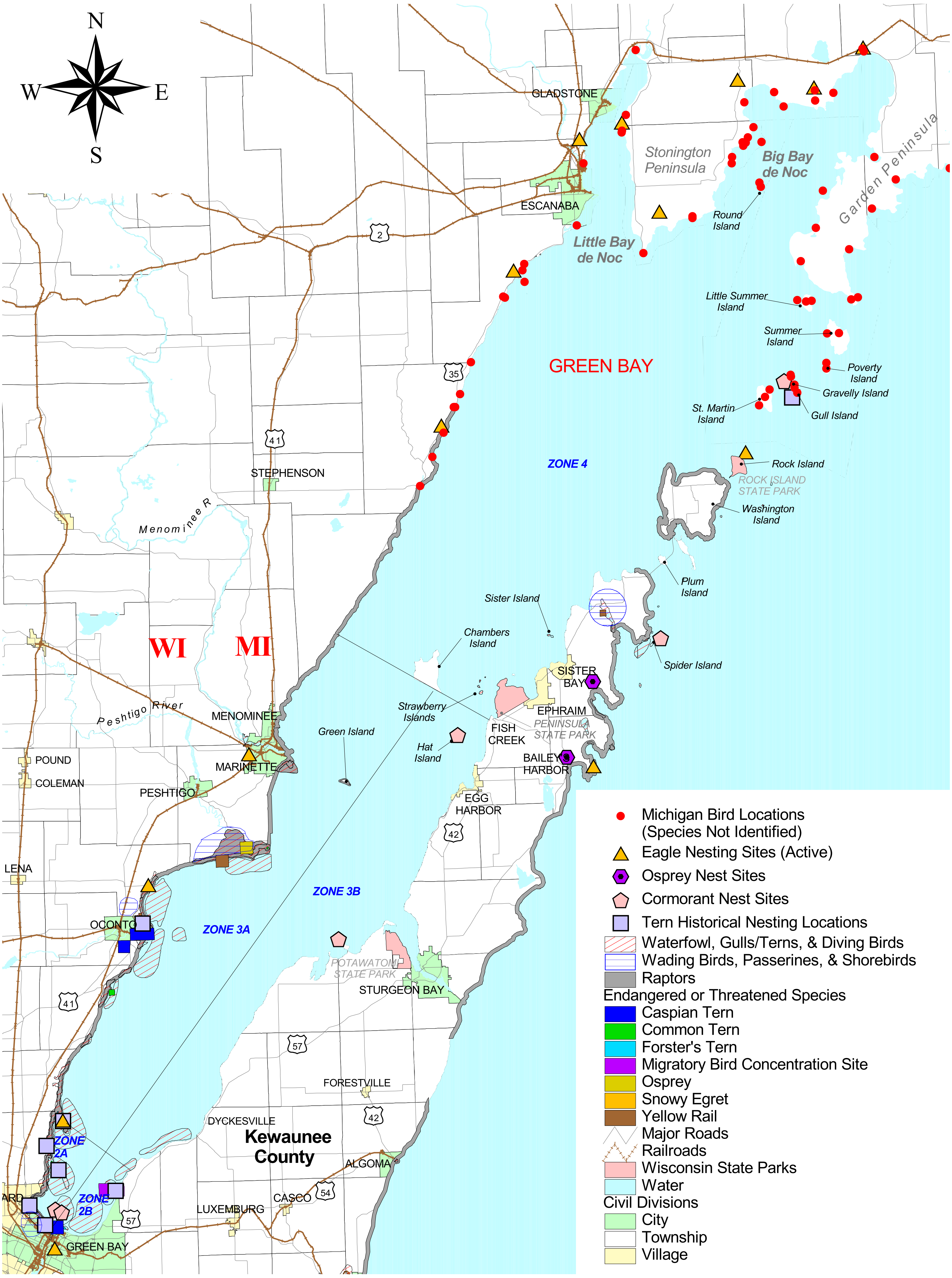


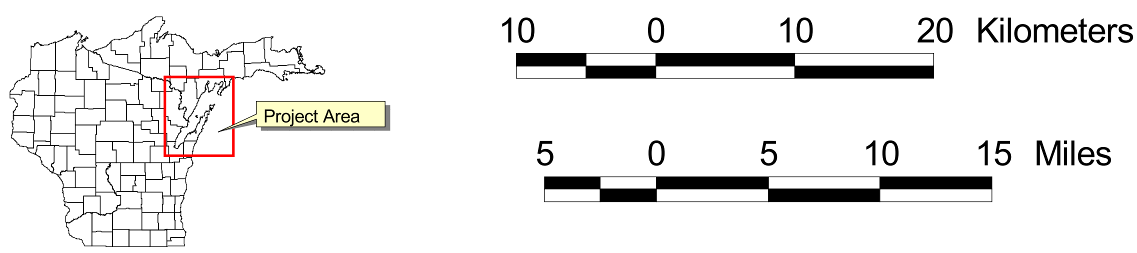
10 0 10 20 Kilometers

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.

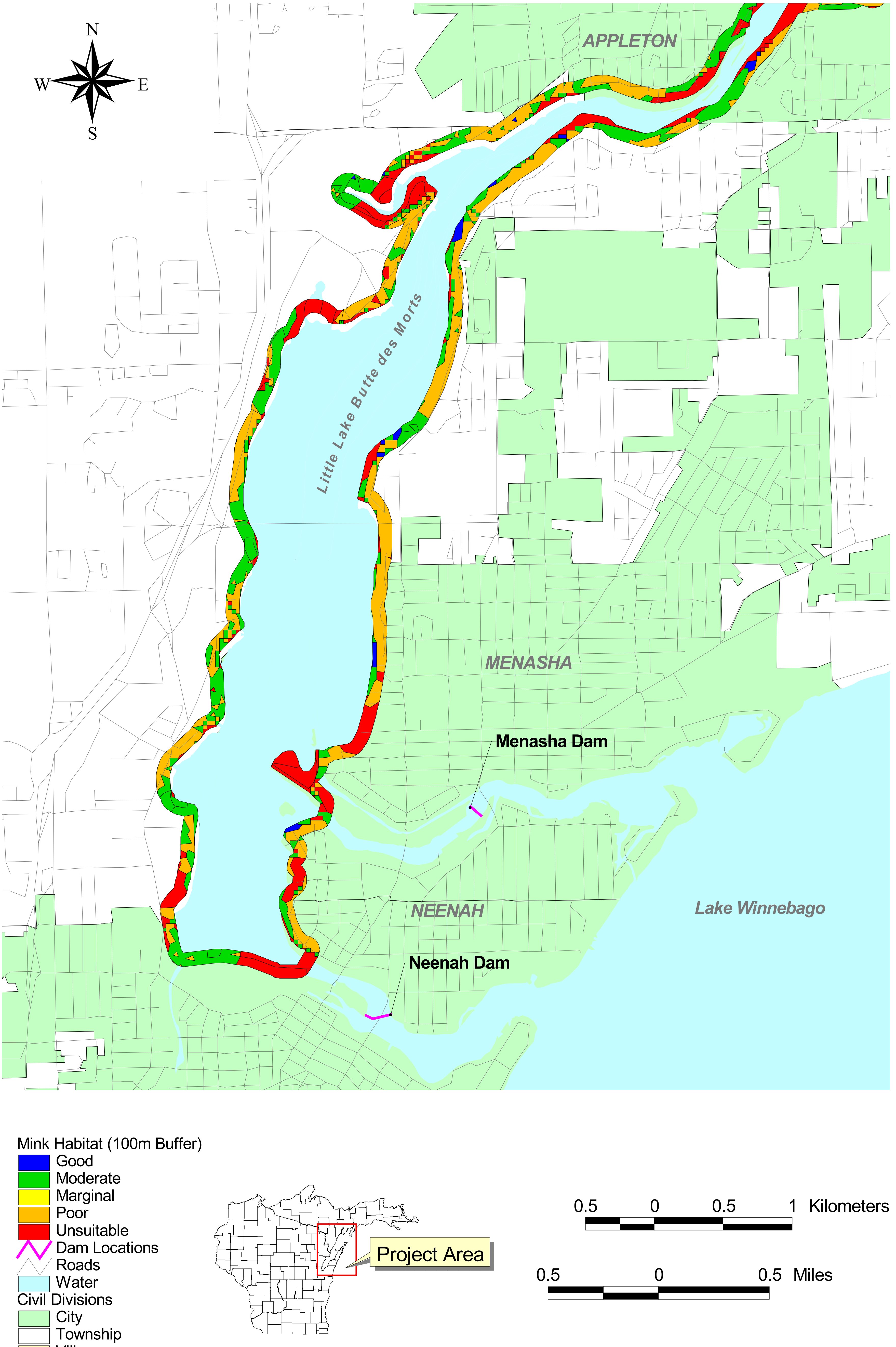
ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Green Bay Spawning Areas by Fish Species: Emerald Shiners and Gizzard Shad	DRAWING NO: RI-4414-340-4-12 PRINT DATE: 3/7/01 CREATED BY: SCJ
			FIGURE 4-12	APPROVED: AGF





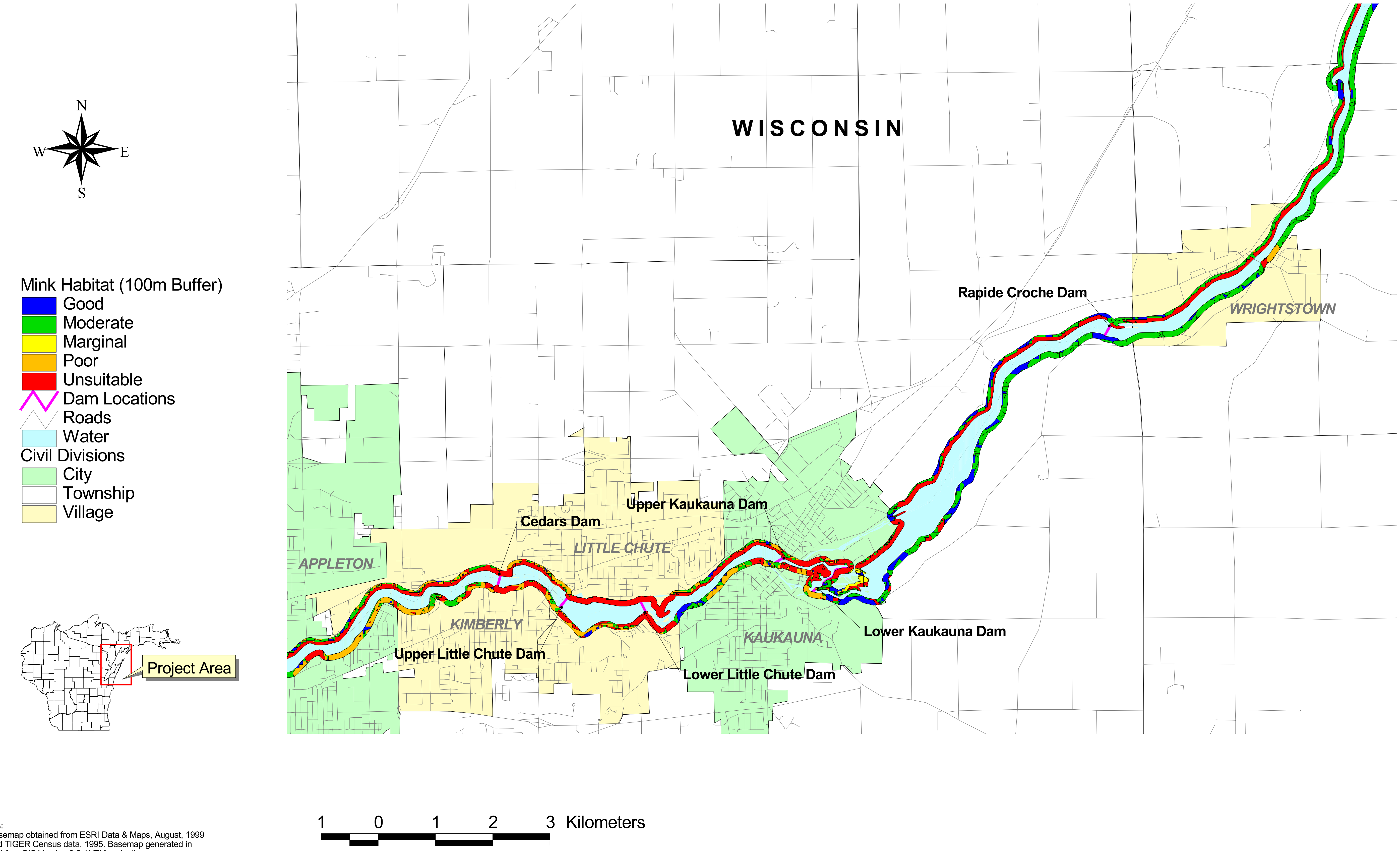
NOTES:
1. Basemap generated from TIGER census data, 1995 in ArcView GIS, version 3.2, WTM projection.
2. Wisconsin bird habitat data obtained from NOAA, 1997 Environmental Sensitivty Index Metadata, and from U. of Wisconsin Sea Grant Institute, 1980.
3. Michigan bird locations obtained from Great Lakes 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	Remedial Investigation Report	Distribution of Birds in Green Bay: Select Species and Groups	DRAWING NO: RI-4414-340-4-13
				PRINT DATE: 3/7/01
				CREATED BY: SCJ
			FIGURE 4-13	APPROVED: AGF



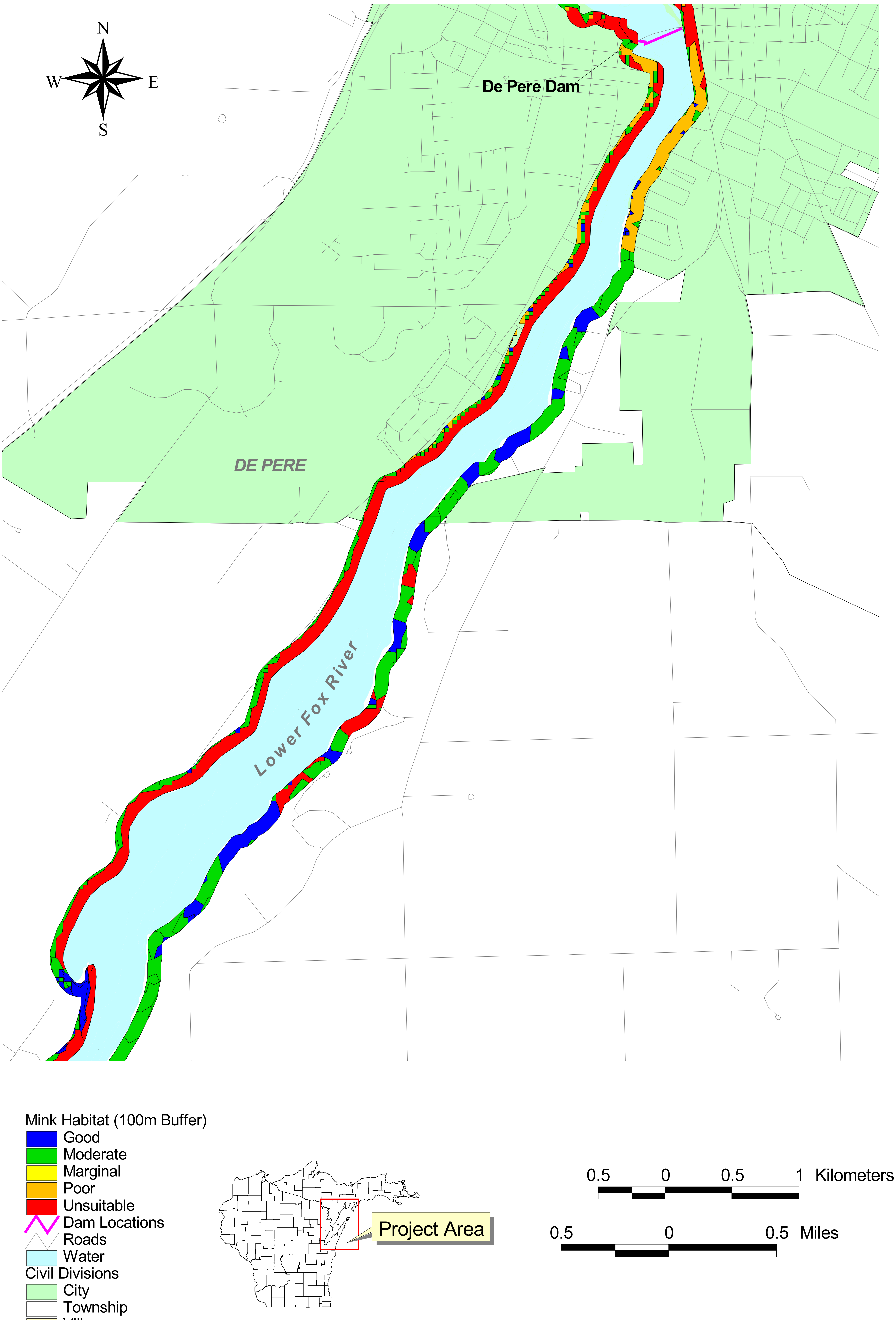
Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Mink data obtained from Exponent, 2000.
3. Suitability Index based on WISCLAND land use maps and WDNR wetland maps. Good = forest shrub/scrub or 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	Remedial Investigation Report	Lower Fox River Mink Habitat Suitability: Little Lake Butte des Morts Reach	REFERENCE NO: RI-14414-340-4-14
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE 4-14	APPROVED: AGF



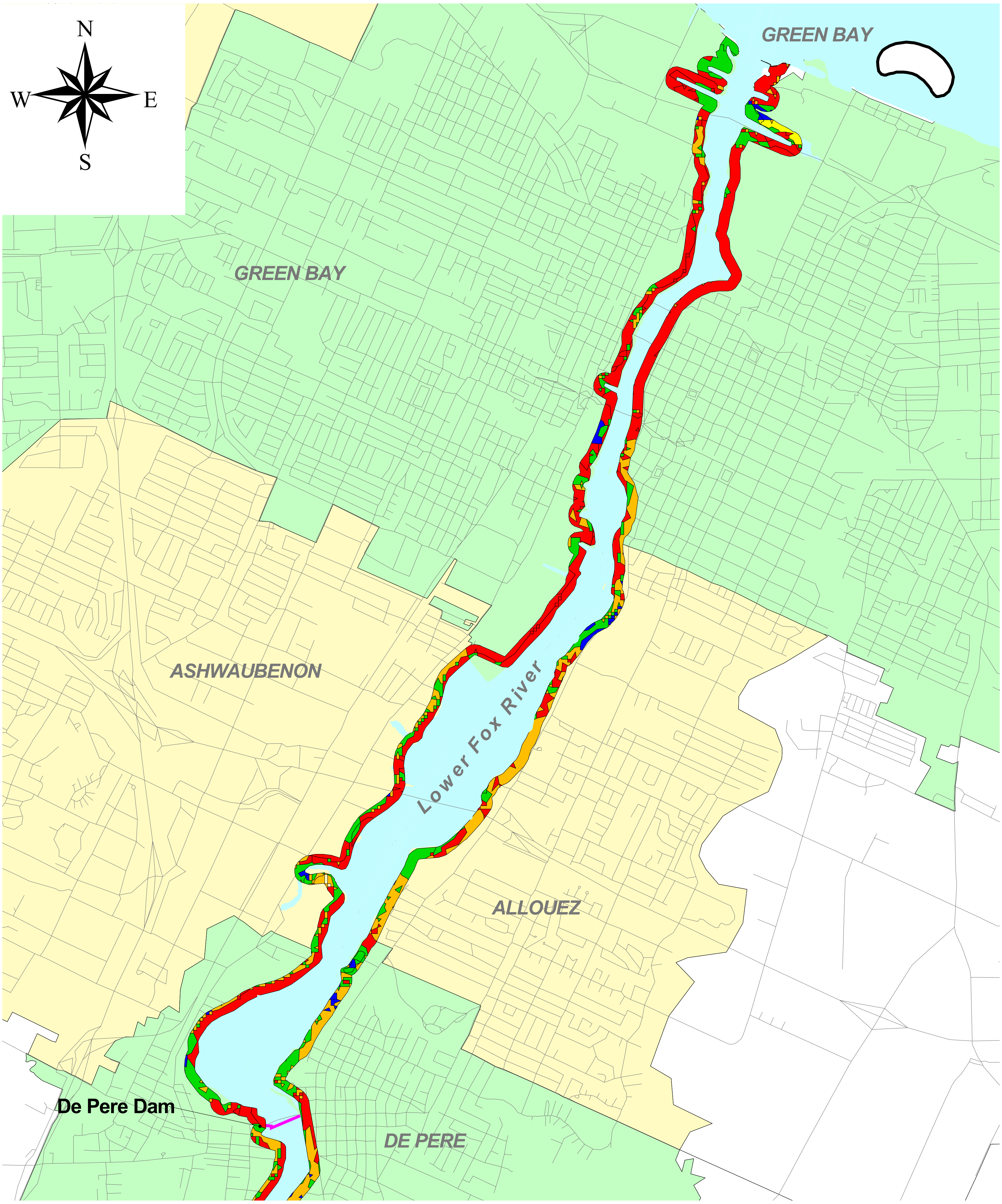
Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Mink data obtained from Exponent, 2000.
3. Suitability Index based on WISCLAND land use maps and WDNR wetland maps. Good = forest shrub/scrub or 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	Remedial Investigation Report	Lower Fox River Mink Habitat Suitability: Appleton to Little Rapids Reach	REFERENCE NO: RI-14414-340-4-15
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE 4-15	APPROVED: AGF



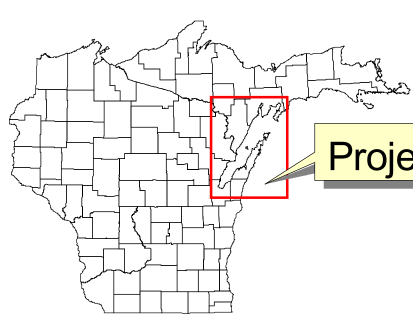
Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Mink data obtained from Exponent, 2000.
3. Suitability Index based on WISCLAND land use maps and WDNR wetland maps. Good = forest shrub/scrub or 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	Remedial Investigation Report	Lower Fox River Mink Habitat Suitability: Little Rapids to De Pere Reach	REFERENCE NO: RI-14414-340-4-16
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE 4-16	APPROVED: AGF



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

Civil Divisions
- City
- Township
- Village

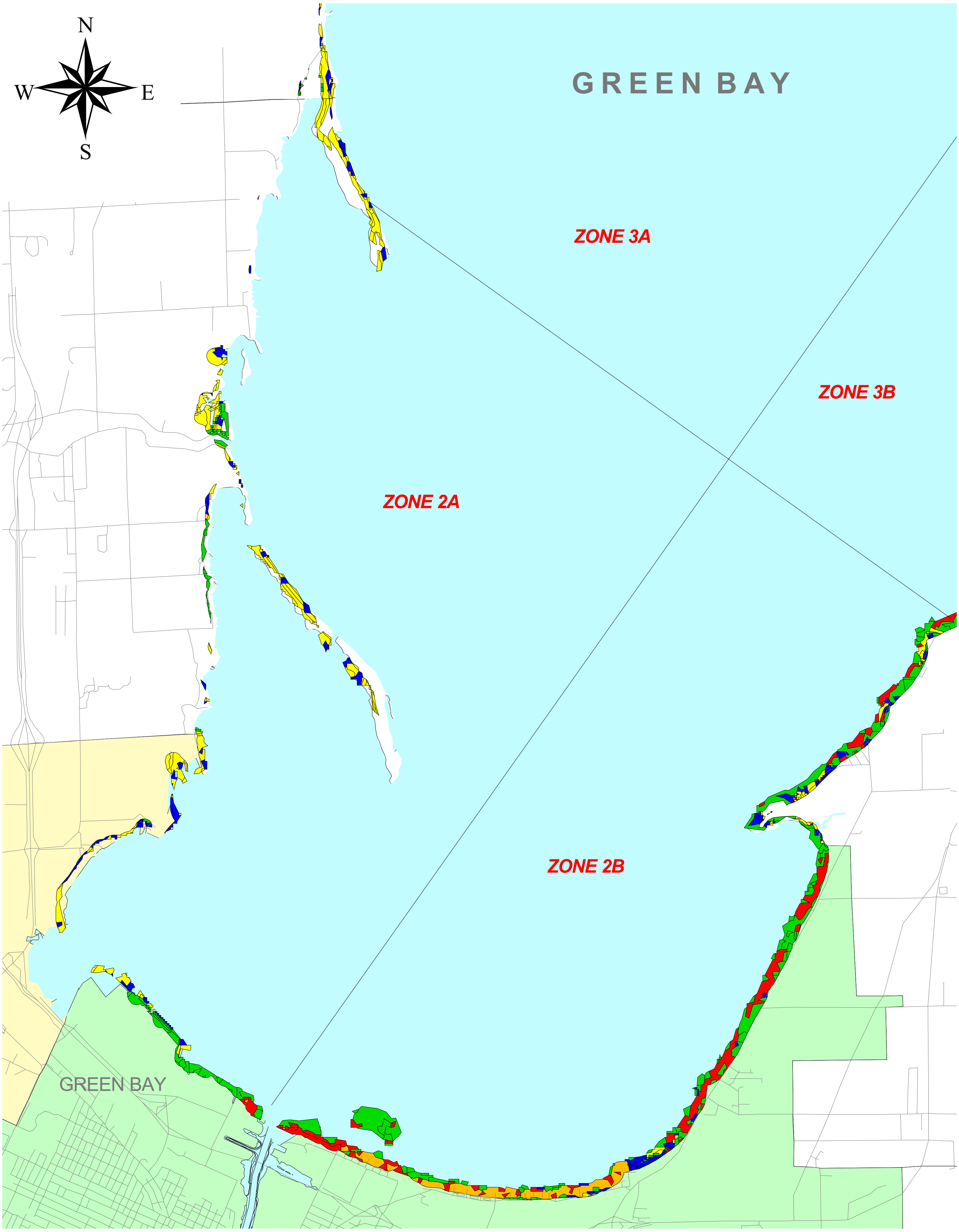


0.5 0 0.5 1 1.5 Kilometers

0.5 0 0.5 1 Miles

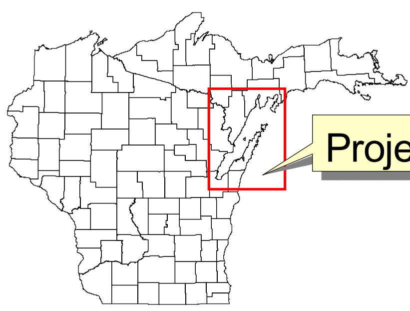
Notes:
1. Basemap obtained from ESRI Data & Maps, August, 1999 and TIGER Census data, 1995. Basemap generated in ArcView GIS Version 3.2, WTM projection.
2. Mink data obtained from Exponent, 2000.
3. Suitability Index based on WISCLAND land use maps and WDNR wetland maps. Good = forest shrub/scrub or 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	Remedial Investigation Report	Lower Fox River Mink Habitat Suitability: De Pere to Green Bay Reach	REFERENCE NO: RI-14414-340-4-17
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE 4-17	APPROVED: AGF



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

Civil Divisions
- City
- Township
- Village

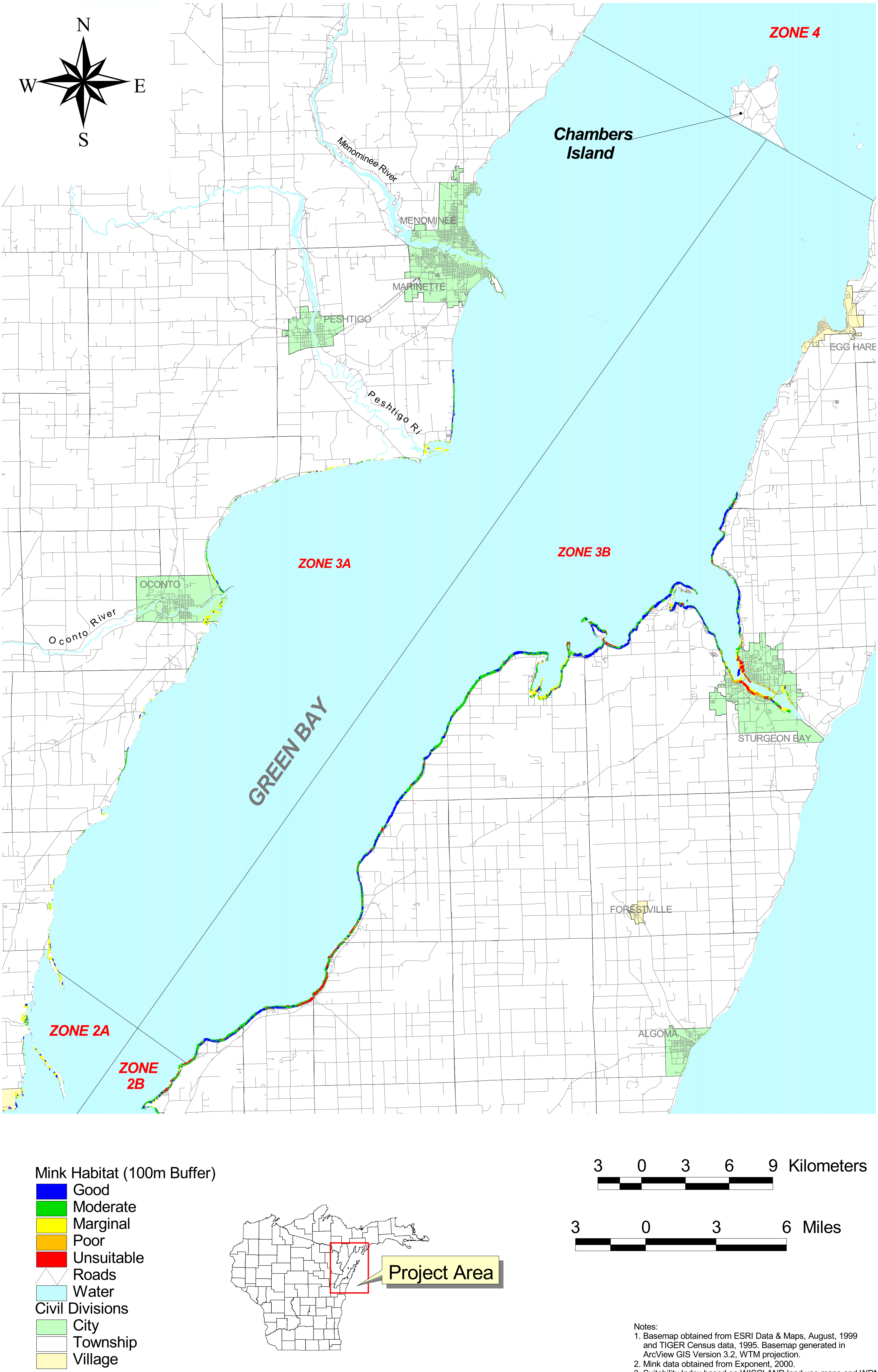


1 0 1 2 Kilometers

1 0 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. 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	Remedial Investigation Report	Green Bay Mink Habitat Suitability: Zone 2	REFERENCE NO: RI-14414-340-4-18
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE 4-18	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	Remedial Investigation Report	Green Bay Mink Habitat Suitability: Zone 3	REFERENCE NO: RI-14414-340-4-19
				CREATED BY: SCJ
				PRINT DATE: 3/7/01
			FIGURE 4-19	APPROVED: AGF

Table 4-1. Major Green Bay Wetland Areas/Complexes[1]

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**	**Miles^2**
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 4-2. 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.			

Prepared from information compiled by Exponent (1998).

Table 4-3. 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%**

Prepared from information compiled by Exponent (1998).

Descriptions of the Areas (Exponent, 1998).

Area 1: LLBdM 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. Howards (Ft. James) RR trestle
Area 3: Fort 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 = Semi-compact 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 4-4. Lower Fox River Fish Species Composition

SPECIES	LLBdM 1983		LLBdM to Little Rapids 1976 - 1977		LLBdM to Little Rapids 1993 - 1994	
	Total Catch	Percent of Catch	Total Catch	Percent of Catch	Total Catch	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%

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 4-4. 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 4-5. Lower Fox River Fish Populations in the De Pere to Green Bay Reach

SPECIES	1987 Catch	1987 % Catch	1988 Catch	1988 % Catch	1989 Catch	1989 % Catch	1990 Catch	1990 % Catch	1991 Catch	1991 % Catch	1992 Catch	1992 % 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%**

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

Table 4-5. 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%**

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

Table 4-6. Green Bay 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	X			
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	X			
Emerald shiner	Notropis atherinoides	X			
Gizzard shad	Dorosoma cepedianum	X			
Lake sturgeon	Acipenser fulvescens			T	
Rainbow smelt	Osmerus mordax	X			
Redfin shiner	Notropis umbratilis	X			
Spottail shiner	Notropis hudsonius	X			
Alewife	Alosa pseudoharengus	X			
Game Fish					
Lake whitefish	Coregonus clupeaformis				
Muskellunge	Esox masquinongy				
Northern pike	Esox lucius				
Sauger	Stizostedion canadense			T	
Walleye	Stizostedion vitreum	X			
Yellow perch	Perca flavescens	X			
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				

E = ENDANGERED D = DELISTED

T = THREATENED X = Included in Risk Assessment Food Web Models.

Table 4-7. Lower Fox River and Green Bay Bird Species

Common Name	Species Name	Food Web	Wisconsin Listing	Michigan Listing	Federal Listing
Raptors					
Bald eagle	Haliaeetus leucocephalus	X	D	T	T
Merlin	Falco Columbarius			T	
Osprey	Pandion haliaetus		T	T	
Peregrine falcon	Falco peregrinus		E	E	E
Gulls and Terns					
Black tern	Chilidonias niger				
Caspian tern	Sterna caspia		E	T	
Common tern	Sterna hirundo	X	E	T	
Forster's tern	Sterna fosteri	X	E		
Herring gull	Larus argentatus				
Ring-billed gull	Larus delawarensis				
Diving Birds					
Belted kingfisher	Megaceryle alcyon				
Common loon	Gavia immer				
Double-crested cormorant	Phalacrocorax auritus	X			
Horned grebe	Podiceps auritus				
Pied-billed grebe	Podilymbus podiceps				
Passerine Bird					
Brewer's blackbird	Euphagus cyanocephalus				
Red-winged blackbird	Agelaius phoeniceus				
Yellow-headed blackbird	Xanthocephalus xanthocephalus				
Marsh wren	Cistothorus palustris				
Sedge wren	Cistothorus platensis				
Tree swallows	Tachycineta bicolor				
Swamp sparrow	Melospiza georgiana				
Shorebird					
Common snipe	Capella gallinago				
Dunlin	Calidris alpina				
Least sandpiper	Calidris minutilla				
Pectoral sandpiper	Calidris melanotos				
Piping plover	Charadrius melodus		E	E	E/T
Sanderling	Calidris alba				
Semipalmated sandpiper	Calidris pusilla				
Spotted sandpiper	Actitis macularia				

E = ENDANGERED　　D = DELISTED
T = THREATENED　　X = Included in Risk Assessment Food Web Models.

Table 4-7. Lower Fox River and Green Bay 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			E	
Least bittern	Ixobrychus exilis			T	
Sandhill crane	Grus canadensis				
Snowy egret	Egretta thula		E		E
Sora rail	Porzana carolina				
Virginia rail	Rallus limicola				
Yellow rail	Coturnicops noveboracensis		T	T	
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				

E = ENDANGERED
D = DELISTED
T = THREATENED
X = Included in Risk Assessment Food Web Models.

5 Nature and Extent of Detected Chemicals

The nature and extent of chemical compounds are presented in this section for the Lower Fox River, including PCBs, pesticides, SVOCs, metals (such as mercury and arsenic), and many other organic and inorganic parameters. In Green Bay, the discussion is limited to the nature and extent of PCBs and mercury, although a number of the same chemicals detected in the Lower Fox River have also been identified.

5.1 Detected Compound Sources

Potential sources of the compounds detected in the Lower Fox River and Green Bay include both point and non-point sources. Point sources are direct discharges or emissions from discrete sources, such as an outfall pipe, landfill, or spill. Sources of detected compounds that are not specifically characterized but which may encompass numerous individual discharges or emissions are non-point sources. Examples of non-point sources include agricultural and urban storm runoff as well as automobile emissions. Each of these types of sources contributes to the compounds found in the Lower Fox River and Green Bay sediments, as described below. Where sufficient information exist, the other Green Bay tributaries are discussed as non-point sources of PCBs and mercury.

5.1.1 Point Sources

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

5.1.1.1 Industrial/Municipal Discharges

Lower Fox River Dischargers

Since the early 1970s, discharges to surface water require WPDES permits issued by the WDNR. The permit records indicate there were 44 major industrial and municipal WPDES dischargers in Brown, Outagamie, and Winnebago counties in 1990. Including both general and specific permittees, 99 industrial dischargers occur within the Fox/Wolf River System (WDNR, 1990a). In 1990, there were over 20 facilities that had a combined discharged of approximately 109 MGD to the Lower Fox River.

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

- **LLBdM Reach**: Badger Paper Mills; P.H. Glatfelter; Menasha Electric and Water Utility; Neenah/Menasha WWTP; Kimberly-Clark Neenah/Badger Globe; U.S. Paper Mills; Wisconsin Tissue Mills

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

- **Little Rapids to De Pere Reach**: None

- **De Pere to Green Bay Reach**: Nicolet Paper; Fort James East; Fort James West; Procter & Gamble Paper; Green Bay Packaging; U.S. Paper Mills; De Pere WWTP; and GBMSD

Historically, specific discharges were identified as the main source for some of the chemical parameters detected in the Lower Fox River, especially with regard to PCBs. In 1999, WDNR completed a hindcast study to evaluate the source of PCBs in the Lower Fox River. Although numerous contributors were recognized, five entities are believed to have contributed over 99 percent of the PCBs discharged into the Lower Fox River between 1954 and 1971 (WDNR, 1999a). These PCB sources include the following: Appleton Papers-Coating Mill (38 percent); P.H. Glatfelter Co. and the associated Arrowhead Park Site (27 percent); Fort James-Green Bay West Mill (formerly Fort Howard) (23 percent); Wisconsin Tissue (10 percent); and Appleton Papers-Locks Mill (2 percent). PCB discharges from all other paper facilities during this time period were less than 1 percent (WDNR, 1999a).

Similarly, elevated levels of mercury identified in Fox River sediments have been attributed to mercuric slimicides (phenyl mercuric acetate) in paper manufacturing. This practice was discontinued in 1971 (Konrad, 1971). A 1970 study of river sediments from upstream of Little Rapids to Green Bay revealed elevated concentrations of mercury in sediments. Also, a number of studies completed in the late 1980s and 1990s indicated that mercury concentrations remained elevated in sediments and the water column more than 20 years after mercury use was discontinued. The studies are summarized in the WDNR Triad Assessment report (1996).

Overall, pollutant loading of PCBs and many other chemicals have been reduced by at least 85 percent since the 1970s, when effluent limits were imposed on facilities discharging more than 1 million gallons of wastewater per day. The discharge limits for many of the parameters discussed in this section, including the seven COPCs identified in the Screening Level Risk Assessment (SLRA), are listed in Wisconsin Administrative Code (W.A.C.) Chapter NR 105 "Surface Water Quality Criteria and Secondary Values for Toxic Substances" (1997). The COPCs include: PCBs, dioxin/furans, DDT, dieldrin, mercury, lead, and arsenic.
Although PCBs have not been used in the Lower Fox River valley in over 20 years, they are still detected in discharge at very low levels from previous point sources due to their ubiquitous nature and general persistence in the environment (WDNR, 1999a). Based on effluent discharge data from 1989/90, WDNR has estimated that current PCB discharge levels range from 3 to 5 kg annually and that there is little that can be done to reduce these sources further (Velleux and Endicott, 1994; WDNR, 1999a).

Few identifiable point sources exist for the other COPCs in the Lower Fox River. Dioxin is not a manufactured compound; rather it is a by-product associated with the manufacture, use, or incomplete combustion of various chlorinated organic compounds. Dioxin is often associated with bleaching activities conducted by the pulp and paper industry. The pesticides DDT and dieldrin had widespread use in agricultural applications but there is no point source associated with these compounds. Similarly, the metals lead and arsenic had widespread uses and are not associated with any specific point sources.

Besides the chemical compounds listed above, discharge limits have also been established for phosphorous, ammonia, and TSS. Compared with PCBs and other anthropogenic compounds detected within river and bay sediments/water, these parameters are not significant toxins for the fish and biota of the river or bay, although ammonia can be detrimental to aquatic species. Rather, these compounds were identified in the lower Green Bay RAP (WDNR, 1988) and subsequent RAP documents due to the role they play in eutrophication of the bay. Therefore, the brief discussion of these compounds is included to provide insight into continued eutrophic conditions within the bay, especially the hypertrophic conditions observed at the southern end of the bay which are associated with discharge from the Lower Fox River.

The 1990 Lower Fox River municipal and industrial discharges of phosphorous, ammonia, and TSS are summarized below and compared with the discharge estimates from the lower Green Bay RAP (WDNR, 1988). The percent of these parameters loads attributable to the industrial or municipal sources is also listed. The remaining percentages of phosphorous and TSS not accounted for in the table below are from non-point sources. Approximately 80 percent and 95 percent of the phosphorous and TSS loads result from non-point sources. An estimate for the total ammonia load into the Lower Fox River is not available.

1990 Industrial/Municipal Loading to the Lower Fox River

Parameters (kg/year)	Industrial (WDNR, 1990a)	Municipal (WDNR, 1990a)	Estimated Annual Discharge*
Total Phosphorous	73,326 (10.5%)	65,827 (9.4%)	700,000
Suspended Solids	3,150,658 (3.5%)	1,433,267 (1.6%)	136,077,000
Ammonia	146,248	743,120	Unknown

* Estimated values include non-point sources such as agricultural and urban areas (Harris, 1994).

Green Bay and Tributary Dischargers

Within Green Bay, considerably less phosphorous, ammonia or TSS are contributed by industrial or municipal sources. WDNR data (Mills, 2000; Oman, 2000) for Marinette, Oconto, Kewaunee, and Door counties, as well as EPA (2000b) discharge data for Delta and Menominee counties, Michigan, are summarized below.

1998/99 County Loading Estimates to Green Bay

Parameters (kg per year)	Door/Kewaunee Counties	Marinette/Oconto Counties	Menominee/Delta Counties
Total Phosphorous	82	14,870	38
TSS	1,130	246,820	382
Ammonia	1,846	905	0.5

The combined discharge data for the six counties listed above indicate that approximately 15,000 kg (3,300 pounds) of phosphorous, 248,300 kg (547,400 pounds) of TSS, and 2,750 kg (6,060 pounds) of ammonia are released into Green Bay annually from these areas. This phosphorous load is just under 11 percent of the combined Lower Fox River industrial and municipal loads. Similarly, this TSS load is only 5.4 percent and the ammonia load represents just over 0.3 percent of the combined Lower Fox River loads. Pollutant loading from these counties is negligible compared to the Lower Fox River levels. Data were not available for non-point contributions of these parameters (e.g., from agricultural practices, etc.) for these counties.

5.1.1.2 Landfills

There are 17 closed municipal and industrial landfills that lie within a quarter mile of the Lower Fox River (EDR, 1995). Sixteen of these landfills are located downstream of the De Pere dam in Brown County and within the lower Green Bay AOC. The other is the former P.H. Glatfelter-Arrowhead Park Landfill (Arrowhead Park) at the southern end of LLBdM. This site was identified by WDNR (1999a) as one of the potential PCB contributors.

Arrowhead Park and three of the other landfills were evaluated for potential contributions of PCBs, dieldrin, lead, and cadmium to the Lower Fox River, and eventually Green Bay, during the Green Bay Mass Balance Groundwater Monitoring Studies. These studies concluded that groundwater migration from these four landfills does not adversely impact surface water bodies adjacent to these waste sites, especially with respect to PCBs, lead, or cadmium (Stoll and Erdmann, 1990 and 1992). The total PCB load from Arrowhead Park is estimated not to exceed 12.8 grams per year (g/year). The PCB load from the other 16 former municipal/industrial landfills located within the Green Bay city limits is estimated to range from 0.005 to 0.02 g/year, indicating that these would not likely contribute more than 1 gram of PCBs annually, combined (Stoll and Erdmann, 1990 and 1992). Additionally, PCB attenuation by soils was not considered in the study and would likely further reduce projected PCB impacts to the river. The estimated daily PCB loads to groundwater from Arrowhead Park is 0.035 g/day (Stoll and Erdmann, 1992). This PCB load is minimal compared to the lowest winter daily PCB loading of 30 to 100 g/day as estimated from concentration data measured in the Lower Fox River downstream of the De Pere dam (Steuer, 1990; WDNR, 1995).

Numerous landfills are present in the vicinity of Green Bay (Plate 5-5) but only those listed below are still active.

Sanitary Landfills in the Green Bay Area

<table>
<tr><th>Landfill Name</th><th>Location</th><th>County</th><th>State</th></tr>
<tr><td>Door County Sanitary Landfill</td><td>Sturgeon Bay</td><td rowspan="2">Door</td><td rowspan="4">WI</td></tr>
<tr><td>Washington Island Landfill/Compost Site</td><td>Washington Island</td></tr>
<tr><td>Mar-Oco Landfill</td><td rowspan="2">Marinette</td><td rowspan="2">Marinette</td></tr>
<tr><td>Badger Paper Mills</td></tr>
<tr><td>United Waste Systems Landfill</td><td rowspan="2">Menominee</td><td rowspan="2">Menominee</td><td rowspan="4">MI</td></tr>
<tr><td>Great Lakes Pulp &Fibre Landfill</td></tr>
<tr><td>Mead Paper Industrial Landfill</td><td rowspan="2">Escanaba</td><td rowspan="2">Delta</td></tr>
<tr><td>Delta County Landfill</td></tr>
</table>

According to WDNR and Michigan Department of Environmental Quality records, these landfills have received both industrial and municipal wastes. Additionally, the Mead Paper, Badger Paper, United Waste Systems Landfill, and Great Lakes Pulp & Fibre landfills have all likely received industrial wastes that contain PCBs. Similar to the landfills located along the Lower Fox River in Brown County, the contribution of PCBs from these landfills to Green Bay is believed to be very low compared to the Lower Fox River sediments.

5.1.1.3 Spills

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

While many spill and LUST incidents have occurred within the Lower Fox River watershed, their potential effect, if any, on the river has not been specifically evaluated. However, spills are limited in volume and duration and the vast majority occur at locations which would not reach the river. When compared with the chemical parameters discharged directly to the river via the municipal and industrial dischargers, recent point source spills likely have little impact, if any, and are not addressed further.

Outside of the Lower Fox River watershed the EPA Toxic Release Inventory (TRI) database was queried to evaluate the possibility of significant releases or spills in the Green Bay region. The database query results are summarized below.

EPA Toxic Release Inventory Sites in the Green Bay Area

City	Number of TRI sites	Total Number of TRI sites in County
Sturgeon Bay	5	5
Oconto/Oconto Falls	6	12
Peshtigo	1	16
Marinette	10	10
Menominee	12	13
Escanaba/Gladstone	3	3

Most of these sites are located in the cities which are either situated on the bay or on one of the Green Bay tributaries just upstream from the bay. Most of these sites are currently being investigated or remediated. Similar to spills in the Lower Fox River watershed, spills near the shores of Green Bay are unlikely to significantly impact water quality in the bay. The TRI database did not reveal that PCBs were a potential compound of concern at any of these sites.

The Lower Menominee River RAP indicates that spills are not significant source of impacts in the Menominee River. Rather, the most significant sources of impacts to the Menominee River resulted from direct discharge of process wastewater containing arsenic from the Ansul facility.

5.1.2 Non-Point Sources

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

Non-point Sources of Pollution (WDNR, 1990b)

Non-Point Sources	Typical Pollutants
Atmospheric deposition from automobiles and point sources	Heavy metals (from autos), carbon dioxide, sulfur dioxide, nitrates, and acids formed from these substances
Agricultural activities and runoff	Pesticides, VOCs, PAHs, inorganic and organic pollutants, BOD, COD, suspended solids, nutrients, and bacteria.
River and Bay Sediments and Green Bay Tributaries	PCBs, Pesticides, VOCs, PAHs, inorganic and organic pollutants, heavy metals, and suspended solids.
Urban Storm Sewer Outfalls	Heavy metals, pesticides, inorganic and organic pollutants, BOD, COD, suspended solids, nutrients, and bacteria.

These non-point sources are discussed below.

5.1.2.1 River and Bay Sediments

As previously cited, an estimated 313,600 kg of PCBs were discharged to the Lower Fox River between 1954 and 1971 (WDNR, 1999a). Based on the FRDB sediment sampling results, a significant percentage of this PCB mass has accumulated in river and bay sediments. Sediments containing elevated concentrations of PCB, as well as other compounds, are dispersed along the entire Lower Fox River and are a continuing source of non-point pollution. PCB modeling studies (Velleux and Endicott, 1994; WDNR, 1995; WDNR, 1999a) evaluated the sources, movement, and fate of PCBs in the Lower Fox River and Green Bay. It is estimated that over 99 percent of the PCB in the river water is due to resuspension, volatilization and/or dissolution of PCBs from the sediments (Fitzgerald and Steuer, 1996). These same processes also control the occurrence of other organic and inorganic compounds within the sediments and water.

In the Menominee River AOC, the main compound of concern was found to be arsenic, which was detected at concentrations as high as 32,300 mg/kg. PCBs and mercury were detected in Menominee River sediments at maximum concentrations of 2.0 mg/kg and 2.6 mg/kg, respectively. In comparison, the maximum detected concentrations of these two compounds in Lower Fox River sediments are 710 mg/kg and 9.82 mg/kg, respectively. PCB and mercury concentrations in the Menominee River are significantly lower than in Lower Fox River sediments.

In 1987 and 1988, the USGS evaluated the loading of PCBs, dieldrin, lead, and cadmium from Green Bay tributaries (House, 1990). The results of this study indicated that low concentrations of PCB and lead were present in bottom sediments of Duck Creek and that lead was found in other tributaries. Dieldrin and cadmium were not detected. Based on this study, the USGS completed an evaluation of PCB loading from the five major tributaries to Green Bay from 1988 to 1990 and these results are summarized below. More than 90 percent of the PCB load into Green Bay is attributable to the Lower Fox River (House, *et al.,* 1993). The Menominee River is the second most significant source of PCBs to Green Bay, accounting for 10 kg (22 pounds) or less of PCBs, which is only about 2 percent to 4.5 percent of total PCB load into the bay. The other Green Bay tributaries are insignificant compared with the Lower Fox River.

PCB Loads from Green Bay Tributaries, 1989-90 (House, 1990)

Tributary	Water Year 1989		Water Year 1990	
	Load (kg)	Percent	Load (kg)	Percent
Fox (De Pere dam)	119.45	54.2%	158.76	66.9%
Fox (Mouth)	201.04	91.2%	227.3	95.8%
Oconto (Mouth)	1.47	0.7%	1.42	0.6%
Peshtigo (Mouth)	4.04	1.8%	2.39	1.0%
Menominee (Mouth)	10.01	4.5%	4.79	2.0%
Escanaba (Mouth)	3.77	1.7%	1.39	0.6%
Total Load	220.33	---	237.29	---

No estimates of mercury loading into Green Bay are available.

Sediment transport within Green Bay was studied by a number of researchers and summarized by the USFWS (Stratus, 1999a). Based on Green Bay currents and flow dynamics, Hawley and Niester (1993) estimated that between 10 percent to 33 percent of the inner bay tributary sediment load, the majority of which is derived from the Lower Fox River, is transported to the outer bay (Stratus, 1999a). Transport of this sediment load mainly occurs between the east shore of Green Bay and Chambers Island.

5.1.2.2 Stormwater Runoff

Soil eroded from agricultural land, construction sites, and street runoff as well as erosion from unstable stream banks is estimated to contribute 100,000 tons of solids to the Lower Fox River each year (WDNR, 1988). Only 5 percent of the solids load results from municipal/industrial dischargers; the remaining 95 percent is from non-point sources, such as agricultural and urban run-off. As indicated above, approximately 150,000 tons of solids are transported into Green Bay annually (Harris, 1994), and these solids contribute significantly to water quality problems in the bay.

Within the Lower Fox River, a portion of these solids settle out and accumulate behind the dams and other areas of low water velocity. Subsequent storm and snow melt events can erode and resuspend particles which may contain nutrients and chemicals adsorbed onto their surfaces. These particles are a continuing non-point pollutant source to downstream reaches of the river, Green Bay, and Lake Michigan. Associated pollutants can be made accessible to the aquatic ecosystem through biological (i.e., algae or bottom feeding fish consumption), physical, (i.e., re-suspension) and chemical (i.e., volatilization or dissolution into the river water) mechanisms.

Previous nutrient loading studies have primarily focused on phosphorus from both agricultural (barnyard runoff, placement and tonnage of winter-spread manure) and urban stormwater sources. Phosphorous contributions to the Lower Fox River from Lake Winnebago comprised approximately 51 percent of the load in 1990 and non-point sources contributed an additional 33 percent (WDNR, 1993). As stated above, only 20 percent of the estimated phosphorous load and 5 percent of the TSS load to the river is accounted for from either industrial or municipal discharge sources. Therefore, it is estimated that the remaining phosphorous load results from non-point sources.

To evaluate the significance of urban areas as a source of PCBs, WDNR collected sediment samples from ten sewer catch basins in May 1989. The PCB residue concentrations were used to extrapolate from the catch basin drainage areas to the entire study area. The sediment load from urban areas within the study area was estimated from the PCB residue concentrations from the catch basins. The maximum PCB concentration in urban stormwater runoff, using the catch basin approach, resulted in an estimated loading of about 1 kg/yr (Konrad, 1992). Therefore, these levels do not appear to be a significant source of PCBs to the Lower Fox River.

Stormwater runoff from urban areas along the shores of Green Bay has not been studied in detail. The Lower Menominee River RAP (WDNR, 1990b) indicates that the AOC is susceptible to pollution from runoff but there is no estimate of the load contributed by the watershed. Similarly, other areas of the Green Bay watershed susceptible to runoff from both urban and agricultural areas have not been evaluated.

5.1.2.3 Atmospheric Deposition and Volatilization

A number of studies have found that PCB volatilization from the bay greatly exceeds the atmospheric deposition of PCBs into bay waters. Airborne concentrations of PCBs in lower Green Bay were as much as 2 to 3 times greater than concentrations in the outer bay and as great as 7 times higher than concentrations over land on the same day. Total PCBs over the water of southern Green Bay were 670 to 2,200 picograms per cubic meter [pg/m^3]. This enrichment of airborne PCB concentrations was attributed to volatilization of the most volatile PCB congeners from the water. Results suggested that volatilization from water can be an important source of atmospheric chemicals and that the magnitude of this release has likely been underestimated previously (Hornbuckle, *et al.,* 1993).

Data from the early 1980s estimated atmospheric deposition of PCBs into Lake Michigan of approximately 650 to 1,000 kg (1,430 to 2,200 pounds) annually (WDNR, 1988). For comparison, the surface area of Lake Michigan is approximately 57,800 km^2 (22,300 mi^2) while Green Bay only covers about 4,150 km^2 (1,600 mi^2). Therefore, the surface area of Green Bay represents only about 7.2 percent of the total Lake Michigan area. Similarly, due to the overall limited surface area of the Lower Fox River compared to the surface area of Green Bay, the direct atmospheric contributions of the PCBs to the river are limited. In the early 1990s the estimated atmospheric contributions of PCBs into Green Bay was approximately 2 to 16 kg (4.5 to 35 pounds) annually (Hornbuckle, *et al.,* 1993 and Achman, *et al.,* 1993). In 1993, Sweet, *et al.* estimated that approximately 35 kg (77 pounds) of PCB were deposited into the bay.

In 1993, Sweet, *et al.* estimated that Green Bay experienced a net loss of approximately 500 kg (1,100 pounds) of PCBs due to volatilization. Hornbuckle, *et al.*(1995), estimated that Lake Michigan, north of Milwaukee (above 43 N. Latitude), experienced a net loss of approximately 520 kg (1,150 pounds) of PCBs while Green Bay net losses were approximately 130 kg (286 pounds) of PCBs annually. Similarly, Hoff, *et al.*(1994) estimated that annual volatilization of PCBs from Lake Michigan decreased from 5,140 kg (11,330 pounds) in 1988 to 2,700 kg (5,950 pounds) in 1994 while annual PCB deposition into the lake fell from 400 kg (881 pounds) to 69 kg (152 pounds) over the same time period. Studies consistently indicate that PCB volatilization exceeds atmospheric deposition.

Atmospheric emissions of PAHs, lead and other compounds are also potential sources of these constituents in sediments. The fate of air emissions is dependent on many factors and their effects on the Lower Fox River are unknown. However, studies of Green Bay have evaluated DDT, benzo(a)pyrene (B[a]P), and lead, as well as the impacts of urban areas. Hoff, *et al.*(1994) found that approximately 99 kg (218 pounds) of DDT were introduced into Lake Michigan in 1994 through both gaseous and particulate deposition while particulate depositions of B[a]P and lead were 250 kg (551 pounds) and 72,000 kg (158,700 pounds), respectively. Levels for all of these compounds except B[a]P generally decreased over time. B[a]P deposition to Lake Michigan increased between 1988 and 1994 (as it did in the other 4 Great Lakes), suggesting that emissions of PAHs and other SVOCs are increasing (Hoff, *et al.,* 1994). Measured concentrations of PCBs, DDT, dieldrin, chromium, and lead at urban and rural sites along Lake Michigan indicated that levels in or near urban areas were as much as 40 times higher than at rural locations (EPA, 1997). However, the measurements of other pesticides, arsenic, and selenium were similar for urban and rural locations.

5.2 Summary of Detected Chemicals

5.2.1 Overview

Numerous chemical and physical parameters have been analyzed and detected in the sediment, water, and biota of the Lower Fox River and Green Bay. The SLRA (RETEC, 1998c) identified seven COPCs for the Lower Fox River which are discussed in this section. These compounds include: PCBs, dioxin/furan, DDT, dieldrin, mercury, lead, and arsenic. Only PCBs and mercury will be discussed for Green Bay. This section discusses the specific sediment and water-sampling chemical results in the FRDB. The FRDB biota results, for both the Lower Fox River and Green Bay, are discussed in detail in the RA. However, a summary of PCB concentration trends in select animal species of the river and bay is included herein.

Sediment samples included in the FRDB have been analyzed for over 206 different parameters in various chemical categories, including PCBs, dioxin/furans, pesticides, SVOCs (including the polynuclear aromatic hydrocarbons and pentachlorophenol), and inorganic compounds, including metals. The chemical parameters detected in Lower Fox River and Green Bay sediments are summarized on Table 5-1. The results are summarized for each reach and zone and include the number of samples analyzed for each parameter, as well as the number and percentage of detections (Table 5-1). Thirty-four (34) compounds were detected in less than four samples (Table 5-1) and are not discussed further.

Two arithmetic average values and the logarithmic mean have been calculated for each parameter sample group (Table 5-1). The two averages are labeled as the "RI Mean" and the "RA Mean" and each was calculated in the following way:

- The RI Mean was calculated using only the laboratory results for all samples in which the chemical was detected. Therefore, all samples that the laboratory labeled as "non-detect" were ignored in calculating the RI Mean.

- The RA Mean was calculated using the detected results. However, a value of one-half the detection limit was assigned to all samples that had "non-detect" results. Therefore, the RA Mean is always less than or equal to the RI Mean because these low concentrations increased the sample population without proportionally increasing the sum of all values.

The RA Mean provides a mechanism for evaluating sample points as though PCB or other chemical were present at concentrations below the laboratory method detection limit in that location. Both the RI Mean and RA Mean are included on Tables 5-1 and 5-2 to show the difference in the deposit/SMU/zone averages when both methods are used to calculate the value. However, the RA mean is the value that is used for discussion purposes in both this RI and the RA.

The logarithmic mean was also calculated for all parameter groups in addition to the two arithmetic averages. The PCB results for many of the deposit/SMU/zone groups exhibited a log-normal distribution. The logarithmic mean calculates an average value that is not skewed by a small number of extremely high values. The log-normal distribution is evidenced by the extreme differences (several orders of magnitude) between the minimum and maximum detected values for many data sets, such as deposits A, C, and POG in LLBdM (Table 5-2). The logarithmic mean was used to calculate an average value for each deposit/SMU/zone and the results are included on Table 5-2. Non-detect samples were assigned values of one-half the detection limit, similar to calculation of the RA mean. The distribution (normal, log-normal, or other) of each particular chemical compound data set is indicated in the FRDB.

Only post-dredging PCB data collected at Deposit N has been used in the PCB distribution evaluation and mapping effort. Also, post remediation data for SMU 56/57 has not been incorporated into the FRDB because dredging activities were not completed to the targeted dredging depths. Rather, pre-dredging sediment results have been used and the estimated PCB mass and sediment volume removed during the SRD project has been subtracted from the calculated totals for SMU 56-61.

5.2.2PCBs

Historically, PCBs were used for a variety of industrial purposes because of their desirable chemical properties, which included general inertness, resistance to both acids and alkalis, and thermal stability. PCBs were useful in a wide variety of applications, including dielectric fluids in transformers and capacitors, heat transfer liquids, and lubricants (Merck and Company, 1989). In general, PCBs are relatively insoluble in water and the solubility decreases with increased chlorination; however, they are also freely soluble in non-polar organic solvents and biological lipids (ATSDR, 1997a). In the Lower Fox River valley, PCBs were specifically used in the manufacture and recycling of carbonless copy paper (WDNR, 1999a).

PCBs are a class of chemical compounds in which 1-10 chlorine atoms are attached to the biphenyl molecule (two benzene rings, which are the basic PCB building blocks), with 209 variations. The 209 individual chlorinated compounds are called PCB congeners. Additionally, various configurations are possible as well since there can be free rotation between the benzene rings. The benzene rings can rotate around the bond connecting them and the two configurations are called planar (or coplanar) and non-planar. Coplanar PCBs have the two benzene rings in the same plane while non-planar PCBs have the benzene rings at an angle anywhere from 1 to 90 degrees of each other. The most toxic congeners with respect to human health and the environment are the coplanar congeners 77, 105, 118, 126, and 169 (ATSDR, 1997a). These coplanar congeners have been evaluated and analyzed as part of previous Lower Fox River and Green Bay sampling efforts. While the presence and distribution of total PCBs is the focus of this report overall, discussions of the PCB congeners herein will mainly focus on these five particular PCB congeners.

In addition to the five coplanar congeners listed above, the USFWS summarized the toxic effects of these and other PCB congeners with regards to birds (Stratus, 1999c). The toxicological effects of PCBs congeners are important because these compounds, especially the coplanars listed above, have a similar molecular configuration as dioxin 2,3,7,8-TCDD. Therefore, these PCBs have a dioxin-like affinity for the same cellular receptors as 2,3,7-8-TCDD (Stratus, 1999c). Congeners 77, 126, and 169 most resemble dioxin (ThermoRetec, 2000). In addition to the five coplanars listed above, congeners 81, 114, 123, 156, 157, 167, and 189 have all been assigned toxic equivalency factors (TEFs) by the

World Health Organization based on the dioxin-like effects that these compounds may have with respect to birds (Stratus, 1999c). PCB congeners also have phenobarbital-like, neurotoxic, and endocrine-disrupting toxicological effects in birds (Stratus, 1999c). Therefore, the presence of other congeners within the Lower Fox River and Green Bay system cannot be discounted. Rather, the presence of these various congeners within the system represent a possible threat to wildlife within the region that are evaluated further in the RA.

PCBs are also categorized by degree of chlorination. The term "homolog" is used for all of the PCB compounds with the same number of chlorines (e.g., dichlorophenyl means two chlorine atoms). The PCBs of a given homolog with different chlorine substitution patterns in the molecules are called isomers (e.g., the dichlorophenyl homolog has twelve isomers). Due to the large number of PCB congeners, homolog plots for particular sediment deposits are discussed in Section 6 to evaluate the movement, degradation, and loss of PCBs from the environment.

In the U.S., PCB mixtures were marketed under the trade name Aroclors by the Monsanto Corporation, the major U.S. producer of PCBs from 1930 to 1977. All the Aroclors, with the exception of Aroclor 1016, were identified by a four-digit numbering code in which the first two digits indicated that the parent molecule was biphenyl (12 carbons) and the last two digits indicated the chlorine content by weight percent. Thus, Aroclor 1242 was a chlorinated biphenyl mixture of varying amounts of mono-through heptachlorinated PCB congeners with an average chlorine content of 42 percent. This numbering system also indicated that the higher numbered Aroclors contained an increasingly greater percentage of higher chlorinated congeners.

PCBs have been detected in 2,332 of the 2,717 sediment samples analyzed (total PCB results, Table 5-1). Both congeners and Aroclors have been analyzed to evaluate the distribution of PCBs in Lower Fox River sediments. The individual PCB congeners have been analyzed in 282 samples in the Lower Fox River and in 818 samples in Green Bay. The various Aroclors have been analyzed in 2,260 samples in the Lower Fox River and in 61 samples from Green Bay (Table 5-1).

The number of samples in which the five coplanar congeners (77 [77/110], 105, 118, 126, and 169) were analyzed and detected are summarized on Table 5-1. Congener 169 was not detected in either Lower Fox River or Green Bay sediments (Table 5-1). According to studies completed on Aroclor mixtures, congener 169 was not found in Aroclors 1016, 1242, 1248, 1254, or 1260 (ATSDR, 1997a). When elevated concentrations of PCBs are present in a sample it becomes difficult for the laboratory to differentiate between congener 77 and 110 due to interference. Therefore, these results are often reported as congener 77/110 (Table 5-1). Although it is possible to evaluate the relationship and determine the percent of congener 77 to congener 110 in samples where each was identified individually, use of such a method in this case is questionable. The ratio determined for samples with lower PCB concentrations is may not be applicable to samples with elevated concentrations. Therefore, for use in this study, it has been assumed that all samples reported as congener 77/110 are congener 77.

In the Lower Fox River, 138 congeners have been detected in sediment samples. At least 253 samples were analyzed for PCB congeners, although not every sample was analyzed for the full list of congeners. Congeners 77/110 and 118 have been detected in 97 percent to 99 percent of the samples analyzed, respectively, while congeners 77 and 105 were detected in about 80 percent of the samples. (Table 5-1). The congeners 77/110 and 118 maximum and mean concentrations were the highest for the coplanar congeners (Table 5-1). Congener 105 is present at relatively low concentrations even though it was detected in about 80 percent of the analyzed samples (Table 5-1). Similarly, congener 126 was detected in less than 30 percent of the samples and had very low concentration results. Congeners 77 (77/110) and 118 are more widespread in sediments than the other coplanar PCBs (Table 5-1).

In Green Bay, at least 97 congeners have been detected in 797 of 818 sediment samples analyzed. Congeners 77/110 and 118 have been detected in well over 95 percent of the analyzed samples (Table 5-1). Maximum and mean concentrations indicate these congeners had the highest results for the coplanar congeners (Table 5-1). Similar to the Lower Fox River, congener 105 was present at relatively low concentrations even though it was detected in approximately 80 percent of the analyzed samples (Table 5-1). Congener 126 was detected in less than 30 percent of the samples and congener 169 was absent (Table 5-1), also similar to the Lower Fox River. Congeners 77 (77/110) and 118 are also more widespread in Green Bay sediments than the other coplanar PCBs. The PCB coplanar congeners are discussed further in the RA.

Aroclor 1242 was the PCB mixture used in the emulsion applied to the manufacture of carbonless copy paper. Approximately, 45 million pounds of this emulsion were reportedly used in the Lower Fox River valley between about 1954 and 1971 (WDNR, 1999a). In the Lower Fox River, Aroclor 1242 was detected in over 90 percent of the sediment samples tested by Aroclor analysis (Table 5-1). By comparison, Aroclors 1254, 1260, and 1268 were only detected in about 9 percent to 25 percent of all samples analyzed while the other five Aroclors (1016, 1221, 1232, 1248, and 1262,) were virtually undetected. Aroclor 1242 is also dominant in Green Bay, being one of only two Aroclors detected (Table 5-1). The Aroclor 1242 maximum and average concentrations are about one to two orders of magnitude higher than the results for the other three detected Aroclors (Table 5-1). Only 61 samples from Green Bay were tested by Aroclor analysis while 818 samples were analyzed for PCB congeners. Aroclor 1242 and 1260 were detected in more than 44 percent and 16 percent, respectively, of the 61 samples analyzed. Other than Aroclors 1242 and 1260, none of the other Aroclors were detected in Green Bay. Specific end-uses of PCB Aroclors 1242, 1254, 1260, and 1268, which are the dominant Aroclors present in the river, are listed below (ATSDR, 1997a).

Summary of Former End Uses for Select Aroclors (ATSDR, 1997a)

End Use	Aroclors			
	1242	1254	1260	1268
Capacitors	X	X		
Transformers	X	X	X	
Heat Transfer	X			
Hydraulics/Lubricants				
Hydraulic Fluids	X	X	X	
Vacuum Pumps		X		
Gas-Transmission Turbines	X			
Plasticizers				
Rubbers	X	X		X
Synthetic Resins		X	X	X
Carbonless Paper	X			
Miscellaneous				
Adhesives	X	X		
Wax Extenders	X	X		X
Dedusting Agents		X	X	
Inks		X		
Cutting Oils		X		
Pesticide Extenders		X		
Sealants/Caulking Compounds		X		

The PCB sample frequency distribution results for each sediment deposit/SMU group/zone have been plotted on Figure 5-1 which illustrate where sediment samples have been collected and where elevated PCB concentrations have been detected. A majority of the samples collected have focused on specific deposits/SMUs.

In the Lower Fox River, there are 12 deposits/SMU groups for which approximately 50 or more total PCB results have been reported and six areas with more than 100 results (Figure 5-1). Additionally, more than 100 samples had been collected from Deposit N prior to remediation, however, less than 50 post-remediation samples are included in the database. Following the 1989/90 sediment investigation, deposits/SMUs exhibiting large areal extent were the focus of subsequent investigations and areally smaller deposits were subject to very limited sampling. Distribution of total PCBs in the Lower Fox River sediments is described below for each reach of the river. Approximately 60 samples have been collected from Green Bay Zone 2 (2A and 2B) and over 150 samples were collected from zones 3A and 4. More than 400 samples have been collected in Green Bay Zone 3B (Figure 5-1).

5.2.3 Dioxin/Furan

Dioxin/furan compounds are a group of chlorinated organic compounds which have a large number of different congeners, similar to PCBs. Dioxin/furan compounds are not manufactured. Rather, they are typically generated through a number of manufacturing processes. Dioxin/furans are often associated with the wood treatment and pulp/paper industries as a by-product of the treatment and bleaching processes, respectively. Based on the production, recycling, and de-inking of carbonless copy paper at mills located along the Lower Fox River, bleaching activities within the valley were limited. Therefore, the formation of dioxin associated with paper bleaching was also limited. In addition, although low levels of polychlorinated dibenzofurans resulted from the processing and manufacture of Aroclors, dibenzo-p-dioxins were not typically produced or associated with Aroclor production (ATSDR, 1997a). Based on this information there are no known specific point sources for these compounds.

Although numerous congeners exist, dioxin 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD) and furan 2,3,7,8-tetrachlorodibenzo-p-furan (2,3,7,8-TCDF) are the two most toxic congeners with respect to human health and the environment. These two congeners were analyzed in 21 sediment samples of the Lower Fox River during the GAS/SAIC RI (1996). No sediment samples from Green Bay were analyzed for either of these congeners. Therefore, the dioxin/furan data is very limited (Table 5-1).

Dioxin/furan samples were collected in locations where PCB concentrations were elevated (e.g., deposits D, E, POG, N, EE, HH, and SMU 56/57). 2,3,7,8-TCDD concentrations range from 0.23 to 10.0 nanograms per kilogram (ng/kg or part per trillion [ppt]) while 2,3,7,8-TCDF concentrations range from 31.78 and 170.0 ng/kg (ppt) (Table 5-3). Nine samples were collected upstream of the De Pere dam; seven were collected from the upper 60 cm (2 ft) of sediments, while the other two samples were collected deeper. All 12 samples downstream of the De Pere dam were collected from a single location to evaluate the vertical distribution of both parameters (Table 5-3). The results for Deposit N, collected prior to the SRD project are not discussed.

5.2.4 Pesticides

The chlorinated pesticides primarily result from non-point sources associated with agricultural activities, although other sources, such as parks, golf courses, and other institutional facilities where pest control is required, may contribute to the occurrence of some of these compounds in the sediments. Given the large percentage of agricultural land use in the vicinity of the Lower Fox River, agricultural uses contribute the majority of the chlorinated pesticides found in sediments. No pesticides were detected in sediment samples collected in Green Bay.

Ninety-eight sediment samples were analyzed for chlorinated pesticides that pose a risk to human health and the environment. At least 17 different chlorinated pesticide compounds were detected in sediment samples from the Lower Fox River and Lake Winnebago (Table 5-1). Pesticide samples were collected from deposits C, D, E, POG, W, X, EE, GG, HH, and downstream of the De Pere dam. The samples from Lake Winnebago were collected and analyzed for use in the RA and to establish background values. The pesticides DDT, DDD, DDE, endrin aldehyde, endrin ketone, gamma-BHC (lindane), and heptachlor were all detected in more than four samples.

Two pesticides were identified as chemicals of potential concern in the SLRA (RETEC, 1998c). DDT was detected in 16 samples and dieldrin was detected in only one river sediment sample (at a concentration of 5.9 μg/kg, Table 5-4). The manufacture and use of both DDT and dieldrin in the United States were discontinued in the early 1970s (ATSDR, 1993a and ATSDR, 1994).

5.2.5 Inorganic Compounds

Numerous inorganic parameters have been analyzed, all of which occur naturally within native soils and river sediments. Parameters analyzed reflect the Resource Conservation and Recovery Act (RCRA) list of heavy metals and include arsenic, barium, cadmium, chromium, lead, mercury, selenium, and silver. It is sometimes difficult to distinguish between naturally occurring concentrations and those resulting from anthropogenic activities. The inorganic compounds were analyzed in approximately 3,200 samples (including the TCLP samples) and they were detected in approximately 85 percent of the samples, which is expected for naturally occurring compounds (Table 5-1).

Mercury, lead, and arsenic were identified as COPCs in the SLRA and concentrations detected in sediments are listed on Table 5-5. Mercury has been analyzed in almost 400 samples while the other RCRA metals were analyzed in approximately 100 to 150 samples (Table 5-1). In addition to the RCRA metals, copper, nickel, and zinc were also analyzed in a large number of samples. Other inorganic compounds have been analyzed in less than 100 samples (Table 5-1).

For comparison purposes, background or reference concentrations are listed at the bottom of the tables for inorganic compounds. These background concentration values were derived from the following:

- The reference results (and average of these results) for sediment samples collected as part of the USGS National Water Quality Assessment (NWQA) program

- The average value for sediment sample results collected from Lake Winnebago as part of this effort (discussed below)

- The WDNR Triad Assessment reference sample results from Lake Butte des Morts (WDNR, 1996)

- The average sediment concentrations for northern Wisconsin streams generated as part of the National Uranium Resources Evaluation (NURE) project (Mudrey and Bradbury, 1992)

- The EPA range of background concentrations for inorganic compounds in soils (EPA, 1983)

All barium values detected were below the NURE and EPA background levels and do not warrant specific discussion in individual river reaches (Table 5-6). Similarly, nickel, selenium and silver occurred within or near the cited ranges of background values, except at SMU 38 of the De Pere to Green Bay Reach, which exhibited the highest concentrations of these three parameters for all samples collected in the river or the bay (Table 5-6). Results from the other Fox River reaches indicate that concentrations are relatively low and stable compared with the De Pere to Green Bay Reach while levels in Green Bay seldom exceed background values. Therefore, nickel, selenium and silver are discussed only in the De Pere to Green Bay Reach.

Over 140 copper and zinc samples exceed the Lake Winnebago, NURE, and WDNR Triad Assessment background concentration values. There are no obvious trends to the occurrence of these elevated concentrations as they are widely distributed in the sediments and the average concentrations for each reach show no clear pattern (Table 5-6). Although concentrations within Green Bay are generally slightly lower, many still exceed these background values. Moreover, zinc values above 75 mg/kg are typically considered to be representative of soils. Due to the fact that these parameters are not significant environmental or human health concerns, especially when compared with PCBs and other organic compounds, copper and zinc are not addressed in the discussions of compounds detected in each reach of the river.

Other inorganic compounds (aluminum, antimony, beryllium, calcium, cobalt, iron, magnesium, manganese, potassium, sodium, thallium and vanadium) have been analyzed in 35 to 71 sediment samples and the results are listed on Table 5-7. Excluding antimony and thallium, the other compounds were detected in almost every sample analyzed. Many of these samples exceed the NURE background levels but do not necessarily exceed the EPA listed range of concentrations typical in natural soil (Table 5-7). These inorganic parameters were detected at relatively consistent levels, indicating that these parameters are widely distributed in the sediments due to background levels of these materials in the native soils of the region. Additionally, most of these parameters are not significant environmental or human health concerns. Due to these factors, these compounds are not addressed in the discussions of compounds detected in the river or bay.

Ammonia (as nitrogen) was detected in 97 samples in the Lower Fox River and in 19 samples in Green Bay (Table 5-8). In sediments, ammonia is usually generated during anaerobic breakdown of organic material; therefore, higher levels of ammonia suggest that anaerobic degradation of organic material is occurring. However, industries along the Lower Fox River also discharge ammonia and organic material into the system. Therefore, it is difficult to distinguish between production of ammonia from the breakdown of naturally occurring compounds or from anthropogenic sources of ammonia/organic material. Ammonia concentrations in Fox River sediments range from 25 to 700 μg/kg and 95 (98 percent) of these samples exceed the reference concentration of 31 μg/kg (Table 5-8). In Green Bay the ammonia concentrations range from 22 to 140 μg/kg and 17 (89 percent) of these samples exceed the reference concentration (Table 5-8). Due to the difficulty in determining the source of ammonia (naturally occurring vs. anthropogenic related) and that the SLRA did not identify ammonia as a compound of potential concern, discussion of ammonia in river and bay sediments is limited.

Cyanide was analyzed in 28 sediment samples but was only detected in three samples (11 percent) collected as part of the SMU 56/57 SRD project. These results ranged from 0.73 to 3 mg/kg. Cyanide was not identified a concern in the SLRA. Due to the low number of detected results and the fact that all three samples were collected from the same location, no further analysis of cyanide impacts will be discussed and these data are not included on any tables.

5.2.6TCLP Results

Thirteen RCRA metal sediment samples collected upstream of the De Pere dam were analyzed by the Toxicity Characteristic Leaching Procedure (TCLP) (Tables 5-1 and 5-9). One additional sample was also analyzed only for TCLP silver. None of the samples had TCLP concentrations approaching the regulatory levels that would classify the sediments as characteristically hazardous.

5.2.7Semi-Volatile Organic Compounds (SVOCs)

None of the SVOCs were identified as chemicals of potential concern in the SLRA (RETEC, 1998c) but are summarized below due to their ubiquitous occurrence in the environment. SVOCs are a class of approximately 10,000 compounds that are found in thousands of products ranging from fuels, paints, and adhesives to skin creams and shampoos. They also result from the burning of solid waste, coal, and other organic material (Wisconsin Division of Health, 1994). Numerous SVOCs have been analyzed in sediments, but only six (not including PAHs) were detected in more than four samples (Table 5-1). SVOC samples were collected from Lake Winnebago, deposits C, E, POG, W, X, EE, GG, HH, and downstream of De Pere dam within the Lower Fox River, and from Green Bay zones 2 through 4 (Table 5-1).

PAHs are a subgroup of SVOCs comprised of 18 different compounds. Some PAHs are compounds of concern in the environment because they are carcinogenic. All 18 PAHs were detected in Lower Fox River and Green Bay sediments and the results are listed on Table 5-10.

In addition to PAHs, PCP is another SVOC of potential concern with respect to human health and the environment. PCP samples, like dioxin/furan, were collected from Lake Winnebago, deposits C, D, E, POG, EE, and downstream of the De Pere dam in the Lower Fox River, and from Green Bay. PCP was detected in 19 samples from the Lower Fox River and Green Bay, with concentrations ranging up to 1,100 μg/kg (Table 5-11). During the GAS/SAIC (1996) investigation, 16 PCP samples were collected from locations to evaluate vertical distribution within sediments. However, the method detection limit was elevated to 176 μg/kg (likely due to laboratory interference) in 14 of these samples and PCP was not detected. Therefore, all but one of these previously collected PCP results are from the upper sediments. PCP results are listed on Table 5-11.

Almost 50 SVOCs were detected in sediments, including all of the PAHs and PCP (Table 5-1). Besides PAHs and PCP, only five other SVOCs were detected in more than four samples, and these generally belonged to the phthalate, chlorobenzene, or phenol groups (Table 5-11). Fourteen of the SVOC/PAH compounds (totaling 153 individual samples) have been detected at concentrations exceeding 1,000 μg/kg (1 ppm); 11 of these compounds are PAHs or PCP (Tables 5-10 and 5-11). Pyrene is the most prevalent PAH in river and bay sediments and typically has the highest concentration in any given sample. Total PAH and SVOC results were compared to total PCB and there is no direct correlation between these parameters.

5.3 Lake Winnebago (Background) Results

Sediment samples were collected from three locations within Lake Winnebago to provide background concentrations of compounds entering the Lower Fox River for use in the RA. The Lake Winnebago sediment samples collected from 0 to 5 cm (0 to 2 in) were analyzed for PCBs (both Aroclors and congeners), SVOCs, pesticides, and metals. Only Aroclors 1242 and 1254 were present at concentrations from 10 to 20 μg/kg, whereas the three detected PCB congeners were below 5.5 μg/kg (Table 5-12). The congener analyses were the same as those used for the Lower Fox River sediments. Therefore, the number of congeners detected at low concentrations suggest that PCBs in Lake Winnebago are not a concern and the PCB congener concentrations are low compared with concentrations observed in the Lower Fox River (Table 5-2). None of the coplanar congeners were detected in Lake Winnebago. Total PCB concentrations in Lake Winnebago sediments ranged as high as 36 μg/kg (Table 5-12).

Dioxin/furan samples were not collected in Lake Winnebago and PCP was not detected.

The pesticides DDE, alpha-BHC, and endosulfan sulfate were the only chlorinated pesticides detected in Lake Winnebago. The three pesticides detected in Lake Winnebago sediments were also less than 3.6 μg/kg (Table 5-12). Downstream of Lake Winnebago, DDE was detected in five samples and alpha-BHC was detected in one sample; endosulfan sulfate was not detected.

Detected SVOCs were limited to eight of the PAHs, 4-Methylphenol, and bis(2-ethylhexyl)phthalate (BEHP). These are some of the same SVOCs found at a number of locations throughout the Lower Fox River (Tables 5-5, 5-6, and 5-12). Background concentrations of these parameters range as high as 350 μg/kg (BEHP, Table 5-12). The detected SVOCs (and PAHs in particular) cannot be attributed to a specific point or non-point source within Lake Winnebago or from further upstream, because these compounds are so widely used in so many different products and purposes. Total PAHs in Lake Winnebago sediments averaged 575 μg/kg (0.575 mg/kg) and ranged up to 842 μg/kg (0.842 mg/kg).

Seven metals, including mercury, lead, and arsenic, were detected in Lake Winnebago sediments (Table 5-12). Concentrations ranged up to 0.17 mg/kg for mercury, up to 39 mg/kg for lead and up to 6 mg/kg for arsenic. These results have been averaged for comparison with results from Lower Fox River sediments.

Metal concentrations detected in Lake Winnebago sediment are approximately 2 to 3 times greater than the average NURE background concentrations listed on Tables 5-7 through 5-9. This difference is likely due to the fact that most of the NURE sediment samples were collected from smaller, more rural streams which have lower population density and less industrial/agricultural activity than the Lake Winnebago/Lower Fox River system.

5.4 Chemical Distribution in Sediments

5.4.1 Overview

This section discusses the magnitude and distribution of the COPCs in the Lower Fox River and Green Bay as well as other selected organic and inorganic parameters that are widely distributed in river and bay sediments. The emphasis of this section is on the occurrence and distribution of PCBs, based on the SLRA findings that PCBs are the primary chemicals of concern (COCs) in the Lower Fox River and Green Bay sediments.

The availability of numerous data points encompassing years of studies enables a more rigorous discussion of PCB distribution relative to other parameters Computer modeling and analysis has been used to assist in compiling these data points into graphical interpretations (i.e., bed maps) which illustrate the PCB distribution in individual sediments deposits/SMUs, the river reechoes, and the bay zones. While sediments in river reaches below Lake Winnebago may be referred to as individual deposits or SMUs in the discussion below, the previously established sediment deposit boundaries are sometimes arbitrary. The large majority of the Lower Fox River bottom contains sediment accumulations of varying depth and the boundaries between identified deposits are not necessarily distinctive and isolated. Rather, some deposits are continuous and transition into others (e.g., deposits EE through HH and SMUs downstream of the De Pere dam), while other deposits are very distinct (e.g., deposits G, H, I, J, etc.). Therefore, individual deposits/SMUs are addressed where the sediments exhibit concentrations or distribution that are relevant to describing the occurrence of compounds in the Lower Fox River.

Given the size and continuity of sediment deposits in the bay, it was not appropriate to establish specific "deposits". Similar to the De Pere to Green Bay Reach, sediments within the bay are continuous and the previously introduced zone designations have been established to facilitate discussion of the distribution of PCBs. A limited number of samples were collected from each zone, due to the size of the bay and the relative consistency of depositional environments for sediments derived from the Lower Fox River.

5.4.2PCB Distribution

A general breakdown of total PCB results for each deposit/SMU group/zone are listed on Table 5-2. PCB concentrations ranged as high as 710,000 μg/kg in the Lower Fox River while the maximum concentration in Green Bay was 17,000 μg/kg. Along with the minimum and maximum PCB concentration results for each deposit/SMU group/zone, the RI, RA, and logarithmic means have been calculated for each area as described above. The RA and logarithmic means are used herein to represent PCB concentrations within a given deposit/SMU group/zone and to compare these results with other areas of the river or bay. These results have been used to map PCB distribution in the river and bay, as well as to estimate both the PCB mass and volume of sediments containing PCBs.

The PCB maximum, minimum, RA Mean, and logarithmic mean results for each deposit/SMU group/zone are plotted to illustrate the general trends for sediment concentrations from Lake Winnebago into Green Bay (Figure 5-2). When viewed alongside Figure 1-3 through 1-6, the summary of total PCB concentrations (Figure 5-2) shows that higher average PCB concentrations are generally found either in the vicinity of where the PCB discharges occurred (LLBdM) and/or locations where significant volumes of sediment have accumulated (Deposit EE behind the De Pere dam).

5.4.2.1 Bed Maps and Sediment Data Interpolation Methods

Bed maps were prepared showing the sediment thickness and occurrence of PCBs in the Lower Fox River and Green Bay from data in the FRDB. The methods used to produce these maps were the same as those outlined in WDNR Technical Memorandum 2e, the addendum to Technical Memorandum 2e, and Technical Memorandum 2f (1999c, 2000e, and 2000c, respectively). In order to prepare these bed maps for the river and the bay, it was necessary to extrapolate PCB concentration and sediment thickness between specific data points. These data interpolations were conducted for PCB concentration, sediment thickness, and sediment bulk density. The sediment thickness and PCB concentration interpolations were used to construct the distribution maps. Bulk density data were interpolated only to compute the PCB mass in sediments, and consequently are not plotted.

The interpolation analyses were conducted using ArcView 3.0 and Spatial Analyst 1.0 (ESRI) in both the river and the bay. However, slightly different approaches were used in each water body due to the availability of data and the size of the water bodies. The following sections discuss the specific methods used in the interpolations in each water body.

PCB Concentration Interpolations for the Fox River

The interpolations for the 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 the following FRDB studies:

- 1989/90 Fox River Mass Balance Study
- 1989/90 Green Bay Mass Balance Study (GLNPO)
- 1994 Woodward-Clyde Deposit A Sediment Data
- 1992-1993 BBL Deposit A Sediment Data
- 1994 GAS/SAIC Sediment Data
- 1995 WDNR Sediment Data
- 1996 FRG/BBL Sediment/Tissue Data
- 1997-1998 Demonstration Project Data - SMU 56/57
- 1998-1999 Deposit N Post-Dredge Sediment Data
- 1998 FRG/BBL Sediment/Tissue Data
- 1998 RETEC RI/FS Supplemental Data

The interpolation of data for the Fox River involved both a screening of historic data and interpolation of the data to each river reach. In order to use the most recent data available, the data were assigned to three different time periods: 1989-1992, 1993-1995, and 1996-1998. All of the data from the period 1996-1998 were considered sufficiently recent and were used in the interpolation. However, data collected prior to 1996 were screened to remove data points that were in close proximity to locations with recent data.

To determine an appropriate distance for deleting pre-1996 data points, a relationship was developed between similar ranges of PCB concentrations and the distances between data points in that range. From this analysis it was determined that pre-1996 sample points located less than 133 m (436 ft) from a more recent sample point should not be used in the interpolations. This analysis was conducted first on the 1993-1996 data set to make a new data set for the 1993-1998 period. The analysis was then repeated using the 1989-1992 data set. In this way, the entire data set from 1989-1998 was used, but older data were superceded by more recent data as appropriate.

The interpolation was then conducted using this revised 1989-1998 data set. The procedure used for the interpolation was to break down the entire area of the Fox

River into a square grid with point's 10 meters apart. The data were then used to interpolate the value at each grid point.

The interpolation was developed using the inverse distance method, which results in the value at a grid point being 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 way 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 the inverse weighting, a set distance was selected for which data points would influence grid point results. For example, if there are no data points close to the grid point, then the grid point value would be interpolated from data that may be located a significant distance away. This can lead to erroneous interpolations as the data have been extrapolated over a long distance. 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 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 (or a "null point") was interpolated for that grid point in Spatial Analyst and the program then ignored these points.

The interpolation radius for computing sediment thickness was set at 100 m. For PCB and bulk density the interpolation radius varied among the river reaches. In the LLBdM Reach, complete coverage of the river required that a radius of 400 m (1,312 ft) be used. 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 m (259 ft), to minimize the influence of separate deposits on the interpolation. For the Little Rapids to De Pere and De Pere to Green Bay reaches, an interpolation radius of 1,000 m (3,280 ft) was used. This is specified in Technical Memorandum 2e and in the Technical Memorandum 2e addendum (WDNR, 1999c; WDNR, 2000e).

Data interpolations for the Fox River were conducted for nine different layers of sediment depth: 0-10 cm, 10-30 cm, 30-50 cm, 50-100 cm, 100-150 cm, 150-200 cm, 200-250 cm, 250-300 cm, and greater than 300 cm. These sediment depths were selected based on previous and current modeling efforts as well as being defined by WDNR (1999c).

PCB Concentration Interpolations for Green Bay

Interpolation of sediment data from Green Bay followed the same methods as used in the Fox River. The data set for the Green Bay interpolations included approximately 240 sample results and locations from the following FRDB studies:

- 1989/90 Fox River Mass Balance Study
- 1989/90 Green Bay Mass Balance Study (GLNPO)
- 1995 WDNR Sediment Data
- 1996 FRG/BBL Sediment/Tissue Data
- 1998 FRG/BBL Sediment/Tissue Data

Because the hydraulic and sediment deposition characteristics of Green Bay are more uniform over larger distances, compared to the Lower Fox River, sediment data interpolations were adjusted accordingly. The methods used are the same as those outlined in Technical Memorandum 2f (WDNR, 2000c). Green Bay was divided into a square grid with 100 m between points, as opposed to a 10 m grid on the Fox River. The same inverse distance approach was used on both the Fox River and Green Bay, but the analysis on Green Bay used the distance squared rather than the distance raised to the fifth power (WDNR, 2000c). Therefore, interpolated results in Green Bay are more affected by data points farther way from the grid point than in the 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 4 times more to the interpolation than does the second point.

The interpolation radius for Green Bay was set at 8,000 m (26,250 ft) (WDNR, 2000c). This means that data points more than 8,000 m (26,250 ft) from a grid point were not used in the interpolation for that grid point. Conversely, grid points more than 8,000 m (26,250 ft) 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 (Plates 3-5 and 5-5).

Data interpolations for Green Bay were conducted for four different layers of sediment depth: 0-2 cm, 2-10 cm, 10-30 cm, and greater than 30 cm. In addition to these four sediment layers, a composite sediment layer was developed for a thickness of 0-10 cm. This layer was computed as a thickness-weighted average of the 0-2 and 2-10 cm layers. The 0-10 cm composite layer was developed for use in the RA and food web modeling. The other two layers were selected to coincide with the layering developed for the river, as well as also supporting modeling efforts.

Sediment Thickness Interpolations

In addition to PCB and other environmental parameters discussed above, interpolated grids were also developed for the presence or absence of sediment in the Fox River and Green Bay. The Fox River grid showing the occurrence of sediment was developed from field measurements of sediment thickness. As discussed previously, the sediment distribution maps for each river reach were shown on Plates 3-1 through 3-4. The occurrence of sediment was interpolated separately for all nine layers on the Fox River. For each layer, if the thickness at a sampling location was less than half the layer thickness, then the area was identified as an absence of sediment in that layer. Using this approach, sediment was also identified as absent in deeper layers if the sample depth did not extend to the modeled depth (e.g., if a sample was collected from 0 to 50 cm, the interpolation results indicate that there is no sediment present in the 50 to 100 cm layer).

For Green Bay, the occurrence-of-sediment grid was developed from the Green Bay Mass Balance Study (Manchester-Neesvig, *et al*., 1996) using a 5,000 m (16,400 ft) by 5,000 m (16,400 ft) grid. Based on sampling results, each grid cell was determined to be either soft sediments or glacial till (no soft sediments present). Grid cells that were not sampled were assigned to either the soft sediment or glacial till categories based on professional judgement, which included consideration of adjacent cells where sampling occurred and the depositional environment. For instance, areas near the mouth of the Fox River that were not sampled were considered to contain soft sediment as this is a depositional zone for sediments from the river. The 5,000 m (16,400 ft) grid was translated into a 100 m (328 ft) grid to match the sediment interpolation grids and allow a direct overlaying of the different grids. The sediment distribution map was shown on Plate 3-5.

The occurrence-of-sediment grids were used to edit the PCB concentration grids. This is necessary due to limitations in the PCB interpolation analysis. The PCB concentration interpolations do not consider whether sediment is present or absent. Consequently, PCB concentrations can be interpolated into areas that do not contain sediment. By using the occurrence-of-sediment grids, the PCB interpolation was restricted to those areas where sediments are present.

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 color contoured into different ranges based on PCB concentration. The PCB bed maps for the Lower Fox River are shown on Plates 5-1 through 5-4 and the Green Bay bed map is shown on Plate 5-5. Areas were sediment is absent or outside the interpolation radius are not included in the color contouring.

PCB Volume and Mass Estimates

The interpolated grids provide a means of computing the PCB mass and contaminated sediment volume in the Lower Fox River and Green Bay. Each grid point represents a grid cell with an area 10 m (33 ft) by 10 m (33 ft) in the Fox River and an area 100 m (330 ft) by 100 m (330 ft) in Green Bay. The sediment volume at each grid cell in a layer is computed as the grid cell area multiplied by the layer thickness. The volume within a layer above some PCB concentration can be estimated by summing the number of grid points above the PCB concentration and multiplying by the area of a grid cell and the thickness of the layer. The grid points can also be counted within a river reach, deposit/SMU area, or Green Bay zone to determine the volume of contaminated sediment within an area of the river or bay. The estimated volume of sediments with PCBs is discussed for each reach or zone below.

Mass calculations are computed in a manner similar to the volume calculation. The PCB mass is computed by multiplying the sediment volume by the bulk density and the PCB concentration at a grid cell. Summing the mass over the grid cells within a reach, deposit/SMU or zone yields the mass of PCB within that area of the river or bay. The estimated mass of PCBs is discussed for each reach or zone below.

The PCB mass and impacted sediment volume estimates obtained from the data interpolations are listed in Tables 5-13, 5-14, and 5-15. Estimated results for the Lower Fox River are listed by concentration range in Table 5-13 and by sediment depth interval in Table 5-14. Results for Green Bay are included in Table 5-15. Due to rounding and significant figure issues, there is a slight difference in the total PCB mass calculated as calculated by concentrations range or by depth for both the river and the bay. The total PCB mass difference in the river is just over 37 kg (81 pounds) or just 0.13 percent of the total estimated mass for the entire river (Tables 5-13 and 5-14). Similarly, in Green Bay the calculated difference in the total PCB mass between the mass by concentration range or by depth is just 3 kg (7 pounds), which is 0.004 percent of the total bay mass. The difference in Green Bay is likely due to the smaller, more intricate grids areas used to interpolate the data over the river bed. These calculated differences are extremely small compared with the total mass in both the river and may and are not of concern in the final evaluation of PCBs in sediments. Due to the fact that the sediment volumes results do not have any digits beyond the decimal, rounding and significant figure issues did not influence these calculations.

5.4.2.2 Lower Fox River and Green Bay PCB Results

Based on the PCB concentration and sediment thickness interpolations, the large majority of PCB mass and impacted sediments are located within Green Bay. The results calculations are summarized below:

	Lower Fox River	Green Bay
PCB Mass in Sediments	28,602 kg (63,060 pounds)	69,954 kg (152,850 pounds)
Volume of Impacted Sediments	9,348,480 m^3 (12,227,350 yd^3)	622,300,000 m^3 (813,937,700 yd^3)

Virtually all of the PCB mass is located within the De Pere to Green Bay Reach of the Lower Fox River and zones 2 and 3 in Green Bay, as shown in Figure 5-3.

The calculated PCB mass for each river reach deposit/SMU group and bay zone are listed on Tables 5-13 through 5-15. These data are also summarized graphically by concentration range on Figures 5-4 through 5-7. The mass and volume plots for Green Bay (Figures 5-6 and 5-7) also include the total mass and volume results for the Lower Fox River for comparison, respectively. In addition, the PCB mass for particular sediment depth intervals has been plotted (Figure 5-8). The depth intervals for the Lower Fox River are 50 cm and extend to 350 cm deep. Two depth intervals, 0 to 30 and below 30 cm, are plotted for Green Bay (Figure 5-8).

As noted above, the volume of sediments containing PCBs rises substantially from the Lower Fox River out into the Green Bay zones. The ratio of the PCB mass in each cubic meter (g/m^3) of sediment in the Lower Fox River and Green Bay has been calculated using the interpolated results. The mass/volume ratios were obtained for each concentration range by dividing the PCB mass by the sediment volume listed for the reach or zone (Tables 5-13 and 5-15, respectively). These ratios were calculated to evaluate which areas of the river or bay contain the highest PCB mass on a volume basis (Tables 5-13 and 5-15). These results are also plotted to facilitate evaluation and comparison of the river reaches and bay zones (Figure 5-9). The greatest ratio of PCB mass per cubic meter of sediment (g/m^3) occurs within the Lower Fox River, and the De Pere to Green Bay Reach in particular, as shown on Figure 5-10.

The PCB mass/sediment volume ratio is important to the consideration of remedial alternatives since it is desirable to treat/remove the greatest contaminant mass per unit volume of sediment. PCB within Green Bay is generally contained within large volumes of sediment at relatively lower concentrations.

The entire Lower Fox River has a PCB mass to sediment volume ratio of 3.32 g/m3 in sediments with concentrations exceeding 50 μg/kg (0.05 ppm) (Table 5-13). Based on the calculated estimates presented on Table 5-13, sediments with less than 50 μg/kg total PCBs account for less than 0.024 percent of the total calculated PCB mass. Similarly, in Green Bay sediments with concentrations exceeding 50 μg/kg (0.05 ppm), the PCB mass to sediment ratio is 0.22 g/m^3 (220 milligrams per m^3) (Table 5-15). Based on the calculated PCB mass estimates, sediments with less than 50 μg/kg PCBs account for less than 2.6 percent of the total PCB mass (Table 5-15). Further, Green Bay sediments with PCB concentrations exceeding 1,000 μg/kg are limited to zones 2A, 2B, and 3A while sediments with PCB concentrations exceeding 5,000 μg/kg are limited to zones 2A and 2B (Table 5-15).

The PCB mass and contaminated sediment volume exceeding the 50 μg/kg (0.05 ppm), 1,000 μg/kg (1 ppm), and 10,000 μg/kg (10 ppm) concentrations are summarized below for each reach or zone. The discussions below focus on those mass and volume results for sediments containing over 50 μg/kg PCB, which is slightly above total PCB concentrations observed in Lake Winnebago. These concentration ranges have been selected, along with Figures 5-4 through 5-7, to facilitate comparison between reaches/zones at given concentrations.

The USFWS reviewed the statistical similarities between PCB congeners in sediments of the Lower Fox River, Inner Green Bay, Outer Green Bay and Lake Michigan as part of the PCB pathway determination (Stratus, 1999a). The Principal Component Analysis of PCB congeners indicated that samples from within each one of these four regions tended to group together. USFWS concluded that the congener patterns tended to be similar within each region and that they could be used to discriminate between regions of the system. Further, the Principal Component Analysis identified the overall degree of congener chlorination was the most important factor in explaining variability between samples and regions (Stratus, 1999a).

5.4.2.3 LLBdM Reach PCB Results

The LLBdM Reach of the Lower Fox River includes nine sediment deposits, A through H and POG (Figure 1-3). A total of 661 PCB samples have been collected along this reach in the previously identified investigations and PCBs were detected in 539 of these samples. These samples were collected from 293 coring locations and many of these represent discrete sample depth intervals within the same core.

Total PCB concentrations for this reach ranged from non-detectable to 222,722 μg/kg (Table 5-2). The average concentrations for deposits in this reach range from 180.00 to 24,373.31 μg/kg while the logarithmic mean ranges from 90.75 to 3,723.42 μg/kg. The mean results for the reach reflect the influence of deposits A and POG. These are the only two areas where the deposit averages exceed the average values for the entire reach (Table 5-2), which shows the influence of deposits where the sediments contain elevated PCB concentration and significant work has been completed.

The PCB sample frequency distribution results for LLBdM indicate that much of the investigation within this reach has focused on sediment deposits A and E, where approximately 325 and 150 total PCB samples results are available (Figure 5-1). Deposits D, C, and POG include 39 to 57 sample results in these deposits (Table 5-2). Only 2 to 12 total PCB sample results were obtained from each of deposits B, F, G, and H (Table 5-2). Only five samples were collected from Deposit B, but there is no physical barrier between deposits A and B. These two deposits are essentially one large, continuous sediment unit. Therefore, the estimated PCB mass and sediment volumes obtained for these two deposits are combined in discussions below.

Large areas and volumes of sediment have accumulated in LLBdM. All seven of the deposits located within the lake (A through F and POG) have a surface area ranging from 12.36 hectares (30.5 acres) to 202.5 hectares (500.4 acres) (Table 5-13). The interpolated total PCB results at select depth intervals are shown on Plate 5-1. Areas of greatest surface (0 to 10 cm) concentrations occur within portions of deposits A, C, E, and POG where total PCB exceeds 10,000 μg/kg. These elevated concentrations continue to be detected at the 10 to 30 cm depth interval in deposits C and E, in the 30 to 50 cm interval in Deposit A, and at sediment depths up to 150 cm at Deposit POG. Elevated concentrations were also estimated to be present in Deposit B from the interpolated data, due to close proximity of upstream Deposit A and the lack of any physical barrier separating these two deposits. In some areas, concentrations increase with depth, such as deposits A and B, where concentrations in the 30 to 50 cm interval are higher in some areas than the surface sediment results (Plate 5-1).

The area with the highest PCB concentrations is located just outside of Deposit POG, where the surface sediments exhibit concentrations exceeding 50,000 μg/kg. However, these concentrations decrease rapidly and only a small area of sediments with such levels is present in the 30 to 50 cm interval (Plate 5-1).

Deposits D, E and F represent a broad section of the LLBdM Reach downstream of deposits A, C, and POG. One area of Deposit E (mentioned above) and a small part of Deposit D have surface sediment concentrations exceeding 5,000 or 10,000 μg/kg. Below a depth of 30 cm, total PCB concentrations exceed 1,000 μg/kg only in isolated areas, indicating that sediment impacts in these areas do not typically extend to great depths. Where sediments have been sampled in the 50 to 100 cm interval, concentrations tend to be less than 50 μg/kg (Plate 5-1).

Beyond the downstream deposits E and F, the LLBdM Reach exhibits little sediment accumulation, except for two relatively small, isolated areas (deposits G and H). Total PCB concentrations in Deposit G ranged up to 250 μg/kg, while concentrations in Deposit H ranged as high as 5,000 μg/kg range (Plate 5-1). However, PCB concentrations in these two deposits declined quickly, as indicated by the results from the 30 to 50 cm interval (Plate 5-1), similar to the results obtained for deposits D, E, and F.

The summary of total PCB concentrations, including the maximum, minimum, RA Mean, and logarithmic mean results for the LLBdM Reach, are plotted on Figure 5-2. Most significantly impacted deposits are located in the vicinity of former sources and/or locations where significant volumes of sediment have accumulated, both within this reach of the river and in downstream reaches as well. The PCB distribution in deposits A, B, and C reflect the influence of the Neenah Slough, the Arrowhead Park Site, and the Kimberly Clark/Badger joint WWTP, all located on the south side of LLBdM, where significant historical releases of PCBs were reported to occur to the Lower Fox River. Elevated PCB sediment concentrations in Deposit POG reflect the impact of discharges from the Neenah-Menasha WWTP, located near the south end of Deposit POG. The Neenah-Menasha WWTP received process wastewater from Wisconsin Tissue Mills which contained PCBs (WDNR, 1999a). The RA Mean PCB values in the upstream end of LLBdM, in the vicinity of deposits A, C, and POG, exceed 9,000 μg/kg, as well as having a logarithmic mean above 1,000 μg/kg. Moving downstream past Deposit POG, the values decline to about 300 g/kg in the vicinity of deposits E through H.

The PCB mass and sediment volume estimates within the LLBdM Reach for the 50 μg/kg, 1,000 μg/kg, and 10,000 μg/kg concentrations ranges is summarized below.

LLBdM PCB Mass and Contaminated Sediment Volume Percentages

Sediment Concentration Range	PCB Mass	Percent of PCB Mass in River	Contaminated Sediment Volume	Percent of Contaminated Sediment Volume in River
>50 ug/kg	1,540 kg (3,395 pounds)	5.38%	1,353,340 m^3 (1.77 mill. yd^3)	15.42%
>1,000 ug/kg	1,427 kg (3,146 pounds)	4.99%	493,480 m^3 (654,448 yd^3)	5.26%
>10,000 ug/kg	859 kg (1,894 pounds)	3.00%	95,140 m^3 (124,438 yd^3)	1.01%

The calculated PCB mass/sediment volume ratios for each of the deposits are included on Table 5-13 but the ratios for sediment with more than 50 μg/kg are summarized below.

LLBdM PCB Mass/Sediment Volume Ratios for Sediments with more than 50 μg/kg

Deposit	PCB Mass (kg)	Sediment Volume (m^3)	PCB Mass to Volume Ratio (g/m^3)
Deposit A	237.4	107,730	2.20
Deposit B	410.9	41,740	9.84
Deposit C	38.9	59,230	0.66
Deposit POG	303.4	103,030	2.95
Deposit D	82.6	66,710	1.24
Deposit E	452.8	869,910	0.52
Deposit F	10.9	95,920	0.11
Deposit G	0.7	8,380	0.09
Deposit H	0.7	690	1.00
Reach Total	1,538.3	1,353,340	1.14

Ignoring Deposit B, the mass/volume ratios indicate that deposits A and POG are the only two locations where there are more than 2.2 g/m^3 of PCB in sediments with concentrations exceeding both 50 μg/kg and 1,000 μg/kg (Table 5-13). In sediments with concentrations exceeding 10,000 μg/kg, deposits A and POG both exceed 7.1 g/m^3 (Table 5-13). Combining the results for deposits A and B, there is approximately 648 kg (1,430 pounds) of PCB in about 149,500 m^3 (195,540 yd^3) of sediment. These combined results yield ratios of about 4.3 g/m^3 and 5.0 g/m^3 of PCB in sediments with concentrations exceeding 50 μg/kg and 1,000 μg/kg, respectively (Table 5-13). In sediments with more than 50,000 μg/kg PCB, the mass/volume ratio is about 21 g/m^3 (Figure 5-9).

Deposits F and G represent very low PCB mass and high sediment volume areas of this reach while deposits G and H contain less than 1 kg of PCBs (Table 5-13). Overall, the most significant deposits within this reach, in order of PCB mass in each cubic meter of sediment, are A/B, POG, E, and C.

The PCB mass distribution in each sediment layer is plotted on Figure 5-8. About 1,080 kg (2,380 pounds)of PCBs are present in the upper 50 cm (Figure 5-8); 315 kg in the 0 to 10 cm layer, 535 kg in the 10 to 30 cm layer, and 411 kg in the 30 to 50 cm layer (Table 5-14). Approximately 70 percent of the PCB mass in LLBdM is located in the upper 50 cm of sediment.

The PCB mass and sediment volume in inter-deposit areas was also estimated as part of the data interpolation efforts. Based on the interpolated results, the LLBdM Reach contains approximately 1,849 kg (4,075 pounds) of PCBs in about 1.68 million m^3 (2.2 million yd^3) (Table 5-13). Almost 310 kg (681 pounds) of PCBs are contained within about 180,000 m^3 (235,430 million yd^3) outside of the deposits (Table 5-13). If the four deposits identified above (A/B, POG, E, and C) are addressed, an estimated 400 kg (880 pounds), or about 30 percent, of PCBs would remain within the river sediments.

5.4.2.4 Appleton to Little Rapids Reach PCB Results

The Appleton to Little Rapids Reach of the river includes 22 sediment deposits, I through DD (Figure 1-4). PCBs have been detected in 188 sediment samples collected along this reach in the previously identified investigations (Table 5-2). These samples were collected from 131 coring locations and many of these represent discrete sample depth intervals within the same core. Total PCB concentrations for this reach ranged from non-detectable to 77,444 μg/kg (Table 5-2). The RA Mean for deposits in this reach ranged from 25 to about 25,720 μg/kg, while the logarithmic mean ranges up to almost 2,300 μg/kg (Table 5-2).

PCBs were detected in more than 10 samples from only seven deposits (N, P, Q, T, W, X, and DD) in this reach (Figure 5-1 and Table 5-2). Of the other 15 sediment deposits, three deposits (O, S, and V) had five or six samples with detected PCBs while the other 12 deposits had two or less samples with PCBs.

Sediment deposits N and O were remediated as part of the SRD project (Section 2.1.8). Sediments in Deposit N were dredged to within approximately 7.5 cm (3 in) of the bedrock substrate. As discussed previously, F&VD estimated that approximately 31 kg (68 pounds) of PCB remain in this area. Calculations conducted for this RI using the PCB distribution results (Plate 5-2) indicate that approximately 29 kg (64 pounds) of PCBs remain. Due to the completion of dredging activities at deposits N and O, these deposits will not be included in the discussion below. In addition, due to the relatively low number of samples collected from deposits S and V, and because the estimated PCB mass in both is 0.12 kg (0.26 pound) or less, further discussion of these two deposits will be limited. Therefore, only the nature and extent of PCB impacts detected within deposits P, Q, T, W, X, and DD are discussed in detail below.

Deposits S, W, X, CC, and DD are the only deposits in this reach that have surface areas greater than 10 hectares (24.7 acres) (Table 5-13). All five of these deposits are either located immediately upstream of a dam or in a location where the river width increases significantly and the corresponding stream flow velocities decrease. In general, the greatest mass of PCBs present within this reach is associated with those deposits where the greatest volume of sediment has accumulated.

This reach exhibits a significant decrease in PCB mass with depth (Figure 5-8). About 95 percent of the PCB mass in this reach is located in the upper 50 cm (20 in) of sediment; about 65 percent is contained in the upper 30 cm (12 in) (Figure 5-8 and Table 5-14). Total PCB concentrations in this reach at select depth intervals are shown on Plate 5-2. Accumulations of PCB are very localized in this reach. Areas of greatest surface (0 to 10 cm) concentrations occur within portions of deposits P, Q, T, W, X, and DD. The PCB distribution map (Plate 5-2) shows that deposits P, Q, T, V, W, and DD were the only other areas where surface concentrations exceed 1,000 μg/kg (1 ppm). However, none of the areas with elevated PCB concentrations are very large and the concentrations decrease rapidly with depth. Only small areas of deposits P, T, W, X, and DD have detectable PCB concentrations in sediments at the 30 to 50 cm interval (Plate 5-2). No samples were collected below 100 cm in this reach of the river.

PCBs seem to accumulate in only a few portions of this reach where the river is slowed by dams or natural features. Specifically, the total PCB RA Mean for deposits N, Q, and DD are elevated compared with the rest of this reach, suggesting that these are favorable locations for the deposition of PCB impacted sediments (Figure 5-2). Excluding Deposit N because the SRD project has been completed, the RA means are below 1,000 μg/kg between deposits I through O. The RA mean at Deposit Q is about 2 to 100 times greater than the value for any other deposits within this reach (Figure 5-2 and Table 5-2). Between deposits Q and BB, the mean values show a decreasing trend but the mean values begin a steady upward trend approaching Deposit DD, which continues into the Little Rapids to De Pere Reach (Figure 5-2).

The Appleton to Little Rapids Reach contains an approximate PCB mass of 94 kg (207 pounds) within about 240,940 m^3 (315,140 yd^3) of impacted sediment

(Table 5-13; Figures 5-4 and 5-5). Excluding deposits N and O mass/volume results due to completion of the SRD project, the approximate percentage of PCB mass and contaminated sediment for the 50 µg/kg, 1,000 µg/kg, and 10,000 µg/kg concentrations ranges is summarized below.

Appleton to Little Rapids PCB Mass and Contaminated Sediment Volume Percentages

Sediment Concentration Range	PCB Mass	Percent of PCB Mass in River	Contaminated Sediment Volume	Percent of Contaminated Sediment Volume in River
>50 ug/kg	62 kg (137 pounds)	0.22%	177,480 m^3 (232,135 yd^3)	2.03%
>1,000 ug/kg	47 kg (104 pounds)	0.16%	19,950 m^3 (26,100 yd^3)	0.21%
>10,000 ug/kg	9.4 kg (20.7 pounds)	0.03%	1,300 m^3 (1,700 yd^3)	0.01%

The calculated PCB mass/sediment volume ratios for each of the deposits are included on Table 5-13 but the ratios for sediment with more than 50 µg/kg are summarized below.

Appleton to Little Rapids PCB Mass/Sediment Volume Ratios for Sediments with more than 50 µg/kg

Deposit	PCB Mass (kg)	Sediment Volume (m^3)	PCB Mass to Volume Ratio (g/m^3)
Deposit I	0.2	3,570	0.05
Deposit J	0.1	1,630	0.05
Deposit K	0.1	480	0.19
Deposit L	0.1	570	0.19
Deposit M	0.2	1,650	0.09
Deposit N	29.6	4,880	6.07
Deposit O	2.0	2,430	0.82
Deposit P	5.3	12,800	0.42
Deposit Q	0.2	210	0.81
Deposit R	0.0	990	0.05
Deposit S	0.1	12,550	0.01
Deposit T	11.3	8,360	1.36
Deposit U	0.2	600	0.25
Deposit V	0.0	60	0.26
Deposit W	6.8	53,490	0.13
Deposit X	2.5	30,820	0.08
Deposit Y	0.3	1,330	0.21
Deposit Z	0.4	4,280	0.10
Deposit AA	0.0	390	0.06
Deposit BB	0.1	780	0.08
Deposit CC	0.7	14,300	0.05
Deposit DD	33.5	28,620	1.17
Reach Total	93.7	184,790	0.51

Deposits Q, T, and DD are the only areas that have more than 1 g/m^3 of PCB in sediments containing more than either 50 µg/kg or 1,000 µg/kg (Table 5-13). In addition to these three deposits, only deposits P, U, V, and W have sediments with PCB concentrations exceeding 1,000 µg/kg (Table 5-13). Deposit DD is the only location where PCB concentrations exceed 10,000 µg/kg and the mass/volume ratio exceeds 7 g/m^3 (Table 5-13). Sediments with more than 50,000 µg/kg PCB have a mass/volume ratio exceeding 16 g/m^3 (Figure 5-9). Deposit DD contains almost 55 percent of the PCB in the reach while Deposit T contains slightly less than 19 percent. Deposits W/X and P have about 13 percent and just over 5 percent of the PCB mass, respectively (Table 5-14).

In addition to the mass and sediment contained with the identified deposits, the PCB mass and sediment volume in inter-deposit areas was also estimated. Based on the interpolated data, the Appleton to Little Rapids Reach contains approximately 77 kg (170 pounds) of PCBs in about 251,600 m^3 (329,100 yd^3). Almost 15 kg (33 pounds), about 20 percent of the PCB, is contained within about 18,000 m^3 (23,540 yd^3) outside of the deposits (Table 5-13). This mass is minor compared to the almost 30,000 kg of PCB present within the river.

5.4.2.5 Little Rapids to De Pere Reach PCB Results

The Little Rapids to De Pere Reach includes four sediment deposits, EE through HH (Figure 1-5). PCBs were detected in 542 of 652 sediment samples collected within this reach. These samples were collected from 224 coring locations and many of these represent discrete sample depth intervals within the same core. Total PCB concentrations for this reach ranged from non-detectable to 54,000 μg/kg. The RA mean results range from 4,578 μg/kg to 11,078 μg/kg while the logarithmic mean ranges from 433 μg/kg to 2,544 μg/kg.

The De Pere dam slows water velocities in the river and creates a favorable environment for the accumulation of sediments. The effect is an increase in the area and thickness of impacted sediments near the dam (Plate 5-3), with sediments being deposited over a distance of approximately 8.5 km (5.3 mi) (Plate 5-3). More total PCB sediment results have been obtained from Deposit EE (Figure 5-1) than any other deposit or SMU group in the river, due to its large areal extent and location immediately upstream of the De Pere dam. About 140 total PCB results were also obtained within deposits GG and HH, which are contiguous with Deposit EE (Figure 1-5). Due to the nature of sediments in this reach, all the deposits are discussed as a single unit, which has an areal extent exceeding 266 hectares (658 acres) (Table 5-13).

Interpolated sediment concentrations in these deposits generally range from 500 to 5,000 μg/kg (Plate 5-3). Surface sediment (0 to 10 cm) concentrations in the southern end of Deposit EE are generally below 5,000 μg/kg, except at the southern tip of the deposit where concentrations exceed 10,000 μg/kg (Plate 5-3). Within the De Pere city limits, concentrations generally exceed 1,000 μg/kg but increase moving downstream towards deposits GG and HH and the De Pere dam. Surface sediments at a number of locations in the northern half of Deposit EE and large portions of deposits GG and HH exceed 10,000 μg/kg.

In the 10 to 30 cm interval PCB concentrations have decreased to less than 50 μg/kg over large portions of Deposit EE. South of the city of De Pere limits, one location at the tip of the deposit has PCB concentrations ranging up to 5,000 μg/kg (5 ppm) and three areas have concentrations ranging up to 1,000 μg/kg (1 ppm) (Plate 5-3). In deposits GG/HH and at the north end of Deposit EE sediment concentrations still exceed 10,000 μg/kg (10 ppm) (Plate 5-3).

PCBs were largely confined to sediments in the north end of Deposit EE and in deposits GG/HH below 30 cm (Plate 5-3). In the central potion of Deposit EE the PCB concentrations range from 250 to 500 μg/kg but increase moving toward the dam. Sediment concentrations in deposits GG/HH still exceed 5,000 μg/kg to 10,000 μg/kg in isolated locations (Plate 5-3). Between 30 and 50 cm, sediments with concentrations above 10,000 μg/kg are confined to Deposit GG and isolated locations in the downstream portion of Deposit EE. Although PCB concentrations decrease with depth, the levels still exceed 1,000 μg/kg (1 ppm) over a large portion of this reach to a depth of 100 cm (1 m or 3.28 ft). Below 100 cm (3.28 ft), only isolated locations in deposits EE/GG/HH have PCB concentrations which range up to 500 μg/kg while over most of the area the concentrations decrease rapidly to less than 50 μg/kg (Plate 5-3).

This reach contains an approximate PCB mass of 985 kg (2,170 pounds) is present in about 2.1 million m^3 (2.7 million yd^3) of impacted sediment (Table 5-13; Figures 5-4 and 5-5). The approximate percentage of PCB mass and contaminated sediment for the 50 μg/kg, 1,000 μg/kg, and 10,000 μg/kg concentrations ranges is summarized below.

Little Rapids to De Pere PCB Mass and Contaminated Sediment Volume Percentages

Sediment Concentration Range	PCB Mass	Percent of PCB Mass in River	Contaminated Sediment Volume	Percent of Contaminated Sediment Volume in River
>50 ug/kg	980 kg (2,160 pounds)	3.48%	1,709,000 m^3 (2,235,300 yd^3)	19.52%
>1,000 ug/kg	858 kg (1,892 pounds)	3.00%	326,180 m^3 (426,627 yd^3)	3.48%
>10,000 ug/kg	408 kg (900 pounds)	1.43%	48,920 m^3 (63,985 yd^3)	0.52%

The calculated PCB mass/sediment volume ratios for each of the deposits are included on Table 5-13 but the ratios for sediment with more than 50 μg/kg are summarized below.

Little Rapids to De Pere PCB Mass/Sediment Volume Ratios for Sediments with more than 50 μg/kg

Deposit	PCB Mass (kg)	Sediment Volume (m^3)	PCB Mass to Volume Ratio (g/m^3)
Deposit EE	828.4	1,660,390	0.50
Deposit FF	0.1	700	0.12
Deposit GG	81.0	18,320	4.42
Deposit HH	70.2	29,550	2.38
Reach Total	979.8	1,708,960	0.57

The mass/volume ratio ranges from about 0.6 g/m^3 to almost 8.4 g/m^3 PCBs for sediments containing more than 50 μg/kg and 10,000 μg/kg total PCBs, respectively (Table 5-13). Sediments with more than 10,000 μg/kg PCB have a mass/volume ratio exceeding 8 g/m^3 (Figure 5-9).

Almost 1,000 kg (2,200 pounds) of PCBs are present in this reach. Similar to the other two upstream reaches, the majority of the PCB mass in this reach is located in the upper 50 cm of sediment (Figure 5-8 and Table 5-14). Approximately 760 kg (1,675 pounds) of PCBs are present in the upper 50 cm; 530 kg (1,170 pounds) are present in the upper 30 cm. The remaining mass (about 220 kg/490 pounds) is present between 50 and 100 cm (Figure 5-8 and Table 5-14).

The PCB mass and sediment volume in inter-deposit areas was also estimated based on the interpolated data. Approximately 265 kg (585 pounds) of PCBs in about 223,730 m^3 (292,630 yd^3) are present outside of the identified deposits. This is about 20 percent of the mass within this reach but less than one percent of the almost 30,000 kg of PCB present within the river.

5.4.2.6 De Pere to Green Bay Reach PCB Results

The De Pere to Green Bay Reach includes the 11 km (7 mi) stretch of the river downstream of the De Pere dam where the 16 SMU groups (and 96 SMUs) are located (Figure 1-6). Over 1,000 sediment samples were collected within this reach and PCBs were detected in about 940 (Table 5-2). These samples were collected from 243 coring locations including many discrete sample depth intervals within the same core.

Total PCB concentrations in this reach range up to 710,000 μg/kg. The RA Mean for the 16 SMU groups range from about 450 μg/kg to about 47,650 μg/kg, while the logarithmic mean ranges from 243 μg/kg to almost 8,200 μg/kg (Table 5-2). The RA and logarithmic mean values for the entire reach are approximately 20,270 μg/kg and 4,100 μg/kg, respectively (Table 5-2). Over 310 sample results exceed 10,000 μg/kg (10 ppm) and over 730 sample results exceed 1,000 μg/kg (1 ppm) (Table 5-2). Approximately 33 percent and 78 percent of all samples exceeded the 10,000 μg/kg and 1,000 μg/kg threshold levels, respectively.

The PCB distribution analysis was completed for each SMU group due to the large number of SMUs. Sampling efforts in this reach have tended to focus on the upstream portion of the reach (Figure 5-1). This reflects the limited amount of soft sediment encountered at the downstream end of the reach resulting from historical dredging activities and maintenance of the navigation channel. Overall, sediments containing more than 50μg/kg PCBs cover over 523.5 hectares (1,294 acres). Over 300 samples have been collected from SMU group 56-61, where

SMU 56/57 is located. Over 150 sediment samples were also collected from SMU groups 20-25 and 44-49, the two SMU groups with the largest areal extent. Five SMU groups, including 20-25, 32-37, 56-61, 62-67, 68-73, have samples exceeding 50,000 μg/kg PCB (Figure 5-1 and Table 5-2). The first two groups are located immediately below and just downstream of the De Pere dam. The other three SMU groups are located at or just downstream of the Fort James turning basin, the location where the SMU 56/57 SRD project was completed. The majority of samples had total PCB concentrations ranging between 1,000 and 10,000 μg/kg (1 and 10 ppm) (Figure 5-1). According to previously completed modeling results, the sediment load decreases between the De Pere dam and the mouth of the river but the PCB load increases over this same stretch (Velleux and Endicott, 1994).

The RA and logarithmic means increase in the vicinity and just downstream of the Fort James turning basin (Figure 5-2), which is an identified historical PCB source (WDNR, 1999a). Starting at the De Pere dam, the RA Mean levels decline from just above 9,000 μg/kg to slightly over 3,700 μg/kg (Figure 5-2). However, at SMU group 56-61, the RA Mean increases to almost 47,650 μg/kg and generally decline downstream. Both the RA and logarithmic means exceed 1,000 μg/kg in 14 of the 16 SMU groups (Figure 5-2 and Table 5-2).

Total PCB results at select depth intervals are shown on Plate 5-4. Areas of greatest surface (0 to 10 cm) concentrations occur in portions of SMU groups 20-25, 26-31, 44-49, 74-79, and 110-115, where total PCBs range from 5,000 μg/kg to 50,000 μg/kg (Plate 5-4). The first two SMU groups are located at and just downstream of the De Pere dam. SMUs 44-49 are located in a wide portion of the river just upstream of the Fort James turning basin while SMUs 74-79 are located downstream of the turning basin and SMUs 110-115 are located at the mouth of the river (Plate 5-4). Similar localized areas occur along the reach where concentrations in the surface sediments are below 1,000 μg/kg (1 ppm). The PCB distribution plot also reflects the impact of historic dredging in the downstream portion of the reach. Sediment deposits in the lower third of this reach are sporadically located and generally less than 100 cm thick (Plate 5-4)

Total PCB concentrations increase significantly below 10 cm between the De Pere dam and SMUs 74-79. Between 10 and 150 cm, large areas of sediment have PCB concentrations ranging from 5,000 to 50,000 μg/kg (5 ppm to 50 ppm) and five areas are present where concentrations exceed 50,000 μg/kg. These five areas are located in SMU groups 20-25, 32-37, 56-61, 62-67, and 68-73 and extend as deep as 300 cm (Plate 5-4). SMUs 56-61 have the largest areas with the greatest depths where total PCBs exceed 50,000 μg/kg (Plate 5-4). In addition to SMUs 56-61, localized areas of SMUs 20-25 have total PCBs exceeding 50,000 μg/kg from 50 to 100 cm while similar areas in SMUs 32-37 and 68-73 are present from 100 to 150 cm. Total PCBs exceeding 50,000 μg/kg are present from 100 to 200 cm in SMUs 62-67.

The highest percentages of PCB mass and contaminated sediment are present in this reach (Table 5-13; Figures 5-4 and 5-5). The approximate percentage of PCB mass and contaminated sediment for the 50 μg/kg, 1,000 μg/kg, and 10,000 μg/kg concentrations ranges is summarized below. The estimated totals for the remaining PCB mass and contaminated sediment volume have been adjusted to reflect the 636 kg of PCB and 31,000m^3 of contaminated sediment removed during the SMU 56/57 SRD project.

De Pere to Green Bay PCB Mass and Contaminated Sediment Volume Percentages

Sediment Concentration Range	PCB Mass	Percent of PCB Mass in River	Contaminated Sediment Volume	Percent of Contaminated Sediment Volume in River
>50 ug/kg	25,984 kg (57,285 pounds)	90.86%	5,550,000 m^3 (7,260,000 yd^3)	59.16%
>1,000 ug/kg	25,719 kg (56,700 pounds)	89.93%	4,181,400 m^3 (5,469,100 yd^3)	44.58%
>10,000 ug/kg	20,000 kg (44,090 pounds)	69.93%	1,857,100 m^3 (2,429,000 yd^3)	19.80%

Based on the above, focusing on sediments with PCB concentrations exceeding 10,000 μg/kg would address slightly more than 70 percent of all PCBs in the river.

De Pere to Green Bay PCB Mass/Sediment Volume Ratios for Sediments with more than 50 µg/kg

SMU Group	PCB Mass (kg)	Sediment Volume (m^3)	PCB Mass to Volume Ratio (g/m^3)
SMUs 20-25	5557.3	1,054,580	5.27
SMUs 26-31	761.2	166,230	4.58
SMUs 32-37	1172.9	233,230	5.03
SMUs 38-43	1149.5	402,360	2.86
SMUs 44-49	5211.2	1,379,690	3.78
SMUs 50-55	1829.7	405,280	4.51
SMUs 56-61A	5174.7	457,490	11.31
SMUs 62-67	861.3	190,570	4.52
SMUs 68-73	1858.2	337,250	5.51
SMUs 74-79	430.2	141,950	3.03
SMUs 80-85	385.3	164,650	2.34
SMUs 86-91	253.1	103,400	2.45
SMUs 92-97	254.8	118,500	2.15
SMUs 98-103	94.3	82,200	1.15
SMUs 104-109	151.1	74,550	2.03
SMUs 110-115	839.0	206,250	4.07
Reach Total	25983.6	5,518,180	4.71

With the exception of SMU group 56-61, PCBs in this reach are spread fairly consistently throughout the sediments. SMU group 56-61 has the highest mass/volume ratio of any group in the reach, even after subtracting the PCB mass and sediment volume removed during the SRD project. The SMU 56-61 mass/volume ratios range from 11 g/m^3 to over 17 g/m^3 for sediments with more than 50 µg/kg and 10,000 µg/kg, respectively (Table 5-13).

Ignoring SMU 56-61, the mass/volume ratio for SMU groups from the De Pere dam to just downstream of the Fort James turning basin (SMUs 20-25 through SMUs 68-73) range from about 3 to 5 g/m^3 (Table 5-13) in sediments with PCB concentrations above 50 µg/kg. Downstream of the Fort James turning basin, from SMU group 74-79 to the mouth of the river, the mass/volume ratios range from 1.15 g/m^3 to 4.07 g/m^3. It is assumed that historic dredging of the navigation channel in this downstream portion of the river has affected the PCB concentrations and mass compared to the other portions of this reach. Sediments with more than 10,000 µg/kg have an overall mass/volume ratio exceeding 11 g/m^3 (Table 5-13 and Figure 5-9), while those with more than 50,000 µg/kg have a ratio exceeding 36 g/m^3 (Figure 5-9).

The mass/volume ratios are fairly consistent in sediments with more than 1,000 µg/kg or 10,000 µg/kg PCBs. Nine of the 16 SMU groups have mass/volume ratios exceeding 10 g/m^3 for sediments with concentrations exceeding 10,000 µg/kg (Table 5-13). In addition to SMU group 56-61, the other three SMU groups with the highest mass/volume ratios are SMUs 62-67, 20-25, and 26-31 (Table 5-13).

Seven SMU groups (20-25, 32-37, 38-43, 56-61, 62-67, 68-73, and 80-85), with either the highest PCB concentrations or greatest mass/volume ratios, contain about 16,160 kg (35,630 pounds) of PCBs in sediments with more than 50 μg/kg PCB (Table 5-13), or about 57 percent of PCBs within the river. Additionally, this mass is contained in approximately 2.84 million m^3 (3.71 million yd^3), or about 32 percent of the total impacted sediment volume in the river.

Just over 7,500 kg (16,535 pounds) of PCBs are present in the upper 50 cm (20 in.) of sediment while approximately 8,600 kg (18,960 pounds) of PCB are present from 50 to 100 cm (20 to 40 in) (Figure 5-8 and Table 5-14). Approximately 10,600 kg (23,370 pounds) of PCBs, or about 36 percent of the PCBs in the entire river, are buried below 100 cm (40 in.).

5.4.2.7 Green Bay Zone 2 PCB Results

Green Bay Zone 2 (zones 2A and 2B) extends from the mouth of the river to a line approximately 12.2 km (7.6 mi) north of the mouth (Figure 1-2). A total of 49 sediment samples were collected from 22 coring locations within this zone and PCBs were detected in 48 (Table 5-2).

Total PCB concentrations in this reach range from 15 to 17,000 μg/kg. The RA Mean for the zone was about 1,110 μg/kg while the logarithmic mean was approximately 622 μg/kg (Table 5-2). PCB concentrations in Green Bay sediments decrease compared with the river (Figure 5-2). Zone 2 is the only area of Green Bay where the RA Mean exceeds 1,000 μg/kg (Table 5-2 and Figure 5-2), compared to the reach averages, which ranged from about 4,590 μg/kg to 20,270 μg/kg.

The interpolated total PCB results are shown on Plate 5-5. The highest PCB concentrations in surface sediments (0 to 2 cm and 2 to 10 cm) are found in one large area within Zone 2B and two isolated locations within Zone 2A (Plate 5-5). Sediments with PCB concentrations exceeding 5,000 μg/kg (5 ppm) are located just beyond the mouth of the Lower Fox River in Zone 2A. Sediments containing more than 1,000 μg/kg (1 ppm) are located in both zones 2A and 2B. In Zone 2A, sediments with PCB concentrations exceeding 1,000 μg/kg (1 ppm) are located near the navigation channel (Plate 5-5). In Zone 2B, sediments with PCB concentrations exceeding 1,000 μg/kg (1 ppm) extend from just north of Kidney Island to a point just south of Point Au Sable (Plate 5-5), where discharge from the Lower Fox River is directed by bay currents.

The Zone 2B sediments with PCB concentrations exceeding 1,000 μg/kg extend from the surface to a depth greater than 30 cm (Plate 5-5). These sediments generally cover the same area throughout the sediment column. In addition to the stability of PCB concentrations in this sediment, the PCB concentrations actually increased to concentrations above 5,000 μg/kg (5 ppm) in two locations below 30 cm (Plate 5-5). These two areas are located along the west side of the navigation channel (just off of the end of Long Tail point) in Zone 2A and on the south side of the sediment area described above in Zone 2B.

Sediment containing PCBs cover approximately 11,080 hectares (27,380 acres) (Table 5-15). Approximately about 14,400 kg (45 percent) of the PCBs in this zone are present in the upper 30 cm of sediment while about 17,600 kg (or 55 percent) are located below 30 cm (Figure 5-8 and Table 5-15). The PCBs in Zone 2 represent about 46 percent of the total bay mass. Therefore, the upper 30 cm of sediment in this zone contain about 21 percent of the total bay mass which are contained in about 30 million m^3 (39 million yd^3), which is slightly less than 5 percent of the total bay sediment volume (Table 5-15). Additionally, about 6,600 kg (14,550 pounds) and 7,900 kg (17,400 pounds) of PCBs are present in the upper 30 cm of sediments in zones 2A and 2B, respectively (Table 5-15).

Just over 32,000 kg (70,550 pounds) of PCB and 39.58 million m^3 (51.77 million yd^3) of impacted sediment are present in this zone (Table 5-15; Figures 5-6 and 5-7). The approximate percentage of PCB mass and contaminated sediment for the 50 μg/kg, 1,000 μg/kg, and 5,000 μg/kg concentration ranges is summarized below.

Green Bay Zone 2 PCB Mass and Contaminated Sediment Volume Percentages

Sediment Concentration Range	PCB Mass	Percent of PCB Mass in Bay	Contaminated Sediment Volume	Percent of Contaminated Sediment Volume in Bay
>50 μg/kg	32,010 kg (70,570 pounds)	46.95%	39,491,600 m^3 (51,653,060 yd^3)	6.35%
>1,000 μg/kg	28,090 kg (61,930 pounds)	41.20%	17,767,600 m^3 (23,239,140 yd^3)	2.86%
>5,000 μg/kg	5,110 kg (11,265 pounds)	7.50%	1,265,000 m^3 (1,654,560 yd^3)	0.20%

Almost one-half of the PCB mass in the bay is contained within Zone 2. Additionally, this PCB mass is contained within slightly more than 6 percent of the estimated contaminated sediment volume in the bay. Sediments with PCB concentrations exceeding 1,000 μg/kg represent slightly more than 40 percent of all PCBs in the bay within a contaminated sediment volume of less than 3 percent of the estimated total (Table 5-15; Figures 5-6 and 5-7).

The PCB mass/volume ratio in sediments with PCB concentrations above 50 μg/kg is approximately 0.80 g/m^3 (800 milligrams/m^3) (Table 5-15 and Figure 5-9). The mass/volume ratios are 1.55 g/m^3 and 3.55 g/m^3 in sediments with PCB concentrations above 1,000 μg/kg and 5,000 μg/kg, respectively (Table 5-15 and Figure 5-9). The calculated PCB mass/volume ratios for Zone 2 are the highest in Green Bay.

5.4.2.8 Green Bay Zone 3 PCB Results

Green Bay Zone 3 (zones 3A and 3B) extends from the east-west line marking the northern boundary of Zone 2 to a line just below Chambers Island (Figure 1-2). This is a distance of approximately 74.5 km (46.3 mi). This is the most heavily sampled zone of Green Bay, with 180 samples collected from Zone 3A and almost 420 samples collected from Zone 3B (Table 5-2). These samples were collected from 14 cores and 40 cores, respectively, and many represent discrete sample depth intervals within the same core. Sediments containing PCBs cover approximately 155,230 hectares (383,580 acres).

Total PCB concentrations in this zone range from 2 to 1,320 μg/kg. The RA Mean for Zone 3A was about 300 μg/kg while the logarithmic mean was approximately 190 μg/kg (Table 5-2). The RA and logarithmic means for Zone 3B were about 440 μg/kg and 320 μg/kg, respectively (Table 5-2). The mean values for subzones 3A and 3B, as well as the PCB distribution plots shown on Plate 5-5, reflect the influence of Green Bay currents in the overall distribution of sediment and PCBs.

PCB concentrations in zones 3A and 3B decreased compared with Zone 2 (Figure 5-2). In Zone 2, the RA Mean exceeded 1,000 μg/kg. However, the RA and logarithmic means for zones 3A, 3B, and 4 are all below 500 μg/kg, and significantly lower than the river reach means (Table 5-2 and Figure 5-2).

Total PCB results at select depth intervals are shown on Plate 5-5. PCBs are located through most of Green Bay Zone 3B, but are generally confined to the eastern half of Zone 3A. As indicated in the sediment distribution maps in Section 3 and the interpolation summary (Section 5.4.1.1) sediment was not present along the western shore of Green Bay; therefore, PCBs are largely absent for a distance of 3 to 8 km (1.9 to 5 mi) from the shore in Zone 3A. PCB concentrations in the surface sediments (0 to 2 cm and 2 to 10 cm) range up to 1,000 μg/kg (1 ppm) in Zone 3A, with the highest concentrations located immediately adjacent to the boundary between zones 3A and 3B in the central portion of the bay (Plate 5-5). PCB concentrations ranging from 500 to 1,000 μg/kg cover an area in Zone 3A of approximately 63 km^2 (24 mi^2). Surface sediment results in Zone 3B are more extensive, as the area where PCB concentrations range up to 1,000 μg/kg (1 ppm) is larger compared to Zone 3A. Sediments with PCB concentrations ranging from 500 to 1,000 μg/kg extend almost from the boundary with Zone 2 to Egg Harbor, a distance of approximately 65 km (40 mi) in the very upper layer of sediment (Plate 5-5). Considering sediment to a depth of 10 cm, the length of this area has decreased but these sediments still cover approximately 280 km^2 (108 mi^2). This is over 4 times as large an area than that estimated for Zone 3A (Plate 5-5).

PCB concentrations decrease in sediments located 10 to 30 cm below the surface (Plate 5-5). PCB concentrations in Zone 3A range only up to 250 μg/kg. Sediments containing PCB concentrations ranging up to 500 μg/kg (0.5 ppm) in Zone 3B are located adjacent to the east shore of Green Bay. These sediments extend from a point near the boundary with Zone 2 to a location just north of Sugar Creek County Park (Plate 5-5), a distance of approximately 28 km (18 mi). In addition, sediments with similar PCB concentrations are also located near Sand Bay, just north of Little Sturgeon Bay. Overall, sediments with PCB concentrations ranging up to 500 μg/kg (0.5 ppm) in Zone 3B cover approximately 140 km^2 (54 mi^2) (Plate 5-5).

Below 30 cm, PCB concentrations range up to 250 μg/kg (0.25 ppm) in the central portion of Zone 3 (Plate 5-5). These sediment cover approximately 400 km^2 (160 mi^2) in both zones 3A and 3B (Plate 5-5) and have an estimated PCB mass of 5,730 kg (12,630 pounds) (Table 5-15).

Almost 36,000 kg (79,370 pounds) of PCB and 436.17 million m^3 (570.50 million yd^3) of impacted sediment are present in this zone (Table 5-15; Figures 5-6 and 5-7). The approximate percentage of PCB mass and contaminated sediment for the 50 μg/kg, 1,000 μg/kg, and 5,000 μg/kg concentration ranges is summarized below.

Green Bay Zone 3 PCB Mass and Contaminated Sediment Volume Percentages

Sediment Concentration Range	PCB Mass	Percent of PCB Mass in Bay	Contaminated Sediment Volume	Percent of Contaminated Sediment Volume in Bay
>50 µg/kg	35,240 kg (77,690 pounds)	51.69%	396,983,200 m^3 (519,234,400 yd^3)	63.79%
>1,000 µg/kg	1.65 kg (3.64 pounds)	0.0024%	8,800 m^3 (11,510 yd^3)	0.0014%
>5,000 µg/kg	None	----	None	----

The PCBs in this zone are spread over a very large area at low concentrations so that less than 0.003 percent of the total bay mass and sediment volume are present in areas where PCB concentrations exceed 1,000 µg/kg (Table 5-15). The PCB mass is split about evenly between zones 3A and 3B (Table 5-15 and Figure 5-8). Compared to Zone 2, where the PCB mass was about equal between the upper 30 cm and deeper sediments, the largest percentage of the PCB mass in this reach is located in the upper sediments (Figure 5-8). Slightly more than 30,000 kg (66,140 pounds or 83 percent) of the PCBs in this zone are located within the upper 30 cm of sediment (Figure 5-8). Just under 6,000 kg (13,230 pounds or 17 percent) of the PCB mass in this zone is located below 30 cm (Figure 5-8).

There are approximately 0.09 g/m^3 (90 milligrams/m^3) and 0.19 g/m^3 (190 milligrams/m^3) in sediments with PCB concentrations above 50 µg/kg and 1,000 µg/kg, respectively (Table 5-15). Compared to the Zone 2 and Lower Fox River PCB mass/sediment volume ratios, these values are extremely low (Figure 5-9). Due to the lack of sediments with PCB concentrations exceeding 5,000 µg/kg, no mass/volume ratio could be determined for this concentration range.

5.4.2.9 Green Bay Zone 4 PCB Results

Green Bay Zone 4 extends from Chambers Island to Big and Little Bays de Noc in Michigan's Upper Peninsula (UP) (Figure 1-2). Just over 200 sediment samples were collected from 31 coring locations in this zone and PCBs were detected in over 98 percent (Table 5-2). Sediments containing PCBs cover approximately 255,000 hectares (630,100 acres).

Total PCB concentrations in this reach range up to 751 µg/kg. The RA Mean for the zone is about 54 µg/kg while the logarithmic mean is approximately 39 µg/kg (Table 5-2). Green Bay Zone 4 sediment PCB concentrations are almost as low as the concentrations in Lake Winnebago, lower than the SMU groups, the other bay zones, and most of the river deposits (Table 5-2 and Figure 5-2).

Five sediment sample results from Lake Michigan are included in the FRDB. The Lake Michigan PCB concentrations range from 18.2 to 271.23 μg/kg. However, the Lake Michigan RA and logarithmic means of almost 123 μg/kg and 77.1 μg/kg, respectively, are higher than the mean values for Zone 4. These results suggest PCB concentrations in Green Bay Zone 4 are approximately background concentrations for Lake Michigan.

PCB concentrations in the upper 2 cm of sediment range as high as 500 μg/kg (0.5 ppm) just north of Chambers Island (Plate 5-5). In general, Zone 4 PCB concentrations decrease to less than 125 μg/kg (0.125 ppm) in sediments from 2 to 10 cm below the surface. The only exceptions to this are in the area where concentrations in the upper sediments ranged up to 500 μg/kg (north of Chambers Island) and one area near the boundary with Zone 3 along the west shore of the bay (Plate 5-5). Sediments with PCBs concentrations less than 50 μg/kg (0.05 ppm) are randomly located throughout Zone 4 (Plate 5-5). PCB concentrations do not exceed 50 μg/kg (0.05 ppm) below 10 cm, and no PCBs were collected from sediment below 30 cm in this reach (Plate 5-5).

Less than 1,960 kg (4,320 pounds) of PCB are present in about 146.55 million m^3 (191.68 million yd^3) of impacted sediment in this zone (Table 5-15; Figures 5-6 and 5-7). The approximate percentage of PCB mass and contaminated sediment for the 50 μg/kg, 1,000 μg/kg, and 5,000 μg/kg concentration ranges is summarized below.

Green Bay Zone 4 PCB Mass and Contaminated Sediment Volume Percentages

Sediment Concentration Range	PCB Mass	Percent of PCB Mass in Bay	Contaminated Sediment Volume	Percent of Contaminated Sediment Volume in Bay
>50 μg/kg	925 kg (2,040 pounds)	1.36%	28,922,000 m^3 (37,828,550 yd^3)	6.21%
>1,000 μg/kg	None	----	None	----
>5,000 μg/kg	None	----	None	---

Only 1.3 percent of the total PCB mass and slightly over 6 percent of the total sediment volume are located in Zone 4. In addition, the PCB mass/volume ratio determined for these sediments is only 0.03 g/m^3 (or 30 milligrams/m^3) (Table 5-15). This is more that two orders of magnitude lower than the calculated ratios for the other bay zones or river reaches (Figure 5-9). No sediments were detected in this zone with concentrations exceeding 500 μg/kg, as indicated on Plate 5-5.

All of the detected PCBs are contained in the upper 30 cm of sediment (Figure 5-8) and a large percentage are concentrated in the upper 10 cm (Table 5-15). Considering all PCBs and sediments, the estimated mass is approximately 1,960 kg (4,320 pounds). About 1,550 kg (80 percent) of this mass is located in the upper 10 cm, with only 420 kg (925 pounds) of PCB located between 10 and 30 cm (Table 5-15).

5.4.2.10 General PCB Homolog Distribution

Overview

ThermoRetec (2000) completed a literature review evaluating the natural PCB degradation/weathering processes that occur in sediments. The USFWS (Stratus, 1999a) also evaluated degradation/weathering of PCBs in sediments of the Lower Fox River and Green Bay. These studies indicate that PCB congeners that belong to the lower chlorinated homolog groups degrade/weather, in general, more quickly than do the PCB congeners which belong to the higher chlorinated homolog groups. To assess the overall PCB degradation/weathering from Aroclor 1242 in the Fox River and Green Bay system, the general percentage of each PCB homolog group within a given reach or zone was analyzed.

As discussed in Section 5.2.2, PCB congeners can be grouped by homolog, which corresponds to the number of chlorine atoms present in a particular PCB molecule. The typical homolog plot for Aroclors 1242, 1254, and 1260 are presented on Figure 5-11. The tables from the ATSDR (1997a) toxicological profile used to construct these plots are included in Appendix H.

Figure 5-11 shows that Aroclor 1242 is predominantly a mixture of di-, tri-, and tetrachlorinated PCBs, whereas Aroclor 1254 is predominantly a mixture of tetra-, penta-, and hexachlorinated PCBs. Aroclor 1260 is comprised of almost equal portions penta- through heptachlorinated PCB with small amounts of tri-, tetra-, octa-, and nonachlorinated PCBs (Figure 5-11).

A listing of the PCB congeners and the homolog group to which each belongs was obtained from the toxicological profile for PCBs (ATSDR, 1997a) and is included in Appendix H. In general, the higher chlorinated homologs are more resilient to aerobic degradation in the environment than do are the lower chlorinated homologs. The higher chlorinated homologs (those with more than 5 or 6 chlorine molecules) are generally recalcitrant to aerobic degradation but, under appropriate conditions can undergo anaerobic dechlorination, which results in the loss of chlorine atoms and the formation of lower chlorinated homologs (ThermoRetec, 2000).

PCB homolog plots were constructed from the PCB congener data included in the FRDB. Because these sediment homolog plots were completed only for each reach or zone, all detected results were used in calculating the relative percentage, regardless of depth or location. The relative percentage of each PCB homolog in a reach or zone has been calculated by the following method:

1) The average PCB congener results (for congeners 1 through 209) were summed for each reach/zone. This summed result was the 100 percent value.

2) The average PCB congener results for each homolog group were then summed and this result was divided by the reach/zone total (the 100 percent value) to obtain the relative percent of the homolog in that reach.

This method was used because of the large number of detected PCB congener results for each reach and zone. The PCB congener data used and the summed values obtained by this method are included in Appendix I. The Aroclor 1242 homolog distribution is plotted with the reach/zone specific PCB homolog results to facilitate evaluation.

The water sample homolog results were determined by the laboratory. However, these results were only determined for the De Pere to Green Bay Reach and Green Bay zones 2, 3, and 4.

Sediment Homolog Distribution

The PCB congener results all the reaches and zones have been divided into the appropriate PCB homolog groups and plotted (Figure 5-12). Compared to Aroclor 1242, the LLBdM PCB homolog distribution suggests that lower chlorinated congeners (di- and trichlorinated) have been lost (degraded/weathered) from the sediment (Figure 5-12). Given that Aroclor 1242 was the PCB mixture used in carbonless paper production, it is assumed that these lower chlorinated congeners were present when the material was released to the environment. The percentage of tetrachlorinated PCBs is approximately the same for both LLBdM sediments and Aroclor 1242 while the percentage of the penta- through nonachlorinated PCBs in the sediments is more than twice as great as that found in Aroclor 1242. The presence of the higher chlorinated PCBs (hepta- through nona-) in sediments likely reflects both aerobic degradation, differential solubilization, and/or volatilization of lower chlorinated PCBs. Additionally, these higher chlorinated compounds may also indicate the presence of Aroclors 1254, 1260, or 1268, all of which were detected in river sediments. Compared with the other reach/zone homolog results, the LLBdM plot suggests that little degradation/weathering of Aroclor 1242 congeners has occurred, as might be expected in the vicinity of PCB source areas. In addition, the RA Mean total PCB concentration in LLBdM is higher than in the other two reaches upstream of the De Pere dam (Figure 5-12).

Compared with Aroclor 1242, the PCB homolog distribution for the Appleton to Little Rapids Reach contains similar percentages of tri- and pentachlorinated congeners in sediments, while containing slightly less dichlorinated and slightly more tetrachlorinated PCBs (Figure 5-12). These four homolog groups account for over 99 percent of Aroclor 1242 and over 98 percent of the PCBs detected in sediments in this reach. The homolog plot for this reach suggests that some of the lower chlorinated PCBs (di-, tri-, and tetrachlorinated PCB) may have been transported downstream from the LLBdM Reach, as the percentage of these homologs is greater in this reach than in LLBdM. The total PCB RA Mean for this reach is about 4,600 μg/kg, down from a concentration of about 12,300 μg/kg in the LLBdM Reach (Figure 5-12). This is the lowest RA Mean for any of the river reaches and may reflect the physical factors (i.e., increased velocities and river gradients, etc.) which inhibit sediment accumulation compared to the other reaches.

In the Little Rapids to De Pere Reach more of the mid- to heavy-end PCBs (tetra- through nonachlorinated) have accumulated, especially compared with Appleton to Little Rapids Reach (Figure 5-12). In addition, the RA Mean is just over 5,200 μg/kg, which is slightly higher than the Appleton to Little Rapids Reach (Figure 5-12). This increase may reflect the physical environment that facilitates accumulation of river sediments behind the De Pere dam.

The PCBs detected in the sediments of the De Pere to Green Bay Reach have a similar homolog plot as Aroclor 1242 (Figure 5-12). The relative percent of di- through pentachlorinated homologs for Aroclor 1242 and sediments in this reach differ by 4 percent or less, possibly reflecting the known PCB discharge location within this reach. Additionally, the total PCB RA Mean value increases to about 20,270 μg/kg (Figure 5-12). This increase in the total PCB RA Mean likely further reflects the presence of a historical PCB discharge location.

Within Green Bay Zone 2, the tetra- through hexachlorinated PCB homologs comprise about 55 percent of the PCBs in sediment compared with 30 percent for Aroclor 1242 (Figure 5-12). Similar decreases in the percentage of the lower chlorinated PCBs is evident in both this zone and the other portions of the bay compared to the Lower Fox River results. This likely reflects the fact that the lower chlorinated PCBs are generally more susceptible to degradation/weathering processes than are the higher chlorinated compounds. Therefore, the relative percentage increase in the penta- through decachlorinated PCBs moving from zones 2 through 4 in the bay reflect the overall general stability of the higher chlorinated PCBs (Figure 5-12).

The homolog plots for Zone 3 do not reflect the PCB composition of Aroclor 1242 (Figure 5-12). As indicated above, the homolog plots for zones 3A and 3B show a slight increase in the relative percentage of the penta- through decachlorinated PCBs compared with Zone 2 (Figure 5-12). Conversely, the relative percentage of mono- through tetrachlorinated PCBs decreased compared to Zone 2 (Figure 5-12). This decrease in the lower chlorinated PCBs likely reflects the fact that Zone 3 is further removed from PCB sources than Zone 2 or any of the river reaches.

In Zone 4, the relative percentage of mono- through tetrachlorinated PCB homologs comprise just over 55 percent of the PCBs detected; however, these same homologs comprised about 92 percent of the PCBs in Aroclor 1242 (Figure 5-12). The homolog plot shows there has been a significant decrease of the lower chlorinated congeners relative to the higher chlorinated homologs, reflecting that Zone 4 is located a significant distance from the nearest PCB source (Figure 5-12).

5.4.3 Dioxin/Furans

Twenty-four sediment samples were collected in various locations throughout the Lower Fox River for analysis of 2,3,7,8-TCDD (dioxin) and 2,3,7,8-TCDF (furan). The SLRA (RETEC, 1998c) indicated that furan concentrations above 2,000 ng/kg are a potential concern; there is no established level for dioxins. Six surface samples were collected at deposits D, E, and POG in LLBdM. Concentrations of dioxin ranged up to 5.44 ng/kg (ppt) in deposits D and POG while concentrations of furan ranged up to 71.29 ng/kg (ppt) in all three deposits (Table 5-3). One sample from Deposit POG was collected to evaluate the vertical extent of impacts. Both dioxin and furan were approximately one-half to one-third lower in the deeper sediment sample (Table 5-3). Comparison of the dioxin/furan results with total PCB results indicates there is no a strong correlation between concentrations of these compounds. Regression analysis results for these data indicate a possible correlation between dioxin and PCBs("R" = 0.65 to 0.68) but a poor correlation between furan and PCBs ("R" = 0.31 to 0.35). Further analysis of such correlations is included in the RA.

In the Appleton to Little Rapids Reach, three samples were collected from Deposit N for analysis of dioxin and furan prior to the 1998/99 sediment remediation activities and no post-dredging samples were collected for dioxin/furan.

In the Little Rapids to De Pere Reach, three samples were collected; one each from surface sediments in deposits EE and HH and one at depth in Deposit EE. Dioxin concentrations ranged up to 6.82 ng/kg (ppt) and furan concentrations ranged up to 117.09 ng/kg (ppt) (Table 5-3). In Deposit EE the dioxin and furan concentrations in the surface sediment were 24 times and four times greater than the subsurface results, respectively. These limited data suggest that dioxin/furan concentrations decrease with depth. Correlation of PCB with dioxin/furan is not appropriate based on the small data set.

As part of the SMU 56/57 SRD project, 12 sediment samples were collected at a single location to evaluate the vertical extent of dioxin/furan compounds. Dioxin was only detected at the base of the core, 3.35 to 3.65 m (11 to 12 ft) below the sediment surface, at a concentration of 10 ng/kg. Furan was present throughout the core at concentrations ranging from 20 to 170 ng/kg. The highest concentrations were detected 1.8 to 2.1 m (6 to 7 ft) below the sediment surface (Table 5-3).

No sediment samples were analyzed for dioxin/furan compounds in Green Bay.

5.4.4 Pesticides

Sixteen pesticides were detected in Lower Fox River sediments (Table 5-4). Only two pesticides, DDT and dieldrin, were identified in the SLRA (RETEC, 1998c) as chemicals of potential concern. Aldrin is also included on Table 5-4 because dieldrin is a degradation by-product of aldrin. Both dieldrin and aldrin were only detected in one sediment sample in the river (Table 5-4). None of the analyzed pesticides were detected in Green Bay.

Pesticide analyses indicate low level detections occur sporadically along the Lower Fox River. No pesticide compound exhibits an apparent trend with respect to occurrence or concentrations. Some pesticides are found at depth within the sediment column, suggesting their occurrence reflects long-term use within the watershed. These data are discussed for each reach below.

5.4.4.1 LLBdM Reach Results

Seven pesticides were detected in 11 samples collected in this reach. Deposit C is the only location in the river (or bay) where dieldrin and aldrin were detected, at concentrations of 5.9 μg/kg and 60 μg/kg, respectively (Table 5-4). The detected dieldrin may be the result of aldrin degradation and the extent of both these compounds appears to be very limited. According to the SLRA, dieldrin concentrations exceeding 11,000 μg/kg are a potential concern (RETEC, 1998c).

DDT was detected in deposits D and POG and, according to the SLRA (RETEC, 1998c), concentrations above 1.6 μg/kg are a potential concern. DDT concentrations ranged between 5.5 and 50 μg/kg, with the highest concentration detected in Deposit POG (Table 5-4). DDT concentrations decrease with depth in Deposit D. Along with the other pesticide results described below, the limited data suggest that pesticide concentrations, in this reach and throughout the remaining parts of the river, decrease with depth. In addition to the DDT, the degradation by-products DDD and DDE were also detected. DDD was detected in deposits C, E, and POG at concentrations below 10 μg/kg while DDE was present in Deposit A at concentrations ranging up to 25 μg/kg.

Other pesticides detected in this reach of the river include endrin ketone and heptachlor. Concentrations for these two pesticides range up to 19 μg/kg and the compounds are sporadically and inconsistently located throughout the deposits.

5.4.4.2 Appleton to Little Rapids Reach Results

DDT and DDD were the only pesticides detected in Deposit X and the concentrations are all below 3.4 μg/kg. These results are from surface samples so that pesticide concentrations at depth cannot be evaluated. Dieldrin was not detected in this reach.

5.4.4.3 Little Rapids to De Pere Reach Results

A number of different pesticides were detected in this reach and except for the two composite samples from deposits EE/GG (EG), all samples were collected from Deposit EE (Table 5-4).

DDT, DDD, and DDE were detected in either three or four samples. DDT concentrations ranged from 5.1 to 20 μg/kg while DDE concentrations ranged up to 22 μg/kg. The maximum DDD concentration was 2.8 μg/kg. Endrin ketone was the most prevalent pesticide in this reach, being detected in 9 samples from Deposit EE with concentrations ranging up to 23 μg/kg. All other pesticides were detected sporadically in only a few samples. Endrin aldehyde, gamma-BHC and heptachlor were all detected in a single sediment sample at concentrations below 9.8 μg/kg.

All but two of the pesticide samples analyzed for this reach of the river were collected during the supplemental data collection activities. Only surface sediment results are available for most of the samples. However, the composite samples were collected at a single location and suggest that DDT concentrations decrease with depth. Dieldrin was not detected in this reach of the river.

5.4.4.4 De Pere to Green Bay Reach Results

During the 1998 WDNR supplemental sampling effort, four surface sediment samples were collected for pesticide analysis from SMUs 20, 45, and 115. These three SMUs are located at each end of this reach and approximately one-third of the way downstream from the De Pere dam. DDD, endrin aldehyde, and endrin ketone were detected in three or four samples while DDE was only detected in one (Table 5-4). The results for these four pesticides were less than 7.2 μg/kg.

DDT and gamma-BHC were detected during SMU 56/57 SRD project sampling. DDT concentrations range from 19 to 28 μg/kg in two samples, collected from near surface (10-30 cm) and deeper (274 to 305 cm) sediments. Gamma-BHC was detected in seven samples collected between 10 and 366 cm (0.32 and 12 ft) deep. These concentrations ranged from 1 to 17 μg/kg, with the highest concentrations detected between 213 and 244 cm (7 and 8 ft) below the sediment surface (Table 5-4). These results are similar to the furan results, where the highest furan concentration was also detected at depth. Dieldrin was not detected in this reach.

5.4.5Inorganic Compounds

5.4.5.1 Mercury

Background mercury levels in Lake Winnebago averaged 0.14 mg/kg. Almost 87 percent of samples in which mercury was detected in the river and bay exceeded this value. Mercury concentrations exceeding 0.15 mg/kg were identified as a potential concern in the SLRA (RETEC, 1998c). Results for the 336 samples analyzed for mercury are summarized below.

Summary of Mercury Results (mg/kg)

River Reach	Number of Samples	Minimum Concentration	Maximum Concentration	Average
LLBdM	95	0.14	6.1	1.18
Appleton to Little Rapids	6	0.34	4.3	2.14
Little Rapids to De Pere	140	0.01	9.82	2.34
De Pere to Green Bay	84	0.1	7.7	1.15
Entire River	325	0.01	9.82	1.95
Green Bay Zone 2	9	0.11	1.5	0.593
Green Bay Zone 3A	0	---	---	---
Green Bay Zone 3B	1	0.19	0.19	0.19
Green Bay Zone 4	1	0.11	0.11	0.11

Mercury use in paper production was discontinued in 1971 (WDNR, 1996), approximately the same time that PCB use ceased. Mercury is present throughout the Lower Fox River and it is speculated its occurrence extends to depths similar to PCBs. Because the sediment sampling where mercury was analyzed focused on specific deposits along the river, it is difficult assess whether differences between reaches are meaningful.

Samples were collected at over 60 locations in deposits D, E, POG, and EE/GG/HH to evaluate vertical distribution of mercury (Table 5-5). With some exceptions, surface sediment concentrations exceeded those observed in deeper samples, typically by a factor of two to five times or more. The results for Deposit POG indicate that in three of the six locations where samples were collected at depth, the deeper sediment results are up to 2 times higher than the surface sediment results.

In the Little Rapids to De Pere Reach, a number of samples were collected from the same location within deposits EE/GG/HH. Almost 90 of the 140 samples from this reach had concentrations exceeding 1 mg/kg, which significantly raised the average concentration for this reach. The mercury samples from 45 locations in these deposits showed that upper sediment concentrations range from 1.5 to over 10 times greater than the deeper sediment results at 43 of these locations. Two locations, one in deposit EE and HH, have a surface sediment concentration lower than the concentration found in sediments below. Additionally, three or more samples were collected at 25 of these locations. At seven of these locations, the mercury concentration of the middle sample was the lowest of all the results (Table 5-5).

Mercury was analyzed and detected in only 11 samples in Green Bay (Table 5-5). Although mercury is a compound of concern within the river, there are insufficient data points to conclude that mercury is of concern in the bay. Seven of the 11 sample results exceed 0.14 mg/kg and six of these samples are located in Zone 2. However, only one sample exceeds any of the average concentrations determined for the four river reaches. Based on the limited amount of data and the relatively low mercury concentrations in bay sediments compared to the Lower Fox River levels, detected mercury concentrations are not considered significant.

Mercury concentrations do not have as wide a concentration range as PCBs; therefore, specific point sources (either recent or historical) are not readily identifiable from the mercury distribution. Compared to Lake Winnebago, the elevated concentrations suggest mercury inputs have occurred along the Lower Fox River. Hoff, *et al.* (1994) estimated atmospheric inputs of mercury to the Lake Superior to be approximately 800 kg (1,760 pounds) annually. Although not directly applicable to Green Bay and the Lower Fox River, atmospheric sources of mercury likely contribute some portion of the total mercury concentrations detected throughout the river and bay.

5.4.5.2 Lead

Lead background levels in Lake Winnebago averaged 35 mg/kg. Almost 78 percent of the 192 samples in which lead was detected in the river and bay exceeded this value. Lead concentrations above 47 mg/kg are a potential concern according to the SLRA (RETEC, 1998c). Lead results are summarized below.

Summary of Lead Results (mg/kg)

River Reach	Number of Samples	Minimum Concentration	Maximum Concentration	Average
LLBdM	30	3.54	549	167.8
Appleton to Little Rapids	10	44	130	75.6
Little Rapids to De Pere	24	2.25	1,400	138.7
De Pere to Green Bay	107	4.44	350	85.0
Entire River	171	2.25	1,400	106.7
Green Bay Zone 2	11	2	42	19.7
Green Bay Zone 3A	2	1.1	1.9	1.5
Green Bay Zone 3B	4	9.6	50	29.9
Green Bay Zone 4	4	2.1	4.5	3.1

Sixty-four sediment samples (37 percent) were collected upstream of the De Pere dam (Table 5-5). A number of samples in these upstream reaches have very high concentrations, ranging up to 1,400 mg/kg. The average lead concentrations upstream of the De Pere dam are approximately 2 to 5 times greater than the Lake Winnebago average (35 mg/kg). The overall distribution of elevated lead levels in the Lower Fox River is sporadic. No specific point sources were identified that can be attributed to elevated lead occurrences. Results for the Appleton to Little Rapids and Little Rapids to De Pere reaches suggest that lead from LLBdM has been transported downstream and accumulated behind the De Pere dam.

Composite sediment sample results, collected to evaluate vertical distribution, indicated that the deeper sediments in Deposit POG have higher concentrations than surface sediments (Table 5-5). However, in Deposit EE the vertical distribution results indicated surface sediments had higher concentrations and deeper sediment levels were well below Lake Winnebago background concentrations.

The large majority of samples were collected in the De Pere to Green Bay Reach. Lead was detected in all 107 samples and concentrations ranged from 4.44 and 350 mg/kg (Table 5-5). The reach average is 85 mg/kg. All but 13 of the samples exceed the background level of 35 mg/kg, indicating that elevated lead values are widespread in this reach. All the samples were collected from surface sediments so the vertical distribution of lead in this reach is unknown. The results do not suggest any distribution pattern for lead within the surface sediments.

Lead concentrations range up to 50 mg/kg in Green Bay (Table 5-5). Lead was detected in all 21 samples collected in the bay and only four samples exceed the

Lake Winnebago background levels. None of the average lead concentrations exceed 35 mg/kg (Table 5-5), suggesting that lead within the bay sediments reflect background values.

Based on the ubiquitous nature of lead in the environment and the fact that lead has historically been used in numerous household and industrial products from paint to gasoline to dishes, it is difficult to fully assess definitive sources. Possible historical and current sources of lead include atmospheric deposition, urban runoff, agricultural practices, and unknown point source discharges.

5.4.5.3 Arsenic

Arsenic background levels in Lake Winnebago averaged 5.33 mg/kg. Almost 42 percent of the samples in which arsenic was detected in the river and bay exceeded this value. According to the SLRA, arsenic concentrations above 8.2 mg/kg are a potential concern (RETEC, 1998c). Arsenic results are summarized below.

Summary of Arsenic Results (mg/kg)

River Reach	Number of Samples	Minimum Concentration	Maximum Concentration	Average
LLBdM	30	0.23	6.80	2.91
Appleton to Little Rapids	10	0.17	9.70	3.23
Little Rapids to De Pere	23	0.90	7.60	4.08
De Pere to Green Bay	89	0.23	385.57 (13.35)	10.19 (5.92)
Entire River	152 (151)	2.25	385.57 (13.35)*	7.37 (4.86)*
Green Bay Zone 2	10	1	3.2	2.25
Green Bay Zone 3A	2	1.4	1.6	1.5
Green Bay Zone 3B	4	3.6	15	8.58
Green Bay Zone 4	4	1.4	8.9	4.98

*excludes highest detected value

Similar to lead, arsenic was detected in 63 sediment samples (37 percent) collected upstream of the De Pere dam (Table 5-5). The average arsenic concentrations for the three reaches upstream of the De Pere dam were below 5.33 mg/kg, the Lake Winnebago average. Since arsenic is naturally occurring, sediments exhibiting higher values are likely within a normal range of variability for background and WDNR (1996) reached similar conclusion.

Arsenic was detected in 89 samples in the De Pere to Green Bay Reach and 56 of these samples exceed 5.3 mg/kg (Table 5-5). Arsenic concentrations ranged up to 385.57 mg/kg. The sample with 3785.57 mg/kg arsenic was collected in SMU 38 and is the same sample which exhibited the highest concentrations of cadmium, nickel, selenium, and silver. Based on the number and relatively high concentrations for parameters detected in this SMU, the results suggest possible point source impacts in this area. The remaining arsenic concentrations range between 0.8 and 13.35 mg/kg, and discarding the highest result, the average for this reach would be 5.92 mg/kg, which is just slightly above the Lake Winnebago average (Table 5-5). Similarly, discarding the SMU 38 results would also yield a river-wide average of 4.86 mg/kg instead of 7.37 mg/kg, thus making the entire river average lower than the Lake Winnebago value.

The arsenic results for Green Bay Zone 2 are below the Lake Winnebago average. However, arsenic concentrations and averages for zones 3B and 4 are higher, exceeding the Lake Winnebago average within Zone 3B. Arsenic at these locations within the bay may not be related to the Lower Fox River. Rather, these concentrations may reflect the influence of the Menominee River AOC, where arsenic was the main chemical of concern.

5.4.6Other Organic Compounds

According to the SLRA (RETEC, 1998c), none of the SVOCs (including the PAHs) were chemicals of potential concern within sediments. However, the presence of PAHs and PCP in river sediments is briefly summarized below.

5.4.6.1 LLBdM Reach SVOC Results

Numerous SVOCs have been detected in sediments from deposits A, C, D, E, and POG (Tables 5-10 and 5-11). In most samples, pyrene was the PAH with the highest concentration. However, in a few samples, the SVOCs BEHP and 4-methylphenol had the highest concentrations. Total PAH results ranged from 148 μg/kg to 44,260 μg/kg and 13 of the 22 samples exceed the WDNR reference value of 4,000 μg/kg. WDNR has previously used a value of 4,000 μg/kg total PAHs as an indicator of impacted sediments that could warrant further evaluation (WDNR, 1992). The lowest and highest total PAH results were detected in Deposit POG (Table 5-10), with all the samples from Deposit C exceeding 4,000 μg/kg.

Overall, comparison of the total PAHs with total PCBs indicates that there is no general trend. Only four samples from deposits A, D, E and three from POG have total PCB results that exceed total PAH results. In the other 15 samples, the total PCBs are less than the total PAHs (Table 5-10). Similarly, there is no trend when comparing SVOC results with total PCBs (Table 5-11).

PCP was detected in seven samples in this reach from deposits C, E, and POG; six surface samples and one subsurface sample. PCP concentrations ranged from 350 to 860 μg/kg (Table 5-11). In Deposit POG, PCP was detected in only one sample (a subsurface sample) collected from 122 to 183 cm (4 to 6 feet) below the sediment surface. This sample had a concentration of 719 μg/kg; however PCP was not detected in either of the samples collected immediately above or below this sample (from 0-60 cm and from 60-120 cm). These results reflect similar findings for other compounds in Deposit POG where concentrations increase with depth.

5.4.6.2 Appleton to Little Rapids Reach SVOC Results

Almost all of the PAHs and a number of SVOCs have been detected in samples from deposits P, W, and X. Similar to LLBdM, pyrene often exhibited the highest concentration. Total PAHs in this reach range from 2,820 μg/kg to 13,920 μg/kg. and were typically one order of magnitude higher than the total PCB concentrations in these deposits. Only the inter-deposit sample had a total PCB result exceeding the total PAH value (Table 5-10). Again, there is no correlation between total PAH results and total PCB values.

PCP was detected in two surface sediment samples at concentrations of 280 to 290 μg/kg. These were generally the lowest PCP concentrations observed in the river and only one other sample, from the De Pere to Green Bay Reach, had a lower PCP result (Table 5-11).

5.4.6.3 Little Rapids to De Pere Reach SVOC Results

SVOCs were detected in up to 21 samples from this reach and the majority of these samples were collected from Deposit EE (Tables 5-10 and 5-11). Similar to the other reaches, pyrene concentrations were generally highest (Table 5-10).

Total PAHs range from 240 to 13,364.6 μg/kg, while total PCBs range from 143 to 18,671 μg/kg. Thirteen (13) of the 21 sample results exceed the WDNR reference standard of 4,000 μg/kg. PAHs appear to be pervasive in this and upstream reaches of the river and are not necessarily associated with PCB occurrences. All but two of the samples (from Deposit EE) have total PAHs values that exceed total PCB results.

PCP was only detected in four surface sediment samples from deposits EE and HH at concentrations from 500 to 1,100 μg/kg. These samples were collected from the downstream half of Deposit EE (water column segments EE/25 and EE/26). The PCP concentrations detected in EE/26 were the highest concentrations detected throughout the Lower Fox River.

5.4.6.4 De Pere to Green Bay Reach SVOC Results

Downstream of the De Pere dam, SVOCs and PAHs were detected in 25 samples. Total PAH concentrations range from 640 to 13,000 μg/kg and 17 of the 25 sample results exceeded 4,000 μg/kg. Additionally, 21 of 25 total PAHs results exceed the total PCB concentrations. Similar to other upstream reaches, PAHs appear to be pervasive in this reach of the river and are not associated with PCB occurrences.

PCP was detected in six surface sediment samples and concentrations range from 20 to 710 μg/kg (Table 5-11). Four of these samples are just downstream of the De Pere dam. The sample results suggest that PCP distribution is limited and sporadic in occurrence.

5.4.6.5 Green Bay SVOC Results

PAHs and SVOCs were only detected in six samples from Green Bay Zone 2 (Table 5-10 and 5-11). Only four PAHs were detected in this zone and pyrene was again the compound with the highest concentrations. Total PAHs in Zone 2 ranged from 98 to 1,310 μg/kg. The only SVOC detected was 4-methylphenol. No SVOCs were detected in Green Bay zones 3 or 4.

5.4.7Other Inorganic Compounds

5.4.7.1 Cadmium/Chromium

Cadmium was detected in 147 sediment samples collected from the river and in 13 samples from the bay (Table 5-6). Similar to lead and arsenic, a disproportionate number of samples were collected downstream of the De Pere dam. Cadmium was detected in 89 samples from the De Pere to Green Bay Reach (Table 5-6). In the Lower Fox River, the reach averages range from 0.97 to 3.48 mg/kg, indicating that all the averages are near or exceed the WDNR Triad Assessment reference background level of 1 mg/kg. Concentrations generally decline moving downstream; however, this may be due to the limited number of samples collected upstream of the De Pere dam. In the De Pere to Green Bay Reach, cadmium ranged up to 10.8 mg/kg at SMU-38, which also exhibited the highest arsenic, cadmium, silver, nickel and selenium concentrations.

The results suggest that cadmium in sediments are slightly elevated in the upstream portions of the Lower Fox River. The highest concentration (12.5 mg/kg) was detected in Deposit A (Table 5-6). No specific point source has been identified. Cadmium has widespread uses, including metal refining and plating, paint pigments, and plastics.

The Green Bay zone averages range up to 0.5625 mg/kg in Zone 3B (Table 5-6) and suggest that cadmium concentrations in the bay are not significant.

Chromium was detected in 171 samples from the river and in 21 samples from the bay (Table 5-6). Similar to cadmium, lead, and arsenic, a disproportionate number of samples (107 samples) were collected in the De Pere to Green Bay Reach. The reach averages range from 47.9 to 73.3 mg/kg (Table 5-6). The results for LLBdM, Appleton to Little Rapids, and De Pere to Green Bay reaches are within a normal range of variability near background while the Little Rapids to De Pere Reach average slightly exceeds the Lake Winnebago background level of 65 mg/kg. No specific point source has been identified and chromium also has widespread uses, including metal refining, finishing, and plating.

Chromium concentrations in Green Bay range up to 40 mg/kg, which is below the Lake Winnebago average and equal to the NURE average (Table 5-6). Like cadmium, these results indicate that chromium concentrations within Green Bay are not significant.

5.4.7.2 Ammonia

Ammonia was detected in 97 river samples and 19 bay samples. As mentioned above, all but four of the samples (two from the river and two from the bay) exceed the Triad Assessment reference concentration of 31 mg/kg (Table 5-8). The maximum concentrations generally increase moving downstream towards the De Pere dam, ranging from 300 mg/kg in LLBdM to 700 mg/kg in the Little Rapids to De Pere Reach (Table 5-8). The maximum concentration in the De Pere to Green Bay Reach declined to 590 mg/kg. However, only four samples were collected in this reach. In Green Bay, the maximum concentration decreased even further to 140 mg/kg (Table 5-8). Due to the formation of ammonia resulting from natural degradation of organic material in sediments, it is difficult to determine if these concentrations result from point source discharges to the river or from natural processes.

5.5 Surface Water Sampling Results

5.5.1 Overview

The total number of water samples collected during previous investigations and the chemical compounds detected are summarized on Table 5-16. In both the river and the bay, the greatest number of samples have been collected and analyzed for PCBs, followed by the inorganic parameters. In addition to the PCBs detected in the waters of the Lower Fox River, 34 other parameters, including a number of pesticides and one SVOC, were also were detected in water in either the dissolved or particulate phase (Table 5-16). PCBs were the only parameters detected in particulate samples in Green Bay. In addition to PCBs, seven inorganic compounds and TOC were detected in dissolved phase (Table 5-16). No pesticides or SVOCs were detected in the bay.

Other than PCBs and mercury, none of the other parameters have been analyzed in more than 50 samples. Due to the limited number of chemical parameters analyzed, the focus of this section is PCBs, mercury, and DDT (and its derivatives DDD and DDE), the only chemicals identified in SLRA which were detected in water samples (Tables 5-17 through 5-19).

Approximately 650 water samples have been collected and analyzed for PCB in either the dissolved or particulate phase, but many difficulties exist in evaluating the water sampling results. Although the water samples can be identified as originating within a certain reach of the river, the exact sampling location may have changed from one investigation to another. Therefore, due to the dynamic nature of the flow system, comparison of the results from one investigation to another relies on the assumption that samples collected within a specific reach are comparable to one another.

Water samples were obtained from a limited number of investigations during specific time periods. Data from 1989/90 were collected by WDNR or the EPA Great Lakes National Program Office (GLNPO) as part of the GBMBS. The 1992/93 data were collected by BBL during sediment investigations of Deposit A on behalf of P.H. Glatfelter and due to the limited amount of this data, it will not be included in the following analysis. Data from 1994/95 were collected as part of the Lake Michigan Mass Balance study completed by EPA and USGS. During 1998, BBL collected a number of Fox River and Green Bay samples on behalf of the FRG and in 1998/99, WDNR collected a number of water samples in conjunction with the Deposit N SRD project.

5.5.2 PCB Distribution

PCB data were collected between 1989 and 1998 and the results for the Lower Fox River and Green Bay are listed on Tables 5-17 and 5-18, respectively. WDNR has evaluated the 1989/90 GBMBS data in previous reports. The analysis presented below evaluates trends for which reliable sample collection location/date information is available subsequent to the 1989/90 sampling event and the results will be discussed and compared to WDNR findings. The 1994/95 data are plotted to evaluate trends in PCB concentrations over a one-year period and to calculate the PCB load from the Lower Fox River into Green Bay. Data collected throughout the Lower Fox River by BBL during 1998 is plotted to evaluate how the PCB load changes from one reach to another. Available temperature data are also plotted with these data to facilitate analysis.

5.5.2.1 Distribution in the Lower Fox River

General Overview of the PCBs in the River

The Lower Fox River PCB concentrations and general results are summarized below.

Summary of the Lower Fox River PCB Water Sampling Results

PCB Concentrations (ng/L)	Dissolved PCB	Particulate PCB	Total PCB
Maximum	32.03	110.36	141.97
Minimum	2.52	1.6	10.15
Average	14.64	39.97	54.6

Approximately, 70 to 75 percent of the detected PCBs are particulate phase while the remaining 25 to 30 percent are dissolved phase (Table 5-16). The results are similar to the GBMBS results (Velleux and Endicott, 1994; WDNR, 1995), such that seasonal variations and ratios of dissolved to solid phase PCB appears consistent over time.

Seasonal PCB Trends

The 1994/95 PCB concentrations (Table 5-17) collected in the De Pere to Green Bay Reach are plotted on Figure 5-13, along with river temperature readings. Figure 5-13 shows the general relationship between the particulate and dissolved phase PCB concentrations and indicate a direct correlation between water temperature and total PCB concentrations. When water temperatures fall below 4°C (40°F), the total PCB concentrations also decline significantly (Figure 5-13). Additionally, during the winter months of December 1994 through February 1995, when total PCB levels decline to about 10 percent of the average concentration (Table 5-17), the concentration of particulate PCB falls below the concentration for the dissolved fraction (Figure 5-13).

WDNR (1995) concluded that this seasonal variation is related to the amount of algae present in the water, which appear to facilitate suspension of PCB in the water column. If water temperature were the only factor in the amount of total PCB suspended in the water column, the winter decline in PCB concentrations would be expected to be more gradual than observed (Figure 5-13). However, since algae populations are also dependent on water temperature and a number of other variables (such as sunlight, which is inhibited in winter by ice cover and overall shorter days), their presence would be expected to increase or decrease rapidly with changes in critical river conditions.

In addition to the decrease in particulate concentrations, significant increases in PCB concentrations are also evident (Figure 5-13). During 1994, total PCB concentrations increase by 2 to 4 times over concentrations observed in the first samples collected as part of this data set (Table 5-17 and Figure 5-13). Based on the historical increase in river discharge observed during this time of year, particulate concentrations are augmented by the large TSS load that would be expected to accompany the increased river discharge and velocities. USGS (1998f) data show that discharge increased from about 62.8 m^3/s (2,220 cfs) on July 1, 1994 to over 272 m^3/s (9,610 cfs) on July 17, 1994. This increased stream discharge correlates with the observed total and particulate PCB concentrations (Figure 5-13).

Downstream PCB Trends

PCB data for each river reach was collected by BBL during 1998 (Table 5-17) and are plotted on Figure 5-14. Total PCB concentrations in the LLBdM Reach are consistently the lowest in the river and the concentrations generally increased downstream from LLBdM to the De Pere to Green Bay Reach. After fluctuating in the spring of March 1998, PCB concentrations in the De Pere to Green Bay Reach begin a steady increase through the August before almost doubling to about 85 ng/L (Figure 5-14). Concentration trends in the other upstream reaches also increase to their maximum in August 1998 (Figure 5-14). However, by September 1998, PCB concentration trends decrease to levels near the reach averages (Figure 5-14), reflecting the seasonal component to PCB transport suggested by WDNR (1995).

PCB Homolog Distribution

Similar to the PCB sediment results, a homolog plot was constructed using data from the De Pere to Green Bay Reach and the Green Bay zones to evaluate the general fate of PCBs moving through the water column and from the river into the bay (Figure 5-15). Data for the LLBdM, Appleton to Little Rapids, and Little Rapids to De Pere river reaches were not in the same format as the data from De Pere to Green Bay and the Green Bay zones. Therefore, the upstream reaches of the river are not included in this analysis.

The PCB homolog data have been plotted for both the dissolved and particulate phase. The dissolved PCB results for the De Pere to Green Bay Reach are data which most closely resemble the plot for Aroclor 1242 (Figure 5-15). This data set exhibits less mono- and dichlorinated PCBs and more tetra- through octachlorinated PCBs than Aroclor 1242. In addition, the percentage of mono- through trichlorinated PCBs is greater in the dissolved samples than in the particulate results (Figure 5-15). Conversely, the percentage of tetra- though nonachlorinated PCBs is greater in particulate samples than in the dissolved samples. These results reflect the overall solubility each homolog group. The mono- trough trichlorinated PCBs are more soluble than are the mid- to higher chlorinated congeners. Additionally, the percentage of mid- and higher chlorinated PCBs increases moving from the river into the bay. This is indicated by the increasing percentage of hexa- through octachlorinated PCBs in each reach/zone moving further out into the bay.

Similar to the homolog results in sediments, the greatest percentage of any homolog groups are the tri- and tetrachlorinated PCBs, which typically comprise 50 percent or more of the detected PCBs (Figure 5-15). PCBs within these two homolog groups (the tri- and tetrachlorinated PCBs) are soluble enough to migrate within the system yet they degrade slow enough so that they comprise a significant portion of the total PCBs detected in the river and the bay.

5.5.2.2 PCB Distribution in Green Bay

PCB results for Green Bay are available from 1989/90 and 1998 (Table 5-18), and other authors previously summarized the 1989/90 data. While the 1989/90 samples were analyzed for PCBs in both a dissolved (filtrate) and particulate phase, the 1998 samples were apparently only analyzed for particulate phase PCBs (Table 5-18).

The 1989/90 and 1998 Green Bay results indicate similar trends. In 1989/90 total PCB concentrations in Zone 2 (zones 2A and 2B) were about 18.5 ng/L. PCB concentrations decreased with distance from the Lower Fox River mouth, from 4.48 ng/L and 3.56 ng/L in zones 3A and 3B, respectively, to 0.99 ng/L in Zone 4 (Table 5-18), suggesting the Fox River as the source.

Similar trends were observed for the 1998 particulate data. The average PCB concentration in Zone 2 (zones 2A and 2B) was about 6.2 ng/L but this value declined to about 1 ng/L in zones 3A and 3B and no PCBs were detected in Zone 4 (Table 5-18). The Green Bay PCB results also indicate that particulate phase PCBs account for approximately 74 percent of the PCBs detected in Zone 2. This is similar to the percentages observed in the Lower Fox River. However, the particulate phase PCB percentage decreases moving away from the mouth of the river and for zones 3A, 3B, and 4 are about 64 percent, 59 percent, and 42 percent, respectively.

5.5.2.3 PCB Distribution in Lake Michigan

The estimated PCB mass transported from Green Bay into Lake Michigan was derived in the early 1990s from modeling activities using water sample data from both the bay and the lake. Raghunathan (1994) concluded that approximately 122 kg (270 pounds) of PCB are transported annually through the water column from Green Bay to Lake Michigan.

5.5.3Mercury Distribution

In the Lower Fox River, particulate phase mercury was detected in 32 samples from the De Pere to Green Bay Reach while dissolved mercury was detected in 46 samples between Appleton and the river mouth. Mercury was only detected in two samples in Green Bay Zone 2 and the concentrations ranged from 1.15 to 2.33 ng/L (Table 5-16).

The 1994/95 total, dissolved, and particulate phase mercury concentrations in water samples (Table 5-19) are plotted along with PCBs on Figure 5-13. Similar to the total PCB results, the particulate concentrations are usually significantly higher than the dissolved phase levels (about 80 to 90 percent of the total mercury result on Table 5-17). The total mercury concentrations also exhibit the same trends observed for PCBs. Concentrations decrease significantly during the winter months, when water temperatures decline, and increase during the spring/summer, with increased stream flow as well as possible increased biological activity. Seasonal variations in the chemical phase exist for both organic and inorganic compounds and may imply that biological activity related to algal growth cycles facilitate the transport of chemical parameters in the Lower Fox River, as well as TSS transport. Dissolved mercury, however, remained relatively constant over the monitoring period, indicating that only very low levels of mercury are transformed into a dissolved state.

5.5.4Pesticide Distribution

DDT, DDD, and DDE were in analyzed in a number of samples from the Lower Fox River and Green Bay. DDT was only detected in seven samples while DDD and DDE were each detected in 38 and 43 samples, respectively. The Lower Fox River sampling results for these pesticides are listed on Table 5-19 and summarized below.

Summary of the Lower Fox River Pesticide Sampling Results

Detected Concentration Ranges (ng/L)	DDT	DDD	DDE
Dissolved	Not Detected	0.05 to 0.07	0.03 to 0.07
Particulate	0.05 to 0.21	0.05 to 0.27	0.03 to 0.41

None of these parameters were detected in samples collected in Green Bay.

5.6 Chemical Loading to Green Bay

5.6.1PCB Loading to Green Bay

Much of the data provided in Table 5-17 has been generated in association with two mass balance studies, the Green Bay Mass Balance Study (GBMBS) and Lake Michigan Mass Balance (LMMB). These studies have quantified the movement of PCBs within the Lower Fox River as well as Green Bay.

The Green Bay Mass Balance Study (GBMBS) was designed to identify the sources, transport pathways, and fate of PCBs within the Lower Fox River and Green Bay. The Lower Fox River portion of the GBMBS consisted of two components which separately evaluated the fate and transport of PCBs in the upper 32 river miles from Lake Winnebago to the DePere dam (WDNR, 1995) and the lower 7 river miles from the DePere dam to Green Bay (Velleux and Endicott 1994, Velleux, *et. al* 1995). PCB concentrations in the water entering the Lower Fox River from Lake Winnebago were negligible with measured concentrations often similar concentrations found in field equipment blank samples. This is confirmed by the minimal amount of transport, 4 kg, estimated at the railroad bridge in the southern portion of Little Lake Butte des Morts. Consistent with the previous observation that PCB concentration generally increases with distance downstream (Figure 3-17), PCB transport also increases downstream with an estimated 143 kg transported over the DePere dam. In the parallel effort downstream of the DePere dam it was estimated that 280 kg of PCB were transported into Green Bay during the same period, May 1989-April 1990. PCB transport fluxes throughout the river and bay are summarized in Table 5-20 and Figure 5-16 (WDNR 1995 and http://www.epa.gov/med/images/gb_massbal.gif).

Following the GBMBS, USEPA GLNPO undertook a similar effort for all of Lake Michigan. The Lake Michigan Mass Balance included quantifying PCB loadings from 11 tributaries around Lake Michigan, including the Lower Fox River, during 1994 and 1995. The LMMB estimated that the Lower Fox River contributed 186 kg of PCB to Lake Michigan (the LMMB considered Green Bay part of Lake Michigan), accounting for more that 60 percent of the total tributary PCB loading (EPA, 2000)

5.6.2Mercury and DDT Loading to Green Bay

Similar to the estimated PCB load into the bay, the annual loads for mercury and DDT were calculated using the 1994/95 water sampling results and the average stream flow discharge. The mercury load may range between approximately 10 and 300 kg (22 to 661 pounds) annually, with an average of about 100 kg (220 pounds). The mercury load may, at times, be as great as the PCB load. Conversely, the estimated DDT load ranges from 0.23 to 0.81 kg (0.51 to 1.8 pounds) annually, much lower than the estimated loads for either PCBs or mercury (Table 5-18). No recent data were available to include in the analysis of mercury and DDT in Green Bay.

5.7 Summary of PCBs in Biota

PCBs have been analyzed in a number of different fish and bird species, as well as fur-bearing mammals and insects/invertebrates. PCB concentrations in these creatures have been evaluated as part of the Human Health and Ecological Risk Assessments.

The number and type of biological samples collected in the Lower Fox River or Green Bay and analyzed for PCBs are listed on Tables 5-21 and 5-22, respectively. The first samples included in the FRDB were collected in 1971 in Green Bay (Table 5-22). Continuous sample collection from Green Bay and the Lower Fox River began in 1975 and 1976, respectively. The total PCB analytical results for all the animal groups listed on Tables 5-21 and 5-22 are used in the evaluation of human health and ecological risks in the RA.

In the Lower Fox River 1,405 fish samples, 154 bird samples, and one fur-bearing mammal sample have been analyzed for total PCBs (Table 5-21). In Green Bay 1,490 fish samples, 227 bird samples, and two mammal samples (one fur-bearing mammal and one deer) have been analyzed for total PCBs (Table 5-22). In addition, a small number of insect/invertebrate samples have been analyzed in both the Lower Fox River and Green Bay (Tables 5-21 and 5-22). These data are discussed in more detail in the RA.

5.8 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 B.

5.8.1 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) 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, with the added benefit that these groups designated non-overlapping spatial sets. The statistical groups analyzed are shown on Figures 5-17 through 5-19.

Depth strata within each deposit group were consistent with the depth used thoughout the RI: 0 to 10 cm, 10 to 30 cm, 30 to 50 cm, 50 to 100 cm and 100+ cm. 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 log normal 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."

5.8.2Fish 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 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.[1]

[1] 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.

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 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.

5.8.3Results

Results of the sediment time trends are presented in Table 5-23, and are represented graphically on Figures 5-17 through 5-19. 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,[2] and within that subset eight were in the 0- to 10-cm segment.

Conducting a meta-analysis on the surface sediment data showed a negative trend in all reaches except Appleton to Little Rapids (Table 5-24). 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 to Little Rapids Reach, -10 percent in the Little Rapids to De Pere Reach, and -15 percent in the De Pere to Green Bay 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 4 inches (0 to 10 cm). While 32 out of the 46 analyses were negative, there is a strong trend toward fewer and weaker negative slopes at increasing depth. Table 5-23 and Figures 5-17 through 5-19 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 to Little Rapids and De Pere to Green

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

Bay reaches. For Little Rapids to De Pere, there are consistently negative trends in the 10- to 30-cm strata, but in the lower strata, the data are consistent with either zero trend (30 to 50 cm), or an increasing trend (50 to 100 cm).

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 5-25). 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.

5.8.3.1 Little Lake Butte des Morts

Time trend results for sediments in Little Lake Butte des Morts are presented in Table 5-23 and on Figures 5-17 through 5-19. With the exception of two strata at 10 to 30 cm 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) 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 5-24) 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 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 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 5-25). 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.

5.8.3.2 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.

5.8.3.3 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 and 10- to 30-cm depth strata. One large positive statistically significant slope occurs at the 30- to 50-cm depth (Table 5-23, Figure 5-18).

The surface sediment (0 to 10 cm) 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 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 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.

5.8.3.4 De Pere to Green Bay (Zone 1)

The time trends analysis for surface sediments in this reach showed primarily negative slopes (Table 5-23). 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), 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, 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, 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 56/57 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 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.

5.8.3.5 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.

5.8.4Conclusion

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 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 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.

5.9 Section 5 Figures, Tables, and Plates

Figures, tables, and plates for Section 5 follow this page, and include:

Figure 5-1 PCB Sampling Frequency Distribution in Lower Fox River and Green Bay Sediments
Figure 5-2 Summary of Total PCB Concentrations in Lower Fox River and Green Bay Sediments
Figure 5-3 PCB Mass Distribution in Sediments for Each River Reach and Bay Zone
Figure 5-4 PCB Mass by Concentration Ranges in Lower Fox River Sediments
Figure 5-5 Contaminated Sediment Volume by Concentration Ranges in the Lower Fox River
Figure 5-6 PCB Mass by Concentration Ranges in Green Bay Sediments
Figure 5-7 Contaminated Sediment Volume by Concentration Ranges in Green Bay
Figure 5-8 PCB Mass Distribution in Lower Fox River and Green Bay Sediments
Figure 5-9 Ratios of PCB Mass/Sediment Volume in the Lower Fox River and Green Bay
Figure 5-10 Distribution of PCB Mass/Sediment Volume Ratios in Sediments with More Than 50 µg/kg PCBs
Figure 5-11 Aroclors 1242/1254/1260 PCB Homolog Plots
Figure 5-12 PCB Homolog Distribution in Lower Fox River and Green Bay Sediments
Figure 5-13 1994/95 Total PCB & Mercury Concentrations in Lower Fox River Water
Figure 5-14 1998 Total PCB Concentrations in Lower Fox River Water
Figure 5-15 PCB Homolog Distribution in Water: De Pere Dam Through Green Bay
Figure 5-16 Lower Fox River and Green Bay System — Estimated PCB Mass and Major PCB Flux Pathways
Figure 5-17 Time Trends of PCBs in Sediments for Depths from 0 to 10 cm and form 10 to 30 cm

Figure 5-18 Time Trends of PCBs in Sediments for Depths from 30 to 50 cm and from 50 to 100 cm
Figure 5-19 Time Trends of PCBs in Sediments for Depths over 100 cm

Table 5-1 Lower Fox River and Green Bay - Sediment Sampling Results: Summary of Detected Compounds
Table 5-2 Lower Fox River and Green Bay - Distribution of Total PCBs in Sediment
Table 5-3 Lower Fox River - Dioxin/Furan (2,3,7,8-TCDD/F) Results
Table 5-4 Lower Fox River and Green Bay - Pesticide Results
Table 5-5 Lower Fox River and Green Bay - Mercury, Lead, and Arsenic Results
Table 5-6 Lower Fox River and Green Bay - Other RCRA Metals, Copper, Nickel, and Zinc
Table 5-7 Lower Fox River and Green Bay - Miscellaneous Inorganic Compounds
Table 5-8 Lower Fox River and Green Bay - Ammonia Results
Table 5-9 Lower Fox River - Toxicity Characteristic Leaching Procedure (TCLP) Results
Table 5-10 Lower Fox River and Green Bay - Semi-Volatile Organic Compound Results (PAHs)
Table 5-11 Lower Fox River and Green Bay - Miscellaneous SVOC Results
Table 5-12 Lake Winnebago Background Sediment Results
Table 5-13 Lower Fox River - PCB Mass and Sediment Volume by Concentration Range
Table 5-14 Lower Fox River - PCB Mass and Sediment Volume by Deposit/SMU Layer
Table 5-15 Green Bay - PCB Mass and Sediment Volume by Concentration Range and Layer
Table 5-16 Lower Fox River and Green Bay - Water Sampling Results: Summary of Detected Compounds
Table 5-17 Lower Fox River - Total PCB Results in Water
Table 5-18 Green Bay - Total PCB Results in Water
Table 5-19 Lower Fox River and Green Bay - Mercury and DDT (DDD/DDE) Water Sampling Results
Table 5-20 PCB Transport within the Lower Fox River and Green Bay System
Table 5-21 Distribution of Resident Tissue Samples over Time in the Lower Fox River - Total PCBs Only
Table 5-22 Distribution of Resident Tissue Samples over Time in Green Bay - Total PCBs Only

Table 5-23 Results of Sediment Time Trends Analysis for the Lower Fox River

Table 5-24 Mass-Weighted Combined Time Trend for 0 tp 10 cm Depth by Reach

Table 5-25 Results of Fish Time Trend Analysis on the Lower Fox River

Plate 5-1 Interpolated PCB Distribution in Sediments: Little Lake Butte des Morts Reach

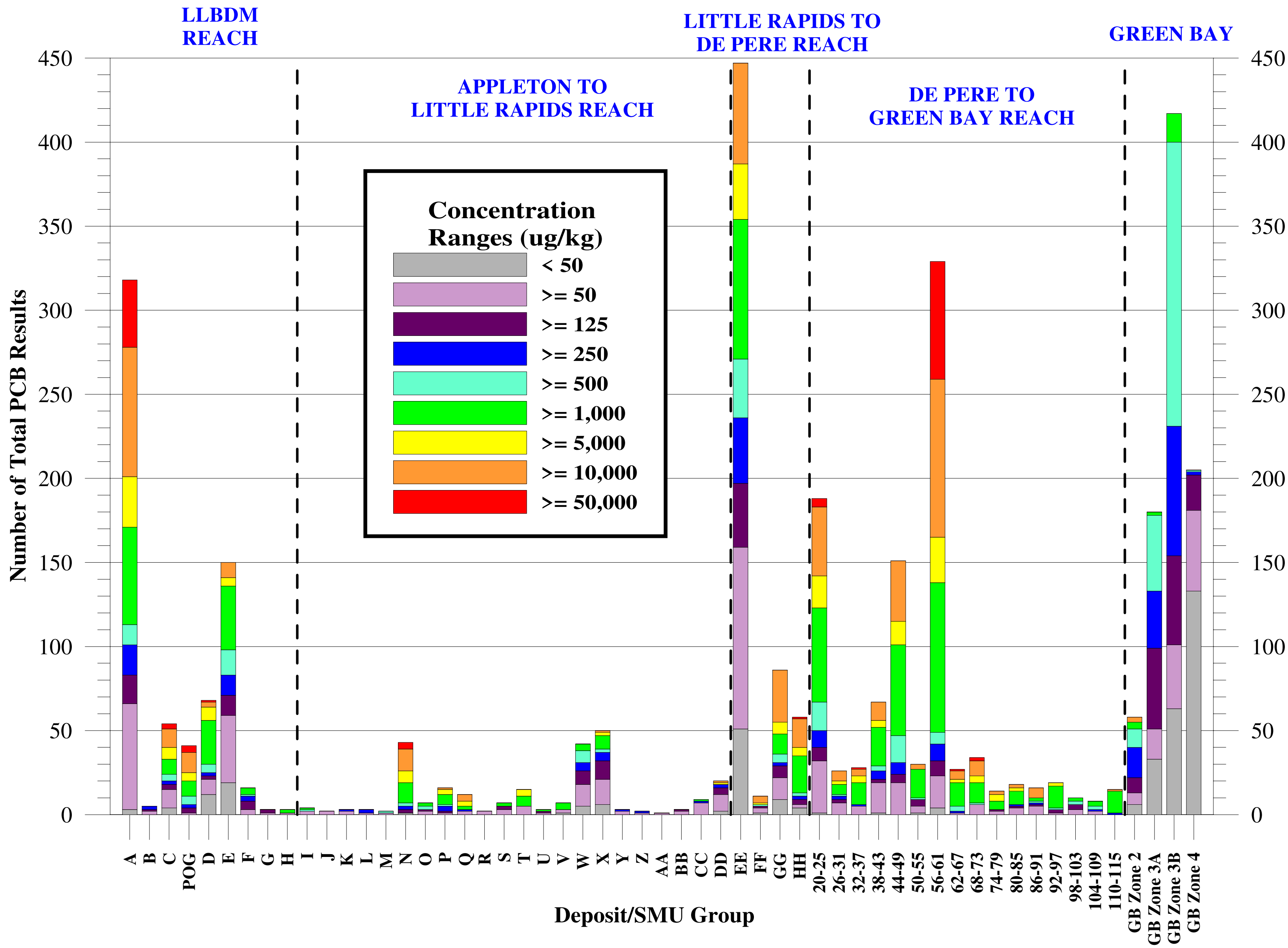
Plate 5-2 Interpolated PCB Distribution in Sediments: Appleton to Little Rapids Reach

Plate 5-3 Interpolated PCB Distribution in Sediments: Little Rapids to De Pere Reach

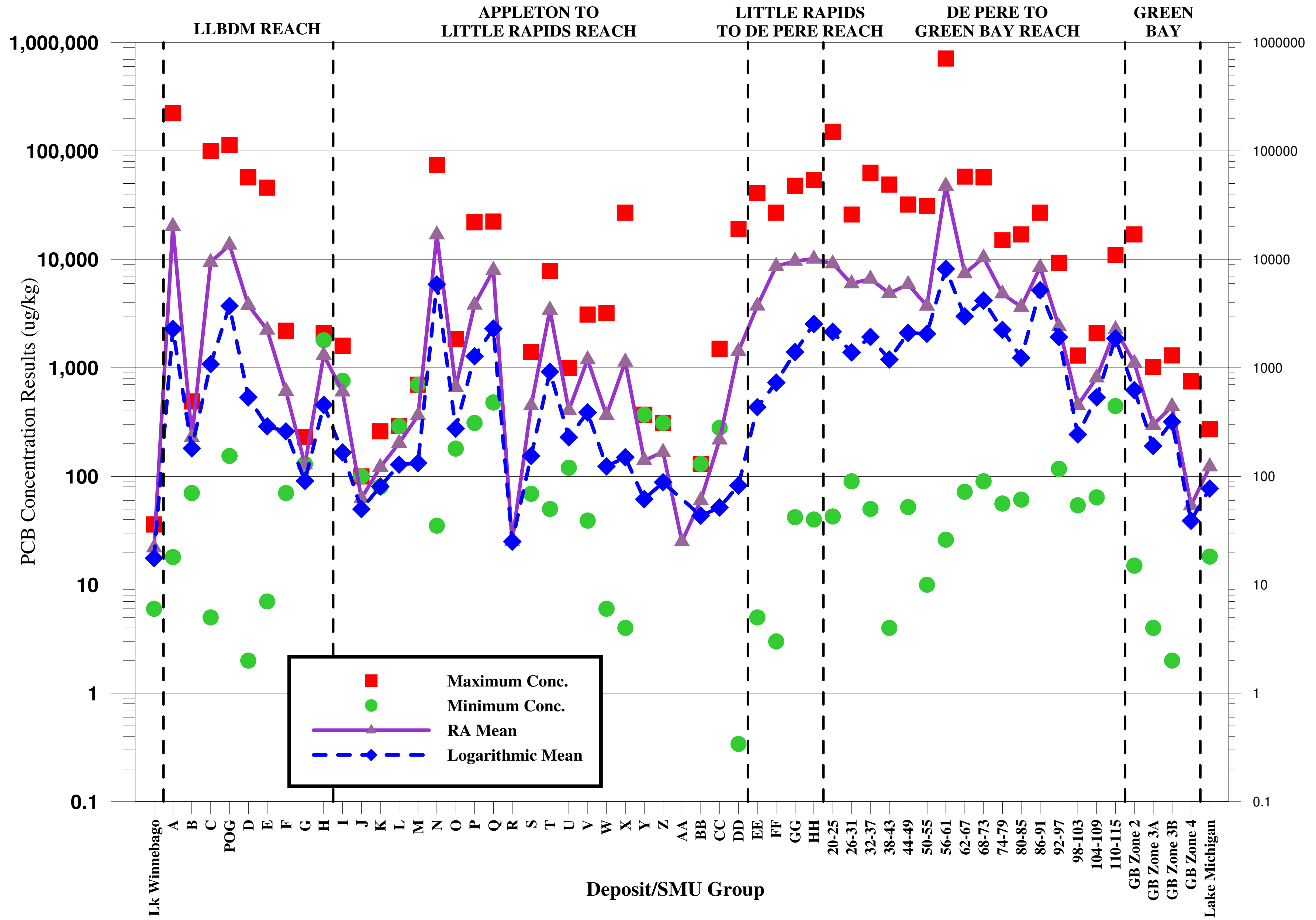
Plate 5-4 Interpolated PCB Distribution in Sediments: De Pere to Green Bay Reach

Plate 5-5 Interpolated PCB Distribution in Sediments: Green Bay

Plate 5-1	Interpolated PCB Distribution in Sediments: Little Lake Butte des Morts Reach
Plate 5-2	Interpolated PCB Distribution in Sediments: Appleton to Little Rapids Reach
Plate 5-3	Interpolated PCB Distribution in Sediments: Little Rapids to De Pere Reach
Plate 5-4	Interpolated PCB Distribution in Sediments: De Pere to Green Bay Reach
Plate 5-5	Interpolated PCB Distribution in Sediments: Green Bay



ThermoRetec Smart Solutions Positive Outcomes	Natural Resource Technology	Remedial Investigation Report	PCB Sampling Frequency Distribution in Lower Fox River and Green Bay Sediments FIGURE: 5-1	REF NO: CREATED BY: PRINT DATE: APPROVED:



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Summary of Total PCB Concentrations in Lower Fox River and Green Bay Sediments

FIGURE: 5-2

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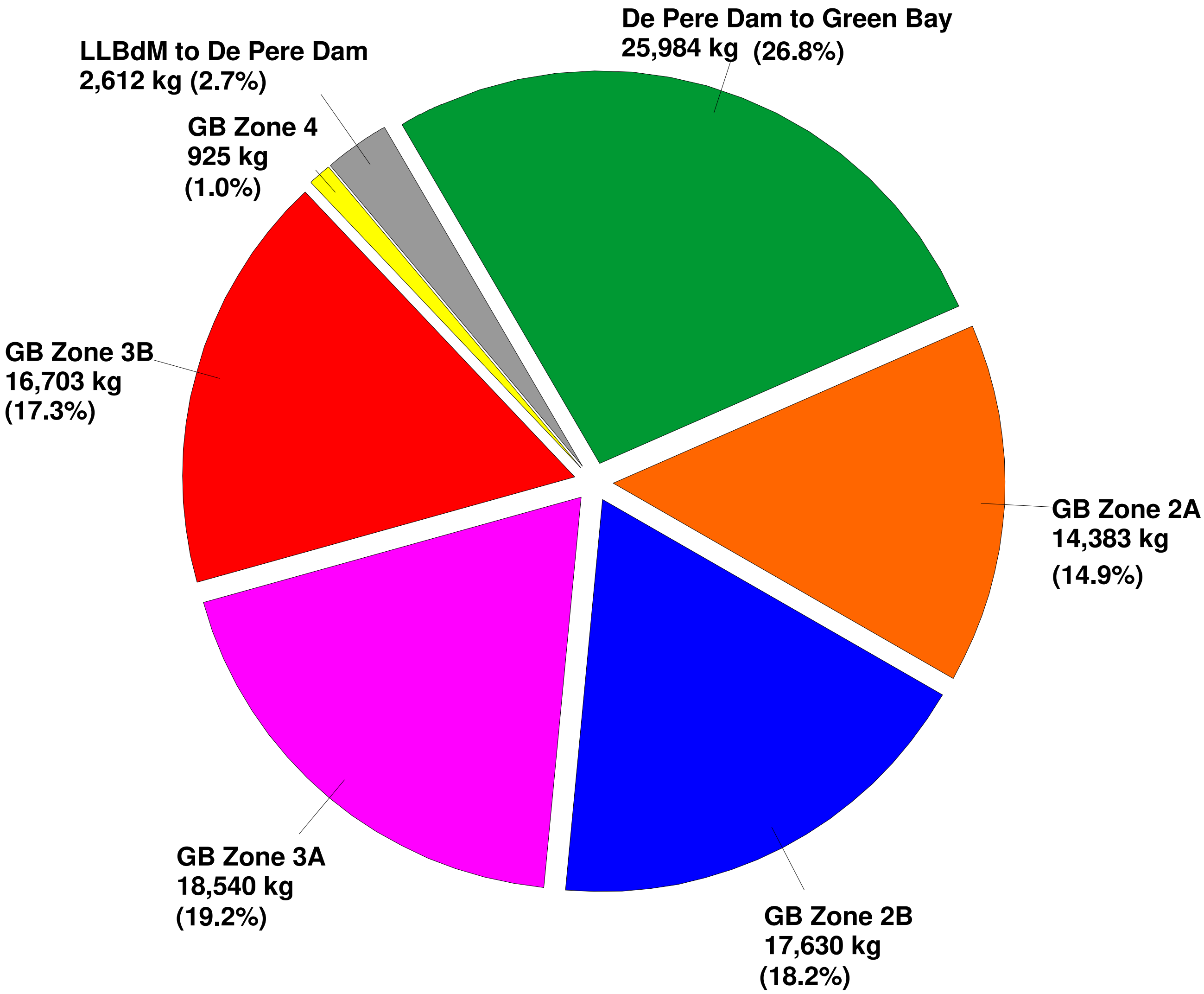
CREATED BY:

PRINT DATE:

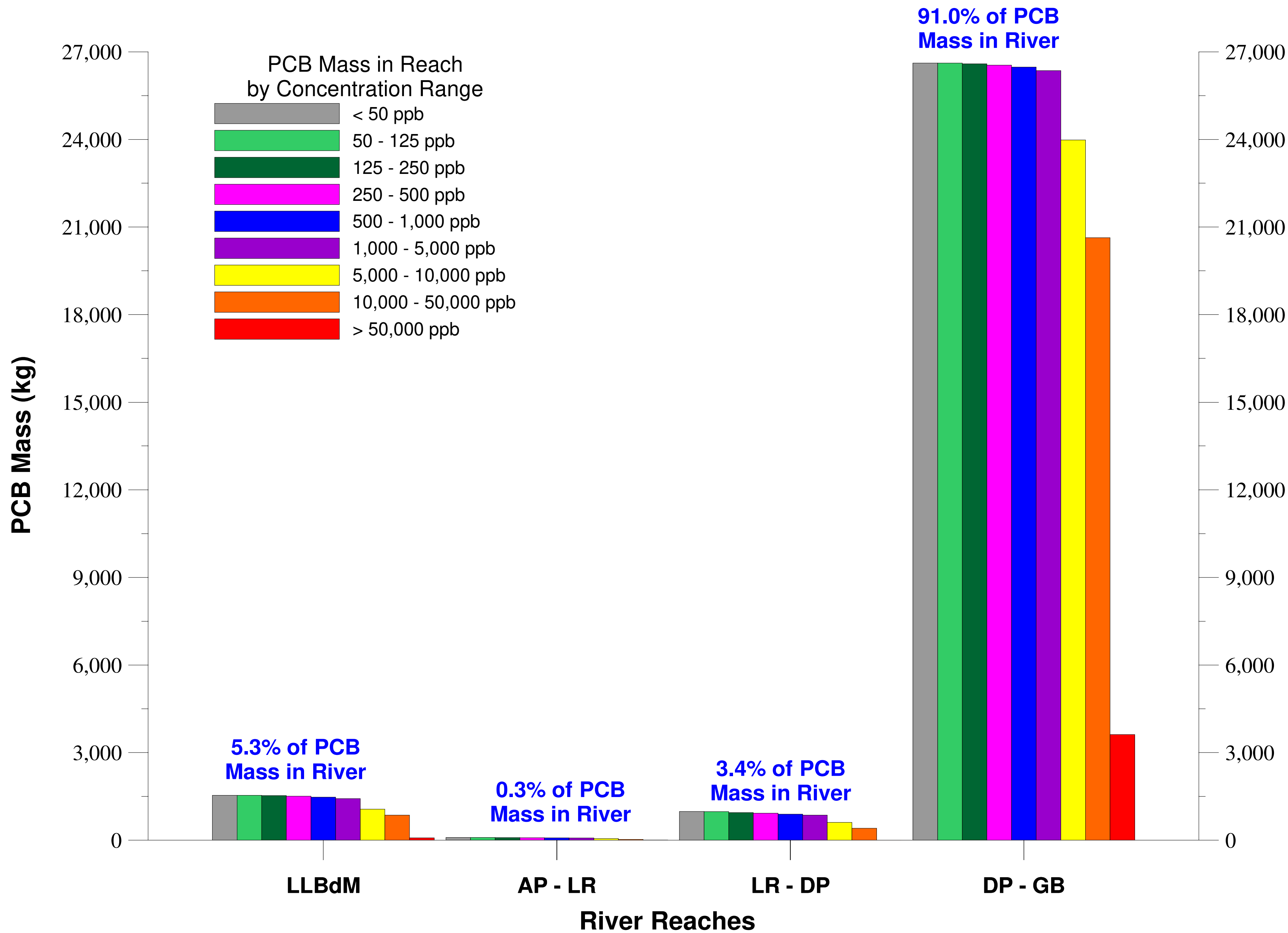
APPROVED:



NOTES:

1) The upper 3 Reaches of the Lower Fox River, from LLBdM to the De Pere Dam, have been combined and contain 2.7% of the total PCB mass in sediments.
2) The combined mass of Zones 2A and 2B is 33.1% of the total PCB mass in sediments.
3) The combined mass of Zones 3A and 3B is 36.5% of the total PCB mass in sediments.

ThermoRetec Smart Solutions Positive Outcomes	Natural Resource Technology	Remedial Investigation Report	PCB Mass Distribution in Sediments for Each River Reach and Bay Zone	REF NO:
				CREATED BY:
				PRINT DATE:
			FIGURE: 5-3	APPROVED:



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PCB Mass by Concentration Ranges in Lower Fox River Sediments

FIGURE: 5-4

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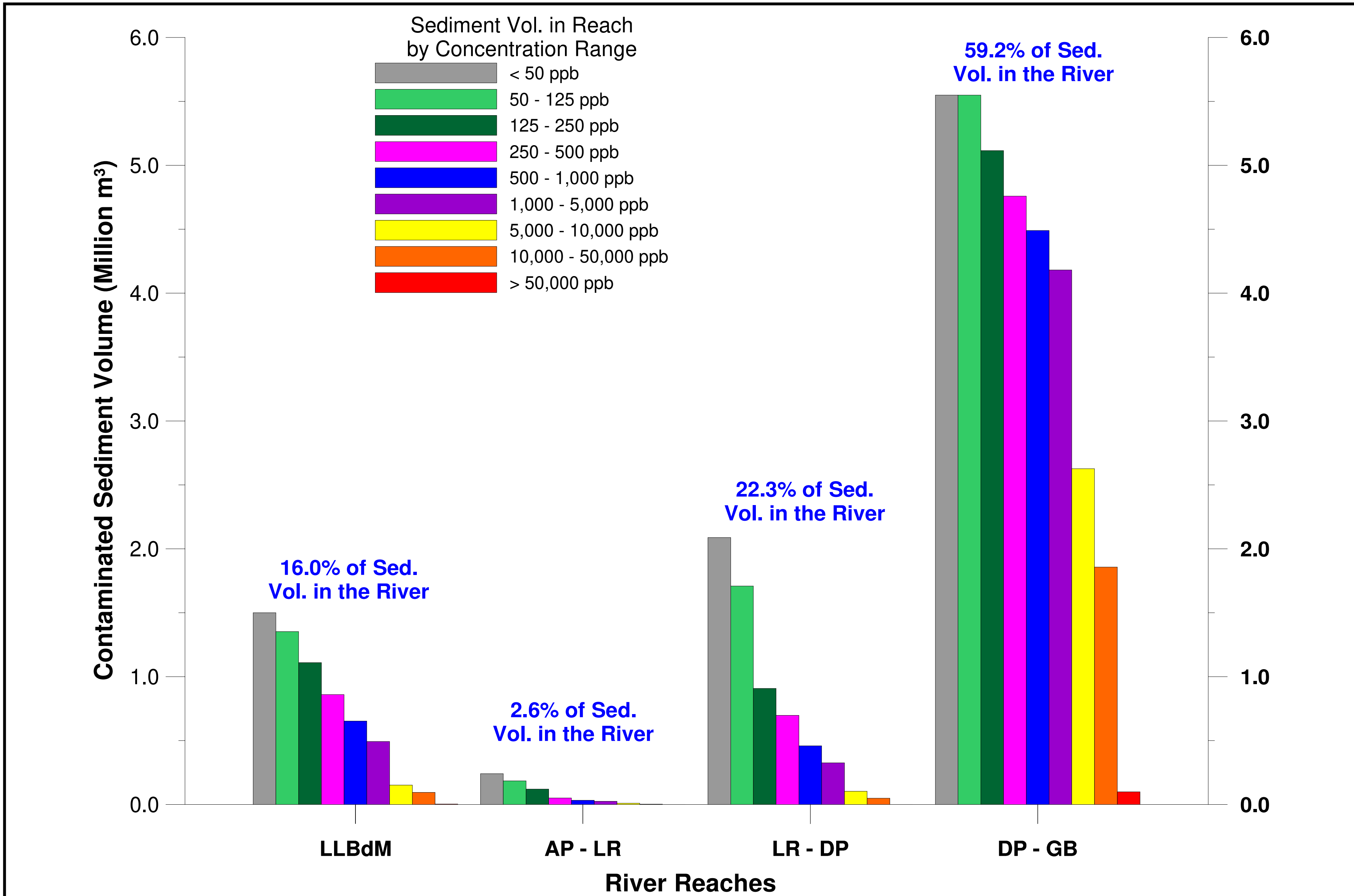
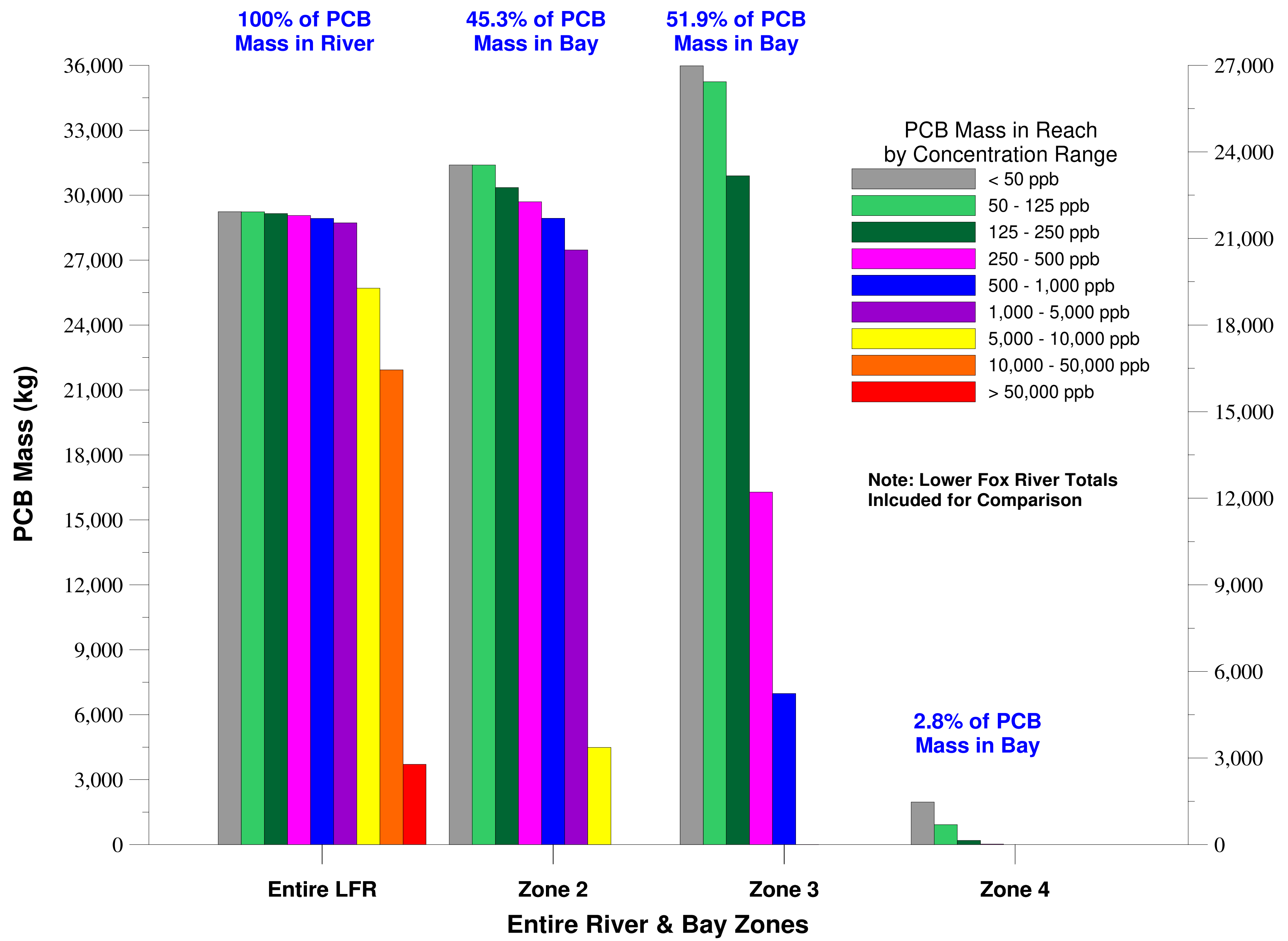
APPROVED:



ThermoRetec Smart Solutions Positive Outcomes	Natural Resource Technology	Remedial Investigation Report	Contaminated Sediment Volume by Concentration Ranges in the Lower Fox River	REF NO:
				CREATED BY:
				PRINT DATE:
			FIGURE: 5-5	APPROVED:



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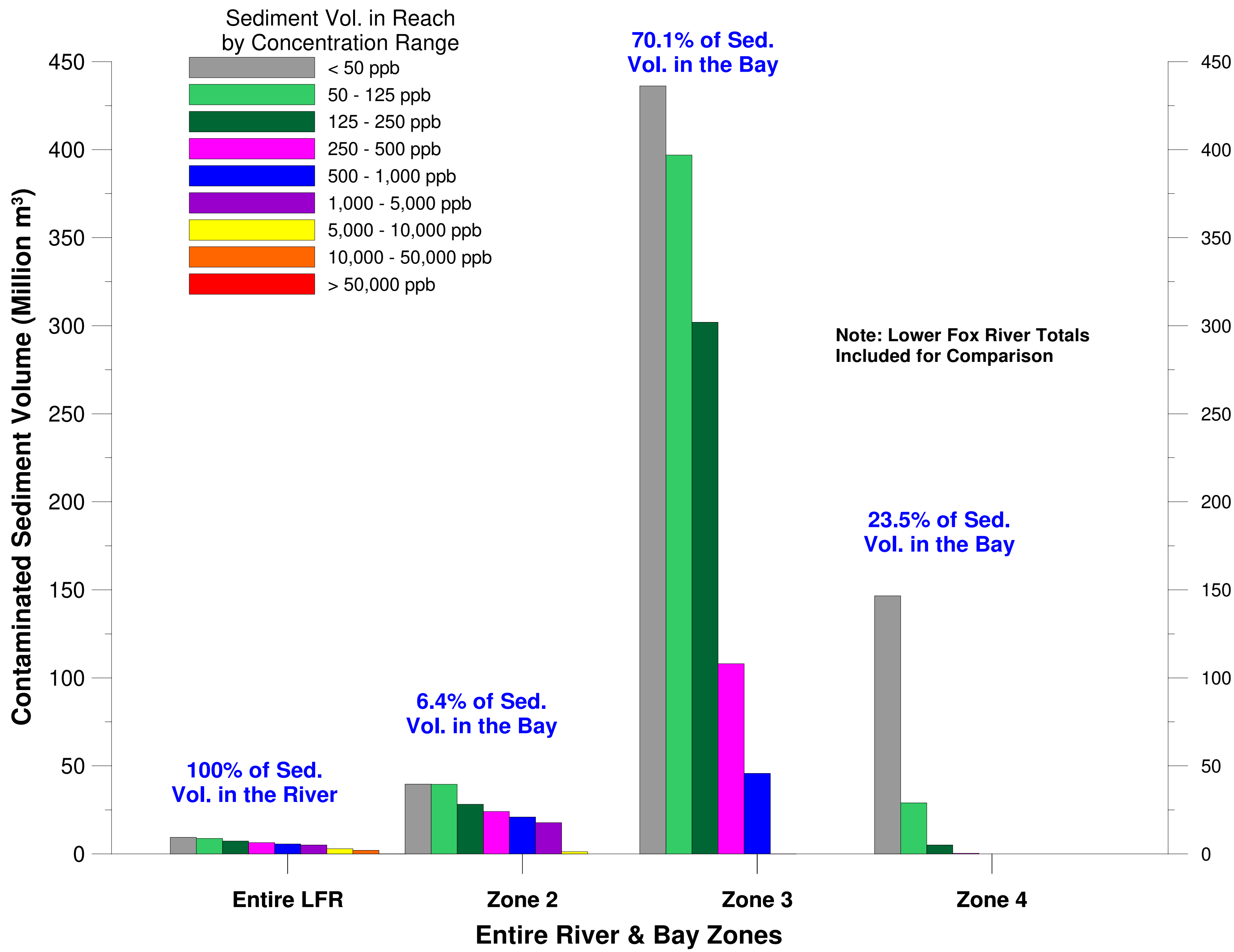
PCB Mass by Concentration Ranges in Green Bay Sediments

FIGURE: 5-6

REF NO:
CREATED BY:
PRINT DATE:
APPROVED:



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Contaminated Sediment Volume by Concentration Ranges in Green Bay

FIGURE: 5-7

REF NO:

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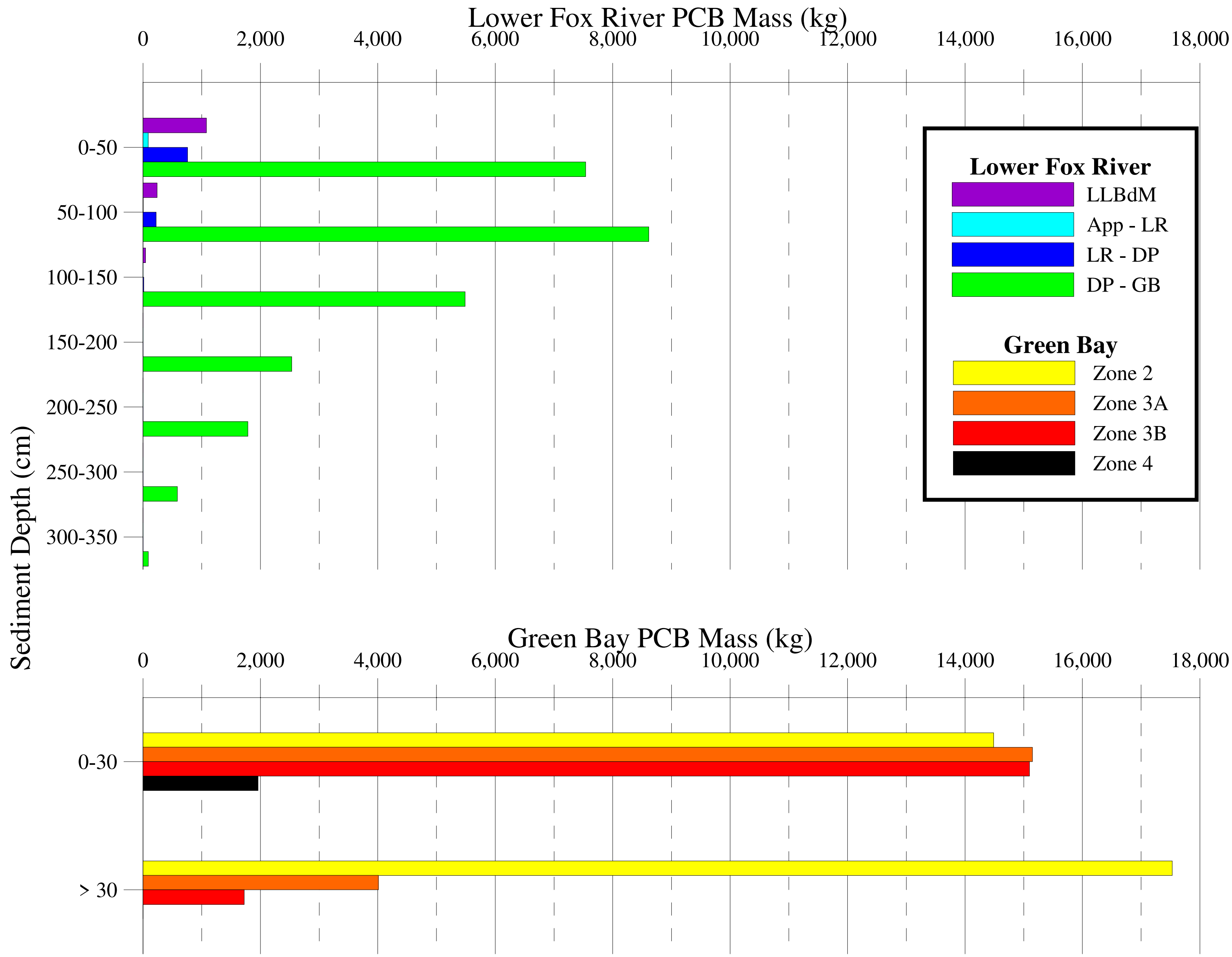
APPROVED:



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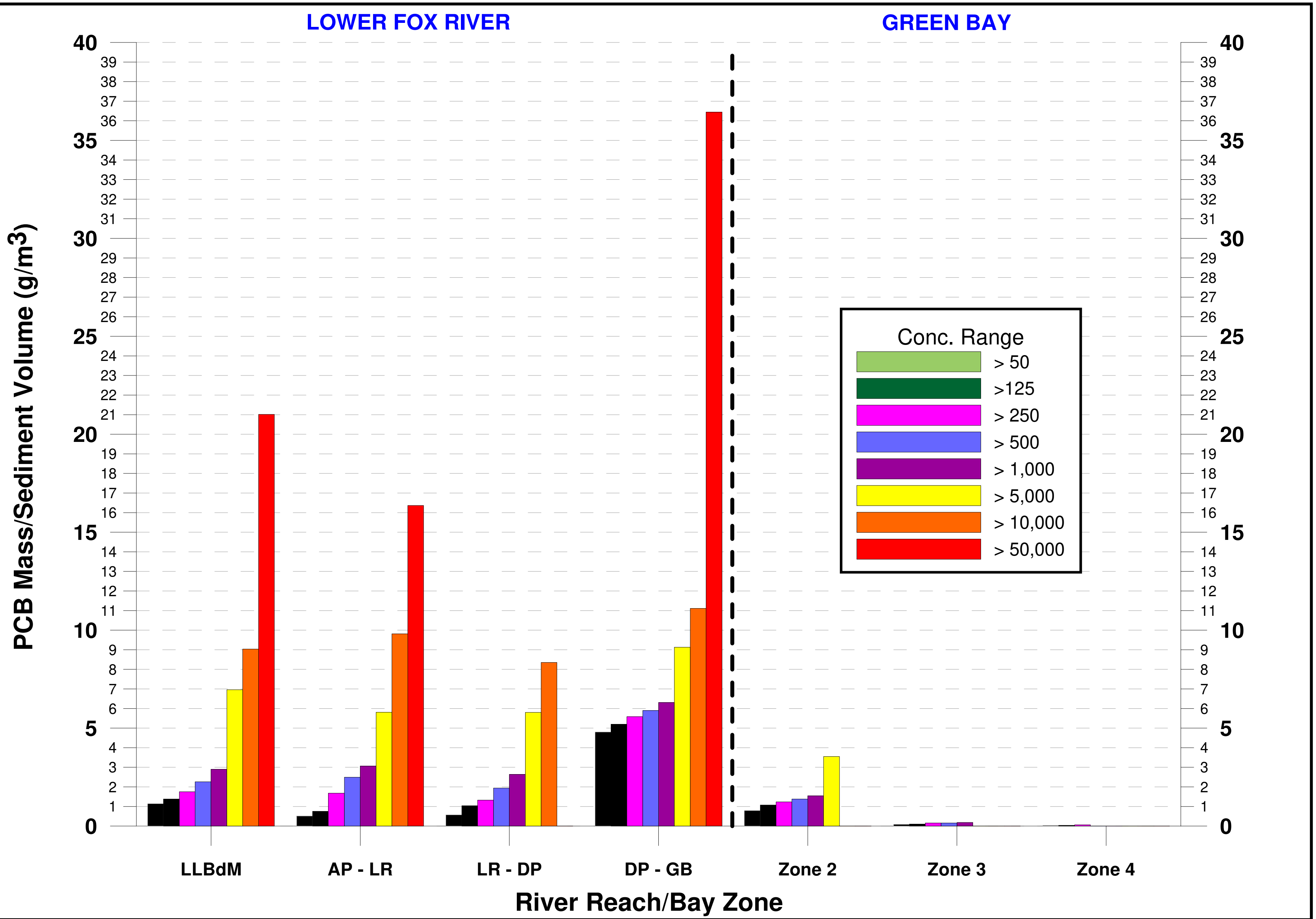
PCB Mass Distribution in Lower Fox River and Green Bay Sediments

FIGURE: 5-8

REF NO:
CREATED BY:
PRINT DATE:
APPROVED:



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Ratios of PCB Mass/Sediment Volume In Lower Fox River and Green Bay Sediments

FIGURE: 5-9

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PRINT DATE:
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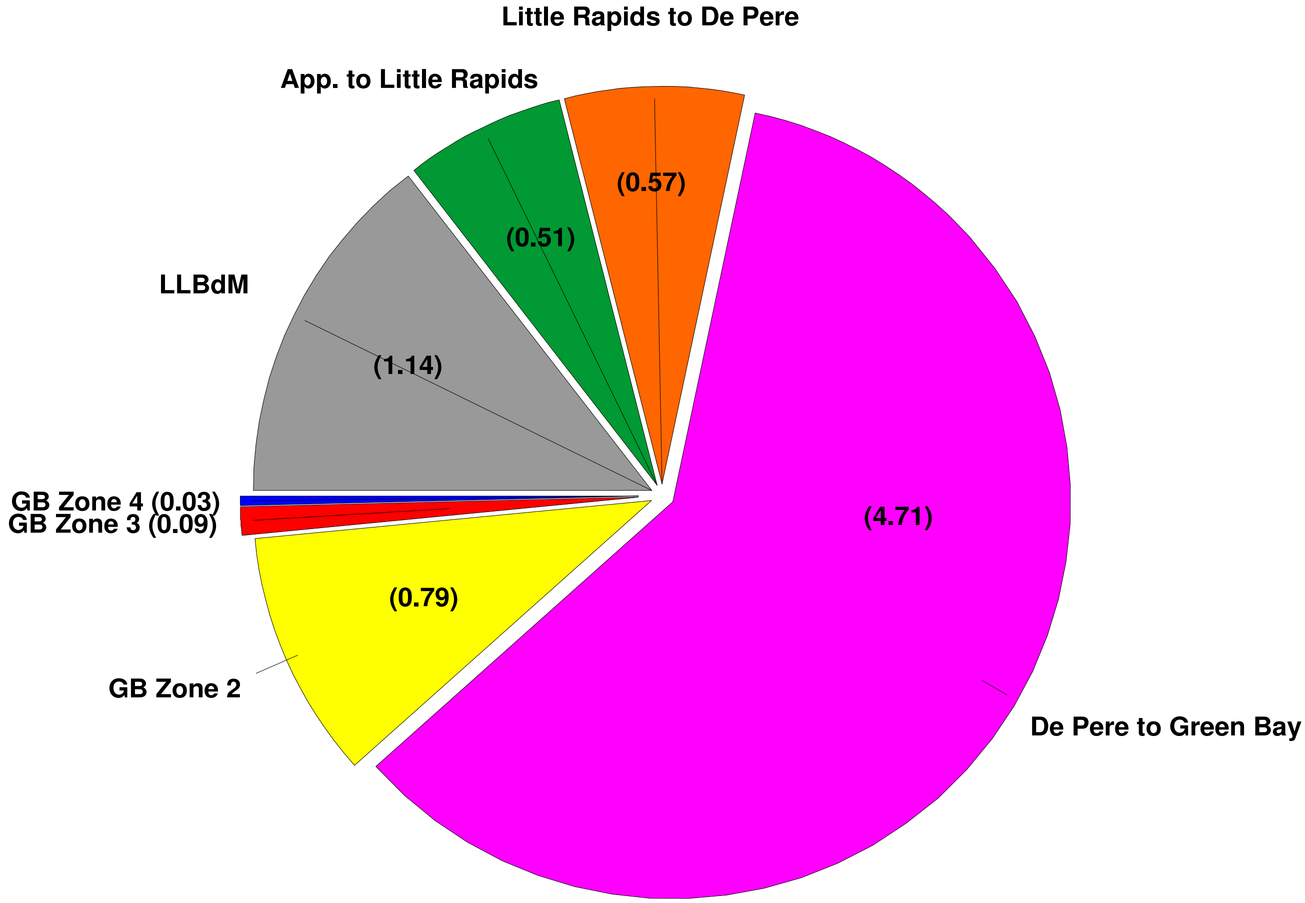
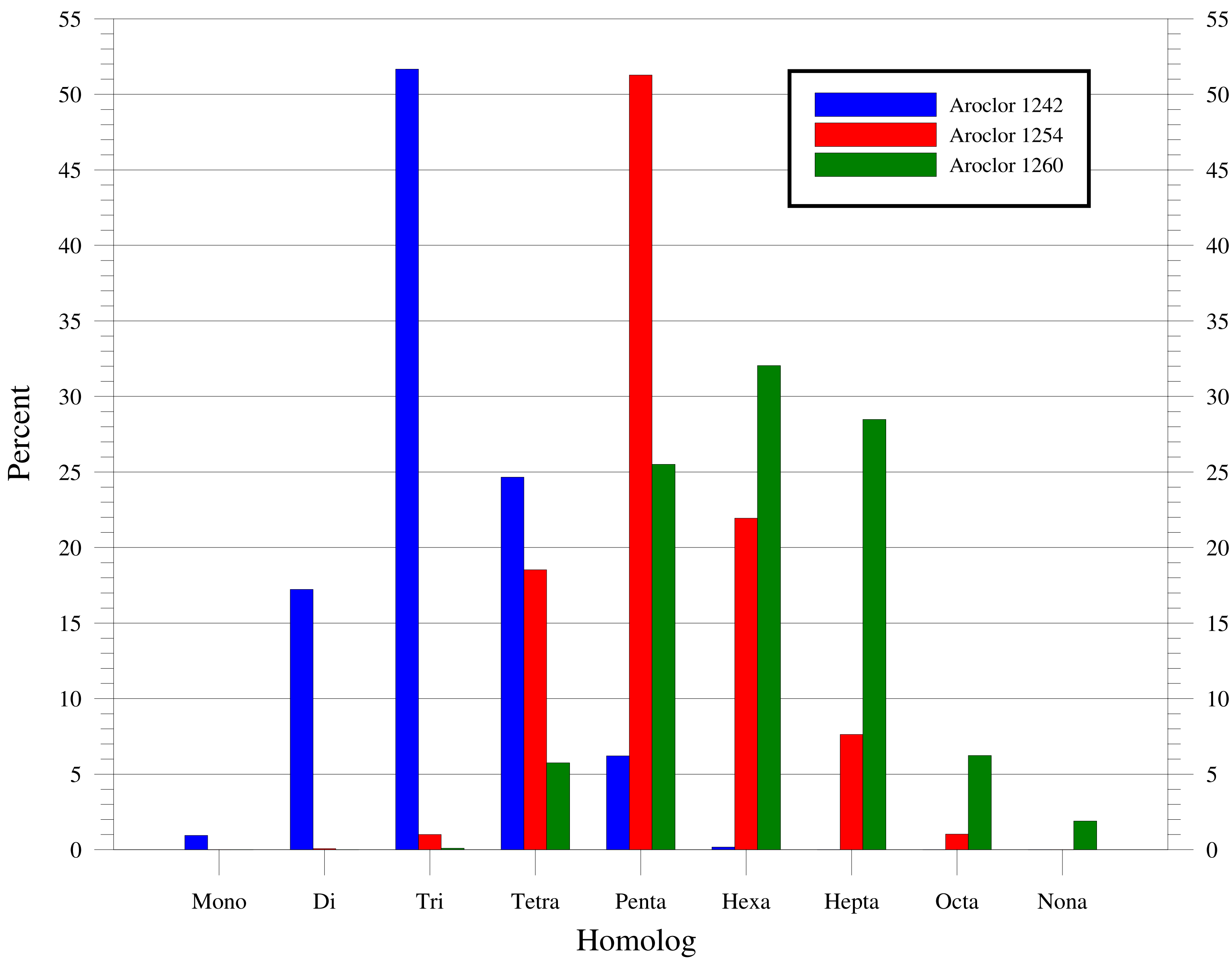


NOTES:

1) Only includes sediments with more than 50 µg/kg PCBs.

ThermoRetec Smart Solutions Positive Outcomes	Natural Resource Technology	Remedial Investigation Report	Distribution of PCB Mass/Sediment Volume Ratios in Sediments with More than 50 µg/kg PCBs	REF NO: CREATED BY: PRINT DATE: APPROVED:
			FIGURE: 5-10	



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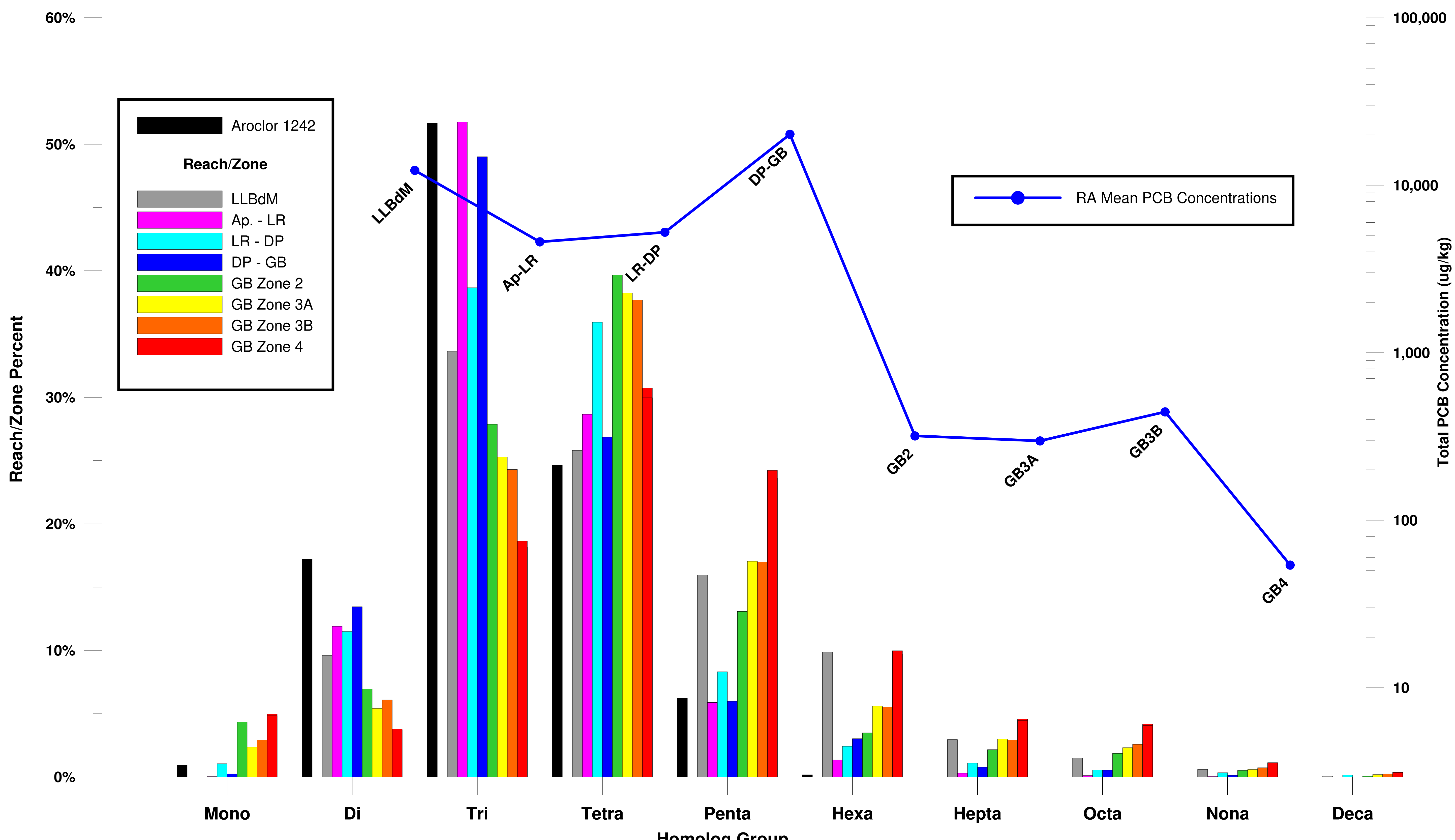
Aroclors 1242/1254/1260 PCB Homolog Plots

FIGURE: 5-11

REF NO:
CREATED BY:
PRINT DATE:
APPROVED:



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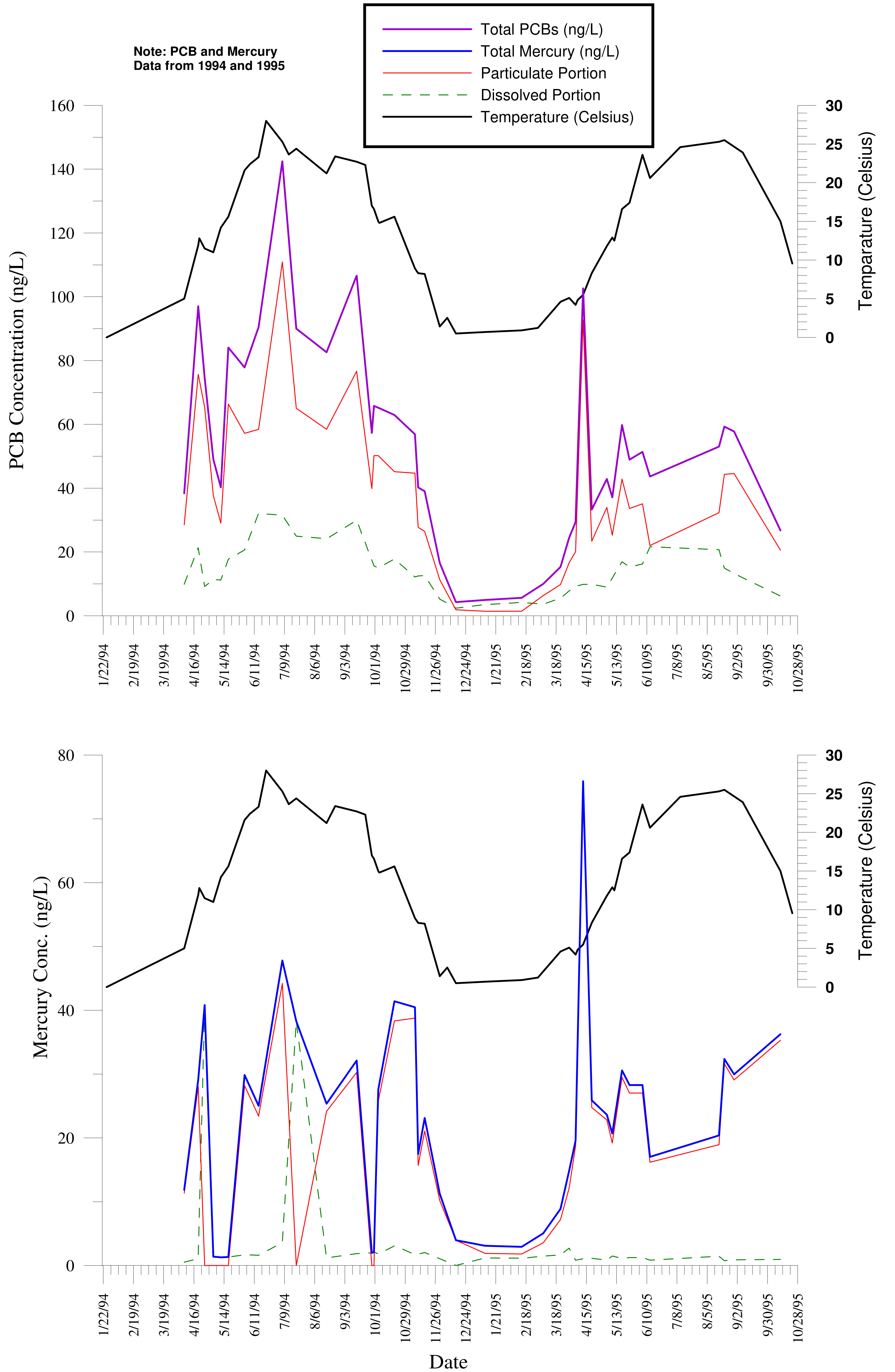
PCB Homolog Distribution in Lower Fox River and Green Bay Sediments

FIGURE: 5-12

REF NO:
CREATED BY:
PRINT DATE:
APPROVED:



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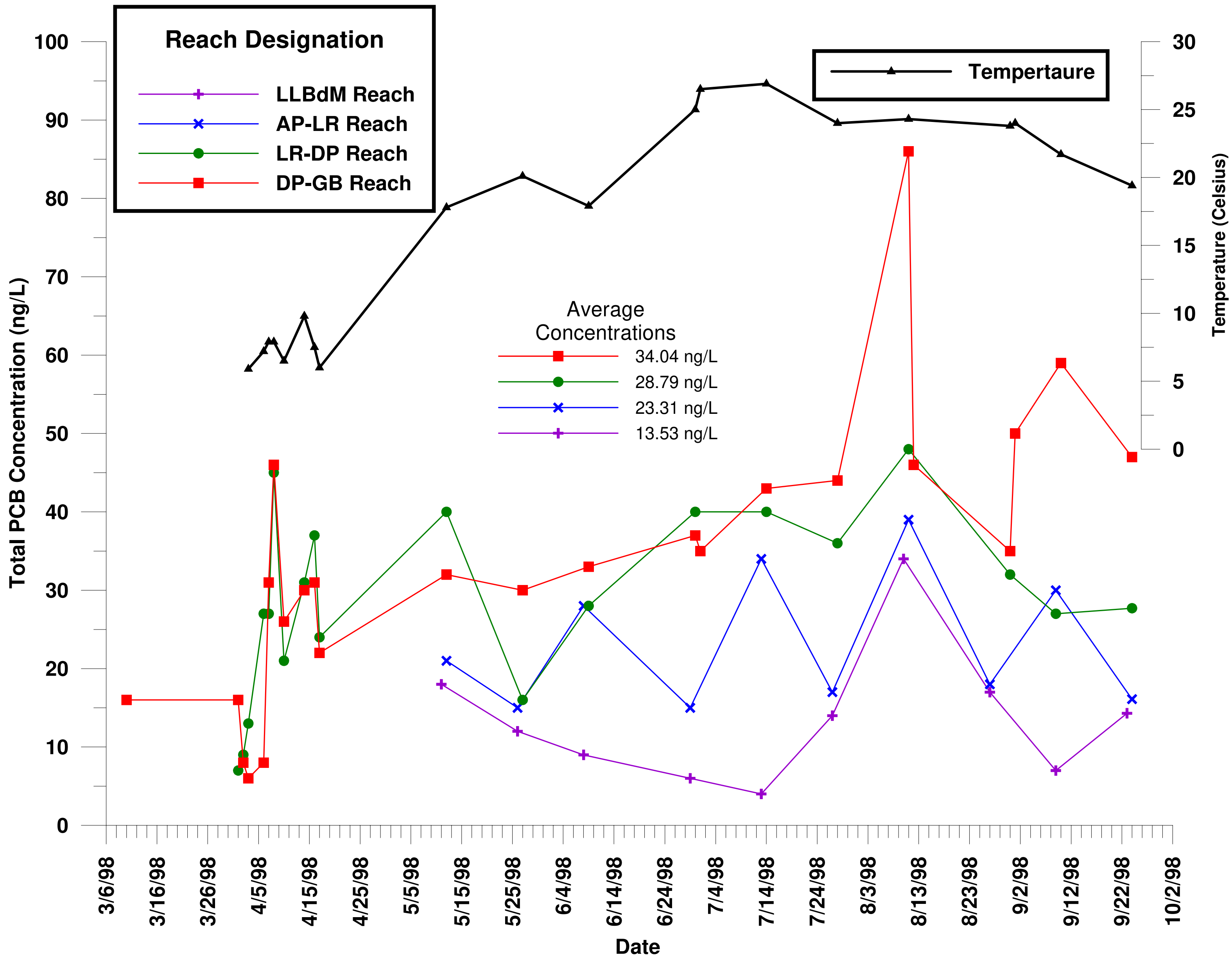
Remedial Investigation Report

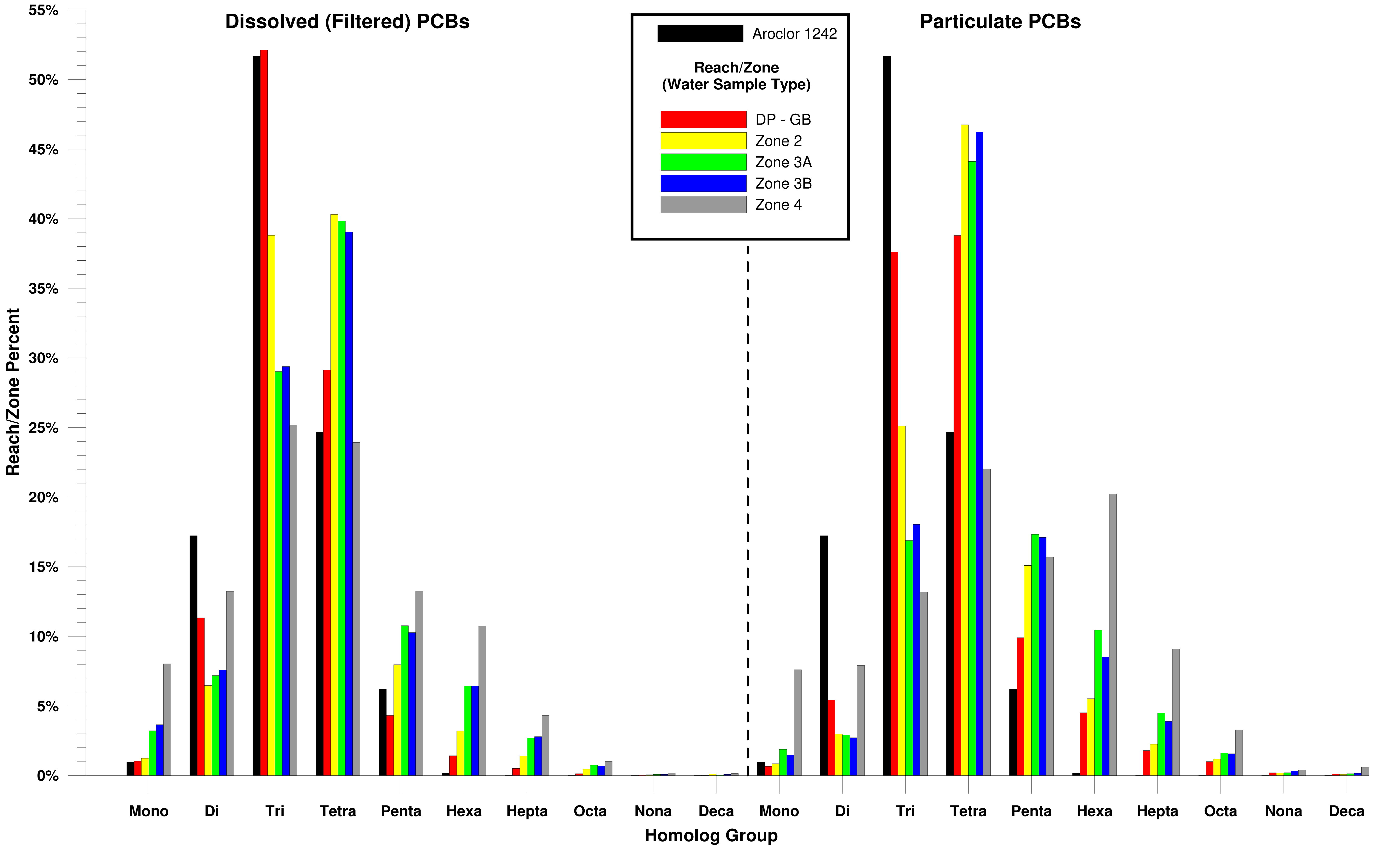
1994/95 Total PCB & Mercury Concentrations in Lower Fox River Water

FIGURE: 5-13

REF NO:
CREATED BY:
PRINT DATE:
APPROVED:



ThermoRetec Smart Solutions Positive Outcomes	Natural Resource Technology	Remedial Investigation Report	1998 Total PCB Concentration in Lower Fox River Water	REF NO:
				CREATED BY:
				PRINT DATE:
			FIGURE: 5-14	APPROVED:



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Remedial Investigation Report

PCB Homolog Distribution in Water:
De Pere Dam Through Green Bay

FIGURE: 5-15

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CREATED BY:
PRINT DATE:
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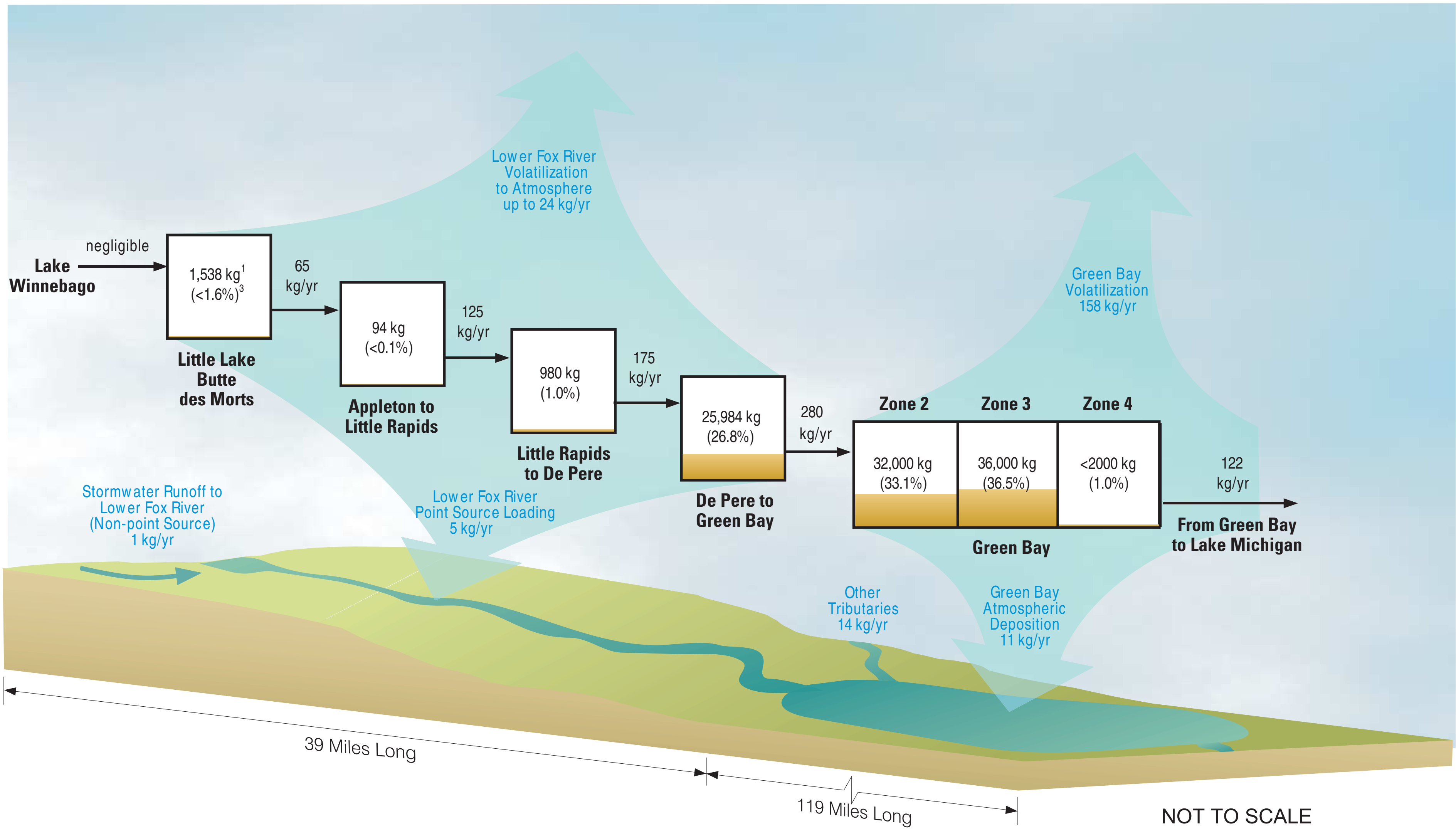
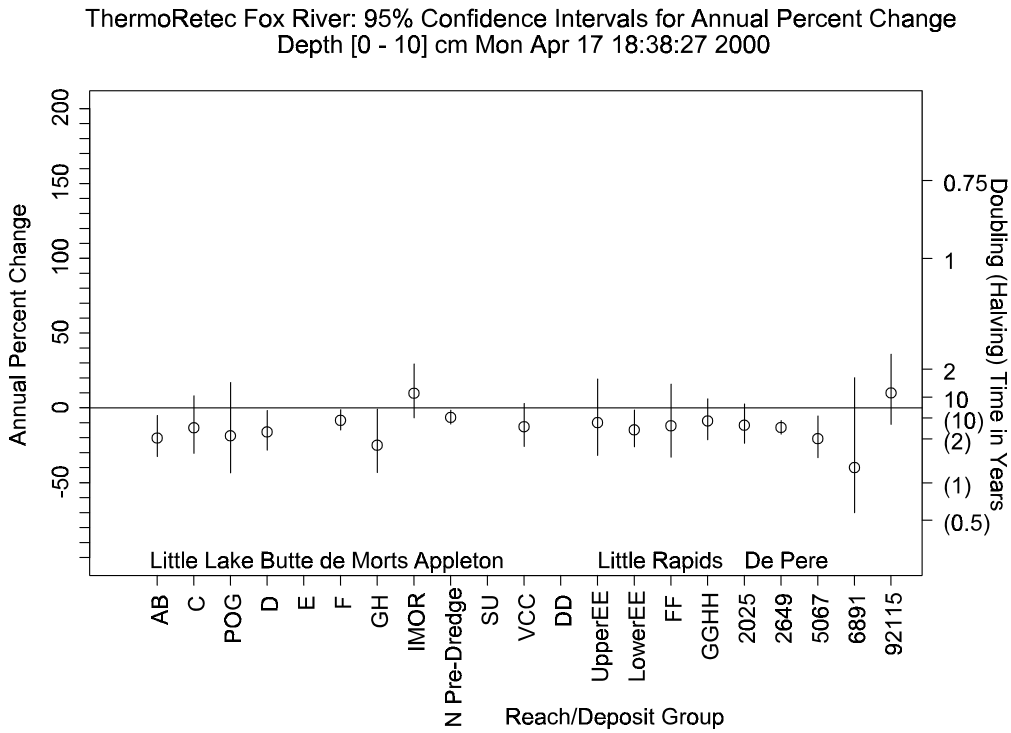
Figure 5-16. Lower Fox River and Green Bay System Estimated PCB Mass and Major PCB Flux Pathways



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.
4. Estimate of PCB loads from WDNR 1995 and www.epa.gov/med/images/gbmassbal.gif

Figure 5-17 Time Trends of PCBs in Sediments for Depths from 0 to 10 cm and from 10 to 30 cm



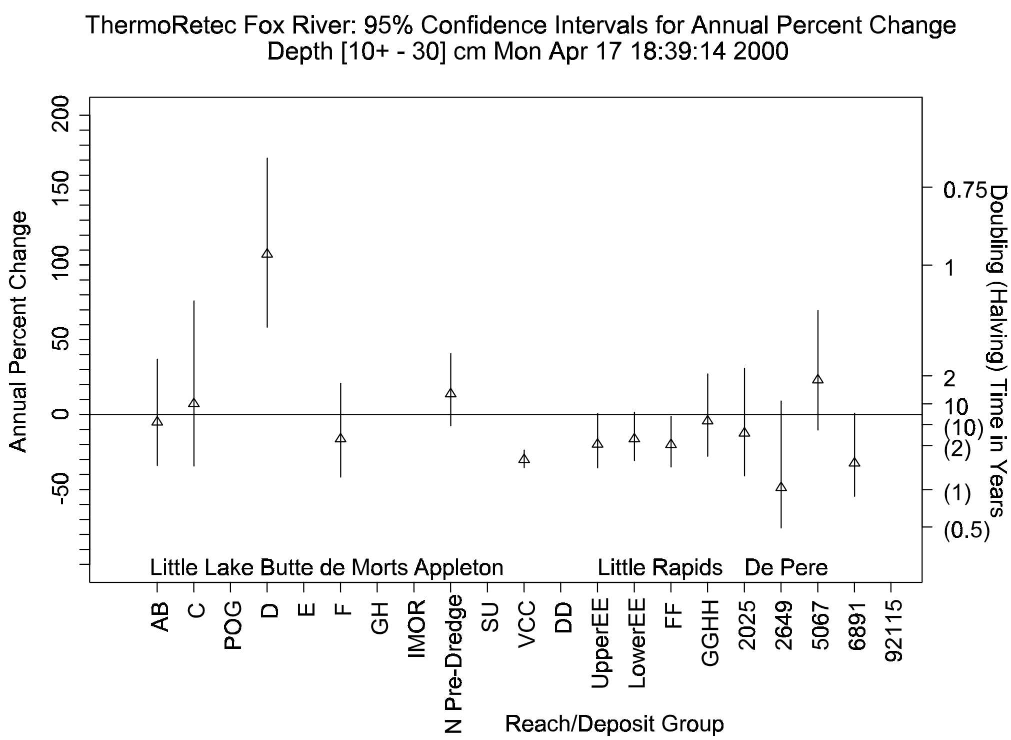
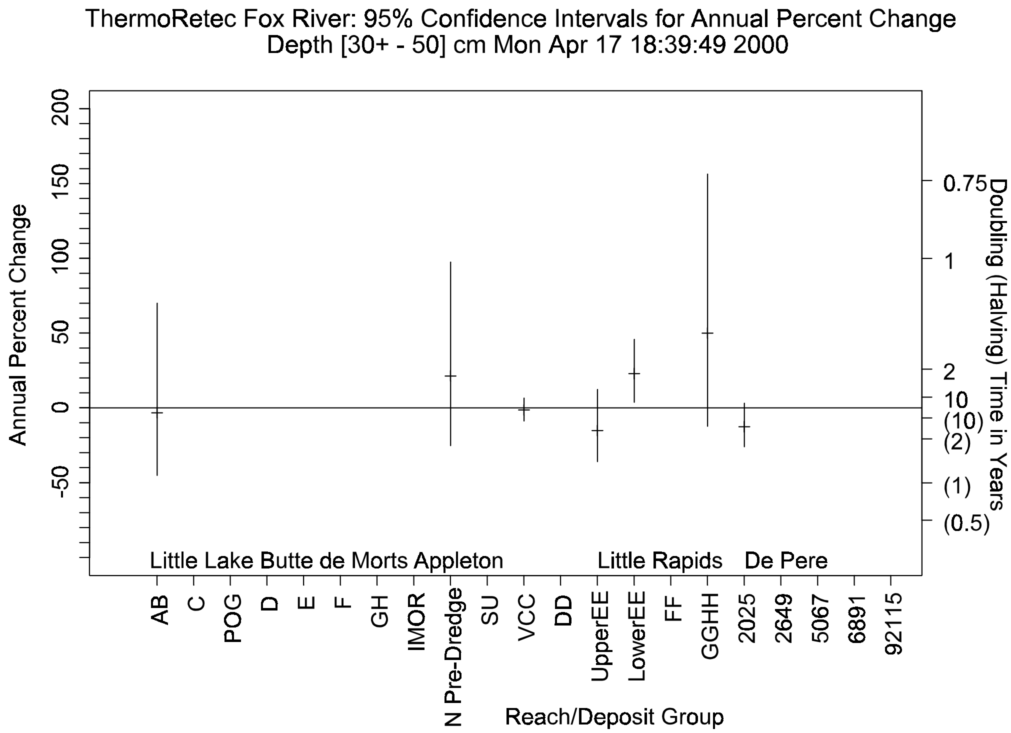


Figure 5-18 Time Trends of PCBs in Sediments for Depths from 30 to 50 cm and from 50 to 100 cm



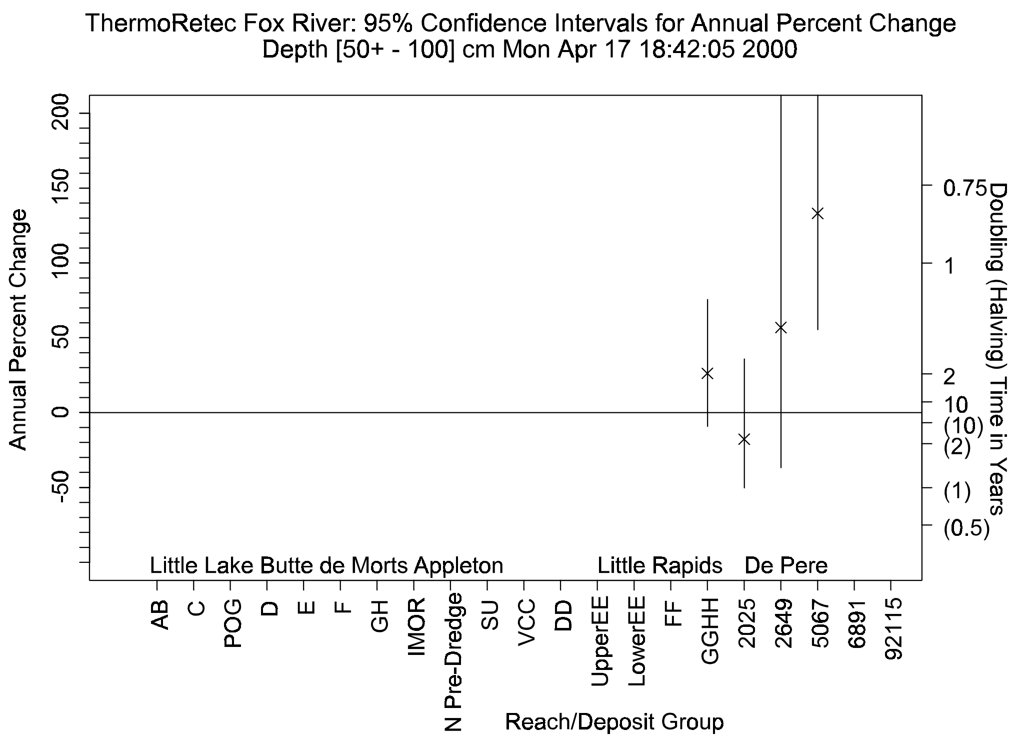


Figure 5-19 Time Trends of PCBs in Sediments for Depths over 100 cm

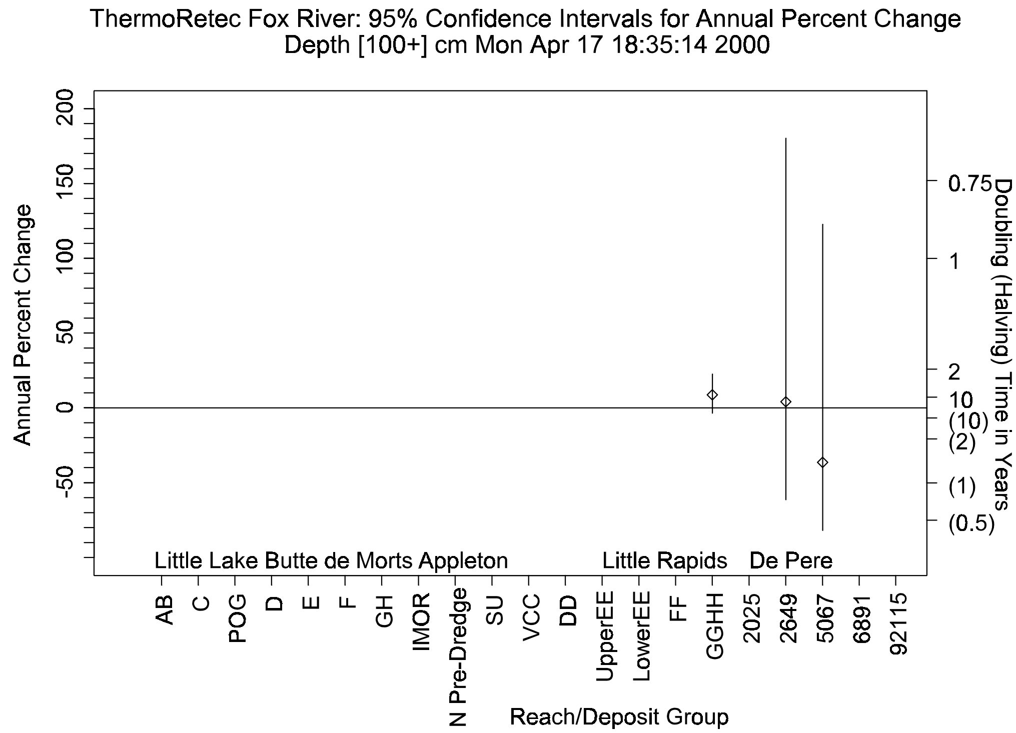


Table 5-1. Lower Fox River and Green Bay - Sediment Sampling Results: Summary of Detected Compounds

Location Reach/Zone	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI Mean[A]	RA Mean[B]	Logarithmic Mean[C]	Units
Lake Winnebago Background Results										
Lake Winnebago	Total PCBs	5	5	100.00%	5.5	36	22.00	22.00	17.56	µg/kg
Lake Winnebago	Ar1242	3	3	100.00%	10	16	13.33	13.33	13.08	µg/kg
Lake Winnebago	Ar1254	3	3	100.00%	16	20	18.33	18.33	18.25	µg/kg
Lake Winnebago	p,p'-DDE	3	2	66.67%	2.4	3.5	2.95	2.68	2.62	µg/kg
Lake Winnebago	alpha-BHC	3	1	33.33%	3.6	3.6	3.60	1.70	1.25	µg/kg
Lake Winnebago	Endosulfan sulfate	3	1	33.33%	3.2	3.2	3.20	2.38	2.31	µg/kg
Lake Winnebago	4-Methylphenol	3	1	33.33%	59	59	59.00	42.50	41.06	µg/kg
Lake Winnebago	bis(2-Ethylhexyl)phthalate	3	3	100.00%	100	350	196.67	196.67	169.85	µg/kg
Lake Winnebago	Benzo(a)pyrene	3	1	33.33%	120	120	120.00	62.83	52.02	µg/kg
Lake Winnebago	Benzo(b)fluoranthene	3	1	33.33%	91	91	91.00	53.17	47.44	µg/kg
Lake Winnebago	Benzo(g,h,i)perylene	3	1	33.33%	100	100	100.00	56.17	48.95	µg/kg
Lake Winnebago	Benzo(k)fluoranthene	3	3	100.00%	87	140	115.67	115.67	113.49	µg/kg
Lake Winnebago	Chrysene	3	3	100.00%	84	140	114.67	114.67	112.17	µg/kg
Lake Winnebago	Fluoranthene	3	3	100.00%	100	120	110.00	110.00	109.70	µg/kg
Lake Winnebago	Indeno(1,2,3-cd)pyrene	3	1	33.33%	87	87	87.00	51.83	46.73	µg/kg
Lake Winnebago	Pyrene	3	3	100.00%	89	110	103.00	103.00	102.50	µg/kg
Lake Winnebago	Arsenic	3	3	100.00%	4	6	5.33	5.33	5.24	mg/kg
Lake Winnebago	Chromium	3	3	100.00%	51	75	65.00	65.00	64.14	mg/kg
Lake Winnebago	Copper	3	3	100.00%	23	33	28.67	28.67	28.34	mg/kg
Lake Winnebago	Lead	3	3	100.00%	30	39	35.00	35.00	34.79	mg/kg
Lake Winnebago	Mercury	3	3	100.00%	0.11	0.17	0.14	0.14	0.14	mg/kg
Lake Winnebago	Nickel	3	3	100.00%	22	30	27.00	27.00	26.75	mg/kg
Lake Winnebago	Zinc	3	3	100.00%	70	100	86.67	86.67	85.73	mg/kg
LOWER FOX RIVER RESULTS										
PCB Results										
LLBdM	Total PCBs	661	539	81.54%	2	222722	15,042.95	12,272.77	1,067.72	µg/kg
APP to LR	Total PCBs	263	188	71.48%	0.34	77444	6,405.94	4,589.09	362.20	µg/kg
LR to DP	Total PCBs	652	542	83.13%	3	54000	6,291.75	5,236.31	626.98	µg/kg
DP to GB	Total PCBs	1023	947	92.57%	0.4	710000	21,721.79	20,139.22	2,612.80	µg/kg
LR to DP	Ar1016	274	1	0.36%	1700	1700	1,700.00	139.53	17.35	µg/kg
LR to DP	Ar1221	274	1	0.36%	1700	1700	1,700.00	116.30	30.07	µg/kg
LR to DP	Ar1232	274	1	0.36%	1700	1700	1,700.00	138.63	17.11	µg/kg

Table 5-1. Lower Fox River and Green Bay - Sediment Sampling Results: Summary of Detected Compounds (Continued)

Location Reach/Zone	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI Mean[A]	RA Mean[B]	Logarithmic Mean[C]	Units
LLBdM	Ar1242	483	416	86.13%	6.5	210000	13,255.69	11,436.46	1,196.91	µg/kg
APP to LR	Ar1242	171	145	84.80%	4.4	51000	4,633.98	3,937.22	495.12	µg/kg
LR to DP	Ar1242	498	440	88.35%	4.8	54000	5,836.52	5,159.64	624.92	µg/kg
DP to GB	Ar1242	1012	938	92.69%	26	710000	22,254.79	20,629.74	2,695.23	µg/kg
LLBdM	Ar1242/1254	2	2	100.00%	660	2500	1,580.00	1,580.00	1,284.52	µg/kg
APP to LR	Ar1242/1254	2	2	100.00%	900	3200	2,050.00	2,050.00	1,697.06	µg/kg
LR to DP	Ar1242/1254	1	1	100.00%	1600	1600	1,600.00	1,600.00	0.00	µg/kg
LR to DP	Ar1242/1254/1260	1	1	100.00%	520	520	520.00	520.00	0.00	µg/kg
DP to GB	Ar1242/1254/1260	1	1	100.00%	350	350	350.00	350.00	0.00	µg/kg
LLBdM	Ar1242/1268	1	1	100.00%	5900	5900	5,900.00	5,900.00	0.00	µg/kg
APP to LR	Ar1242/1268	3	3	100.00%	140	280	220.00	220.00	211.11	µg/kg
LR to DP	Ar1242/1268	6	6	100.00%	200	600	411.67	411.67	380.68	µg/kg
LLBdM	Ar1248	323	2	0.62%	1500	5100	3,300.00	612.55	78.46	µg/kg
LR to DP	Ar1248	274	1	0.36%	1700	1700	1,700.00	136.54	17.22	µg/kg
LLBdM	Ar1248/1254	1	1	100.00%	410	410	410.00	410.00	0.00	µg/kg
LLBdM	Ar1254	328	81	24.70%	4.6	60000	5,139.56	1,773.56	203.82	µg/kg
APP to LR	Ar1254	98	15	15.31%	4.6	340	87.11	377.71	82.78	µg/kg
LR to DP	Ar1254	275	61	22.18%	6	6600	557.26	233.56	39.97	µg/kg
DP to GB	Ar1254	914	41	4.49%	13	3300	465.34	455.56	74.07	µg/kg
LLBdM	Ar1254/1260	1	1	100.00%	80	80	80.00	80.00	0.00	µg/kg
LLBdM	Ar1260	319	13	4.08%	87	1400	615.92	609.21	112.31	µg/kg
APP to LR	Ar1260	97	2	2.06%	120	2100	1,110.00	391.00	68.64	µg/kg
LR to DP	Ar1260	274	49	17.88%	46	1600	552.22	139.33	31.12	µg/kg
DP to GB	Ar1260	914	81	8.86%	8.6	17000	696.64	488.52	78.55	µg/kg
LLBdM	Ar1262	91	1	1.10%	2200	2200	2,200.00	105.85	21.73	µg/kg
LLBdM	Ar1268	94	7	7.45%	32	530	168.00	38.26	14.72	µg/kg
APP to LR	Ar1268	4	4	100.00%	70	110	92.50	92.50	90.73	µg/kg
LR to DP	Ar1268	146	57	39.04%	9.2	270	75.67	40.28	19.23	µg/kg
DP to GB	Ar1268	48	6	12.50%	50	1100	236.83	118.72	43.14	µg/kg
LLBdM	PCB Congener 105	21	18	85.71%	1.2	48	6.72	6.27	3.20	µg/kg
APP to LR	PCB Congener 105	14	10	71.43%	0.44	180	34.60	27.00	4.07	µg/kg
LR to DP	PCB Congener 105	27	24	88.89%	0.94	54.4	15.27	13.78	6.22	µg/kg
DP to GB	PCB Congener 105	26	25	96.15%	0.79	23	5.85	5.65	3.12	µg/kg

Table 5-1. Lower Fox River and Green Bay - Sediment Sampling Results: Summary of Detected Compounds (Continued)

Location Reach/Zone	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI Mean[A]	RA Mean[B]	Logarithmic Mean[C]	Units
LLBdM	PCB Congener 118	102	100	98.04%	0.48	3700	221.53	217.21	44.01	µg/kg
APP to LR	PCB Congener 118	39	37	94.87%	0.56	590	61.31	58.21	13.54	µg/kg
LR to DP	PCB Congener 118	86	82	95.35%	0.49	270	68.30	65.20	27.69	µg/kg
DP to GB	PCB Congener 118	26	26	100.00%	1.4	46	12.71	12.71	6.86	µg/kg
LLBdM	PCB Congener 126	21	8	38.10%	0.017	0.32	0.10	0.60	0.17	µg/kg
APP to LR	PCB Congener 126	10	3	30.00%	0.05	2.5	0.87	0.50	0.17	µg/kg
LR to DP	PCB Congener 126	27	7	25.93%	0.031	0.79	0.30	0.64	0.34	µg/kg
DP to GB	PCB Congener 126	26	5	19.23%	0.027	0.27	0.08	0.24	0.07	µg/kg
LLBdM	PCB Congener 126/129/178	4	1	25.00%	4.4	4.4	4.40	3.74	2.74	µg/kg
LR to DP	PCB Congener 126/129/178	12	2	16.67%	1.4	5.2	3.30	1.76	1.45	µg/kg
LLBdM	PCB Congener 77	21	14	66.67%	1.5	52	14.01	9.79	3.98	µg/kg
APP to LR	PCB Congener 77	10	6	60.00%	0.77	160	35.98	21.81	3.06	µg/kg
LR to DP	PCB Congener 77	27	19	70.37%	2.4	89.1	25.88	18.46	5.84	µg/kg
DP to GB	PCB Congener 77	26	24	92.31%	1.9	85	13.97	12.95	5.59	µg/kg
LLBdM	PCB Congener 77/110	91	91	100.00%	0.37	5900	491.59	491.59	84.34	µg/kg
APP to LR	PCB Congener 77/110	30	30	100.00%	0.73	1400	126.36	126.36	33.96	µg/kg
LR to DP	PCB Congener 77/110	73	72	98.63%	0.4	620	135.46	133.78	46.15	µg/kg
DP to GB	PCB Congener 77/110	8	8	100.00%	2.8	89	40.98	40.98	30.86	µg/kg
Dioxin/Furan Results										
LLBdM	2,3,7,8-TCDD	6	5	83.33%	0.00175	0.00544	0.00	0.00	0.00	µg/kg
LR to DP	2,3,7,8-TCDD	3	3	100.00%	0.00023	0.00682	0.00	0.00	0.00	µg/kg
DP to GB	2,3,7,8-TCDD	12	1	8.33%	0.01	0.01	0.01	0.01	0.01	µg/kg
LLBdM	2,3,7,8-TCDF	6	6	100.00%	0.03222	0.07129	0.06	0.06	0.06	µg/kg
LR to DP	2,3,7,8-TCDF	3	3	100.00%	0.03178	0.11709	0.06	0.06	0.06	µg/kg
DP to GB	2,3,7,8-TCDF	12	10	83.33%	0.02	0.17	0.06	0.05	0.03	µg/kg
Pesticide Results										
LLBdM	p,p'-DDT	24	4	16.67%	5.5	50	20.63	42.96	10.01	µg/kg
APP to LR	p,p'-DDT	10	1	10.00%	3.4	3.4	3.40	9.19	4.74	µg/kg
LR to DP	p,p'-DDT	17	3	17.65%	5.1	20	13.70	14.20	9.38	µg/kg
DP to GB	p,p'-DDT	35	2	5.71%	19	28	23.50	7.61	6.03	µg/kg
LLBdM	p,p'-DDD	27	4	14.81%	4.7	19	9.95	15.29	4.92	µg/kg
APP to LR	p,p'-DDD	10	2	20.00%	0.97	1.7	1.34	8.91	4.13	µg/kg
LR to DP	p,p'-DDD	23	5	21.74%	1.5	2.8	1.92	8.53	3.40	µg/kg
DP to GB	p,p'-DDD	24	3	12.50%	1.2	4.5	2.30	7.16	5.25	µg/kg
LR to DP	p,p'-DDE	22	4	18.18%	6.6	22	14.15	10.93	4.78	µg/kg
DP to GB	p,p'-DDE	34	1	2.94%	1.9	1.9	1.90	6.29	3.64	µg/kg
LLBdM	Aldrin	23	1	4.35%	60	60	60.00	10.53	3.65	ug/kg
LLBdM	Dieldrin	15	1	6.67%	5.9	5.9	5.90	32.06	12.60	ug/kg
LLBdM	Endrin aldehyde	24	1	4.17%	67	67	67.00	18.42	8.20	µg/kg

Table 5-1. Lower Fox River and Green Bay - Sediment Sampling Results: Summary of Detected Compounds (Continued)

Location Reach/Zone	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI Mean[A]	RA Mean[B]	Logarithmic Mean[C]	Units
LR to DP	Endrin aldehyde	23	1	4.35%	4.9	4.9	4.90	10.43	6.38	µg/kg
DP to GB	Endrin aldehyde	23	4	17.39%	5.1	12	7.70	8.88	8.07	µg/kg
LLBdM	Endrin ketone	23	3	13.04%	4.3	17	12.43	17.22	7.75	µg/kg
LR to DP	Endrin ketone	22	9	40.91%	3.2	23	7.98	11.75	7.43	µg/kg
DP to GB	Endrin ketone	21	3	14.29%	1.4	3.4	2.40	7.85	6.51	µg/kg
LR to DP	gamma-BHC (Lindane)	23	1	4.35%	9.8	9.8	9.80	5.29	2.41	µg/kg
DP to GB	gamma-BHC (Lindane)	36	7	19.44%	1	17	6.60	6.35	3.81	µg/kg
LLBdM	Heptachlor	23	4	17.39%	4.4	8.4	5.83	9.71	4.82	µg/kg
LR to DP	Heptachlor	22	1	4.55%	3.1	3.1	3.10	9.76	5.11	µg/kg
Semi-Volatile Organic Compound (SVOC) Results										
LLBdM	1,2-Dichlorobenzene	22	2	9.09%	120	130	125.00	1,705.23	417.95	µg/kg
LR to DP	1,2-Dichlorobenzene	22	8	36.36%	63	370	146.50	1,027.57	287.46	µg/kg
DP to GB	1,2-Dichlorobenzene	22	3	13.64%	79	150	119.67	2,329.73	1,022.55	µg/kg
LLBdM	1,4-Dichlorobenzene	22	4	18.18%	62	282	144.88	1,712.48	429.20	µg/kg
LR to DP	1,4-Dichlorobenzene	22	1	4.55%	60	60	60.00	988.64	187.17	µg/kg
DP to GB	1,4-Dichlorobenzene	22	3	13.64%	36	69	53.00	2,320.64	915.16	µg/kg
LLBdM	4-Methylphenol	26	11	42.31%	75	1530	567.23	1,664.60	645.02	µg/kg
APP to LR	4-Methylphenol	9	6	66.67%	110	1500	510.00	817.78	481.70	µg/kg
LR to DP	4-Methylphenol	22	11	50.00%	210	880	551.27	1,245.82	693.20	µg/kg
DP to GB	4-Methylphenol	20	3	15.00%	29	540	236.33	2,577.63	1,539.62	µg/kg
LLBdM	bis(2-Ethylhexyl)phthalate	26	13	50.00%	87	25000	2,973.69	2,662.23	715.63	µg/kg
APP to LR	bis(2-Ethylhexyl)phthalate	9	9	100.00%	100	1300	531.11	531.11	394.57	µg/kg
LR to DP	bis(2-Ethylhexyl)phthalate	22	12	54.55%	120	803	364.42	1,092.55	404.48	µg/kg
DP to GB	bis(2-Ethylhexyl)phthalate	23	8	34.78%	63	1400	477.88	2,229.26	1,430.39	µg/kg
LLBdM	Carbazole	22	4	18.18%	30	2700	749.25	1,737.82	590.37	µg/kg
APP to LR	Carbazole	9	3	33.33%	64	180	109.33	634.11	269.14	µg/kg
DP to GB	Carbazole	20	2	10.00%	50	1300	675.00	2,485.03	1,205.33	µg/kg
LLBdM	Pentachlorophenol	25	7	28.00%	350	860	612.71	3,742.32	801.77	µg/kg
APP to LR	Pentachlorophenol	9	2	22.22%	280	290	285.00	1,317.78	434.94	µg/kg
LR to DP	Pentachlorophenol	22	4	18.18%	300	1100	725.00	2,502.59	584.46	µg/kg
DP to GB	Pentachlorophenol	24	5	20.83%	20	710	398.00	5,396.42	2,262.03	µg/kg
LLBdM	Phenol	22	1	4.55%	71	71	71.00	1,694.64	367.98	µg/kg
DP to GB	Phenol	22	2	9.09%	46	94	70.00	2,321.61	943.34	µg/kg
Polynuclear Aromatic Hydrocarbons (PAHs)										
LLBdM	Acenaphthene	28	5	17.86%	9.25	580	134.35	1,303.33	234.98	µg/kg
APP to LR	Acenaphthene	10	3	30.00%	66	130	105.33	572.45	217.09	µg/kg
LR to DP	Acenaphthene	23	1	4.35%	9.25	9.25	9.25	948.23	165.96	µg/kg
DP to GB	Acenaphthene	26	7	26.92%	9.25	210	45.71	1,970.02	471.78	µg/kg
LLBdM	Acenaphthylene	28	6	21.43%	9.25	71	29.29	1,385.81	261.37	µg/kg

Table 5-1. Lower Fox River and Green Bay - Sediment Sampling Results: Summary of Detected Compounds (Continued)

Location Reach/Zone	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI Mean[A]	RA Mean[B]	Logarithmic Mean[C]	Units
APP to LR	Acenaphthylene	10	4	40.00%	110	170	127.50	541.85	201.71	µg/kg
LR to DP	Acenaphthylene	23	3	13.04%	9.25	77	53.75	952.23	179.93	µg/kg
DP to GB	Acenaphthylene	26	7	26.92%	9.25	100	33.29	1,966.67	467.08	µg/kg
LLBdM	Anthracene	28	8	28.57%	30	1400	245.95	1,347.41	345.21	µg/kg
APP to LR	Anthracene	10	7	70.00%	58	360	198.29	568.80	288.92	µg/kg
LR to DP	Anthracene	23	6	26.09%	64	210	135.67	975.70	252.56	µg/kg
DP to GB	Anthracene	26	8	30.77%	3.06	640	134.00	1,998.34	651.91	µg/kg
LLBdM	Benzo(a)anthracene	29	13	44.83%	113	3300	645.77	1,384.31	481.59	µg/kg
APP to LR	Benzo(a)anthracene	10	10	100.00%	380	1300	737.00	737.00	670.42	µg/kg
LR to DP	Benzo(a)anthracene	23	14	60.87%	170	1200	417.86	963.04	407.84	µg/kg
DP to GB	Benzo(a)anthracene	27	14	51.85%	135	870	382.14	1,725.93	964.38	µg/kg
LLBdM	Benzo(a)pyrene	29	15	51.72%	77	2900	827.80	1,482.31	534.96	µg/kg
APP to LR	Benzo(a)pyrene	10	8	80.00%	410	1200	823.75	1,039.00	854.12	µg/kg
LR to DP	Benzo(a)pyrene	23	13	56.52%	74	1400	540.38	1,223.61	598.93	µg/kg
DP to GB	Benzo(a)pyrene	27	11	40.74%	134	1700	504.09	2,086.85	1,314.61	µg/kg
LLBdM	Benzo(b)fluoranthene	29	18	62.07%	156	4400	1,389.00	1,470.83	504.58	µg/kg
APP to LR	Benzo(b)fluoranthene	10	7	70.00%	350	900	642.86	885.00	707.97	µg/kg
LR to DP	Benzo(b)fluoranthene	23	16	69.57%	101	3600	995.69	1,095.96	504.31	µg/kg
DP to GB	Benzo(b)fluoranthene	27	24	88.89%	83.5	3300	1,589.31	1,838.65	1,146.81	µg/kg
LLBdM	Benzo(g,h,i)perylene	29	17	58.62%	104	3700	1,311.47	1,345.28	414.30	µg/kg
APP to LR	Benzo(g,h,i)perylene	10	9	90.00%	250	660	446.67	722.00	514.69	µg/kg
LR to DP	Benzo(g,h,i)perylene	23	17	73.91%	200	3000	832.35	953.65	431.98	µg/kg
DP to GB	Benzo(g,h,i)perylene	27	21	77.78%	80	8330	1,629.24	2,039.41	1,158.73	µg/kg
LLBdM	Benzo(k)fluoranthene	26	9	34.62%	76.9	2600	908.88	1,492.46	379.01	µg/kg
APP to LR	Benzo(k)fluoranthene	10	8	80.00%	420	1600	818.75	1,025.00	823.76	µg/kg
LR to DP	Benzo(k)fluoranthene	23	13	56.52%	200	1200	481.54	1,084.96	452.66	µg/kg
DP to GB	Benzo(k)fluoranthene	27	11	40.74%	50.7	800	361.25	2,028.66	1,111.06	µg/kg
LLBdM	Chrysene	29	17	58.62%	71	3800	858.76	1,281.69	478.92	µg/kg
APP to LR	Chrysene	10	10	100.00%	540	2100	972.00	972.00	887.36	µg/kg
LR to DP	Chrysene	23	21	91.30%	79	1400	530.48	487.30	363.20	µg/kg
DP to GB	Chrysene	27	20	74.07%	194	1200	582.00	1,303.33	838.54	µg/kg
LLBdM	Dibenz(a,h)anthracene	26	8	30.77%	30.9	320	129.08	1,457.79	292.69	µg/kg
APP to LR	Dibenz(a,h)anthracene	10	5	50.00%	95	260	165.00	617.50	342.03	µg/kg
LR to DP	Dibenz(a,h)anthracene	23	10	43.48%	66.1	210	116.11	975.92	257.09	µg/kg
DP to GB	Dibenz(a,h)anthracene	26	7	26.92%	12.9	150	77.04	1,978.84	637.81	µg/kg
LLBdM	Fluoranthene	29	15	51.72%	174	6500	1,174.53	1,632.07	613.32	µg/kg
APP to LR	Fluoranthene	10	10	100.00%	580	2300	1,225.00	1,225.00	1,100.44	µg/kg
LR to DP	Fluoranthene	23	15	65.22%	240	2400	670.67	1,114.09	543.69	µg/kg
DP to GB	Fluoranthene	27	20	74.07%	274	1600	731.95	1,332.93	975.27	µg/kg

Table 5-1. Lower Fox River and Green Bay - Sediment Sampling Results: Summary of Detected Compounds (Continued)

Location Reach/Zone	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI Mean[A]	RA Mean[B]	Logarithmic Mean[C]	Units
LLBdM	Fluorene	28	7	25.00%	15.25	580	119.11	1,308.81	272.01	µg/kg
APP to LR	Fluorene	10	3	30.00%	90	190	146.67	584.85	239.38	µg/kg
LR to DP	Fluorene	23	5	21.74%	64	110	81.00	960.96	217.73	µg/kg
DP to GB	Fluorene	24	6	25.00%	15.25	56.3	37.24	2,129.52	693.91	µg/kg
LLBdM	Indeno(1,2,3-cd)pyrene	29	12	41.38%	68.6	3400	811.72	1,378.23	358.60	µg/kg
APP to LR	Indeno(1,2,3-cd)pyrene	10	9	90.00%	240	660	433.33	710.00	499.33	µg/kg
LR to DP	Indeno(1,2,3-cd)pyrene	23	14	60.87%	140	2900	635.00	943.83	373.52	µg/kg
DP to GB	Indeno(1,2,3-cd)pyrene	27	19	70.37%	125	2600	1,145.63	1,709.89	935.84	µg/kg
LLBdM	Naphthalene	27	5	18.52%	9.5	280	96.80	1,444.04	323.22	µg/kg
APP to LR	Naphthalene	9	4	44.44%	87	180	131.75	653.00	343.25	µg/kg
LR to DP	Naphthalene	22	9	40.91%	73	190	147.56	1,036.59	340.42	µg/kg
DP to GB	Naphthalene	25	7	28.00%	9.5	790	199.94	2,091.38	796.58	µg/kg
LLBdM	1-Methylnaphthalene	2	2	100.00%	24.5	24.5	24.50	24.50	24.50	µg/kg
DP to GB	1-Methylnaphthalene	3	3	100.00%	15.3	84.4	53.60	53.60	42.89	µg/kg
LLBdM	2-Methylnaphthalene	27	5	18.52%	18.35	200	136.67	1,480.09	474.51	µg/kg
APP to LR	2-Methylnaphthalene	9	4	44.44%	66	190	129.00	651.78	334.88	µg/kg
LR to DP	2-Methylnaphthalene	22	9	40.91%	84	430	190.00	1,069.59	409.74	µg/kg
DP to GB	2-Methylnaphthalene	23	4	17.39%	14.4	134	80.10	2,226.76	832.71	µg/kg
LLBdM	Phenanthrene	29	13	44.83%	220	4700	835.31	1,412.24	504.14	µg/kg
APP to LR	Phenanthrene	10	9	90.00%	280	1700	794.44	1,035.00	762.34	µg/kg
LR to DP	Phenanthrene	23	14	60.87%	200	1100	427.14	1,048.09	482.09	µg/kg
DP to GB	Phenanthrene	27	12	44.44%	157	1600	550.17	2,031.56	1,261.49	µg/kg
LLBdM	Pyrene	29	20	68.97%	162	7000	1,251.45	1,346.38	517.08	µg/kg
APP to LR	Pyrene	10	10	100.00%	810	3000	1,572.00	1,572.00	1,383.42	µg/kg
LR to DP	Pyrene	23	21	91.30%	80	1800	848.14	777.52	539.41	µg/kg
DP to GB	Pyrene	27	22	81.48%	335	1400	745.32	1,098.04	886.67	µg/kg
Inorganic Compounds										
LLBdM	Aluminum	24	24	100.00%	10860	22900	10,596.25	10,596.25	7,306.10	mg/kg
APP to LR	Aluminum	5	5	100.00%	5600	7500	6,700.00	6,700.00	6,637.13	mg/kg
LR to DP	Aluminum	12	12	100.00%	4500	23300	12,619.17	12,619.17	11,552.90	mg/kg
DP to GB	Aluminum	18	18	100.00%	3200	57000	13,422.22	13,422.22	9,621.52	mg/kg
LLBdM	Ammonia	33	33	100.00%	25	282	95.00	95.00	76.38	mg-N/kg
APP to LR	Ammonia	1	1	100.00%	340	340	340.00	340.00	0.00	mg/kg
LR to DP	Ammonia	21	21	100.00%	96.4	700	315.83	315.83	288.33	mg-N/kg
DP to GB	Ammonia	4	4	100.00%	68.5	590	276.13	276.13	189.30	mg/kg
LLBdM	Ammonia as N	10	10	100.00%	160	300	239.00	239.00	233.36	mg/kg
APP to LR	Ammonia as N	5	5	100.00%	87	180	124.00	124.00	119.17	mg/kg
LR to DP	Ammonia as N	8	8	100.00%	63	410	241.63	241.63	212.76	mg/kg
DP to GB	Ammonia as N	16	15	93.75%	80	390	168.67	160.13	141.32	mg/kg

Table 5-1. Lower Fox River and Green Bay - Sediment Sampling Results: Summary of Detected Compounds (Continued)

Location Reach/Zone	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI Mean[A]	RA Mean[B]	Logarithmic Mean[C]	Units
LLBdM	Antimony	27	8	29.63%	0.562	25	6.57	4.13	1.41	mg/kg
APP to LR	Antimony	6	1	16.67%	25	25	25.00	5.00	1.70	mg/kg
LR to DP	Antimony	13	3	23.08%	0.308	25	9.84	2.94	0.78	mg/kg
DP to GB	Antimony	22	7	31.82%	1	25	8.73	3.55	1.82	mg/kg
LLBdM	Arsenic	31	28	90.32%	1.27	6.8	4.75	4.58	4.21	mg/kg
APP to LR	Arsenic	10	6	60.00%	2.8	9.7	5.36	4.44	3.95	mg/kg
LR to DP	Arsenic	23	21	91.30%	2.17	7.6	4.76	4.64	4.42	mg/kg
DP to GB	Arsenic	107	81	75.70%	0.8	385.567	11.66	9.47	5.35	mg/kg
LLBdM	Barium	24	23	95.83%	14.2	590	105.63	101.23	61.52	mg/kg
APP to LR	Barium	5	5	100.00%	51	73	58.20	58.20	57.74	mg/kg
LR to DP	Barium	12	12	100.00%	35	128	81.86	81.86	76.98	mg/kg
DP to GB	Barium	30	30	100.00%	24	400	109.87	109.87	86.23	mg/kg
LLBdM	Beryllium	27	27	100.00%	0.22	1.31	0.70	0.70	0.62	mg/kg
APP to LR	Beryllium	6	6	100.00%	0.31	0.64	0.52	0.52	0.50	mg/kg
LR to DP	Beryllium	13	12	92.31%	0.17	1.38	0.67	0.64	0.53	mg/kg
DP to GB	Beryllium	23	23	100.00%	0.25	1	0.61	0.61	0.57	mg/kg
LLBdM	Cadmium	31	26	83.87%	0.51	12.5	3.48	3.07	2.04	mg/kg
APP to LR	Cadmium	10	9	90.00%	0.5	2	0.97	0.90	0.79	mg/kg
LR to DP	Cadmium	23	23	100.00%	0.5	7.54	2.44	2.44	1.75	mg/kg
DP to GB	Cadmium	107	89	83.18%	0.43	10.8	1.42	1.22	0.96	mg/kg
LLBdM	Calcium	24	24	100.00%	75300	92700	56,286.46	56,286.46	42,145.83	mg/kg
APP to LR	Calcium	5	5	100.00%	28000	140000	58,400.00	58,400.00	48,669.17	mg/kg
LR to DP	Calcium	12	12	100.00%	47000	50000	29,839.17	29,839.17	7,644.91	mg/kg
DP to GB	Calcium	18	18	100.00%	24000	62000	40,111.11	40,111.11	39,084.03	mg/kg
DP to GB	Cerium	2	2	100.00%	51	62	56.50	56.50	56.23	mg/kg
LLBdM	Chromium	31	31	100.00%	5.12	89	47.86	47.86	42.49	mg/kg
APP to LR	Chromium	10	10	100.00%	20	95	50.40	50.40	44.59	mg/kg
LR to DP	Chromium	23	23	100.00%	21.7	420	73.25	73.25	58.19	mg/kg
DP to GB	Chromium	107	107	100.00%	4.6	220	63.03	63.03	51.36	mg/kg
LLBdM	Cobalt	24	24	100.00%	4.32	12	7.85	7.85	7.57	mg/kg
APP to LR	Cobalt	5	5	100.00%	3.8	8.9	6.20	6.20	5.82	mg/kg
LR to DP	Cobalt	12	12	100.00%	4.8	8.7	6.56	6.56	6.44	mg/kg
DP to GB	Cobalt	18	18	100.00%	4.2	12	5.84	5.84	5.58	mg/kg
LLBdM	Copper	31	31	100.00%	3.5	210	73.85	73.85	58.75	mg/kg
APP to LR	Copper	10	10	100.00%	28	119	63.50	63.50	58.58	mg/kg
LR to DP	Copper	23	23	100.00%	26.9	149	81.47	81.47	76.53	mg/kg
DP to GB	Copper	107	107	100.00%	4.1	160	60.98	60.98	51.80	mg/kg
LLBdM	Iron	24	24	100.00%	23200	32900	17,695.13	17,695.13	13,002.37	mg/kg
APP to LR	Iron	5	5	100.00%	9400	15000	11,880.00	11,880.00	11,707.62	mg/kg

Table 5-1. Lower Fox River and Green Bay - Sediment Sampling Results: Summary of Detected Compounds (Continued)

Location Reach/Zone	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI Mean[A]	RA Mean[B]	Logarithmic Mean[C]	Units
LR to DP	Iron	12	12	100.00%	14400	25000	12,098.17	12,098.17	3,101.06	mg/kg
DP to GB	Iron	30	30	100.00%	7000	29000	16,023.33	16,023.33	15,175.69	mg/kg
LLBdM	Lead	31	31	100.00%	3.54	549	167.83	167.83	70.78	mg/kg
APP to LR	Lead	10	10	100.00%	44	130	75.60	75.60	72.80	mg/kg
LR to DP	Lead	23	23	100.00%	2.25	1400	138.65	138.65	58.76	mg/kg
DP to GB	Lead	107	107	100.00%	4.44	350	85.04	85.04	70.56	mg/kg
LLBdM	Magnesium	24	24	100.00%	38500	71500	27,322.42	27,322.42	19,627.28	mg/kg
APP to LR	Magnesium	5	5	100.00%	12000	18000	15,400.00	15,400.00	15,200.54	mg/kg
LR to DP	Magnesium	12	12	100.00%	28700	24000	13,783.25	13,783.25	3,733.98	mg/kg
DP to GB	Magnesium	18	18	100.00%	11000	26000	17,111.11	17,111.11	16,752.96	mg/kg
LLBdM	Manganese	24	24	100.00%	210	1390	410.42	410.42	373.78	mg/kg
APP to LR	Manganese	5	5	100.00%	200	290	242.00	242.00	240.00	mg/kg
LR to DP	Manganese	12	12	100.00%	220	465	340.33	340.33	333.01	mg/kg
DP to GB	Manganese	30	30	100.00%	150	670	302.67	302.67	288.36	mg/kg
LLBdM	Mercury	117	99	84.62%	0.00275	5.43	1.14	0.99	0.59	mg/kg
APP to LR	Mercury	10	10	100.00%	0.17	2.1	0.77	0.77	0.56	mg/kg
LR to DP	Mercury	146	142	97.26%	0.0109	9.82	2.34	2.28	1.28	mg/kg
DP to GB	Mercury	95	92	96.84%	0.1	7.7	1.07	1.04	0.79	mg/kg
LLBdM	Nickel	31	31	100.00%	4.07	29.1	17.93	17.93	16.91	mg/kg
APP to LR	Nickel	10	10	100.00%	9	21	15.10	15.10	14.73	mg/kg
LR to DP	Nickel	23	23	100.00%	8.9	28	18.55	18.55	17.93	mg/kg
DP to GB	Nickel	107	107	100.00%	3.2	112.113	18.13	18.13	16.43	mg/kg
DP to GB	Nitrogen, NO3 + NO2	12	11	91.67%	0.41	100	9.77	8.99	0.89	mg/L
LLBdM	Potassium	24	24	100.00%	620	4710	1,866.50	1,866.50	1,650.36	mg/kg
APP to LR	Potassium	5	5	100.00%	780	1200	1,034.00	1,034.00	1,019.17	mg/kg
LR to DP	Potassium	12	12	100.00%	760	3590	1,970.00	1,970.00	1,826.38	mg/kg
DP to GB	Potassium	18	18	100.00%	460	22000	3,660.56	3,660.56	1,784.29	mg/kg
LLBdM	Selenium	27	12	44.44%	0.149	3	0.92	0.95	0.61	mg/kg
APP to LR	Selenium	6	5	83.33%	0.83	3.2	2.23	1.98	1.70	mg/kg
LR to DP	Selenium	13	4	30.77%	0.119	2.3	0.95	0.93	0.54	mg/kg
DP to GB	Selenium	102	16	15.69%	0.14	391.592	26.26	6.28	2.22	mg/kg
LLBdM	Silver	27	9	33.33%	0.7	1.7	1.34	1.04	0.81	mg/kg
LR to DP	Silver	13	2	15.38%	0.66	1.12	0.89	0.55	0.48	mg/kg
DP to GB	Silver	89	30	33.71%	0.54	9.6	1.17	0.64	0.47	mg/kg
LLBdM	Sodium	24	23	95.83%	200	2470	1,035.74	1,004.25	780.82	mg/kg
APP to LR	Sodium	5	5	100.00%	220	2200	704.00	704.00	468.11	mg/kg
LR to DP	Sodium	12	12	100.00%	32.3	590	320.63	320.63	244.46	mg/kg
DP to GB	Sodium	18	18	100.00%	62	5200	984.06	984.06	500.53	mg/kg
LLBdM	Thallium	27	3	11.11%	25	25	25.00	3.36	0.61	mg/kg

Table 5-1. Lower Fox River and Green Bay - Sediment Sampling Results: Summary of Detected Compounds (Continued)

Location Reach/Zone	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI Mean[A]	RA Mean[B]	Logarithmic Mean[C]	Units
APP to LR	Thallium	6	1	16.67%	25	25	25.00	4.85	1.44	mg/kg
LR to DP	Thallium	13	3	23.08%	0.193	25	9.13	2.70	0.71	mg/kg
DP to GB	Thallium	21	6	28.57%	2	25	17.43	6.20	2.09	mg/kg
DP to GB	Total Phosphorus	12	12	100.00%	2000	6300	3,866.67	3,866.67	3,676.33	mg/kg
LLBdM	Vanadium	24	24	100.00%	7.04	39.4	25.11	25.11	23.63	mg/kg
APP to LR	Vanadium	5	5	100.00%	16	23	19.60	19.60	19.41	mg/kg
LR to DP	Vanadium	12	12	100.00%	14	36.9	27.17	27.17	26.42	mg/kg
DP to GB	Vanadium	18	18	100.00%	9.6	61	25.09	25.09	22.33	mg/kg
LLBdM	Zinc	28	28	100.00%	11.2	2050	421.00	421.00	244.58	mg/kg
APP to LR	Zinc	10	10	100.00%	83	180	122.80	122.80	119.10	mg/kg
LR to DP	Zinc	23	23	100.00%	56.8	330	162.12	162.12	150.37	mg/kg
DP to GB	Zinc	103	103	100.00%	11.2	485	162.46	162.46	138.43	mg/kg
Toxicity Characteristic Leaching Procedure (TCLP) Results - Inorganic Compounds										
LLBdM	Arsenic, TCLP	9	9	100.00%	0.003	0.012	0.01	0.01	0.01	mg/L
LR to DP	Arsenic, TCLP	4	4	100.00%	0.007	0.031	0.02	0.02	0.02	mg/L
LLBdM	Barium, TCLP	9	9	100.00%	0.357	0.936	0.68	0.68	0.66	mg/L
LR to DP	Barium, TCLP	4	4	100.00%	0.255	0.789	0.54	0.54	0.50	mg/L
LLBdM	Cadmium, TCLP	9	2	22.22%	0.01	0.01	0.01	0.01	0.01	mg/L
LR to DP	Cadmium, TCLP	4	3	75.00%	0.01	0.01	0.01	0.01	0.01	mg/L
LLBdM	Chromium, TCLP	9	5	55.56%	0.01	0.2	0.07	0.04	0.01	mg/L
LR to DP	Chromium, TCLP	4	3	75.00%	0.01	0.01	0.01	0.01	0.01	mg/L
LLBdM	Lead, TCLP	9	6	66.67%	0.06	0.27	0.16	0.11	0.08	mg/L
LR to DP	Lead, TCLP	4	3	75.00%	0.07	0.16	0.11	0.09	0.07	mg/L
LLBdM	Mercury, TCLP	9	2	22.22%	0.0005	0.0005	0.00	0.00	0.00	mg/L
LLBdM	Silver, TCLP	9	9	100.00%	0.02	0.03	0.02	0.02	0.02	mg/L
LR to DP	Silver, TCLP	4	3	75.00%	0.02	0.03	0.02	0.02	0.02	mg/L
Cyanide Results										
LLBdM	Cyanide	14	2	14.29%	0.35	0.64	0.50	0.32	0.24	mg/kg
DP to GB	Cyanide	12	3	25.00%	0.73	3	1.64	1.12	1.03	mg/kg
Miscellaneous Parameters Detected in Less than 4 Samples (These parameters are not included on other Tables)										
DP to GB	1,2,4-Trichlorobenzene	22	1	4.55%	14	14	14.00	2,315.89	790.99	ug/kg
LR to DP	1,2,4-Trichlorobenzene	22	1	4.55%	120	120	120.00	991.73	194.07	ug/kg
DP to GB	1,2-Dimethylnaphthalene	2	2	100.00%	23	220	121.50	121.50	71.13	ug/kg
DP to GB	1,6-Dimethylnaphthalene	2	2	100.00%	160	650	405.00	405.00	322.49	ug/kg
DP to GB	1-Methyl-9H-fluorene	2	1	50.00%	210	210	210.00	117.50	72.46	ug/kg
DP to GB	1-Methylphenanthrene	2	2	100.00%	59	620	339.50	339.50	191.26	ug/kg
DP to GB	1-Methylpyrene	2	2	100.00%	51	630	340.50	340.50	179.25	ug/kg
DP to GB	2,3,6-Trimethylnaphthalene	2	2	100.00%	32	260	146.00	146.00	91.21	ug/kg
DP to GB	2,6-Dimethylnaphthalene	2	2	100.00%	190	560	375.00	375.00	326.19	ug/kg

Table 5-1. Lower Fox River and Green Bay - Sediment Sampling Results: Summary of Detected Compounds (Continued)

Location Reach/Zone	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI Mean[A]	RA Mean[B]	Logarithmic Mean[C]	Units
LLBdM	2-Butanone	3	3	100.00%	26	71	44.33	44.33	40.51	ug/kg
DP to GB	2-Methylanthracene	2	2	100.00%	26	490	258.00	258.00	112.87	ug/kg
DP to GB	4,5-Methylenephenanthrene	2	1	50.00%	55	55	55.00	40.00	37.08	ug/kg
DP to GB	9H-Fluorene	2	2	100.00%	68	270	169.00	169.00	135.50	ug/kg
LLBdM	Acetone	3	1	33.33%	450	450	450.00	169.00	63.61	ug/kg
LR to DP	alpha-BHC	23	1	4.35%	2.2	2.2	2.20	4.53	2.00	ug/kg
LLBdM	alpha-Chlordane	26	2	7.69%	9	25	17.00	8.46	3.36	ug/kg
LR to DP	alpha-Chlordane	22	1	4.55%	2.3	2.3	2.30	4.67	2.20	ug/kg
APP to LR	Benzo(e)pyrene	1	1	100.00%	980	980	980.00	980.00	0.00	ug/kg
DP to GB	Benzo(e)pyrene	1	1	100.00%	720	720	720.00	720.00	0.00	ug/kg
LLBdM	Benzo(e)pyrene	1	1	100.00%	480	480	480.00	480.00	0.00	ug/kg
LR to DP	Benzo(e)pyrene	1	1	100.00%	1600	1600	1,600.00	1,600.00	0.00	ug/kg
LLBdM	beta-BHC	27	2	7.41%	5.8	22	13.90	7.96	3.09	ug/kg
LLBdM	Butylbenzylphthalate	22	1	4.55%	81	81	81.00	1,673.50	201.42	ug/kg
DP to GB	C8-Alkylphenol	2	1	50.00%	11	11	11.00	18.00	16.58	ug/kg
LLBdM	Carbon Disulfide	3	1	33.33%	69	69	69.00	33.50	25.51	ug/kg
APP to LR	Dibenzofuran	9	1	11.11%	120	120	120.00	617.56	210.15	ug/kg
DP to GB	Dibenzofuran	20	1	5.00%	31	31	31.00	2,546.30	1,190.80	ug/kg
LLBdM	Dibenzofuran	25	1	4.00%	86	86	86.00	1,579.98	471.87	ug/kg
DP to GB	Dibenzothiophene	2	2	100.00%	38	110	74.00	74.00	64.65	ug/kg
DP to GB	Diethylphthalate	22	1	4.55%	480	480	480.00	2,337.50	949.27	ug/kg
LLBdM	Diethylphthalate	23	2	8.70%	120	540	330.00	1,629.15	249.40	ug/kg
LLBdM	di-n-Butylphthalate	22	2	9.09%	240	890	565.00	1,608.02	320.93	ug/kg
LLBdM	Endrin	19	2	10.53%	16	44	30.00	42.11	11.54	ug/kg
DP to GB	Gallium	2	2	100.00%	15	25	20.00	20.00	19.36	mg/kg
LLBdM	gamma-Chlordane	26	3	11.54%	7.4	46	20.87	10.48	4.77	ug/kg
LLBdM	Heptachlor epoxide	24	1	4.17%	4.3	4.3	4.30	8.03	3.14	ug/kg
DP to GB	Isoquinoline	2	1	50.00%	20	20	20.00	22.50	22.36	ug/kg
DP to GB	Lanthanum	2	2	100.00%	26	32	29.00	29.00	28.84	mg/kg
DP to GB	Lithium	2	2	100.00%	30	30	30.00	30.00	30.00	mg/kg
DP to GB	Methoxychlor	21	1	4.76%	11	11	11.00	38.77	29.37	ug/kg
LR to DP	Methoxychlor	22	2	9.09%	6.1	98	52.05	47.38	17.59	ug/kg
DP to GB	Neodymium	2	2	100.00%	24	25	24.50	24.50	24.49	mg/kg
DP to GB	p-Cresol	2	2	100.00%	440	550	495.00	495.00	491.93	ug/kg
APP to LR	Perylene	1	1	100.00%	230	230	230.00	230.00	0.00	ug/kg
DP to GB	Perylene	1	1	100.00%	50	50	50.00	50.00	0.00	ug/kg
LLBdM	Perylene	1	1	100.00%	140	140	140.00	140.00	0.00	ug/kg
LR to DP	Perylene	1	1	100.00%	290	290	290.00	290.00	0.00	ug/kg
DP to GB	Phosphorus	2	2	100.00%	0.15	0.15	0.15	0.15	0.15	percent

Table 5-1. Lower Fox River and Green Bay - Sediment Sampling Results: Summary of Detected Compounds (Continued)

Location Reach/Zone	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI Mean[A]	RA Mean[B]	Logarithmic Mean[C]	Units
DP to GB	Quinoline	2	1	50.00%	18	18	18.00	21.50	21.21	ug/kg
DP to GB	Quinoline	2	1	50.00%	18	18	18.00	21.50	21.21	ug/kg
DP to GB	Scandium	2	2	100.00%	9	10	9.50	9.50	9.49	mg/kg
DP to GB	Strontium	2	2	100.00%	150	150	150.00	150.00	150.00	mg/kg
LLBdM	Tetrachloroethene	3	1	33.33%	0.6	0.6	0.60	10.70	5.25	ug/kg
DP to GB	Titanium	2	2	100.00%	0.3	0.32	0.31	0.31	0.31	mg/kg
DP to GB	Ytterbium	2	2	100.00%	2	2	2.00	2.00	2.00	mg/kg
DP to GB	Yttrium	2	2	100.00%	16	19	17.50	17.50	17.44	mg/kg
GREEN BAY RESULTS										
PCB Results										
GB Zone 2	Total PCBs	49	48	97.96%	15	799	324.47	318.54	216.67	ug/kg
GB Zone 3A	Total PCBs	180	157	87.22%	4	1017	322.20	297.50	156.25	ug/kg
GB Zone 3B	Total PCBs	424	418	98.58%	2	1302	447.77	442.99	257.12	ug/kg
GB Zone 4	Total PCBs	203	199	98.03%	1	751	54.31	53.92	25.71	ug/kg
GB Zone 2	Ar1242	11	10	90.91%	26	460	190.30	176.09	116.17	ug/kg
GB Zone 3A	Ar1242	26	3	11.54%	38	990	432.67	163.94	104.24	ug/kg
GB Zone 3B	Ar1242	20	14	70.00%	50	220	134.36	127.05	117.02	ug/kg
GB Zone 3B	Ar1260	20	10	50.00%	21	93	55.20	76.20	67.07	ug/kg
GB Zone 2	PCB Congener 105	11	10	90.91%	0.072	5.2	2.02	1.88	0.94	ug/kg
GB Zone 3A	PCB Congener 105	2	1	50.00%	1.6	1.6	1.60	0.81	0.20	ug/kg
GB Zone 3B	PCB Congener 105	4	4	100.00%	0.31	1.1	0.57	0.57	0.50	ug/kg
GB Zone 4	PCB Congener 105	4	2	50.00%	0.017	0.079	0.05	0.05	0.04	ug/kg
GB Zone 2	PCB Congener 118	49	48	97.96%	0.12	16.887	6.16	6.04	3.52	ug/kg
GB Zone 3A	PCB Congener 118	156	152	97.44%	0.013	32.032	6.29	6.18	2.73	ug/kg
GB Zone 3B	PCB Congener 118	408	401	98.28%	0.04	45.486	11.28	11.09	5.19	ug/kg
GB Zone 4	PCB Congener 118	205	178	86.83%	0.008	25.712	1.93	1.69	0.60	ug/kg
GB Zone 2	PCB Congener 126	11	5	45.45%	0.012	0.082	0.05	0.04	0.04	ug/kg
GB Zone 2	PCB Congener 132/153/105	38	38	100.00%	0.465	21.658	9.00	9.00	6.21	ug/kg
GB Zone 3A	PCB Congener 132/153/105	154	153	99.35%	0.111	36.182	9.15	9.09	4.53	ug/kg
GB Zone 3B	PCB Congener 132/153/105	404	398	98.51%	0.048	52.187	15.00	14.78	7.90	ug/kg
GB Zone 4	PCB Congener 132/153/105	201	180	89.55%	0.027	30.381	2.76	2.50	1.02	ug/kg
GB Zone 2	PCB Congener 77	11	11	100.00%	0.078	9.2	3.23	3.23	1.45	ug/kg
GB Zone 3A	PCB Congener 77	2	2	100.00%	0.017	0.067	0.04	0.04	0.03	ug/kg
GB Zone 3B	PCB Congener 77	4	4	100.00%	0.33	1.4	0.61	0.61	0.49	ug/kg
GB Zone 4	PCB Congener 77	4	2	50.00%	0.013	0.037	0.03	0.04	0.03	ug/kg
GB Zone 2	PCB Congener 77/110	38	38	100.00%	0.546	24.886	10.38	10.38	7.42	ug/kg
GB Zone 3A	PCB Congener 77/110	154	154	100.00%	0.132	42.259	9.94	9.94	4.95	ug/kg
GB Zone 3B	PCB Congener 77/110	404	403	99.75%	0.02	57.987	16.08	16.04	8.42	ug/kg
GB Zone 4	PCB Congener 77/110	201	197	98.01%	0.016	27.29	2.05	2.03	0.93	ug/kg

Table 5-1. Lower Fox River and Green Bay - Sediment Sampling Results: Summary of Detected Compounds (Continued)

Location Reach/Zone	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI Mean[A]	RA Mean[B]	Logarithmic Mean[C]	Units
Semi-Volatile Organic Compound (SVOC) Results										
GB Zone 2	4-Methylphenol	11	1	9.09%	96	96	96.00	1,525.55	1,086.24	ug/kg
Polynuclear Aromatic Hydrocarbons (PAHs)										
GB Zone 2	Benzo(a)anthracene	11	1	9.09%	260	260	260.00	1,420.00	997.86	ug/kg
GB Zone 2	Chrysene	11	4	36.36%	280	440	355.00	880.00	609.86	ug/kg
GB Zone 2	Fluoranthene	11	3	27.27%	370	440	403.33	1,106.36	762.38	ug/kg
GB Zone 2	Pyrene	11	5	45.45%	98	520	377.60	872.55	568.76	ug/kg
Inorganic Compounds										
GB Zone 2	Aluminum	11	11	100.00%	680	7600	3,880.00	3,880.00	3,212.27	mg/kg
GB Zone 3A	Aluminum	2	2	100.00%	460	540	500.00	500.00	498.40	mg/kg
GB Zone 3B	Aluminum	4	4	100.00%	2500	13000	6,075.00	6,075.00	5,008.38	mg/kg
GB Zone 4	Aluminum	4	4	100.00%	410	840	647.50	647.50	621.96	mg/kg
GB Zone 2	Ammonia as N	11	10	90.91%	32	130	74.30	69.23	59.44	mg/kg
GB Zone 3A	Ammonia as N	2	2	100.00%	69	77	73.00	73.00	72.89	mg/kg
GB Zone 3B	Ammonia as N	4	3	75.00%	43	140	90.33	75.13	62.87	mg/kg
GB Zone 4	Ammonia as N	4	4	100.00%	22	62	40.50	40.50	37.44	mg/kg
GB Zone 3B	Antimony	4	1	25.00%	1.5	1.5	1.50	1.49	1.46	mg/kg
GB Zone 4	Antimony	4	1	25.00%	1	1	1.00	0.56	0.51	mg/kg
GB Zone 2	Arsenic	11	10	90.91%	1	3.2	2.25	2.07	1.78	mg/kg
GB Zone 3A	Arsenic	2	2	100.00%	1.4	1.6	1.50	1.50	1.50	mg/kg
GB Zone 3B	Arsenic	4	4	100.00%	3.6	15	8.58	8.58	7.59	mg/kg
GB Zone 4	Arsenic	4	4	100.00%	1.4	8.9	4.98	4.98	4.11	mg/kg
GB Zone 2	Barium	11	11	100.00%	4.9	40	23.32	23.32	19.75	mg/kg
GB Zone 3A	Barium	2	2	100.00%	3.4	5.3	4.35	4.35	4.24	mg/kg
GB Zone 3B	Barium	4	4	100.00%	14	120	52.75	52.75	39.72	mg/kg
GB Zone 4	Barium	4	4	100.00%	4.2	7.2	5.83	5.83	5.72	mg/kg
GB Zone 2	Beryllium	11	10	90.91%	0.048	0.33	0.20	0.19	0.13	mg/kg
GB Zone 3A	Beryllium	2	1	50.00%	0.065	0.065	0.07	0.05	0.05	mg/kg
GB Zone 3B	Beryllium	4	4	100.00%	0.18	0.83	0.42	0.42	0.36	mg/kg
GB Zone 4	Beryllium	4	1	25.00%	0.1	0.1	0.10	0.04	0.03	mg/kg
GB Zone 2	Cadmium	11	8	72.73%	0.097	0.79	0.40	0.30	0.18	mg/kg
GB Zone 3B	Cadmium	4	4	100.00%	0.18	0.81	0.56	0.56	0.49	mg/kg
GB Zone 4	Cadmium	4	1	25.00%	0.067	0.067	0.07	0.03	0.03	mg/kg
GB Zone 2	Calcium	11	11	100.00%	1500	54000	24,863.64	24,863.64	18,880.18	mg/kg
GB Zone 3A	Calcium	2	2	100.00%	3400	4300	3,850.00	3,850.00	3,823.61	mg/kg
GB Zone 3B	Calcium	4	4	100.00%	15000	93000	51,000.00	51,000.00	42,322.91	mg/kg
GB Zone 4	Calcium	4	4	100.00%	2300	23000	11,625.00	11,625.00	8,545.33	mg/kg
GB Zone 2	Chromium	11	11	100.00%	2.4	36	17.83	17.83	13.81	mg/kg
GB Zone 3A	Chromium	2	2	100.00%	1.6	2.7	2.15	2.15	2.08	mg/kg

Table 5-1. Lower Fox River and Green Bay - Sediment Sampling Results: Summary of Detected Compounds (Continued)

Location Reach/Zone	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI Mean[A]	RA Mean[B]	Logarithmic Mean[C]	Units
GB Zone 3B	Chromium	4	4	100.00%	8.4	40	22.35	22.35	19.38	mg/kg
GB Zone 4	Chromium	4	4	100.00%	2.6	4.9	3.88	3.88	3.76	mg/kg
GB Zone 2	Cobalt	11	11	100.00%	0.41	5.1	3.12	3.12	2.62	mg/kg
GB Zone 3A	Cobalt	2	2	100.00%	0.5	0.62	0.56	0.56	0.56	mg/kg
GB Zone 3B	Cobalt	4	4	100.00%	2.3	7.8	4.15	4.15	3.71	mg/kg
GB Zone 4	Cobalt	4	4	100.00%	0.48	1.3	0.76	0.76	0.70	mg/kg
GB Zone 2	Copper	11	10	90.91%	7.9	35	18.96	17.30	12.55	mg/kg
GB Zone 3A	Copper	2	2	100.00%	1.1	1.3	1.20	1.20	1.20	mg/kg
GB Zone 3B	Copper	4	4	100.00%	5.9	36	17.23	17.23	14.02	mg/kg
GB Zone 4	Copper	4	4	100.00%	1.2	3.2	1.88	1.88	1.74	mg/kg
GB Zone 2	Iron	11	11	100.00%	1200	12000	6,954.55	6,954.55	5,894.39	mg/kg
GB Zone 3A	Iron	2	2	100.00%	1600	1900	1,750.00	1,750.00	1,743.56	mg/kg
GB Zone 3B	Iron	4	4	100.00%	5600	26000	15,400.00	15,400.00	13,453.52	mg/kg
GB Zone 4	Iron	4	4	100.00%	2300	7500	4,650.00	4,650.00	4,272.67	mg/kg
GB Zone 2	Lead	11	11	100.00%	2	42	19.73	19.73	13.80	mg/kg
GB Zone 3A	Lead	2	2	100.00%	1.1	1.9	1.50	1.50	1.45	mg/kg
GB Zone 3B	Lead	4	4	100.00%	9.6	50	29.90	29.90	25.61	mg/kg
GB Zone 4	Lead	4	4	100.00%	2.1	4.5	3.10	3.10	2.93	mg/kg
GB Zone 2	Magnesium	11	11	100.00%	670	30000	13,197.27	13,197.27	9,673.11	mg/kg
GB Zone 3A	Magnesium	2	2	100.00%	1700	2300	2,000.00	2,000.00	1,977.37	mg/kg
GB Zone 3B	Magnesium	4	4	100.00%	9800	54000	29,950.00	29,950.00	25,371.46	mg/kg
GB Zone 4	Magnesium	4	4	100.00%	1200	13000	6,325.00	6,325.00	4,546.11	mg/kg
GB Zone 2	Manganese	11	11	100.00%	26	300	177.82	177.82	153.10	mg/kg
GB Zone 3A	Manganese	2	2	100.00%	31	77	54.00	54.00	48.86	mg/kg
GB Zone 3B	Manganese	4	4	100.00%	400	1900	830.00	830.00	666.79	mg/kg
GB Zone 4	Manganese	4	4	100.00%	65	150	108.75	108.75	104.22	mg/kg
GB Zone 2	Mercury	11	9	81.82%	0.11	1.5	0.59	0.49	0.24	mg/kg
GB Zone 3B	Mercury	4	1	25.00%	0.19	0.19	0.19	0.11	0.09	mg/kg
GB Zone 4	Mercury	4	1	25.00%	0.11	0.11	0.11	0.05	0.04	mg/kg
GB Zone 2	Nickel	11	11	100.00%	1.4	12	7.08	7.08	6.07	mg/kg
GB Zone 3A	Nickel	2	2	100.00%	1.3	1.4	1.35	1.35	1.35	mg/kg
GB Zone 3B	Nickel	4	4	100.00%	4.6	23	12.15	12.15	10.39	mg/kg
GB Zone 4	Nickel	4	4	100.00%	1.6	2.3	2.00	2.00	1.98	mg/kg
GB Zone 2	Potassium	11	11	100.00%	90	1600	650.00	650.00	495.42	mg/kg
GB Zone 3A	Potassium	2	2	100.00%	71	79	75.00	75.00	74.89	mg/kg
GB Zone 3B	Potassium	4	4	100.00%	610	2400	1,155.00	1,155.00	986.91	mg/kg
GB Zone 4	Potassium	4	4	100.00%	60	170	105.50	105.50	95.22	mg/kg
GB Zone 3B	Selenium	4	1	25.00%	0.87	0.87	0.87	1.01	0.98	mg/kg
GB Zone 2	Sodium	11	11	100.00%	87	670	256.09	256.09	203.60	mg/kg

Table 5-1. Lower Fox River and Green Bay - Sediment Sampling Results: Summary of Detected Compounds (Continued)

Location Reach/Zone	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI Mean[A]	RA Mean[B]	Logarithmic Mean[C]	Units
GB Zone 3A	Sodium	2	2	100.00%	130	160	145.00	145.00	144.22	mg/kg
GB Zone 3B	Sodium	4	4	100.00%	210	740	382.50	382.50	335.57	mg/kg
GB Zone 4	Sodium	4	4	100.00%	60	160	112.25	112.25	104.58	mg/kg
GB Zone 2	Vanadium	11	11	100.00%	2.8	20	12.22	12.22	10.83	mg/kg
GB Zone 3A	Vanadium	2	2	100.00%	4.4	5.2	4.80	4.80	4.78	mg/kg
GB Zone 3B	Vanadium	4	4	100.00%	8.2	41	21.30	21.30	18.17	mg/kg
GB Zone 4	Vanadium	4	4	100.00%	6.4	10	7.80	7.80	7.66	mg/kg
GB Zone 2	Zinc	11	11	100.00%	4	110	49.73	49.73	34.97	mg/kg
GB Zone 3A	Zinc	2	2	100.00%	3.9	7.7	5.80	5.80	5.48	mg/kg
GB Zone 3B	Zinc	4	4	100.00%	20	110	63.50	63.50	53.92	mg/kg
GB Zone 4	Zinc	4	4	100.00%	7.2	15	10.00	10.00	9.62	mg/kg

Notes:

This table only contains parameters which were sampled and detected in Lower Fox River or Green Bay sediment samples.

A) The RI Mean is the average of all detected sample results.

B) The RA Mean is the average of all detected sample results plus 1/2 the detection limit for samples flagged as non-detect by the laboratory.

C) The Logarithmic Mean was calculated using the RA Mean sample data - this was done because not all sample populations, have a normal distribution. This is especially true for PCBs.

LLBdM - This is the Little Lake Butte des Morts Reach
APP to LR - This is the Appleton to Little Rapids Reach
LR to DP - This is the Little Rapids to DePere
DP to GB - This is the DePere to Green Bay Reach

GB Zone 2 - This is Green Bay Zones 2A & 2B
GB Zone 3A - This is Green Bay Zone 3A
GB Zone 3B - This is Green Bay Zone 3B
GB Zone 4 - This is Green Bay Zone 4

Table 5-2. Lower Fox River and Green Bay - Distribution of Total PCBs in Sediment

Deposit, SMU or Zone	Number of Samples in Selected Concentration Ranges - Total PCBs (µg/kg)									Total Number of		Percent Detected	Detected Values (µg/kg)		Averages (µg/kg)		Logarithmic Mean[C]
	Greater Than or Equal to								Below 50	Samples	Detects		Min.	Max.	RI Mean[A]	RA Mean[B]	
	50,000	10,000	5,000	1,000	500	250	125	50									
Lake Winnebago																	
Reach Totals	0	0	0	0	0	0	0	0	5	5	5	100.00%	6	36	22.00	22.00	17.56
Little Lake Butte des Morts																	
Reach Totals	48	112	55	146	42	41	46	133	38	661	539	81.54%	0	222,722	15,042.95	12,272.77	1,547.92
Deposit A	40	77	30	58	12	18	17	63	3	318	264	83.02%	18	222,722	24,373.31	20,241.28	2,281.54
Deposit B	0	0	0	0	0	2	1	2	0	5	5	100.00%	70	490	229.01	229.01	180.63
Deposit C	3	11	7	9	4	2	3	11	4	54	45	83.33%	5	100,000	11,284.36	9,408.91	1,081.91
Deposit D	1	3	8	26	5	2	2	9	12	68	57	83.82%	2	56,990	4,522.18	3,793.59	535.97
Deposit E	0	9	5	38	15	12	12	40	19	150	113	75.33%	7	45,850	2,962.19	2,237.75	288.28
Deposit F	0	0	0	4	1	3	5	3	0	16	11	68.75%	70	2,200	861.82	610.94	258.95
Deposit G	0	0	0	0	0	0	2	1	0	3	2	66.67%	130	230	180.00	128.33	90.75
Deposit H	0	0	0	2	0	0	0	1	0	3	2	66.67%	1,800	2,100	1,950.00	1,308.33	455.49
Deposit POG	4	12	5	9	5	2	3	1	0	41	39	95.12%	154	113,640	14,312.59	13,618.01	3,723.42
Interdeposit	0	0	0	0	0	0	1	1	0	2	1	50.00%	230	230	230.00	134.00	93.49
Creek Trib.	0	0	0	0	0	0	0	1	0	1	0	0.00%	0	0	0.00	25.00	0.00
Appleton to Little Rapids																	
Reach Totals	6	21	20	49	16	25	31	80	15	263	188	71.48%	0	77,444	6,405.94	4,589.09	1,302.38
Deposit I	0	0	0	1	1	0	0	2	0	4	2	50.00%	760	1,600	1,180.00	602.50	166.04
Deposit J	0	0	0	0	0	0	0	2	0	2	1	50.00%	100	100	100.00	62.50	50.00
Deposit K	0	0	0	0	0	1	0	2	0	3	2	66.67%	80	260	170.00	121.67	80.41
Deposit L	0	0	0	0	0	2	0	1	0	3	2	66.67%	290	290	290.00	201.67	128.11
Deposit M	0	0	0	0	1	0	0	1	0	2	1	50.00%	700	700	700.00	362.50	132.29
Deposit N	4	13	7	12	2	2	2	0	1	43	43	100.00%	35	74,200	16,897.05	16,897.05	5,880.11
Deposit O	0	0	0	2	2	0	1	2	0	7	5	71.43%	180	1,840	920.00	664.29	274.97
Deposit P	0	1	3	6	1	3	1	1	0	16	14	87.50%	310	22,000	4,338.57	3,801.88	1,277.29
Deposit Q	0	4	3	2	0	1	0	2	0	12	10	83.33%	480	22,335	9,576.50	7,984.58	2,298.92
Deposit R	0	0	0	0	0	0	0	2	0	2	0	0.00%	0	0	0.00	25.00	25.00
Deposit S	0	0	0	2	0	0	2	3	0	7	5	71.43%	69	1,400	619.80	449.86	153.85
Deposit T	0	0	4	6	0	0	0	5	0	15	12	80.00%	50	7,800	4,281.67	3,430.33	921.85
Deposit U	0	0	0	1	0	0	1	1	0	3	2	66.67%	120	1,000	560.00	406.67	228.94
Deposit V	0	0	0	4	0	0	0	2	1	7	6	85.71%	39	3,100	1,386.50	1,192.00	388.84
Deposit W	0	0	0	4	7	5	8	13	5	42	28	66.67%	6	3,200	527.07	365.67	123.81
Deposit X	0	1	2	8	2	5	11	15	6	50	33	66.00%	4	27,000	1,701.94	1,138.28	149.95
Deposit Y	0	0	0	0	0	1	0	2	0	3	1	33.33%	370	370	370.00	140.00	61.38
Deposit Z	0	0	0	0	0	1	0	1	0	2	1	50.00%	310	310	310.00	167.50	88.03
Deposit AA	0	0	0	0	0	0	0	1	0	1	0	0.00%	0	0	0.00	25.00	0.00
Deposit BB	0	0	0	0	0	0	1	2	0	3	1	33.33%	130	130	130.00	60.00	43.31
Deposit CC	0	0	0	1	0	1	0	7	0	9	2	22.22%	280	1,500	890.00	217.22	51.53
Deposit DD	0	1	1	0	0	2	4	10	2	20	12	60.00%	0.34	19,000	2,357.45	1,424.47	82.02
Unknowns	2	0	0	0	0	0	0	3	0	5	3	60.00%	56	77,444	42,833.33	25,719.80	884.67
Creek Trib.	0	0	0	0	0	1	0	0	0	1	1	100.00%	340	340	340.00	340.00	0.00
Interdeposit	0	1	0	0	0	0	0	0	0	1	1	100.00%	18,000	18,000	18,000.00	18,000.00	0.00

Notes:
A) Th RI Mean is the average value calculated using all laboratory detected values.
B) The RA Mean is the average value calculated using all laboratory detected results plus 1/2 the detection limit for samples flagged as non-detect by the laboratory.
C) The Logarithmic Mean was calculated using the RA Mean sample data - this was done because not all sample populations have a normal distribution.

Table 5-2. Lower Fox River and Green Bay - Distribution of Total PCBs in Sediment (Continued)

Deposit, SMU or Zone	Number of Samples in Selected Concentration Ranges - Total PCBs (µg/kg)									Total Number of		Percent Detected	Detected Values (µg/kg)		Averages (µg/kg)		Logarithmic Mean[C]
	Greater Than or Equal to								Below 50	Samples	Detects		Min.	Max.	RI Mean[A]	RA Mean[B]	
	50,000	10,000	5,000	1,000	500	250	125	50									
Little Rapids to DePere																	
Reach Totals	1	122	48	128	51	47	58	132	65	652	542	83.13%	0	54,000	6,291.75	5,236.31	797.05
Deposit EE	0	60	33	83	35	39	38	108	51	447	364	81.43%	5	41,000	4,578.62	3,735.19	433.77
Deposit FF	0	4	1	0	1	0	1	3	1	11	9	81.82%	3	27,000	10,560.33	8,647.09	731.80
Deposit GG	0	31	7	12	5	2	7	13	9	86	76	88.37%	42	47,800	10,925.12	9,656.97	1,401.23
Deposit HH	1	17	5	22	2	2	3	2	4	58	53	91.38%	40	54,000	11,078.60	10,126.14	2,544.59
Unknowns	0	2	0	1	0	2	3	3	0	11	9	81.82%	90	25,590	5,067.78	4,150.91	363.66
Creek Trib.	0	0	0	0	0	0	0	2	0	2	0	0.00%	0	0	0.00	25.00	25.00
Interdeposit	0	8	2	10	8	2	6	1	0	37	31	83.78%	216	22,600	5,980.06	5,021.68	1,232.26
DePere to Green Bay																	
Reach Totals	84	228	87	336	58	42	39	129	11	1014	938	92.50%	0	710,000	21,878.20	20,269.87	4,083.00
SMUs 20-25	5	41	19	56	17	10	8	31	1	188	162	86.17%	42.6	150,000	10,573.84	9,122.14	2,146.22
SMUs 26-31	0	6	2	6	1	2	2	7	0	26	22	84.62%	90	26,000	7,082.86	5,997.08	1,390.46
SMUs 32-37	1	4	4	13	0	1	0	5	0	28	26	92.86%	50	63,000	7,123.00	6,616.04	1,926.10
SMUs 38-43	0	11	4	23	3	5	2	18	1	67	56	83.58%	4	49,000	5,572.93	4,872.00	1,192.92
SMUs 44-49	0	36	14	54	16	7	5	19	0	151	142	94.04%	52	32,000	6,168.22	5,898.25	2,101.34
SMUs 50-55	0	3	0	17	1	0	4	4	1	30	28	93.33%	10	31,000	3,985.43	3,721.42	2,064.75
SMUs 56-61	70	94	27	89	7	10	9	19	4	329	319	96.96%	26	710,000	49,142.49	47,649.56	8,175.35
SMUs 62-67	1	5	2	14	3	1	0	1	0	27	27	100.00%	72	58,000	7,421.19	7,421.19	2,987.93
SMUs 68-73	2	9	4	12	1	0	0	6	0	34	31	91.18%	90	57,000	11,398.71	10,396.56	4,164.14
SMUs 74-79	0	2	4	5	0	0	1	2	0	14	14	100.00%	56	15,000	4,820.43	4,820.43	2,240.00
SMUs 80-85	0	2	2	8	0	1	1	4	0	18	16	88.89%	61	17,000	4,092.12	3,640.25	1,237.38
SMUs 86-91	0	6	0	2	1	1	1	5	0	16	12	75.00%	0	27,000	11,282.58	8,468.22	5,198.74
SMUs 92-97	0	0	2	13	1	0	2	1	0	19	19	100.00%	117	9,300	2,400.42	2,400.42	1,925.32
SMUs 98-103	0	0	0	2	2	0	3	3	0	10	9	90.00%	54	1,300	500.33	452.80	243.36
SMUs 104-109	0	0	0	3	2	1	0	2	0	8	7	87.50%	64	2,100	924.86	812.38	534.99
SMUs 110-115	0	1	0	13	0	1	0	0	0	15	15	100.00%	444	11,000	2,260.80	2,260.80	1,869.12
Unknowns	5	8	3	6	3	2	1	2	4	34	33	97.06%	0.4	90,000	17,550.68	17,035.21	1,980.10
Green Bay Zone 2 (2A & 2B)																	
Zone Totals	0	3	0	4	11	18	9	7	6	58	57	98.28%	15	17,000	1,129.02	1,110.14	622.34
Green Bay Zone 3A																	
Zone Totals	0	0	0	2	45	34	48	18	33	180	157	87.22%	4	1,017	322.20	297.50	190.52
Green Bay Zone 3B																	
Zone Totals	0	0	0	17	169	77	53	38	63	417	411	98.56%	2	1,302	447.75	442.89	319.03
Green Bay Zone 4																	
Zone Totals	0	0	0	0	1	2	21	48	133	205	201	98.05%	0	751	54.31	53.92	38.89

Notes:

A) Th RI Mean is the average value calculated using all laboratory detected values.

B) The RA Mean is the average value calculated using all laboratory detected results plus 1/2 the detection limit for samples flagged as non-detect by the laboratory.

C) The Logarithmic Mean was calculated using the RA Mean sample data - this was done because not all sample populations have a normal distribution.

Table 5-3. Lower Fox River - Dioxin/Furan (2,3,7,8-TCDD/F) Results

Deposit/SMU	Sample Identification	Depth (cm)	2,3,7,8-TCDD (ng/kg)	2,3,7,8-TCDF (ng/kg)	Total PCBs (mg/kg)
Little Lake Butte des Morts Reach					
D	D-RI-13(0-2)	0 - 61	1.75	67.81	2,017
D	D-RI-6(0-0.5)	0 - 15	3.00	60.80	5,460
E	E-RI-3(0-2)	0 - 61	ND	71.29	157
POG	P-RI-15(0-2)	0 - 61	1.90	50.20	6,297
POG	P-RI-4(0-2)	0 - 61	5.44	69.93	11,761
POG	P-RI-4(2-3.4)	61 - 104	3.59	32.22	13,870
Little Rapids to DePere Reach					
EE	EE-RI-24(0-2)	0 - 61	6.82	117.09	9,875
EE	EE-RI-24(2-4)	61 - 122	0.23	31.78	96
HH	HH-RI-5(0-2)	0 - 61	3.70	45.70	3,678
DePere to Green Bay Reach					
SMU 56/57	B2 4-12"	10 - 30	ND	20.00	NA
SMU 56/57	B2 1-2'	30 - 61	ND	20.00	NA
SMU 56/57	B2 2-3'	61 - 91	ND	ND	NA
SMU 56/57	B2 3-4'	91 - 122	ND	80.00	NA
SMU 56/57	B2 4-5'	122 - 152	ND	ND	NA
SMU 56/57	B2 5-6'	152 - 183	ND	80.00	NA
SMU 56/57	B2 6-7'	183 - 213	ND	170.00	NA
SMU 56/57	B2 7-8'	213 - 244	ND	20.00	NA
SMU 56/57	B2 8-9'	244 - 274	ND	40.00	NA
SMU 56/57	B2 9-10'	274 - 305	ND	60.00	NA
SMU 56/57	B2 10-11'	305 - 335	ND	30.00	NA
SMU 56/57	B2 11-12'	335 - 366	10.00	80.00	NA

Note: No Green Bay sediment samples were collected/analyzed for dioxin/furan.

Table 5-4. Lower Fox River and Green Bay - Pesticide Results

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	DDT (µg/kg)	DDD (µg/kg)	DDE (µg/kg)	Aldrin (µg/kg)	Dieldrin (µg/kg)	Endrin Aldehyde (µg/kg)	Endrin Ketone (µg/kg)	gamma-BHC (Lindane) (µg/kg)	Heptachlor (µg/kg)
LOWER FOX RIVER											
Little Lake Butte des Morts Reach											
A	BA-SD01comp	0 - 61	na	na	25	na	na	na	7	na	19
A	BA-SD04comp	0 - 43	na	na	9	na	na	na	ND	na	ND
C	SDC-C-1-P-S	0 - 5	ND	ND	ND	ND	5.9	ND	4.3	ND	ND
C	SDC-C-3-P-S	0 - 5	ND	5	ND	60	ND	ND	16	ND	ND
D	D-RI-Comp1(0-2)	0 - 61	13	ND	ND	ND	na	ND	ND	ND	5
D	D-RI-Comp1(2-4)	61 - 122	5.5	ND	ND	ND	na	ND	ND	ND	ND
D	D-RI-Comp2(0-2)	0 - 61	ND	ND	ND	ND	na	ND	ND	ND	4.4
E	E-RI-Comp2(0-2)	0 - 61	ND	ND	ND	ND	na	ND	ND	ND	5.5
E	SDC-E-1-P-S	0 - 5	ND	6	ND	ND	ND	ND	17	ND	ND
POG	P-RI-Comp1(2-4)	61 - 122	14	ND	ND	ND	na	ND	ND	ND	8.4
POG	POG (Tr)	"0"	50	10	ND	na	ND	ND	na	ND	na
Appleton to Little Rapids Reach											
X	SDC-X-1-P-S	0 - 5	ND	1.5	ND	ND	ND	ND	ND	ND	ND
X	SDC-X-3-P-S	0 - 5	3.4	2.8	ND	ND	ND	ND	ND	ND	ND
Little Rapids to DePere Reach											
EE	SDC-EE22-2-P-S	0 - 5	ND	1.5	ND	ND	ND	4.9	7.1	ND	ND
EE	SDC-EE22-3-P-S	0 - 5	ND	2.8	21	ND	ND	ND	7.4	ND	ND
EE	SDC-EE23-2-P-S	0 - 5	ND	ND	ND	ND	ND	ND	7.6	ND	ND
EE	SDC-EE23-3-P-S	0 - 5	ND	1.6	ND	ND	ND	ND	6.6	ND	ND
EE	SDC-EE24-1-P-S	0 - 5	ND	1.9	ND	ND	ND	ND	3.2	ND	ND
EE	SDC-EE24-3-P-S	0 - 5	5.1	ND	6.6	ND	ND	ND	ND	ND	ND
EE	SDC-EE25-1-P-S	0 - 5	ND	ND	ND	ND	ND	ND	4.5	ND	ND
EE	SDC-EE25-3-P-S	0 - 5	ND	1.8	ND	ND	ND	ND	4.8	ND	ND
EE	SDC-EE26-1-P-S	0 - 5	ND	ND	7	ND	ND	ND	7.6	ND	ND
EE	SDC-EE26-5-P-S	0 - 5	20	ND	22	ND	ND	ND	23	9.8	ND
EG	EGH-RI-Comp1(0-2)	0 - 61	16	ND	ND	ND	na	ND	ND	ND	ND
EG	EGH-RI-Comp1(2-4)	61 - 122	ND	ND	ND	ND	na	ND	ND	ND	3.1
DePere to Green Bay Reach											
20	SDC-DPD-1-P-S	0 - 5	ND	4.5	ND	ND	ND	12	ND	ND	ND
20	SDC-DPD-2-P-S	0 - 5	ND	1.2	ND	ND	ND	5.1	2.4	ND	ND
45	SDC-DPD-3-P-S	0 - 5	ND	1.2	ND	ND	ND	6.5	3.4	ND	ND
56/57	B2 4-12"	10 - 30	19	na	ND	ND	ND	na	na	1	ND
56/57	B2 1-2'	30 - 61	ND	na	ND	ND	ND	na	na	4	ND
56/57	B2 2-3'	61 - 91	ND	na	ND	ND	ND	na	na	5	ND
56/57	B2 7-8'	213 - 244	ND	na	ND	ND	ND	na	na	17	ND
56/57	B2 8-9'	244 - 274	ND	na	ND	ND	ND	na	na	3	ND
56/57	B2 9-10'	274 - 305	28	na	ND	ND	ND	na	na	6	ND
56/57	B2 10-11'	305 - 366	ND	na	ND	ND	ND	na	na	10	ND
115	SDC-DPD-5-P-S	0 - 5	ND	ND	1.9	ND	ND	7.2	1.4	ND	ND

Table 5-4. Lower Fox River and Green Bay - Pesticide Results (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	DDT (µg/kg)	DDD (µg/kg)	DDE (µg/kg)	Aldrin (µg/kg)	Dieldrin (µg/kg)	Endrin Aldehyde (µg/kg)	Endrin Ketone (µg/kg)	gamma-BHC (Lindane) (µg/kg)	Heptachlor (µg/kg)
GREEN BAY											
Green Bay Zone 2 (2A & 2B)											
	S00030	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00031	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00032	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00037	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00038	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00039	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00040	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00056	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00057	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00058	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00063	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Green Bay Zone 3A											
	S00042	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00043	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Green Bay Zone 3B											
	S00041	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00047	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00048	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00054	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
Green Bay Zone 4											
	S00044	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00045	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00046	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00055	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND

Notes:
1) Sample results are in micrograms per kilogram (mg/kg).
2) Only samples with detected parameters are listed on table.
3) "0" depth indicates sample was collected from surface sediments.
4) ND = parameter not detected in sample.
5) na = parameter not analyzed in sample.

Table 5-5. Lower Fox River and Green Bay - Mercury, Lead, and Arsenic Results

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Mercury (mg/kg)	Lead (mg/kg)	Arsenic (mg/kg)
LOWER FOX RIVER					
Little Lake Butte des Morts Reach					
A	BA-SD01comp	0 - 61	4.90	497.00	1.40
A	BA-SD04comp	0 - 43	6.10	447.00	1.90
A	BA-SD08comp	0 - 46	5.60	314.00	1.60
A	BA-SD34	0 - 61	6.10	522.00	0.23
A	BA-SD35	0 - 34	ND	3.80	ND
A	S00009	0 - 10	ND	320.00	0.97
C	2C2 (Tr)	"0"	1.50	300.00	6.57
C	SDC-C-1-P-S	0 - 5	1.17	262.00	6.00
C	SDC-C-3-P-S	0 - 5	0.72	162.00	3.80
C	S00003	0 - 10	ND	230.00	1.10
D	D-RI-1(0-0.5)	0 - 15	ND	na	na
D	D-RI-10(0-2.2)	0 - 67	0.85	na	na
D	D-RI-11(0-1.3)	0 - 40	0.18	na	na
D	D-RI-12(0-2)	0 - 61	1.25	na	na
D	D-RI-12(2-3.5)	61 - 107	0.58	na	na
D	D-RI-13(0-2)	0 - 61	1.14	na	na
D	D-RI-13(2-3.6)	61 - 110	ND	na	na
D	D-RI-14(0-0.75)	0 - 23	ND	na	na
D	D-RI-15(0-2)	0 - 61	1.31	na	na
D	D-RI-15(2-3.7)	61 - 113	0.26	na	na
D	D-RI-16(0-1.6)	0 - 49	ND	na	na
D	D-RI-17(0-1.1)	0 - 34	ND	na	na
D	D-RI-18(0-1.5)	0 - 46	1.29	na	na
D	D-RI-19(0-0.5)	0 - 15	ND	na	na
D	D-RI-20(0-2)	0 - 61	0.42	na	na
D	D-RI-20(2-3)	61 - 91	ND	na	na
D	D-RI-21(0-2)	0 - 61	0.42	na	na
D	D-RI-21(2-4)	61 - 122	ND	na	na
D	D-RI-2(0-0.5)	0 - 15	0.51	na	na
D	D-RI-3(0-0.5)	0 - 15	ND	na	na
D	D-RI-4(0-0.5)	0 - 15	0.60	na	na
D	D-RI-5(0-0.5)	0 - 15	ND	na	na
D	D-RI-6(0-0.5)	0 - 15	0.51	na	na
D	D-RI-7(0-1.3)	0 - 40	0.34	na	na
D	D-RI-8(0-1.7)	0 - 52	0.98	na	na
D	D-RI-9(0-2)	0 - 61	0.92	na	na
D	D-RI-9(2-2.8)	61 - 85	0.41	na	na
D	D-RI-Comp1(0-2)	0 - 61	ND	3.99	4.88
D	D-RI-Comp1(2-4)	61 - 122	0.30	3.54	1.27
D	D-RI-Comp2(0-2)	0 - 61	2.60	160.00	4.56
D	S00025	0 - 10	5.00	90.00	0.35
D	S00026	0 - 10	3.80	97.00	0.79
D	S00049	0 - 10	2.60	65.00	0.34
E	2E8 (Tr)	"0"	2.20	99.00	3.70
E	E-RI-1(0-0.5)	0 - 15	0.75	na	na
E	E-RI-10(0-1.5)	0 - 46	0.28	na	na
E	E-RI-11(0-2)	0 - 61	0.52	na	na
E	E-RI-11(2-3.6)	61 - 110	0.61	na	na
E	E-RI-12(0-2)	0 - 61	2.76	na	na
E	E-RI-12(2-4.2)	61 - 128	0.23	na	na
E	E-RI-13(0-2)	0 - 61	1.48	na	na
E	E-RI-13(2-3.75)	61 - 114	0.23	na	na
E	E-RI-14(0-2)	0 - 61	0.72	na	na
E	E-RI-15(0-2)	0 - 61	0.93	na	na
E	E-RI-16(0-2)	0 - 61	2.58	na	na
E	E-RI-16(2-3)	61 - 91	2.25	na	na
E	E-RI-17(0-2)	0 - 61	2.19	na	na
E	E-RI-17(2-4)	61 - 122	3.72	na	na
E	E-RI-2(0-2)	0 - 61	2.69	na	na
E	E-RI-2(2-4)	61 - 122	0.14	na	na
E	E-RI-2(4-4.7)	122 - 143	0.14	na	na
E	E-RI-3(0-2)	0 - 61	0.84	na	na
E	E-RI-3(2-2.8)	61 - 85	1.91	na	na
E	E-RI-4(0-2)	0 - 61	1.25	na	na

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Mercury (mg/kg)	Lead (mg/kg)	Arsenic (mg/kg)
Lower Fox River - Little Rapids to De Pere Continued					
EE	SDC-EE26-5-P-S	0 - 5	9.7	297	5.7
EE	S00021	0 - 10	3.2	68	1.2
EE	S00023	0 - 10	3	45	0.9
EE	S00036	0 - 10	6.1	97	4
EG	EGH-RI-Comp1(0-2)	0 - 61	1.23	6.15	5.08
EG	EGH-RI-Comp1(2-4)	61 - 122	2.75	4.55	7.5
EG	EGH-RI-Comp1(4-6)	122 - 183	1.71	5.04	5.07
EG	EGH-RI-Comp1(6-8)	183 - 244	0.98	2.25	2.17
GG	GG-RI-1(0-2)	0 - 61	6.69	na	na
GG	GG-RI-1(2-4.2)	61 - 128	1.2	na	na
GG	GG-RI-10(0-0.9)	0 - 27	1.27	na	na
GG	GG-RI-11(0-2)	0 - 61	2.57	na	na
GG	GG-RI-11(2-3.7)	61 - 113	0.38	na	na
GG	GG-RI-12(0-2)	0 - 61	0.34	na	na
GG	GG-RI-12(2-2.5)	61 - 76	ND	na	na
GG	GG-RI-13(0-2)	0 - 61	1.45	na	na
GG	GG-RI-13(2-4.1)	61 - 125	0.83	na	na
GG	GG-RI-14(0-1.1)	0 - 34	5.57	na	na
GG	GG-RI-15(0-2)	0 - 61	1.2	na	na
GG	GG-RI-15(2-4.2)	61 - 128	0.78	na	na
GG	GG-RI-2(0-2)	0 - 61	2.23	na	na
GG	GG-RI-2(2-2.9)	61 - 88	0.21	na	na
GG	GG-RI-3(0-2)	0 - 61	0.64	na	na
GG	GG-RI-3(2-3.7)	61 - 113	0.45	na	na
GG	GG-RI-4(0-2)	0 - 61	8.21	na	na
GG	GG-RI-4(2-4)	61 - 122	1.86	na	na
GG	GG-RI-4(4-5.2)	122 - 158	1.2	na	na
GG	GG-RI-5(0-2.2)	0 - 67	0.56	na	na
GG	GG-RI-6(0-2)	0 - 61	7.98	na	na
GG	GG-RI-6(2-4)	61 - 122	1.56	na	na
GG	GG-RI-6(4-5.2)	122 - 158	1.33	na	na
GG	GG-RI-7(0-2)	0 - 61	0.89	na	na
GG	GG-RI-8(0-2)	0 - 61	9.1	na	na
GG	GG-RI-8(2-4)	61 - 122	1.42	na	na
GG	GG-RI-8(4-5.1)	122 - 155	0.69	na	na
GG	GG-RI-9(0-2)	0 - 61	2.41	na	na
GG	GG-RI-9(2-4.2)	61 - 128	0.38	na	na
HH	HH (Tr)	"0"	5.69	1400	5.46
HH	HH-RI-1(0-2)	0 - 61	1.8	na	na
HH	HH-RI-1(2-3)	61 - 91	0.15	na	na
HH	HH-RI-10(0-0.7)	0 - 21	2.04	na	na
HH	HH-RI-2(0-2)	0 - 61	1.64	na	na
HH	HH-RI-2(2-3.25)	61 - 99	0.19	na	na
HH	HH-RI-3(0-2)	0 - 61	6.27	na	na
HH	HH-RI-3(2-4)	61 - 122	5.16	na	na
HH	HH-RI-3(4-6)	122 - 183	0.96	na	na
HH	HH-RI-3(6-6.7)	183 - 204	0.65	na	na
HH	HH-RI-4(0-1.2)	0 - 37	7.9	na	na
HH	HH-RI-5(0-2)	0 - 61	3.79	na	na
HH	HH-RI-5(2-4)	61 - 122	0.54	na	na
HH	HH-RI-5(4-5.1)	122 - 155	0.66	na	na
HH	HH-RI-6(0-2)	0 - 61	0.01	na	na
HH	HH-RI-6(2-4)	61 - 122	7.71	na	na
HH	HH-RI-6(4-5.2)	122 - 158	1.19	na	na
HH	HH-RI-7(0-0.5)	0 - 15	1.47	na	na
HH	HH-RI-8(0-2)	0 - 61	9.82	na	na
HH	HH-RI-8(2-2.9)	61 - 88	1.75	na	na
HH	HH-RI-9(0-2)	0 - 61	8.63	na	na
HH	HH-RI-9(2-3.7)	61 - 113	1.43	na	na
HH	S00001	0 - 10	ND	130	1.3
HH	S00034	0 - 10	3.2	110	4.7
Interdeposit	S00002	0 - 10	ND	76	3
Interdeposit	S00033	0 - 10	5.4	66	1.5
Interdeposit	S00035	0 - 10	4.1	71	2.3
Mean Concentrations Little Rapids-De Pere			2.417	138.652	4.077

Table 5-5. Lower Fox River and Green Bay - Mercury, Lead, and Arsenic Results (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Mercury (mg/kg)	Lead (mg/kg)	Arsenic (mg/kg)
E	E-RI-4(2-3)	61 - 91	1.18	na	na
E	E-RI-5(0-2)	0 - 61	1.12	na	na
E	E-RI-6(0-2)	0 - 61	0.67	na	na
E	E-RI-6(2-4)	61 - 122	0.29	na	na
E	E-RI-7(0-2)	0 - 61	0.64	na	na
E	E-RI-7(2-2.8)	61 - 85	0.17	na	na
E	E-RI-8(0-2)	0 - 61	1.21	na	na
E	E-RI-8(2-3.25)	61 - 99	0.38	na	na
E	E-RI-9(0-2)	0 - 61	0.81	na	na
E	E-RI-9(2-4)	61 - 122	0.38	na	na
E	E-RI-9(4-5.7)	122 - 174	0.26	na	na
E	E-RI-Comp1(0-2)	0 - 61	1.92	7.10	3.57
E	E-RI-Comp1(2-4)	61 - 122	0.62	6.99	2.22
E	E-RI-Comp2(0-2)	0 - 61	2.14	7.79	3.93
E	SDC-E-1-P-S	0 - 5	1.92	289.00	6.80
E	SDC-E-3-P-S	0 - 5	0.23	39.00	4.40
E	S00027	0 - 10	5.00	88.00	0.63
E	S00029	0 - 10	3.20	81.00	0.71
F	S00028	0 - 10	5.70	140.00	1.30
POG	P-RI-1(0-2)	0 - 61	0.68	na	na
POG	P-RI-10(0-0.5)	0 - 15	0.55	na	na
POG	P-RI-11(0-2)	0 - 61	0.96	na	na
POG	P-RI-11(2-4)	61 - 122	1.94	na	na
POG	P-RI-11(4-6.2)	122 - 189	1.91	na	na
POG	P-RI-12(0-1.4)	0 - 43	ND	na	na
POG	P-RI-13(0-1.1)	0 - 34	0.47	na	na
POG	P-RI-14(0-1.2)	0 - 37	ND	na	na
POG	P-RI-15(0-2)	0 - 61	0.98	na	na
POG	P-RI-15(2-4)	61 - 122	1.65	na	na
POG	P-RI-15(4-6)	122 - 183	1.85	na	na
POG	P-RI-16(0-1.3)	0 - 40	1.39	na	na
POG	P-RI-17(0-1.2)	0 - 37	0.51	na	na
POG	P-RI-18(0-1.4)	0 - 43	ND	na	na
POG	P-RI-19(0-0.5)	0 - 15	0.46	na	na
POG	P-RI-2(0-1)	0 - 30	0.40	na	na
POG	P-RI-20(0-2)	0 - 61	1.27	na	na
POG	P-RI-20(2-4.3)	61 - 131	1.34	na	na
POG	P-RI-21(0-1.8)	0 - 55	0.69	na	na
POG	P-RI-22(0-0.4)	0 - 12	0.50	na	na
POG	P-RI-3(0-1.0)	0 - 30	0.69	na	na
POG	P-RI-4(0-2)	0 - 61	3.06	na	na
POG	P-RI-4(2-3.4)	61 - 104	2.29	na	na
POG	P-RI-5(0-0.9)	0 - 27	ND	na	na
POG	P-RI-6(0-2.2)	0 - 67	ND	na	na
POG	P-RI-7(0-2)	0 - 61	2.34	na	na
POG	P-RI-7(2-2.7)	61 - 82	5.43	na	na
POG	P-RI-8(0-1.7)	0 - 52	ND	na	na
POG	P-RI-Comp1(0-2)	0 - 61	2.25	6.08	4.69
POG	P-RI-Comp1(2-4)	61 - 122	ND	549.00	6.51
POG	P-RI-Comp1(4-6)	122 - 183	2.54	5.50	6.40
POG	POG (Tr)	"0"	3.30	110.00	5.14
POG	S00024	0 - 10	4.50	230.00	1.00
Interdeposit	S00022	0 - 10	6.00	67.00	0.49
Mean Concentrations - LLBdM			1.652	167.832	2.908
Appleton to Little Rapids Reach					
P	S00007	0 - 10	ND	75	0.17
P	S00008	0 - 10	ND	44	0.33
W	SDC-W-2-P-S	0 - 5	0.39	60	2.8
W	SDC-W-3-P-S	0 - 5	0.58	57	2.8
W	SDC-X-1-P-S	0 - 5	0.34	84	4.7
W	SDC-X-3-P-S	0 - 5	0.43	71	9.7
W	S00005	0 - 10	ND	73	2.1
X	X (Tr)	"0"	1.5	130	7.88
X	S00004	0 - 10	ND	85	0.32
Interdeposit	S00060	0 - 10	4.3	77	1.5
Mean Concentrations Appleton-Little Rapids			1.257	75.600	3.230

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Mercury (mg/kg)	Lead (mg/kg)	Arsenic (mg/kg)
DePere to Green Bay Reach					
20	95004-01	0 - 10	1.4	90.64	7.95
20	95008-01	0 - 10	1.7	96.24	7.35
20	S00010	0 - 10	ND	64	0.96
20	SDC-DPD-1-P-S	0 - 5	2	113	4.6
20	SDC-DPD-2-P-S	0 - 5	1.22	89	4.6
21	95018-01	0 - 10	1.6	85.04	10.45
21	95020-01	0 - 10	2.2	140.43	8.15
21	S00013	0 - 10	ND	77	1.1
21	S00014	0 - 10	5.4	74	1.8
22	95002-01	0 - 10	1.7	104.43	7.75
22	95006-01	0 - 10	0.97	39.64	ND
23	95016-01	0 - 10	0.3	38.24	ND
23	95022-01	0 - 10	ND	4.44	ND
24	95007-01	0 - 10	0.5	75.44	7.55
24	S00011	0 - 10	ND	67	0.87
25	95013-01	0 - 10	0.96	76.84	9.15
25	S00012	0 - 10	ND	33	0.38
29	95025-01	0 - 10	0.95	80.64	7.05
29	95028-01	0 - 10	0.98	80.54	7.95
35	95030-01	0 - 10	1.7	77.94	8.65
38	95035-01	0 - 10	1.1	166.43	385.57
38	S00015	0 - 10	ND	23	0.32
41	95038-01	0 - 10	2.3	110.43	ND
41	S00016	0 - 10	ND	62	0.75
43	S00018	0 - 10	3.3	32	0.35
44	S00017	0 - 10	ND	49	0.47
44	S00051	0 - 10	5	56	0.6
45	95054-01	0 - 10	1.1	76.74	5.75
45	S00052	0 - 10	ND	61	0.7
45	SDC-DPD-3-P-S	0 - 5	0.81	72	3
46	95041-01	0 - 10	6.1	73.8	1
46	95044-01	0 - 10	1	69.74	8.85
47	95047-01	0 - 10	1.3	85.64	9.65
47	95051-01	0 - 10	1.1	84.1	9.3
47	95058-01	0 - 10	0.91	73.3	ND
47	95109-01	0 - 10	1.1	83.5	9.9
48	95049-01	0 - 10	1.2	77.9	7.8
48	S00061	0 - 10	6.1	60	0.81
48	S00062	0 - 10	6.3	57	0.71
49	95052-01	0 - 10	0.96	65.4	8.5
49	95056-01	0 - 10	0.99	88.4	13
50	95060-01	0 - 10	0.39	29.6	ND
52	95061-01	0 - 10	1.6	83.2	8.1
53	95062-01	0 - 10	0.46	47.8	7.9
54	S00019	0 - 10	3.7	27	0.23
56	95066-01	0 - 10	2.1	108	10.6
56	95068-01	0 - 10	1	76.2	9.9
56/57	B2 4-12"	10 - 30	na	100	2.9
56/57	B2 1-2'	30 - 61	na	120	7.3
56/57	B2 2-3'	61 - 91	na	110	4.5
56/57	B2 3-4'	91 - 122	na	130	5.1
56/57	B2 4-5'	122 - 152	na	170	8.8
56/57	B2 5-6'	152 - 183	na	190	7.3
56/57	B2 6-7'	183 - 213	na	140	5.3
56/57	B2 7-8'	213 - 244	na	180	6.9
56/57	B2 8-9'	244 - 274	na	190	8.9
56/57	B2 9-10'	274 - 305	na	150	7.5
56/57	B2 10-11'	305 - 366	na	180	5.1
56/57	B2 11-12'	335 - 366	na	230	5.3
57	95070-01	0 - 10	1.1	77.2	9.5
57	95071-01	0 - 10	1.2	80.8	6.6
57	95074-01	0 - 10	1.3	88.5	9
61	95072-01	0 - 10	1	78.2	6.8
62	95076-01	0 - 10	1	91.1	7.2
62	S00053	0 - 10	4.4	48	1

Table 5-5. Lower Fox River and Green Bay - Mercury, Lead, and Arsenic Results (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Mercury (mg/kg)	Lead (mg/kg)	Arsenic (mg/kg)
Little Rapids to DePere Reach					
EE	EE-RI-1(0-2)	0 - 61	1.66	na	na
EE	EE-RI-1(2-4)	61 - 122	0.8	na	na
EE	EE-RI-1(6-7.8)	183 - 238	ND	na	na
EE	EE-RI-10(0-2)	0 - 61	7.7	na	na
EE	EE-RI-10(2-4)	61 - 122	1.02	na	na
EE	EE-RI-10(6-7.1)	183 - 216	2.06	na	na
EE	EE-RI-11(0-2)	0 - 61	2.28	na	na
EE	EE-RI-11(2-4)	61 - 122	0.8	na	na
EE	EE-RI-11(4-4.5)	122 - 137	0.19	na	na
EE	EE-RI-12(0-2)	0 - 61	8.06	na	na
EE	EE-RI-12(2-4)	61 - 122	0.43	na	na
EE	EE-RI-12(4-4.7)	122 - 143	ND	na	na
EE	EE-RI-13(0-2)	0 - 61	5.29	na	na
EE	EE-RI-13(4-6)	122 - 183	1.47	na	na
EE	EE-RI-13(6-6.9)	183 - 210	ND	na	na
EE	EE-RI-14(0-0.7)	0 - 21	1.49	na	na
EE	EE-RI-15(0-2)	0 - 61	8.33	na	na
EE	EE-RI-15(2-4)	61 - 122	1.51	na	na
EE	EE-RI-15(6-7.3)	183 - 223	0.77	na	na
EE	EE-RI-16(0-1.8)	0 - 55	1.69	na	na
EE	EE-RI-17(0-2)	0 - 61	6.97	na	na
EE	EE-RI-17(2-3.1)	61 - 94	0.41	na	na
EE	EE-RI-18(0-2)	0 - 61	2.67	na	na
EE	EE-RI-18(2-3.3)	61 - 101	0.25	na	na
EE	EE-RI-19(0-2)	0 - 61	1.48	na	na
EE	EE-RI-19(2-4.1)	61 - 125	0.67	na	na
EE	EE-RI-2(0-2)	0 - 61	3.57	na	na
EE	EE-RI-2(2-4)	61 - 122	1.03	na	na
EE	EE-RI-2(4-5)	122 - 152	0.32	na	na
EE	EE-RI-20(0-2)	0 - 61	3.58	na	na
EE	EE-RI-20(2-4.2)	61 - 128	0.93	na	na
EE	EE-RI-21(0-2)	0 - 61	1.74	na	na
EE	EE-RI-21(2-4)	61 - 122	1.09	na	na
EE	EE-RI-21(4-5.7)	122 - 174	0.38	na	na
EE	EE-RI-22(0-2)	0 - 61	0.65	na	na
EE	EE-RI-22(2-3.2)	61 - 98	0.33	na	na
EE	EE-RI-23(0-2)	0 - 61	2.49	na	na
EE	EE-RI-23(2-4.1)	61 - 125	0.69	na	na
EE	EE-RI-24(0-2)	0 - 61	2.65	na	na
EE	EE-RI-24(2-4)	61 - 122	0.71	na	na
EE	EE-RI-24(6-7.3)	183 - 223	0.84	na	na
EE	EE-RI-25(0-1.6)	0 - 49	0.73	na	na
EE	EE-RI-26(0-2)	0 - 61	0.52	na	na
EE	EE-RI-26(2-4)	61 - 122	1.31	na	na
EE	EE-RI-26(6-6.9)	183 - 210	0.15	na	na
EE	EE-RI-27(0-2)	0 - 61	4.62	na	na
EE	EE-RI-27(2-4)	61 - 122	1.04	na	na
EE	EE-RI-27(4-6.2)	122 - 189	1.01	na	na
EE	EE-RI-28(0-2)	0 - 61	5.67	na	na
EE	EE-RI-28(2-3.4)	61 - 104	1.32	na	na
EE	EE-RI-29(0-2)	0 - 61	1.85	na	na
EE	EE-RI-29(2-2.75)	61 - 84	0.65	na	na
EE	EE-RI-3(0-2)	0 - 61	5.23	na	na
EE	EE-RI-3(2-4)	61 - 122	0.83	na	na
EE	EE-RI-3(6-7)	183 - 213	1.39	na	na
EE	EE-RI-4(0-2)	0 - 61	5.82	na	na
EE	EE-RI-4(2-4)	61 - 122	0.89	na	na
EE	EE-RI-4(4-6.1)	122 - 186	0.27	na	na
EE	EE-RI-5(0-2)	0 - 61	4.15	na	na
EE	EE-RI-5(4-6)	122 - 183	1.02	na	na
EE	EE-RI-5(6-8)	183 - 244	1.81	na	na
EE	EE-RI-6(0-2)	0 - 61	7.18	na	na
EE	EE-RI-6(2-4)	61 - 122	0.54	na	na
EE	EE-RI-6(4-5.7)	122 - 174	0.4	na	na
EE	EE-RI-7(0-2)	0 - 61	4.58	na	na
EE	EE-RI-7(2-4)	61 - 122	0.59	na	na
EE	EE-RI-7(6-6.7)	183 - 204	1.04	na	na

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Mercury (mg/kg)	Lead (mg/kg)	Arsenic (mg/kg)
65	95077-01	0 - 10	1	85.4	11.4
65	95079-01	0 - 10	0.91	74.9	6.1
70	95078-01	0 - 10	1.2	93.8	9.3
70	95080-01	0 - 10	1.1	84.7	8.3
70	95081-01	0 - 10	1.3	98.5	9
71	95082-01	0 - 10	1	71.4	7.2
72	S00020	0 - 10	4.2	51	0.56
76	95084-01	0 - 10	1.1	83.8	8.2
77	95085-01	0 - 10	0.73	121	8
82	95086-01	0 - 10	0.81	85.6	7.2
82	95087-01	0 - 10	1.4	80.4	6.8
82	95088-01	0 - 10	1.4	89.8	ND
83	95089-01	0 - 10	0.92	73.1	ND
88	95090-01	0 - 10	1.1	128	10.6
88	95091-01	0 - 10	1.5	218	ND
89	95092-01	0 - 10	0.64	96.5	10.1
94	95093-01	0 - 10	0.93	71.9	6.5
94	95094-01	0 - 10	0.53	52.1	6.1
95	95095-01	0 - 10	0.37	41.6	7.6
95	95096-01	0 - 10	ND	17.2	ND
96	SDC-DPD-4-P-S	0 - 5	0.52	20	0.8
100	95097-01	0 - 10	0.26	59.6	ND
100	95098-01	0 - 10	0.6	41.9	6.4
101	95099-01	0 - 10	ND	5.3	ND
101	95101-01	0 - 10	0.11	20.2	ND
106	95100-01	0 - 10	0.55	40	7.5
107	95102-01	0 - 10	1.2	79.6	ND
109	95103-01	0 - 10	0.18	49	6.6
112	95104-01	0 - 10	0.61	19.1	ND
112	95105-01	0 - 10	0.85	62.1	8.3
113	95106-01	0 - 10	0.64	62.1	ND
115	SDC-DPD-5-P-S	0 - 5	0.59	58	3.2
	2FRB1 (Tr)	"0"	2.1	99	2.8
	2FRB17 (Tr)	"0"	0.4	27	1.57
	2FRB22 (Tr)	"0"	7.7	180	5.56
	4085139AB	-	4.4	84	1
	4085139B	-	3.8	66	1
	FRB (Tr)	"0"	2.2	350	7.58
	FRB1	-	2.1	99	2.8
?	95010-01	0 - 10	0.95	104.41	13.35
?	95011-01	0 - 10	1.4	84.24	ND
???	95064-01	0 - 10	0.1	9.3	ND
Mean Concentrations De Pere-Green Bay			1.630	85.038	10.185
Mean Concentrations DP - GB (w/o high concentration of 385.57 mg/kg)					*5.920*
GREEN BAY					
Green Bay Zone 2 (2A & 2B)					
	S00030	0 - 10	0.12	8.1	1
	S00031	0 - 10	0.11	10	1.4
	S00032	0 - 10	ND	2	ND
	S00037	0 - 10	0.97	42	2.9
	S00038	0 - 10	0.58	24	2.7
	S00039	0 - 10	1.3	40	3.2
	S00040	0 - 10	1.5	42	2.5
	S00056	0 - 10	ND	4.8	1.8
	S00057	0 - 10	0.43	17	1.9
	S00058	0 - 10	0.2	19	2.5
	S00063	0 - 10	0.13	8.1	2.6
Mean Concentrations Green Bay 2A & 2B			0.593	19.727	2.250
Green Bay Zone 3A					
	S00042	0 - 10	ND	1.1	1.4
	S00043	0 - 10	ND	1.9	1.6
Mean Concentrations Green Bay 3A			0	1.5	1.5
Green Bay Zone 3B					
	S00041	0 - 10	ND	9.6	3.6
	S00047	0 - 10	ND	32	8
	S00048	0 - 10	0.19	28	7.7
	S00054	0 - 10	ND	50	15
Mean Concentrations Green Bay 3B			0.190	29.900	8.575

Table 5-5. Lower Fox River and Green Bay - Mercury, Lead, and Arsenic Results (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Mercury (mg/kg)	Lead (mg/kg)	Arsenic (mg/kg)	Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Mercury (mg/kg)	Lead (mg/kg)	Arsenic (mg/kg)
EE	EE-RI-8(0-2)	0 - 61	7.47	na	na	**Green Bay Zone 4**					
EE	EE-RI-8(4-6)	122 - 183	1.04	na	na		S00044	0 - 10	0.11	2.1	8.9
EE	EE-RI-8(6-7.7)	183 - 235	1.42	na	na		S00045	0 - 10	ND	3.7	1.4
EE	EE-RI-9(0-2)	0 - 61	9.14	na	na		S00046	0 - 10	ND	4.5	4.4
EE	EE-RI-9(2-4)	61 - 122	1.05	na	na		S00055	0 - 10	ND	2.1	5.2
EE	EE-RI-9(4-5.6)	122 - 171	1.01	na	na	Mean Concentrations Green Bay Zone 4			0.110	3.100	4.975
EE	SDC-EE22-2-P-S	0 - 5	0.55	68	4.3	**Reference**					
EE	SDC-EE22-3-P-S	0 - 5	3.1	126	4.7		4072050AW	-	4.4	19	0.06
EE	SDC-EE23-2-P-S	0 - 5	0.6	74	6.7		4072050B	-	3.7	17	0.05
EE	SDC-EE23-3-P-S	0 - 5	0.82	68	4.7		4072050BO	-	8.9	14	ND
EE	SDC-EE24-1-P-S	0 - 5	0.69	62	3.1		4072050BR	-	3	19	0.05
EE	SDC-EE24-3-P-S	0 - 5	0.8	70	3		4085109Q	-	3.3	16	0.04
EE	SDC-EE25-1-P-S	0 - 5	0.58	148	7.6		4085110B	-	26	18	0.13
EE	SDC-EE25-3-P-S	0 - 5	1.58	72	5		REF (Tr)(2)	0	2.78	20	0.18
EE	SDC-EE26-1-P-S	0 - 5	0.73	123	4.8	Mean Concentrations Refs			7.440	17.571	0.085

AVERAGE VALUES AND BACKGROUND CONCENTRATIONS

Comparison of Reach/Zone Averages	Mercury	Lead	Arsenic	Comparison of Reach/Zone Averages	Mercury	Lead	Arsenic
Mean Concentrations LLBdM	1.652	167.832	2.908	Mean Concentrations Green Bay Zone 2	0.593	19.727	2.250
Mean Concentrations AP - LR	1.257	75.600	3.230	Mean Concentrations Green Bay Zone 3A	0.000	1.500	1.500
Mean Concentrations LR - DP	2.417	138.652	4.077	Mean Concentrations Green Bay Zone 3B	0.190	29.900	8.575
Mean Concentrations DP - GB	1.630	85.038	10.185	Mean Concentrations Green Bay Zone 4	0.110	3.100	4.975
Mean Concentrations DP - GB (w/o high concentration of 385 mg/kg).			*5.920*	Mean Concentrations References	7.440	17.571	0.085
NURE Average Background Conc.	**---**	**11.57**	**2.07**	**Lake Winnebago Average Conc.**	**0.14**	**35.0**	**5.33**
WDNR Triad Asses. Ref. Conc.	**0.18**	**20.0**	**2.78**	**EPA Background Levels (1986)**	**0.01-0.3**	**2-200**	**1-50**

Notes:
1) ND = parameter not detected in sample.
2) "0" depth indicates sample was collected from surface sediments.
3) na = parameter not analyzed in sample.

Table 5-6. Lower Fox River and Green Bay - Other RCRA Metals, Copper, Nickel, and Zinc

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Barium (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Nickel (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)
LOWER FOX RIVER										
Little Lake Butte des Morts Reach										
A	BA-SD01comp	0 - 61	109	9.8	85.6	73.5	29.1	1.3	ND	2050
A	BA-SD04comp	0 - 43	136	ND	69.9	97.4	26.4	1.5	ND	357
A	BA-SD08comp	0 - 46	127	ND	72.3	108	21.1	ND	ND	271
A	BA-SD34	0 - 61	148	12.5	56.4	75.5	25.5	3	1.7	1720
A	BA-SD35	0 - 34	24.3	ND	13	11.2	16.3	ND	ND	20.1
A	S00009	0 - 10	79	4.9	57	69	19	ND	1.3	1200
C	2C2 (Tr)	"0"	na	2	48	110	13	0.64	ND	na
C	SDC-C-1-P-S	0 - 5	na	4	64	154	24	na	na	460
C	SDC-C-3-P-S	0 - 5	na	2.2	39	77	18	na	na	420
C	S00003	0 - 10	85	3	53	110	18	ND	1.5	480
D	D-RI-Comp1(0-2)	0 - 61	63.1	4.98	41.8	59.6	16.2	0.34	ND	224
D	D-RI-Comp1(2-4)	61 - 122	14.2	1.06	5.12	3.5	4.07	ND	ND	11.2
D	D-RI-Comp2(0-2)	0 - 61	ND	ND	53.1	69	14.7	0.46	0.7	244
D	S00025	0 - 10	58	1.7	34	38	15	ND	ND	230
D	S00026	0 - 10	70	1.2	39	57	17	ND	ND	230
D	S00049	0 - 10	53	0.74	29	30	12	ND	ND	160
E	2E8 (Tr)	"0"	na	1	60	49	17	0.98	ND	na
E	E-RI-Comp1(0-2)	0 - 61	101	4.7	35.2	34.5	12.5	0.15	ND	na
E	E-RI-Comp1(2-4)	61 - 122	51.2	2.8	15.4	14.2	9.84	ND	ND	35.8
E	E-RI-Comp2(0-2)	0 - 61	78.8	4.2	42.9	47	12.8	ND	1.5	143
E	S00027	0 - 10	81	0.78	41	53	21	ND	ND	230
E	S00029	0 - 10	64	0.51	45	58	19	ND	1.2	180
E	SDC-E-1-P-S	0 - 5	na	3.1	89	127	25	na	na	390
E	SDC-E-3-P-S	0 - 5	na	ND	36	48	24	na	na	110
F	S00028	0 - 10	110	1.6	67	65	25	ND	ND	900
POG	P-RI-Comp1(0-2)	0 - 61	77.9	5.09	55.6	93.9	16.7	0.52	1	236
POG	P-RI-Comp1(2-4)	61 - 122	124	6.15	61.2	117	20.45	0.72	1.55	292
POG	P-RI-Comp1(4-6)	122 - 183	131	8.3	64.2	120	22.1	0.7	1.6	294
POG	POG (Tr)	"0"	na	2	43	60	13	0.71	ND	140
POG	S00024	0 - 10	590	1.2	32	210	13	ND	ND	630
Interdeposit	S00022	0 - 10	54	0.95	36	50	15	ND	ND	130
Reach Average			105.63	3.48	47.86	73.85	17.93	0.92	1.34	421.00

Table 5-6. Lower Fox River and Green Bay - Other RCRA Metals, Copper, Nickel, & Zinc (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Barium (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Nickel (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)
Appleton to Little Rapids Reach										
P	S00007	0 - 10	55	0.93	40	28	18	ND	ND	170
P	S00008	0 - 10	51	ND	29	43	15	2.4	ND	140
W	S00005	0 - 10	57	0.69	39	54	15	3	ND	110
W	SDC-W-2-P-S	0 - 5	na	0.6	26	57	15	na	na	91
W	SDC-W-3-P-S	0 - 5	na	0.5	20	54	9	na	na	83
W	SDC-X-1-P-S	0 - 5	na	1.5	57	90	21	na	na	130
W	SDC-X-3-P-S	0 - 5	na	0.8	40	119	16	na	na	94
X	S00004	0 - 10	73	1	91	43	14	1.7	ND	120
X	X (Tr)	"0"	na	2	95	89	17	0.83	ND	180
Interdeposit	S00060	0 - 10	55	0.74	67	58	11	3.2	ND	110
Reach Average			58.2	0.97	50.40	63.50	15.10	2.23	ND	122.80
Little Rapids to DePere Reach										
EE	S00021	0 - 10	67	1.2	40	67	14	ND	ND	140
EE	S00023	0 - 10	35	0.51	26	49	8.9	ND	ND	74
EE	S00036	0 - 10	94	1.5	65	75	18	ND	ND	160
EE	SDC-EE22-2-P-S	0 - 5	na	0.7	39	61	17	na	na	120
EE	SDC-EE22-3-P-S	0 - 5	na	1.6	88	99	22	na	na	180
EE	SDC-EE23-2-P-S	0 - 5	na	1.5	36	80	17	na	na	116
EE	SDC-EE23-3-P-S	0 - 5	na	1.2	42	88	17	na	na	120
EE	SDC-EE24-1-P-S	0 - 5	na	0.5	40	56	14	na	na	91
EE	SDC-EE24-3-P-S	0 - 5	na	2	46	53	19	na	na	120
EE	SDC-EE25-1-P-S	0 - 5	na	4	83	124	26	na	na	220
EE	SDC-EE25-3-P-S	0 - 5	na	0.9	49	59	18	na	na	130
EE	SDC-EE26-1-P-S	0 - 5	na	6	90	104	27	na	na	210
EE	SDC-EE26-5-P-S	0 - 5	na	3.1	108	149	28	na	na	330
EG	EGH-RI-Comp1(0-2)	0 - 61	128	7.54	92.7	115	21.5	0.39	1.12	276
EG	EGH-RI-Comp1(2-4)	61 - 122	118	7.4	62.2	110	21.8	0.12	0.66	221
EG	EGH-RI-Comp1(4-6)	122 - 183	98.7	5.3	48.2	72.8	20	ND	ND	144
EG	EGH-RI-Comp1(6-8)	183 - 244	40.67	2.89	21.7	26.9	9.54	ND	ND	56.8
HH	HH (Tr)	"0"	na	3	420	95	19	1.01	ND	230
HH	S00001	0 - 10	83	1.1	55	61	20	2.3	ND	160
HH	S00034	0 - 10	94	1.3	74	98	19	ND	ND	180
Interdeposit	S00002	0 - 10	72	1	51	100	16	ND	ND	140
Interdeposit	S00033	0 - 10	73	0.83	52	66	17	ND	ND	140
Interdeposit	S00035	0 - 10	79	1.1	56	65	17	ND	ND	170
Reach Average			81.86	2.44	73.25	81.47	18.55	0.96	0.89	162.12

Table 5-6. Lower Fox River and Green Bay - Other RCRA Metals, Copper, Nickel, & Zinc (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Barium (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Nickel (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)
DePere to Green Bay Reach										
20	95004-01	0 - 10	na	1.6	70	71.7	18.21	ND	0.84	196.08
20	95008-01	0 - 10	na	1.8	73.5	73.1	19.51	ND	0.69	206.07
20	S00010	0 - 10	48	0.81	43	49	12	ND	ND	110
20	SDC-DPD-1-P-S	0 - 5	na	1.6	80	84	22	na	na	190
20	SDC-DPD-2-P-S	0 - 5	na	1.3	65	78	22	na	na	160
21	95018-01	0 - 10	na	1.2	62.3	70.2	17.11	ND	ND	164.08
21	95020-01	0 - 10	na	0.78	26.9	33.8	8.41	ND	ND	143.08
21	S00013	0 - 10	79	1.1	70	80	17	ND	ND	150
21	S00014	0 - 10	71	1.1	63	59	16	ND	ND	150
22	95002-01	0 - 10	na	1.7	75.6	72.1	16.41	ND	0.6	187.08
22	95006-01	0 - 10	na	ND	44	27.1	21.01	ND	ND	68.6
23	95016-01	0 - 10	na	ND	18.7	30.4	6.51	ND	ND	54.7
23	95022-01	0 - 10	na	ND	6.6	5	3.71	ND	ND	13.8
24	95007-01	0 - 10	na	0.66	49.3	56.6	13.51	ND	ND	145.08
24	S00011	0 - 10	59	ND	48	54	13	2.9	ND	130
25	95013-01	0 - 10	na	0.57	54.5	52.7	13.61	ND	ND	124.08
25	S00012	0 - 10	43	ND	31	41	11	ND	ND	72
29	95025-01	0 - 10	na	0.95	64.9	62.9	18.01	ND	ND	184.08
29	95028-01	0 - 10	na	1.3	63.2	63.9	14.31	ND	ND	165.08
35	95030-01	0 - 10	na	1.2	56.1	64.3	17.11	ND	ND	161.08
38	95035-01	0 - 10	na	10.8	102.08	108.05	112.11	391.59	9.6	276.08
38	S00015	0 - 10	29	ND	22	18	10	ND	ND	49
41	95038-01	0 - 10	na	1.8	119.08	75.8	20.81	ND	0.84	255.08
41	S00016	0 - 10	66	1.2	55	54	18	ND	1.4	140
43	S00018	0 - 10	24	0.43	21	18	9	ND	ND	60
44	S00017	0 - 10	54	0.73	43	35	15	ND	ND	120
44	S00051	0 - 10	67	0.69	50	52	16	ND	ND	140
45	95054-01	0 - 10	na	1.4	59.7	59.6	18.71	ND	ND	174.08
45	S00052	0 - 10	61	0.82	49	58	16	ND	ND	140
45	SDC-DPD-3-P-S	0 - 5	na	1.2	58	61	24	na	na	160
46	95041-01	0 - 10	na	1.2	59.7	53.8	19.4	ND	ND	164
46	95044-01	0 - 10	na	0.96	55.9	52.2	16.81	ND	ND	156.07
47	95047-01	0 - 10	na	1.5	64.8	66.8	19.11	ND	1.2	189.07
47	95051-01	0 - 10	na	1.8	64.9	67.3	19.7	ND	0.65	190
47	95058-01	0 - 10	na	1.6	51	57.2	14.4	ND	ND	137
47	95109-01	0 - 10	na	1.4	63	60.4	17.2	ND	ND	162

Table 5-6. Lower Fox River and Green Bay - Other RCRA Metals, Copper, Nickel, & Zinc (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Barium (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Nickel (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)
48	95049-01	0 - 10	na	0.9	56.5	55.7	13.1	ND	ND	129
48	S00061	0 - 10	68	0.93	48	54	16	ND	ND	120
48	S00062	0 - 10	63	0.86	51	50	16	ND	ND	130
49	95052-01	0 - 10	na	0.73	45.8	59.4	14.1	ND	ND	123
49	95056-01	0 - 10	na	0.8	59.2	65.6	16.7	ND	ND	157
50	95060-01	0 - 10	na	0.91	25	21.2	9.3	ND	ND	67.2
52	95061-01	0 - 10	na	1.3	58.5	64.2	17.1	ND	ND	165
53	95062-01	0 - 10	na	1.3	36.3	40.7	12.2	ND	ND	93.7
54	S00019	0 - 10	26	ND	22	19	8.4	ND	ND	55
56	95066-01	0 - 10	na	1.6	72.8	71.1	19.7	ND	0.59	485
56	95068-01	0 - 10	na	1.5	59.9	64.2	18.7	ND	ND	183
56/57	B2 4-12"	10 - 30	81	1.3	78	63	18	ND	na	190
56/57	B2 1-2'	30 - 61	120	2	110	86	23	2	na	270
56/57	B2 2-3'	61 - 91	110	1.5	120	81	21	ND	na	260
56/57	B2 3-4'	91 - 122	110	1.7	160	92	21	1.7	na	310
56/57	B2 4-5'	122 - 152	130	1.5	210	110	22	ND	na	320
56/57	B2 5-6'	152 - 183	140	1.7	220	120	22	ND	na	280
56/57	B2 6-7'	183 - 213	140	1.7	130	110	21	ND	na	250
56/57	B2 7-8'	213 - 244	150	2.3	150	160	23	2.5	na	310
56/57	B2 8-9'	244 - 274	160	3.1	130	140	26	3.9	na	360
56/57	B2 9-10'	274 - 305	210	1.7	130	100	18	2.2	na	240
56/57	B2 10-11'	305 - 366	140	2.2	100	130	23	ND	na	270
56/57	B2 11-12'	335 - 366	170	3.5	89	130	21	1.6	na	280
57	95070-01	0 - 10	na	1.2	60.6	62.8	19.8	ND	ND	178
57	95071-01	0 - 10	na	1.6	64.9	69.2	19.4	ND	ND	178
57	95074-01	0 - 10	na	1.8	73.5	72	22.4	ND	ND	204
61	95072-01	0 - 10	na	1.2	64.2	64	20.2	ND	ND	180
62	95076-01	0 - 10	na	1.2	66.7	69.5	21.2	ND	ND	193
62	S00053	0 - 10	52	0.77	37	44	14	ND	ND	110
65	95077-01	0 - 10	na	1.6	70.5	70.5	22.6	7.8	0.62	196
65	95079-01	0 - 10	na	0.99	67	56.2	18.5	ND	0.77	162
70	95078-01	0 - 10	na	1.8	72.7	74.3	23.6	ND	ND	212
70	95080-01	0 - 10	na	1.3	73.4	74.5	23.4	ND	1	206
70	95081-01	0 - 10	na	1.5	91.2	75.8	19.6	ND	0.98	223
71	95082-01	0 - 10	na	1.2	59.8	57.2	18	ND	0.7	161
72	S00020	0 - 10	55	ND	38	43	13	ND	2.1	110

Table 5-6. Lower Fox River and Green Bay - Other RCRA Metals, Copper, Nickel, & Zinc (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Barium (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Nickel (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)
76	95084-01	0 - 10	na	0.85	66.2	66.1	20.3	ND	0.9	184
77	95085-01	0 - 10	na	0.59	56.7	38.3	14.5	ND	ND	194
82	95086-01	0 - 10	na	1.3	61.2	65.1	28.3	ND	0.98	209
82	95087-01	0 - 10	na	0.63	46.4	46.8	9.5	ND	ND	123
82	95088-01	0 - 10	na	1.4	66	59.7	17.4	ND	0.83	176
83	95089-01	0 - 10	na	1.1	59.3	61.1	19.7	ND	0.79	175
88	95090-01	0 - 10	na	1.5	85.6	65.6	19.9	ND	1.1	220
88	95091-01	0 - 10	na	0.76	18.5	28.2	12	ND	1.1	93.5
89	95092-01	0 - 10	na	0.75	31.1	68.4	23	ND	0.86	169
94	95093-01	0 - 10	na	1.1	57.2	62.6	19.7	ND	1	174
94	95094-01	0 - 10	na	ND	42.1	43.6	15.3	ND	0.62	117
95	95095-01	0 - 10	na	ND	28.2	27.5	15.6	ND	ND	90.2
95	95096-01	0 - 10	na	ND	5.2	6.2	16.2	ND	ND	20.2
96	SDC-DPD-4-P-S	0 - 5	na	ND	8	8	5	na	na	23
100	95097-01	0 - 10	na	0.84	22.2	30.3	16.6	ND	ND	164
100	95098-01	0 - 10	na	ND	15.5	108	10.9	ND	ND	48.1
101	95099-01	0 - 10	na	ND	4.6	4.1	9.2	ND	ND	11.2
101	95101-01	0 - 10	na	ND	9.6	8.7	3.5	ND	ND	28.5
106	95100-01	0 - 10	na	ND	35	39.7	18.6	ND	ND	97.8
107	95102-01	0 - 10	na	1.3	65.3	71.5	28.9	ND	0.93	190
109	95103-01	0 - 10	na	0.65	41.5	41.5	21.3	ND	0.65	113
112	95104-01	0 - 10	na	ND	15	19.6	27.2	ND	ND	51.5
112	95105-01	0 - 10	na	0.88	48.9	52.5	18.3	ND	0.88	143
113	95106-01	0 - 10	na	1.4	50.9	58.1	17.4	ND	ND	152
115	SDC-DPD-5-P-S	0 - 5	na	0.9	50	56	24	na	na	130
unknown	2FRB1 (Tr)	"0"	na	2	66	72	15	0.14	ND	na
unknown	2FRB17 (Tr)	"0"	na	1	17	26	9	0.94	ND	na
unknown	2FRB22 (Tr)	"0"	na	2	100	120	16	0.25	ND	na
unknown	4085139AB	-	400	1.3	100	62	27	0.8	0.6	190
unknown	4085139B	-	370	1.3	99	64	28	0.8	0.6	180
unknown	FRB (Tr)	"0"	na	2	160	87	19	0.84	ND	250
unknown	FRB1	-	na	2	66	72	15	0.14	na	na
unknown	95010-01	0 - 10	na	1.2	69	64	15.61	ND	ND	175.07
unknown	95011-01	0 - 10	na	1	63.6	69.4	16.81	ND	0.54	174.07
unknown	95064-01	0 - 10	na	ND	8.2	5	3.2	ND	ND	19
Reach Average			109.87	1.42	63.03	60.98	18.13	26.26	1.17	162.46

Table 5-6. Lower Fox River and Green Bay - Other RCRA Metals, Copper, Nickel, & Zinc (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Barium (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Nickel (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)
GREEN BAY										
Green Bay Zone 2 (2A & 2B)										
	S00030	0 - 10	15	0.11	8.6	7.9	4.7	ND	ND	22
	S00031	0 - 10	13	ND	8.9	8.7	4.4	ND	ND	26
	S00032	0 - 10	4.9	ND	2.4	ND	1.4	ND	ND	4
	S00037	0 - 10	40	0.72	34	29	12	ND	ND	99
	S00038	0 - 10	23	0.45	19	21	7.2	ND	ND	63
	S00039	0 - 10	37	0.58	32	31	11	ND	ND	95
	S00040	0 - 10	38	0.79	36	35	12	ND	ND	110
	S00056	0 - 10	8.6	0.1	6.2	15	3.4	ND	ND	12
	S00057	0 - 10	23	0.16	15	16	6.9	ND	ND	43
	S00058	0 - 10	27	0.26	21	16	9.1	ND	ND	46
	S00063	0 - 10	27	ND	13	10	5.8	ND	ND	27
Zone Average			23.32	0.40	17.83	18.96	7.08	ND	ND	49.73
Green Bay Zone 3A										
	S00042	0 - 10	3.4	ND	1.6	1.3	1.3	ND	ND	3.9
	S00043	0 - 10	5.3	ND	2.7	1.1	1.4	ND	ND	7.7
Zone Average			4.35	ND	2.15	1.20	1.35	ND	ND	5.80
Green Bay Zone 3B										
	S00041	0 - 10	14	0.18	8.4	5.9	4.6	0.87	ND	20
	S00047	0 - 10	39	0.59	21	14	10	ND	ND	63
	S00048	0 - 10	38	0.67	20	13	11	ND	ND	61
	S00054	0 - 10	120	0.81	40	36	23	ND	ND	110
Zone Average			52.75	0.5625	22.35	17.225	12.15	0.87	ND	63.5
Green Bay Zone 4										
	S00044	0 - 10	6.2	ND	4.5	1.5	2.2	ND	ND	15
	S00045	0 - 10	5.7	0.07	3.5	3.2	2.3	ND	ND	8.7
	S00046	0 - 10	7.2	ND	4.9	1.6	1.9	ND	ND	9.1
	S00055	0 - 10	4.2	ND	2.6	1.2	1.6	ND	ND	7.2
Zone Average			5.825	0.07	3.875	1.875	2	ND	ND	10

Table 5-6. Lower Fox River and Green Bay - Other RCRA Metals, Copper, Nickel, & Zinc (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Barium (mg/kg)	Cadmium (mg/kg)	Chromium (mg/kg)	Copper (mg/kg)	Nickel (mg/kg)	Selenium (mg/kg)	Silver (mg/kg)	Zinc (mg/kg)
Reference										
	4072050AW	-	500.00	0.40	64.00	31.00	30.00	0.80	0.20	96.00
	4072050B	-	450.00	0.50	61.00	23.00	26.00	0.90	0.20	87.00
	4072050BO	-	220.00	0.30	55.00	19.00	31.00	0.80	ND	96.00
	4072050BR	-	490.00	0.40	57.00	23.00	25.00	0.68	0.10	89.00
	4085109Q	-	530.00	0.20	69.00	30.00	34.00	0.50	0.10	78.00
	4085110B	-	na	1.10	57.00	11.00	14.00	1.20	0.20	150.00
	REF (Tr)(2)	"0"	na	1.00	20.00	23.00	12.00	1.56	ND	na
Reference Average			370.00	0.56	54.71	22.86	24.57	0.92	57.54	113.71
NURE Average Background Concentration			455.70	None	40.29	12.84	14.20	0.57	2.13	91.84
WDNR Triad Reference Background Conc.			na	1.00	20.00	23.00	12.00	1.56	ND	34.00
Lake Winnebago Avergae Conc.			na	ND	65.00	28.70	27.00	ND	ND	86.70
EPA Background Level (1986)			100 - 3,000	0.01 - 0.7	1 - 1,000	2 - 100	5 - 500	0.1 - 2	0.01 - 5	10 - 300

Notes:
1) ND = parameter not detected in sample.
2) "0" depth indicates sample was collected from surface sediments.
3) na = parameter not analyzed in sample.

Table 5-7. Lower Fox River and Green Bay - Miscellaneous Inorganic Compounds

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Aluminum (mg/kg)	Antimony (mg/kg)	Beryllium (mg/kg)	Calcium (mg/kg)	Cobalt (mg/kg)	Iron (mg/kg)	Magnesium (mg/kg)	Manganese (mg/kg)	Potassium (mg/kg)	Sodium (mg/kg)	Thallium (mg/kg)	Vanadium (mg/kg)
LOWER FOX RIVER														
Little Lake Butte des Morts Reach														
A	BA-SD01comp	0 - 61	14800.00	ND	0.84	62900.00	11.30	23400.00	17800.00	484.00	2140.00	624.00	ND	34.40
A	BA-SD04comp	0 - 43	14500.00	ND	0.74	33000.00	11.30	19200.00	14300.00	231.00	2220.00	ND	ND	32.60
A	BA-SD08comp	0 - 46	22900.00	ND	0.77	55700.00	9.40	19100.00	22400.00	326.00	3230.00	521.00	ND	37.20
A	BA-SD34	0 - 61	18400.00	ND	1.10	67400.00	8.60	25700.00	22100.00	1390.00	2350.00	688.00	ND	34.30
A	BA-SD35	0 - 34	5720.00	ND	0.25	90600.00	4.80	14100.00	52400.00	332.00	969.00	319.00	ND	30.90
A	S00009	0 - 10	8500.00	ND	0.75	64000.00	8.50	15000.00	25000.00	350.00	1200.00	560.00	ND	21.00
C	2C2 (Tr)	"0"	na	10.00	0.70	na	na	na	na	na	na	na	25.00	na
C	S00003	0 - 10	11000.00	ND	0.76	54000.00	6.60	16000.00	18000.00	310.00	1300.00	490.00	ND	21.00
D	D-RI-Comp1(0-2)	0 - 61	10.00	ND	1.08	75.00	8.65	23.00	38.00	386.00	1750.00	2470.00	ND	23.10
D	D-RI-Comp1(2-4)	61 - 122	2570.00	ND	0.33	57100.00	4.32	2860.00	30400.00	233.00	737.00	1040.00	ND	7.04
D	D-RI-Comp2(0-2)	0 - 61	6880.00	ND	0.48	86900.00	8.10	21500.00	45800.00	416.00	2140.00	1870.00	ND	20.80
D	S00025	0 - 10	7300.00	2.90	0.32	50000.00	6.40	17000.00	19000.00	310.00	1000.00	730.00	ND	19.00
D	S00026	0 - 10	8600.00	ND	0.40	50000.00	7.20	15000.00	20000.00	350.00	1100.00	200.00	ND	20.00
D	S00049	0 - 10	7200.00	ND	0.51	31000.00	4.90	12000.00	11000.00	260.00	950.00	500.00	ND	16.00
E	2E8 (Tr)	"0"	na	10.00	0.70	na	na	na	na	na	na	na	25.00	na
E	E-RI-Comp1(0-2)	0 - 61	10400.00	ND	1.05	57000.00	5.60	14800.00	28300.00	312.00	1750.00	1570.00	ND	20.50
E	E-RI-Comp1(2-4)	61 - 122	9600.00	ND	0.67	16400.00	7.30	19400.00	71500.00	809.00	1520.00	1100.00	ND	17.70
E	E-RI-Comp2(0-2)	0 - 61	7380.00	2.87	1.14	78000.00	7.20	16500.00	40300.00	366.00	1730.00	1720.00	ND	20.00
E	S00027	0 - 10	11000.00	ND	0.44	51000.00	8.10	18000.00	16000.00	370.00	1500.00	350.00	ND	27.00
E	S00029	0 - 10	8100.00	ND	0.22	63000.00	11.00	18000.00	24000.00	370.00	1500.00	880.00	ND	24.00
F	S00028	0 - 10	15000.00	ND	0.61	52000.00	12.00	25000.00	18000.00	450.00	2500.00	880.00	ND	35.00
POG	P-RI-Comp1(0-2)	0 - 61	15800.00	0.66	1.21	92700.00	7.55	25000.00	46700.00	455.00	3480.00	2210.00	ND	29.60
POG	P-RI-Comp1(2-4)	61 - 122	21450.00	0.59	1.30	64100.00	8.15	32900.00	33100.00	421.00	4710.00	2140.00	ND	39.40
POG	P-RI-Comp1(4-6)	122 - 183	16700.00	0.56	1.31	53000.00	8.80	24200.00	27600.00	369.00	3100.00	2120.00	ND	34.00
POG	POG (Tr)	"0"	na	25.00	0.50	na	na	na	na	na	na	na	25.00	na
POG	S00024	0 - 10	3600.00	ND	0.32	58000.00	5.40	13000.00	26000.00	210.00	620.00	340.00	ND	16.00
Interdeposit	S00022	0 - 10	6900.00	ND	0.39	63000.00	7.20	17000.00	26000.00	340.00	1300.00	500.00	ND	22.00
Appleton to Little Rapids Reach														
P	S00007	0 - 10	7400.00	ND	0.64	45000.00	8.90	15000.00	18000.00	260.00	1200.00	430.00	ND	22.00
P	S00008	0 - 10	7400.00	ND	0.54	43000.00	6.40	12000.00	17000.00	240.00	1200.00	220.00	ND	20.00
W	S00005	0 - 10	7500.00	ND	0.59	36000.00	8.10	13000.00	17000.00	220.00	1100.00	270.00	ND	23.00
X	S00004	0 - 10	5600.00	ND	0.43	140000.00	3.80	10000.00	13000.00	290.00	780.00	2200.00	ND	16.00
X	X (Tr)	"0"	na	25.00	0.60	na	na	na	na	na	na	na	25.00	na
Interdeposit	S00060	0 - 10	5600.00	ND	0.31	28000.00	3.80	9400.00	12000.00	200.00	890.00	400.00	ND	17.00

Table 5-7. Lower Fox River and Green Bay - Miscellaneous Inorganic Compounds (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Aluminum (mg/kg)	Antimony (mg/kg)	Beryllium (mg/kg)	Calcium (mg/kg)	Cobalt (mg/kg)	Iron (mg/kg)	Magnesium (mg/kg)	Manganese (mg/kg)	Potassium (mg/kg)	Sodium (mg/kg)	Thallium (mg/kg)	Vanadium (mg/kg)
Little Rapids to DePere Reach														
EE	S00021	0 - 10	8300.00	ND	0.31	42000.00	6.50	13000.00	21000.00	270.00	1400.00	420.00	2.20	23.00
EE	S00023	0 - 10	4500.00	ND	0.17	45000.00	4.80	9100.00	24000.00	220.00	760.00	430.00	ND	14.00
EE	S00036	0 - 10	13000.00	ND	0.36	34000.00	6.90	17000.00	15000.00	310.00	2000.00	590.00	ND	28.00
EG	EGH-RI-Comp1(0-2	0 - 61	19800.00	0.31	1.38	32900.00	8.31	25000.00	18300.00	367.00	2770.00	32.30	ND	34.10
EG	EGH-RI-Comp1(2-4	61 - 122	23300.00	ND	1.28	47.00	8.70	34.00	28.00	456.00	2490.00	68.20	0.19	34.50
EG	EGH-RI-Comp1(4-6	122 - 183	18400.00	ND	1.11	53.00	8.34	30.00	31.00	465.00	3590.00	270.00	ND	36.90
EG	EGH-RI-Comp1(6-8	183 - 244	7730.00	ND	ND	70.00	4.80	14.00	40.00	346.00	1330.00	107.00	ND	23.50
HH	HH (Tr)	"0"	na	25.00	0.70	na	na	na	na	na	na	na	25.00	na
HH	S00001	0 - 10	12000.00	ND	0.89	50000.00	7.00	18000.00	21000.00	380.00	2000.00	480.00	ND	29.00
HH	S00034	0 - 10	11000.00	4.20	0.36	35000.00	5.90	15000.00	17000.00	260.00	1500.00	240.00	ND	25.00
Interdeposit	S00002	0 - 10	9400.00	ND	0.65	44000.00	5.80	15000.00	18000.00	350.00	1400.00	270.00	ND	23.00
Interdeposit	S00033	0 - 10	11000.00	ND	0.31	36000.00	5.60	16000.00	14000.00	350.00	1800.00	400.00	ND	26.00
Interdeposit	S00035	0 - 10	13000.00	ND	0.52	39000.00	6.10	17000.00	17000.00	310.00	2600.00	540.00	ND	29.00
DePere to Green Bay Reach														
	2FRB1 (Tr)	"0"	na	10.00	0.60	na	na	na	na	na	na	na	25.00	na
	2FRB17 (Tr)	"0"	na	10.00	0.40	na	na	na	na	na	na	na	25.00	na
	2FRB22 (Tr)	"0"	na	10.00	0.70	na	na	na	na	na	na	na	25.00	na
	4085139AB	-	57000.00	2.00	1.00	59000.00	11.00	29000.00	26000.00	670.00	22000.00	5200.00	na	61.00
	4085139B	-	52000.00	1.00	1.00	62000.00	12.00	29000.00	23000.00	630.00	21000.00	4900.00	na	61.00
	FRB (Tr)	"0"	na	25.00	0.90	na	na	na	na	na	na	na	25.00	na
	FRB1	-	na	10.00	0.60	na	na	na	na	na	na	na	ND	na
20	S00010	0 - 10	6400.00	ND	0.51	36000.00	4.20	11000.00	16000.00	230.00	920.00	230.00	ND	16.00
21	95015-01	0 - 10	na	na	na	na	na	na	na	na	na	na	na	na
21	S00013	0 - 10	14000.00	ND	0.90	42000.00	5.40	17000.00	18000.00	310.00	2700.00	420.00	ND	30.00
21	S00014	0 - 10	11000.00	ND	0.76	43000.00	5.50	16000.00	18000.00	300.00	1800.00	460.00	ND	25.00
24	S00011	0 - 10	7800.00	ND	0.61	39000.00	4.90	14000.00	17000.00	300.00	1400.00	870.00	2.00	23.00
25	S00012	0 - 10	7600.00	ND	0.49	39000.00	4.30	10000.00	17000.00	240.00	1500.00	770.00	ND	19.00
38	S00015	0 - 10	5800.00	ND	0.37	24000.00	4.20	8000.00	12000.00	150.00	1100.00	550.00	ND	14.00
41	S00016	0 - 10	10000.00	ND	0.69	43000.00	6.20	16000.00	18000.00	320.00	1700.00	460.00	ND	26.00
43	S00018	0 - 10	3200.00	ND	0.25	24000.00	5.20	7000.00	11000.00	150.00	460.00	62.00	ND	9.60
44	S00017	0 - 10	8600.00	ND	0.56	39000.00	5.60	13000.00	17000.00	270.00	1400.00	500.00	ND	21.00
44	S00051	0 - 10	11000.00	ND	0.63	38000.00	5.10	14000.00	16000.00	290.00	2100.00	930.00	ND	25.00
45	S00052	0 - 10	9300.00	ND	0.57	38000.00	5.20	14000.00	16000.00	290.00	1500.00	580.00	2.60	23.00
48	95049-01	0 - 10	na	na	na	na	na	na	na	na	na	na	na	na
48	S00061	0 - 10	11000.00	ND	0.62	43000.00	6.00	15000.00	18000.00	340.00	2000.00	850.00	ND	27.00
48	S00062	0 - 10	8700.00	3.10	0.48	43000.00	5.90	14000.00	18000.00	340.00	1400.00	250.00	ND	23.00

Table 5-7. Lower Fox River and Green Bay - Miscellaneous Inorganic Compounds (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Aluminum (mg/kg)	Antimony (mg/kg)	Beryllium (mg/kg)	Calcium (mg/kg)	Cobalt (mg/kg)	Iron (mg/kg)	Magnesium (mg/kg)	Manganese (mg/kg)	Potassium (mg/kg)	Sodium (mg/kg)	Thallium (mg/kg)	Vanadium (mg/kg)
54	S00019	0 - 10	3400.00	ND	0.29	41000.00	5.60	7700.00	20000.00	210.00	510.00	81.00	ND	11.00
56/57	B2 1-2'	30 - 61	na	na	na	na	na	20000.00	na	410.00	na	na	na	na
56/57	B2 10-11'	305 - 366	na	na	na	na	na	20000.00	na	300.00	na	na	na	na
56/57	B2 11-12'	335 - 366	na	na	na	na	na	19000.00	na	240.00	na	na	na	na
56/57	B2 2-3'	61 - 91	na	na	na	na	na	19000.00	na	320.00	na	na	na	na
56/57	B2 3-4'	91 - 122	na	na	na	na	na	18000.00	na	290.00	na	na	na	na
56/57	B2 4-12"	10 - 30	na	na	na	na	na	15000.00	na	330.00	na	na	na	na
56/57	B2 4-5'	122 - 152	na	na	na	na	na	18000.00	na	270.00	na	na	na	na
56/57	B2 5-6'	152 - 183	na	na	na	na	na	19000.00	na	270.00	na	na	na	na
56/57	B2 6-7'	183 - 213	na	na	na	na	na	18000.00	na	250.00	na	na	na	na
56/57	B2 7-8'	213 - 244	na	na	na	na	na	20000.00	na	260.00	na	na	na	na
56/57	B2 8-9'	244 - 274	na	na	na	na	na	22000.00	na	290.00	na	na	na	na
56/57	B2 9-10'	274 - 305	na	na	na	na	na	15000.00	na	250.00	na	na	na	na
62	S00053	0 - 10	6700.00	ND	0.46	32000.00	4.50	11000.00	12000.00	280.00	1100.00	440.00	ND	17.00
72	S00020	0 - 10	8100.00	ND	0.57	37000.00	4.40	12000.00	15000.00	280.00	1300.00	160.00	ND	20.00
GREEN BAY														
Green Bay Zone 2 (2A & 2B)														
	S00030	0 - 10	2400.00	ND	0.10	15000.00	2.20	4400.00	7800.00	110.00	290.00	170.00	ND	8.90
	S00031	0 - 10	2100.00	ND	0.05	15000.00	2.50	4100.00	7500.00	120.00	310.00	120.00	ND	6.90
	S00032	0 - 10	680.00	ND	ND	1500.00	0.41	1200.00	670.00	26.00	90.00	160.00	ND	2.80
	S00037	0 - 10	7600.00	ND	0.24	54000.00	4.90	12000.00	30000.00	300.00	1600.00	660.00	ND	20.00
	S00038	0 - 10	3500.00	ND	0.11	29000.00	4.40	7200.00	15000.00	180.00	550.00	210.00	ND	11.00
	S00039	0 - 10	6700.00	ND	0.32	52000.00	5.10	12000.00	29000.00	290.00	1300.00	670.00	ND	19.00
	S00040	0 - 10	5800.00	ND	0.26	27000.00	4.60	11000.00	14000.00	250.00	960.00	180.00	ND	17.00
	S00056	0 - 10	1600.00	ND	0.11	22000.00	1.40	3500.00	12000.00	140.00	230.00	100.00	ND	7.80
	S00057	0 - 10	3300.00	ND	0.23	26000.00	3.20	6900.00	14000.00	180.00	510.00	250.00	ND	12.00
	S00058	0 - 10	4900.00	ND	0.33	16000.00	3.20	7700.00	7900.00	200.00	730.00	210.00	ND	14.00
	S00063	0 - 10	4100.00	ND	0.30	16000.00	2.40	6500.00	7300.00	160.00	580.00	87.00	ND	15.00
Green Bay Zone 3A														
	S00042	0 - 10	460.00	ND	ND	3400.00	0.50	1600.00	1700.00	31.00	79.00	130.00	ND	4.40
	S00043	0 - 10	540.00	ND	0.07	4300.00	0.62	1900.00	2300.00	77.00	71.00	160.00	ND	5.20
Green Bay Zone 3B														
	S00041	0 - 10	2500.00	1.50	0.18	93000.00	2.30	5600.00	54000.00	400.00	610.00	210.00	ND	8.20
	S00047	0 - 10	4400.00	ND	0.36	50000.00	3.30	15000.00	29000.00	510.00	810.00	340.00	ND	18.00
	S00048	0 - 10	4400.00	ND	0.30	46000.00	3.20	15000.00	27000.00	510.00	800.00	240.00	ND	18.00
	S00054	0 - 10	13000.00	ND	0.83	15000.00	7.80	26000.00	9800.00	1900.00	2400.00	740.00	ND	41.00

Table 5-7. Lower Fox River and Green Bay - Miscellaneous Inorganic Compounds (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Aluminum (mg/kg)	Antimony (mg/kg)	Beryllium (mg/kg)	Calcium (mg/kg)	Cobalt (mg/kg)	Iron (mg/kg)	Magnesium (mg/kg)	Manganese (mg/kg)	Potassium (mg/kg)	Sodium (mg/kg)	Thallium (mg/kg)	Vanadium (mg/kg)
Green Bay Zone 4														
	S00044	0 - 10	550.00	ND	ND	7200.00	1.30	7500.00	3700.00	150.00	60.00	140.00	ND	6.40
	S00045	0 - 10	790.00	1.00	0.10	14000.00	0.67	2300.00	7400.00	110.00	130.00	60.00	ND	6.40
	S00046	0 - 10	840.00	ND	ND	23000.00	0.48	4600.00	13000.00	110.00	170.00	160.00	ND	8.40
	S00055	0 - 10	410.00	ND	ND	2300.00	0.57	4200.00	1200.00	65.00	62.00	89.00	ND	10.00
Reference														
	4072050AW	-	60000	0.5	1	30000	16	36000	17000	860	29000	7000	na	74
	4072050B	-	53000	0.7	1	32000	14	33000	17000	780	25000	6600	na	69
	4072050BO	-	58000	1	2	160000	12	25000	5700	790	12000	1300	na	120
	4072050BR	-	57000	0.38	1	34000	13	32000	18000	750	28000	7600	na	73
	4085109Q	-	66000	0.3	2	27000	16	36000	20000	560	31000	7200	na	80
	4085110B	-	35000	0.9	ND	12000	10	41000	5400	3100	12000	6600	na	56
	REF (Tr)(2)	"0"	na	10	0.5	na	na	na	na	na	na	na	25	na
Reference Averages			54,833.33	1.97	1.25	49,166.67	13.50	33,833.33	13,850.00	1,140.00	22,833.33	6,050.00	25.00	78.67
NURE Average Background Concentratio			3,399	---	1.49	1138.05	13.19	2006.30	669.40	733.74	1.63	744.9	na	60.94
WDNR Triad Reference Background Con			---	10	0.5	---	---	---	---	---	---	---	25	---
Lake Winnebago Avergae Conc.			na	na	na	na	na	na	na	na	na	na	na	na
EPA Background Level (1986)			10,000 to 300,000	2-10	0.1-40	---	1-40	---	600-6,000	20-3,000	---	---	---	20-500

Notes: 1) ND = parameter not detected in sample.
2) "0" depth indicates sample was collected from surface sediments.
3) na = parameter not analyzed in sample.

Table 5-8. Lower Fox River and Green Bay - Ammonia Results

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Ammonia (mg/kg)
LOWER FOX RIVER			
Little Lake Butte des Morts Reach			
A	S00009	0 - 10	160
C	2C2 (Tr)	"0"	141
C	S00003	0 - 10	220
D	D-RI-12(0-2)	0 - 61	101.4
D	D-RI-15(0-2)	0 - 61	52.3
D	D-RI-15(2-3.7)	61 - 113	45.1
D	D-RI-16(0-1.6)	0 - 49	47.6
D	D-RI-18(0-1.5)	0 - 46	55.0
D	D-RI-19(0-0.5)	0 - 15	25.0
D	D-RI-2(0-0.5)	0 - 15	41.7
D	D-RI-21(0-2)	0 - 61	97.3
D	D-RI-4(0-0.5)	0 - 15	37.6
D	D-RI-9(0-2)	0 - 61	128.7
D	S00025	0 - 10	160
D	S00026	0 - 10	230
D	S00049	0 - 10	290
E	2E8 (Tr)	"0"	68.5
E	E-RI-10(0-1.5)	0 - 46	59.2
E	E-RI-12(0-2)	0 - 61	155
E	E-RI-13(0-2)	0 - 61	73
E	E-RI-13(2-3.75)	61 - 114	70
E	E-RI-15(0-2)	0 - 61	75
E	E-RI-16(0-2)	0 - 61	200
E	E-RI-17(0-2)	0 - 61	213
E	E-RI-2(0-2)	0 - 61	54.7
E	E-RI-4(0-2)	0 - 61	69.4
E	E-RI-7(0-2)	0 - 61	167.2
E	E-RI-9(0-2)	0 - 61	135.9
E	S00027	0 - 10	220
E	S00029	0 - 10	280
F	S00028	0 - 10	300
POG	P-RI-12(0-1.4)	0 - 43	37
POG	P-RI-15(0-2)	0 - 61	282
POG	P-RI-17(0-1.2)	0 - 37	35
POG	P-RI-19(0-0.5)	0 - 15	29.05
POG	P-RI-2(0-1)	0 - 30	62.1
POG	P-RI-21(0-1.8)	0 - 55	87.2
POG	P-RI-22(0-0.4)	0 - 12	36.95
POG	P-RI-5(0-0.9)	0 - 27	41.2
POG	P-RI-7(0-2)	0 - 61	171
POG	POG (Tr)	"0"	240
POG	S00024	0 - 10	230
Interdeposit	S00022	0 - 10	300
Little Rapids to DePere Reach - cont.			
GG	GG-RI-1(0-2)	0 - 61	361
GG	GG-RI-10(0-0.9)	0 - 27	113
GG	GG-RI-13(0-2)	0 - 61	341.5
GG	GG-RI-4(0-2)	0 - 61	272
GG	GG-RI-6(0-2)	0 - 61	341
GG	GG-RI-8(0-2)	0 - 61	370
GG	GG-RI-9(0-2)	0 - 61	421
HH	HH (Tr)	"0"	700
HH	HH-RI-2(0-2)	0 - 61	276
HH	HH-RI-3(0-2)	0 - 61	336
HH	HH-RI-5(0-2)	0 - 61	160
HH	HH-RI-7(0-0.5)	0 - 15	96.4
HH	HH-RI-9(0-2)	0 - 61	323
HH	S00001	0 - 10	410
HH	S00034	0 - 10	280
Interdeposit	S00002	0 - 10	300
Interdeposit	S00033	0 - 10	280
Interdeposit	S00035	0 - 10	240
DePere to Green Bay Reach			
	2FRB1 (Tr)	"0"	89
	2FRB17 (Tr)	"0"	68.5
	2FRB22 (Tr)	"0"	357
	FRB (Tr)	"0"	590
20	S00010	0 - 10	150
21	S00013	0 - 10	170
21	S00014	0 - 10	170
24	S00011	0 - 10	170
25	S00012	0 - 10	130
38	S00015	0 - 10	80
41	S00016	0 - 10	390
43	S00018	0 - 10	150
44	S00017	0 - 10	180
44	S00051	0 - 10	120
45	S00052	0 - 10	150
48	S00061	0 - 10	90
54	S00019	0 - 10	120
62	S00053	0 - 10	180
72	S00020	0 - 10	280
GREEN BAY			
Green Bay Zone 2 (2A & 2B)			
	S00030	0 - 10	98
	S00031	0 - 10	83
	S00032	0 - 10	33
	S00037	0 - 10	65

Notes: 1) "0" depth indicates sample was collected from surface sediments.

Table 5-8. Lower Fox River and Green Bay - Ammonia Results (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Ammonia (mg/kg)	Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Ammonia (mg/kg)
Appleton to Little Rapids Reach					S00038	0 - 10	59
P	S00007	0 - 10	180		S00039	0 - 10	80
P	S00008	0 - 10	150		S00040	0 - 10	130
W	S00005	0 - 10	110		S00056	0 - 10	32
X	S00004	0 - 10	93		S00057	0 - 10	43
X	X (Tr)	"0"	340		S00058	0 - 10	120
Interdeposit	S00060	0 - 10	87	**Green Bay Zone 3A**			
Little Rapids to DePere Reach					S00042	0 - 10	69
EE	EE-RI-1(0-2)	0 - 61	191		S00043	0 - 10	77
EE	EE-RI-12(0-2)	0 - 61	280	**Green Bay Zone 3B**			
EE	EE-RI-19(0-2)	0 - 61	464.5		S00041	0 - 10	43
EE	EE-RI-24(0-2)	0 - 61	412		S00048	0 - 10	88
EE	EE-RI-29(0-2)	0 - 61	347		S00054	0 - 10	140
EE	EE-RI-4(0-2)	0 - 61	206	**Green Bay Zone 4**			
EE	EE-RI-5(0-2)	0 - 61	280		S00044	0 - 10	48
EE	EE-RI-8(0-2)	0 - 61	341		S00045	0 - 10	62
EE	S00021	0 - 10	63		S00046	0 - 10	22
EE	S00023	0 - 10	120		S00055	0 - 10	30
EE	S00036	0 - 10	240	**Reference**	**REF (Tr)(2)**	**"0"**	**31**

Notes: 1) "0" depth indicates sample was collected from surface sediments.

Table 5-9. Lower Fox River - Toxicity Characteristic Leaching Procedure (TCLP) Results

Deposit	Sample Identification	Depth (cm)	Arsenic (mg/L)	Barium (mg/L)	Cadmium (mg/L)	Chromium (mg/L)	Lead (mg/L)	Mercury (mg/L)	Selenium (mg/L)	Silver (mg/L)
Little Lake Butte des Morts Reach										
Deposit D	D-RI-Comp1(0-2)	0 - 61	0.009	0.936	ND	0.20	0.11	0.0005	ND	0.02
Deposit D	D-RI-Comp1(2-4)	61 - 122	0.003	0.591	ND	ND	ND	ND	ND	0.03
Deposit D	D-RI-Comp2(0-2)	0 - 61	0.0011	0.794	ND	0.12	0.11	ND	ND	0.02
Deposit E	E-RI-Comp1(0-2)	0 - 61	0.005	0.684	ND	0.01	ND	ND	ND	0.03
Deposit E	E-RI-Comp1(2-4)	61 - 122	0.003	0.789	ND	0.01	ND	ND	ND	0.02
Deposit E	E-RI-Comp2(0-2)	0 - 61	0.007	0.697	ND	0.01	0.06	ND	ND	0.02
Deposit POG	P-RI-Comp1(0-2)	0 - 61	0.006	0.588	0.01	ND	0.27	ND	ND	0.02
Deposit POG	P-RI-Comp1(2-4)	61 - 122	0.012	0.710	0.01	ND	0.27	0.0005	ND	0.02
Deposit POG	P-RI-Comp1(4-6)	122 - 183	0.011	0.357	ND	ND	0.11	ND	ND	0.02
Little Rapids to DePere Reach										
Deposit EG	EGH-RI-Comp1(0-2)	0 - 61	0.020	0.255	0.01	0.01	0.16	ND	ND	0.02
Deposit EG	EGH-RI-Comp1(2-4)	61 - 122	0.031	0.629	0.01	0.01	0.09	ND	ND	ND
Deposit EG	EGH-RI-Comp1(4-6)	122 - 183	0.029	0.503	0.01	ND	0.07	ND	ND	0.02
Deposit EG	EGH-RI-Comp1(6-8)	183 - 244	0.007	0.789	ND	0.01	ND	ND	ND	0.03
DePere to Green Bay Reach										
	FRB1	0	na	na	na	na	na	na	na	ND
Regulatory Levels			**5**	**100**	**1**	**5**	**5**	**0.2**	**1**	**5**

Notes: 1) ND = parameter not detected in sample.
2) na = parameter not analyzed in sample.

Table 5-10. Lower Fox River and Green Bay - Semi-Volatile Organic Compound Results (PAHs).

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Acenaphthene (µg/kg)	Acenaphthylene (µg/kg)	Anthracene (µg/kg)	Benzo(a)anthracene (µg/kg)	Benzo(a)pyrene (µg/kg)	Benzo(b)fluoranthene (µg/kg)	Benzo(ghi)perylene (µg/kg)	Benzo(k)fluoranthene (µg/kg)	Chrysene (µg/kg)	Dibenz(a,h)anthracene (µg/kg)
LOWER FOX RIVER												
Little Lake Butte des Morts Reach												
A	BA-SD01comp	0 - 61	64	ND	ND	390	440	920	150	na	ND	na
A	BA-SD04comp	0 - 43	ND	ND	ND	ND	ND	370	120	na	ND	na
A	BA-SD08comp	0 - 46	ND	54	48	ND	ND	620	230	na	270	na
A	S00009	0 - 10	ND	ND	ND	1300	2500	4100	3700	2300	2200	ND
C	S00003	0 - 10	ND	ND	ND	ND	1000	ND	1400	ND	1200	ND
C	2C2 (Tr)	"0"	9.25	9.25	116	573	691	446	684	243	1240	45.6
C	SDC-C-1-P-S	0 - 5	110	110	110	470	910	430	780	590	920	170
C	SDC-C-3-P-S	0 - 5	ND	71	160	710	1300	910	620	1100	1100	210
D	S00025	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
D	S00026	0 - 10	ND	ND	ND	ND	ND	2900	2600	ND	590	ND
D	S00049	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
E	2E8 (Tr)	"0"	9.25	9.25	47.6	236	289	175	317	76.9	341	30.9
E	E-RI-Comp2(0-2)	0 - 61	ND	ND	ND	113	142	156	ND	ND	143	90
E	SDC-E-1-P-S	0 - 5	ND	23	56	490	980	470	850	560	810	320
E	SDC-E-3-P-S	0 - 5	ND	ND	30	230	450	480	240	420	410	100
E	S00029	0 - 10	ND	ND	ND	ND	ND	3900	3200	ND	680	ND
F	S00028	0 - 10	ND	ND	ND	ND	ND	4100	3600	ND	ND	ND
POG	P-RI-Comp1(0-2)	0 - 61	ND	ND	ND	148	148	174	ND	ND	192	ND
POG	P-RI-Comp1(2-4)	61 - 122	ND	ND	ND	ND	77	ND	ND	ND	71	ND
POG	P-RI-Comp1(4-6)	122 - 183	ND	ND	ND	125	200	161	104	ND	182	ND
POG	S00024	0 - 10	580	ND	1400	3300	2900	4400	3400	2600	3800	ND
POG	POG (Tr)	"0"	9.25	9.25	110	310	390	290	300	290	450	66.1
Appleton to Little Rapids Reach												
P	S00007	0 - 10	ND	ND	ND	440	ND	ND	250	550	690	ND
P	S00008	0 - 10	ND	ND	180	1300	1200	ND	440	1600	2100	ND
W	SDC-W-2-P-S	0 - 5	ND	ND	100	380	410	360	280	440	540	100
W	SDC-W-3-P-S	0 - 5	130	110	360	980	950	810	530	800	1000	210
X	SDC-X-1-P-S	0 - 5	ND	ND	58	390	410	350	260	420	550	95
X	SDC-X-3-P-S	0 - 5	66	110	260	1000	1,100.00	810	660	1200	1200	260
W	S00005	0 - 10	ND	ND	ND	540	510	660	450	ND	660	ND
X	X (Tr)	"0"	120	120	270	1000	1100	900	660	900	1300	160
X	S00004	0 - 10	ND	170	160	870	910	610	490	640	990	ND
Interdeposit	S00060	0 - 10	ND	ND	ND	470	ND	ND	ND	ND	690	ND
Little Rapids to DePere Reach												
EE	SDC-EE22-2-P-S	0 - 5	ND	75	140	540.00	910	780	480	840	710	210
EE	SDC-EE22-3-P-S	0 - 5	ND	ND	64	250.00	330	220	200	300	350	70
EE	SDC-EE23-2-P-S	0 - 5	ND	ND	130	410.00	440	380	260	370	520	110
EE	SDC-EE23-3-P-S	0 - 5	ND	77	120	480.00	660	750	400	480	620	120
EE	SDC-EE24-1-P-S	0 - 5	ND	ND	150	530.00	690	660	340	500	650	130
EE	SDC-EE24-3-P-S	0 - 5	ND	ND	ND	170.00	310.00	190	250	310	280	85
EE	SDC-EE25-1-P-S	0 - 5	ND	ND	ND	290.00	410	220	370	380	470	100
EE	SDC-EE25-3-P-S	0 - 5	ND	ND	ND	280.00	520	470	290	440	420	130
EE	SDC-EE26-1-P-S	0 - 5	ND	ND	ND	340.00	600	250	540	570	600	140
EE	SDC-EE26-5-P-S	0 - 5	ND	ND	ND	310.00	600	310	690	200	620	ND
EE	S00021	0 - 10	ND	ND	ND	380	ND	2200	2000	ND	580	ND
EE	S00023	0 - 10	ND	ND	ND	300	ND	1600	1300	280	400	ND
EE	S00036	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	570	ND

Notes:
1) Sample results are in micrograms per kilogram (mg/kg).
2) ND = parameter not detected in sample.
3) na = parameter not analyzed in sample.
4) "0" depth indicates sample was collected from surface sediments.

Table 5-10. Lower Fox River and Green Bay - Semi-Volatile Organic Compound Results (PAHs) (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	Acenaphthene (µg/kg)	Acenaphthylene (µg/kg)	Anthracene (µg/kg)	Benzo(a)anthracene (µg/kg)	Benzo(a)pyrene (µg/kg)	Benzo(b)fluoranthene (µg/kg)	Benzo(ghi)perylene (µg/kg)	Benzo(k)fluoranthene (µg/kg)	Chrysene (µg/kg)	Dibenz(a,h)anthracene (µg/kg)
EG	EGH-RI-Comp1(0-2)	0 - 61	ND	ND	ND	ND	81	ND	ND	ND	79	ND
EG	EGH-RI-Comp1(2-4)	61 - 122	ND	ND	ND	ND	74	101	ND	ND	81	ND
HH	HH (Tr)	"0"	9.25	9.25	210	1200.00	1400	1200	700	1200	1400	66.1
HH	S00001	0 - 10	ND	ND	ND	ND	ND	ND	340	ND	530	ND
HH	S00034	0 - 10	ND	ND	ND	ND	ND	3000	2600	ND	540	ND
Interdeposit	S00002	0 - 10	ND	ND	ND	370	ND	ND	390	390	460	ND
Interdeposit	S00033	0 - 10	ND	ND	ND	ND	ND	3600	3000	ND	660	ND
Interdeposit	S00035	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	600	ND
DePere to Green Bay Reach												
20	SDC-DPD-1-P-S	0 - 5	ND	ND	56	400	910	650	640	730	630	150
20	SDC-DPD-2-P-S	0 - 5	ND	ND	ND	190	280	300	180	390	380	ND
20	S00010	0 - 10	ND	ND	ND	ND	ND	2700	2400	ND	650	ND
21	S00013	0 - 10	ND	ND	ND	540	ND	3300	2800	ND	800	ND
21	S00014	0 - 10	ND	ND	ND	ND	ND	3200	2800	ND	740	ND
24	S00011	0 - 10	ND	ND	ND	510	ND	3000	2600	ND	770	ND
25	S00012	0 - 10	ND	ND	ND	ND	ND	2300	1900	ND	ND	ND
38	S00015	0 - 10	ND	ND	ND	ND	ND	1400	1200	ND	240	ND
41	S00016	0 - 10	ND	ND	ND	ND	ND	3100	2700	ND	ND	ND
43	S00018	0 - 10	ND	ND	ND	ND	ND	1500	ND	ND	ND	ND
44	S00017	0 - 10	ND	ND	ND	610	ND	2500	2200	ND	960	ND
44	S00051	0 - 10	ND	ND	ND	ND	ND	2900	ND	ND	680	ND
45	SDC-DPD-3-P-S	0 - 5	ND	ND	ND	270	450	420	280	800	660	ND
45	S00052	0 - 10	ND	ND	ND	ND	ND	3000	ND	ND	ND	ND
54	S00019	0 - 10	ND	ND	ND	ND	ND	1600	1300	ND	280	ND
62	S00053	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
72	S00020	0 - 10	ND	ND	ND	ND	ND	3300	2700	ND	640	ND
96	SDC-DPD-4-P-S	0 - 5	31	34	92	360	420	310	180	320	420	77
115	SDC-DPD-5-P-S	0 - 5	85	85	85	150	240	240	170	300	330	85
unknown	2FRB1 (Tr)	"0"	9.25	9.25	52.3	217	277	223	377	126	350	51.3
unknown	2FRB17 (Tr)	"0"	9.25	9.25	25.6	135	134	83.5	8330	50.7	194	12.9
unknown	2FRB22 (Tr)	"0"	9.25	9.25	103	398	444	367	707	124	706	137
unknown	FRB (Tr)	"0"	9.25	9.25	3.06	480	530	710	190	400	710	66.1
unknown	4085139A	-	42	62	100	220	160	200	80	63	300	45
unknown	4085139AC	-	210	100	640	870	1700	840	480	670	1200	ND
GREEN BAY												
Green Bay Zone 2 (2A & 2B)												
	S00030	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
	S00037	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	350	ND
	S00039	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	350	ND
	S00040	0 - 10	ND	ND	ND	ND	ND	ND	ND	ND	440	ND
	S00057	0 - 10	ND	ND	ND	260	ND	ND	ND	ND	280	ND
None of the listed PAHs were detectedin Green Bay Zone 3												
None of the listed PAHs were detectedin Green Bay Zone 4												
Reference												
	REF (Tr)(2)	"0"	9.25	9.25	3.06	18.2	24.1	23.5	40.4	11	20.8	66.1
	4072050BS	-	ND	ND	ND	ND	ND	ND	18.9	ND	ND	ND
	4085110A	-	ND	ND	ND	14	57	24	6	ND	13	ND

Notes:
1) Sample results are in micrograms per kilogram (mg/kg).
2) ND = parameter not detected in sample.
3) na = parameter not analyzed in sample.
4) "0" depth indicates sample was collected from surface sediments.

Table 5-10. Lower Fox River and Green Bay - Semi-Volatile Organic Compound Results (PAHs) (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	1-Methylnaphthalene (µg/kg)	2-Methylnaphthalene (µg/kg)	Fluoranthene (µg/kg)	Fluorene (µg/kg)	Indeno(1,2,3-cd)pyrene (µg/kg)	Naphthalene (µg/kg)	Phenanthrene (µg/kg)	Pyrene (µg/kg)	Total PAHs (µg/kg)	Total PCBs (µg/kg)
LOWER FOX RIVER												
Little Lake Butte des Morts Reach												
A	BA-SD01comp	0 - 61	na	140	990	99	260	120	640	1400	5,613	7,500
A	BA-SD04comp	0 - 43	na	ND	390	ND	ND	ND	220	580	1,680	2,300
A	BA-SD08comp	0 - 46	na	ND	390	ND	190	ND	230	580	2,612	120
A	S00009	0 - 10	na	ND	2900	ND	3400	ND	1400	2800	26,600	15,000
C	S00003	0 - 10	na	ND	1100	ND	760	ND	390	1400	7,250	4,400
C	2C2 (Tr)	"0"	24.5	165	1190	15.25	222	9.5	752	1330	7,765.35	500
C	SDC-C-1-P-S	0 - 5	na	110	540	110	350	110	370	1200	7,390	6,146
C	SDC-C-3-P-S	0 - 5	na	200	1100	82	490	280	760	2400	11,493	1,782
D	S00025	0 - 10	na	ND	ND	ND	ND	ND	ND	580	580	740
D	S00026	0 - 10	na	ND	ND	ND	ND	ND	ND	690	6,780	1,000
D	S00049	0 - 10	na	ND	ND	ND	ND	ND	ND	500	500	1,100
E	2E8 (Tr)	"0"	24.5	18.35	437	15.25	68.6	9.5	287	482	2,874.1	350
E	E-RI-Comp2(0-2)	0 - 61	na	ND	174	ND	ND	ND	ND	162	980	1,070
E	SDC-E-1-P-S	0 - 5	na	160	450	27	440	65	300	1200	7,201	1,070
E	SDC-E-3-P-S	0 - 5	na	ND	580	ND	260	ND	220	710	4,130	324
E	S00029	0 - 10	na	ND	ND	ND	ND	ND	ND	870	8,650	290
F	S00028	0 - 10	na	ND	ND	ND	ND	ND	ND	ND	7,700	1,100
POG	P-RI-Comp1(0-2)	0 - 61	na	ND	ND	ND	ND	ND	ND	242	904	9,630
POG	P-RI-Comp1(2-4)	61 - 122	na	ND	ND	ND	ND	ND	ND	ND	148	na
POG	P-RI-Comp1(4-6)	122 - 183	na	ND	207	ND	ND	ND	ND	263	1,242	na
POG	S00024	0 - 10	na	ND	6500	580	3100	ND	4700	7000	44,260	60,000
POG	POG (Tr)	"0"	na	na	670	15.25	200	na	590	640	4,339.85	16,000
Appleton to Little Rapids Reach												
P	S00007	0 - 10	na	ND	930	ND	350	ND	320	840	4,370	370
P	S00008	0 - 10	na	ND	2300	ND	600	ND	1200	3000	13,920	1,100
W	SDC-W-2-P-S	0 - 5	na	100	670	ND	260	100	470	1000	5,210	338
W	SDC-W-3-P-S	0 - 5	na	190	1800	160	480	180	1700	2700	13,090	347
X	SDC-X-1-P-S	0 - 5	na	66	580	ND	240	87	350	900	4,756	150
X	SDC-X-3-P-S	0 - 5	na	160	1500	90	660	160	1000	2500	12,736	434
W	S00005	0 - 10	na	ND	680	ND	290	ND	280	810	4,880	1,800
X	X (Tr)	"0"	na	na	1800	190	610	na	1300	1700	12,130	1,600
X	S00004	0 - 10	na	ND	1200	ND	410	ND	530	1400	8,380	140
Interdeposit	S00060	0 - 10	na	ND	790	ND	ND	ND	ND	870	2,820	18,000
Little Rapids to DePere Reach												
EE	SDC-EE22-2-P-S	0 - 5	na	140	830	87	380	150	580	1600	8,452	655
EE	SDC-EE22-3-P-S	0 - 5	na	95	310	ND	140	100	280	680	3,389	18,671
EE	SDC-EE23-2-P-S	0 - 5	na	210	640	64	210	190	540	1200	5,674	332
EE	SDC-EE23-3-P-S	0 - 5	na	170	710	70	340	170	570	1400	7,137	599
EE	SDC-EE24-1-P-S	0 - 5	na	150	900	74	320	170	630	1300	7,194	1,166
EE	SDC-EE24-3-P-S	0 - 5	na	84	270	ND	150	73	200	610	2,982	613
EE	SDC-EE25-1-P-S	0 - 5	na	430	470	ND	210	190	360	800	4,700	143
EE	SDC-EE25-3-P-S	0 - 5	na	91	470	ND	230	95	300	780	4,516	1,192
EE	SDC-EE26-1-P-S	0 - 5	na	340	490	ND	250	190	390	1100	5,800	510
EE	SDC-EE26-5-P-S	0 - 5	na	ND	240	ND	200	ND	240	1000	4,410	4,303
EE	S00021	0 - 10	na	ND	610	ND	1800	ND	ND	790	8,360	450
EE	S00023	0 - 10	na	ND	550	ND	1200	ND	290	640	6,560	280
EE	S00036	0 - 10	na	ND	ND	ND	ND	ND	ND	530	1,100	7,300

Notes:
1) Sample results are in micrograms per kilogram (mg/kg).
2) ND = parameter not detected in sample.
3) na = parameter not analyzed in sample.
4) "0" depth indicates sample was collected from surface sediments.

Table 5-10. Lower Fox River and Green Bay - Semi-Volatile Organic Compound Results (PAHs) (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	1-Methylnaphthalene (µg/kg)	2-Methylnaphthalene (µg/kg)	Fluoranthene (µg/kg)	Fluorene (µg/kg)	Indeno(1,2,3-cd)pyrene (µg/kg)	Naphthalene (µg/kg)	Phenanthrene (µg/kg)	Pyrene (µg/kg)	Total PAHs (µg/kg)	Total PCBs (µg/kg)
EG	EGH-RI-Comp1(0-2)	0 - 61	na	ND	ND	ND	ND	ND	ND	80	240	na
EG	EGH-RI-Comp1(2-4)	61 - 122	na	ND	ND	ND	ND	ND	ND	101	357	na
HH	HH (Tr)	"0"	na	na	2400	110	560	na	1100	1800	13,365	11,000
HH	S00001	0 - 10	na	ND	590	ND	ND	ND	250	580	2,290	810
HH	S00034	0 - 10	na	ND	ND	ND	ND	ND	ND	720	6,860	6,400
Interdeposit	S00002	0 - 10	na	ND	580	ND	ND	ND	250	560	3,000	1,000
Interdeposit	S00033	0 - 10	na	ND	ND	ND	2900	ND	ND	880	11,040	780
Interdeposit	S00035	0 - 10	na	ND	ND	ND	ND	ND	ND	660	1,260	1,100
DePere to Green Bay Reach												
20	SDC-DPD-1-P-S	0 - 5	na	98	540	55	440	90	400	970	6,759	5,057
20	SDC-DPD-2-P-S	0 - 5	na	ND	490	ND	150	ND	190	620	3,170	2,360
20	S00010	0 - 10	na	ND	660	ND	2200	ND	ND	680	9,290	1,300
21	S00013	0 - 10	na	ND	800	ND	2600	ND	ND	800	11,640	1,700
21	S00014	0 - 10	na	ND	760	ND	2600	ND	ND	800	10,900	1,600
24	S00011	0 - 10	na	ND	820	ND	2400	ND	ND	870	10,970	780
25	S00012	0 - 10	na	ND	ND	ND	1800	ND	ND	ND	6,000	350
38	S00015	0 - 10	na	ND	ND	ND	ND	ND	ND	ND	2,840	280
41	S00016	0 - 10	na	ND	ND	ND	2500	ND	ND	610	8,910	730
43	S00018	0 - 10	na	ND	ND	ND	ND	ND	ND	ND	1,500	200
44	S00017	0 - 10	na	ND	1500	ND	2100	ND	680	1300	11,850	480
44	S00051	0 - 10	na	ND	920	ND	ND	ND	ND	880	5,380	630
45	SDC-DPD-3-P-S	0 - 5	na	ND	650	ND	240	ND	260	1000	5,030	1,691
45	S00052	0 - 10	na	ND	740	ND	ND	ND	ND	690	4,430	680
54	S00019	0 - 10	na	ND	380	ND	ND	ND	ND	380	3,940	220
62	S00053	0 - 10	ND	ND	ND	ND	ND	ND	ND	640.00	640	670
72	S00020	0 - 10	na	ND	680	ND	2600	ND	ND	710	10,630	930
96	SDC-DPD-4-P-S	0 - 5	na	ND	700	34	200	34	340	630	4,182	117
115	SDC-DPD-5-P-S	0 - 5	na	85	360	85	140	85	200	460	3,185	1,468
unknown	2FRB1 (Tr)	"0"	61.1	74	429	40.2	125	45	265	488	3,219.4	5,000
unknown	2FRB17 (Tr)	"0"	15.3	14.4	274	22.7	135	9.5	157	335	9,947.1	310
unknown	2FRB22 (Tr)	"0"	84.4	134	806	56.3	207	91.1	560	934	5,877.3	21,000
unknown	FRB (Tr)	"0"	na	na	1000	15.25	170	na	1600	800	6,692.91	51,000
unknown	4085139A	-	na	na	530	na	160	340	450	400	3,152	na
unknown	4085139AC	-	na	na	1600	na	1000	790	1500	1400	13,000	1,400
GREEN BAY												
Green Bay Zone 2 (2A & 2B)												
	S00030	0 - 10	na	ND	ND	ND	ND	ND	ND	98	98	57
	S00037	0 - 10	na	ND	440	ND	ND	ND	ND	450	1,240	390
	S00039	0 - 10	na	ND	400	ND	ND	ND	ND	420	1,170	340
	S00040	0 - 10	na	ND	ND	ND	ND	ND	ND	520	960	460
	S00057	0 - 10	na	ND	370	ND	ND	ND	ND	400	1,310	180
None of the listed PAHs were detectedin Green Bay Zone 3												
None of the listed PAHs were detectedin Green Bay Zone 4												
Reference												
	REF (Tr)(2)	"0"	24.45	18.35	56.4	15.25	50	9.25	31.5	45	475.86	50
	4072050BS	-	na	na	13.2	na	ND	ND	ND	10.2	42.3	50
	4085110A	-	na	na	25	na	ND	ND	14	20	173	100

Notes:
1) Sample results are in micrograms per kilogram (mg/kg).
2) ND = parameter not detected in sample.
3) na = parameter not analyzed in sample.
4) "0" depth indicates sample was collected from surface sediments.

Table 5-11. Lower Fox River and Green Bay - Miscellaneous SVOC Results

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	1,2-Dichlorobenzene (µg/kg)	1,4-Dichlorobenzene (µg/kg)	bis(2-Ethylhexyl)phthalate (BEHP) (µg/kg)	4-Methylphenol (µg/kg)	Pentachlorophenol (PCP) (µg/kg)	Carbazole (µg/kg)
LOWER FOX RIVER								
Little Lake Butte des Morts Reach								
A	BA-SD01comp	0 - 61	na	na	1300.00	120.00	na	0.00
A	BA-SD04comp	0 - 43	na	na	ND	110.00	na	0.00
A	BA-SD08comp	0 - 46	na	na	ND	75.00	na	0.00
A	S00009	0 - 10	ND	ND	2100.00	ND	ND	ND
C	2C2 (Tr)	"0"	na	na	na	na	410.00	0.00
C	S00003	0 - 10	ND	ND	970.00	ND	850.00	ND
C	SDC-C-1-P-S	0 - 5	110.00	110.00	25000.00	280.00	500.00	110.00
C	SDC-C-3-P-S	0 - 5	130.00	71.00	1700.00	1400.00	350.00	170.00
D	D-RI-Comp1(2-4)	61 - 122	ND	ND	113.00	ND	ND	ND
E	2E8 (Tr)	"0"	na	na	na	na	600.00	0.00
E	E-RI-Comp2(0-2)	0 - 61	ND	ND	87.00	442.00	ND	ND
E	SDC-E-1-P-S	0 - 5	120.00	62.00	2800.00	340.00	860.00	30.00
E	SDC-E-3-P-S	0 - 5	ND	ND	210.00	75.00	ND	97.00
POG	P-RI-Comp1(0-2)	0 - 61	ND	282.00	137.00	869.00	ND	ND
POG	P-RI-Comp1(2-4)	61 - 122	ND	164.50	125.00	998.50	ND	ND
POG	P-RI-Comp1(4-6)	122 - 183	ND	ND	216.00	1530.00	719.00	ND
POG	S00024	0 - 10	ND	ND	3900.00	ND	ND	2700.00
Appleton to Little Rapids Reach								
P	S00007	0 - 10	ND	ND	460.00	ND	ND	ND
P	S00008	0 - 10	ND	ND	1300.00	170.00	280.00	ND
W	SDC-W-2-P-S	0 - 5	ND	ND	300.00	610.00	ND	ND
W	SDC-W-3-P-S	0 - 5	ND	ND	240.00	110.00	ND	180.00
W	S00005	0 - 10	ND	ND	290.00	170.00	290.00	ND
X	S00004	0 - 10	ND	ND	280.00	ND	ND	ND
X	SDC-X-1-P-S	0 - 5	ND	ND	100.00	500.00	ND	64.00
X	SDC-X-3-P-S	0 - 5	ND	ND	510.00	1500.00	ND	84.00
Interdeposit	S00060	0 - 10	ND	ND	1300.00	ND	ND	ND
Little Rapids to DePere Reach								
EE	SDC-EE22-2-P-S	0 - 5	63.00	ND	530.00	400.00	ND	ND
EE	SDC-EE22-3-P-S	0 - 5	210.00	60.00	380.00	880.00	ND	ND
EE	SDC-EE23-2-P-S	0 - 5	ND	ND	200.00	580.00	ND	ND
EE	SDC-EE23-3-P-S	0 - 5	66.00	ND	540.00	600.00	ND	ND
EE	SDC-EE24-1-P-S	0 - 5	63.00	ND	300.00	490.00	ND	ND
EE	SDC-EE24-3-P-S	0 - 5	120.00	ND	160.00	210.00	ND	ND
EE	SDC-EE25-1-P-S	0 - 5	ND	ND	ND	750.00	500.00	ND
EE	SDC-EE25-3-P-S	0 - 5	140.00	ND	300.00	320.00	ND	ND
EE	SDC-EE26-1-P-S	0 - 5	140.00	ND	120.00	750.00	1000.00	ND
EE	SDC-EE26-5-P-S	0 - 5	370.00	ND	180.00	390.00	1100.00	ND
EG	EGH-RI-Comp1(0-2	0 - 61	ND	ND	803.00	ND	ND	ND
EG	EGH-RI-Comp1(2-4	61 - 122	ND	ND	ND	694.00	ND	ND
HH	S00001	0 - 10	ND	ND	570.00	ND	300.00	ND
Interdeposit	S00002	0 - 10	ND	ND	290.00	ND	ND	ND

Table 5-11. Lower Fox River and Green Bay - Miscellaneous SVOC Results (Continued)

Deposit, SMU, or Zone	Sample Identification	Depth (cm)	1,2-Dichlorobenzene (µg/kg)	1,4-Dichlorobenzene (µg/kg)	bis(2-Ethylhexyl)phthalate (BEHP) (µg/kg)	4-Methylphenol (µg/kg)	Pentachlorophenol (PCP) (µg/kg)	Carbazole (µg/kg)
DePere to Green Bay Reach								
20	SDC-DPD-1-P-S	0 - 5	150.00	54.00	550.00	540.00	460.00	ND
20	SDC-DPD-2-P-S	0 - 5	ND	ND	240.00	ND	ND	ND
24	S00011	0 - 10	ND	ND	1400.00	ND	ND	ND
44	S00017	0 - 10	ND	ND	ND	ND	ND	1300.00
45	SDC-DPD-3-P-S	0 - 5	ND	ND	320.00	140.00	ND	ND
96	SDC-DPD-4-P-S	0 - 5	ND	ND	63.00	29.00	ND	50.00
115	SDC-DPD-5-P-S	0 - 5	85.00	85.00	360.00	85.00	420.00	85.00
unknown	FRB (Tr)	-	na	na	na	na	400.00	0.00
unknown	2FRB1 (Tr)	"0"	na	na	na	na	400.00	0.00
unknown	2FRB17 (Tr)	"0"	na	na	na	na	20.00	0.00
unknown	2FRB22 (Tr)	"0"	na	na	na	na	710.00	0.00
unknown	4085139A	-	79.00	36.00	250.00	na	na	0.00
unknown	4085139AC	-	130.00	69.00	640.00	na	na	0.00
GREEN BAY								
Green Bay Zone 2 (2A & 2B)								
	S00032	0 - 10	ND	ND	ND	96.00	ND	ND
None of the listed SVOCs were detected in Green Bay Zone 3								
None of the listed SVOCs were detected in Green Bay Zone 4								
Reference								
	REF (Tr)(2)	"0"	na	na	na	na	10.00	0.00
	4072050A	-	ND	ND	210.00	na	na	0.00
	4072050BS	-	ND	ND	21.60	na	na	0.00
	4085110A	-	ND	ND	22.00	na	na	0.00

Notes:
1) Sample results are in micrograms per kilogram (mg/kg).
2) ND = parameter not detected in sample.
3) "0" depth indicates sample was collected from surface sediments.
4) na = parameter not analyzed in sample.

Table 5-12. Lake Winnebago Background Sediment Results

Parameter	Units	Sampling Locations			Average Concentration
		SDC-LW-1	SDC-LW-2	SDC-LW-3	
PCBs					
Ar1242	µg/kg	10.0	16.0	14.0	13.3
Ar1254	µg/kg	16.0	20.0	19.0	18.3
PCB Congener 170	µg/kg	2.8	nd	nd	0.9
PCB Congener 194	µg/kg	3.1	nd	nd	1.0
PCB Congener 20/33/53	µg/kg	3.4	5.5	nd	3.0
Calculated Total PCB Results					
Total PCBs (Aroclors)	µg/kg	26.0	36.0	33.0	NA
Total PCBs (Congeners)	µg/kg	9.3	5.5	0.0	NA
Pesticides					
DDE	µg/kg	2.4	nd	3.5	2.0
alpha-BHC	µg/kg	nd	3.6	nd	1.2
Endosulfan Sulfate	µg/kg	3.2	nd	nd	1.1
SVOCs					
Benzo(a)pyrene	µg/kg	120.0	nd	nd	40.0
Benzo(b)fluoranthene	µg/kg	91.0	nd	nd	30.3
Benzo(g,h,i)perylene	µg/kg	100.0	nd	nd	33.3
Benzo(k)fluoranthene	µg/kg	140.0	87.0	120.0	115.7
Chrysene	µg/kg	84.0	120.0	140.0	114.7
Fluoranthene	µg/kg	110.0	100.0	120.0	110.0
Indeno(1,2,3-cd)pyrene	µg/kg	87.0	nd	nd	29.0
Pyrene	µg/kg	110.0	89.0	110.0	103.0
4-Methylphenol	µg/kg	59.0	nd	nd	19.7
bis(2-Ethylhexyl)phthalate	µg/kg	100.0	140.0	350.0	196.7
Metals					
Arsenic	mg/kg	4.0	6.0	6.0	5.3
Cadmium	mg/kg	nd	nd	nd	nd
Chromium	mg/kg	51.0	69.0	75.0	65.0
Copper	mg/kg	23.0	30.0	33.0	28.7
Lead	mg/kg	30.0	36.0	39.0	35.0
Mercury	mg/kg	0.11	0.14	0.17	0.14
Nickel	mg/kg	22.0	29.0	30.0	27.0
Zinc	mg/kg	70.0	90.0	100.0	86.7

Table 5-13. Lower Fox River - PCB Mass and Sediment Volume by Concentration Range

Deposit or SMU Group	PCB Mass (kg) by Concentration Range									Total PCB Mass (kg)
	< = 50 µg/kg	50-125 µg/kg	125-250 µg/kg	250-500 µg/kg	500-1,000 µg/kg	1,000-5,000 µg/kg	5,000-10,000 µg/kg	10,000-50,000 µg/kg	>50,000 µg/kg	
LLBdM Reach										
Deposit A	-	0.01	0.04	0.07	0.56	103.01	21.98	111.70	-	237.37
Deposit B	-	0.71	1.25	2.23	2.86	31.75	48.81	312.29	10.96	410.87
Deposit C	0.04	0.10	0.24	3.14	0.41	14.79	17.25	2.98	-	38.96
Deposit POG	-	0.03	0.38	1.89	3.00	26.38	15.90	183.62	72.25	303.46
Deposit D	0.00	0.01	0.25	1.89	3.30	56.04	21.11	-	-	82.60
Deposit E	1.65	8.19	18.26	16.40	37.14	130.29	77.18	165.34	-	454.46
Deposit F	-	0.13	0.94	5.41	1.89	2.51	-	-	-	10.87
Deposit G	-	0.40	0.32	-	-	-	-	-	-	0.72
Deposit H	-	-	-	-	0.27	0.42	-	-	-	0.69
Reach Total	**1.70**	**9.58**	**21.69**	**31.03**	**49.44**	**365.19**	**202.23**	**775.93**	**83.21**	**1,540.00**
Appleton to Little Rapids Reach										
Deposit I	-	0.04	0.14	-	-	-	-	-	-	0.18
Deposit J	-	0.08	-	-	-	-	-	-	-	0.08
Deposit K	-	0.02	-	0.03	0.03	-	-	-	-	0.09
Deposit L	-	0.03	-	0.04	0.04	-	-	-	-	0.11
Deposit M	-	0.01	-	0.14	-	-	-	-	-	0.15
Deposit N	-	-	-	-	0.19	8.02	2.44	13.71	5.24	29.61
Deposit O	-	0.00	0.01	0.01	1.08	0.90	-	-	-	2.00
Deposit P	-	-	-	1.06	0.04	4.22	-	-	-	5.32
Deposit Q	-	-	-	0.00	0.01	0.16	-	-	-	0.17
Deposit R	-	0.05	-	-	-	-	-	-	-	0.05
Deposit S	-	0.12	-	-	-	-	-	-	-	0.12
Deposit T	-	0.07	-	-	-	4.65	6.63	-	-	11.35
Deposit U	-	-	-	0.06	-	0.09	-	-	-	0.15
Deposit V	-	-	-	0.00	-	0.01	-	-	-	0.02
Deposit W	0.24	0.88	2.56	1.46	1.46	0.47	-	-	-	7.07
Deposit X	0.20	0.04	1.95	0.23	0.23	-	-	-	-	2.65
Deposit Y	-	0.07	-	0.11	0.11	-	-	-	-	0.28
Deposit Z	-	0.14	-	0.16	0.16	-	-	-	-	0.45
Deposit AA	-	0.02	-	-	-	-	-	-	-	0.02
Deposit BB	-	0.03	0.03	-	-	-	-	-	-	0.06
Deposit CC	-	0.48	0.17	0.03	0.03	-	-	-	-	0.69
Deposit DD	0.05	0.39	1.22	0.50	0.58	2.68	18.74	9.42	-	33.58
Reach Total	**0.49**	**2.46**	**6.07**	**3.84**	**3.95**	**21.20**	**27.81**	**23.13**	**5.24**	**94.18**
Little Rapids to De Pere Reach										
Deposit EE	4.73	35.56	17.31	34.54	33.24	219.45	180.87	307.43	-	833.14
Deposit FF	0.00	0.01	-	0.04	0.04	-	-	-	-	0.09
Deposit GG	-	-	0.04	0.04	0.05	9.14	5.08	66.68	-	81.03
Deposit HH	0.01	0.00	0.10	-	0.57	24.19	10.81	34.56	-	70.25
Reach Total	**4.74**	**35.57**	**17.45**	**34.62**	**33.90**	**252.78**	**196.76**	**408.68**	**-**	**984.51**
De Pere to Green Bay Reach										
SMUs 20-25	-	6.30	9.09	14.91	31.80	386.67	431.18	4,361.45	315.89	5,557.29
SMUs 26-31	-	1.32	2.76	1.36	2.56	128.20	192.17	432.87	-	761.24
SMUs 32-37	-	1.03	0.99	6.21	2.93	121.94	390.17	551.62	97.99	1,172.86
SMUs 38-43	-	3.41	4.01	9.12	12.17	200.83	208.19	703.85	7.92	1,149.49
SMUs 44-49	-	3.06	4.79	13.55	30.88	487.74	1,023.15	3,647.99	-	5,211.15
SMUs 50-55	-	1.50	3.76	4.85	10.17	223.58	201.32	1,383.28	1.21	1,829.66
SMUs 56-61[A]	0.00	0.22	0.28	0.62	6.96	128.52	178.48	2,881.26	2,614.38	5,174.71
SMUs 62-67	-	1.31	1.07	1.62	2.99	115.37	93.61	288.73	356.56	861.25
SMUs 68-73	-	0.90	2.29	2.12	3.53	105.65	112.02	1,405.55	226.11	1,858.16
SMUs 74-79	-	1.66	1.16	1.26	1.50	110.31	108.66	205.63	-	430.18
SMUs 80-85	-	2.03	3.66	5.56	2.44	63.52	85.99	222.13	-	385.33
SMUs 86-91	-	1.10	3.72	0.77	0.83	20.65	145.88	80.15	-	253.10
SMUs 92-97	-	0.86	2.54	1.82	3.77	137.10	108.75	-	-	254.84
SMUs 98-103	-	2.21	4.83	1.05	3.25	11.57	-	71.34	-	94.25
SMUs 104-109	-	0.62	0.32	0.79	3.89	51.72	-	93.73	-	151.08
SMUs 110-115	-	-	0.49	1.51	2.36	83.57	63.91	687.19	-	839.02
Reach Total	**0.00**	**27.53**	**45.77**	**67.10**	**122.03**	**2,376.92**	**3,343.47**	**17,016.77**	**3,620.04**	**25,983.63**
RIVER TOTALS	**6.93**	**75.15**	**90.98**	**136.59**	**209.32**	**3,016.09**	**3,770.28**	**18,224.51**	**3,708.48**	**28,602.32**

Table 5-13. Lower Fox River - PCB Mass and Sediment Volume by Concentration Range (Continued)

Deposit or SMU Group	Impacted Sediment Volume (m^3) by Concentration Range									Total Volume (m^3)
	< = 50 µg/kg	50-125 µg/kg	125-250 µg/kg	250-500 µg/kg	500-1,000 µg/kg	1,000-5,000 µg/kg	5,000-10,000 µg/kg	10,000-50,000 µg/kg	>50,000 µg/kg	
LLBdM Reach										
Deposit A	-	180	450	470	1,840	81,650	7,420	15,720	-	107,730
Deposit B	-	6,520	5,280	3,660	3,260	7,190	4,570	11,100	160	41,740
Deposit C	3,900	2,780	3,560	29,820	3,200	14,160	4,750	960	-	63,130
Deposit POG	-	470	3,240	9,590	13,680	37,540	5,500	29,210	3,800	103,030
Deposit D	150	90	1,460	5,660	7,780	45,690	6,030	-	-	66,860
Deposit E	142,460	222,040	215,830	102,630	118,180	147,990	29,050	34,190	-	1,012,370
Deposit F	-	6,100	17,410	54,270	11,570	6,570	-	-	-	95,920
Deposit G	-	5,580	2,800	-	-	-	-	-	-	8,380
Deposit H	-	-	-	-	460	230	-	-	-	690
Reach Total	**146,510**	**243,760**	**250,030**	**206,100**	**159,970**	**341,020**	**57,320**	**91,180**	**3,960**	**1,499,850**
Appleton to Little Rapids Reach										
Deposit I	-	1,530	1,360	-	680	-	-	-	-	3,570
Deposit J	-	1,630	-	-	-	-	-	-	-	1,630
Deposit K	-	320	-	160	-	-	-	-	-	480
Deposit L	-	380	-	190	-	-	-	-	-	570
Deposit M	-	240	-	940	470	-	-	-	-	1,650
Deposit N	-	-	-	10	370	2,300	610	1,270	320	4,880
Deposit O	-	60	60	60	1,440	810	-	-	-	2,430
Deposit P	-	-	-	5,330	400	7,070	-	-	-	12,800
Deposit Q	-	-	-	20	40	150	-	-	-	210
Deposit R	-	990	-	-	-	-	-	-	-	990
Deposit S	-	7,510	2,960	-	2,080	-	-	-	-	12,550
Deposit T	-	3,520	-	-	-	2,870	1,970	-	-	8,360
Deposit U	-	-	-	400	-	200	-	-	-	600
Deposit V	-	-	-	40	-	20	-	-	-	60
Deposit W	26,170	20,720	25,910	5,900	210	750	-	-	-	79,660
Deposit X	26,580	1,000	28,230	1,590	-	-	-	-	-	57,400
Deposit Y	-	900	-	430	-	-	-	-	-	1,330
Deposit Z	-	3,550	-	730	-	-	-	-	-	4,280
Deposit AA	-	390	-	-	-	-	-	-	-	390
Deposit BB	-	520	260	-	-	-	-	-	-	780
Deposit CC	-	10,890	2,200	90	1,120	-	-	-	-	14,300
Deposit DD	3,400	9,330	9,660	2,190	520	1,410	4,210	1,300	-	32,020
Reach Total	**56,150**	**63,480**	**70,640**	**18,080**	**7,330**	**15,580**	**6,790**	**2,570**	**320**	**240,940**
Little Rapids to De Pere Reach										
Deposit EE	379,050	800,070	207,970	237,700	130,330	201,520	48,720	34,080	-	2,039,440
Deposit FF	700	340	-	360	-	-	-	-	-	1,400
Deposit GG	-	-	500	250	100	5,810	1,790	9,870	-	18,320
Deposit HH	650	100	2,450	-	2,610	14,460	4,960	4,970	-	30,200
Reach Total	**380,400**	**800,510**	**210,920**	**238,310**	**133,040**	**221,790**	**55,470**	**48,920**	**-**	**2,089,360**
De Pere to Green Bay Reach										
SMUs 20-25	-	98,170	78,040	65,090	78,140	266,670	113,590	340,880	14,000	1,054,580
SMUs 26-31	-	17,820	20,770	4,650	5,310	46,470	33,740	37,470	-	166,230
SMUs 32-37	-	15,810	6,590	19,180	7,450	60,400	61,470	59,430	2,900	233,230
SMUs 38-43	-	56,650	28,050	33,830	31,550	123,590	44,250	84,190	250	402,360
SMUs 44-49	-	50,940	44,220	62,070	93,520	378,170	268,850	481,920	-	1,379,690
SMUs 50-55	-	21,070	29,180	18,920	24,600	135,130	42,030	134,290	60	405,280
SMUs 56-61[A]	150	4,650	3,200	3,550	15,190	98,000	53,850	253,670	56,380	457,640
SMUs 62-67	-	17,100	8,330	7,810	9,240	79,250	22,120	31,570	15,150	190,570
SMUs 68-73	-	16,210	23,080	10,980	9,630	70,760	28,150	167,840	10,600	337,250
SMUs 74-79	-	25,720	9,770	4,590	2,750	54,900	24,660	19,560	-	141,950
SMUs 80-85	-	37,950	32,610	19,830	4,460	32,510	17,500	19,790	-	164,650
SMUs 86-91	-	23,430	30,330	2,630	640	10,810	26,310	9,250	-	103,400
SMUs 92-97	-	6,890	13,890	3,430	5,330	69,620	19,340	-	-	118,500
SMUs 98-103	-	33,250	23,690	2,720	6,710	9,530	-	6,300	-	82,200
SMUs 104-109	-	8,940	1,790	2,580	7,610	43,930	-	9,700	-	74,550
SMUs 110-115	-	-	2,530	6,490	6,610	75,090	13,630	101,900	-	206,250
Reach Total	**150**	**434,600**	**356,070**	**268,350**	**308,740**	**1,554,830**	**769,490**	**1,757,760**	**99,340**	**5,518,330**
RIVER TOTALS	**583,210**	**1,542,350**	**887,660**	**730,840**	**609,080**	**2,133,220**	**889,070**	**1,900,430**	**103,620**	**9,348,480**

Table 5-13. Lower Fox River - PCB Mass and Sediment Volume by Concentration Range (Continued)

Deposit or SMU Group	Impacted Sediment Volume (m^3) by Concentration Range			PCB Mass (kg) by Concentration Range			PCB Mass to Impacted Sediment Volume (g/m^3)		
	> 50 µg/kg	> 1,000 µg/kg	> 10,000 µg/kg	> 50 µg/kg	> 1,000 µg/kg	> 10,000 µg/kg	> 50 µg/kg	> 1,000 µg/kg	> 10,000 µg/kg
LLBdM Reach									
Deposit A	107,730	104,790	15,720	237.37	236.69	111.70	2.20	2.26	7.11
Deposit B	41,740	23,020	11,260	410.87	403.81	323.25	9.84	17.54	28.71
Deposit C	59,230	19,870	960	38.92	35.02	2.98	0.66	1.76	3.11
Deposit POG	103,030	76,050	33,010	303.46	298.15	255.86	2.95	3.92	7.75
Deposit D	66,710	51,720	-	82.60	77.15	-	1.24	1.49	-
Deposit E	869,910	211,230	34,190	452.80	372.81	165.34	0.52	1.76	4.84
Deposit F	95,920	6,570	-	10.87	2.51	-	0.11	0.38	-
Deposit G	8,380	-	-	0.72	-	-	0.09	-	-
Deposit H	690	230	-	0.69	0.42	-	1.00	1.82	-
Reach Total	**1,353,340**	**493,480**	**95,140**	**1,538.30**	**1,426.55**	**859.13**	**1.14**	**2.89**	**9.03**
Appleton to Little Rapids Reach									
Deposit I	3,570	-	-	0.18	-	-	0.05	-	-
Deposit J	1,630	-	-	0.08	-	-	0.05	-	-
Deposit K	480	-	-	0.09	-	-	0.19	-	-
Deposit L	570	-	-	0.11	-	-	0.19	-	-
Deposit M	1,650	-	-	0.15	-	-	0.09	-	-
Deposit N	4,880	4,500	1,590	29.61	29.42	18.95	6.07	6.54	11.92
Deposit O	2,430	810	-	2.00	0.90	-	0.82	1.11	-
Deposit P	12,800	7,070	-	5.32	4.22	-	0.42	0.60	-
Deposit Q	210	150	-	0.17	0.16	-	0.81	1.04	-
Deposit R	990	-	-	0.05	-	-	0.05	-	-
Deposit S	12,550	-	-	0.12	-	-	0.01	-	-
Deposit T	8,360	4,840	-	11.35	11.28	-	1.36	2.33	-
Deposit U	600	200	-	0.15	0.09	-	0.25	0.47	-
Deposit V	60	20	-	0.02	0.01	-	0.26	0.61	-
Deposit W	53,490	750	-	6.83	0.47	-	0.13	0.62	-
Deposit X	30,820	-	-	2.45	(0.00)	-	0.08	-	-
Deposit Y	1,330	-	-	0.28	-	-	0.21	-	-
Deposit Z	4,280	-	-	0.45	-	-	0.10	-	-
Deposit AA	390	-	-	0.02	-	-	0.06	-	-
Deposit BB	780	-	-	0.06	-	-	0.08	-	-
Deposit CC	14,300	-	-	0.69	-	-	0.05	-	-
Deposit DD	28,620	6,920	1,300	33.53	30.84	9.42	1.17	4.46	7.24
Reach Total	**184,790**	**25,260**	**2,890**	**93.69**	**77.37**	**28.37**	**0.51**	**3.06**	**9.82**
Little Rapids to De Pere Reach									
Deposit EE	1,660,390	284,320	34,080	828.41	707.75	307.43	0.50	2.49	9.02
Deposit FF	700	-	-	0.08	-	-	0.12	-	-
Deposit GG	18,320	17,470	9,870	81.03	80.90	66.68	4.42	4.63	6.76
Deposit HH	29,550	24,390	4,970	70.24	69.57	34.56	2.38	2.85	6.95
Reach Total	**1,708,960**	**326,180**	**48,920**	**979.77**	**858.22**	**408.68**	**0.57**	**2.63**	**8.35**
De Pere to Green Bay Reach									
SMUs 20-25	1,054,580	735,140	354,880	5,557.29	5,495.19	4,677.34	5.27	7.48	13.18
SMUs 26-31	166,230	117,680	37,470	761.24	753.24	432.87	4.58	6.40	11.55
SMUs 32-37	233,230	184,200	62,330	1,172.86	1,161.72	649.61	5.03	6.31	10.42
SMUs 38-43	402,360	252,280	84,440	1,149.49	1,120.78	711.77	2.86	4.44	8.43
SMUs 44-49	1,379,690	1,128,940	481,920	5,211.15	5,158.88	3,647.99	3.78	4.57	7.57
SMUs 50-55	405,280	311,510	134,350	1,829.66	1,809.39	1,384.49	4.51	5.81	10.31
SMUs 56-61[A]	457,490	430,900	279,050	5,174.71	5,166.63	4,859.64	11.31	11.99	17.41
SMUs 62-67	190,570	148,090	46,720	861.25	854.26	645.29	4.52	5.77	13.81
SMUs 68-73	337,250	277,350	178,440	1,858.16	1,849.32	1,631.65	5.51	6.67	9.14
SMUs 74-79	141,950	99,120	19,560	430.18	424.59	205.63	3.03	4.28	10.51
SMUs 80-85	164,650	69,800	19,790	385.33	371.63	222.13	2.34	5.32	11.22
SMUs 86-91	103,400	46,370	9,250	253.10	246.69	80.15	2.45	5.32	8.66
SMUs 92-97	118,500	88,960	-	254.84	245.85	-	2.15	2.76	-
SMUs 98-103	82,200	15,830	6,300	94.25	82.91	71.34	1.15	5.24	11.32
SMUs 104-109	74,550	53,630	9,700	151.08	145.46	93.73	2.03	2.71	9.66
SMUs 110-115	206,250	190,620	101,900	839.02	834.66	687.19	4.07	4.38	6.74
Reach Total	**5,518,180**	**4,150,420**	**1,826,100**	**25,983.63**	**25,721.20**	**20,000.82**	4.71	6.20	10.95
RIVER TOTALS	**8,765,270**	**4,995,340**	**1,973,050**	**28,595.39**	**28,083.35**	**21,296.99**	**3.26**	**5.62**	**10.79**

Table 5-13. Lower Fox River - PCB Mass and Sediment Volume by Concentration Range (Continued)

Mass and Volume Total for Deposit and Interdeposit Areas in Each Reach						
Reach	Mass (kg)			Volume (m^3)		
	Deposits	All Areas	Difference[B]	Deposits	All Areas	Difference[B]
LLBdM	1,540.00	1,849.00	309.00	1,499,850	1,679,715	179,865
App-LR	94.18	108.95	14.77	240,940	258,905	17,965
LR-DP	984.51	1,250.31	265.80	2,089,360	2,313,090	223,730
DP-GB	26,619.63	26,647.63	28.00	5,549,330	6,481,960	932,630
Totals	**29,238.32**	**29,855.89**	**617.57**	**9,379,480**	**10,733,670**	**1,354,190**

Deposit/SMU Area (hectares[C])					
Dep. A	15.26	Dep. Q	0.42	Dep. HH	4.46
Dep. B	14.74	Dep. R	0.77	SMU 20-25	113.39
Dep. C	12.36	Dep. S	16.64	SMU 26-31	22.04
Dep. POG	21.32	Dep. T	2.08	SMU 32-37	26.78
Dep. D	25.24	Dep. U	1.74	SMU 38-43	46.46
Dep. E	202.51	Dep. V	2.41	SMU 44-49	107.15
Dep. F	16.91	Dep. W	56.41	SMU 50-55	32.91
Dep. G	4.11	Dep. X	25.60	SMU 56-61	29.66
Dep. H	1.08	Dep. Y	3.19	SMU 62-67	18.22
Dep. I	2.98	Dep. Z	2.44	SMU 68-73	21.58
Dep. J	2.51	Dep. AA	0.81	SMU 74-79	11.81
Dep. K	0.53	Dep. BB	1.58	SMU 80-85	10.62
Dep. L	1.06	Dep. CC	8.47	SMU 86-91	11.27
Dep. M	1.33	Dep. DD	14.92	SMU 92-97	19.76
Dep. N	2.25	Dep. EE	258.81	SMU 98-103	14.00
Dep. O	1.85	Dep. FF	0.49	SMU 104-109	17.02
Dep. P	3.14	Dep. GG	2.40	SMU 110-115	20.82

Table Notes:

A: Total PCB Mass and Total Sediment Volume results for SMU Group 56-61 reflect the subtraction of 636 kg of PCBs and 31,000 m^3 of sediment removed as part of the Demonstration Project.

B: The PCB mass and sediment volumes for the Interdeposit Areas are represented by the difference between the totals for the deposit and all areas in each reach.

C: 1 Hectare = 10,000 m^2

Table 5-14. Lower Fox River - PCB Mass and Sediment Volume by Deposit/SMU Layer

Deposit or SMU Group	PCB Mass (kg) by Depth Range									Total PCB Mass (kg)
	0-10 cm	10-30 cm	30-50 cm	50-100 cm	100-150 cm	150-200 cm	200-250 cm	250-300 cm	300-350 cm	
LLBdM Reach										
Deposit A	45.05	88.63	35.39	68.44	-	-	-	-	-	237.51
Deposit B	12.02	110.63	282.59	6.12	-	-	-	-	-	411.36
Deposit C	22.23	13.73	0.91	2.22	-	-	-	-	-	39.09
Deposit POG	35.79	56.34	40.59	128.85	43.03	-	-	-	-	304.59
Deposit D	19.80	35.20	20.00	8.23	0.00	-	-	-	-	83.23
Deposit E	176.64	227.45	30.81	22.99	1.60	0.00	-	-	-	459.48
Deposit F	3.26	2.88	1.19	3.57	-	-	-	-	-	10.89
Deposit G	0.32	0.40	-	-	-	-	-	-	-	0.72
Deposit H	0.42	0.27	-	-	-	-	-	-	-	0.69
Reach Total	**315.52**	**535.52**	**411.47**	**240.41**	**44.63**	**0.00**	**-**	**-**	**-**	**1,547.56**
Appleton to Little Rapids Reach										
Deposit I	0.27	0.14	0.02	0.02	-	-	-	-	-	0.45
Deposit J	0.03	0.05	0.00	-	-	-	-	-	-	0.08
Deposit K	0.03	0.02	-	-	-	-	-	-	-	0.06
Deposit L	0.04	0.03	-	-	-	-	-	-	-	0.07
Deposit M	0.15	0.14	0.01	-	-	-	-	-	-	0.30
Deposit N	6.93	14.86	7.32	0.67	-	-	-	-	-	29.78
Deposit O	0.90	1.11	-	-	-	-	-	-	-	2.00
Deposit P	1.06	1.72	1.59	1.03	-	-	-	-	-	5.40
Deposit Q	0.06	0.11	-	-	-	-	-	-	-	0.17
Deposit R	0.02	0.03	-	-	-	-	-	-	-	0.05
Deposit S	0.05	0.06	-	-	-	-	-	-	-	0.12
Deposit T	4.36	6.92	0.04	0.03	-	-	-	-	-	11.35
Deposit U	0.09	0.06	-	-	-	-	-	-	-	0.15
Deposit V	0.01	0.00	-	-	-	-	-	-	-	0.02
Deposit W	2.64	1.58	0.43	1.00	-	-	-	-	-	5.66
Deposit X	0.87	0.45	0.38	0.73	-	-	-	-	-	2.42
Deposit Y	0.11	0.06	0.00	-	-	-	-	-	-	0.17
Deposit Z	0.16	0.06	0.03	0.04	-	-	-	-	-	0.29
Deposit AA	0.01	0.01	-	-	-	-	-	-	-	0.02
Deposit BB	0.03	0.03	-	-	-	-	-	-	-	0.06
Deposit CC	0.61	0.44	0.06	-	-	-	-	-	-	1.12
Deposit DD	3.91	14.13	14.79	0.51	-	-	-	-	-	33.34
Reach Total	**22.33**	**42.03**	**24.68**	**4.02**	**-**	**-**	**-**	**-**	**-**	**93.06**
Little Rapids to De Pere Reach										
Deposit EE	225.48	247.46	184.16	182.58	3.97	0.70	0.08	-	-	844.44
Deposit FF	0.04	0.00	0.01	-	-	-	-	-	-	0.05
Deposit GG	8.46	23.59	22.89	20.03	5.98	0.08	-	-	-	81.03
Deposit HH	10.02	19.68	17.89	19.22	3.34	0.10	0.01	-	-	70.25
Reach Total	**244.00**	**290.73**	**224.95**	**221.83**	**13.29**	**0.89**	**0.09**	**-**	**-**	**995.78**
De Pere to Green Bay Reach										
SMUs 20-25	225.60	813.62	950.30	1,569.27	935.71	430.01	637.88	-	-	5,562.39
SMUs 26-31	57.40	271.18	180.75	247.42	3.90	0.85	0.18	-	-	761.68
SMUs 32-37	56.81	324.13	199.43	382.77	176.70	16.93	13.84	4.07	-	1,174.68
SMUs 38-43	53.43	264.65	300.18	435.82	57.25	5.86	6.43	11.44	16.45	1,151.52
SMUs 44-49	189.20	696.55	856.47	2,069.46	1,020.76	274.63	71.78	33.36	3.17	5,215.39
SMUs 50-55	48.61	121.37	280.75	583.52	345.12	256.37	142.65	50.80	2.33	1,831.52
SMUs 56-61	31.91	207.06	553.26	2,060.71	1,439.05	874.27	494.50	102.99	48.20	5,175.95
SMUs 62-67	11.84	25.27	34.16	120.62	232.86	209.17	189.63	16.00	22.05	861.59
SMUs 68-73	23.81	108.91	166.85	425.02	460.19	234.92	200.03	238.67	-	1,858.41
SMUs 74-79	22.30	93.32	37.51	80.72	20.47	20.41	27.13	128.32	-	430.18
SMUs 80-85	21.25	30.45	70.59	183.25	73.26	4.14	2.38	-	-	385.33
SMUs 86-91	4.75	14.00	17.41	98.49	114.71	2.58	0.76	-	-	252.71
SMUs 92-97	7.30	34.43	34.44	118.61	60.34	0.91	-	-	-	256.03
SMUs 98-103	4.08	3.58	4.67	11.67	71.34	-	-	-	-	95.35
SMUs 104-109	9.11	7.77	14.53	25.72	93.73	-	-	-	-	150.85
SMUs 110-115	16.61	23.91	14.27	200.58	382.50	201.87	-	-	-	839.73
Reach Total	**783.99**	**3,040.22**	**3,715.57**	**8,613.66**	**5,487.89**	**2,532.92**	**1,787.20**	**585.65**	**92.20**	**26,003.30**
RIVER TOTALS	**1,365.85**	**3,908.51**	**4,376.68**	**9,079.92**	**5,545.80**	**2,533.81**	**1,787.29**	**585.65**	**92.20**	**28,639.70**

Table 5-14. Lower Fox River - PCB Mass and Sediment Volume by Deposit/SMU Layer (Continued)

Deposit or SMU Group	Impacted Sediment Volume (m3) by Depth Range									Total Volume (m^3)
	0-10 cm	10-30 cm	30-50 cm	50-100 cm	100-150 cm	150-200 cm	200-250 cm	250-300 cm	300-350 cm	
LLBdM Reach										
Deposit A	12,110	24,160	21,960	49,500	-	-	-	-	-	107,730
Deposit B	9,690	19,380	11,120	1,550	-	-	-	-	-	41,740
Deposit C	9,710	19,080	13,740	20,600	-	-	-	-	-	63,130
Deposit POG	20,290	29,100	18,040	24,800	10,800	-	-	-	-	103,030
Deposit D	18,990	24,800	12,120	10,800	150	-	-	-	-	66,860
Deposit E	154,940	303,920	271,960	265,800	15,450	300	-	-	-	1,012,370
Deposit F	12,620	25,180	20,220	37,900	-	-	-	-	-	95,920
Deposit G	2,800	5,580	-	-	-	-	-	-	-	8,380
Deposit H	230	460	-	-	-	-	-	-	-	690
Reach Total	**241,380**	**451,660**	**369,160**	**410,950**	**26,400**	**300**	**-**	**-**	**-**	**1,499,850**
Appleton to Little Rapids Reach										
Deposit I	680	1,360	780	750	-	-	-	-	-	3,570
Deposit J	530	1,060	40	-	-	-	-	-	-	1,630
Deposit K	160	320	-	-	-	-	-	-	-	480
Deposit L	190	380	-	-	-	-	-	-	-	570
Deposit M	470	940	240	-	-	-	-	-	-	1,650
Deposit N	1,680	1,940	1,060	200	-	-	-	-	-	4,880
Deposit O	810	1,620	-	-	-	-	-	-	-	2,430
Deposit P	2,440	2,740	2,520	5,100	-	-	-	-	-	12,800
Deposit Q	70	140	-	-	-	-	-	-	-	210
Deposit R	330	660	-	-	-	-	-	-	-	990
Deposit S	3,090	6,180	3,280	-	-	-	-	-	-	12,550
Deposit T	1,620	3,220	2,020	1,500	-	-	-	-	-	8,360
Deposit U	200	400	-	-	-	-	-	-	-	600
Deposit V	20	40	-	-	-	-	-	-	-	60
Deposit W	15,060	29,860	17,740	17,000	-	-	-	-	-	79,660
Deposit X	11,230	21,740	13,280	11,150	-	-	-	-	-	57,400
Deposit Y	430	860	40	-	-	-	-	-	-	1,330
Deposit Z	730	1,460	940	1,150	-	-	-	-	-	4,280
Deposit AA	130	260	-	-	-	-	-	-	-	390
Deposit BB	260	520	-	-	-	-	-	-	-	780
Deposit CC	4,020	8,020	2,260	-	-	-	-	-	-	14,300
Deposit DD	7,480	14,820	5,820	3,900	-	-	-	-	-	32,020
Reach Total	**51,630**	**98,540**	**50,020**	**40,750**	**-**	**-**	**-**	**-**	**-**	**240,940**
Little Rapids to De Pere Reach										
Deposit EE	229,110	456,700	414,580	844,950	54,150	33,150	6,800	-	-	2,039,440
Deposit FF	360	700	340	-	-	-	-	-	-	1,400
Deposit GG	2,180	3,720	3,120	5,500	3,050	750	-	-	-	18,320
Deposit HH	3,560	5,300	4,740	8,100	5,300	2,550	650	-	-	30,200
Reach Total	**235,210**	**466,420**	**422,780**	**858,550**	**62,500**	**36,450**	**7,450**	**-**	**-**	**2,089,360**
De Pere to Green Bay Reach										
SMUs 20-25	98,050	175,280	154,500	291,200	192,150	94,850	48,550	-	-	1,054,580
SMUs 26-31	20,100	34,460	26,820	49,550	24,600	8,700	2,000	-	-	166,230
SMUs 32-37	26,080	45,620	32,880	63,650	39,050	16,250	7,300	2,400	-	233,230
SMUs 38-43	43,280	72,400	63,280	124,350	63,850	23,400	8,300	2,400	1,100	402,360
SMUs 44-49	104,730	198,500	181,860	389,300	284,350	150,100	62,350	7,300	1,200	1,379,690
SMUs 50-55	30,930	54,940	51,360	113,050	83,900	49,100	17,750	4,000	250	405,280
SMUs 56-61	27,910	52,340	49,540	114,650	98,750	75,450	42,800	18,400	8,800	457,640
SMUs 62-67	11,700	17,720	16,900	39,650	35,650	33,700	22,850	6,600	5,800	190,570
SMUs 68-73	13,390	26,780	26,780	66,950	66,950	66,950	41,150	28,300	-	337,250
SMUs 74-79	7,350	14,700	14,700	36,750	22,850	22,600	12,200	10,800	-	141,950
SMUs 80-85	8,050	16,100	16,100	40,250	38,200	23,700	22,250	-	-	164,650
SMUs 86-91	6,170	12,340	12,340	22,750	21,950	18,600	9,250	-	-	103,400
SMUs 92-97	9,960	19,920	19,920	49,800	11,550	7,350	-	-	-	118,500
SMUs 98-103	7,590	15,180	15,180	37,950	6,300	-	-	-	-	82,200
SMUs 104-109	9,860	19,720	13,820	21,450	9,700	-	-	-	-	74,550
SMUs 110-115	13,000	24,680	24,020	58,650	55,900	30,000	-	-	-	206,250
Reach Total	**438,150**	**800,680**	**720,000**	**1,519,950**	**1,055,700**	**620,750**	**296,750**	**80,200**	**17,150**	**5,518,330**
RIVER TOTALS	**966,370**	**1,817,300**	**1,561,960**	**2,830,200**	**1,144,600**	**657,500**	**304,200**	**80,200**	**17,150**	**9,348,480**

Table 5-15. Green Bay - PCB Mass and Sediment Volume by Concentration Range and Layer

PCB Mass (kg) and Sediment Volume (m^3) by Concentration Range

	PCB Mass (kg) by Concentration Range (µg/kg)							Total Mass (kg)
ZONE	**0-50**	**50-125**	**125-250**	**250-500**	**500-1,000**	**1,000-5,000**	**> 5,000**	
2A	3.28	832.75	438.95	310.86	288.67	8,558.35	3,953.23	14,386.09
2B	0.04	203.82	221.97	451.80	1,173.96	14,419.39	1,159.49	17,630.47
Zone 2	*3.33*	*1,036.58*	*660.92*	*762.66*	*1,462.63*	*22,977.74*	*5,112.71*	*32,016.57*
3A	619.32	3,298.71	9,766.72	3,316.07	2,156.97	1.65	0.00	19,159.44
3B	119.64	1,045.95	4,843.46	5,997.05	4,816.45	0.00	0.00	16,822.55
Zone 3	*738.96*	*4,344.67*	*14,610.18*	*9,313.12*	*6,973.42*	*1.65*	*0.00*	*35,981.99*
4	1,034.55	730.25	172.15	22.18	0.00	0.00	0.00	1,959.13
Entire Bay	**1,776.84**	**6,111.50**	**15,443.25**	**10,097.95**	**8,436.06**	**22,979.38**	**5,112.71**	**69,957.69**
	Sediment Volume (m^3) by Concentration Range (µg/kg)							**Total Volume (m^3)**
ZONE	**0-50**	**50-125**	**125-250**	**250-500**	**500-1,000**	**1,000-5,000**	**> 5,000**	
2A	87,400	8,692,600	2,753,000	1,373,800	645,800	5,535,400	1,033,000	20,121,000
2B	1,000	2,570,000	1,375,000	1,808,800	2,505,000	10,967,200	232,000	19,459,000
Zone 2	*88,400*	*11,262,600*	*4,128,000*	*3,182,600*	*3,150,800*	*16,502,600*	*1,265,000*	*39,580,000*
3A	30,398,200	50,100,800	101,372,200	17,355,800	12,464,200	8,800	0	211,700,000
3B	8,787,600	44,952,400	92,554,800	44,910,000	33,264,200	0	0	224,469,000
Zone 3	*39,185,800*	*95,053,200*	*193,927,000*	*62,265,800*	*45,728,400*	*8,800*	*0*	*436,169,000*
4	117,629,000	23,866,600	4,668,400	387,000	0	0	0	146,551,000
Entire Bay	**156,903,200**	**130,182,400**	**202,723,400**	**65,835,400**	**48,879,200**	**16,511,400**	**1,265,000**	**622,300,000**

	PCB Mass to Impacted Sediment Volume (grams/m^3)			
ZONE	**> 50**	**> 500**	**> 1,000**	**> 5,000**
2A	0.72	1.77	1.90	3.83
2B	0.91	1.22	1.39	5.00
Zone 2	*0.81*	*1.41*	*1.58*	*4.04*
3A	0.10	0.17	0.19	na
3B	0.08	0.14	na	na
Zone 3	*0.09*	*0.15*	*0.19*	*na*
4	0.03	na	na	na
Entire Bay	**0.15**	**0.55**	**1.58**	**4.04**

Notes: na - Not Applicable.

Table 5-15. Green Bay - PCB Mass and Sediment Volume by Concentration Range and Layer (Continued)

PCB Mass (kg) and Sediment Volume (m^3) by Layer

PCB Mass (kg) by Layer (cm)					
ZONE	**0-2**	**2-10**	**10-30**	**> 30**	**Total Mass (kg)**
2A	616.13	2,411.29	3,557.13	7,801.55	14,386.09
2B	853.03	3,348.01	3,702.21	9,727.22	17,630.47
Zone 2	*1,469.16*	*5,759.29*	*7,259.34*	*17,528.77*	*32,016.56*
3A	1,933.85	6,084.29	7,130.75	4,007.55	19,156.44
3B	1,523.76	5,820.64	7,753.49	1,724.66	16,822.55
Zone 3	*3,457.61*	*11,904.93*	*14,884.24*	*5,732.21*	*35,978.99*
4	391.17	1,147.11	420.85	0.00	1,959.13
Entire Bay	**5,317.95**	**18,811.33**	**22,564.43**	**23,260.97**	**69,954.68**

Sediment Volume (m^3) by Layer (cm)					
ZONE	**0-2**	**2-10**	**10-30**	**> 30**	**Total Volume (m^3)**
2A	1,099,800	4,399,200	10,784,000	3,838,000	20,121,000
2B	929,000	3,716,000	8,876,000	5,938,000	19,459,000
Zone 2	*2,028,800*	*8,115,200*	*19,660,000*	*9,776,000*	*39,580,000*
3A	13,112,400	52,449,600	100,036,000	46,102,000	211,700,000
3B	12,891,400	51,565,600	125,844,000	34,168,000	224,469,000
Zone 3	*26,003,800*	*104,015,200*	*225,880,000*	*80,270,000*	*436,169,000*
4	14,017,800	56,071,200	76,462,000	0	146,551,000
Entire Bay	**42,050,400**	**168,201,600**	**322,002,000**	**90,046,000**	**622,300,000**

PCB Mass to Impacted Sediment Volume (grams/m^3)				
ZONE	**0-2**	**2-10**	**10-30**	**> 30**
2A	0.56	0.55	0.33	2.03
2B	1.58	1.55	0.82	2.95
Zone 2	*1.03*	*1.01*	*0.55*	*2.59*
3A	0.15	0.12	0.07	0.09
3B	0.27	0.23	0.12	0.17
Zone 3	*0.21*	*0.17*	*0.10*	*0.12*
4	0.03	0.02	0.01	0.00
Entire Bay	**0.13**	**0.11**	**0.07**	**0.26**

Notes: na - Not Applicable.

Table 5-16. Lower Fox River and Green Bay - Water Sampling Results: Summary of Detected Compounds

Reach/Zone	Type	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI Mean[A]	RA Mean[B]	Log-Normal Mean[C]	Units
Lake Winnebago - Filtered Water Results											
Lake Winnebago	filtered	Total PCBs	10	2	20.00%	5	7	6	11.2	10.7488	ng/L
Lake Winnebago	filtered	Ar1242	10	2	20.00%	5	7	6	4.6	4.4762	ng/L
Lake Winnebago	filtered	Mercury	1	0	0.00%	0	0	0	40	0.0000	ng/L
Lake Winnebago - Particulate Results											
Lake Winnebago	particulate	Total PCBs	10	3	30.00%	3.2	6	4.4	9.87	8.8776	ng/L
Lake Winnebago	particulate	Ar1242	10	3	30.00%	3.2	6	4.4	4.52	4.4231	ng/L
PCB Particulate Results											
Little Lake Butte des Morts	particulate	Total PCBs	41	34	82.93%	0.13	40.16	17.4424	16.5863	9.1379	ng/L
Appleton to Little Rapids	particulate	Total PCBs	86	82	95.35%	0.01	52.17	11.9519	11.9483	4.0719	ng/L
Little Rapids to DePere	particulate	Total PCBs	98	94	95.92%	0.17	96.3	30.5349	29.8753	20.8616	ng/L
DePere to Green Bay	particulate	Total PCBs	143	129	90.21%	1.433	149.0546	47.5894	44.2450	33.6712	ng/L
Green Bay Zone 2 (2A & 2B)	particulate	Total PCBs	71	71	100.00%	1.2702	91.7033	12.9643	12.9643	8.8221	ng/L
Green Bay Zone 3A	particulate	Total PCBs	66	61	92.42%	0.2181	16.9315	2.8102	2.7867	1.8689	ng/L
Green Bay Zone 3B	particulate	Total PCBs	45	40	88.89%	0.2528	9.4496	2.1790	2.2146	1.3947	ng/L
Green Bay Zone 4	particulate	Total PCBs	86	66	76.74%	0.1237	2.3816	0.4226	0.9057	0.5303	ng/L
Little Lake Butte des Morts	particulate	Ar1242	12	5	41.67%	5	15	9.2000	6.5000	5.8777	ng/L
Appleton to Little Rapids	particulate	Ar1242	13	9	69.23%	6	15	9.3333	8.0000	7.3670	ng/L
Little Rapids to DePere	particulate	Ar1242	24	20	83.33%	9	28	19.7000	18.0833	17.0671	ng/L
Little Rapids to DePere	particulate	Ar1254	24	1	4.17%	20	20	20.0000	6.8542	6.5639	ng/L
DePere to Green Bay	particulate	Ar1242	46	32	69.57%	12	45	22.2500	17.7935	15.2527	ng/L
Green Bay Zone 2 (2A & 2B)	particulate	Ar1242	9	9	100.00%	2.5	9.6	6.1889	6.1889	5.8004	ng/L
Green Bay Zone 3A	particulate	Ar1242	6	1	16.67%	0.66	0.66	0.6600	0.8600	0.8547	ng/L
Green Bay Zone 3B	particulate	Ar1242	7	2	28.57%	0.65	1.8	1.2250	0.9929	0.9485	ng/L
Green Bay Zone 4	particulate	Ar1242	20	0	0.00%	0	0	0.0000	0.9000	0.9000	ng/L
Little Lake Butte des Morts	particulate	PCB Congener 77/110	29	29	100.00%	0.04	1.3	0.5997	0.5997	0.3992	ng/L
Appleton to Little Rapids	particulate	PCB Congener 77/110	74	63	85.14%	0.023	1.5	0.3818	0.3705	0.1633	ng/L
Little Rapids to DePere	particulate	PCB Congener 77/110	74	74	100.00%	0.04	2.9	0.7661	0.7661	0.5302	ng/L
DePere to Green Bay	particulate	PCB Congener 77/110	86	86	100.00%	0.0486	2.5934	1.0373	1.0373	0.8672	ng/L
Green Bay Zone 2 (2A & 2B)	particulate	PCB Congener 77/110	61	61	100.00%	0.043	2.4525	0.3797	0.3797	0.2553	ng/L
Green Bay Zone 3A	particulate	PCB Congener 77/110	60	60	100.00%	0.007	0.4559	0.0824	0.0824	0.0526	ng/L
Green Bay Zone 3B	particulate	PCB Congener 77/110	38	38	100.00%	0.0074	0.2725	0.0633	0.0633	0.0370	ng/L
Green Bay Zone 4	particulate	PCB Congener 77/110	66	66	100.00%	0.0025	0.0283	0.0084	0.0084	0.0074	ng/L
Green Bay Zone 2 (2A & 2B)	particulate	PCB Congener 77/110	61	61	100.00%	0.043	2.4525	0.3797	0.3797	0.2553	ng/L

Table 5-16. Lower Fox River and Green Bay - Water Sampling Results: Summary of Detected Compounds (Continued)

Reach/Zone	Type	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI MeanA	RA MeanB	Log-Normal MeanC	Units
Appleton to Little Rapids	particulate	PCB Congener 132/153/105	50	37	74.00%	0.026	0.49	0.1105	0.1428	0.0742	ng/L
DePere to Green Bay	particulate	PCB Congener 132/153/105	78	75	96.15%	0.08038	2.3348	0.7472	0.7193	0.5542	ng/L
Green Bay Zone 2 (2A & 2B)	particulate	PCB Congener 132/153/105	61	52	85.25%	0.0537	0.7381	0.2669	0.2276	0.0865	ng/L
Green Bay Zone 3A	particulate	PCB Congener 132/153/105	60	58	96.67%	0.0134	0.3031	0.0820	0.0793	0.0513	ng/L
Green Bay Zone 3B	particulate	PCB Congener 132/153/105	38	35	92.11%	0.0063	0.204	0.0585	0.0539	0.0287	ng/L
Green Bay Zone 4	particulate	PCB Congener 132/153/105	66	65	98.48%	0.0021	0.046	0.0144	0.0142	0.0115	ng/L
Little Lake Butte des Morts	particulate	PCB Congener 118	27	27	100.00%	0.03	0.65	0.3100	0.3100	0.2188	ng/L
Appleton to Little Rapids	particulate	PCB Congener 118	71	56	78.87%	0.016	0.8	0.2176	0.2072	0.0927	ng/L
Little Rapids to DePere	particulate	PCB Congener 118	72	72	100.00%	0.0203	1.2	0.4133	0.4133	0.3040	ng/L
DePere to Green Bay	particulate	PCB Congener 118	86	85	98.84%	0.01894	1.5584	0.5552	0.5488	0.4510	ng/L
Green Bay Zone 2 (2A & 2B)	particulate	PCB Congener 118	61	61	100.00%	0.0263	2.5922	0.2300	0.2300	0.1470	ng/L
Green Bay Zone 3A	particulate	PCB Congener 118	60	59	98.33%	0.0048	0.2406	0.0492	0.0484	0.0309	ng/L
Green Bay Zone 3B	particulate	PCB Congener 118	38	38	100.00%	0.0043	0.1703	0.0374	0.0374	0.0224	ng/L
Green Bay Zone 4	particulate	PCB Congener 118	66	66	100.00%	0.001	0.1021	0.0075	0.0075	0.0050	ng/L
Pesticide Particulate Results											
DePere to Green Bay	particulate	alpha-Chlordane	27	26	96.30%	0.022	0.2	0.0402	0.0391	0.0328	ng/L
DePere to Green Bay	particulate	cis-Nonachlor	3	3	100.00%	0.025	0.047	0.0327	0.0327	0.0313	ng/L
DePere to Green Bay	particulate	gamma-Chlordane	9	8	88.89%	0.028	0.24	0.0739	0.0669	0.0456	ng/L
DePere to Green Bay	particulate	p,p'-DDD	40	38	95.00%	0.054	0.27	0.1164	0.1119	0.0988	ng/L
DePere to Green Bay	particulate	p,p'-DDE	42	41	97.62%	0.032	0.41	0.1763	0.1725	0.1472	ng/L
DePere to Green Bay	particulate	p,p'-DDT	8	7	87.50%	0.05	0.21	0.0799	0.0730	0.0613	ng/L
DePere to Green Bay	particulate	trans-Nonachlor	45	18	40.00%	0.018	0.17	0.0306	0.0157	0.0096	ng/L
SVOC Particulate Results											
DePere to Green Bay	particulate	Hexachlorobenzene	42	40	95.24%	0.0073	0.0300	0.0151	0.0146	0.0131	ng/L
Inorganic Compound Particulate Results											
DePere to Green Bay	particulate	Mercury	32	32	100.00%	0.0018	0.0748	0.0230	0.0230	0.0177	µg/L
PCB Filtered Water Results											
Little Lake Butte des Morts	filtered	Total PCBs	46	40	86.96%	1.4	19	8.9708	11.0615	8.3044	ng/L
Appleton to Little Rapids	filtered	Total PCBs	85	84	98.82%	0.026	18.86	4.7567	4.8420	2.3967	ng/L
Little Rapids to DePere	filtered	Total PCBs	98	97	98.98%	0.185	27.6	11.2496	11.2726	9.2104	ng/L
DePere to Green Bay	filtered	Total PCBs	143	142	99.30%	2.414	45	16.6654	16.6397	14.7317	ng/L
Green Bay Zone 2 (2A & 2B)	filtered	Total PCBs	63	63	100.00%	0.9962	13.6814	4.8232	4.8232	3.9619	ng/L
Green Bay Zone 3A	filtered	Total PCBs	60	60	100.00%	0.4749	5.136	1.6307	1.6307	1.3759	ng/L
Green Bay Zone 3B	filtered	Total PCBs	40	40	100.00%	0.5181	3.9201	1.4468	1.4468	1.2250	ng/L
Green Bay Zone 4	filtered	Total PCBs	66	66	100.00%	0.315	1.323	0.5840	0.5840	0.5556	ng/L

Table 5-16. Lower Fox River and Green Bay - Water Sampling Results: Summary of Detected Compounds (Continued)

Reach/Zone	Type	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI MeanA	RA MeanB	Log-Normal MeanC	Units
Little Lake Butte des Morts	filtered	Ar1242	18	12	66.67%	4	19	8.4417	13.9611	11.3055	ng/L
Appleton to Little Rapids	filtered	Ar1242	13	12	92.31%	4.6	10	7.2250	7.2077	7.0177	ng/L
Little Rapids to DePere	filtered	Ar1242	24	23	95.83%	7	25	12.2043	11.9667	10.9744	ng/L
DePere to Green Bay	filtered	Ar1242	46	43	93.48%	5	45	12.5349	12.1630	10.6920	ng/L
Little Lake Butte des Morts	filtered	PCB Congener 77/110	28	28	100.00%	0.08	0.54	0.1982	0.1982	0.1763	ng/L
Appleton to Little Rapids	filtered	PCB Congener 77/110	73	34	46.58%	0.022	0.3	0.1396	0.1251	0.0641	ng/L
Little Rapids to DePere	filtered	PCB Congener 77/110	72	72	100.00%	0.0236	0.34	0.1469	0.1469	0.1255	ng/L
DePere to Green Bay	filtered	PCB Congener 77/110	86	86	100.00%	0.0437	0.41648	0.1606	0.1606	0.1501	ng/L
Green Bay Zone 2 (2A & 2B)	filtered	PCB Congener 77/110	62	62	100.00%	0.002	0.1842	0.0735	0.0735	0.0606	ng/L
Green Bay Zone 3A	filtered	PCB Congener 77/110	60	60	100.00%	0.0079	0.1055	0.0309	0.0309	0.0255	ng/L
Green Bay Zone 3B	filtered	PCB Congener 77/110	40	39	97.50%	0.0068	0.0791	0.0271	0.0265	0.0202	ng/L
Green Bay Zone 4	filtered	PCB Congener 77/110	66	66	100.00%	0.0052	0.0234	0.0117	0.0117	0.0112	ng/L
Appleton to Little Rapids	filtered	PCB Congener 132/153/105	50	3	6.00%	0.026	0.043	0.0343	0.0859	0.0366	ng/L
DePere to Green Bay	filtered	PCB Congener 132/153/105	77	52	67.53%	0.04156	0.175	0.0895	0.0665	0.0511	ng/L
Green Bay Zone 2 (2A & 2B)	filtered	PCB Congener 132/153/105	62	62	100.00%	0.013	0.1549	0.0481	0.0481	0.0414	ng/L
Green Bay Zone 3A	filtered	PCB Congener 132/153/105	60	60	100.00%	0.0075	0.0847	0.0300	0.0300	0.0245	ng/L
Green Bay Zone 3B	filtered	PCB Congener 132/153/105	40	39	97.50%	0.0097	0.1119	0.0290	0.0283	0.0202	ng/L
Green Bay Zone 4	filtered	PCB Congener 132/153/105	66	66	100.00%	0.0075	0.0792	0.0143	0.0143	0.0131	ng/L
Little Lake Butte des Morts	filtered	PCB Congener 118	28	28	100.00%	0.03	0.12	0.0746	0.0746	0.0690	ng/L
Appleton to Little Rapids	filtered	PCB Congener 118	71	24	33.80%	0.021	0.5	0.0988	0.0808	0.0409	ng/L
Little Rapids to DePere	filtered	PCB Congener 118	70	70	100.00%	0.007	0.1939	0.0554	0.0554	0.0437	ng/L
DePere to Green Bay	filtered	PCB Congener 118	86	83	96.51%	0.01881	0.14079	0.0507	0.0494	0.0455	ng/L
Green Bay Zone 2 (2A & 2B)	filtered	PCB Congener 118	62	62	100.00%	0.0053	0.0583	0.0225	0.0225	0.0193	ng/L
Green Bay Zone 3A	filtered	PCB Congener 118	60	60	100.00%	0.0029	0.0339	0.0104	0.0104	0.0088	ng/L
Green Bay Zone 3B	filtered	PCB Congener 118	40	40	100.00%	0.003	0.026	0.0091	0.0091	0.0078	ng/L
Green Bay Zone 4	filtered	PCB Congener 118	66	66	100.00%	0.002	0.0084	0.0038	0.0038	0.0036	ng/L
Pesticide Filtered Water Results											
DePere to Green Bay	filtered	alpha-BHC	31	30	96.77%	0.058	1.1	0.2101	0.2042	0.1502	ng/L
DePere to Green Bay	filtered	alpha-Chlordane	14	12	85.71%	0.022	0.039	0.0263	0.0240	0.0227	ng/L
DePere to Green Bay	filtered	Atrazine	13	13	100.00%	40.6	81.07	58.8308	58.8308	57.5880	ng/L
DePere to Green Bay	filtered	Desethylatrazine	13	13	100.00%	36.5	62.49	46.5208	46.5208	46.1231	ng/L
DePere to Green Bay	filtered	Desisopropylatrazine	13	13	100.00%	14.1	33.9	22.5638	22.5638	21.8316	ng/L
DePere to Green Bay	filtered	gamma-BHC (Lindane)	31	28	90.32%	0.053	0.83	0.2035	0.1864	0.1301	ng/L
DePere to Green Bay	filtered	gamma-Chlordane	8	8	100.00%	0.024	0.053	0.0328	0.0328	0.0317	ng/L
DePere to Green Bay	filtered	p,p'-DDD	7	5	71.43%	0.05	0.067	0.0560	0.0474	0.0447	ng/L
DePere to Green Bay	filtered	p,p'-DDE	19	19	100.00%	0.034	0.072	0.0407	0.0407	0.0401	ng/L
DePere to Green Bay	filtered	trans-Nonachlor	36	9	25.00%	0.006	0.019	0.0094	0.0050	0.0042	ng/L
DePere to Green Bay	filtered	Hexachlorobenzene	44	44	100.00%	0.0074	0.026	0.0123	0.0123	0.0118	ng/L

Table 5-16. Lower Fox River and Green Bay - Water Sampling Results: Summary of Detected Compounds (Continued)

Reach/Zone	Type	Parameter	Number of Samples	Number Detected	Percent Detected	Minimum Result	Maximum Result	RI MeanA	RA MeanB	Log-Normal MeanC	Units
Inorganic Compound Filtered Water Results											
Little Lake Butte des Morts	filtered	Aluminum	1	1	100.00%	20.70	20.70	20.7000	20.7000	0.0000	µg/L
Little Rapids to DePere	filtered	Aluminum	2	2	100.00%	12.70	15.64	14.1700	14.1700	14.0935	µg/L
Green Bay Zone 2 (2A & 2B)	filtered	Aluminum	2	2	100.00%	5.56	12.40	8.9800	8.9800	8.3033	µg/L
Little Lake Butte des Morts	filtered	Cadmium	1	1	100.00%	0.0057	0.0057	0.0057	0.0057	0.0000	µg/L
Little Rapids to DePere	filtered	Cadmium	2	2	100.00%	0.0107	0.0182	0.0145	0.0145	0.0140	µg/L
Green Bay Zone 2 (2A & 2B)	filtered	Cadmium	2	2	100.00%	0.0124	0.0187	0.0156	0.0156	0.0152	µg/L
DePere to Green Bay	filtered	Calcium, dissolved	29	29	100.00%	31,700	48,770	38,657.59	38,657.59	38,357.98	µg/L
Little Rapids to DePere	filtered	Chromium	1	1	100.00%	0.3310	0.3310	0.3310	0.3310	0.0000	µg/L
Green Bay Zone 2 (2A & 2B)	filtered	Chromium	2	2	100.00%	0.1910	0.3730	0.2820	0.2820	0.2669	µg/L
Little Lake Butte des Morts	filtered	Copper	1	1	100.00%	1	1	1	1	0.0000	µg/L
Little Rapids to DePere	filtered	Copper	2	2	100.00%	0.8580	0.8910	0.8745	0.8745	0.8743	µg/L
Green Bay Zone 2 (2A & 2B)	filtered	Copper	2	2	100.00%	1.9200	2.0100	1.9650	1.9650	1.9645	µg/L
Little Lake Butte des Morts	filtered	Lead	1	1	100.00%	0.1170	0.1170	0.1170	0.1170	0.0000	µg/L
Little Rapids to DePere	filtered	Lead	2	2	100.00%	0.1180	0.1240	0.1210	0.1210	0.1210	µg/L
Green Bay Zone 2 (2A & 2B)	filtered	Lead	2	2	100.00%	0.0440	0.0442	0.0441	0.0441	0.0441	µg/L
DePere to Green Bay	filtered	Magnesium, dissolved	29	29	100.00%	17,290	24,500	20,970.66	20,970.66	20,892.48	µg/L
Little Lake Butte des Morts	filtered	Mercury	2	0	0.00%	0	0	0	0.0400	0.0400	µg/L
Appleton to Little Rapids	filtered	Mercury	2	1	50.00%	0.09	0.09	0.09	0.0650	0.0600	µg/L
Little Rapids to DePere	filtered	Mercury	3	2	66.67%	1.26	2.52	1.89	1.2733	0.5027	µg/L
DePere to Green Bay	filtered	Mercury	45	43	95.56%	0.00053	0.04081	0.00323	0.00487	0.00182	µg/L
Green Bay Zone 2 (2A & 2B)	filtered	Mercury	10	2	20.00%	1.15	2.33	1.74	0.3910	0.1035	µg/L
Green Bay Zone 3A	filtered	Mercury	6	0	0.00%	0	0	0	0.0508	0.0496	µg/L
Green Bay Zone 3B	filtered	Mercury	7	0	0.00%	0	0	0	0.0543	0.0528	µg/L
Green Bay Zone 4	filtered	Mercury	20	0	0.00%	0	0	0	0.0523	0.0504	µg/L
DePere to Green Bay	filtered	Potassium, dissolved	29	29	100.00%	2,233.00	4,530.00	2,861.38	2,861.38	2,824.25	µg/L
DePere to Green Bay	filtered	Sodium	29	29	100.00%	9,419	28,900	15,752.34	15,752.34	15,191.06	µg/L
Little Lake Butte des Morts	filtered	Zinc	1	1	100.00%	0.438	0.438	0.438	0.438	0.0000	µg/L
Little Rapids to DePere	filtered	Zinc	2	2	100.00%	1.24	2.59	1.915	1.915	1.7921	µg/L
Green Bay Zone 2 (2A & 2B)	filtered	Zinc	2	2	100.00%	1.2	1.81	1.505	1.505	1.4738	µg/L

Notes: This table only contains parameters which were sampled and detected in Lower Fox River or Green Bay water/particulate samples.

A) The RI Mean is the average of all detected sample results.

B) The RA Mean is the average of all detected sample results plus 1/2 the detection limit for samples flagged as non-detect by the lab.

C) The Log-Normal Mean was calculated using the RA Mean sample data - this was done because not all sample populations have a normal distribution.

Table 5-17. Lower Fox River - Total PCB Results in Water

Sample Idenifcation	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate	Temp. (°C)	Sample Idenifcation	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate	Temp. (°C)
LLBdM Reach							#46	4/11/90	4.710	11.390	16.100	70.75%	NA
9003244	4/20/89	NA	17.090	17.090	100.0%	NA	#47	4/17/90	6.730	16.540	23.270	71.08%	NA
9003450	5/2/89	13.270	34.810	48.080	72.4%	NA	OB004149	4/19/90	5.470	13.620	19.090	71.35%	NA
9003619	5/17/89	11.930	35.610	47.540	74.9%	NA	OB004150	4/19/90	6.350	13.360	19.710	67.78%	NA
9003621	5/17/89	13.150	36.160	49.310	73.3%	NA	#48	4/24/90	10.970	29.910	40.880	73.17%	NA
9003777	5/31/89	3.660	14.460	18.120	79.8%	NA	#49	4/24/90	11.100	30.950	42.050	73.60%	NA
9004429	6/27/89	16.610	38.930	55.540	70.1%	NA	#50	5/1/90	15.030	39.390	54.420	72.38%	NA
A	6/14/89	8.510	24.070	32.580	73.9%	NA	4085000AU	6/16/92	NA	NA	NA	NA	22.5
AO001179	7/26/89	14.610	33.660	48.270	69.7%	NA	4085000BU	8/13/92	NA	NA	NA	NA	20.5
BA-SW01	11/18/92	50.000	NA	50.000	0.0%	2.0	4085000CU	10/21/92	NA	NA	NA	NA	7.0
BA-SW04	11/18/92	50.000	NA	50.000	0.0%	2.0	4085000DU	3/12/93	NA	NA	NA	NA	2.0
BA-SW05a	12/16/92	50.000	NA	50.000	0.0%	0.5	4085000EU	5/13/93	NA	NA	NA	NA	15.0
BA-SW05b	3/9/93	50.000	NA	50.000	0.0%	3.0	4085000FU	8/24/93	NA	NA	NA	NA	25.0
BA-SW08a	12/16/92	50.000	NA	50.000	0.0%	2.0	4085000GU	10/19/93	NA	NA	NA	NA	12.0
BA-SW08b	3/9/93	50.000	NA	50.000	0.0%	3.0	4085000HU	3/29/94	NA	NA	NA	NA	4.5
OA001183	7/12/89	18.950	40.160	59.110	67.9%	NA	4085000IU	5/19/94	NA	NA	NA	NA	17.0
OA001626	8/22/89	16.200	33.060	49.260	67.1%	NA	4085000JU	8/24/94	NA	NA	NA	NA	25.0
OA001633	8/8/89	16.230	39.180	55.410	70.7%	NA	SW4-F1	4/1/98	7.000	ND	7.000	0.00%	NA
OA002394	10/3/89	12.580	24.940	37.520	66.5%	NA	SW4-F2	4/2/98	9.000	ND	9.000	0.00%	NA
OA003238	9/20/89	16.170	26.330	42.500	62.0%	NA	SW4-F3	4/3/98	13.000	ND	13.000	0.00%	5.9
OA003239	9/20/89	15.780	22.560	38.340	58.8%	NA	SW4-F4	4/6/98	27.000	ND	27.000	0.00%	6.7
OA003243	9/5/89	17.910	27.830	45.740	60.8%	NA	SW4-F5	4/7/98	7.000	20.000	27.000	74.07%	7.0
OA004474	10/17/89	14.610	28.490	43.100	66.1%	NA	SW4-F6	4/8/98	7.000	38.000	45.000	84.44%	7.6
OA004478	10/31/89	9.590	27.160	36.750	73.9%	NA	SW4-F7	4/10/98	8.000	13.000	21.000	61.90%	6.4
OB000378	11/14/89	4.140	0.470	4.610	10.2%	NA	SW4-F8	4/14/98	8.000	23.000	31.000	74.19%	9.0
OB000379	11/15/89	2.690	5.200	7.890	65.9%	NA	SW4-F9	4/16/98	13.000	24.000	37.000	64.86%	7.1
OB000387	12/5/89	2.350	1.050	3.400	30.9%	NA	SW4-F10	4/17/98	8.000	16.000	24.000	66.67%	6.6
OB001106	1/18/90	2.450	0.220	2.670	8.2%	NA	SW4-F11	5/12/98	12.000	28.000	40.000	70.00%	17.1
OB001112	2/13/90	2.710	0.810	3.520	23.0%	NA	SW4-F12	5/27/98	7.000	9.000	16.000	56.25%	19.3
OB001115	3/13/90	2.120	0.860	2.980	28.9%	NA	W00005	6/9/98	9.000	19.000	28.000	67.86%	16.9
OB001116	3/23/90	1.400	0.130	1.530	8.5%	NA	W00014	6/30/98	13.000	27.000	40.000	67.50%	24.5
OB002900	3/13/90	7.630	13.300	20.930	63.5%	NA	W00032	7/14/98	18.000	22.000	40.000	55.00%	26.6
OB002901	3/19/90	2.930	2.820	5.750	49.0%	NA	W00035	7/14/98	15.000	24.000	39.000	61.54%	26.6
OB002902	3/23/90	2.600	1.950	4.550	42.9%	NA	W00047	7/28/98	17.000	14.000	31.000	45.16%	23.8
OB002904	4/2/90	3.020	4.920	7.940	62.0%	NA	W00048	7/28/98	20.000	16.000	36.000	44.44%	23.8
OB002905	4/18/90	3.730	10.810	14.540	74.3%	NA	SW00066	8/11/98	25.000	23.000	48.000	47.92%	24.3

Table 5-17. Lower Fox River - Total PCB Results in Water (Continued)

Sample Idenifcation	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate	Temp. (°C)	Sample Idenifcation	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate	Temp. (°C)
SW00064	8/10/98	19.000	15.000	34.000	44.1%	25.6	SW00067	8/11/98	24.000	22.000	46.000	47.83%	24.3
SW2-F11	5/11/98	11.000	7.000	18.000	38.9%	15.9	W00092	8/31/98	11.000	19.000	30.000	63.33%	24.2
SW2-F12	5/26/98	7.000	5.000	12.000	41.7%	19.2	W00093	8/31/98	13.000	19.000	32.000	59.38%	24.2
W00002	6/8/98	9.000	ND	9.000	0.0%	16.4	W00103	9/9/98	9.000	18.000	27.000	66.67%	21.2
W00012	6/29/98	5.000	ND	5.000	0.0%	25.1	W00127	9/24/98	7.700	20.000	27.700	72.20%	19.0
W00017	6/29/98	6.000	ND	6.000	0.0%	25.1	**DePere to Green Bay**						
W00030	7/13/98	4.000	ND	4.000	0.0%	24.9	89GG25S70	5/4/89	19.725	116.812	136.532	85.56%	NA
W00045	7/27/98	14.000	ND	14.000	0.0%	24.3	89GG25S61	5/4/89	19.725	116.835	136.560	85.56%	NA
W00090	8/27/98	8.000	9.000	17.000	52.9%	24.0	89GG25S90	5/5/89	27.607	149.052	176.659	84.37%	NA
W00099	9/9/98	7.000	ND	7.000	0.0%	19.3	89GG26D10	5/5/89	24.500	84.486	108.986	77.52%	NA
W00100	9/9/98	7.000	ND	7.000	0.0%	19.3	89GG26S01	5/5/89	23.832	95.007	118.839	79.95%	NA
W00124	9/23/98	4.300	10.000	14.300	69.9%	17.9	89GG26S10	5/5/89	23.088	105.363	128.451	82.03%	NA
Appleton to Little Rapids							89GG26S30	5/5/89	25.449	86.668	112.117	77.30%	NA
9003241	4/19/89	7.540	29.000	36.540	79.4%	NA	89GG26S50	5/5/89	25.816	82.140	107.956	76.09%	NA
9003452	5/3/89	11.040	42.640	53.680	79.4%	NA	89GG25S81	5/5/89	27.628	149.055	176.682	84.36%	NA
9003620	5/16/89	13.570	51.610	65.180	79.2%	NA	89GG26S21	5/5/89	25.457	86.676	112.133	77.30%	NA
9003778	6/1/89	6.020	35.910	41.930	85.6%	NA	89GG26S41	5/5/89	25.879	82.153	108.032	76.04%	NA
B	6/14/89	9.660	29.690	39.350	75.5%	NA	89GG26S70	5/6/89	25.128	103.808	128.936	80.51%	NA
9004428	6/27/89	18.860	46.180	65.040	71.0%	NA	89GG26S41(2)	5/6/89	25.138	103.911	129.048	80.52%	NA
9004430	6/27/89	17.460	32.880	50.340	65.3%	NA	89GG31S01	6/7/89	11.112	55.073	66.185	83.21%	NA
OA001184	7/11/89	17.820	41.200	59.020	69.8%	NA	89GG31S41	6/7/89	18.476	37.250	55.726	66.85%	NA
OA001178	7/26/89	14.920	44.100	59.020	74.7%	NA	89GG31S61	6/7/89	12.607	27.543	40.150	68.60%	NA
OA001632	8/9/89	15.930	52.170	68.100	76.6%	NA	89GG31D81	6/8/89	16.775	55.267	72.042	76.71%	NA
OA001625	8/23/89	15.020	46.940	61.960	75.8%	NA	89GG31S81	6/8/89	17.021	30.954	47.975	64.52%	NA
OA003244	9/6/89	11.480	27.110	38.590	70.3%	NA	89GG31S21	6/8/89	14.416	47.912	62.328	76.87%	NA
OA003237	9/20/89	13.510	27.330	40.840	66.9%	NA	89GG32S01	6/8/89	16.095	56.626	72.721	77.87%	NA
OA002395	10/3/89	16.490	31.390	47.880	65.6%	NA	89GG41S01	7/27/89	20.660	29.276	49.936	58.63%	NA
OA004473	10/17/89	8.380	32.000	40.380	79.2%	NA	89GG41S21	7/27/89	25.961	46.474	72.436	64.16%	NA
OA004476	11/1/89	8.780	31.390	40.170	78.1%	NA	89GG41S41	7/27/89	31.230	78.100	109.330	71.43%	NA
OB000380	11/15/89	2.820	4.850	7.670	63.2%	NA	89GG41S61	7/27/89	24.313	41.177	65.490	62.88%	NA
OB000383	12/6/89	1.960	0.450	2.410	18.7%	NA	89GG41S81	7/27/89	29.582	70.632	100.214	70.48%	NA
OB000385	12/6/89	2.810	0.550	3.360	16.4%	NA	89GG42S01	7/27/89	25.280	77.837	103.117	75.48%	NA
OB001108	1/18/90	0.780	0.500	1.280	39.1%	NA	89GG56D61	9/20/89	17.747	36.163	53.910	67.08%	NA
OB001114	2/14/90	NA	2.480	NA	NA	NA	89GG56S61	9/20/89	17.078	28.538	45.616	62.56%	NA
OB004144	3/13/90	4.310	10.140	14.450	70.2%	NA	89GG56S01	9/20/89	18.507	37.570	56.077	67.00%	NA
OB004146	4/2/90	3.400	3.670	7.070	51.9%	NA	89GG56S21	9/20/89	23.396	55.882	79.278	70.49%	NA
OB004148	4/18/90	5.170	12.660	17.830	71.0%	NA	89GG56S41	9/20/89	26.960	38.234	65.194	58.65%	NA
SW3-F11	5/12/98	10.000	11.000	21.000	52.4%	16.5	89GG56S81	9/20/89	25.588	44.956	70.544	63.73%	NA

Table 5-17. Lower Fox River - Total PCB Results in Water (Continued)

Sample Idenifcation	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate	Temp. (°C)	Sample Idenifcation	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate	Temp. (°C)
SW-D4-F	5/26/98	9.000	6.000	15.000	40.0%	19.9	89GG57S01	9/20/89	21.200	39.011	60.211	64.79%	NA
SW3-F12	5/26/98	8.000	6.000	14.000	42.9%	19.9	90GG01S01	10/17/89	15.851	48.207	64.058	75.26%	NA
W00003	6/8/98	6.000	22.000	28.000	78.6%	17.7	90GG01S21	10/17/89	16.360	86.972	103.332	84.17%	NA
W00004	6/8/98	6.000	22.000	28.000	78.6%	17.7	90GG01D61	10/18/89	26.137	75.326	101.463	74.24%	NA
W00013	6/29/98	7.000	8.000	15.000	53.3%	16.0	90GG01S61	10/18/89	25.021	97.590	122.611	79.59%	NA
W00031	7/13/98	7.000	27.000	34.000	79.4%	26.2	90GG01S41	10/18/89	20.492	72.636	93.128	78.00%	NA
W00046	7/27/98	10.000	7.000	17.000	41.2%	25.4	90GG01S81	10/18/89	23.791	78.765	102.557	76.80%	NA
SW00065	8/11/98	24.000	15.000	39.000	38.5%	24.5	90GG02S01	10/18/89	25.067	100.037	125.104	79.96%	NA
W00091	8/27/98	8.000	10.000	18.000	55.6%	25.1	90GG26S10	4/30/90	17.424	47.710	65.134	73.25%	NA
W00101	9/9/98	6.000	24.000	30.000	80.0%	21.4	90GG26S01	4/30/90	17.433	47.749	65.182	73.25%	NA
W00125	9/24/98	4.600	10.000	14.600	68.5%	19.2	90GG26S50	5/1/90	21.969	92.734	114.703	80.85%	NA
W00126	9/24/98	5.100	11.000	16.100	68.3%	19.2	90GG26S70	5/1/90	20.565	43.288	63.853	67.79%	NA
D-1	10/21/98	0.044	0.011	0.055	20.0%	NA	90GG26S90	5/1/90	25.042	49.271	74.313	66.30%	NA
U-1	10/21/98	0.026	0.010	0.036	27.8%	NA	90GG27S10	5/1/90	18.858	60.028	78.886	76.09%	NA
D-03	11/12/98	4.117	25.881	29.998	86.3%	NA	90GG26S41	5/1/90	22.067	92.895	114.962	80.80%	NA
U-03	11/12/98	4.925	32.733	37.658	86.9%	NA	90GG26S61	5/1/90	20.670	43.409	64.079	67.74%	NA
D-04	11/18/98	1.089	5.077	6.166	82.3%	NA	90GG26S81	5/1/90	25.142	49.380	74.522	66.26%	NA
U-04	11/18/98	0.658	4.317	4.975	86.8%	NA	90GG27S01	5/1/90	18.929	60.161	79.090	76.07%	NA
D-05	11/25/98	0.389	3.506	3.895	90.0%	NA	4085139CU	11/24/93	NA	NA	NA	NA	2.9
U-05	11/25/98	0.367	3.082	3.449	89.4%	NA	4085139DU	12/8/93	NA	NA	NA	NA	1.5
D-06	11/27/98	5.399	6.201	11.600	53.5%	NA	4085139EU	1/25/94	NA	NA	NA	NA	0.0
U-06	11/27/98	0.256	3.346	3.602	92.9%	NA	TFOXRB01	4/7/94	9.898	28.504	38.402	74.23%	5.0
D-07	11/30/98	1.510	7.072	8.582	82.4%	NA	TFOXRB02	4/20/94	21.356	75.664	97.020	77.99%	11.9
U-07	11/30/98	0.781	4.663	5.444	85.7%	NA	4085139FU	4/21/94	NA	NA	NA	NA	12.8
D-08	12/1/98	5.294	8.513	13.807	61.7%	NA	TFOXRB03	4/26/94	9.201	65.382	74.583	87.66%	11.5
U-08	12/1/98	1.322	5.477	6.799	80.6%	NA	TFOXRB04	5/4/94	11.380	37.707	49.087	76.82%	11.0
D-09	12/3/98	5.399	21.643	27.042	80.0%	NA	TFOXRB05	5/11/94	11.196	29.060	40.256	72.19%	14.2
U-09	12/3/98	1.556	5.039	6.595	76.4%	NA	TFOXRB06	5/18/94	17.731	66.348	84.079	78.91%	NA
D-10	12/4/98	3.380	13.543	16.923	80.0%	NA	TFOXRB06R1	5/18/94	17.723	66.207	83.930	78.88%	15.6
U-10	12/4/98	1.049	3.845	4.894	78.6%	NA	TFOXRB06R2	5/18/94	19.060	52.458	71.518	73.35%	15.6
D-11	12/8/98	3.976	11.166	15.142	73.7%	NA	TFOXRB06U	5/18/94	NA	NA	NA	NA	15.6
U-11	12/8/98	1.482	2.262	3.744	60.4%	NA	TFOXRB07	6/2/94	20.665	57.182	77.847	73.45%	21.6
U-12	12/8/98	1.781	2.159	3.940	54.8%	NA	4085139IU	6/7/94	NA	NA	NA	NA	22.4
D-12	12/9/98	5.320	14.583	19.903	73.3%	NA	TFOXRB08	6/15/94	32.074	58.430	90.504	64.56%	23.3
D-13	12/9/98	6.252	12.490	18.742	66.6%	NA	4085139JU	6/22/94	NA	NA	NA	NA	28.0
U-13	12/9/98	1.039	1.261	2.300	54.8%	NA	TFOXRB09	7/7/94	31.532	110.918	142.450	77.86%	25.3
PE-15	12/10/98	2.666	2.319	4.985	46.5%	NA	4085139KU	7/13/94	NA	NA	NA	NA	23.7
D-14	12/13/98	3.580	14.649	18.229	80.4%	NA	TFOXRB10	7/20/94	24.949	65.061	90.010	72.28%	24.4

Table 5-17. Lower Fox River - Total PCB Results in Water (Continued)

Sample Idenifcation	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate	Temp. (°C)
U-14	12/13/98	0.493	0.982	1.475	66.6%	NA
D-15	12/14/98	1.308	5.436	6.744	80.6%	NA
U-15	12/14/98	0.446	1.063	1.509	70.4%	NA
PE-21	12/16/98	2.544	1.455	3.999	36.4%	NA
D-16	12/18/98	0.777	2.919	3.696	79.0%	NA
U-16	12/18/98	0.433	1.025	1.458	70.3%	NA
D-17	12/19/98	0.784	2.521	3.305	76.3%	NA
U-17	12/19/98	0.612	1.626	2.238	72.7%	NA
D-18	12/22/98	1.173	2.643	3.816	69.3%	NA
D-19	12/29/98	0.734	0.481	1.215	39.6%	NA
U-18	12/29/98	0.442	0.036	0.478	7.5%	NA
D-20	12/30/98	1.229	1.594	2.823	56.5%	NA
U-19	12/30/98	0.488	0.058	0.546	10.6%	NA
D-21	1/6/99	1.092	2.299	3.391	67.8%	NA
D-22	1/6/99	2.699	1.584	4.283	37.0%	NA
U-20	1/6/99	0.370	0.063	0.433	14.5%	NA
D-23	1/7/99	0.617	0.775	1.392	55.7%	NA
U-21	1/7/99	0.633	0.212	0.845	25.1%	NA
D-24	1/19/99	1.858	7.360	9.218	79.8%	NA
U-22	1/19/99	0.385	0.077	0.462	16.7%	NA
D-25	1/20/99	1.661	10.045	11.706	85.8%	NA
U-23	1/20/99	0.289	0.063	0.352	17.9%	NA
U-24	1/20/99	0.412	0.052	0.464	11.2%	NA
Little Rapids to DePere						
# 1	1/19/89	25.910	3.450	29.360	11.75%	NA
# 2	4/13/89	4.240	7.230	11.470	63.03%	NA
# 3	4/19/89	1.330	30.490	31.820	95.82%	NA
# 4	4/19/89	27.600	42.430	70.030	60.59%	NA
9003240	4/19/89	8.000	23.720	31.720	74.78%	NA
# 5	4/26/89	12.860	48.660	61.520	79.10%	NA
# 6	5/3/89	18.300	96.300	114.600	84.03%	NA
9003449	5/3/89	15.950	35.630	51.580	69.08%	NA
# 7	5/11/89	15.660	72.410	88.070	82.22%	NA
# 8	5/17/89	18.720	56.360	75.080	75.07%	NA
9003622	5/17/89	14.660	40.600	55.260	73.47%	NA
# 9	5/24/89	15.460	31.660	47.120	67.19%	NA
# 10	6/1/89	9.110	50.870	59.980	84.81%	NA
9003779	6/1/89	10.440	83.520	93.960	88.89%	NA

Sample Idenifcation	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate	Temp. (°C)
TFOXRB10R1	7/20/94	24.795	65.075	89.870	72.41%	24.4
TFOXRB11R2	7/20/94	26.563	78.404	104.967	74.69%	24.4
TFOXRB12	8/17/94	24.157	58.466	82.623	70.76%	21.2
4085139NU	8/25/94	NA	NA	NA	NA	23.4
TFOXRB13	9/14/94	29.970	76.644	106.614	71.89%	22.7
4085139OU	9/22/94	NA	NA	NA	NA	22.3
TFOXRB14	9/28/94	17.460	39.890	57.350	69.56%	17.0
TFOXRB15	9/30/94	15.616	50.188	65.804	76.27%	16.6
TFOXRB16	10/4/94	15.027	50.203	65.230	76.96%	15.0
TFOXRB16R1	10/4/94	15.166	50.227	65.393	76.81%	15.0
TFOXRB17R2	10/4/94	15.846	50.744	66.590	76.20%	15.0
4085139PU	10/5/94	NA	NA	NA	NA	14.8
TFOXRB18	10/19/94	17.790	45.173	62.963	71.75%	15.6
TFOXRB19	11/7/94	12.177	44.714	56.891	78.60%	8.9
TFOXRB20	11/10/94	12.511	27.713	40.224	68.90%	8.3
TFOXRB21	11/16/94	12.603	26.448	39.051	67.73%	8.2
TFOXRB22	11/30/94	5.238	11.310	16.548	68.35%	1.4
4085139RU	12/7/94	NA	NA	NA	NA	2.5
TFOXRB23	12/15/94	2.414	1.896	4.310	43.99%	0.5
TFOXRB24	1/11/95	3.554	1.433	4.987	28.73%	0.7
TFOXRB25	2/14/95	4.187	1.457	5.644	25.82%	0.9
4085139TU	3/1/95	NA	NA	NA	NA	1.2
TFOXRB26	3/6/95	3.679	6.329	10.008	63.24%	NA
TFOXRB27	3/22/95	5.516	9.816	15.332	64.02%	4.6
TFOXRB28	3/30/95	7.822	16.640	24.462	68.02%	5.1
TFOXRB29	4/5/95	9.273	20.108	29.381	68.44%	4.2
4085139VU	4/7/95	NA	NA	NA	NA	4.9
TFOXRB30	4/12/95	9.873	92.754	102.627	90.38%	5.5
TFOXRB31	4/20/95	9.917	23.389	33.306	70.22%	8.3
TFOXRB32	5/4/95	8.922	33.973	42.895	79.20%	11.8
TFOXRB33	5/9/95	11.851	25.276	37.127	68.08%	12.9
4085139WU	5/11/95	NA	NA	NA	NA	12.5
TFOXRB34	5/18/95	16.936	42.855	59.791	71.67%	16.6
TFOXRB35	5/25/95	15.327	33.627	48.954	68.69%	17.4
TFOXRB36	5/25/95	16.261	35.103	51.364	68.34%	17.4
TFOXRB36	6/6/95	16.261	35.103	51.364	68.34%	23.6
TFOXRB37	6/13/95	21.643	22.010	43.653	50.42%	20.6
4085139XU	7/11/95	NA	NA	NA	NA	24.6

Table 5-17. Lower Fox River - Total PCB Results in Water (Continued)

Sample Idenifcation	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate	Temp. (°C)	Sample Idenifcation	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate	Temp. (°C)
# 11	6/6/89	9.990	63.660	73.650	86.44%	NA	TFOXRB38	8/16/95	20.703	32.342	53.045	60.97%	25.3
# 12	6/13/89	14.950	54.290	69.240	78.41%	NA	TFOXRB39	8/21/95	14.961	44.337	59.298	74.77%	25.5
C	6/15/89	12.440	71.910	84.350	85.25%	NA	TFOXRB40	8/30/95	13.223	44.557	57.780	77.11%	NA
# 12(2)	6/21/89	0.185	ND	0.185	0.00%	NA	TFOXRB40R1	8/30/95	13.321	44.564	57.885	76.99%	NA
# 13	6/21/89	17.200	63.420	80.620	78.67%	NA	TFOXRB41R2	8/30/95	14.444	43.282	57.726	74.98%	NA
# 14	6/28/89	21.740	63.520	85.260	74.50%	NA	4085139ADU	9/7/95	NA	NA	NA	NA	23.9
9004431	6/28/89	17.560	32.700	50.260	65.06%	NA	TFOXRB42	10/12/95	6.183	20.567	26.750	76.89%	15.0
# 15	7/5/89	14.550	36.790	51.340	71.66%	NA	4085139AEU	10/23/95	NA	NA	NA	NA	9.6
OA001176	7/11/89	13.700	36.110	49.810	72.50%	NA	SW5-F1Pa	3/10/98	8.000	ND	8.000	0.00%	NA
# 16	7/12/89	17.190	35.480	52.670	67.36%	NA	SW5-F2Pa	3/10/98	6.000	ND	6.000	0.00%	NA
# 17	7/20/89	17.010	45.310	62.320	72.71%	NA	SW5-F3Pa	3/10/98	16.000	ND	16.000	0.00%	NA
# 18	7/25/89	16.420	39.340	55.760	70.55%	NA	SW5-F1Pb	4/1/98	9.000	ND	9.000	0.00%	NA
OA001181	7/27/89	13.670	39.940	53.610	74.50%	NA	SW6-F1	4/1/98	16.000	ND	16.000	0.00%	NA
OA001182	7/27/89	14.180	40.950	55.130	74.28%	NA	SW-D1-F	4/2/98	8.000	ND	8.000	0.00%	NA
# 19	7/31/89	19.660	53.380	73.040	73.08%	NA	SW5-F2Pb	4/2/98	8.000	ND	8.000	0.00%	NA
# 20	8/9/89	17.180	60.330	77.510	77.84%	NA	SW6-F2	4/2/98	6.000	ND	6.000	0.00%	NA
OA001630	8/9/89	15.170	45.150	60.320	74.85%	NA	SW5-F3Pb	4/3/98	6.000	ND	6.000	0.00%	5.9
# 21	8/14/89	18.220	64.930	83.150	78.09%	NA	SW6-F3	4/3/98	6.000	ND	6.000	0.00%	5.9
# 22	8/23/89	17.880	51.040	68.920	74.06%	NA	SW5-F4	4/6/98	8.000	ND	8.000	0.00%	7.2
OA001627	8/23/89	12.750	39.050	51.800	75.39%	NA	SW6-F4	4/6/98	ND	ND	0.000	0.00%	7.2
# 23	8/29/89	16.780	43.870	60.650	72.33%	NA	SW5-F5	4/7/98	9.000	12.000	21.000	57.14%	NA
# 24	9/6/89	14.830	31.470	46.300	67.97%	NA	SW6-F5	4/7/98	8.000	23.000	31.000	74.19%	7.9
OA003246	9/7/89	10.750	25.530	36.280	70.37%	NA	SW-D2-F	4/8/98	8.000	19.000	27.000	70.37%	7.9
# 25	9/13/89	15.230	38.720	53.950	71.77%	NA	SW5-F6	4/8/98	6.000	40.000	46.000	86.96%	7.9
OA003240	9/19/89	13.930	26.540	40.470	65.58%	NA	SW6-F6	4/8/98	8.000	18.000	26.000	69.23%	7.9
# 26	9/20/89	13.930	34.460	48.390	71.21%	NA	SW5-F7	4/10/98	11.000	14.000	25.000	56.00%	6.5
# 27	9/27/89	10.970	24.070	35.040	68.69%	NA	SW6-F7	4/10/98	7.000	19.000	26.000	73.08%	6.5
OA002397	10/3/89	10.450	22.750	33.200	68.52%	NA	SW5-F8	4/14/98	10.000	18.000	28.000	64.29%	9.8
# 28	10/4/89	12.920	32.800	45.720	71.74%	NA	SW6-F8	4/14/98	11.000	19.000	30.000	63.33%	9.8
# 29	10/12/89	11.880	33.080	44.960	73.58%	NA	SW5-F9	4/16/98	9.000	22.000	31.000	70.97%	7.5
OA004475	10/17/89	9.380	26.400	35.780	73.78%	NA	SW6-F9	4/16/98	5.000	25.000	30.000	83.33%	7.5
# 30	10/18/89	12.130	43.330	55.460	78.13%	NA	SW5-F10	4/17/98	8.000	14.000	22.000	63.64%	6.0
# 31	10/24/89	NA	28.790	28.790	100.00%	NA	SW6-F10	4/17/98	7.000	15.000	22.000	68.18%	6.0
# 32	10/31/89	12.320	43.270	55.590	77.84%	NA	SW-D3-F	5/12/98	11.000	14.000	25.000	56.00%	17.8
OA004477	11/1/89	10.880	40.970	51.850	79.02%	NA	SW5-F11	5/12/98	13.000	17.000	30.000	56.67%	17.8
# 33	11/7/89	6.810	20.710	27.520	75.25%	NA	SW6-F11	5/12/98	14.000	18.000	32.000	56.25%	17.8
# 34	11/14/89	4.000	11.100	15.100	73.51%	NA	SW5-F12	5/27/98	9.000	15.000	24.000	62.50%	20.1
OB000382	11/15/89	4.410	8.750	13.160	66.49%	NA	SW6-F12	5/27/98	13.000	17.000	30.000	56.67%	20.1

Table 5-17. Lower Fox River - Total PCB Results in Water (Continued)

Sample Idenifcation	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate	Temp. (°C)	Sample Idenifcation	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate	Temp. (°C)
# 35	11/30/89	2.630	5.170	7.800	66.28%	NA	W00006	6/9/98	10.000	23.000	33.000	69.70%	17.9
# 36	11/30/89	2.680	4.520	7.200	62.78%	NA	W00009	6/9/98	14.000	19.000	33.000	57.58%	17.9
OB000384	12/6/89	3.810	0.990	4.800	20.63%	NA	W00015	6/30/98	17.000	20.000	37.000	54.05%	25.0
# 37	12/13/89	5.920	6.040	11.960	50.50%	NA	W00018	7/1/98	17.000	18.000	35.000	51.43%	26.5
# 38	1/11/90	2.460	2.810	5.270	53.32%	NA	W00033	7/14/98	15.000	24.000	39.000	61.54%	26.9
OB001109	1/17/90	2.570	0.170	2.740	6.20%	NA	W00036	7/14/98	17.000	26.000	43.000	60.47%	26.9
# 39	1/25/90	3.360	3.260	6.620	49.24%	NA	W00050	7/28/98	24.000	18.000	42.000	42.86%	24.0
# 40	2/6/90	2.710	3.510	6.220	56.43%	NA	W00052	7/28/98	24.000	20.000	44.000	45.45%	24.0
OB001113	2/14/90	3.500	0.570	4.070	14.00%	NA	SW00068	8/11/98	45.000	41.000	86.000	47.67%	24.3
# 41	2/21/90	3.260	3.920	7.180	54.60%	NA	SW00072	8/12/98	33.000	13.000	46.000	28.26%	NA
# 42	3/6/90	3.460	4.400	7.860	55.98%	NA	W00094	8/31/98	15.000	20.000	35.000	57.14%	23.8
OB004145	3/14/90	5.050	69.750	74.800	93.25%	NA	W00096	9/1/98	18.000	32.000	50.000	64.00%	24.0
# 43	3/21/90	5.270	17.580	22.850	76.94%	NA	W00104	9/10/98	14.000	45.000	59.000	76.27%	21.7
# 44	3/28/90	2.180	4.740	6.920	68.50%	NA	W00107	9/10/98	17.000	39.000	56.000	69.64%	21.7
# 45	4/4/90	3.550	6.700	10.250	65.37%	NA	W00130	9/24/98	13.000	34.000	47.000	72.34%	19.4
OB004147	4/4/90	6.260	69.750	76.010	91.76%	NA	W00132	9/24/98	14.000	31.000	45.000	68.89%	19.4

Notes:
NA = not analyzed or not applicable.
ND = parameter not detected.

Table 5-18. Green Bay - Total PCB Results in Water

Sample Label	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate	Sample Label	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate
Green Bay Zone 2 (2A & 2B)						Green Bay Zone 3B					
89GG23S23	5/4/89	4.2591	13.4858	17.7449	76.00%	89GG22S03	5/2/89	1.6678	1.6818	3.3496	50.21%
89GG24S43	5/4/89	1.5192	3.1478	4.6670	67.45%	89GG22S23	5/3/89	2.3824	4.0211	6.4035	62.80%
89GG24S63	5/4/89	1.2662	4.4715	5.7377	77.93%	89GG22S63	5/3/89	2.0548	3.3630	5.4178	62.07%
89GG24D83	5/7/89	2.0170	7.5630	9.5800	78.95%	89GG23S43	5/4/89	2.4047	4.4670	6.8717	65.01%
89GG24S83	5/7/89	2.5490	6.3840	8.9330	71.47%	89GG34S23	6/11/89	0.5926	0.4923	1.0849	45.38%
89GG24S23	5/7/89	5.7575	24.5617	30.3192	81.01%	89GG34S43	6/11/89	0.7703	0.5436	1.3139	41.37%
89GG25S03	5/7/89	8.5871	34.6872	43.2743	80.16%	89GG34S83	6/11/89	1.7502	4.1919	5.9421	70.55%
89GG25S23	5/7/89	11.7412	nd	NA	NA	89GG35S03	6/12/89	2.1651	5.1126	7.2777	70.25%
89GG30S23	6/6/89	4.2494	17.2158	21.4652	80.20%	89GG36S03	6/12/89	2.5723	4.6485	7.2208	64.38%
89GG30S43	6/6/89	7.9892	19.0331	27.0223	70.43%	89GG44D23	7/30/89	0.7630	0.3330	1.0960	30.38%
89GG30S63	6/7/89	7.3719	24.1046	31.4765	76.58%	89GG44S23	7/30/89	0.7150	0.3570	1.0720	33.30%
89GG30S83	6/7/89	10.6050	15.3509	25.9559	59.14%	89GG44S43	7/30/89	0.6358	0.3283	0.9641	34.05%
89GG36D23	6/12/89	3.3350	8.9610	12.2960	72.88%	89GG44S45	7/30/89	0.9569	0.7594	1.7163	44.25%
89GG36S23	6/12/89	3.5460	10.0400	13.5860	73.90%	89GG44S83	7/30/89	1.4562	nd	NA	NA
89GG36S63	6/12/89	1.6878	7.2942	8.9820	81.21%	89GG45S03	7/31/89	1.1743	0.7890	1.9633	40.19%
89GG36S83	6/13/89	2.4347	7.7539	10.1886	76.10%	89GG46S03	7/31/89	3.9201	4.8777	8.7978	55.44%
89GG37S03	6/13/89	4.0294	15.5546	19.5840	79.43%	89GG52S03	9/15/89	0.5520	0.2528	0.8048	31.41%
89GG40S23	7/25/89	3.0374	3.8066	6.8440	55.62%	89GG52S23	9/15/89	0.5181	0.3101	0.8282	37.44%
89GG40D83	7/26/89	9.7520	12.7330	22.4850	56.63%	89GG52S25	9/15/89	0.8785	0.4101	1.2886	31.83%
89GG40S83	7/26/89	10.5420	16.7230	27.2650	61.34%	89GG52S63	9/16/89	0.6920	0.3541	1.0461	33.85%
89GG40S43	7/26/89	6.2045	8.8988	15.1033	58.92%	89GG52S65	9/16/89	0.6295	0.4813	1.1108	43.33%
89GG40S63	7/26/89	10.2613	18.2040	28.4653	63.95%	89GG52S83	9/16/89	0.8172	0.5422	1.3594	39.89%
89GG46S23	7/31/89	5.5478	7.5313	13.0791	57.58%	89GG52S85	9/16/89	1.0042	0.8345	1.8387	45.39%
89GG46S63	7/31/89	2.3196	3.5235	5.8431	60.30%	89GG53S83	9/17/89	2.1602	4.2145	6.3747	66.11%
89GG46S83	8/1/89	4.9369	9.2617	14.1986	65.23%	90GG04S23	10/22/89	0.7135	1.1884	1.9019	62.48%
89GG47S03	8/1/89	7.0899	16.0486	23.1385	69.36%	90GG04S43	10/22/89	1.2857	2.3768	3.6625	64.90%
89GG54D83	9/17/89	3.2580	6.6070	9.8650	66.97%	90GG04S83	10/23/89	1.1825	2.4696	3.6521	67.62%
89GG54S83	9/17/89	2.9450	6.4430	9.3880	68.63%	90GG05S03	10/23/89	2.1452	7.0119	9.1571	76.57%
89GG54S03	9/17/89	2.6925	7.7311	10.4236	74.17%	90GG06S03	10/23/89	3.0102	9.4496	12.4598	75.84%
89GG54S43	9/17/89	2.8475	8.9130	11.7605	75.79%	90GG14S03	2/8/90	2.2230	1.2903	3.5133	36.73%
89GG54S63	9/17/89	3.7449	10.1071	13.8520	72.96%	90GG11S23	2/10/90	3.8697	1.9230	5.7927	33.20%
89GG55S23	9/18/89	2.9977	7.9842	10.9819	72.70%	90GG10D83	2/14/90	1.2270	0.4090	1.6360	25.00%
89GG55S43	9/18/89	6.5528	18.1046	24.6574	73.42%	90GG10S83	2/14/90	1.3420	0.3370	1.6790	20.07%
89GG55S63	9/18/89	6.9258	16.3010	23.2268	70.18%	90GG12S63	2/15/90	0.9679	0.6161	1.5840	38.90%
89GG55S83	9/18/89	9.9293	30.4949	40.4242	75.44%	90GG13S63	2/17/90	2.2210	1.7075	3.9285	43.46%
90GG06S23	10/23/89	2.3468	4.9780	7.3248	67.96%	90GG22S03	4/28/90	0.6111	nd	NA	NA

Table 5-18. Green Bay - Total PCB Results in Water (Continued)

Sample Label	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate	Sample Label	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate
90GG07D03	10/24/89	3.8690	18.4450	22.3140	82.66%	90GG22S23	4/28/90	0.5218	0.9117	1.4335	63.60%
90GG07S03	10/24/89	3.6820	21.8410	25.5230	85.57%	90GG22S63	4/28/90	1.0839	3.2187	4.3026	74.81%
90GG06S63	10/24/89	1.3106	4.8875	6.1981	78.85%	90GG22S83	4/29/90	1.3308	4.6207	5.9515	77.64%
90GG06S83	10/24/89	2.1391	7.6522	9.7913	78.15%	90GG23S83	4/29/90	0.9051	3.8128	4.7179	80.82%
90GG00S23	10/25/89	1.8380	8.5205	10.3585	82.26%	W00057	7/30/98	na/nf	1.800	NA	NA
90GG00S43	10/25/89	7.1645	37.0277	44.1922	83.79%	W00058	7/30/98	na/nf	nd	NA	NA
90GG00S63	10/25/89	5.5142	26.0140	31.5282	82.51%	W00059	7/30/98	na/nf	nd	NA	NA
90GG00S83	10/25/89	9.0273	38.7390	47.7663	81.10%	W00084	8/26/98	na/nf	nd	NA	NA
90GG14S43	2/10/90	4.3581	2.0272	6.3853	31.75%	W00085	8/26/98	na/nf	nd	NA	NA
90GG15S03	2/11/90	2.2379	1.2702	3.5081	36.21%	W00120	9/23/98	na/nf	nd	NA	NA
90GG16S43	2/11/90	4.1655	4.9257	9.0912	54.18%	W00121	9/23/98	na/nf	0.6500	NA	NA
90GG14D83	2/12/90	4.4750	3.4440	7.9190	43.49%	**Green Bay Zone 4**					
90GG14S83	2/12/90	4.5140	3.1730	7.6870	41.28%	89GG20S23	4/30/89	0.9549	0.9912	1.9461	50.93%
90GG11S63	2/12/90	6.0247	7.4375	13.4622	55.25%	89GG20S83	4/30/89	0.832	0.5691	1.4011	40.62%
90GG11S83	2/12/90	3.9445	3.5032	7.4477	47.04%	89GG21S03	4/30/89	0.7005	2.0739	2.7744	74.75%
90GG12D23	2/13/90	4.1110	4.3830	8.4940	51.60%	89GG21D23	5/1/89	1.323	1.148	2.4710	46.46%
90GG12S03	2/13/90	5.2700	5.3020	10.5720	50.15%	89GG21S23	5/1/89	0.624	1.452	2.0760	69.94%
90GG12S23	2/13/90	4.1060	4.7310	8.8370	53.54%	89GG20S43	5/1/89	0.7316	2.3816	3.1132	76.50%
90GG12S01	2/13/90	5.3070	5.3278	10.6348	50.10%	89GG20S63	5/1/89	0.8123	0.4399	1.2522	35.13%
90GG24S03	4/29/90	1.1582	6.0120	7.1702	83.85%	89GG32S83	6/8/89	0.7967	0.1864	0.9831	18.96%
90GG24S43	4/29/90	0.9962	3.3693	4.3655	77.18%	89GG32D63	6/9/89	1.155	0.372	1.5270	24.36%
90GG24S63	4/30/90	1.3058	5.6180	6.9238	81.14%	89GG32S63	6/9/89	0.751	0.372	1.1230	33.13%
90GG24S83	4/30/90	3.4651	14.7202	18.1853	80.95%	89GG32S65	6/9/89	0.5051	0.2393	0.7444	32.15%
90GG25S23	4/30/90	1.2463	4.5023	5.7486	78.32%	89GG33S03	6/9/89	0.656	0.3533	1.0093	35.00%
90GG25S43	4/30/90	2.2155	7.1608	9.3763	76.37%	89GG33D05	6/10/89	0.51	0.212	0.7220	29.36%
90GG25S83	4/30/90	13.6814	89.0234	102.7048	86.68%	89GG33S05	6/10/89	0.408	0.226	0.6340	35.65%
90GG25S63	5/1/90	9.8610	91.7033	101.5643	90.29%	89GG33S23	6/10/89	0.4485	0.27	0.7185	37.58%
W00039	7/28/98	na/nf	7.2	NA	NA	89GG33S43	6/10/89	0.4947	0.2702	0.7649	35.32%
W00040	7/28/98	na/nf	5.3	NA	NA	89GG33S63	6/10/89	0.5715	0.3731	0.9446	39.50%
W00027	7/30/98	na/nf	2.5	NA	NA	89GG33S65	6/10/89	0.5724	0.4676	1.0400	44.96%
W00073	8/24/98	na/nf	7.3	NA	NA	89GG33S83	6/11/89	0.531	0.3485	0.8795	39.62%
W00074	8/24/98	na/nf	4.2	NA	NA	89GG33S85	6/11/89	0.5756	0.3837	0.9593	40.00%
W00075	8/24/98	na/nf	4.9	NA	NA	89GG42D83	7/28/89	0.375	0.291	0.6660	43.69%
W00108	9/21/98	na/nf	7.4	NA	NA	89GG42S83	7/28/89	0.494	0.252	0.7460	33.78%
W00109	9/21/98	na/nf	9.6	NA	NA	89GG42S63	7/28/89	0.4402	0.2394	0.6796	35.23%
W00122	9/23/98	na/nf	7.3	NA	NA	89GG42S65	7/28/89	0.3851	0.2373	0.6224	38.13%

Table 5-18. Green Bay - Total PCB Results in Water (Continued)

Sample Label	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate	Sample Label	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate
Green Bay Zone 3A						89GG43D05	7/29/89	0.461	0.231	0.6920	33.38%
89GG21S83	5/1/89	0.7689	1.0032	1.7721	56.6%	89GG43S05	7/29/89	0.504	0.21	0.7140	29.41%
89GG23D03	5/3/89	1.2750	4.7520	6.0270	78.8%	89GG43S65	7/29/89	nd	0.2792	na	na
89GG23S03	5/3/89	3.1700	3.1830	6.3530	50.1%	89GG43S03	7/29/89	0.4544	0.286	0.7404	38.63%
89GG22S43	5/3/89	1.4587	1.3621	2.8208	48.3%	89GG43S23	7/29/89	0.3995	0.2096	0.6091	34.41%
89GG22S83	5/3/89	1.6969	1.8752	3.5721	0.0%	89GG43S25	7/29/89	0.3788	0.2963	0.6751	43.89%
89GG23S63	5/4/89	1.7689	2.5277	4.2966	58.8%	89GG43S43	7/29/89	0.3488	0.2208	0.5696	38.76%
89GG23S83	5/4/89	1.3557	2.0317	3.3874	60.0%	89GG43S45	7/29/89	0.5094	0.2979	0.8073	36.90%
89GG24S03	5/4/89	1.8877	6.6734	8.5611	78.0%	89GG43S63	7/29/89	0.4119	0.2319	0.6438	36.02%
89GG34S03	6/11/89	0.5580	0.3517	0.9097	38.7%	89GG43S83	7/30/89	0.4968	nd	na	na
89GG34S63	6/11/89	0.6461	0.5130	1.1591	44.3%	89GG50S43	9/13/89	0.4488	0.1668	0.6156	27.10%
89GG35D43	6/12/89	1.1800	1.7950	2.9750	60.3%	89GG50S45	9/13/89	0.69	0.1237	0.8137	15.20%
89GG35S43	6/12/89	1.1270	1.6930	2.8200	60.0%	89GG50S63	9/13/89	0.4795	0.1638	0.6433	25.46%
89GG35S23	6/12/89	1.0520	1.0316	2.0836	49.5%	89GG50D85	9/14/89	0.549	0.316	0.8650	36.53%
89GG35S63	6/12/89	1.2592	2.6778	3.9370	68.0%	89GG51D23	9/14/89	0.967	0.137	1.1040	12.41%
89GG35S83	6/12/89	1.9399	2.9471	4.8870	60.3%	89GG50S85	9/14/89	0.424	0.226	0.6500	34.77%
89GG36S43	6/12/89	1.6512	2.9827	4.6339	64.4%	89GG51S23	9/14/89	0.454	0.149	0.6030	24.71%
89GG44S03	7/30/89	0.7645	0.3448	1.1093	31.1%	89GG50S83	9/14/89	0.5503	0.1844	0.7347	25.10%
89GG44S63	7/30/89	0.7867	0.5217	1.3084	39.9%	89GG51S03	9/14/89	0.3768	0.1858	0.5626	33.03%
89GG45D83	7/31/89	4.2190	6.7440	10.9630	61.5%	89GG51S05	9/14/89	0.4788	0.1877	0.6665	28.16%
89GG46D43	7/31/89	2.8570	8.7780	11.6350	75.4%	89GG51S25	9/14/89	0.6567	0.3848	1.0415	36.95%
89GG45S83	7/31/89	4.1630	7.1080	11.2710	63.1%	89GG51S43	9/15/89	0.6275	0.1982	0.8257	24.00%
89GG46S43	7/31/89	5.1360	7.1440	12.2800	58.2%	89GG51S45	9/15/89	0.607	0.3336	0.9406	35.47%
89GG45S23	7/31/89	1.4747	1.8647	3.3394	55.8%	89GG51S63	9/15/89	0.5457	0.2135	0.7592	28.12%
89GG45S43	7/31/89	1.3766	1.5784	2.9550	53.4%	89GG51S65	9/15/89	0.4869	0.236	0.7229	32.65%
89GG45S63	7/31/89	1.7533	2.8136	4.5669	61.6%	90GG02S63	10/20/89	0.7347	0.3665	1.1012	33.28%
89GG51S83	9/15/89	0.4749	0.2181	0.6930	31.5%	90GG02D83	10/21/89	0.484	0.31	0.7940	39.04%
89GG51S85	9/15/89	0.6852	0.5754	1.2606	45.6%	90GG03D03	10/21/89	0.63	0.27	0.9000	30.00%
89GG53D23	9/16/89	1.2380	1.7300	2.9680	58.3%	90GG02S83	10/21/89	0.675	1.051	1.7260	60.89%
89GG53S23	9/16/89	1.3210	1.7970	3.1180	57.6%	90GG03S03	10/21/89	0.638	0.357	0.9950	35.88%
89GG52S43	9/16/89	0.6974	0.4725	1.1699	40.4%	90GG03S23	10/21/89	0.6541	0.426	1.0801	39.44%
89GG52S45	9/16/89	0.9148	0.3982	1.3130	30.3%	90GG03S43	10/21/89	0.8833	0.5134	1.3967	36.76%
89GG53S03	9/16/89	1.1371	0.4354	1.5725	27.7%	90GG03S63	10/21/89	0.8871	0.593	1.4801	40.06%
89GG53S43	9/16/89	2.3149	4.0736	6.3885	63.8%	90GG03S83	10/22/89	0.8308	1.2295	2.0603	59.68%
89GG53S63	9/17/89	1.8531	2.8194	4.6725	60.3%	90GG10S63	2/17/90	0.8311	0.5155	1.3466	38.28%
89GG54S23	9/17/89	2.6680	5.3212	7.9892	66.6%	90GG20S43	4/26/90	0.4508	0.2474	0.6982	35.43%

Table 5-18. Green Bay - Total PCB Results in Water (Continued)

Sample Label	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate	Sample Label	Sample Date	Dissolved (ng/L)	Particulate (ng/L)	Total (ng/L)	Percent Particulate
90GG04S03	10/22/89	1.1422	1.6604	2.8026	59.2%	90GG21D23	4/27/90	0.32	0.178	0.4980	35.74%
90GG04S63	10/22/89	1.0737	1.1126	2.1863	50.9%	90GG21S23	4/27/90	0.315	0.312	0.6270	49.76%
90GG05D43	10/23/89	1.2720	2.5770	3.8490	67.0%	90GG20S63	4/27/90	0.4171	0.3183	0.7354	43.28%
90GG05S43	10/23/89	1.4360	2.4120	3.8480	62.7%	90GG20S83	4/27/90	0.5233	0.3217	0.8450	38.07%
90GG05S23	10/23/89	2.7463	6.5042	9.2505	70.3%	90GG21S03	4/27/90	0.4085	0.4611	0.8696	53.02%
90GG05S63	10/23/89	1.1955	4.3856	5.5811	78.6%	90GG21S43	4/27/90	0.5558	0.4019	0.9577	41.97%
90GG05S83	10/23/89	3.0853	12.0662	15.1515	79.6%	90GG21S63	4/28/90	0.3532	0.3993	0.7525	53.06%
90GG06S43	10/24/89	3.7436	16.9315	20.6751	81.9%	W00041	7/29/98	na/nf	nd	NA	NA
90GG11S03	2/9/90	2.3735	0.8352	3.2087	26.0%	W00042	7/29/98	na/nf	nd	NA	NA
90GG14S23	2/9/90	1.9557	1.1348	3.0905	36.7%	W00043	7/29/98	na/nf	nd	NA	NA
90GG11S43	2/10/90	3.1821	1.7872	4.9693	36.0%	W00054	7/29/98	na/nf	nd	NA	NA
90GG14S63	2/10/90	2.2468	1.9353	4.1821	46.3%	W00055	7/29/98	na/nf	nd	NA	NA
90GG16S23	2/11/90	2.7744	2.2326	5.0070	44.6%	W00056	7/29/98	na/nf	nd	NA	NA
90GG13S23	2/15/90	1.1663	0.5011	1.6674	30.1%	W00076	8/25/98	na/nf	nd	NA	NA
90GG16D03	2/18/90	1.4480	0.7750	2.2230	34.9%	W00077	8/25/98	na/nf	nd	NA	NA
90GG16S03	2/18/90	1.4730	0.6330	2.1060	30.1%	W00079	8/25/98	na/nf	nd	NA	NA
90GG21S83	4/28/90	0.4971	1.0251	1.5222	67.3%	W00080	8/25/98	na/nf	nd	NA	NA
90GG22S43	4/28/90	0.6564	1.1386	1.7950	63.4%	W00081	8/26/98	na/nf	nd	NA	NA
90GG23D03	4/29/90	0.6780	1.6640	2.3420	71.1%	W00082	8/26/98	na/nf	nd	NA	NA
90GG23D63	4/29/90	0.7360	2.2670	3.0030	75.5%	W00083	8/26/98	na/nf	nd	NA	NA
90GG23S03	4/29/90	0.6750	1.9290	2.6040	74.1%	W00111	9/22/98	na/nf	nd	NA	NA
90GG23S63	4/29/90	0.5910	1.8070	2.3980	75.4%	W00112	9/22/98	na/nf	nd	NA	NA
90GG23S23	4/29/90	0.8127	2.8370	3.6497	77.7%	W00113	9/22/98	na/nf	nd	NA	NA
90GG23S43	4/29/90	0.8063	2.8786	3.6849	78.1%	W00114	9/22/98	na/nf	nd	NA	NA
90GG24S23	4/29/90	1.4425	5.5950	7.0375	79.5%	W00115	9/22/98	na/nf	nd	NA	NA
W00060	7/30/98	na/nf	nd	NA	NA	W00116	9/22/98	na/nf	nd	NA	NA
W00061	7/30/98	na/nf	nd	NA	NA	W00117	9/22/98	na/nf	nd	NA	NA
W00086	8/26/98	na/nf	0.6600	NA	NA						
W00087	8/26/98	na/nf	nd	NA	NA						
W00118	9/23/98	na/nf	nd	NA	NA						
W00119	9/23/98	na/nf	nd	NA	NA						

Notes: na/nf - indicates that a sample results was either not available of found within the FRDB for this sample.
nd - indciates that the analyte was not detected.
NA - Not Applicable because one of the two results was either na/nf or nd.

Table 5-19. Lower Fox River and Green Bay - Mercury & DDT (DDD/DDE) Water Sampling Results

Reach or Zone	Sample Identification	Sample Date	Mercury (ng/L)			DDT (ng/L)		
			Dissolved	Particulate	Particulate Percent	Dissolved	Particulate	Particulate Percent
Fall 1992/Spring 1993 Results								
Little Rapids to DePere	Wrightstown	Fall 1992	2520.00	na	0.0%	na	na	na
Little Rapids to DePere	Wrightstown(2)	Spring 1993	1260.00	na	0.0%	na	na	na
Green Bay Zone 2 (2A & 2B)	Oneida	Fall 1992	1.15	na	0.0%	na	na	na
Green Bay Zone 2 (2A & 2B)	Oneida(2)	Spring 1993	2.33	na	0.0%	na	na	na
April 1994 through October 1995 Results								
DePere to Green Bay	TFOXRB01	07-Apr-94	0.53	11.33	95.5%	ND	ND	na
DePere to Green Bay	TFOXRB02	20-Apr-94	1.07	28.06	96.3%	ND	ND	na
DePere to Green Bay	TFOXRB03	26-Apr-94	40.81	na	0.0%	ND	0.21	100%
DePere to Green Bay	TFOXRB04A	04-May-94	1.38	na	0.0%	na	na	na
DePere to Green Bay	TFOXRB04	04-May-94	na	na	na	ND	ND	na
DePere to Green Bay	TFOXRB05A	11-May-94	1.28	na	0.0%	na	na	na
DePere to Green Bay	TFOXRB05	11-May-94	na	na	na	ND	ND	na
DePere to Green Bay	TFOXRB06	18-May-94	1.33	na	0.0%	ND	ND	na
DePere to Green Bay	TFOXRB06R1	18-May-94	na	na	na	na	na	na
DePere to Green Bay	TFOXRB06R2	18-May-94	na	na	na	na	na	na
DePere to Green Bay	TFOXRB07	02-Jun-94	1.67	28.19	94.4%	ND	ND	na
DePere to Green Bay	TFOXRB08	15-Jun-94	1.60	23.42	93.6%	ND	ND	na
DePere to Green Bay	TFOXRB09	07-Jul-94	3.59	44.21	92.5%	ND	ND	na
DePere to Green Bay	TFOXRB10	20-Jul-94	38.29	na	0.0%	ND	ND	na
DePere to Green Bay	TFOXRB10R1	20-Jul-94	na	na	na	na	na	na
DePere to Green Bay	TFOXRB11R2	20-Jul-94	na	na	na	na	0.05	100%
DePere to Green Bay	TFOXRB12	17-Aug-94	1.19	24.16	95.3%	ND	ND	na
DePere to Green Bay	TFOXRB13	14-Sep-94	1.86	30.26	94.2%	ND	ND	na
DePere to Green Bay	TFOXRB14	28-Sep-94	1.97	na	0.0%	ND	ND	na
DePere to Green Bay	TFOXRB15	30-Sep-94	2.09	na	0.0%	ND	ND	na
DePere to Green Bay	TFOXRB16R1	04-Oct-94	1.83	25.73	93.4%	na	na	na
DePere to Green Bay	TFOXRB16A	04-Oct-94	2.17	na	0.0%	na	na	na
DePere to Green Bay	TFOXRB16	04-Oct-94	na	na	na	ND	ND	na
DePere to Green Bay	TFOXRB17R2	04-Oct-94	na	na	na	na	na	na
DePere to Green Bay	TFOXRB18	19-Oct-94	3.08	38.33	92.6%	ND	ND	na
DePere to Green Bay	TFOXRB19	07-Nov-94	1.72	38.76	95.8%	ND	ND	na

Table 5-19. Lower Fox River and Green Bay - Mercury & DDT (DDD/DDE) Water Sampling Results (Continued)

Reach or Zone	Sample Identification	Sample Date	Mercury (ng/L)			DDT (ng/L)		
			Dissolved	Particulate	Particulate Percent	Dissolved	Particulate	Particulate Percent
DePere to Green Bay	TFOXRB20	10-Nov-94	1.77	15.70	89.9%	ND	ND	na
DePere to Green Bay	TFOXRB21	16-Nov-94	2.04	21.07	91.2%	ND	ND	na
DePere to Green Bay	TFOXRB22	30-Nov-94	1.06	10.18	90.6%	ND	ND	na
DePere to Green Bay	TFOXRB23	14-Dec-94	na	3.95	100.0%	ND	ND	na
DePere to Green Bay	TFOXRB23	15-Dec-94	na	3.95	100.0%	ND	ND	na
DePere to Green Bay	TFOXRB24	11-Jan-95	1.18	1.91	61.7%	ND	ND	na
DePere to Green Bay	TFOXRB25	14-Feb-95	1.13	1.80	61.5%	ND	ND	na
DePere to Green Bay	TFOXRB26	06-Mar-95	1.48	3.57	70.7%	ND	ND	na
DePere to Green Bay	TFOXRB27	22-Mar-95	1.66	7.20	81.2%	ND	0.06	100%
DePere to Green Bay	TFOXRB26	26-Mar-95	1.48	3.57	70.7%	ND	ND	na
DePere to Green Bay	TFOXRB28	30-Mar-95	2.72	12.14	81.7%	ND	ND	na
DePere to Green Bay	TFOXRB29	05-Apr-95	0.83	18.75	95.8%	ND	ND	na
DePere to Green Bay	TFOXRB30	12-Apr-95	1.06	74.85	98.6%	ND	0.06	100%
DePere to Green Bay	TFOXRB31	20-Apr-95	1.12	24.76	95.7%	ND	ND	na
DePere to Green Bay	TFOXRB32	04-May-95	0.83	22.81	96.5%	ND	ND	na
DePere to Green Bay	TFOXRB33A	09-May-95	1.44	na	0.0%	na	na	na
DePere to Green Bay	TFOXRB33	09-May-95	1.49	19.20	92.8%	ND	ND	na
DePere to Green Bay	TFOXRB34	18-May-95	1.10	29.47	96.4%	ND	ND	na
DePere to Green Bay	TFOXRB36	25-May-95	1.24	27.03	95.6%	ND	ND	na
DePere to Green Bay	TFOXRB36(2)	25-May-95	1.25	19.44	93.9%	na	na	na
DePere to Green Bay	TFOXRB35	25-May-95	1.29	na	0.0%	ND	ND	na
DePere to Green Bay	TFOXRB36	06-Jun-95	1.24	27.03	95.6%	ND	ND	na
DePere to Green Bay	TFOXRB37	13-Jun-95	0.84	16.19	95.1%	ND	ND	na
DePere to Green Bay	TFOXRB38	16-Aug-95	1.45	18.94	92.9%	na	ND	na
DePere to Green Bay	TFOXRB39	21-Aug-95	0.76	31.61	97.7%	ND	ND	na
DePere to Green Bay	TFOXRB40R1	30-Aug-95	0.89	29.08	97.0%	na	0.06	100%
DePere to Green Bay	TFOXRB40A	30-Aug-95	0.89	na	0.0%	na	na	na
DePere to Green Bay	TFOXRB40	30-Aug-95	na	na	na	ND	0.06	100%
DePere to Green Bay	TFOXRB41R2	30-Aug-95	na	na	na	na	0.05	100%
DePere to Green Bay	TFOXRB42	12-Oct-95	0.97	35.29	97.3%	ND	ND	na
DePere to Green Bay	TFOXRB42A	12-Oct-95	1.00	na	0.0%	na	na	na
May 1998 Results								
Appleton to Little Rapids	SW3-FW12	26-May-98	90.00	na	0.0%	na	na	na

Table 5-19. Lower Fox River and Green Bay - Mercury & DDT (DDD/DDE) Water Sampling Results (Continued)

Reach or Zone	Sample Identification	Sample Date	DDD (ng/L)			DDE (ng/L)		
			Dissolved	Particulate	Particulate Percent	Dissolved	Particulate	Particulate Percent
Fall 1992/Spring 1993 Results								
Little Rapids to DePere	Wrightstown	Fall 1992	na	na	na	na	na	na
Little Rapids to DePere	Wrightstown(2)	Spring 1993	na	na	na	na	na	na
Green Bay Zone 2 (2A & 2B)	Oneida	Fall 1992	na	na	na	na	na	na
Green Bay Zone 2 (2A & 2B)	Oneida(2)	Spring 1993	na	na	na	na	na	na
April 1994 through October 1995 Results								
DePere to Green Bay	TFOXRB01	07-Apr-94	ND	0.06	100%	ND	na	na
DePere to Green Bay	TFOXRB02	20-Apr-94	ND	0.19	100%	na	na	na
DePere to Green Bay	TFOXRB03	26-Apr-94	ND	0.22	100%	0.04	0.23	86.1%
DePere to Green Bay	TFOXRB04A	04-May-94	na	na	na	na	na	na
DePere to Green Bay	TFOXRB04	04-May-94	ND	0.10	100%	ND	na	na
DePere to Green Bay	TFOXRB05A	11-May-94	na	na	na	na	na	na
DePere to Green Bay	TFOXRB05	11-May-94	ND	0.07	100%	0.04	0.15	79.4%
DePere to Green Bay	TFOXRB06	18-May-94	ND	0.11	100%	ND	0.21	100%
DePere to Green Bay	TFOXRB06R1	18-May-94	na	0.11	100%	na	0.21	100%
DePere to Green Bay	TFOXRB06R2	18-May-94	na	0.15	100%	0.07	0.23	76.2%
DePere to Green Bay	TFOXRB07	02-Jun-94	ND	0.25	100%	0.04	0.30	89.0%
DePere to Green Bay	TFOXRB08	15-Jun-94	0.06	0.07	54.1%	0.04	0.24	87.3%
DePere to Green Bay	TFOXRB09	07-Jul-94	0.07	0.27	80.1%	0.04	0.41	90.7%
DePere to Green Bay	TFOXRB10	20-Jul-94	0.05	0.14	73.7%	0.04	0.25	85.9%
DePere to Green Bay	TFOXRB10R1	20-Jul-94	0.05	0.14	73.7%	0.04	0.25	85.9%
DePere to Green Bay	TFOXRB11R2	20-Jul-94	0.06	0.14	71.1%	0.04	0.26	87.5%
DePere to Green Bay	TFOXRB12	17-Aug-94	ND	0.14	100%	0.03	0.23	87.1%
DePere to Green Bay	TFOXRB13	14-Sep-94	ND	0.17	100%	0.04	0.26	86.4%
DePere to Green Bay	TFOXRB14	28-Sep-94	ND	0.12	100%	0.04	0.19	82.3%
DePere to Green Bay	TFOXRB15	30-Sep-94	ND	0.08	100%	ND	0.18	100%
DePere to Green Bay	TFOXRB16R1	04-Oct-94	na	0.14	100%	0.04	0.26	85.5%
DePere to Green Bay	TFOXRB16A	04-Oct-94	na	na	na	na	na	na
DePere to Green Bay	TFOXRB16	04-Oct-94	ND	0.14	100%	0.04	0.26	85.5%
DePere to Green Bay	TFOXRB17R2	04-Oct-94	na	0.12	100%	0.05	0.23	82.7%
DePere to Green Bay	TFOXRB18	19-Oct-94	ND	0.10	100%	ND	0.14	100%
DePere to Green Bay	TFOXRB19	07-Nov-94	ND	0.09	100%	ND	0.15	100%

Table 5-19. Lower Fox River and Green Bay - Mercury & DDT (DDD/DDE) Water Sampling Results (Continued)

Reach or Zone	Sample Identification	Sample Date	DDD (ng/L)			DDE (ng/L)		
			Dissolved	Particulate	Particulate Percent	Dissolved	Particulate	Particulate Percent
DePere to Green Bay	TFOXRB20	10-Nov-94	ND	0.08	100%	ND	0.14	100%
DePere to Green Bay	TFOXRB21	16-Nov-94	ND	0.05	100%	ND	0.10	100%
DePere to Green Bay	TFOXRB22	30-Nov-94	ND	ND	na	ND	0.07	100%
DePere to Green Bay	TFOXRB23	14-Dec-94	ND	ND	na	ND	ND	na
DePere to Green Bay	TFOXRB23	15-Dec-94	ND	ND	na	ND	ND	na
DePere to Green Bay	TFOXRB24	11-Jan-95	ND	ND	na	ND	ND	na
DePere to Green Bay	TFOXRB25	14-Feb-95	ND	ND	na	ND	ND	na
DePere to Green Bay	TFOXRB26	06-Mar-95	ND	ND	na	ND	0.03	100%
DePere to Green Bay	TFOXRB27	22-Mar-95	ND	ND	na	ND	0.05	100%
DePere to Green Bay	TFOXRB26	26-Mar-95	ND	ND	na	ND	0.03	100%
DePere to Green Bay	TFOXRB28	30-Mar-95	ND	ND	na	ND	0.07	100%
DePere to Green Bay	TFOXRB29	05-Apr-95	ND	ND	na	ND	0.08	100%
DePere to Green Bay	TFOXRB30	12-Apr-95	ND	0.19	100%	ND	0.24	100%
DePere to Green Bay	TFOXRB31	20-Apr-95	ND	0.08	100%	ND	0.11	100%
DePere to Green Bay	TFOXRB32	04-May-95	ND	0.06	100%	ND	0.10	100%
DePere to Green Bay	TFOXRB33A	09-May-95	na	na	na	na	na	na
DePere to Green Bay	TFOXRB33	09-May-95	ND	ND	na	ND	0.08	100%
DePere to Green Bay	TFOXRB34	18-May-95	ND	0.08	100%	ND	0.12	100%
DePere to Green Bay	TFOXRB36	25-May-95	ND	0.08	100%	ND	0.11	100%
DePere to Green Bay	TFOXRB36(2)	25-May-95	na	na	na	na	na	na
DePere to Green Bay	TFOXRB35	25-May-95	ND	0.07	100%	ND	0.12	100%
DePere to Green Bay	TFOXRB36	06-Jun-95	ND	0.08	100%	ND	0.11	100%
DePere to Green Bay	TFOXRB37	13-Jun-95	ND	0.06	100%	ND	0.08	100%
DePere to Green Bay	TFOXRB38	16-Aug-95	na	0.08	100%	ND	0.13	100%
DePere to Green Bay	TFOXRB39	21-Aug-95	ND	0.11	100%	0.04	0.20	84.7%
DePere to Green Bay	TFOXRB40R1	30-Aug-95	na	0.11	100%	0.04	0.22	86.3%
DePere to Green Bay	TFOXRB40A	30-Aug-95	na	na	na	na	na	na
DePere to Green Bay	TFOXRB40	30-Aug-95	ND	0.11	100%	0.04	0.22	86.3%
DePere to Green Bay	TFOXRB41R2	30-Aug-95	na	0.11	100%	0.04	0.21	85.7%
DePere to Green Bay	TFOXRB42	12-Oct-95	ND	0.06	100%	ND	0.11	100%
DePere to Green Bay	TFOXRB42A	12-Oct-95	na	na	na	na	na	na
May 1998 Results								
Appleton to Little Rapids	SW3-FW12	26-May-98	na	na	na	na	na	na

Notes: 1) ND: Parameter not detected
2) na: Sample not analyzed for parameter.

Table 5-20. PCP Transport within the Lower Fox River and Green Bay System

Reach	Transported PCB (kg)
Lake Winnebag	Negligible[1]
LLBdM Railroad Bridge	4 kg[1]
Appleton Dam	65 kg[1]
Little Rapids Dam	125 kg[1]
DePere Dam	175 kg[1]
River Mouth	280 kg[2]
To Lake Michigan	122 kg[3]

Note:

1 = From WDNR 1995

2 = From Velleux and Edicott 1994 and Velleux et al 1995

3 = From Raghunathan 1994

Table 5-21 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 5-22 Distribution of Resident Tissue Samples over Time in Green Bay - Total PCBs Only

Year	Fish															
	Benthic Fish				Game Fish				Pelagic Fish				Trout			
	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
1971	0	0	0	0	0	0	0	0	0	0	0	0	14	1	0	0
1975	7	1	0	0	18	1	0	0	0	0	0	0	1	1	0	0
1976	15	3	20	0	20	8	28	0	1	1	3	0	0	0	0	0
1977	5	2	11	0	21	3	36	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
1979	8	4	0	8	17	4	8	9	9	3	0	9	5	3	0	5
1980	3	1	3	0	4	3	4	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
1982	5	1	5	0	4	1	4	0	0	0	0	0	5	1	5	0
1983	12	3	10	2	13	4	13	0	4	1	2	2	4	2	4	0
1984	8	3	8	0	23	6	23	0	9	4	4	4	20	4	20	0
1985	0	0	0	0	3	2	2	0	4	3	0	3	125	5	120	0
1986	5	1	5	0	9	3	9	0	2	1	0	2	3	2	3	0
1987	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1988	20	2	20	0	11	2	11	0	10	1	11	0	0	0	0	0
1989	166	1	28	77	101	2	35	66	169	3	0	169	68	3	29	39
1990	0	0	0	0	22	3	22	0	9	2	0	9	22	2	22	0
1991	5	1	5	0	16	2	10	0	18	3	12	6	0	0	0	0
1992	10	1	0	10	35	3	25	10	7	2	0	7	46	5	43	3
1993	6	2	2	4	0	0	0	0	2	1	0	2	16	2	16	0
1994	0	0	0	0	19	2	19	0	4	1	0	4	16	3	16	0
1995	0	0	0	0	1	1	0	0	4	1	0	4	0	0	0	0
1996	0	0	0	0	60	3	20	24	0	0	0	0	29	4	10	19
1997	0	0	0	0	71	2	0	15	0	0	0	0	1	1	0	0
1998	12	2	0	12	32	4	10	22	8	2	0	8	0	0	0	0
1999	0	0	0	0	8	1	8	0	0	0	0	0	0	0	0	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.

Table 5-22 Distribution of Resident Tissue Samples over Time in Green Bay - Total PCBs Only (Continued)

Year	Birds									Mammals		Other
	Cormorant		Piscivorous Birds		Raptors	Swallow		Waterfowl		Deer	Fur Bearer	
	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
1975	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	4	2	0	0	0
1985	0	0	0	0	0	0	0	0	0	0	0	0
1986	0	0	1	1	0	0	0	13	1	0	0	1
1987	0	0	0	0	1	0	0	16	3	1	0	0
1988	0	0	0	0	0	0	0	10	2	0	0	0
1989	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	15	1	0	0	0	0	0
1994	60	1	0	0	0	0	0	0	0	0	0	0
1995	80	1	0	0	0	0	0	0	0	0	0	1
1996	0	0	15	2	0	0	0	5	1	0	0	0
1997	0	0	5	1	0	0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0	2	1	0	0	3
1999	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.

Table 5-23. 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 5-23. 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 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 5-23. 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
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:

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

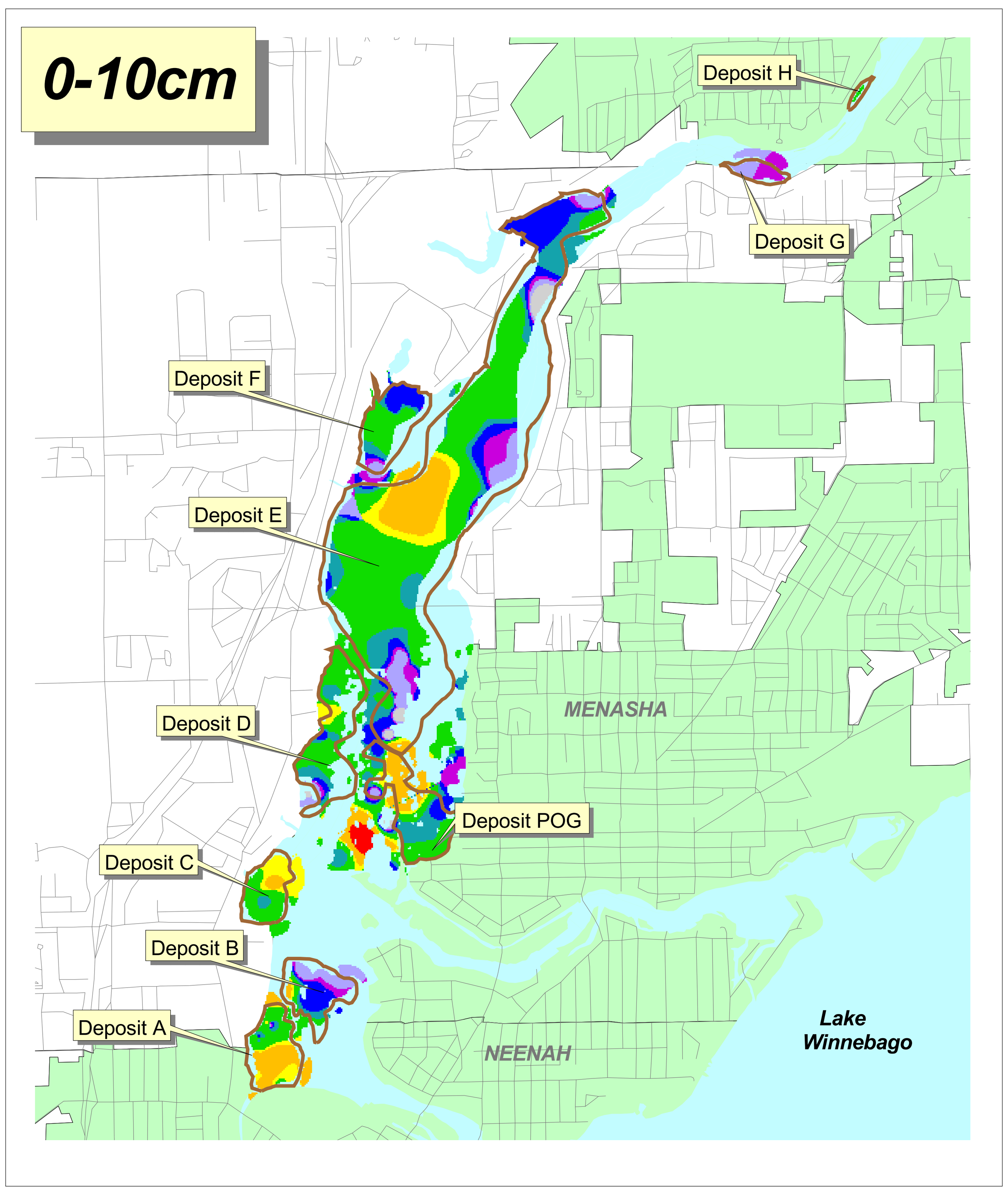
Table 5-24. Mass-weighted Combined Time Trend for 0 to 10 cm Depth by Reach

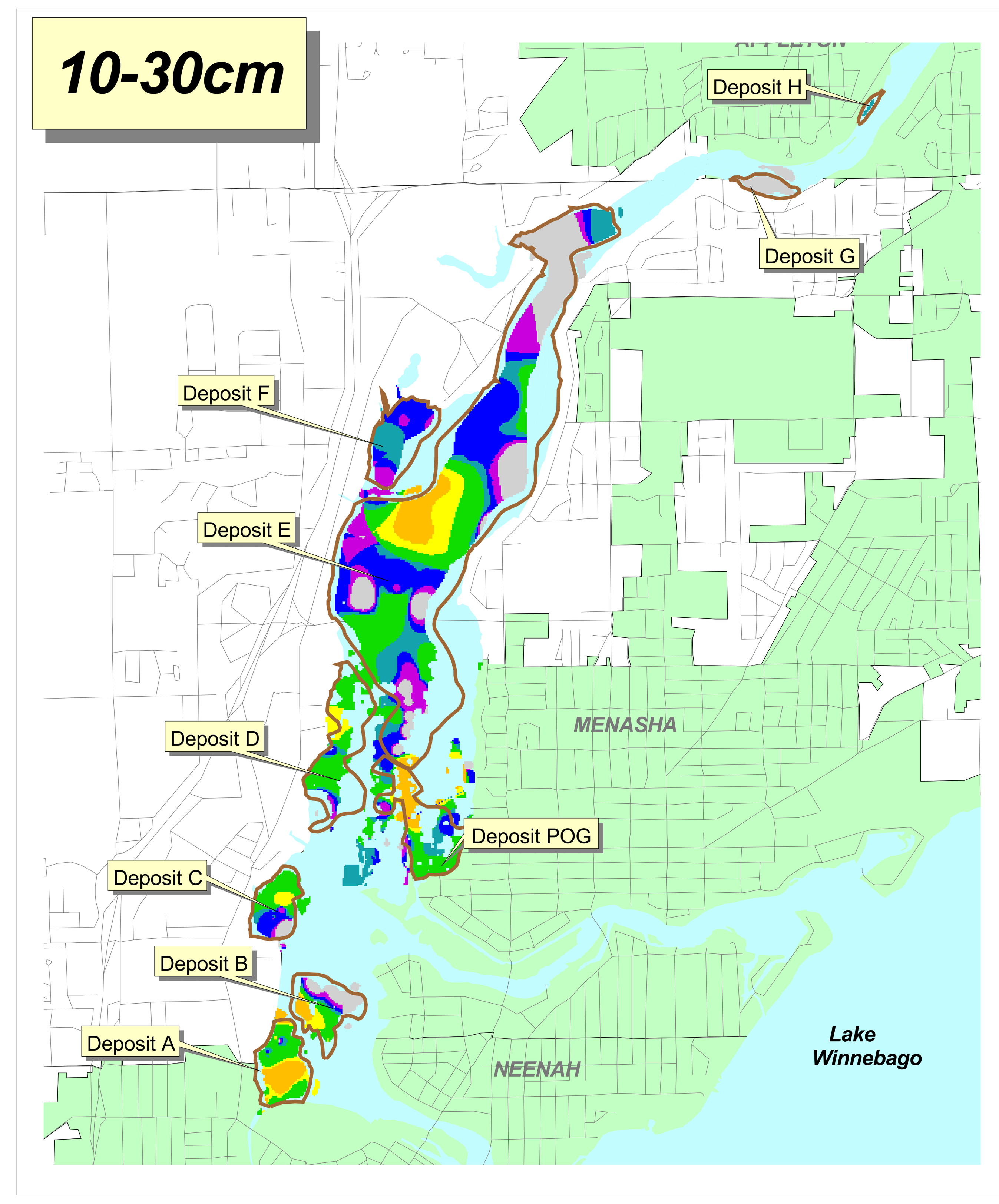
Deposit Group	Log_{10}(PCB) Time Trend Slope Estimate	WSEV Standard Error	PCB Mass (kg)	*p*-value	Annual Percent Change in PCB Concen-tration	Percent Change 95% Lower-bound	Percent Change 95% Upper-bound
Little Lake Butte des Morts							
AB	-0.09705	0.034798	71.7				
C	-0.06124	0.03423	25.4				
POG	-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

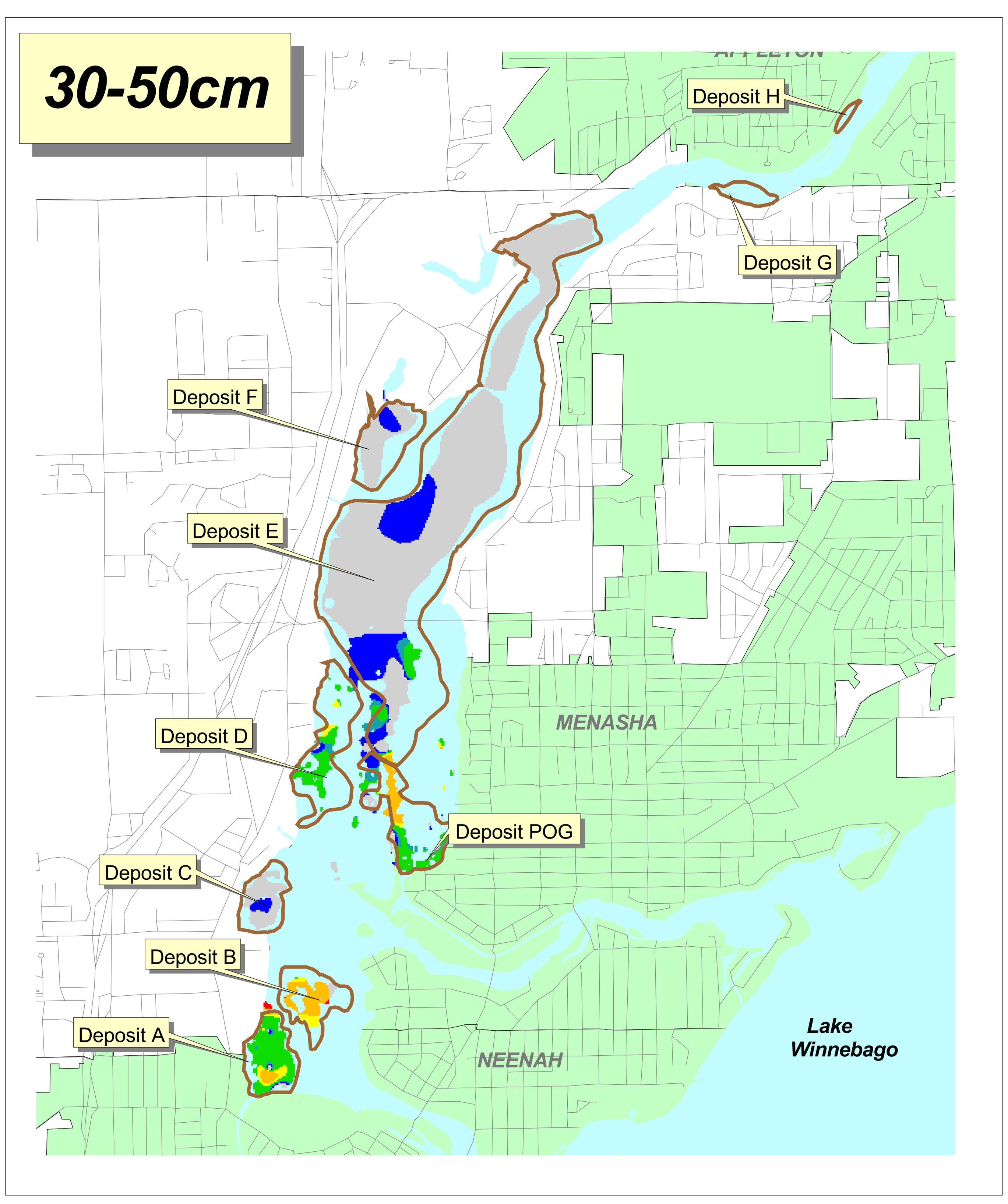
Notes:
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

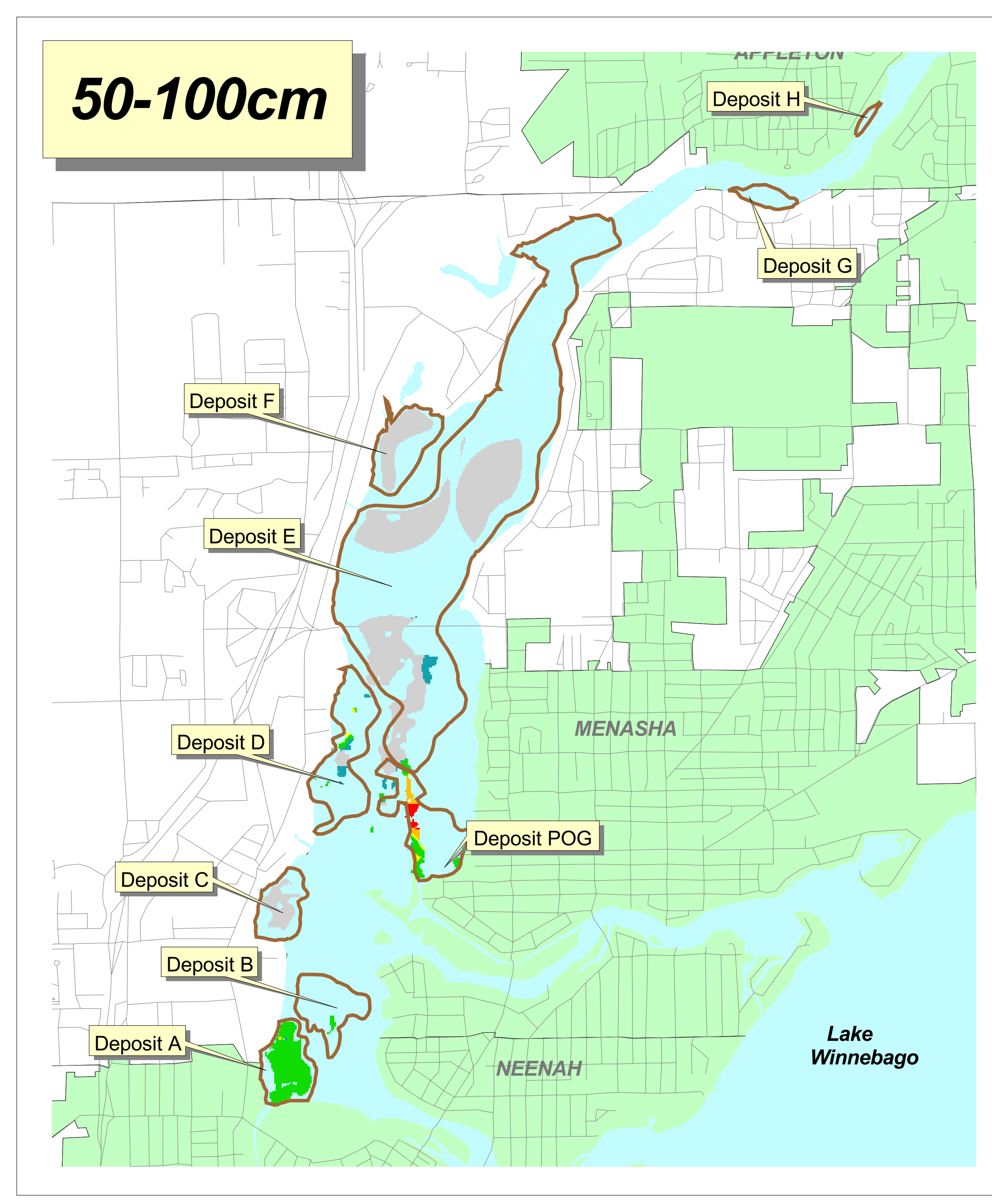
Table 5-25. Results of Fish Time Trends Analysis on the Lower Fox River

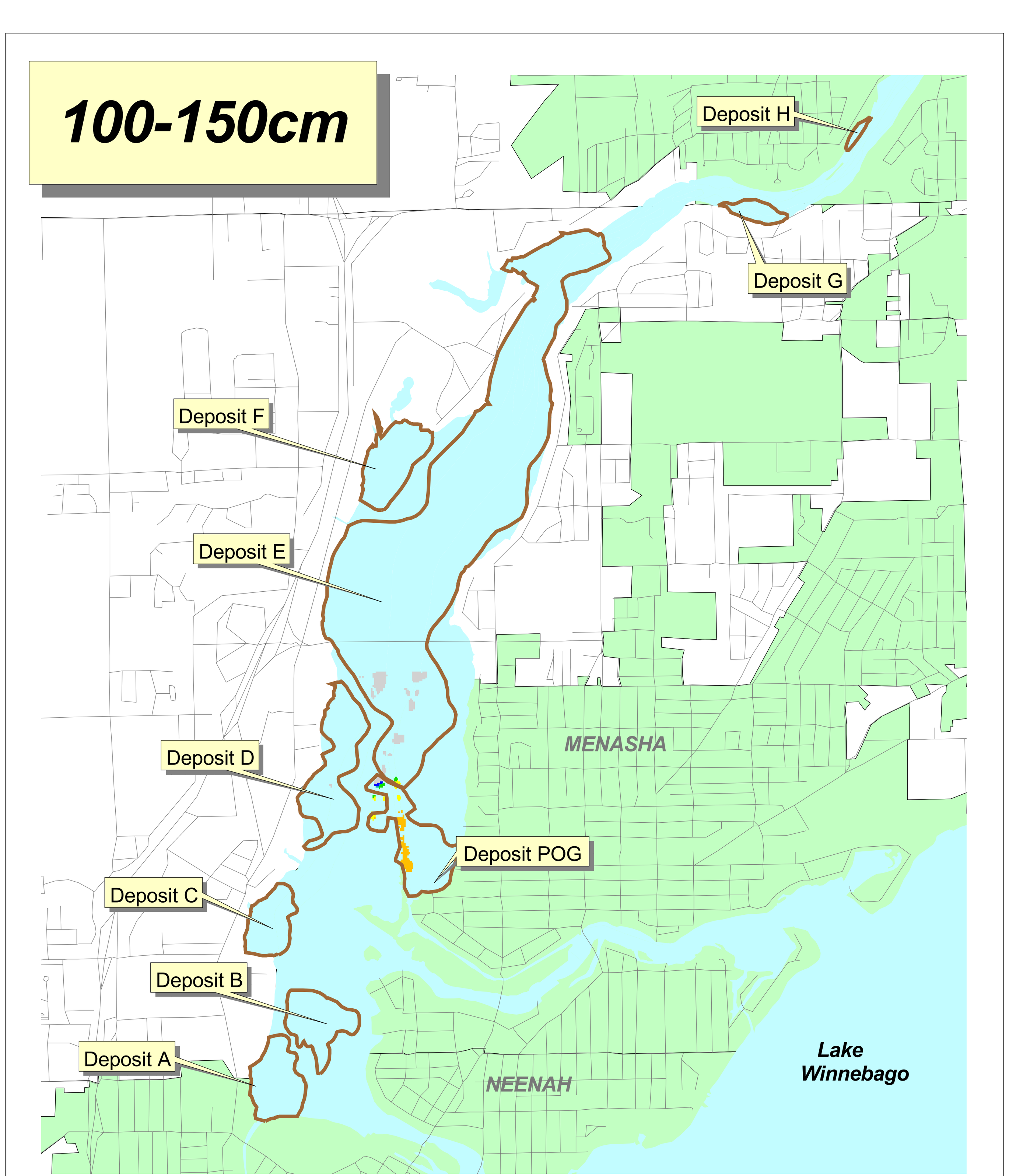
Species	Type	Sample Size	Year of Breakpoint	Percent Change per Year	95% Confidence Interval		p-Value
					LCL	UCL	
Little Lake Butte des Morts							
Carp	fillet on skin	55	1979	-6.15	-10.9	-1.1	0.0177
Carp	whole fish	40	1987	0.71	-12.3	15.6	0.9172
Northern Pike	fillet on skin	19		-11.83	-16.7	-6.7	0.0003
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







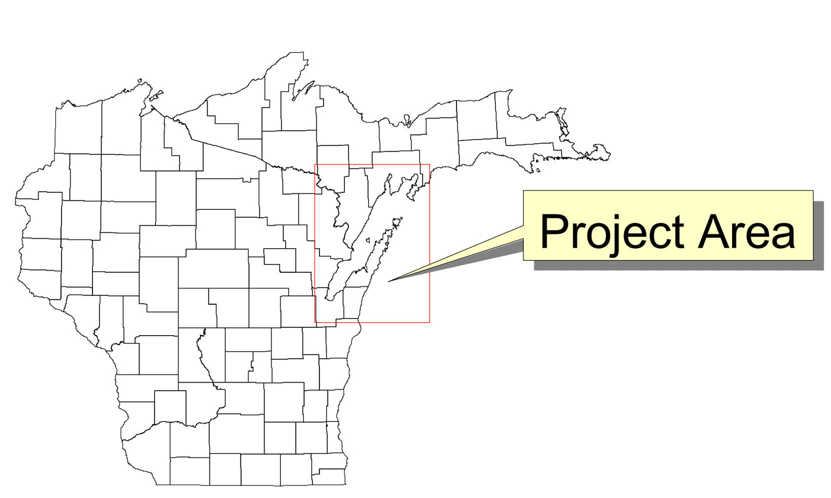




PCB Sediment Concentrations (ug/kg)
- <50
- 50-125
- 125-250
- 250-500
- 500-1,000
- 1,000-5,000
- 5,000-10,000
- 10,000-50,000
- >50,000
- Deposits
- Roads
- Water

Civil Divisions
- City
- Township
- Village

N
W E
S

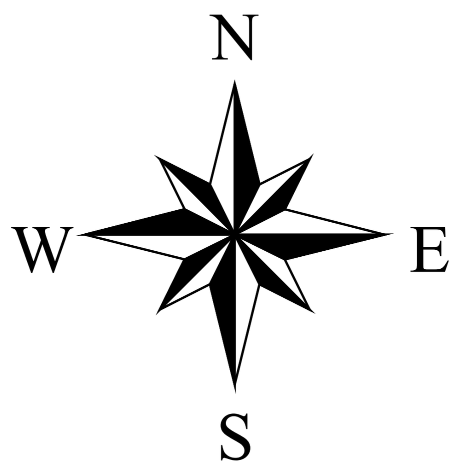


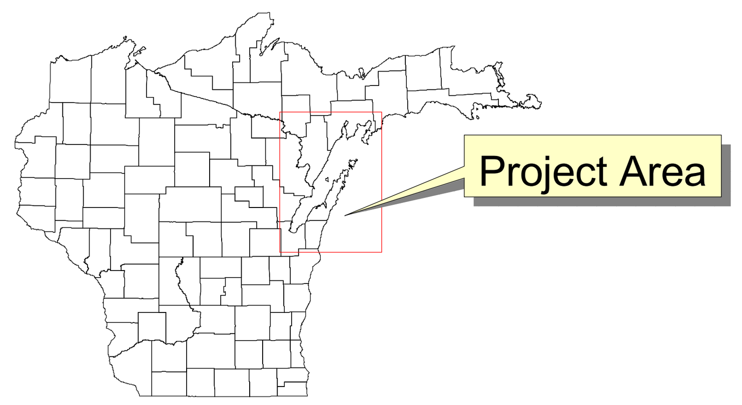
1 0 1 2 3 Kilometers

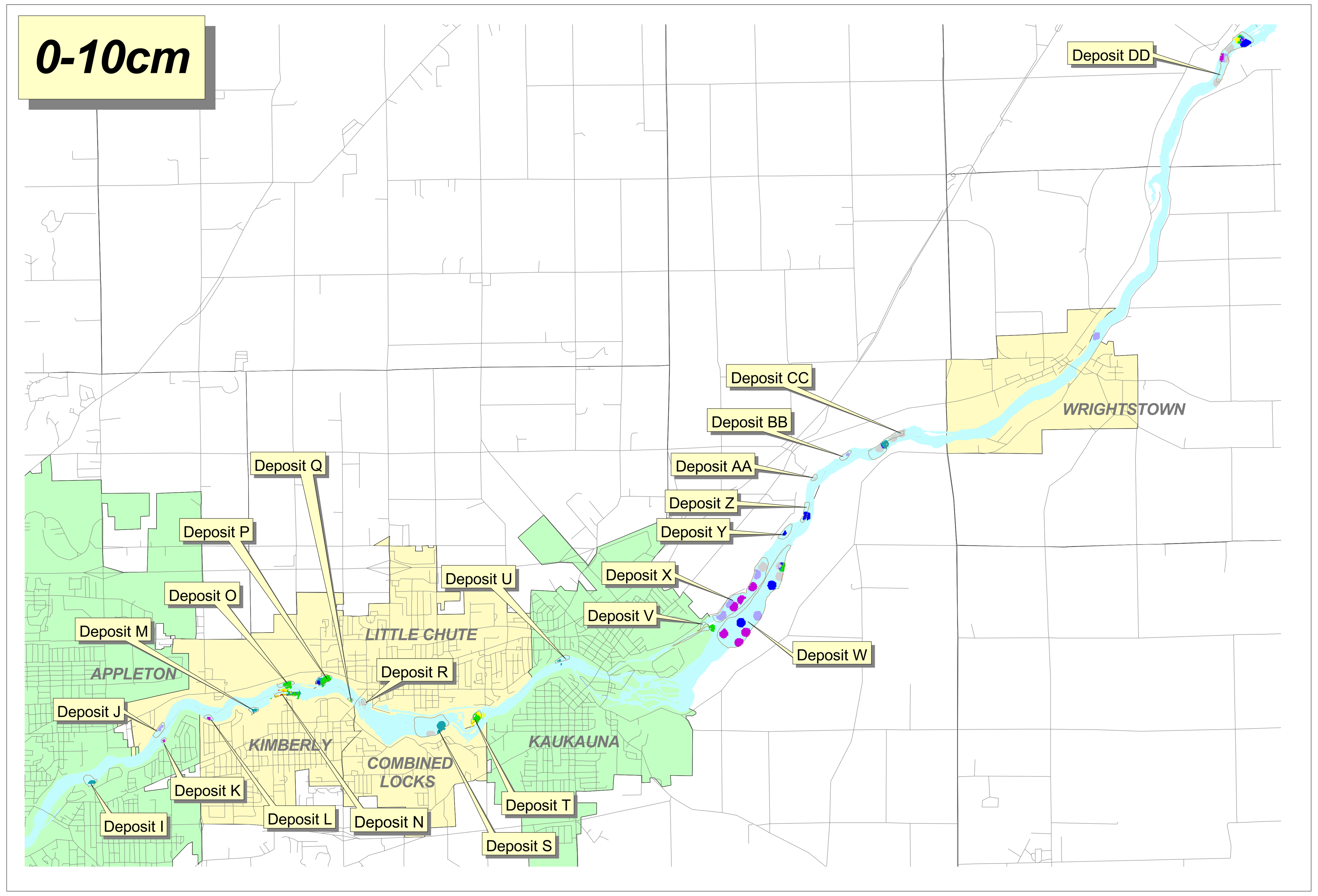
1 0 1 2 Miles

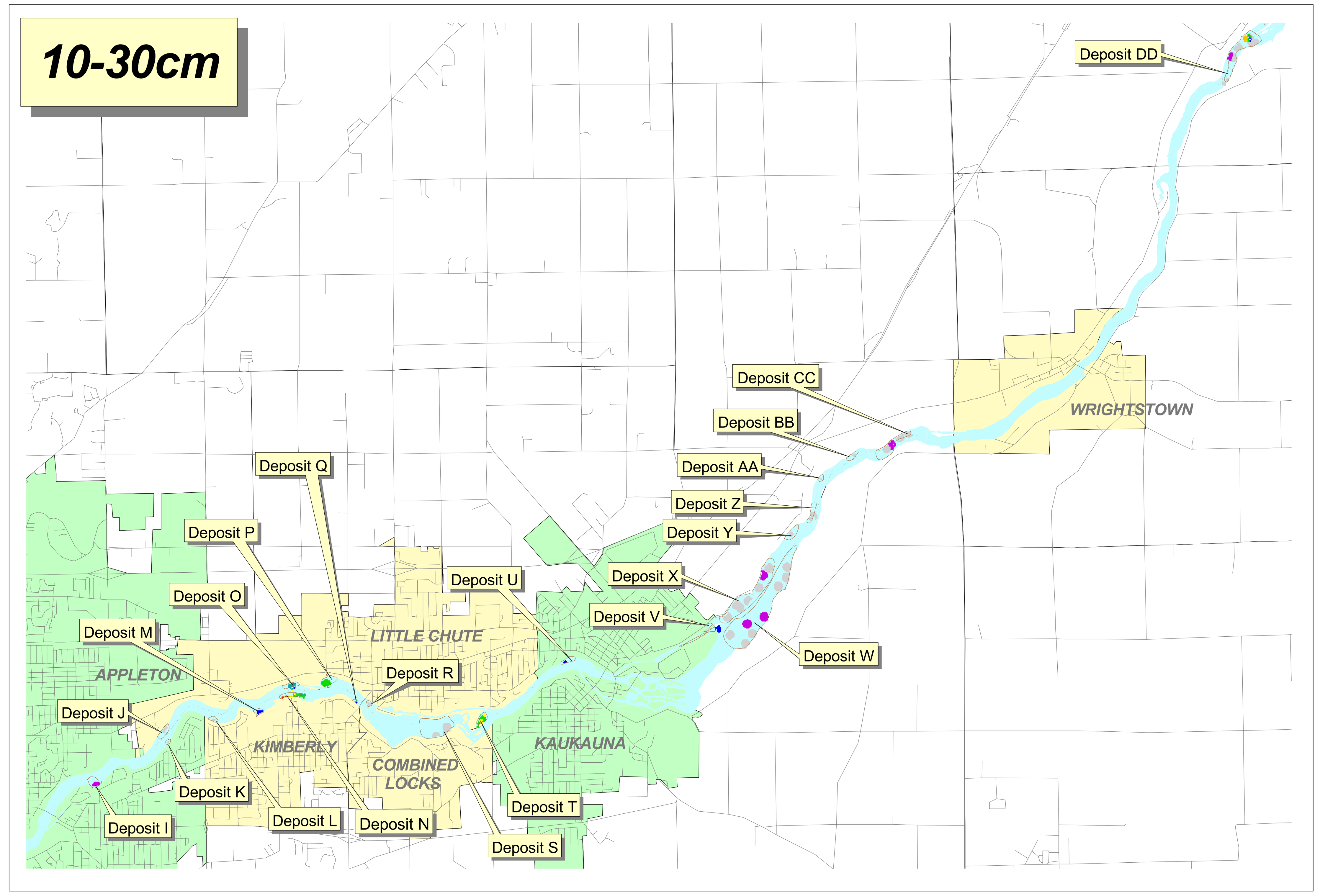
NOTES:
1. Basemap generated in ArcView GIS, version 3.2, 1998 and TIGER census data, 1995.
2. PCB sediment concentration data obtained from WDNR, and was generated in ArcView Spatial Analyst, version 1.1.
3. Distribution of PCB-impacted sediment defined by interpolated depth intervals (layers) below surfaces greater than 300 cm depths. Assume no exceedences beyond depths shown.
4. The less than 50 ug/kg layer implies the presence of soft sediment with detectable PCB concentrations.

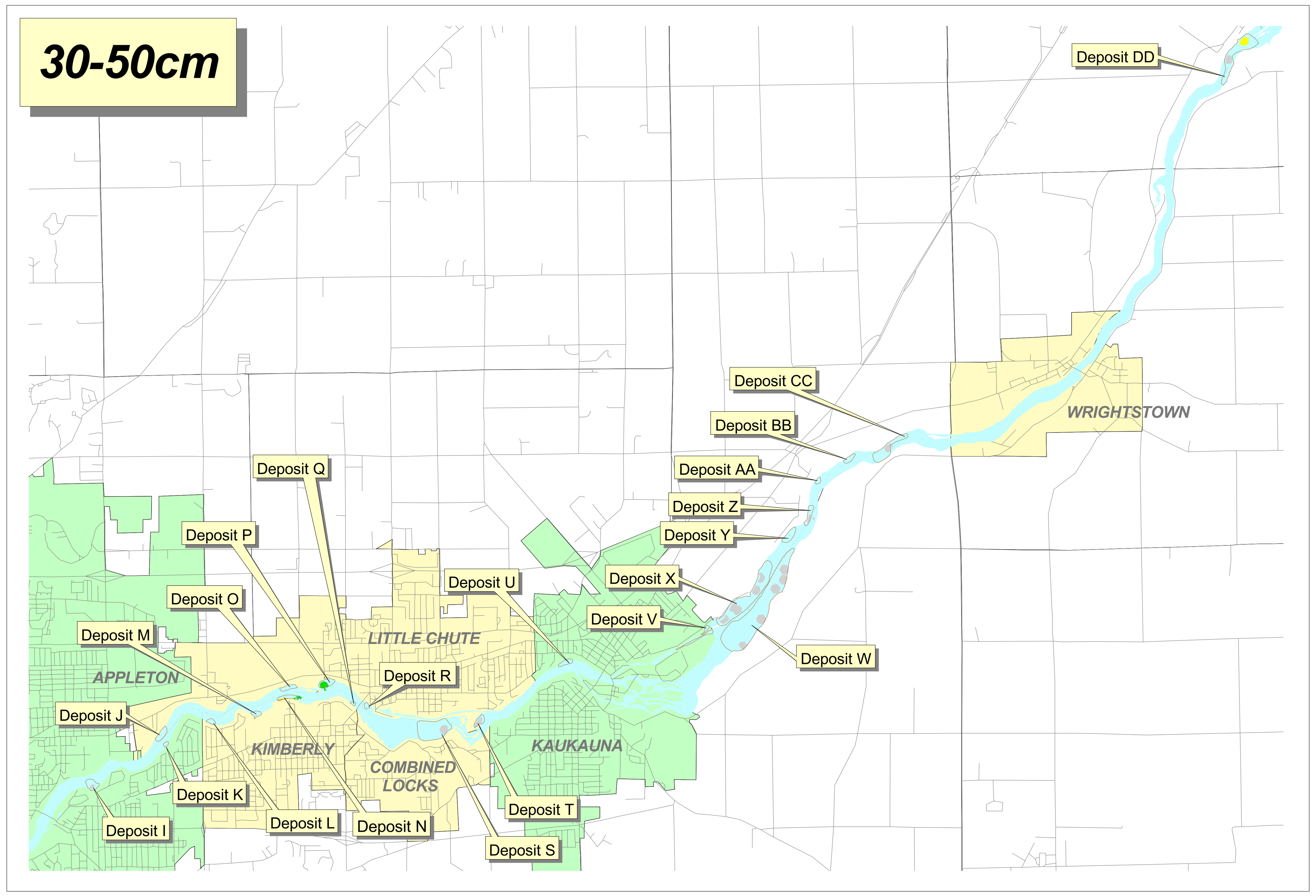
ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Interpolated PCB Distribution in Sediments: Little Lake Butte des Morts Reach	DRAWING NO: RI-14414-340-5-1
				PRINT DATE: 3/8/01
				CREATED BY: SCJ
			PLATE 5-1	APPROVED: AGF

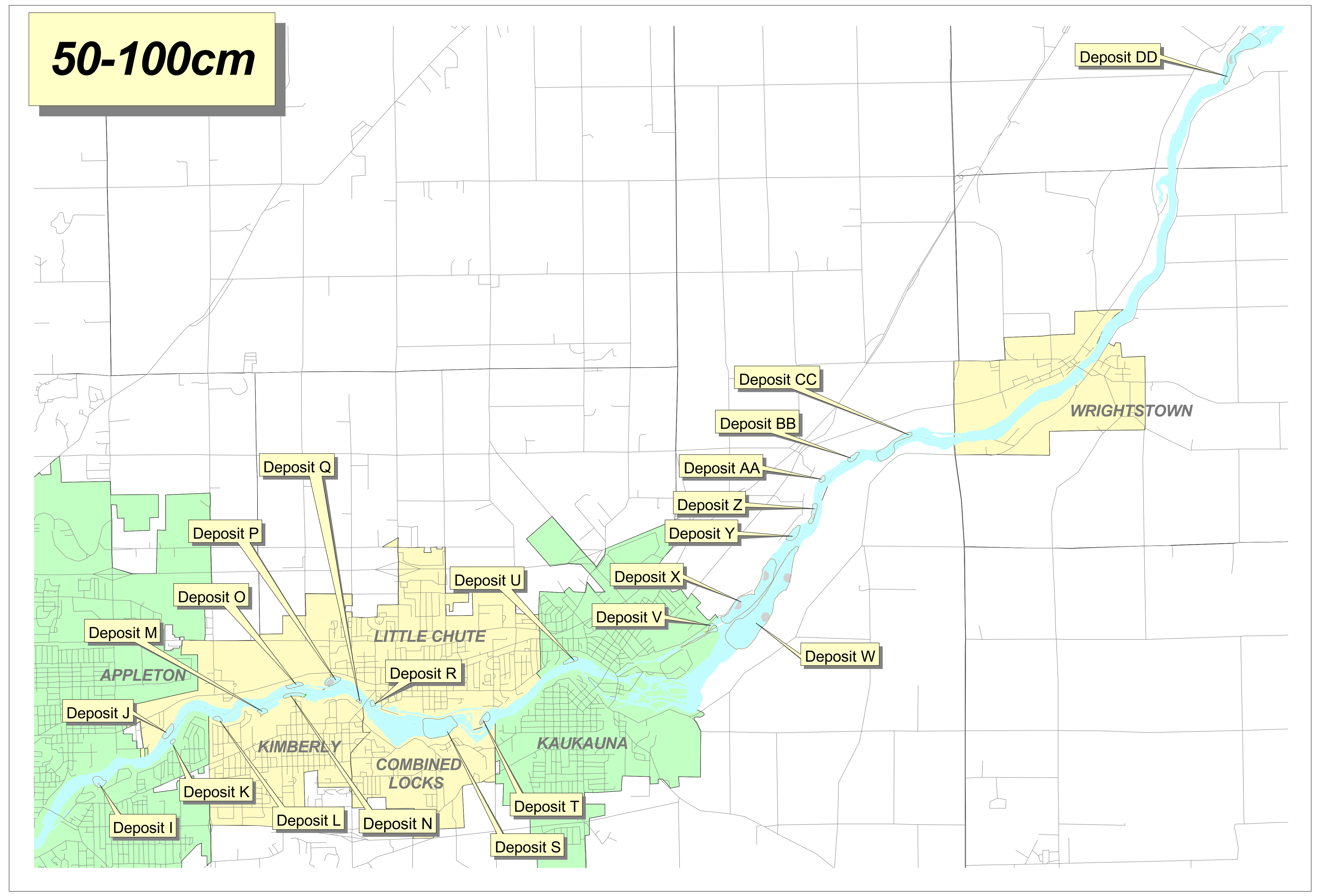












PCB Sediment Concentrations (ug/kg)

- <50
- 50-125
- 125-250
- 250-500
- 500-1,000
- 1,000-5,000
- 5,000-10,000
- 10,000-50,000
- >50,000
- Deposits
- Roads
- Water

Civil Divisions

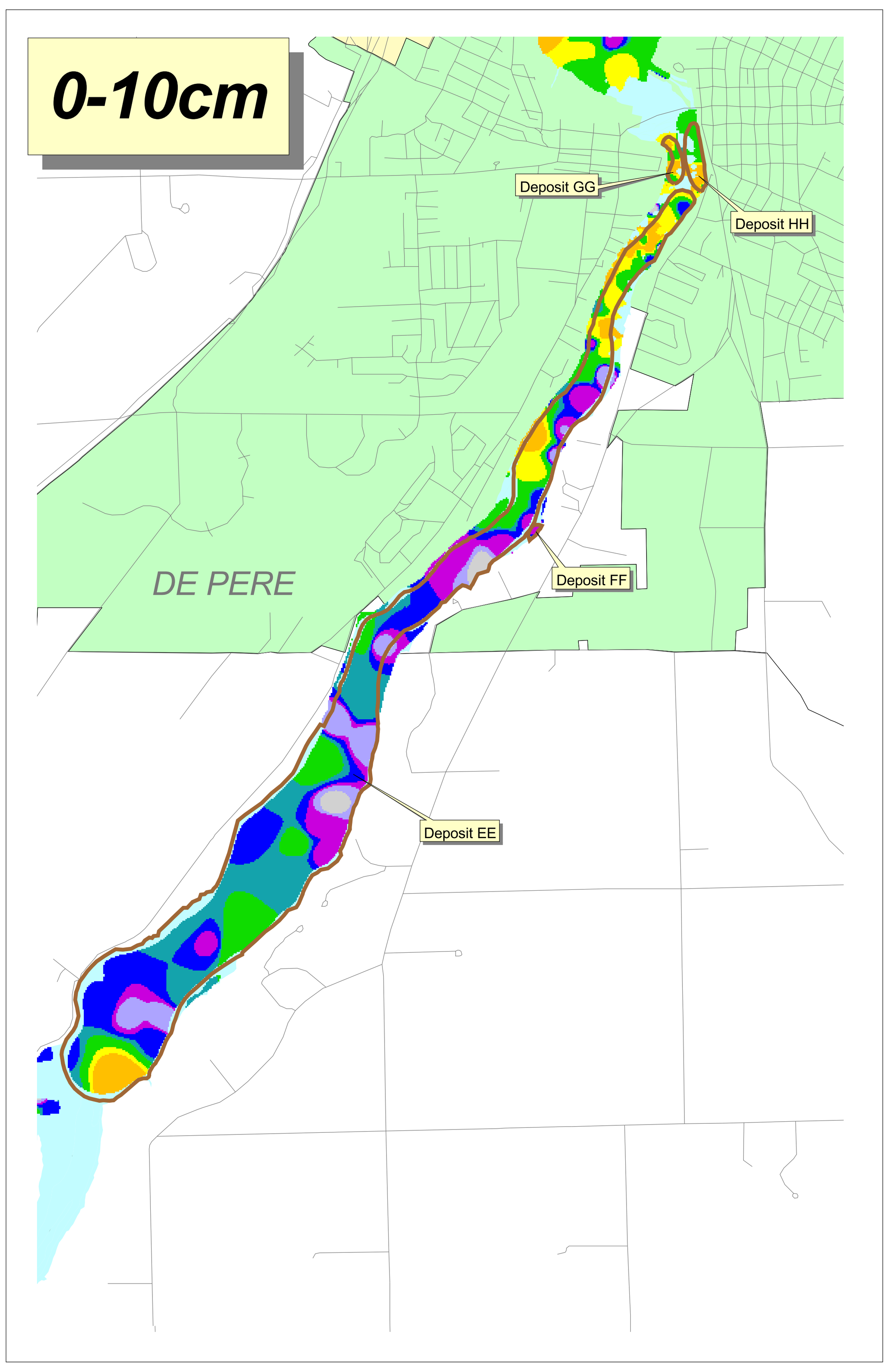
- City
- Township
- Village

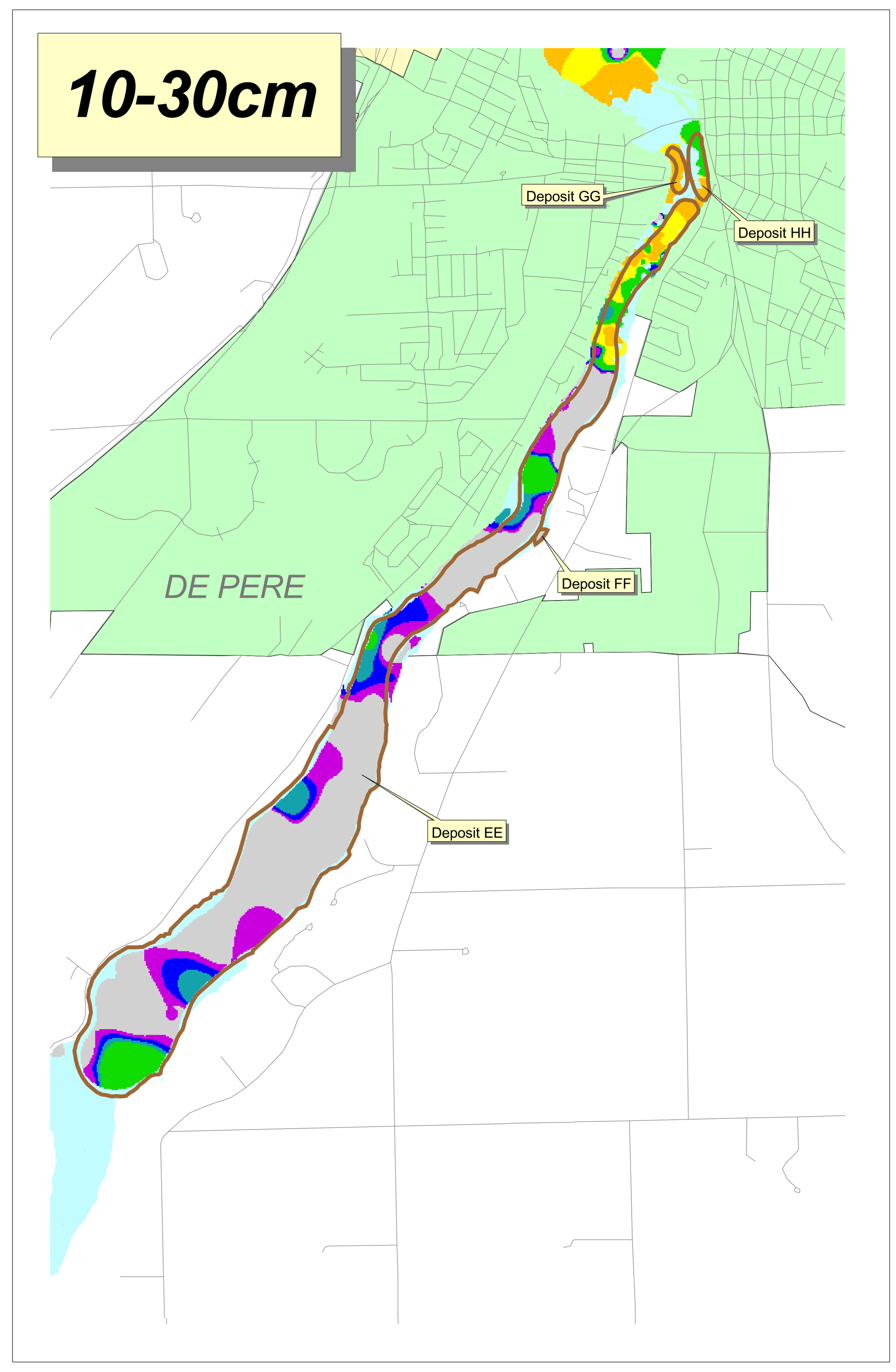
NOTES:
1. Basemap generated in ArcView GIS, version 3.2, 1998 and TIGER census data, 1995.
2. PCB sediment concentration data obtained from WDNR, and was generated in ArcView Spatial Analyst, version 1.1.
3. Distribution of PCB-impacted sediment defined by interpolated depth intervals (layers) below surfaces greater than 300 cm depths. Assume no exceedences beyond depths shown.
4. The less than 50 ug/kg layer implies the presence of soft sediment with detectable PCB concentrations.

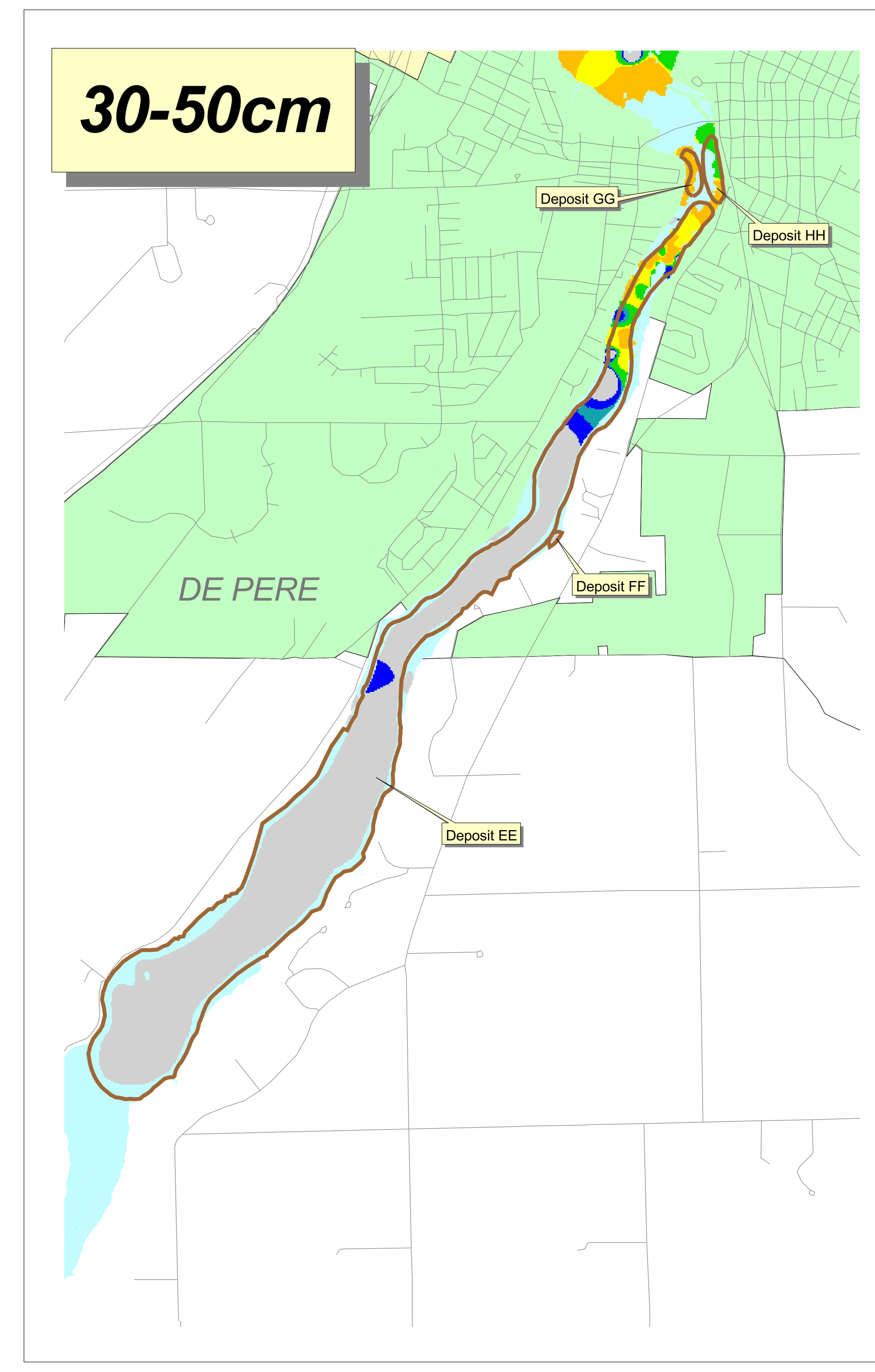
2 0 2 4 6 Kilometers

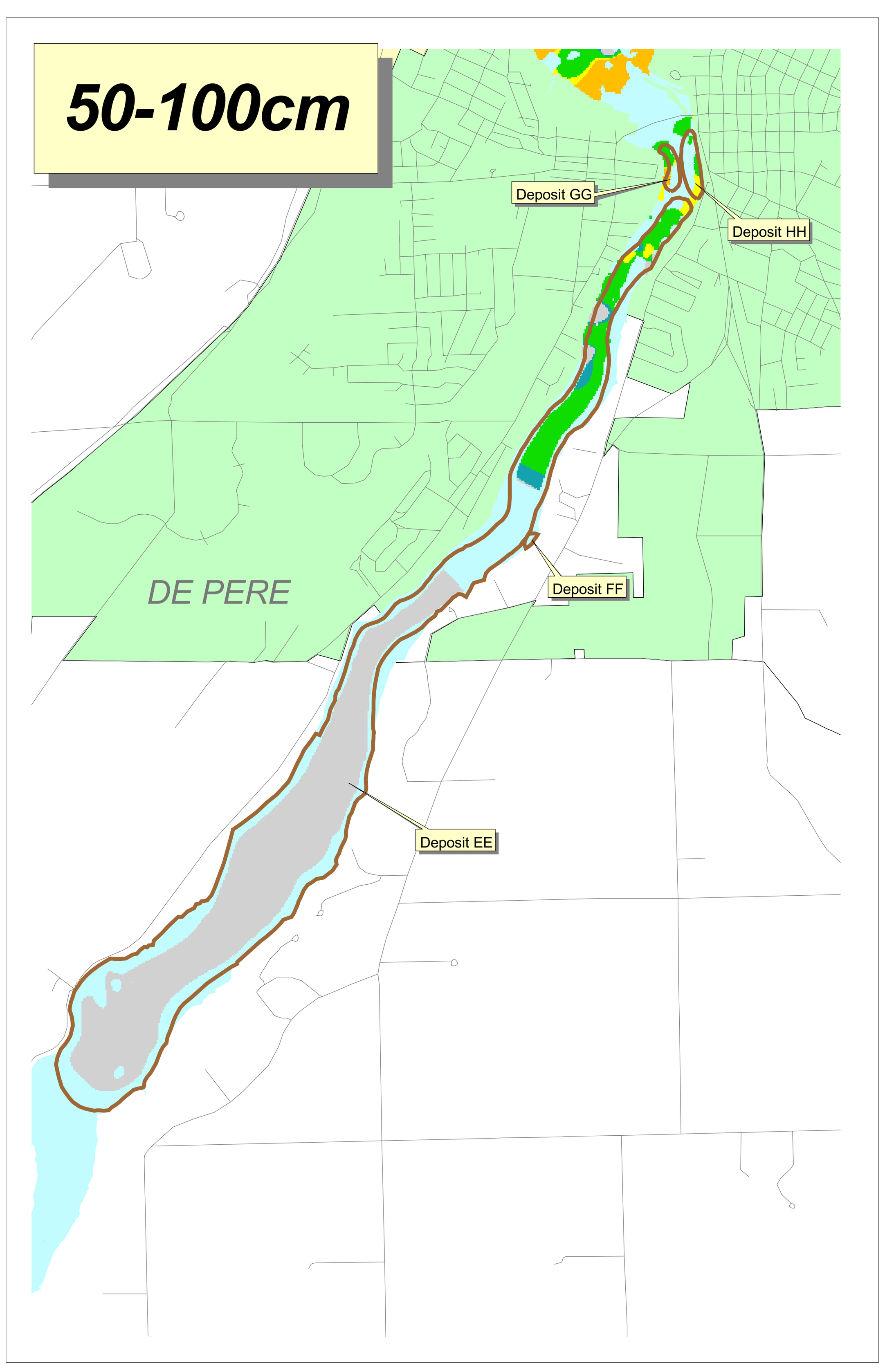
2 0 2 4 Miles

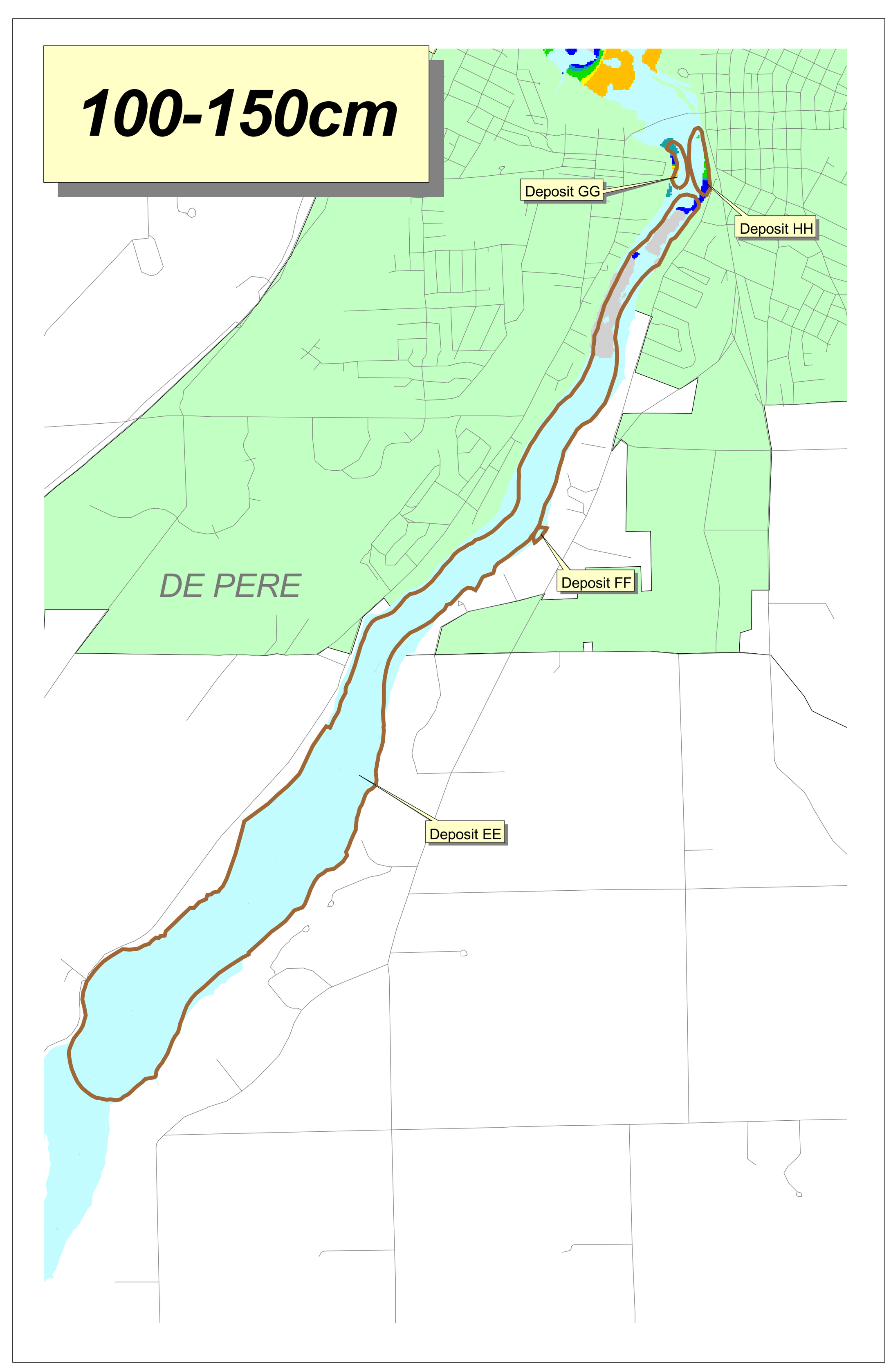
ThermoRetec	Natural Resource Technology	Remedial Investigation Report	Interpolated PCB Distribution in Sediments: Appleton to Little Rapids Reach	DRAWING NO: RI-14414-340-5-2
				PRINT DATE: 3/8/01
			PLATE 5-2	CREATED BY: SCJ
				APPROVED: AGF

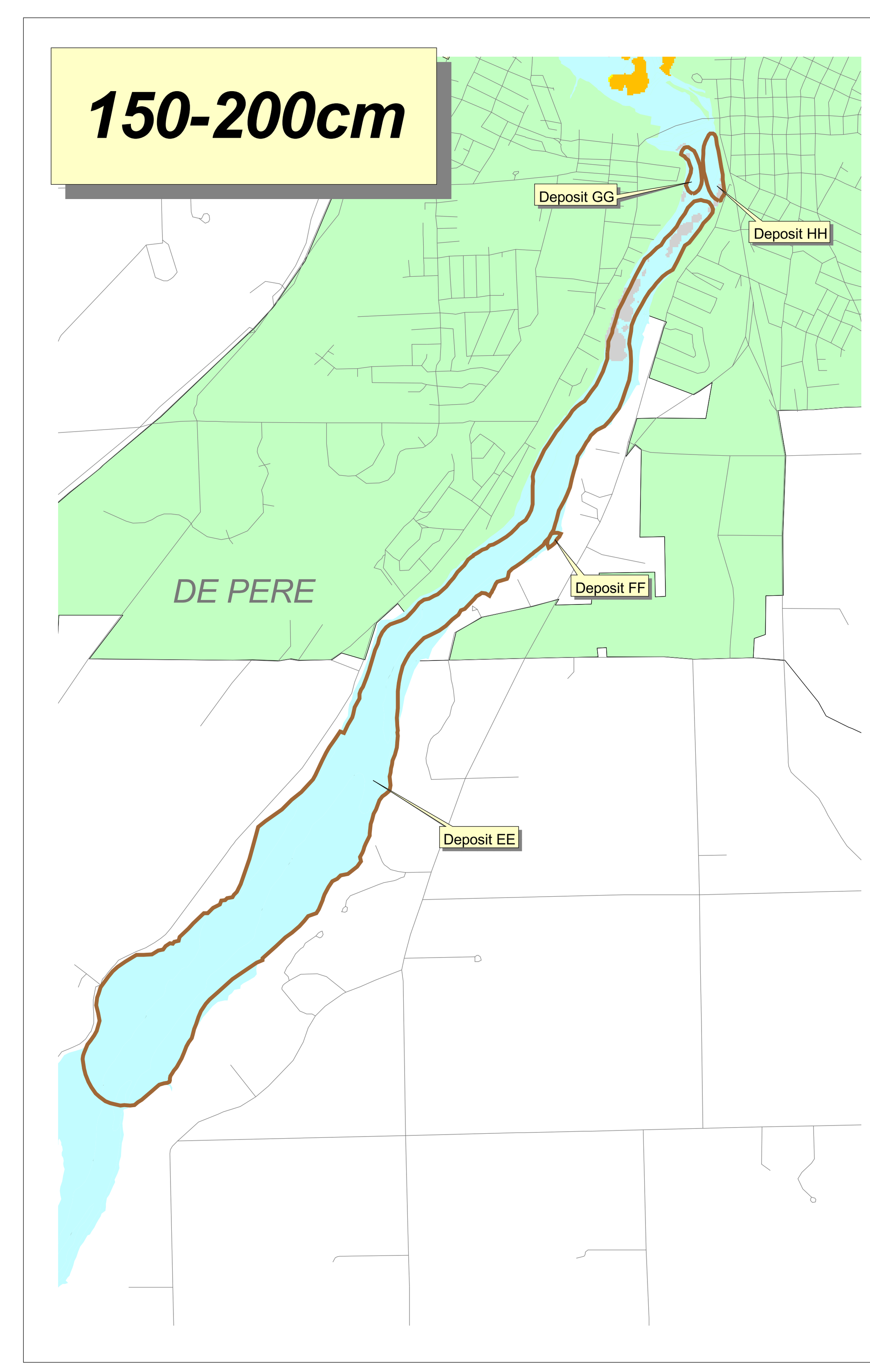


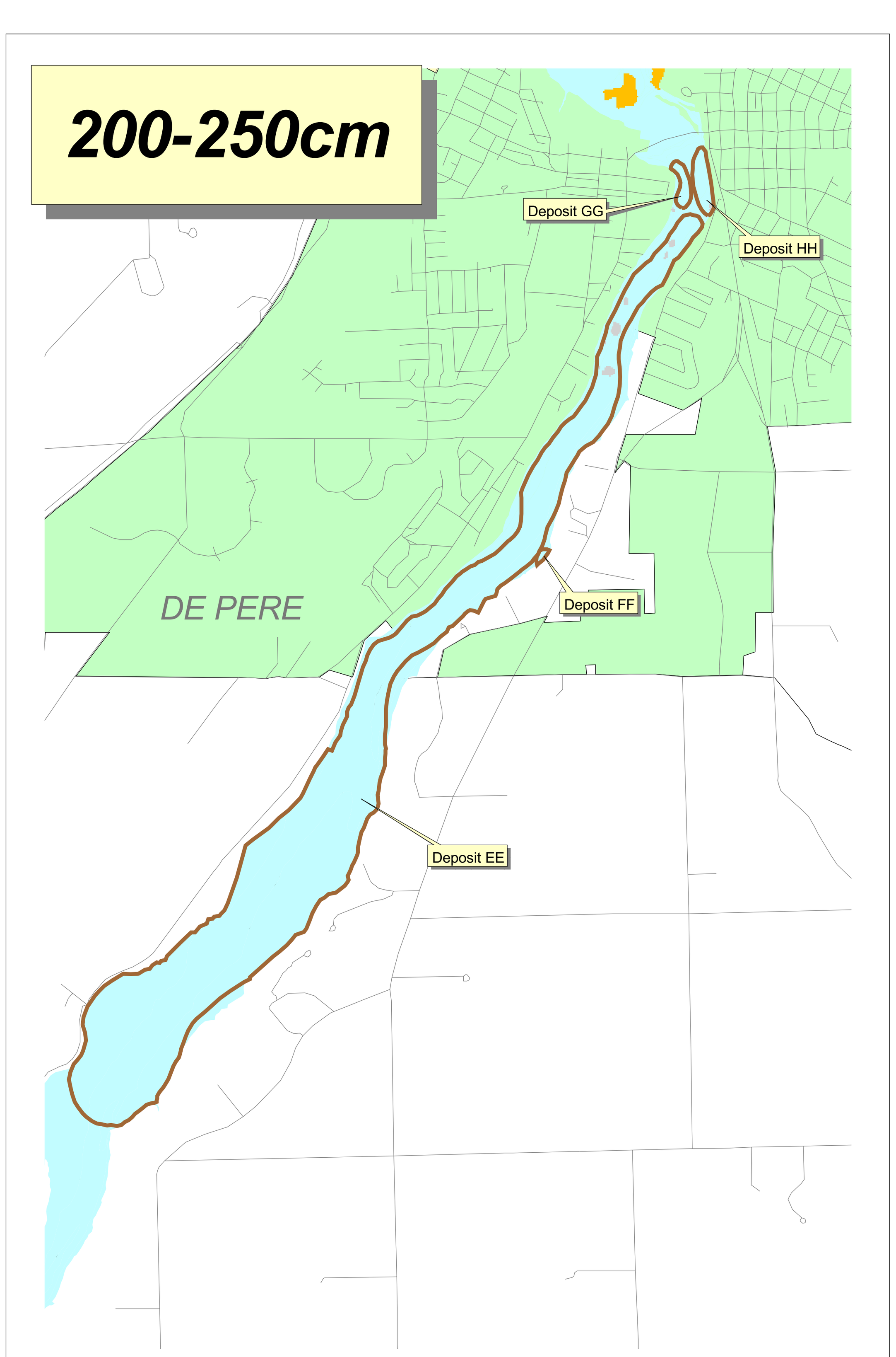






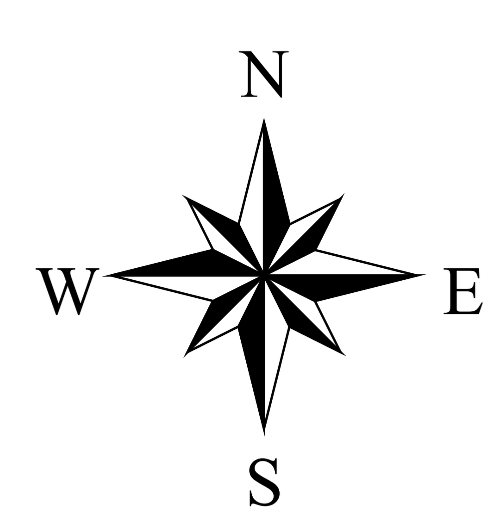


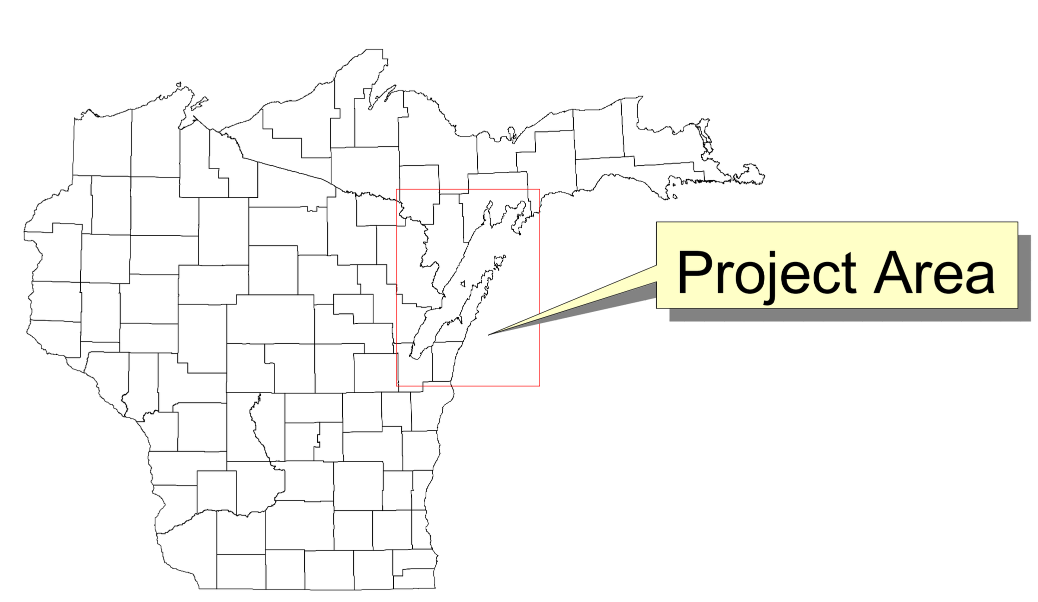




PCB Sediment Concentrations (ug/kg)
- <50
- 50-125
- 125-250
- 250-500
- 500-1,000
- 1,000-5,000
- 5,000-10,000
- 10,000-50,000
- >50,000
- Deposits
- Roads
- Water

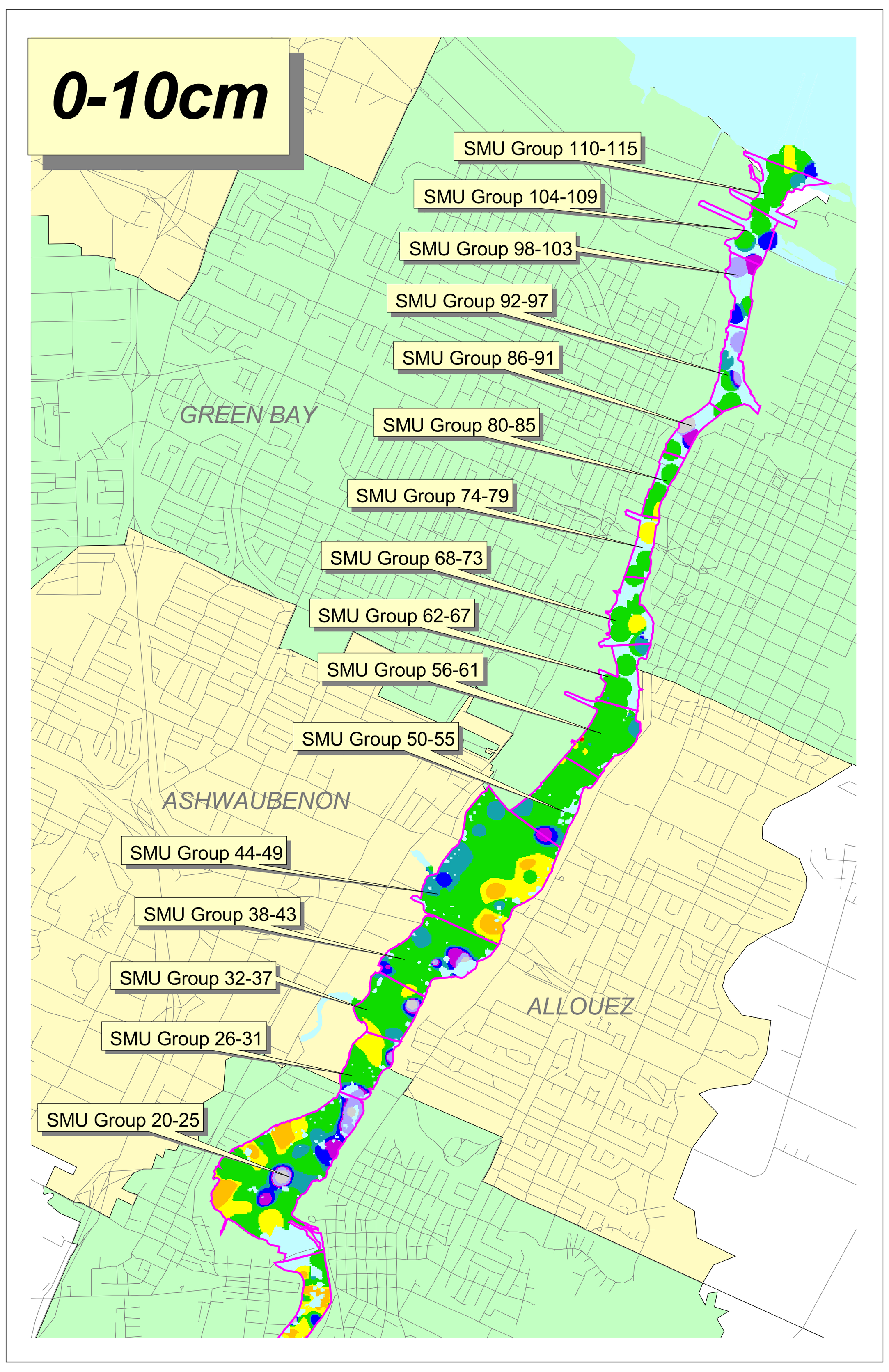
Civil Divisions
- City
- Township
- Village

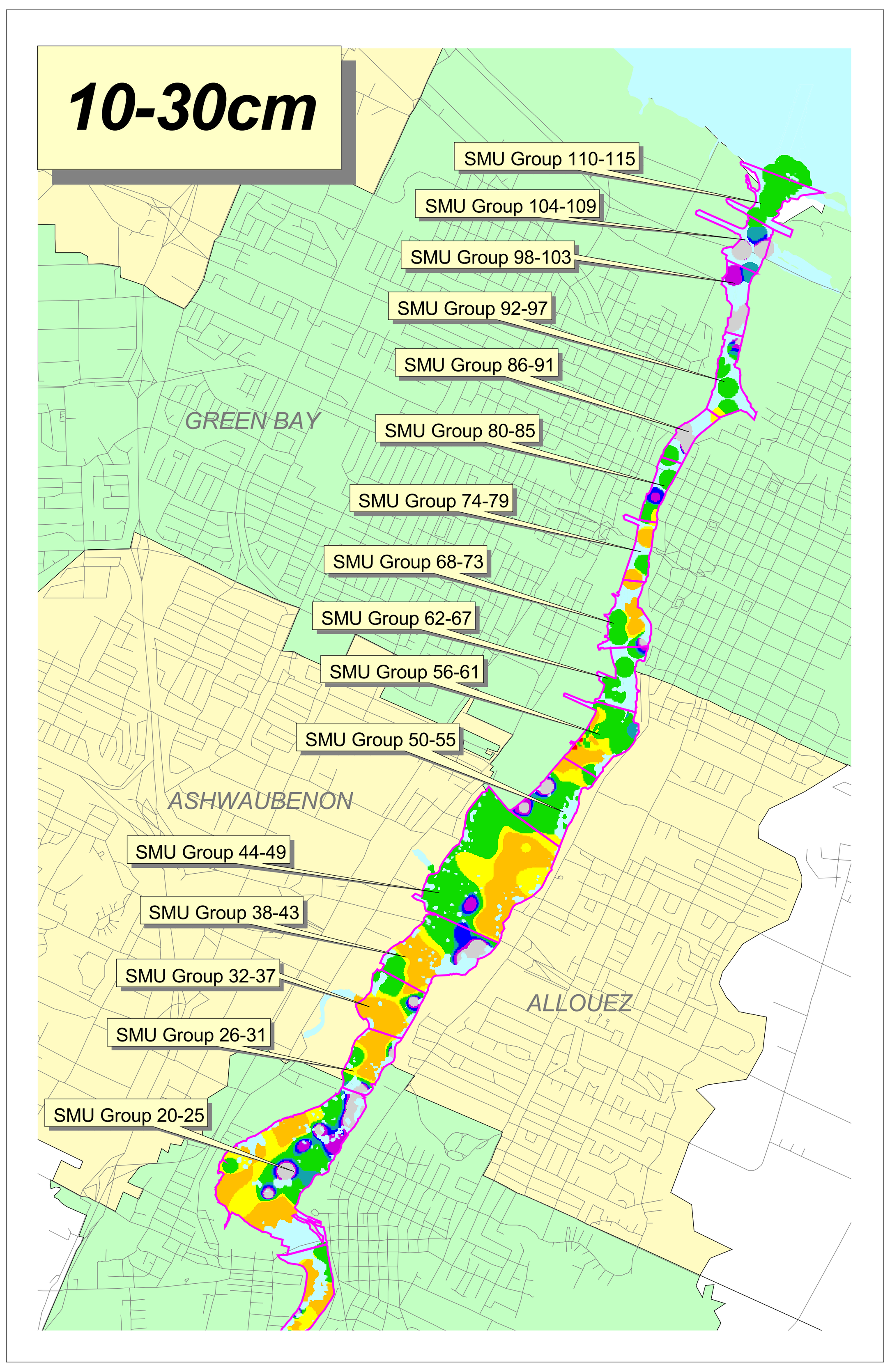


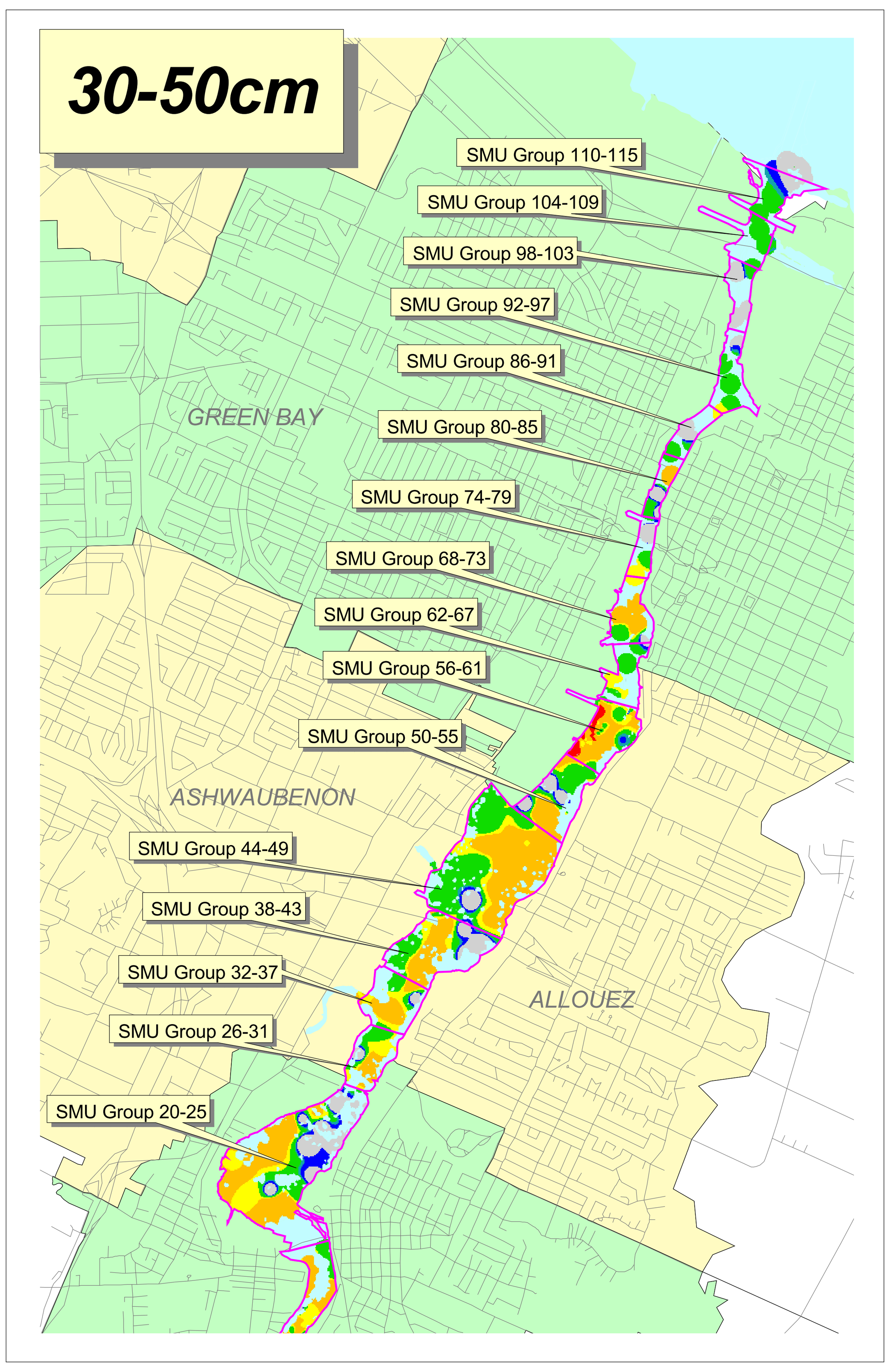


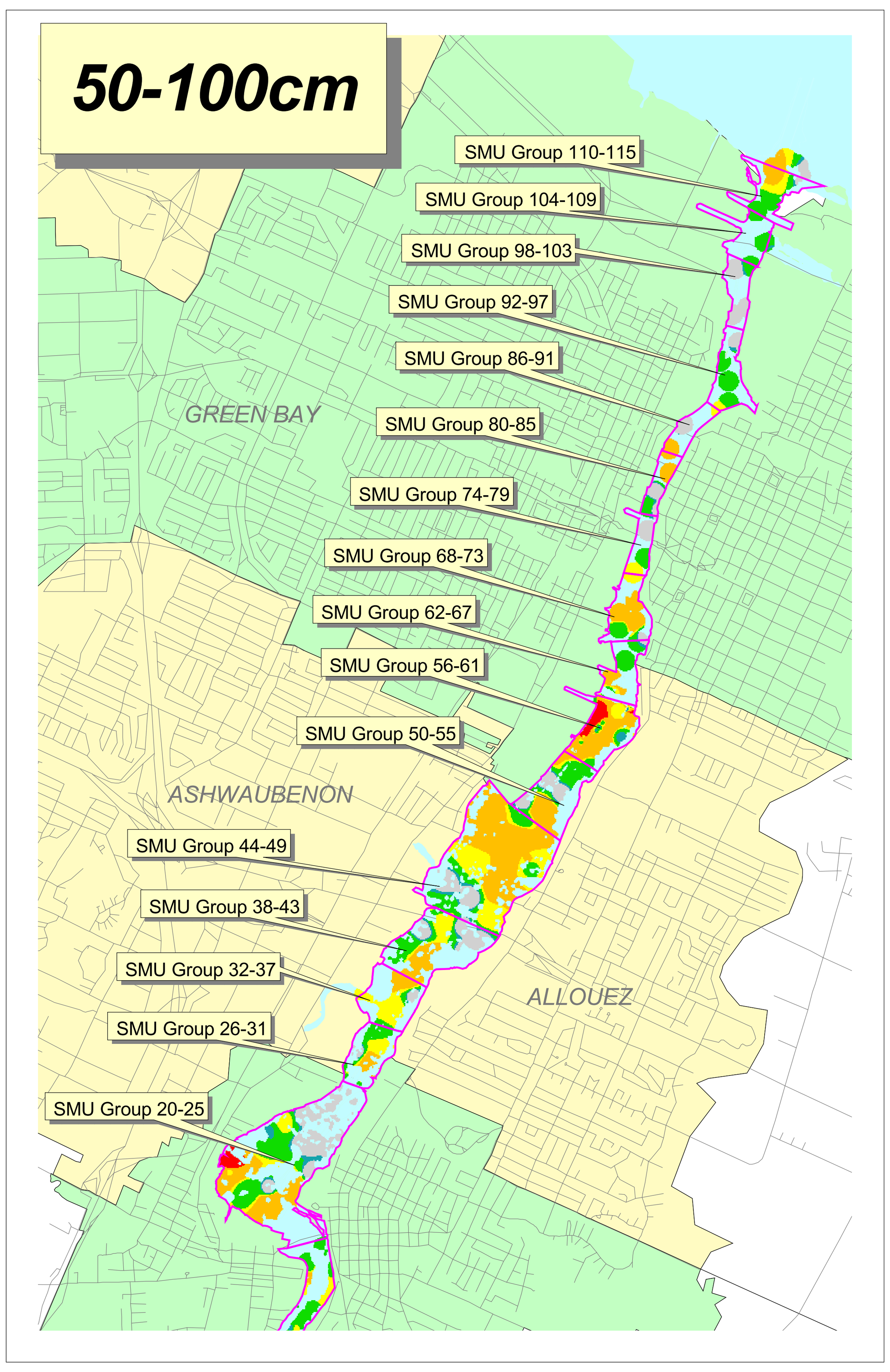
NOTES:
1. Basemap generated in ArcView GIS, version 3.2, 1998 and TIGER census data, 1995.
2. PCB sediment concentration data obtained from WDNR, and was generated in ArcView Spatial Analyst, version 1.1.
3. Distribution of PCB-impacted sediment defined by interpolated depth intervals (layers) below surfaces greater than 300 cm depths. Assume no exceedences beyond depths shown.
4. The less than 50 ug/kg layer implies the presence of soft sediment with detectable PCB concentrations.

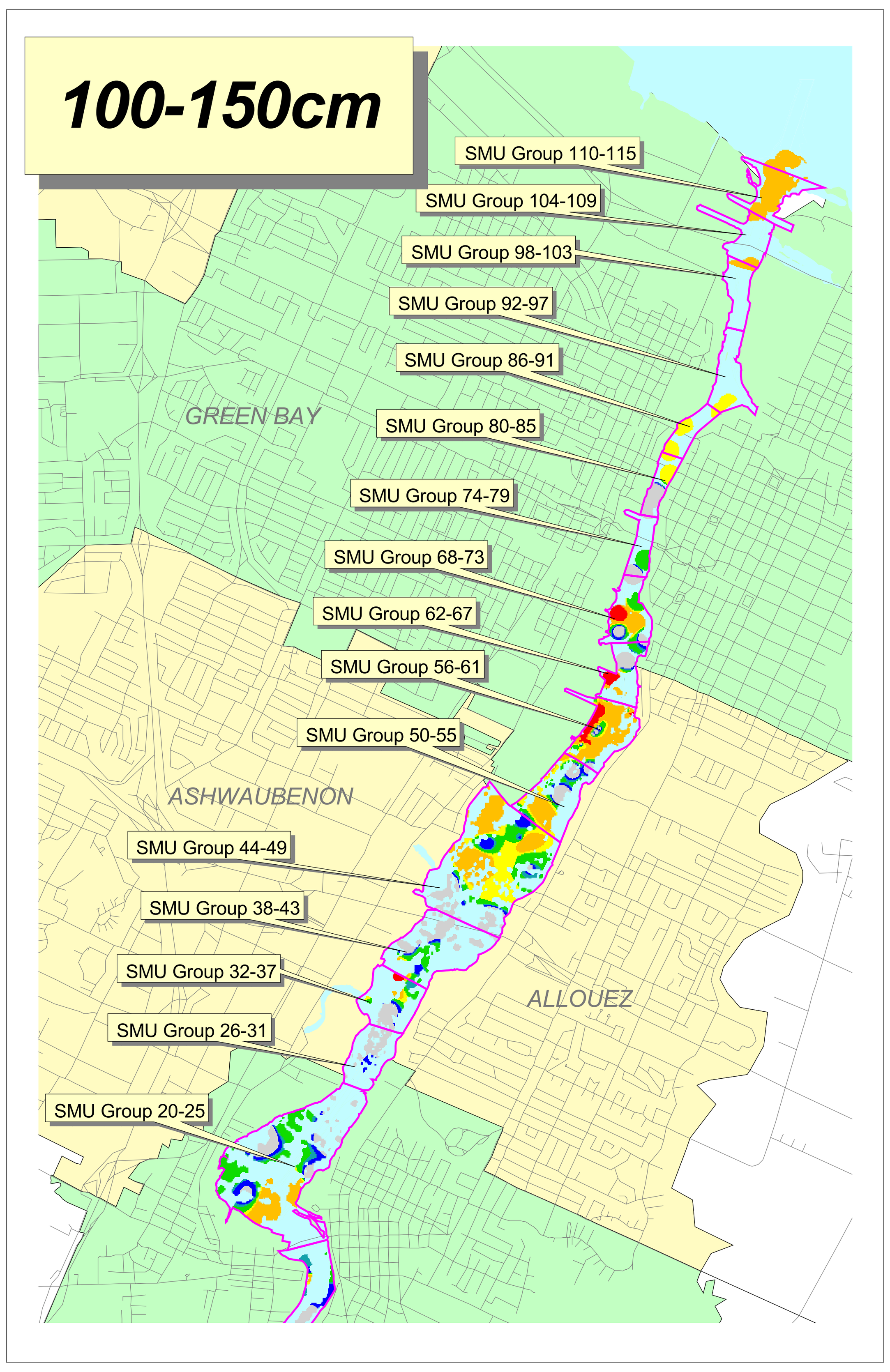
ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Interpolated PCB Distribution in Sediments: Little Rapids to De Pere Reach	DRAWING NO: RI-14414-340-5-3 PRINT DATE: 3/8/01 CREATED BY: SCJ APPROVED: AGF
			PLATE 5-3	

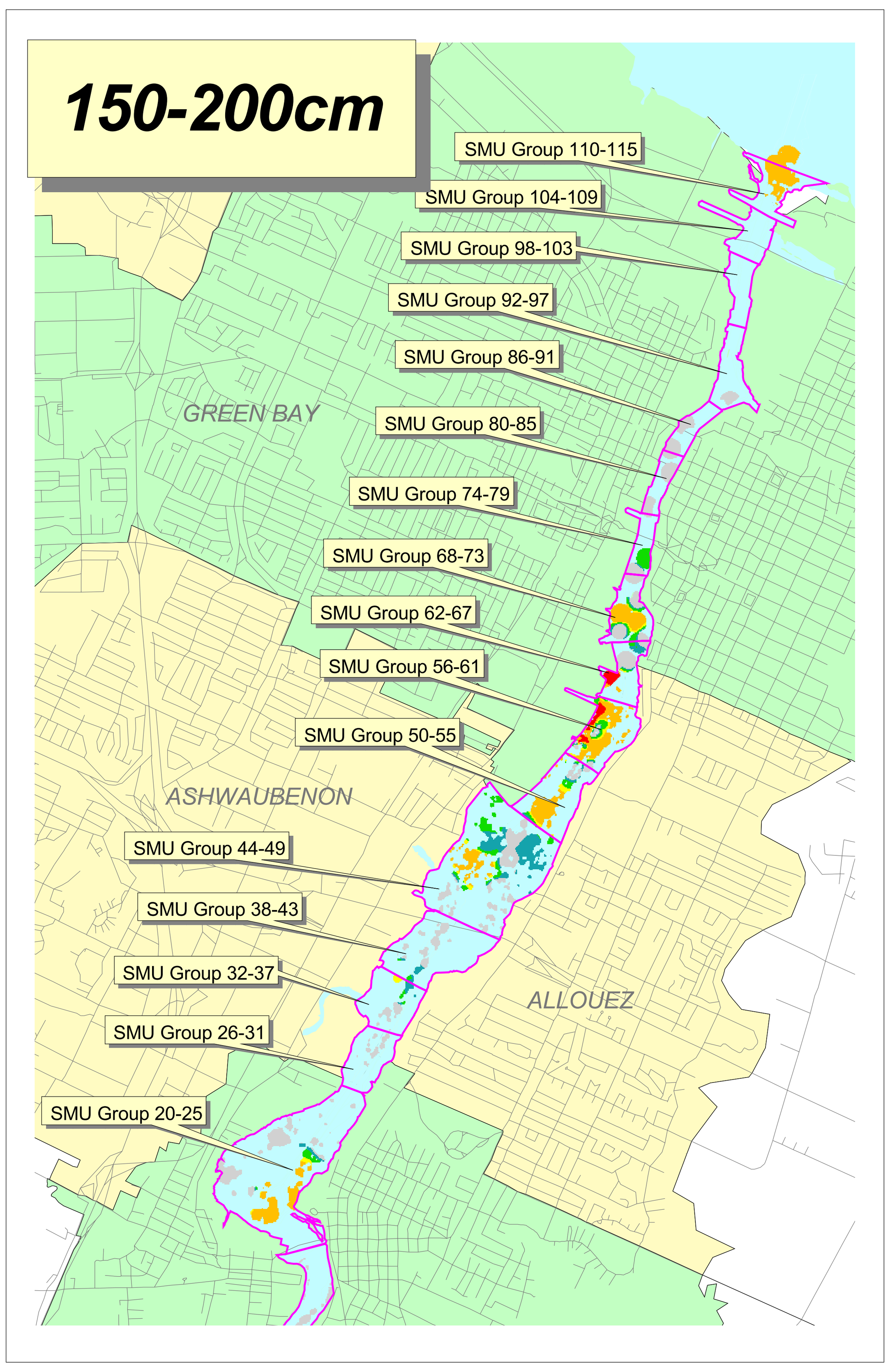


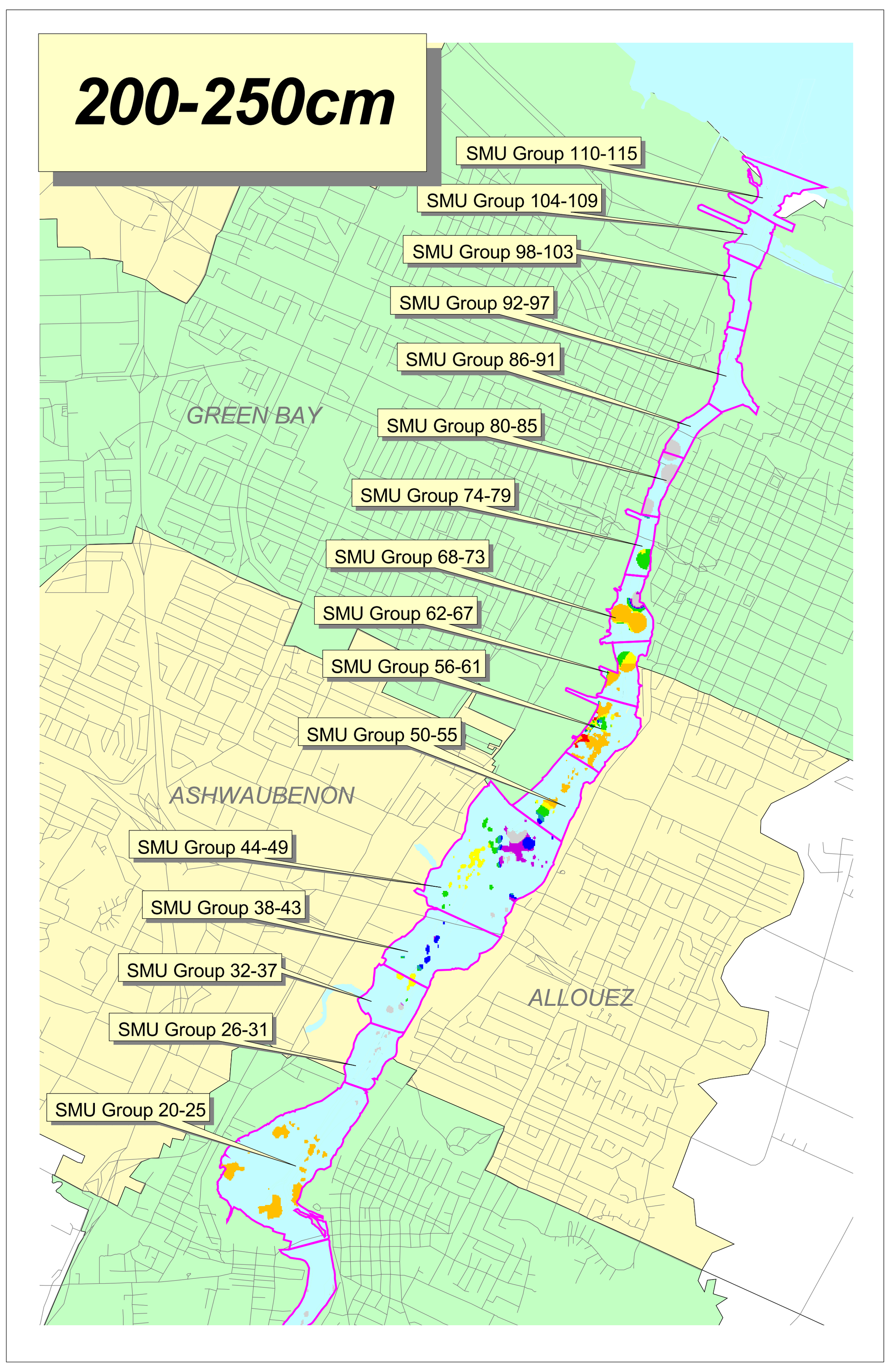


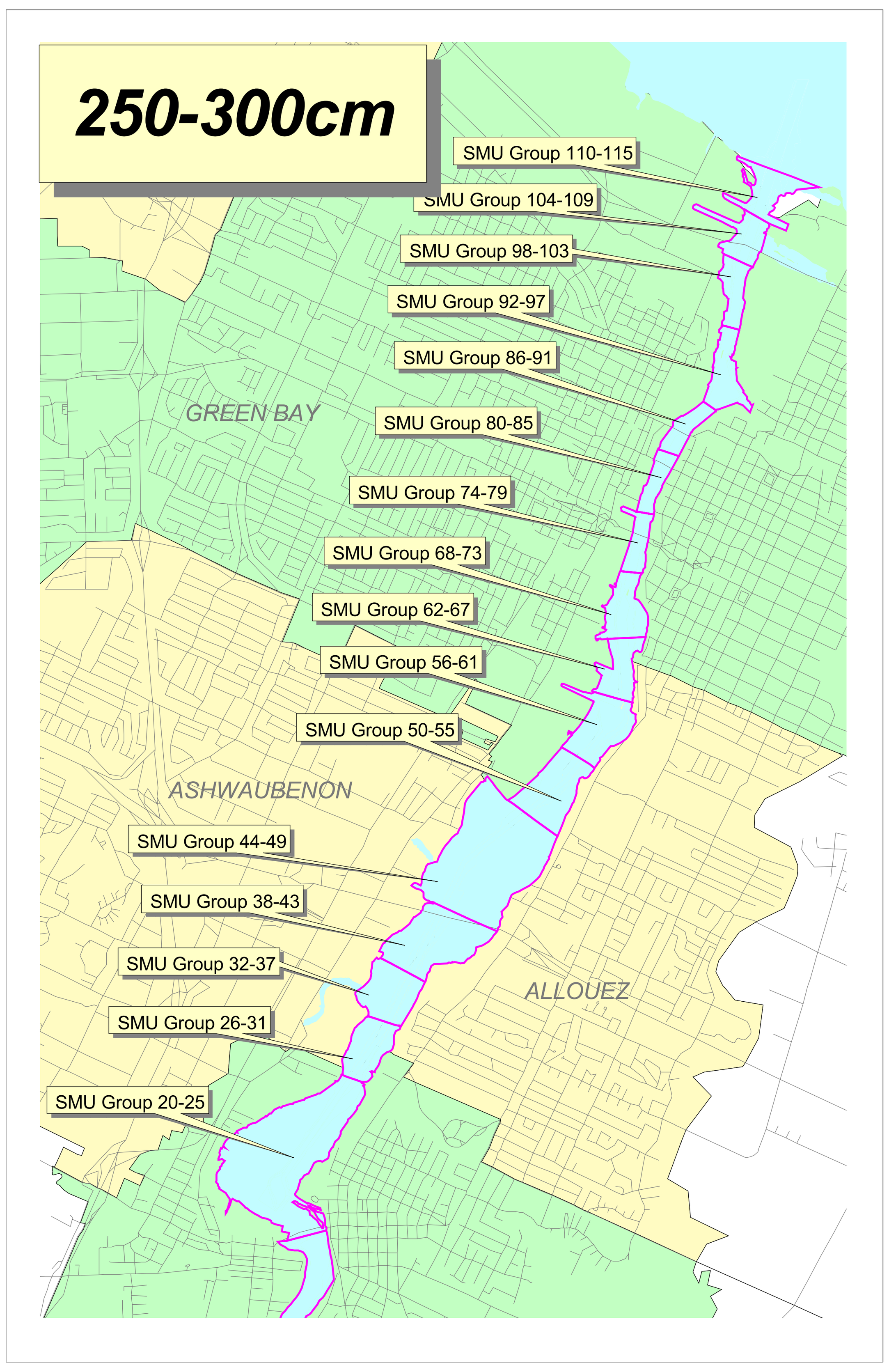












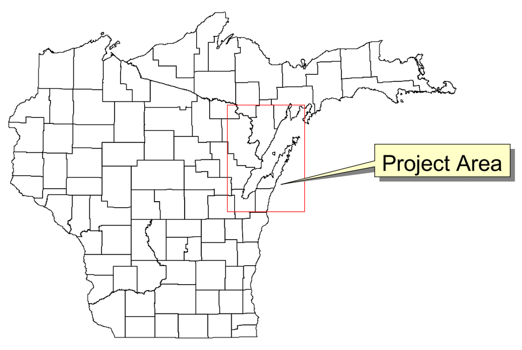
PCB Sediment Concentrations (ug/kg)

- <50
- 50-125
- 125-250
- 250-500
- 500-1,000
- 1,000-5,000
- 5,000-10,000
- 10,000-50,000
- >50,000
- Sediment Management Units
- Roads
- Water

Civil Divisions

- City
- Township
- Village

N S E W

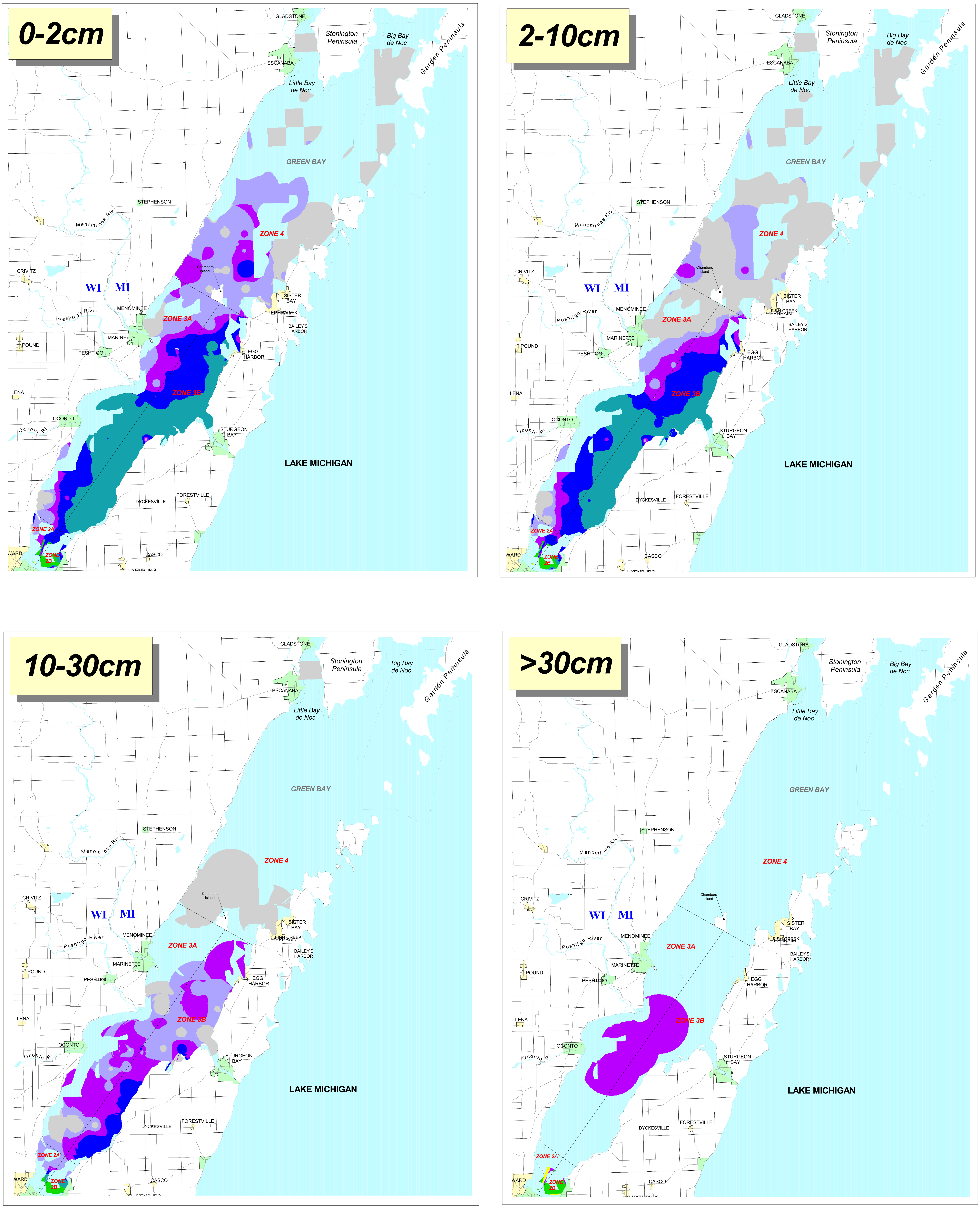


2 0 2 4 Kilometers

2 0 2 Miles

NOTES:
1. Basemap generated in ArcView GIS, version 3.2, 1998 and 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.
4. The less than 50 ug/kg layer implies the presence of soft sediment with detectable PCB concentrations.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Interpolated PCB Distribution in Sediments: De Pere to Green Bay Reach	DRAWING NO: RI-14414-340-5-4
				PRINT DATE: 3/8/01
				CREATED BY: SCJ
			PLATE 5-4	APPROVED: AGF

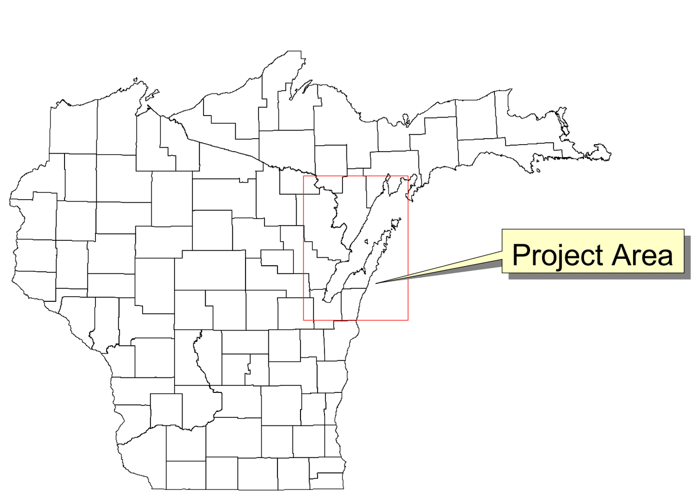


PCB Sediment Concentrations (ug/kg)

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

Civil Divisions

- City
- Township
- Village



N
W E
S

20 0 20 40 Kilometers

20 0 20 Miles

NOTES:
1. Basemap generated in ArcView GIS, version 3.2, 1998 and 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 up tp >30 cm depths.
4. The less than 50 ug/kg layer implies the presence of soft sediment with detectable PCB concentrations.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Remedial Investigation Report	Interpolated PCB Distribution in Sediments: Green Bay	DRAWING NO: RI-14414-340-5-5
				PRINT DATE: 3/8/01
				CREATED BY: SCJ
			PLATE 5-5	APPROVED: AGF

6 Chemical Transport and Fate

6.1 Introduction

This section summarizes the physical and chemical properties of the chemicals of concern (COCs) that influence their transport and fate in the Lower Fox River and Green Bay. Transport and fate processes affect how these compounds behave in the natural environment and move from source areas to potential human and environmental receptors. The discussion addresses PCBs, dioxin, dieldrin, DDT, arsenic, lead, and mercury, which were identified in the SLRA as chemicals of potential concern. In addition, the models to be used for the evaluation of PCB fate/transport and bioaccumulation are introduced and summarized. However, the results are not presented herein but can be found within the documentation report for each model.

A number of important physical and chemical processes affect contaminant fate and transport:

- Wind and stream flow/water movement
- Chemical-specific factors affecting partitioning between solid and dissolved phases
- Interactions between the dissolved and particulate phase of each compound (or compound group) within sediment, water column or biota
- Chemical partitioning or transformation in sediment, water, or biota

Once discharged into the environment, all of the chemicals discussed herein partition to sediment particles to some degree. Chemicals adsorbed onto the sediments are predominantly transported within the river system by physical processes. Important chemical and biological processes which facilitate uptake within the food chain include partitioning coefficients, metabolic processes, and species-specific bioaccumulation or bioconcentration factors. These processes are discussed in greater detail below.

6.2 Transport and Fate Processes

6.2.1 Chemical Transport Interactions

Chemical transport occurs through a variety of processes, including the following:

- Dissolution in the water column
- Volatilization into the atmosphere
- Adsorption to sediment (which may be deposited or suspended in the water column) and/or
- Incorporation into the food chain

In general, the chemicals of potential concern (COPC) tend to sorb to sediment particles, are resistant to biodegradation, volatilize slowly and bioaccumulate in aquatic organisms. Some chemical-specific measures, which are generally interrelated, that affect these tendencies include the following:

- Water solubility
- Organic carbon partitioning coefficient (K_{oc})
- Octanol-water partitioning coefficient (K_{ow})
- Vapor pressure
- Henrys Law constant (H_c) vapor: water partitioning coefficient
- Biodegradation rate
- Bioaccumulation factor

The water solubility of a chemical partly determines the extent to which a substance can partition between sediments and pore water/surface water. Because water is a polar solvent, polar covalent and ionic compounds are more likely to dissolve than non-polar compounds. Dissolution of non-polar organic chemicals are further controlled by their affinity for organic carbon phases in sediments or water. Both the K_{oc} and K_{ow} partitioning coefficients may be used to predict the degree of chemical sorption to organics in soil, sediment and particulate matter. The higher the K_{ow}, the greater affinity for partitioning to organic carbon. Vapor pressure and the Henrys Law constant are an indication of how readily a compound will volatilize from water into the atmosphere. The biodegradation rate, when known, provides the rate at which microbial processes may be expected to break down a chemical. Although the bioaccumulation factor is not a specific chemical property, it is a function of K_{oc} and can enable estimates of the degree to which a given chemical may be expected to be incorporated into tissues of aquatic organisms.

These are usually the most important factors effecting the overall fate of a chemical in the environment and they can be used to predict the mechanisms by which each contaminant (or group of contaminants) will move through or transform in the environment. Typical values for some of these chemical factors are included on Table 6-1 to enable general comparison with the other chemicals in the system.

6.2.2Physical Transport

Flowing water is the primary transport mechanisms for movement of contaminated sediment in the Lower Fox River downstream to Green Bay. Additionally, bay currents move sediments from southern Green Bay along the east shore, as discussed in Sections 3 and 5. Sediment transport is the primary mechanism for chemical movement in the Lower Fox River and Green Bay.

Surface water transport mechanisms depend on the type of water body present. In the Lower Fox River, the water velocity and sediment particle characteristics are the two main factors which influence the physical movement of sediment and the chemicals adsorbed onto their surfaces. The stream flow characteristics and physical movement of sediment particles as TSS in the Lower Fox River and Green Bay were discussed in detail in Section 3.

Chemicals sorbed to sediments and organic matter may be transported in suspension or as bed load by river currents. Fine-grained material, such as silts and clays, will generally be entrained in the water column and migrate downstream as suspended solids. As water velocities increase due to storm events or seasonal runoff, coarser-grained material (medium to coarse-grained sand or larger particles) will become suspended and/or move along the river bottom as bed load. Chemicals may accumulate as deposits as river velocities decrease. After deposition, bottom sediments are subject to resuspension.

In the case of larger water bodies, such as lakes (e.g., LLBdM and Green Bay), chemical/sediment transport occurs through wind and water driven currents as well as wave action. In general, currents are relatively slow and transport only fine-grained material. Large waves along near shore areas of Green Bay and Lake Michigan are capable of moving boulder size particles along the shoreline.

If a chemical dissolves in surface water, its chemical transport properties will be identical to those of water. Compounds present as an immiscible liquid phase will either sink or float on water depending on the compound's specific gravity.

Nonaqueous-phase liquids with a specific gravity of less than one will tend to remain close to, or float on the surface and may become susceptible to attenuation by volatilization and photolysis. Immiscible liquids more dense than water will move along the river bottom and/or become absorbed onto sediment particles.

Substances dissolved in surface waters can also partition out of the dissolved phase to a liquid phase or adsorb onto particles suspended in the water or onto bottom sediment. The latter process transfers the substances from the water to the sediment matrix. Conversely, chemicals may desorb from sediment back into the water.

Dispersion is a rapid process because of turbulent eddying (advection) and diffusion along concentration gradients. The amount of dilution can be approximated by comparing rates of chemical introduction to river flow discharge rates. In stagnant water bodies, such as marshes, advective forces are less important, and primary attenuation may be through diffusion.

6.2.3Biological Interactions

Other important processes that affect long-term chemical persistence include bioturbation of sediments and bioaccumulation. Sediment bioturbation will generally improve degradation rates of organic compounds through oxygenation of surface sediments. Although bioturbation can have an effect on the anaerobic dechlorination of PCBs, it has little impact on the degradation rates of inorganic metals.

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

Benthic infauna occur in the upper strata of sediment in the Lower Fox River and Green Bay. Sediment is mixed by these organisms throughout their life cycles. The depth of sediment that is susceptible to mixing by various infaunal organisms varies with the sediment grain size, density, sediment chemistry, bottom current velocity, and type of habitat available. Benthic insect larvae, ingest bulk sediment and strip detritus from the surface of the particles. PCBs (and other chlorinated compounds) partitioned to sediments may enter into the food web principally from uptake of sediment solids (Capel and Eisenrich, 1990). Various oligochaetes (worms) and chironomid larvae (insects) were observed to depths up to 2 feet in the Lower Fox River deposits (GAS/SAIC, 1996), suggesting that bioturbation in the system may occur in the upper 2 feet of the river and bay sediments.

6.3 Compounds of Potential Concern

The following summaries were largely derived from the Agency for Toxic Substances and Disease Registry (ATSDR) Toxicological Profiles for each compounds or group of compounds discussed.

6.3.1 Organic Constituents

6.3.1.1 PCBs

PCBs exhibit low water solubility, are moderately volatile, strongly adsorb to organics, and preferentially partition to soil and sediment. The major fate process for PCBs in water is adsorption to sediment or other organic matter. Consequently, PCB concentrations in sediment and suspended matter are generally higher than in the associated water column (ATSDR, 1997a). The more highly chlorinated Aroclors sorb more strongly than the less chlorinated Aroclors, reflecting their differences in water solubilities and octanol-water partition coefficients. Adsorption and subsequent sedimentation may immobilize PCBs for relatively long periods of time in aquatic systems. However, redissolution into the water column may occur. PCBs contained in layers nearest the sediment surface may be slowly released over a long period of time. PCBs present in the lower layers of sedimentary deposits may be effectively sequestered from environmental distribution (ATSDR, 1997a).

The estimated Henry's law constants for individual Aroclors indicate that volatilization may be a significant environmental transport process for PCBs dissolved in natural water. However, adsorption to sediment significantly decreases the volatilization rate of highly chlorinated Aroclors from the aquatic phase. The redissolution rate of PCBs from sediment to water is greater in the summer than in the winter because of more rapid volatilization from water at higher temperatures.

The ability of PCBs to bioaccumulate has been related to corresponding octanol-water partition coefficients (K_{ow}). Compounds with high K_{ow} values more readily bind to sediments (particularly sediments with elevated organic carbon) and are more readily bioaccumulated by organisms. Experimentally determined bioconcentration factors (BCFs) in freshwater aquatic animals range from 600 to 274,000 (ATSDR, 1997a). The BCFs in aquatic animals may depend on the water depth in which they predominantly feed. Certain benthic organisms accumulate PCBs from water at the water/sediment interface and via intake of phytoplankton and zooplankton which contain higher levels of PCBs than the surrounding water (ATSDR, 1997a). In addition, the bioconcentration of PCBs in bottom-feeding species is also expected to be high because the PCB concentrations in sediment are several orders of magnitude higher than those in water.

PCBs also biomagnify within the food chain, as indicated by the PCB concentrations in higher trophic levels of aquatic organisms and in several species of piscivorous birds and seals (ATSDR, 1997a). The biotransfer factors of Aroclor 1254 were estimated to be 0.052 and 0.011 kg/day, "respectively, while the estimated mean BCF value for PCBs in human fat was 128 (ATSDR, 1997a). The BCF value is the PCB concentration in tissue over the PCB concentration in the diet."

The ability of PCBs to be degraded or transformed in the environment depends on the degree of chlorination of the biphenyl molecule in addition to the isomeric substitution pattern (ATSDR, 1997a). Aroclor 1242 appears to be persistent in this aquatic environment, given that it was the PCB mixture used by the PRPs in the production/recycling of carbonless copy paper and due to the detected concentrations and predominance of this mixture in both river and bay sediments.

Analysis of the movement of PCBs in the Lower Fox River was evaluated in several investigations. Studies indicate that suspended solids are the most important factor in the transport and fate of PCBs (Gailani, 1991; Velleux and Endicott, 1994; WDNR, 1995; and Velleux, *et al.,* 1995). WDNR (1995) found a strong correlation and dependency between total PCB (dissolved and particulate) and suspended solids concentrations in the water column. This PCB-suspended solids correlation was not observed at the upstream boundary where PCB concentrations leaving Lake Winnebago were low, ranging from 1 to 3 ng/L.

6.3.1.2 Dioxins and Furans

Chlorinated dioxins are a group of over 75 different compounds, and chlorinated dibenzofurans comprise over 135 compounds (ATSDR, 1989). These compounds have been found to be very persistent in the environment due to their low solubility in water and affinity for organic matter in sediments. The fate of 2,3,7,8-TCDD is not understood with certainty. According to some studies, surface water sediments are the ultimate environmental sink of airborne particulate 2,3,7,8-TCDD (ATSDR, 1997a).

2,3,7,8-TCDD is expected to be immobile in most soils. A rate of transport of 10 cm in 12 years has been observed with soils from Elgin Air Force Base. Leaching is possible, but very unlikely, in soils with a very low organic carbon content. Bacterial degradation of dioxins and furans is possible but it is a very slow process and is usually limited by the populations of organisms in the native material. However, both volatilization and photolysis will remove 2,3,7,8-TCDD from surface soils. Therefore, the half-life in surface soils may range from 1 to 3 years but for contaminants buried a few inches below the surface the half-life may be 10 to 12 years or more (ATSDR, 1989). In surface and groundwater, degradation of

2,3,7,8-TCDD is similar to that in soils, and volatilization and photolysis are again the two most significant processes (ATSDR, 1989).

Dioxins and furans have been found to highly bioconcentrated in aquatic organisms and wildlife. Experiments with fathead minnows (Pimephales promelas) have yielded a BCF of 7,900 to 9,300 on a wet weight basis. Similarly, studies completed on rainbow trout (Salmo gairdneri) have been extrapolated to yield a BCF of approximately 39,000 (ATSDR, 1989).

6.3.1.3 DDT

DDT, and its principal metabolites DDD and DDE, are organochlorine compounds that were used as insecticides until 1972, when their use in the United States was banned because of adverse toxicity to wildlife. These compounds may be transported from one medium to another by adsorption, bioaccumulation, dissolution, or volatilization. The major fate process for DDT in water is adsorption to sediment or other organic matter and the primary loss route is the transportation of the particulates to which the compound is bound (ATSDR, 1994). Studies have shown that in soils/sediments, DDT transformations have prolonged persistence. These compounds undergo extensive adsorption to soil particles, especially those with high TOC levels.

Photo-oxidation of DDT is known to occur on soil surfaces; however, it is not known to hydrolyze (ATSDR, 1994). Biodegradation may occur under both aerobic and anaerobic conditions by microorganisms including fungi, algae and mixed microbial populations. Under aerobic conditions DDT slowly converts to DDE whereas under anaerobic conditions it converts to DDD much more rapidly. However, the estimated DDT half-life ranges from 2 to more than 15 years (ATSDR, 1994; Stewart and Chisolm, 1971).

Studies have found that plants, fish, mammals, and birds, as well as phytoplankton and zooplankton in an aquatic environment, bioaccumulate DDT. DDT has a high potential to bioaccumulate and the BCF for rainbow trout has been estimated to be 12,000 while the estimated human BCF is above 1,650, primarily from the consumption of fish (ATSDR, 1994). A study completed in northern Canada found that biota living in the bottom of the sea had much higher levels of total DDT than biota living in the open sea (ATSDR, 1994). This is likely a result of DDT adsorption onto particulates which settled into bottom sediments. Additionally, the ring necked seal apparently biomagnified DDT, indicating that biomagnification is possible in other species as well (ATSDR, 1994). Others have also found DDT biomagnification from soil sediment to mosquito fish, and a study completed in Lake Michigan indicated that DDE biomagnified 28.7 times from phytoplankton to fish and 21 times from sediments to amphipods (ATSDR, 1994).

In sediments, DDE is the major metabolite formed (Montgomery, 2000). Both DDD and DDE are stable and biologically active, but DDE is non-insecticidal (Montgomery, 2000). DDT has a low solubility and preferentially binds to sediments. If consumed, DDT and metabolites are stored in fat and, as shown above, biomagnify up the food chain.

6.3.1.4 Dieldrin

Dieldrin is both a manufactured pesticide and a breakdown product of the pesticide aldrin. Therefore, the presence of dieldrin in the environment may result from either the application and use of dieldrin or aldrin. The use of both products has been banned in the United States since 1974. Therefore, the presence of dieldrin in river sediments is due to their continued persistence in the environment.

Dieldrin is extremely non-polar, has a low volatility, sorbs readily to sediment organic matter and has a high potential for bioaccumulation with a BCF of 4,670 (ATSDR, 1993a). Dieldrin is persistent in sediments and surface water with a half-life of 3 and 6 years, respectively (Howard, 1991). Direct photolysis of dieldrin can occur creating a half-life of about 2 months (ATSDR, 1993a). Dieldrin degradation is unaffected by aerobic or anaerobic conditions (Montgomery, 2000), but dieldrin can be biotransformed by soil microbes to a substance more toxic to insects. The persistence of dieldrin within soil and sediment is exemplified by a study in soil plots which had been treated with dieldrin for 15 years. The dieldrin concentrations were the same 4 years after treatment stopped (ATSDR, 1993a).

Volatilization is the principle route of loss from soil; however, the process is slow due to the low vapor pressure. Once in the atmosphere, dieldrin can travel great distances. Studies in the Northwest Territories of Canada have found mean concentrations of 0.75 ng/L in arctic snow. There were no known local sources.

Experimental evidence has shown that aldrin converts rapidly to dieldrin, which readily bioaccumulates and biomagnifies (ATSDR, 1993a). Radiolabeled aldrin was added to an ecosystem and was converted to dieldrin. Sampling results indicate that of the radiolabeled aldrin, approximately 96 percent of the total stored in fish, 92 percent of the total found in snails, and about 86 percent of the total found in algae was in the form of dieldrin (ATSDR, 1993a). Measured BCFs are approximately 2,700 in fish and 61,657 in snails. In rainbow trout, a biomagnification factor of 1.0 has been determined on a lipid weight basis and 2.3

for the wet weight. Additionally, biotransfer factors evaluated for beef and cow milk were estimated to be 0.008 and 0.011, respectively (ATSDR, 1993a). These results all indicate the strong affinity of dieldrin for organic matter and the increased likelihood of biomagnification to higher trophic levels of the food chain.

6.3.2Inorganic Constituents

The primary factor influencing the fate and transport of heavy metals is their speciation and adsorption capacity, which are affected by and change with the geochemistry of the environment. The transport of metals via surface water is affected by adsorption of metals to soil or other organic matter. The degree to which a metal will adsorb depends on the presence of competing ions, water chemistry, and metal speciation, which is, in turn affected by such factors as pH and reduction/oxidation (redox) potential. The interaction among these factors is complex.

In instances where metals are present in solution with other ions, competition for sorption sites on soil particles or on organic material may enhance the mobility of weakly sorbed metals such as cadmium. Adsorption of metals is also strongly influenced by pH, due in part to increased competition between protons (H+) and metal ions for the same binding sites. Furthermore, pH affects the speciation and solubility of metals through the formation of hydroxide complexes. Speciation of metals is also controlled by the redox potential of the environment, which determines the oxidation state of the metal. The fate and transport of individual metals of concern are discussed below.

6.3.2.1 Mercury

The transport and partitioning of mercury in surface waters and soil is influenced by the particular form of the compound. Volatile forms (e.g., metallic mercury and dimethylmercury) evaporate to the atmosphere, whereas solid forms partition to particulates or are transported in the water column, depending upon their solubility. However, the dominant process controlling the distribution of mercury compounds in the environment is the sorption of non-volatile forms to soil and sediment particulates. The sorption process is related to the organic matter content of the soil or sediment; the pH of the medium apparently does not affect the process. Inorganic mercury sorbed to particulate material forms stable complexes with organic compounds and is not readily desorbed or removed from sediment (ATSDR, 1997b). Consequently, freshwater and marine sediment are repositories for inorganic forms of mercury. Mobilization of sorbed mercury from particulates can occur through chemical or biological reduction to elemental mercury and bioconversion to volatile organic forms (ATSDR, 1997b).

Methylmercury produced from biotransformation processes is soluble and mobile, and quickly enters aquatic food chains. Methylmercury is not only the most biologically available form of mercury, it is also the most toxic. Mercury bioaccumulation and biomagnification have been demonstrated in the aquatic food chain by the elevated levels found in piscivorous fish compared with organisms lower on the food chain. Almost all mercury accumulated is in the methylated form, primarily as a result of the consumption of prey containing methylmercury. Methylmercury accumulates in carnivorous fish to levels of 10,000 to 100,000 times those found in ambient water (ATSDR, 1997b). Bioaccumulation of methylmercury in aquatic food chains is of interest because it is generally the most important source of nonoccupational human exposure to the compound (EPA, 1984). Mercury methylation in ecosystems depends on mercury loadings, microbial activity, nutrient content, pH, redox conditions, suspended sediment load, sedimentation rates, and other variables (ATSDR, 1997b). Conversion of inorganic mercury to methylmercury is favored by low pH and low dissolved organic carbon levels.

6.3.2.2 Lead

The primary sources of lead in the environment are anthropogenic emissions to the atmosphere. A significant fraction of lead carried by river water is in an undissolved form, consisting of colloidal particles or larger undissolved particles of metallic lead, lead carbonate, lead oxide, lead hydroxide, or other lead compounds incorporated in other components of surface particulate matter from runoff. Lead may occur either as sorbed ions or surface coatings on sediment particles, or it may be carried as a part of suspended living or nonliving organic matter in water. Lead in aquatic environments often precipitates out of solution by binding to carbonate or phosphate ions or it can be readily sorbed to either organic or inorganic components in sediments.

Factors affecting the degree of sorption include: the sediment type, pH, organic carbon content, cation exchange capacity, the form of the lead and other constituents in the sediment such as metal oxides, aluminum silicates, and carbonates. Sorption is high in sediments containing clay and lower in sediments containing a higher percentage of sand or sand and loam (ATSDR, 1993c). Lead can bioaccumulate but does not biomagnify.

Plants and animals may bioconcentrate lead. In general, the highest lead concentrations are found in organisms near lead mining, smelting, and refining facilities; storage battery recycling plants; areas affected by high automobile and truck traffic; sewage sludge and spoil disposal areas; sites where dredging has occurred; areas of heavy hunting (from spent shot); and in urban and industrialized areas. Lead is not biomagnified in aquatic or terrestrial food chains.

Older organisms tend to contain the greatest body burdens of lead. In aquatic organisms, lead concentrations are usually highest in benthic organisms and algae, and lowest in upper trophic level predators (e.g., carnivorous fish). High BCFs were determined in studies using oysters (6,600 for Crassostrea virginica), freshwater algae (92,000 for Selenastrum capricornitim), and rainbow trout (726 for Oncorhynchus mykiss), although most median BCF values for aquatic biota are significantly lower: 42 for fish, 536 for oysters, 500 for insects, 725 for algae, and 2,570 for mussels (ATSDR, 1993c). Lead is toxic to all aquatic biota, and organisms higher on the food chain may experience lead poisoning as a result of eating lead-contaminated food.

6.3.2.3 Arsenic

Most naturally occurring arsenic in the environment exists in soil or rock. This material may be transported by wind or water erosion of small particles. Arsenic can also leach from soil or rock into rainfall or snow melt (ATSDR, 1993b). However, because many arsenic compounds tend to absorb to soil or sediment, leaching usually results in transportation only over short distances (EPA, 1982; Welch, *et al.,* 1988).

Transport and partitioning of arsenic in water depend upon its chemical species, oxidation state, and on interactions with other materials present. Soluble forms may be carried long distances through rivers (ATSDR, 1993b). However, arsenic may be adsorbed from water onto sediment or soil, especially clays, iron oxides, aluminum hydroxides, manganese compounds, and organic material (Callahan, 1979; EPA, 1982; Welch, *et al.,* 1988). Sediment-bound arsenic may be released back into the water by chemical or biological interconversions of arsenic species. In an oxidized environment, arsenic is generally present as arsenate (As^{5+}), an immobilized form that will be ionically bound to soil. However, under reduced conditions, arsenate is transformed to arsenite (As^{3+}), which is water soluble and, therefore, more mobile.

Arsenic present in Lower Fox River sediment may be associated with agricultural chemicals such as pesticide and herbicides and with wood treatment facilities. Arsenic in this form is tightly bound and generally not as bioavailable as soil- or sediment-bound arsenic. Bioconcentration of arsenic occurs in aquatic organisms, primarily in algae and lower invertebrates. BCFs measured in freshwater invertebrates and fish for several arsenic compounds ranged from 0 to 17 (EPA, 1980) and biomagnification in the aquatic food chain does not appear to be significant (ATSDR, 1993b; EPA, 1982).

6.4 Lower Fox River/Green Bay Modeling

Computer models have been employed in the RI/FS/RA to assist in the evaluation PCB fate and transport, historically and into the future. These models also enable the evaluation of various remedial scenarios on future PCB distribution in various environmental media as well as the food web in the Lower Fox River and Green Bay. These models are briefly described below and additional information is included in the documentation report for each specific model.

6.4.1GBTOXe Model

The enhanced Green Bay toxics model (GBTOXe) was developed by HydroQual to simulate the fate and transport of PCBs in Green Bay for the RI/FS. GBTOXe is an enhanced version of an existing WASP4 based toxics model developed as part of the GBMBS by Bierman, *et al.* (1992) and updated by De Pinto, *et al.* (1993). Enhancements include a higher spatial resolution and linkage to a hydrodynamics model (GBHYDRO) and a sediment transport model (GBSED) of Green Bay. GBTOXe was calibrated against 1989-90 GLNPO PCB and carbon data. GBTOXe was used to run 100-year simulations of PCB fate and transport for several management scenarios, including no action.

GBTOXe is used to model total PCBs and three phases of carbon in the water column and sediments. The carbon phases considered are dissolved, biotic, and particulate detritus. The model domain consists of 1490 water column and 596 sediment segments. The water column consists of 10 layers of 149 horizontal segments. Segment volumes vary to maintain a water balance. The layers represent biologically active sediments, and deeper biologically inactive sediments. The volume of the segments in the upper 10cm of the sediment are assumed to be constant in time, while the fourth sediment layer changes in volume in response to deposition and resuspension. PCB transport mechanisms include advection, dispersion, volatilization, deposition and resuspension of sorbed phase, and pore water exchange. GBTOXe accounts for sediment bed armoring.

The GBTOXe results are published as a separate document which supplements this RI/FS/RA.

6.4.2GBFood Model

The GBFood bioaccumulation model is a mathematical description of contaminant transfer within the food web of Green Bay zones 2 through 4. The food web is comprised of the primary energy transfer pathways from the exposure sources (sediment and water) to the fish species of interest, described in Section 4.4. These pathways include: chemical uptake across the gill surface, chemical uptake from food and chemical losses due to excretion and growth dilution. The mathematical descriptions are generic (common to all aquatic food webs) and were updated as part of the FS.

GBFood was used in the RI/FS to estimate PCB concentrations in the food webs leading to brown trout and walleye in the Lower Fox River (from the dam at De Pere to the mouth) and Green Bay. This was accomplished by specifying values for the various physiological, bioenergetic and toxicokinetic parameters in the model and the PCB exposure levels in sediments and water. The parameter values were derived from peer reviewed studies published in the literature and/or site-specific data. The sediment and water column PCB concentrations were provided by the whole Lower Fox River Model (wLFRM) and GBTOXe model outputs. The calibrated GBFood was used to evaluate the efficacy of several remedial alternatives in reducing PCB levels in fish of the Lower Fox River and Green Bay.

The GBFood results are published as a separate document which supplements this RI/FS/RA.

6.4.3 Fox River Food (FRFood) Model

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

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

The primary objectives in using the FRFood model was to 1) estimate potential risk-based remedial clean-up levels called sediment quality thresholds (SQTs), and

2) project fish tissue concentrations that would be associated with a specific remedy. To facilitate the selection of a remedy that will result in a decrease in human and ecological risks, it is necessary to establish a link between levels of PCBs toxic to human and ecological receptors, and the principle source of those PCBs, the Lower Fox River and Green Bay sediment. The FRFood model defines this link.

6.4.4Whole Lower Fox River Model

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

The wLFRM is used to simulate the fate and transport of solids and PCBs in the water and sediments in the Fox River. The model area is divided into 40 water column segments, 165 surficial sediment segments, and 330 subsurface sediment segments. The model predicts the movement of solids and PCBs among these various model segments. In addition, the model simulates the concentration of organic carbon in the water column. Transport mechanisms in wLFRM include advection, dispersion, volatilization, deposition, and resuspension. Deposition is a function of particle size or density with different settling rates to represent sand, silt and clay-size particles. The settling rate for clay-size particles can also be used to simulate the settling of low-density organic matter. Resuspension is based on surface water velocity and the effect of sediment bed armoring over time.

The results from the wLFRM are used as input to other modeling efforts being conducted for the Fox River/Green Bay RIFS. The wLFRM results from reaches above the De Pere dam are used as input to the FRFood model. Results from below De Pere dam to the mouth of the river are used as input to the GBFood model. Finally, the predicted solids and PCB discharges at the mouth of the river are used as inputs to the GBTOXe model.

The wLFRM results are published as a separate document which supplements this RI/FS/RA.

6.5 Section 6 Tables

Tables for Section 6 follow this page, and include:

Table 6-1 Lower Fox River - Fate and Transport Chemical Factors

Table 6-1. Lower Fox River - Fate and Transport Chemical Factors

Chemical Name	Water Solubility (mg/L)	Vapor Pressure (mm Hg)	Henry's Law Constant (atm-m^3/mol)	Koc (ml/g)	Kow (ml/g)
Polychlorinated Biphenyls (PCBs)					
PCBs (General values)	3.10E-02	7.70E-05	1.07E-03	5.30E+05	1.10E+06
Aroclor 1016	4.20E-01	4.00E-04	2.90E-04	NA	2.40E+04
Aroclor 1221	1.50E+01	6.70E-03	3.50E-03	NA	1.23E+04
Aroclor 1232	1.45E+00	4.06E-03	NA	NA	1.58E+03
Aroclor 1242	2.40E-01	4.10E-04	5.60E-04	NA	1.29E+04
Aroclor 1248	5.40E-02	4.90E-04	3.50E-03	NA	5.62E+05
Aroclor 1254	1.20E-02	7.70E-05	2.70E-03	4.25E+04	1.07E+06
Aroclor 1260	2.70E-03	4.10E-05	7.10E-03	NA	1.38E+07
Dioxin					
2,3,7,8-TCDD	2.00E-04	1.70E-06	3.60E-03	3.30E+06	5.25E+06
Pesticides					
DDT	5.00E-03	5.50E-06	5.13E-04	2.43E+05	1.55E+06
Dieldrin	1.95E-01	1.78E-07	4.58E-07	1.70E+03	3.16E+03
SVOCs/PAHs					
Acenaphthylene	3.93E+00	2.90E-02	1.48E-03	2.50E+03	5.01E+03
Acenaphthene	3.42E+00	1.55E-03	9.20E-05	4.60E+03	1.00E+04
Anthracene	4.50E-02	1.95E-04	1.02E-03	1.40E+04	2.82E+04
Benzo(a)anthracene	5.70E-03	2.20E-08	1.16E-06	1.38E+06	3.98E+05
Benzo(a)pyrene	1.20E-03	5.60E-09	1.55E-06	5.50E+06	1.15E+06
Benzo (b)fluoranthene	1.40E-02	5.00E-07	1.19E-05	5.50E+05	1.15E+06
Benzo(ghi)perylene	7.00E-04	1.03-E-10	5.34E-08	1.60E+06	3.24E+06
Benzo(k)fluoranthene	4.30E-03	5.10E-07	3.94E-05	5.50E+05	1.15E+06
Chrysene	1.80E-03	6.30E-09	1.05E-06	2.00E+05	4.07E+05
Dibenz(a,h)anthracene	5.00E-04	1.00E-10	7.33E-08	3.30E+06	6.31E+06
Fluoranthene	2.06E-01	5.00E-06	6.46E-06	3.80E+04	7.94E+04
Fluorene	1.69E+00	7.10E-04	6.42E-05	7.30E+03	1.58E+04
Indeno(1,2,3-cd)pyrene	5.30E-04	1.00E-10	6.86E-08	1.60E+06	3.16E+06
2-Methylnapthalene	2.54E+01	NA	NA	8.50E+03	1.30E+04
Naphthalene	3.17E+01	2.30E-01	1.15E-03	1.30E+03	2.76E+03
Phenanthrene	1.00E+00	6.80E-04	1.59E-04	1.40E+04	2.88E+04
Pyrene	1.32E-01	2.50E-06	5.04E-06	3.80E+04	7.59E+04
Pentachlorophenol	1.40E+01	1.10E-04	2.75E-06	5.30E+04	1.00E+05
Bis(2-ethylhexyl) phthalate	2.85E-01	2.00E-07	3.61E-07	5.90E+03	9.50E+03
Inorganic Compounds					
Ammonia	5.30E+05	7.60E+03	3.21E-04	3.10E.00	1.00E+00
Arsenic and Compounds	NA	0.00E+00	NA	NA	NA
Barium and Compounds	NA	NA	NA	NA	NA
Cadmium and Compounds	NA	0.00E+00	NA	NA	NA
Chromium III and Compounds	NA	0.00E+00	NA	NA	NA
Chromium VI and Compounds	NA	0.00E+00	NA	NA	NA
Copper and Compounds	NA	0.00E+00	NA	NA	NA
Lead and Compounds	NA	0.00E+00	NA	NA	NA
Mercury and Compounds	3.00E-02	2.00E-03	1.10E-02	NA	NA
Nickel and Compounds	NA	0.00E+00	NA	NA	NA
Selenium and Compounds	NA	0.00E+00	NA	NA	NA
Silver and Compounds	NA	0.00E+00	NA	NA	NA
Zinc and Compounds	NA	0.00E+00	NA	NA	NA

Notes: 1) Values obtained from "Basics of Pump-and-Treat Ground-Water Remediation Technology" EPA document EPA-600/8-90/003 or from the specific ATSDR Toxicological Profile.
2) NA - Vaule not available.

7 Summary of Findings

7.1 Introduction

The RI study area includes the Lower Fox River, extending 63 km (39 mi) from the outlet of Lake Winnebago to its mouth, as well as Green Bay, from the city of Green Bay and extending 190 km (119 mi), to Michigan's Big and Little Bay de Nocs. Both the Lower Fox River, and to a lesser extent, Green Bay were historically used as general discharge points for municipal, industrial, and agricultural entities located within the watershed. Many of the historical discharge practices occurred with minimal treatment of wastes during an era of little environmental regulation and without an adequate understanding of the fate and effects the chemicals posed to the environment. As a result, numerous compounds have been detected in the sediments and water of the Lower Fox River and Green Bay, as well as in the aquatic and wildlife species living in or frequenting the system.

The data evaluated in this RI report include selected sediment and water sample analytical results collected between 1989 and 1999 along the entire 63 km (39 mi) stretch of the river as well as all of Green Bay. Sediment samples were analyzed for over 200 different chemical parameters. In addition, biological sampling data has been collected since the 1970s. Data that was used in preparing the RI report was derived from the FRDB. The FRDB was developed following quality assurance review and acceptance of data gathered during previous investigations (EcoChem, 2000). Further, the conclusions of an EPA authorized peer review included the following:

- The quantity and quality of data are good enough to support the need for cleanup action
- The data are adequate to determine the distribution of contaminants within the system and direct where cleanup actions should focus
- The data are adequate to support identification and selection of possible remedy technologies (Weston, 1999)

The FRDB was used in this RI to evaluate the distribution of select compounds in the sediment and water of both the Lower Fox River and Green Bay. Information pertaining to the distribution of chemical compounds within fish and wildlife evaluated along the Lower Fox River and Green Bay, as well as other potential risks to human health and the environment, are addressed in the SLRA (RETEC, 1998c) and the RA (RETEC, 2002), performed in conjunction with this RI.

Compounds of potential concern, representing potential risks to human and ecological health, were identified in the SLRA (RETEC, 1998c) based on conservative risk screening procedures. These compounds include the chlorinated organic compound (PCBs and dioxins/furans), the chlorinated pesticides (DDT and dieldrin), and the inorganic compounds (mercury, lead, and arsenic). Of the substances evaluated in the SLRA, PCBs are the primary compounds of concern within the Lower Fox River and Green Bay.

Between the mid 1950s and the early 1970s, PCBs were used and released to the environment through carbonless copy paper production and recycling by a number of facilities along the Lower Fox River. During this time period, PCB use was unregulated. The WDNR estimated that between about 1954 and the early 1970s the cumulative mass of PCBs discharged into the Lower Fox River was about 313,600 kg (691,370 pounds), with a possible range between 126,450 and 399,450 kg (278,775 and 880,640 pounds) (WDNR, 1999a). According to WDNR estimates, approximately 98 percent of the total PCBs were released by the end of 1971. Five point sources are estimated to have contributed over 99 percent of the PCBs detected in the river sediments (WDNR, 1999a).

Point source discharges of the compounds of potential concern (COPC) have decreased significantly since the Clean Water Act and other environmental regulations were implemented in the early 1970s. As a result, additional input of PCB into the Lower Fox River from regulated discharges has now been essentially eliminated (WDNR, 1999a). However, residual sources for PCBs and other detected compounds remain in river and bay sediments, which continue to affect water quality, fish, wildlife, and potentially humans. The RA (RETEC, 2002) identified total PCB concentrations in sediments above 250 μg/kg as a potential concern for at least 50 percent of all potential receptors. Some of the documented adverse effects associated with PCBs include altered benthic community structure and reproductive impairments in fish-eating birds (WDNR, 1996; Matteson, 1998). The WDNR issued consumption advisories for fish in both the river and the bay as early as 1976, and waterfowl advisories were issued in 1987 due to continuing elevated levels of PCBs in tissue samples. The MDNR issued a fish consumption advisory for Green Bay fish in 1977.

7.2 Physical and Ecological Characteristics

The average annual discharge rate from the Lower Fox River into Green Bay is approximately 122 m^3/s (4,300 cfs). The locations of sediment deposits are related to flow characteristics along the river channel and typically occur where water velocities decrease, such as behind dams or where the river widens. The most significant sediment accumulation in the Lower Fox River occurs downstream of the De Pere dam, partially due to the water level and seiche effect of Green Bay where streamflow direction frequently reverses in this reach.

Water currents within Green Bay are more complex than the Lower Fox River and are affected by wind speed and direction, river discharge, thermal gradients, and ice cover. These currents generally move counter-clockwise and water from the Lower Fox River moves north along the east side of the bay while water from Lake Michigan moves south along the west side. These currents also control the distribution of sediments discharged from the Lower Fox River into Green Bay. Because the mouth of the Lower Fox River is located at the southern end of Green Bay, most of the river discharge, associated sediment load, and PCBs are directed along the east shore of Green Bay.

The bay bathymetry is also influenced by water currents and, in turn, affects the distribution of sediments. Regionally, bedrock dips to the east and river tributaries to Green Bay are more prevalent along the west side of the bay. Based on current patterns, a number of spits and shallows have formed near these tributaries mouths. These spits and shallows direct the currents towards the center of the bay, thereby establishing areas within the bay where lower velocity circular currents occur. Both Long Tail Point and Little Tail Point extend at least 3.4 km (2.1 mi) into the bay. Significant sediment accumulations occur between the mouth of the Lower Fox River and a line between Long Tail Point (on the west) and Point Au Sable (on the east). Bathymetry measurements are typically less than 3.7 m (12 ft) within this area. Moving north from the mouth of the Lower Fox River, the water depth in the bay increases and the influence of the spits and shallow areas on current movement decreases.

The southern end of Green Bay is a lacustrine estuary with hypereutrophic conditions. Water quality on the south end of the bay reflects the influence of runoff and the sediment load from the Lower Fox River and other tributaries. The hypereutrophic conditions of the southern bay support a large and diverse population of fish species due to the availability of nutrients. Due to the shallow water depths, this portion of the bay warms rapidly during summer months, supporting extensive biological activity. Historically, fish dies-offs occurred during periods of extremely warm water or extended ice cover because of reduced dissolved oxygen levels from biological and chemical processes. No significant die-offs have been recorded since the 1960s or early 1970s (Lychwick, 2000c).

Water quality conditions in the northern part of the bay, especially near the passage connecting with Lake Michigan are generally oligotrophic, except in the northern portion of Big Bay de Noc or near the tributary mouths on the west side where mesotrophic or eutrophic conditions may exist.

Significant habitat areas present within the river and bay include wetlands and associated submerged SAV. Wetlands offer nesting, feeding, and refuge opportunities for birds and terrestrial animals of the region. The SAV typically associated with wetlands provide spawning, feeding and refuge habitat for a variety of forage and game fish in the river and bay. Wading birds, shorebirds, and waterfowl feed on the SAV or fish that frequent these areas, as well as nesting in these areas. Wetland habitat are preferred by mink, although these animals will also live and feed in grassland and agricultural areas, if necessary.

In addition to wetland/SAV habitat, islands offer nesting and feeding opportunities to birds and terrestrial animals, while cuts/coves offer quiet water areas where fish will congregate, birds will feed, and terrestrial animals will seek refuge or food. Eagles, double-crested cormorants, gulls/terns, and numerous other birds nest in the vicinity of the river and bay and these birds feed on the fish of the system.

Exposure of biota to PCB-impacted sediments fosters uptake of PCBs into the food chain. Therefore, the presence of PCB impacted sediments in locations near wetlands/SAV, islands, quiet water cuts/coves, and other habitat areas within or along the shores of the Lower Fox River and Green Bay are of concern and described in this report.

7.3 Nature and Extent of Sediment Impacts

7.3.1 Overview

Sediment and water samples collected from Lake Winnebago reflect relatively low background concentrations of most constituent groups compared with those observed in Lower Fox River. The sources of PCBs, and most other COPC, are located downstream of Lake Winnebago. Water samples collected from both the river and bay indicate that PCBs and the other chemical compounds are continuing to migrate through the system as particulates absorbed to river/bay sediments and in a dissolved phase.

Below Lake Winnebago and upstream of the De Pere dam, PCB impacted sediments have accumulated in specific deposit areas that reflect the dynamics of the river hydrology. Downstream of the De Pere dam and out into Green Bay, sediments and PCBs have accumulated over large continuous areas. The highest total PCB concentrations in sediments within the Lower Fox River are typically found in the vicinity of historical point source discharges, including deposits in LLBdM and SMUs 56/57. Although a number of PCB discharge points were located in LLBdM, sediment transport has since dispersed the PCBs throughout the river and over large areas downstream of the De Pere dam, especially within the bay.

Approximately 96,800 kg of PCBs are distributed in sediments with PCB concentrations greater than 50 ug/kg. This PCB mass is contained in about 474 million m^3 of sediment. 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	**96,779 kg**	**474.16 million m^3**

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

Because PCBs are no longer discharged, more recent sediment loading into the river is gradually mixing with and accumulating over PCB impacted deposits. The vertical distribution of PCB concentrations within river and bay sediments frequently increase with depth. As noted previously, the river stage and discharge rate significantly affect resuspension, mixing, transport, and redeposition of impacted sediments in the system.

PCB concentrations in surface sediments in the Lower Fox River and Green Bay are generally decreasing over time, but apparent detectable loss is limited to the top 4 inches of sediment. 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. Just below the top 4 inches, there is no distinguishable change in the sediment PCB concentrations constant. 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 and carp in Green Bay Zone 1, where steep significant increases in PCB concentrations were observed.

7.3.2Lower Fox River PCB Impacts

7.3.2.1 Overview

Large volumes of soft sediment have accumulated at a number of locations throughout the Lower Fox River. Upstream of the De Pere dam there are 35 previously identified sediment deposits, exhibiting total PCB concentrations greater than 50 μg/kg. As indicated above, these deposits comprise approximately 2.7 percent of the total PCB mass in the system. A large majority of the PCBs in the upper three reaches of the river occur within several specific sediment deposits. Approximately 1,932 kg (4,260 pounds) of PCBs (74 percent of the total PCB mass upstream of the De Pere dam) is contained within sediment deposits A, B, POG, and EE/FF/GG/HH. The mass of PCB associated with Deposit N is not included in these estimates due to completion of the SRD project.

In the De Pere to Green Bay Reach there is one large, continuous sediment deposit between the dam and just downstream of the Fort James turning basin. Small sediment deposits are located downstream of the turning basin due to navigation channel dredging activities. Approximately 27 percent of the total estimated PCB mass in the river/bay system is located in this reach. Further, the estimated 25,984 kg (57,285 pounds) of PCB in this reach represents almost 91 percent of the total mass in the river.

The following summarizes the magnitude and extent of impacted sediments and PCBs for each reach of the river.

7.3.2.2 Little Lake Butte des Morts 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 yd^3) of sediment with concentrations greater than 50 μg/kg PCB. RI findings for this reach include the following:

- These deposits cover about 314 hectares (775 acres) and the deposits range up to approximately 1.9 m (6.2 ft) thick.

- The highest total PCB concentration was 222,722 μg/kg.

- Upstream deposits A, B, and POG have the highest PCB mass to 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 yd^3) of sediment. Also, about 910 kg (2,000 pounds) of the PCBs in these three deposits is present in the upper 100 cm (3.28 ft) of sediment.

- Deposit E contains about 454 kg (1,000 pounds) of PCBs. However, the mass to sediment volume ratios for this deposit is much lower than deposits A, B, and POG.

Habitat associated with this reach include Stroebe Island, located on the northeast side of Deposit E. The wetlands located between Stroebe Island and the river bank are the largest in-river wetlands in this reach. Also, an eagle nest has been observed in this area. Smaller wetland areas are located in the vicinity of deposits A, C, and POG and SAV are present in the shallow waters nearby, including near Deposit B. Two large areas of cuts/coves are present on the west side of Deposit C and just south of Deposit POG. Most of the shoreline in the LLBdM Reach is characterized as either poor or unsuitable for mink.

7.3.2.3 Appleton to Little Rapids Reach

Sediment accumulation in the Appleton to Little Rapids Reach is more localized compared with the other three reaches. Deposits I through DD contain about 94 kg (207 pounds) of PCBs in about 184,790 m^3 (241,700 yd^3) of sediment with concentrations greater than 50 μg/kg PCB. RI findings for this reach include the following:

- Deposits I through DD cover approximately 153 hectares (378 acres) and these deposits 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.).

- The highest total PCB concentration was 77,444 μg/kg.

- Only deposits W, X, and DD have a volume exceeding 30,000 m^3 (39,240 yd^3) 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 yd^3) and sediments range up to approximately 100 cm (3.28 ft) thick.

- Deposits T and DD contain a combined mass of about 45 kg (100 pounds) of PCBs, and these PCBs are located at depths less than 100 cm (3.28 ft).

- Approximately 32 kg (71 pounds) of PCBs remain in deposits N and O following completion of the SRD project and no future attempt to remove this mass is currently under consideration.

The Thousand-Islands Nature Conservancy, located near the city of Kaukauna and just upstream of deposits W and X, is an important habitat area in this reach. The nature conservancy is protected island habitat in which eagles nest and other birds and terrestrial animals nest and feed. The wetland and SAV habitat associated with the shores of the conservancy are the largest in the reach. Additional wetlands and SAV areas are located near the Little Rapids dam, which is in the vicinity of Deposit DD. Mink habitat in this reach varies. Between Appleton and Kaukauna the mink habitat is generally characterized as either poor or unsuitable. However, between Kaukauna and Little Rapids, the shoreline habitat is characterized as moderate to good.

7.3.2.4 Little Rapids to De Pere Reach

Sediment accumulation in this reach extends over a long distance and large area. Deposits EE through HH contain 980 kg (2,160 pounds) of PCBs in approximately 1.71 million m^3 (2.24 million yd^3) of sediment with concentrations greater than 50 μg/kg PCB. The four deposits in this reach are essentially a single sediment unit. RI findings for this reach include the following:

- These sediments cover about 266 hectares (657 acres) and are up to 2.3 m (7.5 ft) thick in select areas, especially near the De Pere dam.

- The highest total PCB concentration was 54,000 μg/kg. Further, PCB concentrations are lowest at the upstream end of Deposit EE and increase near the De Pere dam.
- Almost all of the PCB are contained in the upper 100 cm (3.28 ft) of sediments.

No significant wetland or SAV areas are located in this reach. However, this reach is generally less developed than the other three reaches and large expanses of the shoreline are characterized as marginal to good for mink habitat.

7.3.2.5 De Pere to Green Bay Reach

This reach exhibits the largest volume and areal extent of impacted sediments found in the Lower Fox River. 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 yd^3) of sediments with concentrations greater than 50 μg/kg PCB. RI findings for this reach include the following:

- Sediments cover about 524 hectares (1,295 acres) and range in thickness up to 4 m (13 ft).

- The highest total PCB concentration was 710,000 μg/kg.

- The mass of PCB decreases 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, are located in the upper 100 cm (3.28 ft) of sediments in this reach. Approximately 10,600 kg (23,370 pounds) of PCBs (36 percent of the PCBs in the river) are buried below 100 cm (3.28 ft).

- Approximately 636 kg (1,400 pounds) of PCB and 31,000 m^3 (40,550 yd^3) of sediment were removed from SMUs 56-61 during the SMU 56/57 SRD project. Further, removal of additional sediment and PCB 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, 68-73, and 80-85) contain almost 11,000 kg (24,250 pounds) of PCB, 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.

Both banks of the river in this reach are extensively developed. Therefore, significant habitat locations within this reach are largely confined to submerged wetland areas associated with the mouth of the river. Only 16 hectares (40 acres) of wetlands and SAV were identified in this reach. Additionally, two large areas of cuts/coves are located in SMUs 20-25, just downstream of the De Pere dam, and in SMUs 44-49. These are both areas with elevated PCB concentrations in surface sediments. Mink habitat in this reach is generally characterized as unsuitable.

7.3.3Green Bay PCB Impacts

7.3.3.1 Overview

The PCB mass and impacted sediment volume in Green Bay are much larger than in the Lower Fox River. Considering sediments with concentrations greater than 50 μg/kg PCB, the estimated mass in Green Bay exceeds 68,180 kg (150,310 pounds) and the volume exceeds 465 million m^3 (608 million yd^3). This represents almost 71 percent of the PCB mass and over 98 percent of the contaminated sediment volume in the system.

Estimates of the PCB load transported from the Lower Fox River into Green Bay were completed using data from 1994/95 and 1998. Approximately 220 kg (485 pounds) of PCBs were transported from the river into the bay during 1994/95. Based on water samples collected during 1998, this load decreased to about 125 kg (275 pounds). The PCB load from the river into the bay is affected by the seasonal and yearly changes in stream flow as well as the declining finite source of PCBs located within the river.

Total PCB concentrations in sediment are highest, and the mass/volume ratios greatest, near the mouth of the Lower Fox River and decrease with distance. The presence and distribution of PCBs within Green Bay reflect the influence of discharge from the Lower Fox River as well as the predominantly counter-clockwise current patterns in Green Bay. Sediments with the highest PCB concentrations are located in the immediate vicinity of the river mouth or along the east shore of the bay.

7.3.3.2 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 yd^3) of sediment. 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. RI findings for this zone include the following:

- Sediments in Zone 2A cover about 5,930 hectares (14,650 acres) and have an average thickness of about 0.34 m (1.1 ft). In Zone 2B the sediments cover about 5,150 hectares (12,725 acres) and have an average thickness of about 0.38 m (1.25 ft).

- The highest total PCB concentration was 17,000 μg/kg.

- Considering only sediments with PCB concentrations greater than 1,000 μg/kg reduces the mass and volume estimates to 28,100 kg (61,950 pounds) and 17.8 million m^3 (23.3 million yd^3), respectively. This represents slightly more than 29 percent of the PCBs in the system but less than 5 percent of the total estimated contaminated sediment volume.

- Considering only the upper 30 cm (1 ft) of sediments, approximately 14,5000 kg (31,900 pounds) of PCBs are contained within about 29.8 million m^3 (39 million yd^3) of sediment. This represents about 15 percent of the total PCB mass and 6 percent of the contaminated sediment volume in the system.

The most significant habitat types within Green Bay are wetlands and islands. A number of wetland areas are located within Zone 2. The Point Au Sable and Whitney Slough wetland areas are located along the east shore of Green Bay (Zone 2B). Atkinson Marsh, Long Tail Point, Dead Horse Bay, and portions of the Little Tail Point wetland areas are all located along the west shore of the bay (Zone 2A).

Fish spawn and feed throughout Zone 2 due to the shallow water depths and abundant nutrients available in this hypereutrophic environment. Although sediment impacts are greater in Zone 2B than in Zone 2A, the discharge of the Lower Fox River and the seiche effect both contribute to the dispersal of PCB-impacted sediments throughout this entire zone.

In addition to the wetland areas, both Bay Port and Kidney Island CDFs are located in this zone. Both CDFs have received PCB impacted sediments removed during navigation channel dredging activities and gulls/terns nest on Kidney Island while waterfowl and other birds nest and feed in the vicinity of Bay Port. Mink habitat associated with the two CDFs are generally marginal. Mink habitat in Zone 2B is generally poor to unsuitable, although moderate to good habitat is present with increasing distance from the mouth of the Lower Fox River. Zone 2A mink habitat is generally marginal or better north of the mouth of Duck Creek.

7.3.3.3 Green Bay Zone 3

This zone contains approximately 35,240 kg (77,700 pounds) of PCBs in approximately 397 million m^3 (519 million yd^3) of sediment. 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. RI findings for this zone include the following:

- Sediments in Zone 3A cover about 85,890 hectares (212,240 acres) and have an average thickness of just 0.21 m (0.7 ft). In Zone 3B, the sediments cover about 69,340 hectares (171,340 acres) and have an average thickness of about 0.31 m (1 ft).

- The highest total PCB concentration was 1,320 μg/kg.

- Considering only sediments with concentrations greater than 1,000 μg/kg PCB reduces the mass and volume estimates to 1.65 kg (3.64 pounds) and 8,800 m^3 (11,510 yd^3), respectively. This zone represents very small percentages of the estimated total PCB mass and contaminated sediment volume in the system.

- Considering only the upper 30 cm (1 ft) of sediments, approximately 30,000 kg (66,000 pounds) of PCBs are contained within about 355.9 million m^3 (465.5 million yd^3) of sediment. However, a large majority of this mass is located in sediments which have less than 1,000 μg/kg PCBs.

Similar to Zone 2, wetlands and islands are the main habitat located along or within the bay. Extensive wetland areas are located along the west shore of Green Bay and fish spawn and feed throughout this area. However, sediments with the highest PCB concentrations in Zone 3 are located along the east shore of Green Bay. Only two large wetland areas, the Little Sturgeon Bay and Sand Bay wetlands, are located along the east shore. Also, on the east side of the bay, fish spawn and feed within a very narrow band of shallow water located near the shore as well as in the vicinity of Little Sturgeon Bay and the islands located in this area. In addition to the wetlands, a number of small islands are located along the east shore of Green Bay, extending from Little Sturgeon Bay to the tip of the Door Peninsula. These islands offer secure nesting locations for numerous types of birds.

Mink habitat was only characterized only as far north as the city of Marinette on the west side of the bay and just north of the city of Sturgeon Bay on the east side. The Zone 3 shoreline is generally characterized as marginal to good, except in areas where development has occurred, such as the cities of Dyckesville and Sturgeon Bay.

7.3.3.4 Green Bay Zone 4

Based on the estimates of the PCB mass and sediment volume, Zone 4 is relatively unaffected compared to zones 2 and 3. Zone 4 contains less than 925 kg (2,040 pounds) of PCBs, or only about one percent of the total mass in the system. Total PCB concentrations in sediment within Zone 4 are all less than 500 μg/kg except for one sample which had a concentration of 751 μg/kg.

Habitat present in this zone includes wetlands, SAV, islands, and other areas which support fish, birds, and wildlife. Based on the small mass of PCBs and the low concentrations (compared with the other river reaches and bay zones), habitat within this zone is relatively unimpacted.

7.3.4Other Chemical Compounds

Elevated concentrations of the other six COPCs are typically widespread in river and bay sediments with little or no spatial relation to specific discharge sources.

The distribution of these chemicals reflects the dynamic nature of the river and bay environments, the effect of downstream transport of sediments in the system, and/or non-point pollution sources.

The RI findings with respect to other chemical parameters in sediments include the following:

- Mercury was used in a number of pulp and paper production activities to reduce organic slime (Konrad, 1971). 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.

- Except for PCB and mercury, no specific existing or historical discharge sources were identified for the other COPCs.

- 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/F detected in sediments ranged from 0.23 to 170 ng/kg (ppt). The SLRA identified furan concentrations above 2,000 ng/kg as a potential concern.

- Sixteen chlorinated pesticides, which are 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 run-off 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 were detected in more than four sediment samples. These included DDT, and its derivatives DDD and DDE, endrin aldehyde, endrin ketone, gamma-BHC (lindane), and heptachlor. Distribution of these compounds was generally sporadic. Only DDT and dieldrin were identified by the SLRA as being COPCs. 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 LLBdM, 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. However, a disproportionately large number of samples for these two compounds were collected in the De Pere to Green Bay Reach. The SLRA identified lead concentrations above 47 mg/kg as a potential concern. While some deposits exhibit 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 and background 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 either the Lake Winnebago background concentration or the SLRA level 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 from non-detectable to 60,000 μg/kg. A number of locations from LLBdM 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.

7.4 Chemical Transport and Fate

The organic COPCs, including PCBs, dioxin/furan, pesticides, and PAHs, exhibit strong affinities for organic material in the sediments. The suspension and transport of these 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 snow melt). The Lower Fox River has an average discharge of 122 m^3/s (4,300 cfs). Data from Water Years 1989-99 indicate that river discharge exceeds both 272 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 which moves over the De Pere dam and into Green Bay (Velleux and Endicott, 1994; WDNR, 1995).

Water samples collected during 1994/95, confirm these results as well as the estimate of the PCB mass transported into Green Bay. Particulate PCB concentrations suspended in the water column increase moving downstream. Also, downstream of LLBdM, the particulate PCB concentration is approximately three times greater than the dissolved PCB concentration. Particulate PCB concentrations are related to water temperatures and flow whereas the dissolved PCB concentrations are generally constant and never exceeded 33 μg/kg. Particulate PCB concentrations decline dramatically during the winter months, when water temperatures are below 4°C (40°F), and increase in response to high flow events during the summer. WDNR (1995) concluded that this seasonal variation is related to the amount of algae present in the water, which appear to facilitate suspension and transport of PCB in the water column. Similar results were found for mercury in samples collected at the mouth of the river.

The overall PCB flux through the Lower Fox River and Green Bay system is estimated to be as follows:

- Approximately 125 kg (275 pounds) to 220 kg (485 pounds) of PCB are annually transported from the Lower Fox River into Green Bay as part of the suspended sediment load. According to some estimates, this load may have ranged as high 550 kg (1,210 pounds) annually in the past.

- The estimated annual PCB load into Green Bay from tributaries other than the Lower Fox River is estimated to be approximately 10 kg (22 pounds).

- The estimated annual stormwater runoff from non-point sources into the Lower Fox River is estimated to be 1 kg (2.2 pounds).

- Estimates for annual atmospheric deposition of PCB into the Lower Fox River range from 3 kg (6.6 pounds) to 5 kg (11 pounds) while deposition into Green Bay ranges from 2 kg (4.4 pounds) to 35 kg (77 pounds).

- Estimates for annual volatilization of PCBs from surface waters into the atmosphere range up to 5 kg (11 pounds) for the Lower Fox River while volatilization from Green Bay ranges from 130 kg (287 pounds) to 500 kg (1,100 pounds).

- Approximately 122 kg (270 pounds) of PCB are transported annually from Green Bay into Lake Michigan.

At present, roughly 0.4 percent to 1 percent of the PCB mass within the river was discharged into the bay annually. Atmospheric contributions and losses of PCBs are minimal compared to the mass in the river and bay and the amount of PCB transported in dissolved or particulate phase.

7.5 Investigative Assumptions/Uncertainties

Due to the heterogeneity and dynamic nature of the river and bay sediments, various assumptions are necessary in evaluating and interpreting the data and results. These assumptions are discussed below:

- The data used in this RI includes results from numerous investigations performed over an extended period of time. Sediment data were collected over a 10 year period while tissue samples date from 1971. In sediments, temporal changes in the magnitude and extent of the compounds of concern will occur over this time period, particularly at the sediment/water interface. In general, however, sediment mobility decreases with depth and the occurrence and mass of the compounds of concern as described herein is not likely to have appreciably changed over the period of these investigations. Although surface sediment concentrations decrease over time, once sediments are buried, the PCBs tend to remain in place and increase concentrations with depth (The Mountain-Whisper-Light, 2001). The PCB mass exported from the river into Green Bay (estimated to be 1 percent or less annually) is far less than the amount that remains in place. Although shallower PCB sediment concentrations may vary more significantly over the short term, declining PCB concentrations in the sediment and water column on a large scale are a long-term phenomena. Temporal variability in PCB occurrence and mass is believed to be less significant than its spatial heterogeneity. Therefore, the Fox River Database considered all usable analytical results over the period of these investigations, subject to the specified acceptance criteria. In tissue samples, decreasing concentration trends have been observed but the rate of decrease has slowed significantly since the 1980s. Also, some fish species show stable or increasing tissue concentration trends. Therefore, the analyses completed as part of this effort are not suitable for predicting future trends.

- The density of sediment sampling points in the river and bay affects the accuracy of the interpolated distribution of PCBs and the general distribution of the other COPCs described in this report. Some sediment locations (deposits/SMUs/zones) have been sampled extensively while others have been characterized by relatively few samples. However, it is believed that sufficient sampling has been conducted to characterize the compounds present and areas of the Lower Fox River and Green Bay of greatest concern.

- The precision and accuracy of laboratory analytical results for specific sediment samples can be affected by factors such as sampling methods, the representativeness of the sample at a specific location, matrix interferences and analytical protocols. Total PCBs were either analyzed and reported by the laboratory or were calculated from Aroclor or PCB congener results for a given sample. However, the analytical results in the FRDB are assumed to reasonably reflect sediment and water quality, based on the independent quality assurance review and acceptance criteria.

- Sediment bed properties (grain size, cohesion, water content, etc.) generally change more rapidly with depth than horizontally over a large area. It is possible that there is compaction of the sediments when sediment cores are collected. Sample core lengths and the corresponding analytical results have not been adjusted to correct for possible sediment compaction or the percentage of core length recovered, which may tend to underestimate PCB distribution and mass at depth.

Based on the data contained within the FRDB, sufficient sampling and analysis has been conducted to characterize the magnitude and distribution of COPCs in the Lower Fox River and Green Bay as well as allow development of the Baseline Risk Assessment and Feasibility Study.

8 References

Achman, D.R., K.C. Hornbuckle, and S.J. Eisenreich, 1993. "Volatilization of Polychlorinated Biphenyls from Green Bay, Lake Michigan." *Environ. Sci. Technol*. 27(1):75-87.

Ahrnsbrak, W.F., and R.A. Ragotzkie, 1970. "Mixing Processes in Green Bay." *Proceedings of the 13th Conference on Great Lakes Research*, Buffalo, New York, pp. 880-890.

Albert, D.A., 2000. Personal Communication to Anne Fitzpatrick, ThermoRetec, Seattle, Washington regarding the size of viable wetlands studied by Michigan Natural Features Inventory. January 25.

Ankley, G.T., G.J. Niemi, K.B. Lodge, H.J. Harris, D.L. Beaver, D.E. Tillit, T.R. Schwartz, J.P. Giesy, P.D. Jones, and C. Hagley, 1993. "Uptake of planar polychlorinated biphenyls and 2,3,7,8-substituted polychlorinated dibenzofurans and dibenzo-p-dioxins by birds nesting in the Lower Fox River and Green Bay, Wisconsin, USA." *Archives of Environmental Contamination and Toxicol*ogy. 24(3):332-344.

Assel, R.A., C.R. Snider, and R. Lawrence, 1984. *Great Lakes Winter Weather and Ice Conditions for 1982-83*. NOAA Technical Memorandum ERL GLERL-55. Great Lakes Environmental Research Laboratory, Ann Arbor, MI.

Assel, R.A., D.E. Boyce, B.H. DeWitt, J. Wartha, and F.A. Keyes, 1979. *Summary of Great Lakes Weather and Ice Conditions, Winter 1977-78*. NOAA Technical Memorandum ERL GLERL-26. Great Lakes Environmental Research Laboratory, Ann Arbor, MI.

ATSDR, 1989. *Toxicological Profile for 2,3,7,8-Tetrachlorodibenzo-p-dioxin*. US Department of Health and Human Services. 129 pp.

ATSDR, 1993a. *Toxicological Profile for Aldrin/Dieldrin (Update)*. US Department of Health and Human Services. 184 pp.

ATSDR, 1993b. *Toxicological Profile for Arsenic (Update)*. US Department of Health and Human Services. 175 pp.

ATSDR, 1993c. *Toxicological Profile for Lead (Update)*. US Department of Health and Human Services. 307 pp.

ATSDR, 1994. *Toxicological Profile for: 4,4-DDT, 4,4-DDE, 4,4-DDD (Update)*. US Department of Health and Human Services. 166 pp.

ATSDR, 1997a. *Toxicological Profile for Polychlorinated Biphenyls (Update)*. US Department of Health and Human Services. 427 pp.

ATSDR, 1997b. *Toxicological Profile for Mercury (Draft)*. US Department of Health and Human Services. 485 pp.

Attig, J.W., L. Clayton, and M.D. Johnson, *et al.,* 1988. “Pleistocene stratigraphic units of Wisconsin, 1984-87.” WGNHS. *Information Circular 62.*

Axness, K. A., et. al., 2002. *When the Well Runs Dry: Examining the Water Supply Issues in Brown County, Wisconsin*. WDNR Water Resources IMPACT.

Baumann. T., 2000. Personal communication from the Director of the Bay Beach Wildlife Sanctuary regarding Bay Beach Wildlife Sanctuary. March 7.

Batten, W. G., and Bradbury, K.R., 1996. *Regional groundwater flow system between Wolf and Fox Rivers near Green Bay, Wisconsin*: WGNHS Information Circular 75

BBL, 1993. *Remedial Investigation/Feasibility Study: Little Lake Butte Des Morts Sediment Deposit A*. P.H. Glatfelter Company, Spring Grove, Pennsylvania

BBL, 1998. Sediment, Tissue, and Water Sample Data Collected from the Lower Fox River and Green Bay on Behalf of the Fox River Group. Data contained in the FRDB and cited in the EcoChem Data Management Report, 2000.

Beck, D.R.M., 1995. “Return to Nama'o Uskiwamit: The Importance of Sturgeon in Menominee Indian History.” *Wisconsin Magazine of History*, Autumn 1995:32-48.

Becker, G.C., 1983. *Fishes of Wisconsin*. University of Wisconsin Press. Madison, Wisconsin.

Belonger, B., 2000. Personal communication from WDNR regarding the fish of west shores of Green Bay and the rate at which walleye and yellow perch fish reach maturity. January 13.

Bertrand, G., J. Lang, and J. Ross, 1976. *The Green Bay Watershed Past/Present/Future*. Institute for Environmental Studies. University of Wisconsin - Madison.

Bierman, V.J., J.V. De Pinto, T.C. Young, P.W. Rodgers, S.C. Martin, R. Raghunathan, S.C. Hintz, 1992. *Development and Validation of an Integrated Exposure Model for Toxic Chemicals in Green Bay, Lake Michigan.* Prepared for USEPA Large Lakes and Rivers Research Branch, Environmental Research Laboratory, Duluth, Michigan, September 1.

Blumberg, A., 2000. Personal Communication from HydroQual, Inc. to Anne Fitzpatrick, ThermoRetec, Seattle, Washington. Summary of August 1989 Green Bay Surface and Bottom Currents. August 2.

Bosley, T.R., 1976. *Green Bay's West Shore Coastal Wetlands -- A History of Change*. University of Wisconsin-Green Bay, Master of Science Thesis.

Bosley, T.R., 1978. "Loss of Wetlands on the West Shore of Green Bay." *Transactions of the Wisconsin Academy of Sciences, Arts, and Letters* (LXVI), Forest Stearns, ed., p. 235-245.

Bowerman, W.W., 1993. "Regulation of bald eagles (*Haliaeetus leucocephalus*) productivity in the Great Lakes Basin: An ecological and toxicological approach." *Philosophy.* Michigan Sate University.

Bradbury, K., 2002. Personal Communication from WGNHS regarding hydrogeology of Lower Fox River. May 17.

Brandt, S.B., J.J. Magnuson, and L.B. Crowder, 1980. "Thermal Habitat Partitioning by Fishes in Lake Michigan." *Canadian Journal of Fish. Aquat*. Sci. 37:1557-1564.

Brandt, S., D. Mason, *et al.*, 1987. "Predation by Alewives on Larvae of Yellow Perch in Lake Ontario." *Transactions of the American Fisheries Society* 116: 641-645.

Brazner, J.C., and J.J. Magnuson. 1994. "Patterns of Fish Species Richness and Abundance in Coastal Marshes and Other Nearshore Habitats in Green Bay, Lake Michigan." *Verh. Internat. Verein. Limnol*. 25:2098-2104.

Brazner, J. 1997. "Regional, Habitat, and Human Development Influences in Coastal Wetland and Beach Fish Assemblages in Green Bay, Lake Michigan." *Journal of Great Lakes Research* 23(1):36-51.

Brazner, J.C. and E.W. Beals, 1997. "Patterns in fish assemblages from coastal wetland and beach habitats in Green Bay, Lake Michigan: A multivariate analysis of abiotic and biotic forcing factors." *Canadian Journal of Fisheris and Aquatic Sciences.* 54:1743–1761.

Brown County Planning Commission, 1990. *The Fox River Corridor Land Use Map*.

Brown County Planning Department, 1999. Census Information. *Brown County website* at http://www.co.brown.wi.us/planning/census.html.

Burridge, G.N., 1997. *La Mystique du Renard: The Fox River and the Passage to the West*. Brown County Historical Society. Green Bay, Wisconsin. 39 pp.

Call, D.J., M.D. Balcer, L.T. Brooke, S.J. Lozano, and D.D. Vaishnav, 1991. *Sediment Quality Evaluation in the Lower Fox River and Southern Green Bay of Lake Michigan*. University of Wisconsin Center for Lake Superior Environmental Studies, Superior, WI.

Callahan, M.A., M.W. Slimak, N.W. Gabel, I.P. May, C.F. Fowler, J.R. Freed, P. Jennings, R.L. Durfee, F.C. Whitmore, B. Maestri, W.R. Mabey, B.R. Holt, C. Gould, 1979. *Water-Related Environmental Fate of 129 Priority Pollutants*. EPA-440/4-79-029a. United States Environmental Protection Agency, Washington, D.C.

Campbell, S., 1999. "Plan to restore Cat Island gets federal support." Newspaper article in the *Green Bay Press Gazette*. December 22,1999.

Capel, P., and S. Eisenreich. 1990. "Relationship between chlorinated hydrocarbons and organic carbon in sediment and porewater." *Journal of Great Lakes Research* 16(2):245-257.

Chroneer, Z., 1996. *Sediment and Contaminant Transport in Green Bay*. University of California Santa Barbara. Ph.D. Dissertation.

Cogswell, S., and D. Bougie, 1998. *Duck Creek Fisheries Assessment, Final Report*. Report 98-2, U.S. Fish and Wildlife Service, Green Bay Fishery Resources Office; Wisconsin Dept. of Natural Resources, Green Bay Area, October 30, 1998.

Conlon, T. D., 1998. *Hydrogeology and Simulation of Ground-water Flow in the Sandstone Aquifer, Northeastern Wisconsin*. USGS Water Resources Investigations Report 97-4096, Middleton, Wisconsin.

Conlon, T. D., 2002. Personal Communication from USGS regarding hydrogeology of Lower Fox River. May 17.

Custer, C., T. Custer, P. Allen, K. Stromberg, and M. Melancon, 1998. "Reproduction and environmental contamination in tree swallows nesting in the Fox River drainage and Green Bay, Wisconsin, USA." *Environmental Toxicology and Chemistry*. 17(9):1786-1798.

Cuthbert, F., 1998. Personal communication of Francine Cuthbert, University of Minnesota, with L. Mortensen, ThermoRetec, regarding tern populations. November.

Dale, T.B., and K.L. Stromberg, 1993. *Reconnaissance Surveys of Contaminants Potentially Affecting Green Bay and Gravel Island National Wildlife Refuges*. U.S. Fish and Wildlife Service, Green Bay Ecological Services Field Office, 1015 Challenger Court, Green Bay, WI 54311, December 1993.

De Pinto, J.V., V.J. Bierman, T.C. Young, 1993. *Recalibration of GBTOX: An Integrated Exposure Model for Toxic Chemicals in Green Bay, Lake Michigan.* Prepared for USEPA Large Lakes and Rivers Research Branch, Environmental Research Laboratory, Grosse Ile, Michigan. December 31.

DeVault, D.S., R. Hesselberg, P.W. Rodgers, T.J. Feist, 1996. "Contaminant trends in lake trout and walleye from the Laurentian Great Lakes." *Journal of Great Lakes Research*. 22(4):884-895.

De Vore, S., 1999. *Northern Flights: Tracking the Birds and Birders of Michigan's Upper Peninsula*. Mountain Press Publishing Company. Missoula, MT. 152 pp.

Dykstra, C.J.R. and M.W. Meyer, 1996. *Effects of Contaminants on Reproduction of Bald Eagles on Green Bay, Lake Michigan.* U. S. Fish and Wildlife Service and Wisconsin Dept. of Natural Resources. February.

Eadie, B.J., G.L. Bell, and N. Hawley, 1991. *Sediment Trap in the Green Bay Mass Balance Program: Mass and Organic Carbon Fluxes, Resuspension, and Particle Settling Velocities*. NOAA Technical Memorandum ERL GLERL-75. Great Lakes Environmental Research Laboratory, Ann Arbor, MI. 29 pp.

East Central Wisconsin Regional Planning Commission, 1996. *The Fox Cities Area Existing Land Use Map*.

EcoChem, 2000. *Data Management Summary Report: Fox River Remedial Investigation and Feasibility Study*.

EDR, 1995. *The EDR-Radius Map Reports: Fox River - De Pere, Neenah and Menasha, and Kimberly*. Included in GAS/SAIC, 1996.

EPA, 1980. *Ambient water quality criteria for arsenic*. Washington DC: Office of Water Regulations and Standards. EPA 440/5-80-021.

EPA, 1982. *An exposure and risk assessment for arsenic*. Washington DC: Office of Water Regulations and Standards. EPA Report 440/4-85-005.

EPA, 1983. *Hazardous Waste Land Treatment, SW-874*. Washington DC. Office of Solid Waste and Emergency Response. Page 273, Table 6.46.

EPA, 1984. *Mercury Health effects updates: Health issue assessment. Final Report*. Washington DC. Office of Health and Environmental Assessment. EPA-600-8-84-019F.

EPA, 1989. *Green Bay Mass Balance Study Plan: A Strategy for Tracking Toxics in the Bay of Green Bay, Lake Michigan*. US Environmental Protection Agency Great Lakes National Program Office. Chicago, Illinois. EPA-905/8-89/001.

EPA, 1993a. *Wildlife Exposure Handbook*. U.S. EPA Office of Health and Environmental Assessment, ORD. Washington, D.C.

EPA, 1993b. Updated version of the Region 8 CWA Section 304(a) criteria chart. United States Environmental Protection Agency.

EPA, 1994. *Estimating Exposure to Dioxin-Like Compounds, Volume II: Properties, Sources, Occurrence and Background Exposures.* Review Draft. EPA/600-6-88/005Cb. United States Environmental Protection Agency, Washington, D.C.

EPA, 1997. Lower Green Bay and Fox River Area of Concern. *EPA website* www.epa.gov/glnpo/aoc/greenbay.html.

EPA 2000a. Agreement of Consent. Summarized in the *Fox River Current*. http://www.epa.gov/region5/foxriver/current/july00/index.html.

EPA, 2000b. *Permit Compliance System Website* for Michigan NPDES Permittees. http://www.epa.gov/enviro/html/pcs/pcs_query_java.html

EPA, 2000c. *Hudson River PCBs Reassessment RI/FS Responsiveness Summary for Volume 2E - Baseline Ecological Risk Assessment*.

EPA, 2002. *Principles for managing contaminated sediment risks at hazardous waste sites.* United States Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER Directive 9285.6-08. Drafted October 22, 2001. Signed February 12, 2002.

Erdman, T, 1999a. Personal communication from Richter Museum Curator, UW-GB regarding Cat Island Chain, Green Bay wetlands, Bay Port and Kidney Island CDFs, and other miscellaneous bay information. December 14.

Erdman, T, 1999b. Personal communication from Richter Museum Curator, UW-GB regarding re-establishment of Cat Island Chain and use of bay sediments for this project. December 15.

EVS, 1998. *Sheboygan River and Harbor Aquatic Ecological Risk Assessment (Volume 1 of 3), Seattle, Washington.* Prepared by EVS Environmental Consultants and National Oceanic and Atmospheric Administration.

EWI Engineering Associates, Inc., 1991. *Dep A - Technical Memo:, Task 3: Sediment Transport LLBdM*. Project No. 15605.00.

Exponent, 1998. *Habitat Characterization for the Lower Fox River and Green Bay Assessment Area*. Prepared for the Fox River Group and the Wisconsin Department of Natural Resources. Landover, MD.

Fitzgerald, S.A. and J.J. Steuer, 1996. *The Fox River PCB Transport Study - Stepping Stone to a Healthy Great Lakes Ecosystem*. USGS Fact Sheet FS-116-96.

Fitzpatrick, W., 2000. Personal communication from WDNR regarding remedial dredging activities at Deposit N. February 22.

Foth & Van Dyke, 2000. *Summary Report, Fox River Deposit N*. Completed on behalf of the Wisconsin Department's of Administration and Natural Resources.

Fox River Remediation Advisory Team (FRRAT), 2000. *Evaluation of the Effectiveness of Remediation Dredging: The Fox River Deposit N Demonstration Project, November 1998 - January 1999*. Madison, Wisconsin, June 2000.

Flath, L.E. and J.S. Diana, 1985. "Seasonal energy dynamics of the alewife in southeastern Lake Michigan." *Transactions of the American Fisheries Society.* 114:328–337.

Gailani, J., C.K. Ziegler, and W. Lick, 1991. "The transport of suspended solids in the Lower Fox River." *Journal of Great Lakes Research*, 17:479-494, International Association of Great Lakes Research.

Gilbertson, M., 1988. "Epidemics in Birds and Mammals Caused by Chemicals in the Great Lakes." *Toxic Contaminants and Ecosystem Health; A Great Lakes Focus*. Pages 133-140. M.S. Evans ed., John Wiley & Sons, Inc.

Gobas, F.A.P.C., 1993. A model for predicting the bioaccumulation of hydrophobic organic chemicals in aquatic food-webs: Application to Lake Ontario. *Ecological Modeling.* 69:1-17. December 8.

Gobas, F.A.P.C., M.N.Z'Graggen, X. Zhang, 1995. "Time response of the Lake Ontario Ecosystem to virtual elimination of PCBs." *Environmental Science & Technology*. 29(8):2038-2046

Gottlieb, E.S., J.H. Saylor, and G.S. Miller, 1990. *Current and Water Temperatures Observed in Green Bay, Lake Michigan - Part I: Winter 1988/89 - Part II: Summer 1989.* NOAA Technical Memorandum ERL GLERL-73. Great Lakes Environmental Research Laboratory, Ann Arbor, MI.

Graef, Anhalt, Schloemer & Associates Inc. and Science Applications International Corporation (GAS and SAIC), 1996. *Remedial Investigation Report for Contaminated Sediment Deposits on the Fox River (Little Lake Butte des Morts to the De Pere dam)*. Wisconsin Department of Administration, Madison, Wisconsin.

Great Lakes Commission, 2000, Metafile (electronic) fish and bird location data for the Upper Peninsula of Michigan. From NOAA Environmental Sensitivity Index report. Supplied by Tom Rayburn, February 8, 2000.

Haen, D., 2000. Personal communication from Port of Green Bay regarding Port of Green Bay operations and the Bay Port CDF. January 25.

Harris, H.J., 1991. *The State of the Bay, A Capsule Review*. University of Wisconsin-Green Bay Institute for Land and Water Studies. 20 pp.

Harris, H.J., 1994. *The State of the Bay, A Watershed Perspective - The Condition of the Bay of Green Bay/Lake Michigan 1993*. University of Wisconsin-Green Bay Institute for Land and Water Studies. 24 pp.

Harrison, C., A. Greensmith, 1993. *Birds of the World*. DK Publishing, Inc., New York, NY. 416 pp.

Hawley, N. and J. Niester. 1993. "Measurement of Horizontal Sediment Transport in Green Bay, May-October, 1989." *Journal of Great Lakes Research*. 19(2): 368-378.

Heagerty, P., T. Lumley, 2000. "Window subsampling of estimating functions with application to regression models." *Journal of the American Statistical Association* 95: 197 - 211.

Heaps, N.S, C.H. Mortimer, E.J. Fee, 1982. *Numerical Models and Observations of Water Motion in Green Bay, Lake Michigan*. University of Wisconsin Sea Grant College Program, Publication WIS-SG-82-737.

Hewett, S.W., D.J. Stewart, 1989. "Zooplanktivory by alewives in Lake Michigan: Ontogenetic, seasonal, and historical patterns." *Transaction of the American Fisheries Society.* 118(6):581–596.

HNTB, 1996. *Brown County Year 2020 Land Use and Transportation Plan, Final Report*. Prepared for Brown County Planning.

Hoff, R.M., W.M.J. Strachan, C.W. Sweet, C.H. Chan, M. Shackleton, T.F. Bidleman, K.A. Brice, D.A. Burniston, S. Cussion, D.F. Gatz, K. Harlin, W.H. Schroeder, 1994. *Atmospheric Deposition of Toxic Chemicals to the Great Lakes: A Review of Data through 1994*. International Joint Commission.

Hornbuckle, K.C., D.R. Achman, and S.J. Eisenreich, 1993. "Over-water and over-land polychlorinated biphenyls in Green Bay, Lake Michigan." *Environmental Science Technology* 27(1):87-98.

Hornbuckle, K.C., C.W. Sweet, R.F. Pearson, D.L. Swackhammer, and S.J. Eisenreich. 1995. "Assessing annual water-air fluxes of polychlorinated biphenyls in Lake Michigan." *Environmental Science and Technology*, 29:869-877.

House, L.B., 1990. *Data on Polychlorinated Biphenyls, Dieldrin, Lead, and Cadmium in Wisconsin and Upper Michigan Tributaries to Green Bay, July 1987 through April 1988*. U.S. Geological Survey Open-File Report 89-52.

House, L.B., P.E. Hughes, R.J. Waschbusch, 1993. *Concentrations and Loads of Polychlorinated Biphenyls in Major Tributaries Entering Green Bay, Lake Michigan, 1989-90*. U.S. Geological Survey Open-File Report 93-132. Prepared by USGS in cooperation with USEPA and the WDNR.

Howard, P. H. (Ed.), 1991. *Handbook of Environmental Degradation Rates*. Lewis Publishers, Boca Raton, Florida.

Howe, R.W., A.T. Wolf, T.C. Erdman, 1993. *A Study of Wintering Bald Eagles on the Fox River of Northeastern Wisconsin*. Department of Natural and Applied Sciences, UWGB. Submitted to Repap Wisconsin, Inc.

HydroQual, Inc., 1999. *Hydrodynamics, Sediment Transport and Sorbent Dynamics in Green Bay*. Prepared for WDNR.

IJC, 1992. *Sixth Biennial Report Under the Great Lakes Water Quality Agreement of 1978*.

IPS, 1993a. *Benthic Community Characterization in Little Lake Butte des Morts, Winnebago County, Wisconsin - 1992*. Appleton, Wisconsin. Project 5058. 49 pp.

IPS, 1993b. *Benthic Community Component, Fox River Sediment Quality Triad Assessment - 1992*. Appleton, Wisconsin. Project 5059. 40 pp.

IPS 1994. *Benthic Community Component, Fox River Sediment Quality Triad Assessment - 1993*. Appleton, Wisconsin. Project 5064. 36 pp.

IPS, 1995. *Lower Fox River/Bay of Green Bay Biological Water Quality Study - 1994*. Appleton, Wisconsin. Project 5073. 100 pp.

Jones, M.L., G.W. Eck, D.O. Evans, M.C. Fabrizio, M.H. Hoff, P.L. Hudson, J. Janssen, D. Jude, R.O. O'Gorman, J.F. Savino, 1995. Limitations to lake trout (*Salvelinus namaycush*) rehabilitation in the Great Lakes imposed by biotic interactions occurring at early life stages. *Journal of Great Lakes Research.* 21 (Supplement 1): 505-517.

Konrad, J.G., 1971. *Mercury content of various bottom sediments, sewage treatment plant effluents, and water supplies in Wisconsin*. Research Report #74, WDNR. As cited in WDNR, 1996.

Konrad, J.G., 1992. "Estimates of Lead Cadmium, and PCB Loading to the Lower Fox River and Lower Green Bay." *Research Management Findings, Number 33*, May 1992. WDNR Bureau of Research.

Krohelski, J.T., B.A. Brown, 1986. *Hydrogeology and Ground-water Use and Quality, Brown County, Wisconsin*. WGNHS Information Circular Number 57.

Krohelski, J. 2002. Personal Communication from USGS regarding hydrogeology of Lower Fox River. May 29.

Krug, W.R., D.H. Conger, W.A. Gebert, 1992. *Flood-Frequency Characteristics of Wisconsin Streams*. USGS Water-Resources Investigations Report 91-4128, prepared in cooperation with the Wisconsin Department of Transportation.

Kubiak, T.J., D.A. Best, 1991. *Wildlife Risks Associated with Passage of Contaminated, Anadromous Fish at Federal Energy Regulatory Commission Licensed Dams in Michigan.* Contaminants Program, Division of Ecological Services. East Lansing, Michigan. August 16.

Lamon III, E.C., S.R. Carpenter, *et al.*, 1998. "Forecasting PCB concentrations in Lake Michgan salmonids: A dynamic linear model approach. *Ecological Applications*. 8(3):659-668.

Lathrop, R.G.J., J.R. Vande Castle, T.M. Lillesand, 1990. "Monitoring River Plume Transport and Mesoscale Circulation in Green Bay, Lake Michigan, Through Satellite Remote Sensing." *Journal of Great Lakes Research* 16(3):471-484.

LeRoux, E. F., 1957. *Geology and Ground-Water resources of Outagamie County, Wisconsin*.
USGS Water Supply Paper 1421.

Leshkevich, G.A., 1977. *Great Lakes Ice Cover, Winter 1975-76*. NOAA Technical Memorandum ERL GLERL-12. Great Lakes Environmental Research Laboratory, Ann Arbor, MI.

Lick, W., Y. Xu, J. McNeil. 1995. "Resuspension Properties of Sediments from the Fox, Saginaw, and Buffalo Rivers." *Journal of Great Lakes Research*. 21(2): 257-274.

LTI Environmental Engineering, 1999. *Fox River and Green Bay Fate and Transport Model Evaluation: Tehcnical Memorandum 2b-Computation of Watershed Solids and PCB Load Estimates for Green Bay*. Ann Arbor Michigan.

Lychwick, T., 2000a. Personal communication from WDNR regarding walleye spawning and longevity in Green Bay. February 21.

Lychwick, T., 2000b. Personal communication from WDNR and comments regarding fish of Green Bay. June 22.

Lychwick, T., 2000c. Personal communication from WDNR regarding fish die-offs in Green Bay. June 30.

Magnuson, J.J., D.L. Smith, 1987. *Food Chain Modeling Needs Obtained Through Stomach Analysis of Walleye and Brown Trout.* Final Report to U.S. EPA. University of Wisconsin.

Maitland, P.S., N.C. Morgan, 1997. *Conservation Management of Freshwater Habitats: Lakes, Rivers and Wetlands*. Chapman and Hall. London, England. 233 pp.

Manchester-Neesvig, J. B., A.W. Andren, and D.N. Edgington, 1996. "Patterns of mass sedimentation and of deposition of sediment contaminated by PCBs in Green Bay." *Journal of Great Lakes Research* 22:444-462.

Markert, B.E., 1978. *The Distribution and Abundance of Benthic Invertebrates in Green Bay, Lake Michigan From 1938 - 1978, with Special Reference to Long-Term Water Quality Changes*. Institute of Paper Chemistry. Appleton, Wisconsin.

Mason, D.M., S.B. Brandt, 1996. "Effect of alewife predation on survival of larval yellow perch in an embayment of Lake Ontario." *Canadian Journal of Fish. Aquat. Sci.* 53:1609–1617.

Matteson, S.W., 1988. *Wisconsin Common Tern Recovery Plan.* Wisconsin Endangered Resources Report 41. Bureau of Endangered Resources, Wisconsin DNR. Madison, Wisconsin. June.

Matteson, S.W., 1998. Personal communication of Sumner Matteson, WDNR, with L. Mortensen, ThermoRetec, regarding double-crested cormorant population levels. October.

Matteson, S.W., P.W. Rasmussen, K. Stromberg, T.I. Meier, J. Van Stappen, E. Nelson. 1998. *Changes in the Status, Distribution, and Management of Double-Crested Cormorants in Wisconsin*. WDNR, Bureau of Endangered Resources.

McAllister, L.S., 1991. *Factors Influencing the Distribution of Submerged Macrophytes in Green Bay, Lake Michigan A Focus on Light Attenuation and Vallisneria Americana*. University of Wisconsin-Green Bay. Master of Science Thesis.

Merck & Company, Inc., 1989. *The Merck Index, 11th Edition: An Encyclopedia of Chemicals, Drugs, and Biologicals*. Rahway, N.J. S. Budavari, ed. 1606 pp plus appendices.

Meyer, M.W., C. Sindelar, R. Eckstein, and D. Evans, 1997. *An Evaluation of the Effects of Environmental Contaminants on Wisconsin Bald Eagle Reproduction (1976-1987) - Draft*. WDNR, Bureau of Research.

MDNR, 1998. *Portage Marsh Restoration and Management Plan, Final Version*. August 28, 1998

MDNR, 2000. Peregrine Falcon. *Wildlife Division*. Internet publication at http://www.dnr.state.mi.us/Wildlife/Species/indicies/peregrine.htm.

Mickelson, D.M., L. Clayton, R.W. Baker, *et al.,* 1984. *Pleistocene stratigraphic units of Wisconsin*. WGNHS Miscellaneous Paper 84-1.

Miller, G.S., J.H. Saylor. 1985. "Currents and Temperatures in Green Bay, Lake Michigan." *Journal of Great Lakes Research* 11:97-109.

Miller, G.S., J.H. Saylor. 1993. "Low-Frequency Water Volume Transport through the Midsection of Green Bay, Lake Michigan, Calculated from Current and Temperature Observations." *Journal of Great Lakes Research* 19:361-367.

Mills, G., 2000. Personal communication from WDNR sent with WDNR discharge records for Door and Kewaunee Counties. July 13.

Minc, L.D., D.A. Albert, 1998. "Great Lakes Coastal Wetlands: Abiotic and Floristic Characterization." *Michigan Natural Features Inventory*. Ann Arbor, MI. 15 pp.

Modlin, R.F., A.M. Beeton, 1970. "Dispersal of Fox River Water in Green Bay, Lake Michigan." *Proceedings 13th Conference Great Lakes Research*. 468-476 pp.

Montgomery Watson, 1998. *Fox River SMU 56/57 Basis of Design Report for Sediment Remediation Demonstration Project*. Pages 1-1 through 3-17.

Montgomery Watson, 2000. *Draft Summary Report: Sediment Removal Demonstration Project, Sediment Management Unit 56/57, Fox River, Green Bay, Wisconsin.* April.

Montgomery, J.H., 2000. *Groundwater Chemicals Desk Reference*. Third Edition. Lewis Publishers, Boca Raton, Florida.

Mortimer, C.H., 1978. "Water Movement, Mixing, and Transport in Green Bay, Lake Michigan." *Proceedings of the Green Bay Research Workshop, Green Bay, Wisconsin*. Sponsored by the University of Wisconsin Sea Grant College Program. September 14-16, 1978. Pages 10-57. Harris & Garsow, ed. 184 pp.

Mossman, M.J., 1988. *Wisconsin Forster's Tern Recovery Plan*. Wisconsin Endangered Resources Report 42. Wisconsin Department of Natural Resources, Bureau of Endangered Resources

Mountain-Whisper-Light, 2001. *Time Trends in PCB Concentrations in Sediment and Fish, Lower Fox River, Wisconsin.* The Mountain-Whisper-Light Statistical Consulting and ThermoRetec Consulting Corporation. March 30.

Mudrey, M.G. and K.R. Bradbury, 1992. *Evaluation of NURE Hydrogeochemcial Data for Use in Wisconsin Groundwater Studies*. Wisconsin Geologic and Natural History Survey Open File Report 93-2.

National Agricultural Statistics Service (NASS), 2000. *Mink*. U.S. Department of Agriculture. 8 pp.

Natural Heritage Inventory, 2000. Metafile (electronic) of Endangered and Threatened Species. Endangered Resources Program, WDNR. E-mail to Stephen Jesse, ThermoRetec, Seattle, February 3, 2000.

Need, E.A., 1983. *Pleistocene geology of Brown County, Wisconsin*. WGNHS Information Circular 48.

Neville Public Museum of Brown County, 1845. *Chart of Green Bay*. Map in Museum Collection. Included in Bosley, 1976.

Nikolai, R., 1998. Personal communication from WDNR regarding waterfowl surveys from 1975 through 1998, birds of the region and mink and otter populations. August 24.

Nikolai, R., 2000a. Personal communication from WDNR regarding various aspects of the biological and ecological aspects of the Lower Fox River and Green Bay system. June 22.

Nikolai, R., 2000b. Personal communication from WDNR regarding various aspects of the biological and ecological aspects of the Lower Fox River and Green Bay system. October 11.

NOAA, 1991. *Recreational Chart 14908 Dutch Johns Point to Fishery Point, 17th Edition*. U.S. Department of Commerce.

NOAA, 1992. *Recreational Chart 14916 Lake Winnebago and Lower Fox River, 8th Edition*. U.S. Department of Commerce.

NOAA, 1996. *Recreational Chart 14902 North End of Lake Michigan Including Green Bay, 27th Edition*. U.S. Department of Commerce.

NOAA, 1997a. *Recreational Chart 14917 Menominee and Marinette Harbors, 23rd Edition*. U.S. Department of Commerce.

NOAA, 1997b. *Recreational Chart 14919 Sturgeon Bay and Canal, 27th Edition*. U.S. Department of Commerce.

NOAA, 1997c. Environmental Sensitivity Index Metadata (electronic). E-mail to Stephen Jesse, ThermoRetec, Seattle, October 27, 1999.

NOAA, 1998a. *Recreational Chart 14909 Upper Green Bay, 19th Edition*. U.S. Department of Commerce.

NOAA, 1998b. *Recreational Chart 14910 Lower Green Bay - Algoma and Oconto, 22nd Edition*. U.S. Department of Commerce.

NOAA, 1998c. *Recreational Chart 14918 Head of Green Bay including Fox River Below De Pere, 26th Edition*. U.S. Department of Commerce.

NRC, 2001. *A Risk Management Strategy for PCB Contaminated Sediments.* Committee on Remediation of PCB-Contaminated Sediments, National Research Council. National Academy Press, Washington, D.C,.

Offenberg, J.H., J.E. Baker, 2000. "PCBs and PAHs in Southern Lake Michigan in 1994 and 1995: Urban atmospheric influences and long-term declines." *Journal of Great Lakes Research*. 26(2):196-208.

Olcott, P.G., 1968. "Water Resources of Wisconsin Fox-Wolf River Basin." *USGS Hydrologic Investigations Atlas HA-321*, 4 Plates.

Olejniczak, M., R. Florence., 1995. *Door County Development Plan*. Door County Resource Planning Committee. Sturgeon Bay, Wisconsin.

Oman, B., 2000. Personal communication from WDNR sent with WDNR discharge records for Marinette and Oconto Counties. July 25.

OSI/Exponent., 1999. Metafile (electronic) GIS data from the 1998 Exponent Habitat Characterization for the Lower Fox River and Green Bay Assessment Area. E-mail to Stephen Jesse, ThermoRetec, Seattle, February 4, 2000.

Palmer, R.S., 1988. "Bald Eagle - Haliaeetus leucocephalus (Linnaeus)." *Handbook of North American Birds*, Vol. 4. R.S. Palmer (Ed.) Yale University Press. New Haven, Connecticut. P. 187-237.

Patnode, K., 1998. Personal communication from Kathy Patnode of WDNR regarding mink populations in the Lower Fox River.

Raghunathan, R.K.,1994. *The Development and Calibration of a Coupled Sorbent-Toxics Model for PCBs in Green Bay, Lake Michigan*. Ph.D. Dissertation, State University of New York - Buffalo.

RAP Biota & Habitat Work Group, April 1994. *Green Bay Habitat Restoration Workshop Summary*. 21 pp.

RAP Biota & Habitat Work Group, April 1996. *Lower Green Bay Habitat Restoration Goals*. 4 pp.

RETEC, 1998a. *Work Plan - Data Management, Remedial Investigation/Feasibility Study, and Risk Assessment for the Lower Fox River*. Project No. 3-3584-000.

RETEC, 1998b. *Quality Assurance Project Plan for Supplemental Data Collection, Fox River RI/FS (QAPP)*. Project No. 3-3584-000.

RETEC, 1998c. *Screening Level Risk Assessment, Fox River RI/FS*. Project No. 3-3584-000.

RETEC, 2002. *Baseline Human Health and Ecological Risk Assessment, Lower Fox River, Wisconsin, Remedial Investigation and Feasibility Study*.

Rezabeck, C., 1998. Personal communication from WDNR regarding bird and bat studies in the Lower Fox River region. September 23.

Rodgers, J., 2000. Personal communication from Wisconsin Central Railroad Company regarding Port of Escanaba and the WCRR operations. January 26.

Sager, P.E, 1986. "Update on Trophic Status of the Bay - Trends, 1970-85." *The Proceedings of the 1986 Green Bay/Fox River Research Symposium, March 24-25, 1986*. Sponsored by the RETEC, WDNR, and Brown County Neville Public Museum. 47 pp.

Sager, P.E., S. Richman, 1991. "Functional Interaction of Phytoplankton and Zooplankton along the Trophic Gradient in Green Bay, Lake Michigan." *Canadian Journal of Fisheries and Aquatic Sciences*. 48: 116-122.

Schideler, G.L, 1994a. "Temporal Variability of Shoreline Positions and Coastal Wetland Along Lower Green Bay, Oconto and Brown Counties, Wisconsin." *Miscellaneous Field Studies Map MF-2254*.

Schideler, G.L., 1994b. "Shoreline and Coastal Wetland Variability along the West Shore of Green Bay, Marinette and Oconto Counties, Wisconsin." *Miscellaneous Field Studies Map MF-2252*.

Schneeberger, P., 1999. Personal communication from MDNR regarding fish spawning areas in northern Green Bay. December 28.

Schneeberger, P., 2000. Personal communication from MDNR regarding water characteristics and fish of northern Green Bay. January 25.

Scott, W.B., E.J. Crossman, 1973. *Freshwater fishes of Canada*. Bulletin 184. Fisheries Resources Board of Canada. Ottawa, Canada.

SCS, 1972. *Soil Survey of Brown County, Wisconsin*. U.S. Department of Agriculture.

SCS, 1978. *Soil Survey of Door County, Wisconsin*. U.S. Department of Agriculture.

SCS, 1988. *Soil Survey of Oconto County, Wisconsin*. U.S. Department of Agriculture.

SCS, 1989. *Soil Survey of Menominee County, Michigan*. U.S. Department of Agriculture.

SCS, 1991. *Soil Survey of Marinette County, Wisconsin*. U.S. Department of Agriculture.

SCS, 1994. *Soil Survey of Delta County and Hiawatha National Forest of Alger and Schoolcroft Counties, Michigan*. U.S. Department of Agriculture.

Shepherd, W.C., E.L. Mills, 1996. "Diel feeding, daily food intake, and Daphnia consumption by age-0 gizzard shad in Oneida Lake, New York." *Transactions of the American Fisheries Society.* 125:411–421.

Sinclair, W.C., 1960. *Reconnaissance of the Ground-Water Resources of Delta County, Michigan*. Michigan Department of Conservation - Geological Survey Division, Progress Report #24, 93 pp.

Smith, J., 1999a. Personal communication from USFWS regarding loss of the former Cat Island Chain. November 10.

Smith, J., 1999b. Personal communication from USFWS regarding restoration of the former Cat Island Chain. December 15.

Smith, P.L., R.A. Ragotzkie, A.W. Andren, and H.J. Harris. 1988. "Estuary Rehabilitation: The Green Bay Story." University of Wisconsin Sea Grant Program Reprint (WIS-SG-88-864), reprinted from *Oceanus*, 31(3):12-20.

Smith, D.W., 2000. "Analysis of rates of decline in PCBs in different Lake Superior media." *Journal of Great Lakes Research.* 26(2):152-163.

Steuer, J.J., December 20,1990. *Little Lake Butte des Morts; Bergstrom Landfill*. Memorandum to Tom Sheffy, WDNR.

Stewart, D. and D. Chisolm, 1971. "Long-term persistence of BHC, DDT, and chlordane in a sandy loam soil." *Canadian Journal of Soil Science* 51:379-383.

Stiller, D. 1998. *A Multitude of Fishes; A Century of Fishing on Green Bay*. Alt Publishing Company. Green Bay, Wisconsin.

Stoll, R., K. Erdmann, 1990. *Preliminary Green Bay Mass Balance Groundwater Monitoring Reports* (An Assessment of the Bayshore Landfill). WDNR

Stoll, R., K, Erdmann, 1992. *Green Bay Mass Balance Groundwater Monitoring Results*. WDNR

Stratus Consulting, Inc. (Stratus), 1999a. *PCB Pathway Determination for the Lower Fox River/Green Bay Natural Resource Damage Assessment*. Prepared for the US Fish and Wildlife Service.

Stratus Consulting, Inc., 1999b. *Injuries to Fisheries Resources, Lower Fox River/Green Bay Natural Resource Damage Assessment*. Prepared for the US Fish and Wildlife Service.

Stratus Consulting, Inc., 1999c. *Injuries to Avian Resources, Lower Fox River/Green Bay Natural Resource Damage Assessment*. Prepared for the US Fish and Wildlife Service.

Stubenvoll, S.C., April 17, 1998. Eagle and osprey nest locations. Memorandum to George Boronow, WDNR.

Surber, E.W., H.L. Cooley, 1952. *Bottom Fauna Studies of Green Bay, Wisconsin in Relation to Pollution*. U. S. Public Health Service and Wisconsin Committee on Water Pollution. 7 pp.

Sullivan, J.R., J.J. Delfino. 1982. *A Select Inventory of Chemicals Used in Wisconsin's Lower Fox River Basin*. University of Wisconsin Sea Grant Institute, WIS-SG-82-238. 176 pp.

Sweet, C. W., T. J. Murphy, J. H. Bannasch, C. A. Kelsey, J. Hong. 1993. "Atmospheric Deposition of PCBs into Green Bay." *Journal of Great Lakes Research* 19(1):109-128.

Szymanski, S., 1998. Personal communication from WDNR regarding clam/mussel beds in the Lower Fox River. September 28.

Szymanski, S., 2000. Personal communication from WDNR regarding zebra mussels and wetlands in the Lower Fox River and Green Bay. June 22.

Temple, S.A., J.R. Cary, R. Rolley, 1997. *Wisconsin Birds: A Seasonal and Geographical Guide. Second Edition*. The University of Wisconsin Press. Madison, WI. 320 pp.

ThermoRetec Consulting Corporation, 2000. *Draft Review of Natural PCB Degradation Processes in Sediments*. Project No. WISC-14414-530.

Toneys, M., 1999. Personal communication from WDNR regarding the fish of Green Bay. December 16.

USACE, 1905. "Head of Green Bay including Fox River Below De Pere, Wisconsin." *Lake Survey Chart No. 725*. Included in Bosley, 1976.

USACE, September 1985. *Appleton Upper Dam, Dam Stability Analysis, Fox River, Wisconsin, Final Report*. Detroit District.

USACE, 1985. *Final Environmental Impact Statement, Green Bay Harbor, Wisconsin - Confined Disposal Facility*.

USACE, December 1987. *Menasha Dam, Dam Stability Analysis, Fox River Wisconsin*. Detroit District, NCD.

USACE, August 1994. *Menasha Dam, Fourth Periodic Inspection, Fox River Wisconsin.* Detroit District.

USACE, August 1994. *Rapide Croche Dam, Fourth Periodic Inspection, Fox River Wisconsin.* Detroit District.

USACE, June 1995. *Appleton Dams, Fifth Periodic Inspection, Fox River Wisconsin.* Detroit District.

USACE, June 1995. *Cedars Dam, Fifth Periodic Inspection, Fox River Wisconsin.* Detroit District.

USACE, June 1995. *DePere Dam, Fifth Periodic Inspection, Fox River, Wisconsin.* Detroit District.

USACE, May 1996. *Kaukauna Dam, Fifth Periodic Inspection, Fox River, Wisconsin.* Detroit District.

USACE, May 1996. *Little Chute Dam, Fifth Periodic Inspection, Fox River, Wisconsin.* Detroit District.

USACE, May 1996. *Little Kaukauna Dam, Fifth Periodic Inspection, Fox River, Wisconsin.* Detroit District.

USACE, November 1996. *Little Kaukauna Dam, Stability Analysis, Fox River, Wisconsin, Final Report.* Detroit District.

USACE, 1996. *International Great Lakes Datum 1985.* Internet publication at http://lre.usace.army.mil/IGLD.1985/igldhmpg.html.

USACE, January 1997. *Appleton Lower Dam, Dam Stability Analysis, Fox River, Wisconsin, Final Report.* Detroit District.

USACE, January 1997. *Cedars Dam, Dam Stability Analysis, Fox River, Wisconsin, Final Report.* Detroit District.

USACE, April 1997. *DePere Dam, Stability Analysis, Fox River, Wisconsin, Final Report.* Detroit District.

USACE, April 1997. *Little Chute Dam, Stability Analysis, Fox River, Wisconsin, Final Report.* Detroit District.

USACE, May 1997. *Kaukauna Dam, Stability Analysis, Fox River, Wisconsin, Final Report* Detroit District.

USACE, May 1997. *Rapide Croche Dam, Dam Stability Analysis, Fox River, Wisconsin, Final Report.* Detroit District.

USACE, 1998a. *Lake Winnebago Facts Book*. Internet publication at http://superior.lre.usace.army.mil/COASTAL/lwfacts.html.

USACE, 1998b. *Great Lakes Long-Term Average, Maximum, and Minimum Lake Levels*. Website-http://lre.usace.army.mil/levels/maxmin.html.

USACE, 1998c. *Cat Island Restoration Project Area - Site Layout Map Figure 2*. Map number e:*greenbay*sec204*c1106o97.dgn, dated June 25, 1998. Provided by Janet Smith, USFWS, Green Bay, Wisconsin

USACE, 1998d. *Great Lakes Erosion Fact Sheet*. August 10, 1998. Website-http://huron.lre.usace.army.mil/hes/erosfacttml.

USACE, 1999. *Annual Report/Contract Dredging Report*. Fox River/Green Bay, Wisconsin. http://huron.lre.usace.army.mil/OandM/text/green.txt

USACE, 2000a. *Great Lakes Update - 1999 Annual Summary*. Vol. No. 138. January 3, 2000. Detroit District.

USACE, 2000b. *Great Lakes Update - Water Levels Continue to Decline*. Vol. No. 139. April 6, 2000. Detroit District.

USFWS, 1979. *Classification of Wetlands and Deepwater Habitats of the United States*. Publication FWS/OBS-79/31. U.S. Department of the Interior.

USFWS, 1981. *Fish and Wildlife Resources of the Great Lakes Coastal Wetlands within the United States. Volume 5: Lakes Michigan, Parts 2 and 3*. U.S. Department of the Interior. Publication FWS/OBS-81/02 - V5.

USFWS, 1982. *Habitat Suitability Index Models: Common Carp*. Publication FWS/OBS-82/10.12. U.S. Department of Interior.

USFWS, 1983a. *Habitat Suitability Information: Yellow Perch*. Publication FWS/OBS-82/10.55. U.S. Department of Interior.

USFWS, 1983b. *Habitat Suitability Information: Common Shiner*. Publication FWS/OBS-82/10.40. U.S. Department of Interior.

USFWS, 1984. *Habitat Suitability Information: Walleye*. Publication FWS/OBS-82/10.56. U.S. Department of Interior.

USFWS, 1985. *Habitat Suitability Index Models and Instream Flow Suitability Curves: Gizzard Shad*. Biological Report 82(10.112). U.S. Department of Interior.

USFWS, 1986. *Habitat Suitability Index Models: Mink*. Biological Report 82(10.127). U.S. Department of Interior.

USFWS, 1993. *Atlas of Green Bay Coastal Wetlands Influenced by Lake Level Changes. Green Bay Special Wetlands Inventory Study*. Prepared for the U.S. EPA, Region 5, by the Green Bay Field Office, U.S. Fish & Wildlife Service.

USFWS, 1995. "Evaluation of the Re-Introduction of Lake Sturgeon into the Waters of the Menominee Reservations." *FY 1995 Fisheries Stewardship Accomplishment Report*. Region 3. Green Bay, Wisconsin.

USFWS, 1998. "Great Lakes Native Fish Restoration Lake Sturgeon *(Acipenser fulvescens*)." *Annual Fisheries Stewardship Progress Report Lake Michigan*. Green Bay Fisheries Resource Office, Green Bay, Wisconsin.

USGS, 1992. *Groundwater Atlas of the United States: Segment 9 - Iowa, Michigan, Minnesota, Wisconsin, Hydrologic Investigations Atlas 730-J*. U.S. Department of the Interior. Reston, VA. 31 pp.

USGS, 1995a. *Water Use*. In Michigan Watersheds including the Cedar-Ford (04030109), Escanaba (04030110), Fishdam-Sturgeon, (04030112) and Menominee (04030108) at http://water.usgs.gov.cgi-bin and downloaded into Excel Spreadsheet

USGS, 1995b. *Water Use*. In Wisconsin Watersheds including the Duck - Pensaukee (04030103), Lower Fox (04030204, Menominee (04030108), Oconto (04030104), and Peshtigo (04030105) at http://water.usgs.gov.cgi-bin and downloaded into Excel Spreadsheet.

USGS, 1998a. *Water Resources Information, Fox River at Appleton, Wisconsin*. http://h20.usgs.gov/swr/WI/?statnum=04084445.

USGS, 1998b. *Water Resources Information, Fox River at State Highway 55 at Kaukauna, Wisconsin*. http://h20.usgs.gov/swr/WI/?statnum=04084475.

USGS, 1998c. *Water Resources Information, Fox River at Rapide Croche Dam-Wrightstown, Wisconsin*. http://h20.usgs.gov/swr/WI/?statnum=04084500.

USGS, 1998d. *Water Resources Information, Fox River at Little Rapids, Wisconsin*. http://h20.usgs.gov/swr/WI/?statnum=04085054.

USGS, 1998e. *Water Resources Information, Fox River at De Pere, Wisconsin*. http://h20.usgs.gov/swr/WI/?statnum=04085059.

USGS, 1998f. *Water Resources Information, Fox River at Oil Tank Depot, Green Bay, Wisconsin*. http://h20.usgs.gov/swr/WI/?statnum=040851385.

USGS, 2000. *Water Resources Information, Fox River at Oil Tank Depot, Green Bay, Wisconsin*. http://h20.usgs.gov/swr/WI/?statnum=040851385.

UWSGI, 1979. *Green Bay: Portrait of a Waterway*. Madison, Wisconsin. Publication WIS-SG-79-130. 22 pp.

UWSGI, 1980. *Fish Spawning Grounds in Wisconsin Waters of the Great Lakes*. Publication WIS-SG-80-235. 35 pp.

UWSGI, 2000a. "Fish of the Great Lakes: Rainbow Smelt." *UWSGI website* at http://h2o.seagrant.wisc.edu/Communications/Publications/Fish/

UWSGI, 2000b. "Fish of the Great Lakes: Alewife." *UWSGI website* at http://h2o.seagrant.wisc.edu/Communications/Publications/Fish/

UWSGI. 2000c. "Fish of the Great Lakes: Yellow perch." *UWSGI website* at http://h2o.seagrant.wisc.edu/Communications/Publications/Fish/

UWSGI, 2000d. "Fish of the Great Lakes: Carp." *UWSGI website* at http://h2o.seagrant.wisc.edu/Communications/Publications/Fish/

UWSGI, 2000e. Fish of the Great Lakes: Walleye. *UWSGI website* at http://h2o.seagrant.wisc.edu/Communications/Publications/Fish/

Vanlier, K.E., 1963. *Ground-Water in Menominee County, Michigan*. Michigan Department of Conservation - Geological Survey Section, Water Investigation #2, 42 pp.

Velleux, M., D. Endicott, 1994. "Development of a Mass Balance Model for Estimating PCB Export from the Lower Fox River to Green Bay." *Journal of Great Lakes Research*, 20(2):416-434, International Association of Great Lakes Research.

Velleux, M., D. Endicott, J. Steuer, S. Jaeger, D. Patterson, 1995. "Long-Term Simulation of PCB Export from the Fox River to Green Bay." *Journal of Great Lakes Research*, 21(3):359-372, International Association of Great Lakes Research.

Velleux, M., 2000. Personal communication from WDNR regarding the coordinates for boundaries of Green Bay zones 2/3 and 3/4. March 13.

WCC, 1994. *Estimate of PCB Losses During Remediation, Little Lake Butte Des Morts, Deposit A Winnebago County, Wisconsin*.

WCC, 1996. *Sediment/Site Characterization Summary, Little Lake Butte Des Morts, Deposit A Neenah-Menasha, Wisconsin*.

WDNR, 1968. *Report on an Investigation of the Pollution in the Lower Fox River and Green Bay Made During 1966 and 1967*. Division of Resource Development. Issued January 4 and revised January 18, 1968.

WDNR, 1970. *Reproduction and Early Life History of the Walleye in the Lake Winnebago Region.* Technical bulletin 45. Wisconsin Department of Natural Resources. Madison, Wisconsin.

WDNR, January 1980. *Water Quality Modeling of the Lower Fox River for Wasteload Allocation Development* - Tables 4 and 5. Bureau of Water Quality.

WDNR, 1985. *Public Water Supply Data Book*. Public Water Supply Section. 212 pp.

WDNR, 1988. *Lower Green Bay Remedial Action Plan for the Lower Fox River and Lower Green Bay Area of Concern*. WDNR, PUBL-WR-175-87, Rev 88.

WDNR, 1989/90. Sediment, Tissue, and Water Sample Data Collected from the Lower Fox River and Green Bay. Data contained in the FRDB and cited in the EcoChem Data Management Report, 2000.

WDNR, 1990a. *WPDES Permit Records Summary for RAP Update Evaluation*. Available from WDNR NER Office.

WDNR, 1990b. *The Lower Menominee River Remedial Action Plan - A Water Quality Restoration and Protection Plan*. Published in conjunction with the MDNR. WDNR Publication PUBL-WR-246 90.

WDNR, 1992. *Sheboygan River and Harbor Superfund Site: Sediment Quality Criteria for PAHs and Need for Additional Data Collection*. Memorandum from Duane Schuettpeltz to Mark Giesfeldt, August 20, 1992. WDNR, Bureau of Watershed Management.

WDNR, 1993. *The Lower Green Bay Remedial Action Plan 1993 Update for the Lower Green Bay and Fox River Area of Concern*. WDNR, Bureau of Water Resources, Madison, Wisconsin.

WDNR, 1995. *A Deterministic PCB Transport Model for the Lower Fox River Between Lake Winnebago and De Pere, Wisconsin*. Publication PUBL WR 389-95, WDNR, Water Resources, Madison, Wisconsin.

WDNR, 1996. *Lower Fox River System Sediment Characterization - Sediment Quality Triad Assessment and Application of Sediment Quality Guidelines*. Sediment Management and Remedial Techniques Team, Madison, Wisconsin.

WDNR, 1997. *Nonpoint Source Control Plan for Duck, Apple, and Ashwaubenon Creeks Priority Watershed Project - Summary*. Publication WT-493-97.

WDNR, 1998. *Assessment of PCBs in Sediment of the Lower Fox River from De Pere dam to Green Bay*. Publication PUBL-WT-519-98, Bureau of Watershed Management, Madison, Wisconsin.

WDNR, 1999a. *Lower Fox River and Green Bay PCB Fate and Transport Model Evaluation, Technical Memorandum 2d, Compilation and Estimation of Historical Discharges of Total Suspended Solids and Polychlorinated Biphenyls from Fox River Point Sources*.

WDNR, 1999b. *Wisconsin Wildlife Surveys, August 1999*. Compiled by Brian Dhuey, Bureau of Integrated Science Services, Monona, WI.

WDNR, 1999c. *Model Evaluation Workgroup Technical Memorandum 2e, Estimation of Lower Fox River Sediment Bed Properties*.

WDNR, 1999d. Metafile (electronic) of wetland coverages for Green Bay and the Lower Fox River. E-mail to Anne Fitzpatrick, ThermoRetec, Seattle, January 5, 2000.

WDNR, 2000a. *Post Dredging Results from SMU 56/57*. Memorandum from Bob Paulson to Bruce Baker and Greg Hill, February 21, 2000. WDNR, Bureau of Watershed Management.

WDNR, 2000b. *Summary and maps of the Green Bay West Shores Wildlife Area, Gardner Swamp Area, and Red Bank Glades State Natural Area*. January 28, 2000 Letter from Terrence L. Gardon (WDNR Real Estate Specialist - Lakeshore/Lower Fox Basin) to Eric P. Kovatch, Natural Resource Technology, Inc.

WDNR, 2000c. *Model Evaluation Workgroup Technical Memorandum 2f, Estimation of Sediment Bed Properties for Green Bay*. December 15, 2000.

WDNR, 2000d. *Memorandum of Agreement Between the Department of the Army and the State of Wisconsin for the Transfer of the Locks and Appurtenant Features of the Federal Fox River Project*, Wisconsin. 7 pp. Received from Ed Lynch, WDNR, via facsimile.

WDNR, 2000e. *Model Evaluation Workgroup Technical Memorandum 2e, Estimation of Sediment Bed Properties for the Lower Fox River: Addendum (4 reach effort).*

Weaver, M.J., J.J. Magnuson, M. K. Clayton, 1997. "Distribution of littoral fishes in structurally complex macrophytes." *Canadian Journal of Fisheries and Aquatic SciencesJuly 3, 2001.* 54:2277–2289.

Weber, J.J., K.J. Otis, 1984. *Life History of Carp in the Lake Winnebago System, Wisconsin 131.* Department of Natural Resources Research. Madison, Wisconsin. December.

Welch, A.H., M.S. Lico, J.L. Hughes, 1988. "Arsenic in groundwater of the western United States." *Ground Water* 26:333-347.

Weseloh, D.V., P.J. Ewins, C.A. Bishop, J. Struger, P. Mineau, 1994. "Double-crested cormorants (*Phalacrocorax auritus*) of the Great Lakes: Changes in population size, breeding distribution and reproductive output, 1913–1991." *The Double-crested Cormorant: Biology, Conservation and Management, Vol. Colonial Waterbirds: 18(Special Publication).* D. N. Nettleship and D. C. Duffy (Eds.). p. 48–59.

Weston, 1999. *Peer Review of the Remedial Investigation and Data Management Reports for the Lower Fox River Natural Resource Damage Assessment*. Prepared for the U.S. EPA. RFW021-2A-ADPO. 15 pp.

Wiley, A.J., 1944. *Review of Two Field Surveys of the February, 1944 Fish Kill on the East Shore of Green Bay*. Memorandum from the Sulphite Pulp Manufacturer's Committee on Waste Disposal.

Wisconsin Administrative Code (W.A.C.), 1997. Chapter NR 105, Surface Water Quality Criteria and Secondary Values for Toxic Substances.

Wisconsin Division of Health, 1994. *Polycyclic Aromatic Hydrocarbons*, Toxic Chemical Series.

Wisconsin Paper Council, 2000. *Industry Facts*. Website http//www.wipapercouncil.org/industry.htm

Wisconsin Sate Climatology Office, 2000. *Cities of Appleton, Green Bay, Oconto, and Marinette Wisconsin and Fayette Michigan Weather Information*. Internet webpage http://mcc.sws.uiuc.edu/Summary.

Wisconsin State Board of Health, 1939. *Investigation of the Pollution of the Fox and East Rivers and of Green Bay in the Vicinity of the city of Green Bay*. Committee on Water

Pollution in collaboration with the Green Bay Metropolitan Sewerage District (GBMSD).

Wisconsin State Board of Health, 1948. *Pollution Survey of the Lower Fox River*. 16 pp. Plus Tables and Figures. Committee on Water Pollution.

Wisconsin State Board of Health, 1956. Letter to Mr. O.J. Muegge, State Sanitary Engineer, dated October 15, 1956. 4 pp. Committee on Water Pollution.

APPENDIX A

DATA MANAGEMENT SUMMARY REPORT (ECOCHEM, 2000)

Data Management Summary Report

Fox River Remedial Investigation/Feasibility Study

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October 3, 2000

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Table of Contents

1 Introduction 1-1

2 Data Collection 2-1
2.1 Electronic Data Collection 2-1
2.2 Collection of Historical Analytical Data and Supporting Quality Assurance and Quality Control Documents 2-2

3 Data Manipulation and Assessment 3-1
3.1 Data Management and Data Validation Overview 3-1
3.2 Data Sets 3-5
3.2.1 1989/1990 Fox River and Green Bay Mass Balance Study Data 3-5
3.2.2 1992/1993 Blasland, Bouck & Lee Deposit A Sediment Collection 3-6
3.2.3 1993 Triad Assessment 3-7
3.2.4 1994 Graef, Anhalt, Schloemer & Associates/Science Application International Corporation Sediment Data 3-8
3.2.5 1995 Wisconsin Department of Natural Resources Sediment Collection 3-8
3.2.6 Sediment and Tissue Data for the Fox River Group by Blasland, Bouck & Lee in 1996 3-9
3.2.7 1996 Wisconsin Department of Natural Resources Fish Tissue Collection 3-9
3.2.8 1996 U.S. Fish & Wildlife Service Natural Resource Damage Assessment Fish Tissue Collection 3-10
3.2.9 1997 U.S. Fish & Wildlife Service Natural Resource Damage Assessment Waterfowl Data, 1994–1995 Cormorant Data, and 1993–1996 Tree Swallow Data 3-11
3.2.10 Fox River Fish Consumption Advisory Data – Fox River and Green Bay 3-11
3.2.11 Wisconsin Department of Natural Resources Wildlife Tissue Data Collection 3-12
3.2.12 Lake Michigan Tributary Monitoring Study 3-12
3.2.13 Stromberg Eagle Data 3-13
3.2.14 U.S. Geological Survey National Water Quality Assessment Program 3-13
3.2.15 1994 Woodward Clyde Deposit A Sediment Samples 3-14

Table of Contents

3.2.16 Wisconsin Pollutant Discharge Elimination System Permit Influent Data for Water Intakes along the Fox River 3-14
3.2.17 Lower Fox River Background Metals Assessment – Wisconsin Department of Natural Resources Watershed Management Program 3-15
3.2.18 1997 Wisconsin Department of Natural Resources Caged Fish Bioaccumulation Study Data 3-15
3.2.19 1997 Demonstration Project Data – Deposit N 3-16
3.2.20 1998 Demonstration Project Data – SMU 56/57 3-16
3.2.21 1998 RETEC RI/FS Supplemental Data Collection 3-17
3.2.22 Lake Michigan Mass Balance Data 3-18
3.2.23 Minergy Mineralogical Data 3-19
3.2.24 1998 Fox River Group/Exponent Data 3-19
3.2.25 1998 Fox River Group/Blasland, Bouck & Lee Sediment/Tissue Data Collection 3-20
3.2.26 1998 Deposit N Pilot Remediation 3-21
3.2.27 Ankley and Call Data – Sediment Quality Evaluation in the Lower Fox River and Southern Green Bay of Lake Michigan 3-21
3.2.28 State of Michigan Fish Consumption Advisory Data 3-22
3.2.29 1999 Demonstration Project Data – SMU 56/57 3-22
3.3 Data Usability 3-23
3.3.1 Fully Validated Data 3-23
3.3.2 Supporting Data 3-24
3.3.3 Indeterminate Data 3-24

4 Analytical and Archive Databases 4-1

Appendix A Data Validation Report

Attachment 1 Data Structure Outline
Attachment 2 Lookup Tables
Attachment 3 Table Structure and Relationships
Attachment 4 Data Importing Instructions

List of Tables

Table 3-1 Data Set Analysis 3-26
Table 3-2 QC Elements for Data Sets Supporting the Fox River RI/FS and RA.3-27

1 Introduction

This report summarizes the processes and data utilized to create the Fox River Database (FRDB). The FRDB was created to provide data management support to the Lower Fox River Remedial Investigation/Feasibility Study (RI/FS) and Risk Assessment (RA). The data management and data quality assessment have been conducted with two primary goals in mind:

- The identification and incorporation of available electronic data sets for immediate use in the support of RA and RI/FS activities and the assessment of these data sets for overall quality and defensibility.

- The generation of a useable database of Fox River data produced through the identification, acquisition, review (quality assessment or validation), catalog, classification, and archive of all available data (electronic and hardcopy) pertinent to the Fox River RA and RI/FS.

Environmental data generated by numerous sources in support of several different actions on the Fox River were collected and assessed for overall quality and included in the FRDB.

For the purposes of this document the following definitions will apply:

- **Data Set -** an electronic set of data that is associated with or is identified by a unique study name or sampling event. Identified data sets were submitted in many different formats (e.g., spreadsheets, databases, ASCII files, etc.).

- **Sample –** a unique, representative fraction of a matrix of interest (sediment, fish tissue, water, etc.) collected during a discrete time period.

- **Record –** collection of all data associated with a single analytical result in the FRDB (location, qualifiers, comments, etc.).

- **Data Validation (DV) -** data validation is the process of independent data review which provides information pertaining to limitations of data based on specific quality control criteria.

- **Useable Data -** useable data have been thoroughly assessed through review of the analytical data itself and associated quality assurance/quality control (QA/QC) documents. The data are of known and verifiable quality. Useable data is identified as such in the "qa_status" field in the FRDB.

- **Supporting Data -** supporting data have not been subjected to as rigorous an assessment as the useable data. As such, the precise data quality is not known. This is due to insufficient or incomplete QA/QC information available at the present time. In these cases, QA/QC information may or may not exist. The collection and assessment of this information might render the data fully useable. Until a full data validation is conducted, these data should be used for supporting purposes only. Supporting data is identified as such in the "qa_status" field in the FRDB.

- **Indeterminate Data –** status of a data set is described as indeterminate if: it is unknown whether the data set has been validated, and/or, QC data to support validation is not available. Indeterminate data is identified as such in the "qa_status" field in the FRDB.

2 Data Collection

2.1 Electronic Data Collection

The data management process began with the initial collection of electronic data sets from the Wisconsin Department of Natural Resources (WDNR) the week of March 30, 1998. The data collection effort proceeded in two stages, corresponding with the report delivery schedule developed for the RI/FS and RA documents. Data collection for Stage 1 continued through November 30, 1998, and all data were available to support the Draft RI/FS and RA documents published in February of 1999. Stage 2 of data collection began in March of 1999, and continues through the present (May 2000). Data were received in many different formats and were reviewed, standardized, and organized into a database-compatible format. The following table lists the data received and the stage that it was collected.

Data Source	
Stage 1	**Stage 2**
1989–1990 Fox River Mass Balance Study	1997 Demonstration Project Data - Deposit N
1989–1990 Green Bay Mass Balance Study (GLNPO)	1997–1998 Demonstration Project Data - SMU 56/57
1992–1993 BBL Deposit A Sediment Data	1998 FRG/BBL Sediment/Tissue Data
1993 Triad Assessment	1998–1999 Deposit N Data:
1993 USFWS Tree Swallow Data	Remediation
1994 GAS/SAIC Sediment Data	Pre-Dredge
1994 Woodward-Clyde Deposit A Sediment Data	Post-Dredge
1994–1995 Cormorant Data	Operational Monitoring
1995 WDNR Sediment Data	1998 FRG/Exponent Data
1996 FRG/BBL Sediment/Tissue Data	1999 Demonstration Project Data - SMU 56/57
1995–1996 WDNR Fish Tissue Data	Ankley and Call Data
1997 USFWS NRDA Waterfowl Tissue Data	State of Michigan Fish Consumption Advisory Data
1997 WDNR Caged Fish Bioaccumulation Study Data	Lake Michigan Mass Balance Data
1998 RETEC RI/FS Supplemental Data	Lake Michigan Tributary Monitoring Data
Fox River Fish Consumption Advisory Data	Minergy Mineralogical Data
Lower Fox River Background Metals Assessment	
Stromberg Eagle Data	
1996–1999 USFWS NRDA Fish Tissue Data	
USGS NAWQA Data	
WDNR Wildlife Tissue Data	
WPDES Permit Influent Data	

2.2 Collection of Historical Analytical Data and Supporting Quality Assurance and Quality Control Documents

The goal of the review was to assess previously generated analytical data sets and associated Sampling and Analysis Plans (SAPs), Quality Assurance Project Plans (QAPPs), Laboratory Standard Operating Procedures (SOPs), and other project-specific documents. Historical data (both hardcopy and electronic) and supporting QA documents were collected for review and verification.

3 Data Manipulation and Assessment

3.1 Data Management and Data Validation Overview

Most of the data sets required a substantial amount of manipulation to transform the structure to a common database format. The data were usually obtained from report documents that had undergone extensive formatting. This formatting had to be removed to restore the data set to its most basic state and transform individual data sets into a useable condition.

The formats in which data were received are included in Table 3-1. A brief description of how the data were adapted is provided below.

- **Spreadsheet:** Numerous data tables were provided in spreadsheets, but not necessarily in a database-compatible format. It was often necessary to manually rearrange data within the spreadsheet from a horizontally oriented format (multiple results on a single line) to a vertical format (one individual result per record). Spreadsheet columns were then rearranged into the proper record order as necessary and the file appended to the FRDB.

- **ASCII:** Data were imported into a spreadsheet or database table. The table was then checked to verify that the information was separated into individual fields properly. Information was then rearranged into the proper record order as necessary and the file appended to the FRDB.

- **Database:** Data were provided in multiple database formats. When necessary, the data were exported to FoxPro tables. Field headers were then standardized to match the established database format and the file appended to the FRDB.

- **Hardcopy:** Information was provided in a written report with data tables (one data set only). Information was gathered from the tables provided and the supporting text. The data were hand entered into an empty spreadsheet table with the same record setup as the database. All hand-entered information was proofread by a second party to insure accuracy prior to inclusion in the FRDB.

In addition to reducing the data to a database useable format, the disparate data sets required standardization. This process consists of developing master lists of acceptable entries for pertinent data types (valid value lists) and verifying that all new data sets conform to those master lists. The following items offer examples of the standardization that took place:

- A single analyte list was developed in order to account for different naming conventions reported by multiple laboratories. A cross-reference table was used to update each data set to a standardized list of analytes. For example, all instances of 4,4'-DDT were changed to p,p'-DDT and all PCB congener results were put into the format "PCB Congener XXX." The original analyte name as received in the import file is maintained in the "analyte_old" field of the FRDB.

- Units were standardized to parts per million (mg/L or mg/kg) for inorganic constituents and parts per billion (mg/L or mg/kg) for organic analytes. Two different possibilities exist for unit changes: unit changes that do not require numeric calculations, e.g., ng/ml to mg/L (both represent parts per billion units) and units changes that require numeric calculations e.g., 10 mg/kg changed to 0.01 mg/kg. All original values and units were concatenated and placed in the "result_old" field of the FRDB.

- Qualifiers were standardized to the extent possible. For the most part, this consisted of changing "<" signs to "U," and interpreting laboratory-assigned qualifiers. Where this information is unavailable or has yet to be obtained, original qualifiers have been maintained. In those data sets where multiple qualifiers are available (laboratory qualifiers and validation qualifier), the multiple qualifiers have been merged to a single qualifier (i.e., "U" qualified from laboratory and "UJ" qualified by the validator = "UJ" qualified). When non-standard qualifiers where present in data received, the data provider was contacted and a list of qualifiers and definitions was requested. Qualifiers where standardized accordingly. The original qualifiers received in the import file are maintained in the "qual_old" field of the FRDB.

- All sample dates were standardized to one common data format where possible: mm/dd/yyyy.

- The media field was populated using a standard list of sample matrices: ambient air, pore water-sediment, sediment, tissue, or water.

- The species (common name) was standardized. For example, Northern Pike was also listed as N. Pike, northern pike, and Northern pike. The most accurate descriptor was chosen and all permutations were changed to match.

- The sample type (whole body, surface sediment, fillet skin-on) was standardized.

- Sample depth was standardized to measurement in centimeters. For some sediment samples, the sampling depth was included in the sample identification. This information was moved to the "depthfrom" and "depthto" fields in the database. Units of measurement were placed in the "depthunits" field.

Beyond the standardization process, information was added to delivered data sets in order to provide unique information where required, and to enable grouping of information (by location, analysis type, etc.) in support of the RI/FS or RA.

- Unique sample identifiers (IDs) were generated for samples that did not have a single unique identifier. Tissue samples generated by different researchers often had identical sample IDs. In these cases, a letter in parenthesis was appended to the original sample ID to indicate the researcher [(P) - Patnode data, (S) - Stromberg data, etc.]. In other cases, multiple researchers used an identical counting scheme to identify samples, based on the year and the numerical sample count (i.e., the first sample in 1995 was 95001, the second was 95002). In cases where more that one researcher collected samples in this manner, the samples were identified as 95001a, 95001b, and so forth. Water samples were often analyzed as filtered and unfiltered, or filtered and particulate. When such samples had similar sample IDs, a (U) – unfiltered, (F) – filtered, or (P) – particulate was appended to the sample ID making it unique.

- Individual samples from various data sets were assigned location information to allow for spatial association to other data sets. All samples were assigned one of the following nine designations:

background or reference; Little Lake Butte des Morts; Appleton to Little Rapids; Little Rapids to De Pere; De Pere to Green Bay; Green Bay Zone 2 (2A & 2B); Green Bay Zone 3A; Green Bay Zone 3B; or Green Bay Zone 4. Descriptive location information and coordinate information were used to successfully associate 99.9 percent of the samples with one of the above areas. Where possible, samples collected on the upper stretch of the river were also associated with the deposit from which they were sampled.

- The "northing" and "easting" fields contain specific coordinate information provided by the originator of the data or WDNR based on original site mapping.

- The "lab" and "validator" fields were populated if the information was available.

- The spelling, case, and date format (where applicable) were standardized for the fields titled "Source," "Methodtype," "Group," "Group2," "Importfile," and "Timestamp."

- The following fields were populated if the information was provided: "labid," "date_recd," "date_ext," "detlimit," "sdg," "aliquot," "method," "blind_id," "sampler," "comment," "loc_description," and county." No standardization was applied to this information.

Tabular results of analysis for all data sets included in the FRDB are provided in Table 3-1.

The quality assessment of the historical data followed a stepwise approach. First, it was determined whether the data had been subjected to an independent third-party data validation. If the data were validated and the validation report or validation worksheets were available, they were reviewed. If the validation was determined to follow basic U.S. EPA quality assurance guidelines (at a minimum), the data were considered to be acceptable for use (useable) in the RI/FS and risk assessment decision-making process.

If the data were not validated or concurrence was not reached with the previous validation (and the QC results were available), a limited review was performed. All available documents were reviewed to determine what quality control measures were included and what data quality objectives (DQOs) were required. The measures of accuracy and precision were evaluated against either the control limits/DQOs in the QAPP, the method, the laboratory SOPs, or U.S. Environmental Protection Agency (EPA) National Functional Guidelines. QC elements such as sample duplicates, matrix spike/matrix spike duplicates (MS/MSD), laboratory control sample/laboratory control sample duplicate (LCS/LCSD), and field duplicates were acceptable measures of precision. QC elements such as blanks, calibration standards (initial and continuing), surrogates, MS/MSD, LCS/LCSD, and standard reference materials (SRMs) were acceptable measures of accuracy. A determination of the usability of the data was made from the findings of these reviews. The analysis of the available QA/QC elements for each data set are summarized in Table 3-2.

3.2 Data Sets

The reduced and standardized data sets were compiled in a working database for use in support of the ongoing RA and RI/FS. This interim database is essentially a large flat file, currently containing more than 450,000 records from 35 individual data sets. Each data set is discussed in the following subsections of this report.

3.2.1 1989–1990 Fox River Mass Balance Study and 1989–1990 Green Bay Mass Balance Study (GLNPO)

The 1989–1990 Fox River Mass Balance data were collected by WDNR along the length of the river in 1989 and 1990. The sediment and water matrices of this data set were received from WDNR in six spreadsheet files (1989-1.wks, 1989-2.wks, allsed.wks, basic-5.wks, deep-cor.wks, and gravity.wks). These spreadsheets contain polychlorinated biphenyl (PCB) congener and total PCB concentrations, as well as grain size and total organic carbon (TOC) information. Each file exists in a unique format and was transformed into a standard database format. These data represent 1,967 samples and 25,457 analytical records in the FRDB. Data management occurred during Stage 1 of the data collection process.

The Green Bay Mass Balance (GBMB) data are represented in their entirety in the files posted on the Great Lakes National Program Office (GLNPO) website. Several mass balance studies have been conducted by different regulatory agencies and groups. Consequently, there is a significant overlap of data which is considered "common" data within the different studies. Redundant data identified in the collective GLNPO set were segregated and removed prior to inclusion of the GLNPO data into the FRDB (2,069 samples and 201,701 records). Data management occurred during Stage 1 of the data collection process except for the phyto- and zooplankton fractions of the data. These data were originally omitted from the FRDB. During Stage 2 of the data collection and management process, these data were determined to be required for food chain models and were added to the FRDB.

Samples were analyzed and data were generated by eight different laboratories for the GBMB study. Seven of the laboratories performed PCB analyses; one laboratory performed metals analyses. Each of the seven laboratories analyzing samples for PCBs were required to analyze a series of 10 performance evaluation (PE) samples (of differing concentration levels) prior to analyzing samples for the study. The results of these PE sample analyses were available for review by EcoChem for four laboratories. A wide range of percent recovery (%R) values were reported (60% to 233%).

Prior to the study, each laboratory was given a copy of the document, *Quality Assurance Plan Green Bay Mass Balance Study - PCBs and Dieldrin*, which outlined general guidelines and data quality objectives. According to this document, data sets generated for the GBMB Study were reviewed and approved by the Green Bay Quality Assurance Coordinator (QAC) prior to the release of data. EcoChem, Inc. interviewed the GBMB QAC at the University of Minnesota in September 1998 regarding the data review procedures. It was determined from that meeting that the data were not fully validated. The review of the data consisted of verification of laboratory-generated QA/QC forms prior to data release. A formal comparison to any specific project DQOs was not made, thus no validation qualifiers were assigned to the data.

One participating laboratory, the Wisconsin State Laboratory of Hygiene (SLOH), was visited by EcoChem personnel who interviewed analysts and managers. Sample handling, preparation, and analysis systems were reviewed. In-depth discussions occurred concerning peak identification and quantitation. All hardcopy and electronic data are available and could be validated if requested. The disposition of the data and supporting information for the other labs is not known. Thus, it was determined that, in general, the data from the GBMB Study should be used as supporting data only. Refer to 2.2.18 for a discussion of the review of more recent data generated by SLOH.

3.2.2 1992–1993 BBL Deposit A Sediment Data

Sediment and water samples were collected in late 1992 and early 1993 by Blasland, Bouck and Lee (BBL) at Deposit A. The samples were analyzed for volatiles, semivolatiles, PCB Aroclor, pesticides, metals, and wet chemistry tests. Aroclor™ data was received during Stage 1 of the data management process, the other analyses during Stage 2. These data represent 117 samples in the FRDB and accounts for 1,094 data records.

EcoChem, Inc. conducted a full data validation of these data in 1999 (Stage 2). The samples were analyzed by Hazleton Environmental Services, Inc. in Madison, Wisconsin. Analytical data were reviewed using quality control criteria documented in the analytical method, National Functional Guidelines, and the project QAPP. Validation was performed on volatile, semivolatile, PCB as Aroclor™, pesticide, and metals data. Accuracy and precision were generally acceptable. Qualifiers were assigned by EcoChem due to blank contamination, calibration outliers, secondary column confirmation precision outliers, laboratory control sample outliers, MS/MSD outliers, surrogate outliers, laboratory duplicate results, and graphite furnace post-digestion spike recovery results. Data, as qualified by EcoChem, are acceptable for use. The Data Validation Report is included as Appendix A of this report.

3.2.3 1993 Triad Assessment

The Triad data were collected by WDNR from several sites and analyzed in 1992 and 1993. The data were received from WDNR in 11 spreadsheet files (joint.wb2, orgpest.wb2, rtrben.wb2, tables.wb2, toxicity.wb2, triad92.wb2, triad92b.wb2, triad93.wb2, triaddat.wb2, triadhis.wb2, and foxriver.wq1) during Stage 1 data collection. All data were represented in files triad92b and triad93, and were redundant in the rest of the files. These spreadsheets contain polynuclear aromatic hydrocarbon (PAH), metals, Aroclor™, chlorinated pesticide, invertebrate, and benthos data. These data represent 27 samples and 631 analytical records in the FRDB. The original Triad data were modified to create unique sample IDs. A designation of "(Tr)" was appended to the existing sample IDs to ensure uniqueness. Data management occurred during Stage 1 of the data collection process.

Samples collected for the Triad Study were submitted to several different laboratories for physical and chemical characterization. These laboratories include University of Wisconsin-Extension's Soil and Plant Analysis (particle size and soil texture analyses); the State Laboratory of Hygiene (bulk sediment chemistry); and Hazleton Laboratory (PAHs collected in 1993). Quality control data were not available for review; however, full data validation on SLOH data could be conducted if requested. As these data have not undergone full validation, these data should be used as supporting data only.

3.2.4 1994 GAS/SAIC Sediment Data

The Graef, Anhalt, Schloemer & Associates/Science Application International Corporation (GAS/SAIC) data were collected during late 1994 for the Fox River Coalition. This data set includes sediment data collected at several deposits above the De Pere dam. Samples were analyzed for PCB Aroclors™, chlorinated pesticides, volatile organics, semivolatile organics, metals, and dioxins. These data were delivered by WDNR in six files (clp_data.xls, cnv_data.xls, dxn_data.xls, hg_data.xls, pcb_data.xls, and frgrnsiz.xls). The GAS/SAIC data set consists of 253 samples that comprise 5,654 records in the FRDB. Data management occurred during Stage 1 of the data collection process.

Approximately 20 percent of the GAS/SAIC data was fully validated by SAIC. The remainder of the data underwent a cursory review that excluded verification of compound identifications and raw data calculation checks. This evaluation followed specified methods described in the November 1994 *Final Report Sampling and Analysis Plan, Fox River Remedial Investigation*. The data validation reports do not specifically address chain of custody records associated with the samples.

In the process of reviewing the initial PCB and pesticide data reported by the initial laboratory involved, SAIC found incorrect PCB quantitations, inconsistent pesticide identifications, consistently poor surrogate recoveries, retention time shifts, and overall poor quality of work associated with the pesticides/PCB data. Based on EcoChem's review, these data should be used as supporting data only.

PCB-only analyses (from archived samples) and dioxin analyses were performed later by Analytical Resources, Inc. and Triangle Laboratories. In general, precision and accuracy for these analyses were judged acceptable by SAIC. PCB results were qualified as estimated by SAIC due to continuing calibration verification percent difference exceedances and poor surrogate recoveries. The dioxin results received minor qualifications due to blank contamination and elevated matrix spike recovery values. These data, as qualified by SAIC, are acceptable for use.

3.2.5 1995 WDNR Sediment Data

The 1995 sediment collection was conducted by WDNR and consists of sediment data collected from below the De Pere dam. Samples were analyzed for PCB Aroclors™ and metals. These data were provided by WDNR in eight files (corelocs.xls, convdata.xls, 95sedata.xls, metals.xls, metals2.xls, pcbdata.xls, pcbdata2.xls, and sumdata.xls). The data set consists of 488 samples comprising 6,433 records. Data management occurred during Stage 1 of the data collection process.

Data validation was conducted by the M. A. Kuehl Company on approximately 20 percent of the 1995 De Pere data. The data validation reports were reviewed by EcoChem. Based on this evaluation, it was determined that the laboratory followed the specified methods described in the September 1995 *Quality Assurance Project Plan for Assessment of PCBs in Sediment of the Lower Fox River from De Pere to Green Bay*. Chain of custody records were reviewed, and they indicated that samples were received in good condition. These data, as qualified by M. A. Kuehl, are acceptable for use.

3.2.6 1996 FRG/BBL Sediment/Tissue Data

The 1996 BBL data set consists of 25 sediment and fish tissue samples collected for the Fox River Group (FRG). These samples were analyzed for PCB congeners and TOC. These data were provided by WDNR in six spreadsheet files (02771543.wq1, 02671543.wq1, 02571543.wq1, 03071543.wq1, 03171543.wq1, and 03271543.wq1) and comprise 2,771 records in the FRDB. Data management occurred during Stage 1 of the data collection process.

These data were validated by BBL to ensure that they met method quality control criteria and the project data quality objectives. No formal SAP or QAPP was issued prior to implementation of sample collection or analysis; however, BBL stated they used collection and analytical procedures that had been approved by U.S. EPA Region 5 for other projects. Samples were submitted to Inchcape Testing Services Laboratory of Vermont for chemical analysis. PCB results were not surrogate-corrected.

The memorandum written by BBL dated April 4, 1998, indicates that PCB and TOC data for sediment samples and PCB data for biota were reviewed. Chain of custody procedures were not documented by BBL in this *Data Quality Assessment Memorandum*. Qualifiers were applied to sediment and biota data because of quantitative confirmation differences, blank contamination, and surrogate and matrix spike outlier values. The data, as qualified by BBL, are acceptable for use.

3.2.7 1995–1996 WDNR Fish Tissue Data

The WDNR collected fish tissue samples along the length of the river in 1996. These data were provided by WDNR in a single, multiple-page spreadsheet (all_fish.wb1). Samples were analyzed for PCB Aroclors™ and TOC. This data set comprises 1,673 records in the FRDB and consists of 200 samples. Data management occurred during Stage 1 of the data collection process.

Data validation was performed by the M. A. Kuehl Company on 20 fish tissue samples collected by the WDNR in 1996. The data validation report for SDG-1 was reviewed by EcoChem. This data validation was performed using the specified methods described in the April 1996 *Addendum to the Quality Assurance Project Plan for Assessment of PCBs in Sediment of the Lower Fox River from De Pere to Green Bay for PCB Analysis of Fish Tissue*. Chain of custody records were reviewed and they indicated that samples were received in good condition. Precision and accuracy were judged to be acceptable by the M. A. Kuehl Company. PCB results were qualified because they were detected above the MDL but below the PQL. The data, as qualified by the M. A. Kuehl Company, are acceptable for use.

3.2.8 1996–1999 USFWS NRDA Fish Tissue Data

As part of the Natural Resource Damage Assessment (NRDA) investigation, the U.S. Fish & Wildlife Service (USFWS) collected and analyzed 376 tissue samples in 1996. Samples were collected below De Pere and in Green Bay. The samples were analyzed for PCB congeners or PCB Aroclors™ and TOC. The USFWS NRDA data represents 16,017 records in the FRDB and was provided by the USFWS in a single file (pcbsecd.dbf.) Data management occurred during Stage 1 of the data collection process.

A full data validation was conducted by EcoChem on 376 tissue samples analyzed for the Green Bay NRDA project. This data validation was performed based on the specified method criteria described in the Battelle Laboratory SOP, *Identification and Quantitation of Polychlorinated Biphenyls (by Congener and Aroclor™) and Chlorinated Pesticides by Gas Chromatography/Electron Capture Detection*. Accuracy and precision were generally acceptable. Qualifiers were assigned by EcoChem due to blank contamination, continuing calibration verification percent difference outliers, blank spike results, surrogate outliers, laboratory duplicate results, reference material recovery results, and chromatographic interferences. Data, as qualified by EcoChem, are acceptable for use.

3.2.9 1997 USFWS NRDA Waterfowl Tissue Data, 1994–1995 Cormorant Data, and 1993 USFWS Tree Swallow Data

Results from waterfowl tissue sample analyses were provided by USFWS in two files (tcuster2.mdb and tcuster2.wpd). The samples were analyzed for chlorinated pesticides. This data set consists of 70 samples and 1,680 analytical data points.

Results from cormorant tissue sample analyses were provided by USFWS in two files (tcuster1.mdb and tcuster1.wpd). The samples were analyzed for PCB Aroclors™, chlorinated pesticides, and dioxins. This data set consists of 193 samples and 6,178 analytical data points.

Results from tree swallow tissue sample analyses were provided by the USFWS in two files (ccuster.mdb and ccuster.wpd). The samples were analyzed for PCB congeners, chlorinated pesticides, and dioxins. This data set consists of 200 samples and 5,429 analytical data points. Data management for all data types occurred during Stage 1 of the data collection process.

Three electronic text files were reviewed by EcoChem for data validation information regarding these data sets. Files reviewed include 1997 waterfowl data from Green Bay and Lake Michigan (tcuster1.wpd), 1994 through 1995 double-crested cormorants data from Green Bay (tcuster2.wpd), and Fox River and Green Bay 1993 through 1995 Tree Swallow Study (ccuster.wpd). Of these three documents, one (tcuster1.wpd) gives a brief synopsis of field sampling and chemical analysis procedures used to collect and analyze the samples. The information provided did not specifically address chain of custody records associated with the samples. No qualifiers were assigned based on this review although the statement "concentrations of PCB 118 may be overestimated because of coelution with PCB 106" may be considered a qualification. With regards to quality assurance and quality control approval, a reference is made to the Patuxent Analytical Control Facility (Patuxent) of USFWS, Laurel, Maryland. It is not clear from this statement if Patuxent established the quality control criteria, approved the method of analysis, or reviewed the results of the study. For these reasons the data should be used only as supporting data.

3.2.10 Fox River Fish Consumption Advisory Data

The initial fish contaminant data in the FRDB represents tissue samples collected by WDNR in the Fox River and Green Bay between 1971 and 1996 were addressed as part of the Stage 1 effort. These samples were analyzed for

PCB congeners, PCB Aroclors™, metals, chlorinated pesticides, and dioxins. The FRDB contains 1,766 samples from the fish contaminant study comprising 11,620 records. This data set is primarily tissue data with a small number of sediment samples. Data management occurred during Stage 1 of the data collection process. A second delivery of 1998 fish contaminant data (tissue) was received during Stage 2 data collection. These data represent 130 samples and 777 data records in the FRDB and was conducted during Stage 2 of the data management process.

In 1995, the M. A. Kuehl Company conducted a laboratory audit at the Wisconsin SLOH. The purpose of this audit was to assess the laboratory capability to analyze tissue and sediment samples for PCB, TOC, and metals. Although she made a few observations and had a few findings, Ms. Kuehl found the laboratory to be capable of performing the requested analyses. The Wisconsin SLOH was also visited by EcoChem personnel, and analysts and managers were interviewed. Sample handling, preparation, and analysis systems were reviewed. In-depth discussions occurred concerning peak identification and quantitation. All hardcopy and electronic data are available, and could be fully validated if requested. As these data have not undergone full validation, these data should be used as supporting data only. Refer to Section 2.2.1 for further discussion of data generated by SLOH and refer to 2.2.18 for a discussion of the review of more recent data generated by SLOH.

3.2.11 WDNR Wildlife Tissue Data

This data set is a collection of wildlife tissue sample data collected by WDNR during the time period from 1984 to 1996 and collated in three files (all.db, geese.db, and ducks.db). The data set represents bird and mammal tissue samples analyzed for chlorinated pesticides. This data set contains 417 samples and 2,532 analytical data points. Data management occurred during Stage 1 of the data collection process.

Quality control information was not available, therefore these data should be used as supporting data only.

3.2.12 Lake Michigan Tributary Monitoring Data

The Lake Michigan Tributary Monitoring samples from the Fox River were collected by the U.S. Geological Survey (USGS) in support of the Lake Michigan Mass Balance Study, administered by the U.S. EPA's GLNPO. These water samples were analyzed for PCB congeners, chlorinated pesticides, and mercury. This data set consists of 88 samples and 5,722 analytical data points. Data management occurred during Stage 1 of the data collection process.

These data were validated by the M. A. Kuehl Company, and these data are considered useable, as qualified.

3.2.13 Stromberg Eagle Data

Eagle samples were collected for the USFWS under the direction of Ken Stromberg between 1991 and 1996. The data were provided by the USFWS in a text file report (strmbrg.wpd) and required manual extraction point by point. The samples were analyzed for PCB congeners, chlorinated pesticides, and dioxins. This data set contains 31 samples and 954 analytical data points. Data management occurred during Stage 1 of the data collection process.

Quality control information was not available, therefore these data should be used as supporting data only.

3.2.14 USGS NAWQA Data

The National Ambient Water Quality Assessment Program (NAWQA) data represent samples collected by the USGS between 1992 and 1997. There are 441 samples of sediment, water, and tissue. These samples were analyzed for an extensive list of chlorinated pesticides and herbicides, organophosphorus pesticides, semivolatile, and metallic analytes. These data were provided by the USGS in 21 files with additional information obtained on the NAWQA website. These sample analyses represent 11,879 records in the FRDB, approximately 90 percent of which is from waterways other that the Fox River and is noted as "reference." Data management occurred during Stage 1 of the data collection process.

Of the 441 environmental samples collected between 1992 and 1997, approximately 15 percent were quality control samples collected concurrently during field sampling activities. Types of quality control samples collected include field blanks and trip blanks for surface water and groundwater matrices, and field replicates and splits for all matrices. Surface water and groundwater samples were spiked to assess precision and accuracy of the volatile and pesticide methods. Surrogates were added to all environmental samples undergoing pesticide, volatile, and other trace organic analyses.

The results of the quality control samples were reviewed by the USGS NAWQA group and were reported in the USGS Water-Resources Investigations Report 97-4148, *Results of Quality-Control Sampling of Water, Bed Sediment, and Tissue in the Western Lake Michigan Drainages Study Unit of the National Water-Quality Assessment Program*. All results were found to be acceptable by NAWQA. Accuracy was generally acceptable, as demonstrated by the percent recovery values of the surrogate and matrix spike values. Precision was generally acceptable, as demonstrated by the relative percent difference values of the sample duplicates. While thorough investigations, and in some cases corrective actions, were performed to explain quality control anomalies (e.g., blank contamination, occasional poor spike recovery values, and possible interferences causing bias), no qualifiers were applied directly to the analytical results. In summary, the data user should refer to this report when using these data to gain a complete understanding of its limitations. As the content of the data packages is not known, the data may or may not be amenable to independent validation. For the reasons mentioned above, the NAWQA data should be used as supporting data only.

3.2.15 1994 Woodward-Clyde Deposit A Sediment Data

Sediment samples were collected by Woodward-Clyde in 1994 at Deposit A. These samples were analyzed for PCB Aroclors™ and TOC. They were provided by WDNR in 12 files, only one of which contained analytical data (pcb_to~1.xls). This data set contains 66 samples and represents 585 records in the FRDB. Data management occurred during Stage 1 of the data collection process.

A limited data validation was conducted by EcoChem (September 1998) on these data for the Little Lake Butte des Morts (LLBdM) Deposit A project. This data validation was performed using the specified methods described in the August 1994 *Quality Assurance Project Plan (QAPP) for the Pre-Design Study on Little Lake Butte des Morts*. It should be noted that the specific procedures to be used for data validation (Sections 2 and 9 of the QAPP) were slightly modified to account for differences in laboratory deliverables. For instance, holding times could not be assessed since chain of custody forms were not provided and a case narrative describing any deviations from proposed analysis was not provided. Accuracy was generally acceptable, as demonstrated by the percent recovery values of the surrogate, and matrix/blank spikes. Precision was generally acceptable, as demonstrated by the relative percent difference values of the sample and laboratory duplicates. Qualifiers were assigned by EcoChem due to poor matrix spike recovery values. Based on this limited review, all data, as qualified by EcoChem, are acceptable for use.

3.2.16 WPDES Permit Influent Data

Influent water samples along the Fox River were collected by various entities (commercial and governmental) as part of the Wisconsin Pollutant Discharge Elimination System (WPDES) regulatory program, then analyzed for various fractions by WDNR-certified laboratories. These data were provided by WDNR in a spreadsheet and consist of samples collected in 1993 and 1997. These data do not adhere to a regular sampling schedule and were provided as supplemental water quality data. These data do not have associated QA/QC data, as the samples were not collected for an RI/FS-type activity. This data set consisted of eight samples and 847 records. Data management occurred during Stage 1 of the data collection process.

As QC information was not available, these data should be used only as supporting data.

3.2.17 Lower Fox River Background Metals Assessment

These data were collected from 1991 to 1993 and consist of 14 samples and 78 records in the FRDB. Data management occurred during Stage 1 of the data collection process.

Raw data and accompanying quality control information were not available for review. The data should be used only as supporting data.

3.2.18 1997 WDNR Caged Fish Bioaccumulation Study Data

WDNR placed caged fish near the demonstration projects conducted at Deposit N and SMU 56/57 prior to the initiation of the projects. The fish and collocated sediment samples were collected and analyzed for PCB congeners by the Wisconsin SLOH (for more discussion of SLOH, see Section 2.2.1). This data set consists of 25 samples and 1,672 records in the FRDB. Data management occurred during Stage 1 of the data collection process.

At the request of WDNR, select sediment and fish tissue data from this study were reviewed to show the quality of the older data (e.g., Green Bay Mass Balance) was consistent with that of the new data sets. The data packages from the laboratory consisted of strip charts containing the chromatograms and associated instrument printouts of the standards, QC sample results, and field sample results. Data packages summarizing calibration and other ancillary QC results (as provided under the EPA Contract Laboratory Program) were not available from the laboratory. The samples were analyzed using the protocol outlined in the *Quality Assurance Plan* (QAP), *Green Bay Mass Balance Study* (March 11, 1988). The data were reviewed using the criteria listed in the QAP and the *U.S. EPA National Functional Guidelines for Organic Data Review* (February 1994).

Overall, these sets of data met the QC criteria as specified in the QAP. Although not assigned in this review, qualifiers could be assigned due to surrogate and matrix spike outliers indicating the potential for high bias. It is unlikely that any data would be rejected.

As determined by this review, these data should be used as supporting data. Refer to Sections 2.2.1 and 2.2.10 for further discussion of data generated by SLOH.

3.2.19 1997 Demonstration Project Data – Deposit N

Sediment, water, and wipe samples were collected by Foth & Van Dyke from Deposit N. The environmental samples were analyzed for PCB Aroclors™, mercury, and TOC. This data set contains 10 samples and represents 83 records in the FRDB. Data management occurred during Stage 2 of the data collection process.

Full data validation was conducted by the M. A. Kuehl Company on approximately 10 percent of the 1997 Fox River Deposit N data (PCBs and mercury). A limited data review was conducted on the remainder of the data (PCBs, mercury, and TOC). Results of this evaluation indicate that the laboratory followed the specified methods described in the October 1997 *Fox River Deposit N Removal Project Pre-Design Phase Quality Assurance Project Plan*. Chain of custody documentation, although not referred to directly by M. A. Kuehl's December 26, 1997 *Technical Memorandum - Data Validation for Fox River Deposit N*, was acceptable (report mentions discrepancies only). PCB data were qualified due to holding time exceedances and poor matrix spike recovery. No qualifiers were assigned to the TOC and mercury data. Matrix spike and lab duplicates were not performed on water samples submitted for PCB analysis due to insufficient sample volumes. No action was taken because the laboratory performed alternative QC measures (control spikes) with acceptable recoveries. The data, as qualified by M. A. Kuehl, are acceptable for use.

3.2.20 1997–1998 Demonstration Project Data – SMU 56/57

Sediment samples were collected in late 1997 and early 1998. Montgomery Watson and Harrington Engineering & Construction implemented a sediment removal demonstration project at SMU 56/57 on behalf of the WDNR. The environmental samples were analyzed for a full suite of parameters that included PCB Aroclors™, mercury, and TOC. This data set contains 295 samples and represents 3,114 records in the FRDB. Data management occurred during Stage 2 of the data collection process.

Data validation was performed by Montgomery Watson on over 100 analytical batches of data collected at SMU 56/57 in 1997 and 1998. Full data validation was performed on sediment PCB and mercury data and a limited data review was conducted on all other analytical parameters. The full data validation and limited review were performed using the specified methods described in the *Field Sampling Plan Pre-Design Investigation Sediment Management Unit 56/57 Sediment Removal Demonstration Project* and accompanying *Quality Assurance Project Plan* (May 1998) and *U.S. EPA Contract Laboratory Program National Functional Guidelines for Organic Analysis Review* (February 1994). Chain of custody documentation was not covered in the data validation or the review. Precision and accuracy were judged to be acceptable by Montgomery Watson. PCB results were qualified as estimated by Montgomery Watson because PCBs were analyzed beyond holding times. Mercury results were qualified as estimated because matrix spike percent recovery values exceeded the control limit criteria. Results from other analytical methods were qualified for holding time exceedances (total Kjeldahl nitrogen results) and blank contamination (variety of conventionals analyses). Only the QC elements for the PCB and mercury sediment results were summarized in Table 3-2 due to the number of analytical tests performed on the effluent samples. Based on Montgomery Watson's limited review, the data are considered usable.

3.2.21 1998 RETEC RI/FS Supplemental Data

Supplemental sediment samples were collected from the Lower Fox River in June of 1998 by Remediation Technologies, Inc. (RETEC) for the WDNR. Samples were collected according to procedures outlined in the *Sampling and Analysis Plan and Quality Assurance Project Plan for Supplemental Data Collection, Fox River RI/FS*. This data set consists of 252 samples and 10,781 records in the FRDB. Data management occurred during Stage 1 of the data collection process.

A full data validation was conducted by EcoChem, Inc. (1998). Analytical data were reviewed using quality control criteria documented in the analytical method, National Functional Guidelines, and the project QAPP. Validation was performed on PCB, semivolatile, pesticide, metals, and conventional (TOC and total solids) data packages. Accuracy and precision were generally acceptable. Qualifiers were assigned by EcoChem due to holding time exceedances, blank contamination, continuing calibration verification percent difference outliers, lack of secondary column confirmation, blank and matrix spike outliers, surrogate outliers, laboratory duplicate results, and reference material recovery results. Data, as qualified by EcoChem, are acceptable for use.

3.2.22 Lake Michigan Mass Balance Data

The Lake Michigan Mass Balance samples were collected in 1994 and 1995. Sediment, water, tissue, and air samples were collected and were analyzed for PCB congeners, volatiles, pesticides/herbicides, metals, and wet chemistry tests. Electronic data were received on compact disc (CD) for 21 focus groups. This data set contains 6,987 samples and represents 91,621 records in the FRDB. Data management occurred during Stage 2 of the data collection process.

EcoChem, Inc. performed a review of the Lake Michigan Mass Balance (LMMB) Study QA program and assessed the quality of the data generated for the study. This evaluation of the quality assurance program included a review of the measurement quality objectives (MQOs), the *Lake Michigan Mass Balance (LMMB) Study QA and Data Management Workgroups Peer Review Meeting Briefing Book* (April 29–30, 1999), and the *Lake Michigan Mass Budget/Mass Balance Work Plan* (October 14, 1993). To clarify the QA process followed in this study, telephone interviews with several LMMB Study participants were conducted. Third-party review of the data was not performed, nor were raw data available for this review. Thus, the quality of the data was judged on the assumption that the QA program and the MQOs were met. Although the data were not reviewed by an independent third-party, sufficient information was available about the QA program to render a judgment on the probable usability of the data. The samples were analyzed for PCB congeners, pesticides, metals, atrazine, nutrients, conventionals, various biological measurements, lead 210 and cesium 137.

The samples were analyzed by reputable commercial and academic/research laboratories that were audited prior to sample analysis and again during sample analysis by the program QA personnel and by the U.S. EPA. The MQOs that were followed by the academic/research laboratories were different than those employed under the U.S. EPA Contract Laboratory Program (CLP); the U.S. EPA *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, 3rd Edition* (as updated); or the *U.S. EPA National Functional Guidelines* (NFG) *for Organic Data Review* (February 1994) and *U.S. EPA National Functional Guidelines for Inorganic Data Review* (February 1994). For instance, the acceptability of the initial calibration, as specified by NFG, is measured by a correlation coefficient (r). The correlation coefficient must be greater than or equal to 0.995 (or $r^2 \geq 0.990$). For the congener analyses of the samples in this study, the criterion for several laboratories was that r^2 must be greater than or equal to 0.95. The criteria for this study used by each laboratory were approved by the U.S. EPA. However, because the QC criteria are different from NFG, the precision and accuracy may differ from that of the data sets collected using NFG. Because of this, the data should be considered as supporting data only. Although it is likely that some data would be estimated if the data were reviewed by an independent third party using the U.S. EPA NFG criteria, it is unlikely that any data would be rejected.

3.2.23 Minergy Mineralogical Data

The Minergy data are comprised of results from the analysis of 15 sediment samples for 11 different mineral oxides, sulfur, chloride, and two different loss on ignition (LOI) procedures. Two hundred nineteen (219) analytical records were generated. Data management occurred during Stage 2 of the data collection process. The Mineral Lab analyzed the samples for mineral oxides, sulfur, and chloride. Badger Laboratories & Engineering performed the loss on ignition procedure.

EcoChem, Inc. performed a review of the Minergy site data generated for the study. The evaluation of the quality control elements with these analyses included telephone interviews with personnel at each laboratory. Third-party review of the data was not performed, nor were raw data available for this review. Thus, the quality of the data was judged solely on the information obtained during the telephone interviews. Although the data were not reviewed by an independent third party, sufficient information was available about the QA program to render a judgment on the probable usability of the data.

Based on the information received during the telephone interview with Badger Laboratories and Engineering, the LOI data are usable as reported.

Based on the information received during the telephone interview with The Mineral Lab, the mineral oxide, sulfur, and chloride data should be considered as estimated. The data users should be aware that these data may be potentially biased. The mineral oxide, sulfur, and chloride data should be considered as supporting data only; it is unlikely that any data would be rejected during a full validation.

3.2.24 1998 FRG/Exponent Data

Exponent collected tissue samples in the summer of 1998 for the Fox River Group (FRG). Samples were collected from Little Lake Butte des Morts to Green Bay Zone 3 and were analyzed for PCB congeners and PCB Aroclors™, pesticides/herbicides, metals, and wet chemistry tests. The data set contains

225 samples that account for 17,708 records in the FRDB. Data management occurred during Stage 2 of the data collection process.

EcoChem performed a review of the FRG 1998 data validation reports authored by Exponent, Inc. EcoChem evaluated the validation reports for completeness and technical agreement. To clarify some of the findings, raw data were reviewed. The samples were analyzed by U.S. EPA SW-846 methodology and other miscellaneous EPA methods. The data were validated by BBL using the *U.S. EPA National Functional Guidelines for Organic Data Review* (February 1994); *U.S. EPA National Functional Guidelines for Inorganic Data Review* (February 1994), and *Lower Fox River System NRDA Quality Assurance Project Plan* (December 1998).

Overall, the data are of acceptable quality. The samples were analyzed and validated as specified in the QAPP. A more detailed review of the data would result in additional qualifiers being assigned. As determined by this review, the data, as qualified, are usable for the intended purpose.

3.2.25 1998 FRG/BBL Sediment/Tissue Data

BBL collected tissue, sediment and water samples in 1998 for the FRG. Samples were analyzed for semivolatiles, PCB congeners and PCB Aroclors™, pesticides/herbicides, radchem, metals, and wet chemistry tests. The data set contains 1,315 samples that account for 18,824 records in the FRDB. Data management occurred during Stage 2 of the data collection process.

EcoChem performed a review of the FRG 1998 data validation reports authored by BBL. EcoChem evaluated the validation reports for completeness and technical agreement. To clarify some of the findings, raw data were reviewed. The samples were analyzed by U.S. EPA SW-846 methodology and other miscellaneous EPA methods. The data were validated by BBL using the *U.S. EPA National Functional Guidelines for Organic Data Review* (February 1994), *U.S. EPA National Functional Guidelines for Inorganic Data Review* (February 1994), and *Lower Fox River System NRDA Quality Assurance Project Plan* (December 1998).

Overall, the data are of acceptable quality. The samples were analyzed and validated as specified in the QAPP. In some cases, criteria from NFG, rather than the analytical method criteria, were used to evaluate the data. A more detailed review of the data would result in additional qualifiers being assigned. It is unlikely that any more data would be rejected. As determined by this review, the data, as qualified, are usable for the intended purpose.

3.2.26 1998–1999 Deposit N Data: Remediation/Pre-Dredge/Post-Dredge/Operational Monitoring

Data for the Deposit N pilot remediation project was received in four sections: pre-dredge data, post-dredge data, operational monitoring data, and sediment remediation (environmental monitoring) data. Collectively, sediment, tissue, and water samples were collected and analyzed for PCB Aroclors™, PCB congeners, metals, and wet chemistry tests. The Deposit N pilot remediation data represents 305 samples and accounts for 12,514 records in the FRDB. Data management occurred during Stage 2 of the data collection process.

EcoChem performed a review of the data validation reports authored by the M. A. Kuehl Company. EcoChem evaluated the validation reports for completeness and technical agreement. To clarify some of the findings, raw data were reviewed.

The samples were analyzed by U.S. EPA SW-846 methodology. The data were validated using the Region 5 Modifications to *U.S. EPA National Functional Guidelines for Organic Data Review* (February 1994), *U.S. EPA National Functional Guidelines for Inorganic Data Review* (February 1994), and the *Fox River Group Deposit N Demonstration Project Quality Assurance Project Plan* (1998).

Overall, the data are of acceptable quality. The samples were analyzed and validated as specified in the QAPP. A more detailed review of the data would result in additional qualifiers being assigned in some cases and qualifiers being removed in others. It is unlikely that any more data would be rejected. As determined by this review, the data, as qualified, are usable for the intended purpose.

3.2.27 Ankley and Call Data

EcoChem conducted a data entry process on data presented in the *Sediment Quality Evaluation in the Lower Fox River and Southern Green Bay of Lake Michigan Report*. A second party verified the data entry. These data represent 62 individual samples and comprises 1,607 records in the FRDB. Data management occurred during Stage 2 of the data collection process.

EcoChem did not conduct any data quality assessment on these data. The quality of the data is therefore indeterminate.

3.2.28 State of Michigan Fish Consumption Advisory Data

The State of Michigan Fish Consumption Advisory data included in the FRDB are the results of fish tissue samples collected between 1983 and 1999. The samples were from Green Bay zones 3A and 4, as well as from tributaries flowing into Green Bay. The samples were analyzed for PCB Aroclors™, pesticides/herbicides, dioxins, metals, and wet chemistry tests. The data represents 434 samples and accounts for 6,979 records in the FRDB. Data management occurred during Stage 2 of the data collection process.

At the request of the WDNR, EcoChem performed a review of the FRG 1998 data validation reports authored by Exponent, Inc. See Table 3-1 for a listing of reports and samples. EcoChem was to evaluate the validation reports for completeness and technical agreement. To clarify some of the findings, raw data were reviewed.

The samples were analyzed by U.S. EPA SW-846 methodology and other miscellaneous EPA methods. The data were validated by BBL using the *U.S. EPA National Functional Guidelines for Organic Data Review* (February 1994), *U.S. EPA National Functional Guidelines for Inorganic Data Review* (February 1994), and *Lower Fox River System NRDA Quality Assurance Project Plan* (December 1998).

Overall, the data are of acceptable quality. The samples were analyzed and validated as specified in the QAPP. A more detailed review of the data would result in additional qualifiers being assigned.

As determined by this review, the data are usable for the intended purpose.

3.2.29 1999 Demonstration Project Data – SMU 56/57

These data are in the process of being appended to the database.

At the request of the WDNR, EcoChem performed a review of the FRG data validation reports for the 1999 SMU 56/57 and Deposit N demonstration projects authored by the M. A. Kuehl Company.

The samples were analyzed according to U.S. EPA SW-846 methodology. The data were validated using *U.S. EPA Region 5 Standard Operating Procedure for Validation of CLP Organic Data* (February 1997), *U.S. EPA National Functional Guidelines for Organic Data Review* (February 1994), *U.S. EPA National Functional Guidelines for Inorganic Data Review* (February 1994), *Draft Quality Assurance Project Plan Environmental Monitoring of SMU 56/57 Demonstration*

Project – Mass Balance Approach, Revision I (August 1999), and the *Draft Quality Assurance Project Plan Monitoring of Deposit N Demonstration Project – Mass Balance Approach* (December 1998).

Overall, the data are of acceptable quality. The samples were analyzed and validated as specified in the QAPP. A more detailed review of the data would result in additional qualifiers being assigned in some cases. It is unlikely that any more data would be rejected. As determined by this review, the data are usable for the intended purpose. No further review is recommended at this time.

3.3 Data Usability

3.3.1 Fully Validated Data

The following data sets have been validated by an independent party and are considered useable, as qualified:

- 1994 GAS/SAIC Sediment Data;
- 1994 Woodward-Clyde Deposit A Sediment Data;
- 1995 WDNR Sediment Data;
- 1996–1999 USFWS NRDA Fish Tissue Data;
- 1995–1996 WDNR Fish Tissue Data;
- 1997–1998 Demonstration Project Data – SMU 56/57;
- 1998 RETEC RI/FS Supplemental Data;
- 1996 FRG/BBL Sediment/Tissue Data;
- 1997 Demonstration Project Data – Deposit N;
- 1992–1993 BBL Deposit A Sediment Data;
- 1998 FRG/Exponent Data;
- 1998 FRG/BBL Sediment/Tissue Data;

- 1998–1999 Deposit N Data: Remediation/Pre-Dredge/Post-Dredge/Operational Monitoring;
- 1999 Demonstration Project Data – SMU 56/57;
- State of Michigan Fish Consumption Advisory Data; and
- Lake Michigan Tributary Monitoring Data.

Although the data sets (listed above) were found to be validated and useable, it must be stressed that there were individual data points that were rejected. These rejected data points have not been used in support of the RI/FS or RA.

3.3.2 Supporting Data

The following data sets have not been validated and, in general, should be used only as supporting data. The data have been collected within different programs and with different data quality objectives therefore, varying degrees of supporting documentation may be available.

- 1989–1990 Fox River Mass Balance Study,
- 1989–1990 Green Bay Mass Balance Study (GLNPO),
- 1993 Triad Assessment,
- 1993 USFWS Tree Swallow Data,
- 1994–1995 Cormorant Data,
- 1997 USFWS NRDA Waterfowl Tissue Data,
- 1997 WDNR Caged Fish Bioaccumulation Study Data,
- Fox River Fish Consumption Advisory Data,
- Stromberg Eagle Data,
- USGS NAWQA Data,
- WDNR Wildlife Tissue Data,
- WPDES Permit Influent Data,
- Lake Michigan Mass Balance Data,
- Minergy Mineralogical Data, and
- Lower Fox River Background Metals Assessment.

3.3.3 Indeterminate Data

The following data sets have not been validated and have not been subjected to a data quality review. This is due to complete lack of supporting QA/QC documentation; or, the hardcopy data and documents were not received by

EcoChem by the date of this report. At this time, the overall quality of these data sets is unknown and the data should be used with that fact in mind.

- Ankley and Call Data

Table 3-1 Data Set Analysis

Data Source	Number of Samples	Matrices[1]	Analyses Conducted[2]	Number of Records	Number of Files in Delivery	File Type	Report Section	Earliest Year of Collection	Latest Year of Collection
1989–1990 Fox River Mass Balance Study	1,967	S, W	PCB-A, PCB-C, W	25,457	6	Spreadsheet	2.2.01	1989	1990
1989–1990 Green Bay Mass Balance Study (GLNPO)	2,069	S, T, W	B, PCB-C, W	201,701	92	Database	2.2.01	1987	1990
1992–1993 BBL Deposit A Sediment Data	117	S, W	M, P/H, PCB-A, SVOA, V, W	1,094	1	Spreadsheet	2.2.02	1992	1993
1993 Triad Assessment	27	S	B, M, P/H, PCB-A, SVOA, W	631	11	Spreadsheet	2.2.03	1992	1993
1993 USFWS Tree Swallow Data	200	T	B, DXN, P/H, V, W	5,429	2	Database	2.2.09	1993	1993
1994 GAS/SAIC Sediment Data	253	S	DXN, M, P/H, PCB-A, SVOA, V, W	5,654	6	Spreadsheet	2.2.04	1994	1994
1994 Woodward-Clyde Deposit A Sediment Data	66	S	PCB-A, W	585	12	Spreadsheet	2.2.15	1994	1994
1994–1995 Cormorant Data	193	T	B, DXN, P/H, PCB-C, W	6,178	2	Database	2.2.09	1994	1995
1995 WDNR Sediment Data	488	S	M, PCB-A, W	6,433	8	Spreadsheet	2.2.05	1995	1995
1996 FRG/BBL Sediment/Tissue Data	25	S, T	B, PCB-C, W	2,771	6	Spreadsheet	2.2.06	1996	1996
1995–1996 WDNR Fish Tissue Data	200	T	B, PCB-A, W	1,673	1	Spreadsheet	2.2.07	1995	1996
1997 Demonstration Project Data - Deposit N	10	S	M, PCB, W	83	1	Spreadsheet	2.2.19	1997	1997
1997–1998 Demonstration Project Data - SMU 56/57	295	S, W	DXN, M, P/H, PCB-A, SVOA, V, W	3,114	12	Spreadsheet	2.2.20	1997	1998
1997 USFWS NRDA Waterfowl Tissue Data	70	T	B, P/H, PCB, V, W	1,680	2	Database	2.2.09	1997	1997
1997 WDNR Caged Fish Bioaccumulation Study Data	25	S, T	B, PCB-C, W	1,672	2	Spreadsheet	2.2.18	1997	1997
1998 FRG/BBL Sediment/Tissue Data	1,315	S, T, W	B, M, P/H, PCB-A, PCB-C, RAD, SVOA, W	18,824	1	Database	2.2.25	1998	1998
1998–1999 Deposit N Data: Post-Dredge	43	S	PCB-A, PCB-C, W	690	8	Spreadsheet	2.2.26	1999	1999
1998–1999 Deposit N Data: Pre-Dredge	53	S	PCB-A, PCB-C, W	1,437	6	Spreadsheet	2.2.26	1998	1998
1998 FRG/Exponent Data	225	T	B, M, P/H, PCB-A, PCB-C, W	17,708	3	Database	2.2.24	1998	1998
1998 RETEC RI/FS Supplemental Data	252	S, T	B, DXN, M, P/H, PCB-A, PCB-C, SVOA, V, W	10,781	1	ASCII	2.2.21	1998	1998
Fox River Fish Consumption Advisory Data: 1998 WDNR Fish Consumption Data	130	T	B, M, PCB-A, W	777	1	ASCII	2.2.10	1998	1998
1998–1999 Deposit N Data: Remediation Data	197	T, W	PCB-C, W	10,264	1	Spreadsheet	2.2.26	1998	1999
Ankley and Call Data	62	PW, S, T, W	DXN, M, P/H, PCB, SVOA, W	1,607	0	Hardcopy	2.2.27	1989	1989
1998–1999 Deposit N Data: Operational Monitoring Data	12	S	M, PCB-A, W	123	1	Spreadsheet	2.2.26	1998	1998
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	2.2.10	1971	1996
State of Michigan Fish Consumption Advisory Data	434	T	B, DXN, M, P/H, PCB-A, W	6,979	1	Database	2.2.28	1983	1999
Lake Michigan Mass Balance Data	6,987	A, S, T, W	M, P/H, PCB-C, V, W	91,621	211	Database	2.2.22	1993	1996
Lake Michigan Tributary Monitoring Data	88	W	M, P/H, PCB-C, V	5,722	5	Spreadsheet	2.2.12	1994	1995
Lower Fox River Background Metals Assessment	14	W	M	78	1	Spreadsheet	2.2.17	1991	1993
Minergy Mineralogical Data	15	S	W	219	1	Spreadsheet	2.2.23	1995	1999
Stromberg Eagle Data	31	T	B, DXN, P/H, PCB-A, PCB-C, SVOA, V, W	954	1	ASCII	2.2.13	1991	1996
1996–1999 USFWS NRDA Fish Tissue Data	376	T	DXN, P/H, PCB-A, PCB-C, W	16,017	5	Spreadsheet	2.2.08	1996	1999
USGS NAWQA Data	441	S, T, W	B, M, P/H, PCB, SVOA, V, W	11,879	21	Spreadsheet	2.2.14	1992	1997
WDNR Wildlife Tissue Data	417	T	B, M, P/H, PCB-A	2,532	3	Database	2.2.11	1984	1996
WPDES Permit Influent Data	8	W	B, DXN, M, P/H, PCB-A, RAD, SVOA, V, W	847	1	Spreadsheet	2.2.16	1993	1997
Total: 35 Data Sets	**18,871**			**474,834**	**438**				

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

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

Table 3-2 QC Elements for Data Sets Supporting the Fox River RI/FS and RA

Parameters: Requirements	1989–1990 Green Bay Mass Balance Study (GLNPO) PCBs Sediment	1995–1996 WDNR Fish Tissue Data PCB Fish Tissue	1996 USFWS/ Hagler Bailly Data PCB Fish Tissue	1995 WDNR Sediment Data PCBs Sediment	1995 WDNR Sediment Data TOC Sediment	1995 WDNR Sediment Data Metals Sediment
SDG #s	University of Minnesota - Data groups: IN0042, IN0047, IN0052, IN0057, IN0061, IN0070, IN0076, IN0078, IN0037, and IN0041	SLOH Fish SDG-1	Battelle Laboratory Multiple SDGs	Hazleton SDG #s TBD2, 10, 1 & 20	Hazleton SDG #s TBD2, 10, 1 & 20	Hazleton SDG #s TBD2 & 20
Data Review						
1) Third-party Validation Performed	Verification Only Deborah Swackhamer, Ph.D.	M. A. Kuehl Co.	EcoChem	Y - M. A. Kuehl	Y - M. A. Kuehl	Y - M. A. Kuehl
Deliverables						
1) Electronic Deliverables	Y	Y	Y	Y	Y	Y
2) Hardcopy	Some - Not sure if this is a complete set	Y	Y	Some	Some	Some
Data Review Details						
1) Package Completeness	Not determined	Y	Y	Y	Y	Y
2) Chain of Custody Procedures	Not determined	Not determined	Y - Minor issues	Not determined	Not determined	Not determined
3) Holding Times	Not summarized on the QA/QC Summary Report Sheet	Y	Y	Y	Y	Y
4) Initial Calibration	Not summarized on the QA/QC Summary Report Sheet	Y (25%)	Y (35%)	25%	Y	Y
Curve (# of standards)	Not summarized on the QA/QC Summary Report Sheet	5 pt	5 pt	5 pt	Daily 1 pt	1 pt/6 pt for Hg
5) Calibration Verification	Not summarized on the QA/QC Summary Report Sheet	15 %D	Varies between GC/ECD & GC/MS, <25% for 75% analytes	15%	20%	10% for metals & 20% for Hg
Secondary Column	Not summarized on the QA/QC Summary Report Sheet	25 %D	Y - Data not used	25 %D for CC on 2nd column	NA	NA
6) Laboratory Blanks	Not clear	Y	Y	Y	Y	Y
7) Surrogate Recoveries (# required)	Y - 50%–120%	Y - 70%–120%	Y - 50%–125%	60%–150%	NA	NA
8) Matrix Spike (# required)	Y - 50%–120%	Y - 65%–125%	Y - 50%–125% tri- & deca- 30%–125% for mono- & dichloro-	65%–125%	75%–125%	75%–125%
9) Lab Duplicate	Y - Not clear what limits are	Y - 26% limit	Y - 50%	26%	20%	20%
Lab Control Sample (SRM results?)	None/QAPP says that series of blindly-coded QA samples will be analyzed	N	SRM NRC %D Carp-1 <35%	NA	NA	Y - EPA
10) Gel Permeation/Forisil Cleanup	Not provided	Y	Not mentioned	Y	NA	NA
11) Detection Limit	Not provided	50 μg/kg	Results reported to 0	50 ppb	NA	CRDL
12) Calc and Transposition Verification (Qualitative verification?)	Not able to determine if this was done	Y - Recalc.	Y - Recalc. & verification	Y - Recalc. performed >10% frequency	NA	10%
13) Field QC Results	Not apparent	NA	None	None	None	None
14) Usability Usable/ Supporting	Y	Usable	Usable	Usable	Usable	Usable
Qualifiers	Qualifiers mentioned but not defined	Y - Minor J quals due to detections below PQL	Y - Quals due to CCV %D outliers, BS results, surr. outliers, lab dups., SRM results & inteferences	Y - Minor J flags due to low surr. recovery or below PQL and above MDL	Y - Minor J flags due to poor lab RPD	None
15) Other	NA					
IC Samples	NA			NA	NA	20%
SAP	N - Study Plan		N	Y		
QAPP	Y		Y - Tech Memo	Y		
Lab QAM	Answer Pending/U of M SOPs?	Y	Y - Tech Memo	Y - Hazleton SOPs		

Table 3-2 QC Elements for Data Sets Supporting the Fox River RI/FS and RA

	Lake Michigan Mass Balance Data	1998 Fox River NRDA				
Parameters: Requirements	Asst. Convs., Pest/PCB, Hg, Atrazine, DEA, DIA Water (open lake, tributary), Air, Sediment, Phytoplankton	PCB Fish Tissue	PCB Congener Fish Tissue	PCB Congener Fish Tissue	Pesticide Fish Tissue	Mercury Fish Tissue
SDG #s	BALN, GPLN, GRAN, GRLN, IUAA, IUAP, LHTL, LHTM, LHTN, LHTP, MDLH, MIAH, MNPH, RUAP, RULA, RUTA, SSSP, USTN, WSAA, WWTH, WWTN	Enchem Multiple SDGs	Michigan State University	Quanterra	Enchem Multiple SDGs	Enchem Multiple SDGs
Data Review						
1) Third-party Validation Performed	N - Data reviewed by QC Coordinators	Exponent	Exponent	Exponent	Exponent	Exponent
Deliverables						
1) Electronic Deliverables	Y	Y	Y	Y	Y	Y
2) Hardcopy	Unknown	Y	Y	Y	Y	Y
Data Review Details						
1) Package Completeness	Not addressed	Y	Y	Y	Y	Y
2) Chain of Custody Procedures	Not addressed	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
3) Holding Times	No DV reports provided	Y	Some exceedances samples J/UJ	Y	Some exceedances samples J/UJ	Y
4) Initial Calibration	No DV reports provided	Y	Y	Y	Y	Y
Curve (# of standards)	No DV reports provided	Y	Y	Y	Y	Y
5) Calibration Verification	No DV reports provided	20%	20%	20%	20%	10%
Secondary Column	No DV reports provided	Y	Y	Y	Y	NA
6) Laboratory Blanks	No DV reports provided	Y	Y - U based on BC	Y	Y	Y
7) Surrogate Recoveries (# required)	No DV reports provided	Y	Y	Y	Y	Y
8) Matrix Spike (# required)	No DV reports provided	Y - No quals. for %R outliers	Y - No quals. for %R outliers	Y - No quals. for %R outliers	Y	Y
9) Lab Duplicate	No DV reports provided	Y - MS/MSD	Y - MS/MSD	Y - MS/MSD	Y - MS/MSD	Y
Lab Control Sample (SRM results?)	No DV reports provided	Y	Y	Y	Y	Y
10) Gel Permeation/Forisil Cleanup	No DV reports provided	Not mentioned	Not mentioned	Not mentioned	Not mentioned	NA
11) Detection Limit	No DV reports provided	NA	NA	NA	NA	NA
12) Calc and Transposition Verification (Qualitative verification?)	No recalculations were provided unable to determine if transcription checks were done	No recalcs. provided, unable to determine if transcription checks were done	No recalcs. provided, unable to determine if transcription checks were done	No recalcs. provided, unable to determine if transcription checks were done	No recalcs. provided, unable to determine if transcription checks were done	No recalcs. provided, unable to determine if transcription checks were done
13) Field QC Results	Not addressed	None identified	None identified	None identified	None identified	None identified
14) Usability Usable/ Supporting	Supporting	Usable	Usable - Some results rejected for low surr. %R	Usable	Usable	Usable
Qualifiers	Y - Specific LLMB 3-character qual. codes	Y - HT, surr. %R, LCS %R	Y - Surr. %R, BC, U, coplanars, J/UJ diff between GC & HRGCMS, interference, coelutions	Y - Coelutions >calibration range	Y - HT, MS/MSD %R, surr. %R, PCB interference, all +J	Y - Dup RPD
15) Other IC Samples						
SAP						
QAPP						
Lab QAM						

Table 3-2 QC Elements for Data Sets Supporting the Fox River RI/FS and RA

Parameters: Requirements	1994 GAS/SAIC Sediment Data							
	PCBs Sediment	PCBs Sediment	PCBs Sediment	PCBs Sediment	PCBs Sediment	PCBs Sediment	PCBs Sediment	PCBs Sediment
SDG #s	ARI M172	ARI M174	ARI M176	ARI M177	ARI M178/ M179/M364	ARI M365	ARI M367/M368	ARI M370
Data Review								
1) Third-party Validation Performed	Y - SAIC	Y - SAIC	Y - SAIC	Y - SAIC	Y - SAIC	Y - SAIC	Y - SAIC	Y - SAIC
Deliverables								
1) Electronic Deliverables	Y	Y	Y	Y	Y	Y	Y	Y
2) Hardcopy	Y - but not easily accessed	Y - but not easily accessed	Y - but not easily accessed	Y - but not easily accessed	Y - but not easily accessed	Y - but not easily accessed	Y - but not easily accessed	Y - but not easily accessed
Data Review Details								
1) Package Completeness	Y	Y	Y	Y	Y	Y	Y	Y
2) Chain of Custody Procedures	Not determined	Not determined	Not determined	Not determined	Not determined	Not determined	Not determined	Not determined
3) Holding Times	Y (frozen)	Y - Some exceedances	Y	Y	Y - Some exceedances, 1 sample qual. J for gross exceedances (M178)	Y - Exceedances, several samples qual. J for gross exceedances (M365)	Y - Minor violations	Y - Minor violations
4) Initial Calibration	Y	Y	Y	Y	Y	Y	Y	Y
Curve (# of standards)	3–5 pt	3–5 pt	5 pt	5 pt	5 pt	5 pt	5 pt	5 pt
5) Calibration Verification	15 %D but avg. was higher, results flagged (J/UJ)	15 %D but avg. was higher, results flagged (J/UJ)	15 %D but avg. was higher, results flagged (J/UJ)	15 %D but avg. was higher, results flagged (J/UJ)	15 %D but avg. was higher, results flagged (J/UJ)	15 %D but avg. was higher, results flagged (J/UJ)	15 %D but avg. was higher, results flagged (J/UJ)	15%
Secondary Column	Not indicated	Not indicated	Not indicated	Not indicated	Not indicated	Not indicated	Not indicated	Not indicated
6) Laboratory Blanks	Y	Y	Y	Y	Y	Y	Y	Y
7) Surrogate Recoveries (# required)	TCMX 55%–115%/DCB 70%–125%	TCMX 55%–115%/DCB 70%–125%	TCMX 55%–115%/DCB 70%–125%	TCMX 55%–115%/DCB 70%–125%	TCMX 55%–115%/DCB 70%–125%	TCMX 55%–115%/DCB 70%–125%	TCMX 55%–115%/DCB 70%–125%	TCMX 55%–115%/DCB 70%–125%
8) Matrix Spike (# required)	35% min–130% max	35% min–130% max	35% min–130% max	35% min–130% max	35% min–130% max	35% min–130% max	35 min%–130% max	35 min%–130% max
9) Lab Duplicate	N	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned
Lab Control Sample (SRM results?)	Y	Y	Y	Y	Y	Y	Y	Y
10) Gel Permeation/Forisil Cleanup	Y - If necessary	Y - If necessary	Not sure	Not sure	Not sure	Not sure	Not sure	Not sure
11) Detection Limit	50 ppb wet wt	NA	NA	NA	NA	NA	NA	NA
12) Calc and Transposition Verification (Qualitative verification?)	Y - 10%?	N - No chros	ID & quants. could not be verified, raw data not provided	ID & quants. could not be verified, raw data not provided	ID & quants. could not be verified, raw data not provided	Data verified	N	Not verified
13) Field QC Results	None	None	None	Not identified	Not identified	Not identified	Not identified	Not identified
14) Usability Usable/ Supporting	Usable	Usable	Usable	Usable	Usable	Usable	Usable	Usable
Qualifiers	Y - Minor quals. assigned due to CCV (J/UJ)	Y - Minor quals. assigned due to CCV (J/UJ)	Y - Minor quals. assigned due to CCV, surr. recoveries J/UJ	Y - Minor quals. assigned due to CCV, surr. recoveries J/UJ	Y - Minor quals. assigned due to CCV, surr. recoveries J/UJ	Y - Minor quals. assigned due to CCV, surr. recoveries J/UJ	Y - Minor quals. assigned due to CCV, surr. recoveries J/UJ	Y - Minor quals. assigned due to surr. recoveries J/UJ
15) Other IC Samples								
SAP	Y							
QAPP	Y							
Lab QAM								

Table 3-2 QC Elements for Data Sets Supporting the Fox River RI/FS and RA

Parameters: Requirements	1994 GAS/SAIC Sediment Data (Continued)						
	Dioxins Sediment	**CLP Pest/PCBs Sediment**	**CLP SVOCs Sediment**	**CLP Metals Sediment**	**TCLP Metals Sediment**	**Mercury Sediment**	**Mercury Sediment**
SDG #s	Triangle Lab SDG #35589	Swanson/SDG 948521	Swanson/SDG 948521	Swanson/SDGs 12718, 12724, 12745, 12806, 12816, 12941	Swanson/SDGs 12718, 12724, 12730, 12827, 12718, 12802, 12833, 12844	Swanson WL12941	Swanson WL12745
Data Review							
1) Third-party Validation Performed	Y - SAIC	Y - SAIC	Y - SAIC	Y - SAIC	Y - SAIC	Y - SAIC	Y - SAIC
Deliverables							
1) Electronic Deliverables	Y	Y	Y	Y	Y	Y	Y
2) Hardcopy	Y - but not easily accessed	Y - but not easily accessed	Y - but not easily accessed	Y - but not easily accessed	Y - but not easily accessed	Y - but not easily accessed	Y - but not easily accessed
Data Review Details							
1) Package Completeness	Y	Y	N - Forms 1 not supplied by lab	Y	Y	N - Forms 1 not supplied by lab	Y
2) Chain of Custody Procedures	Not determined	Not determined	Not determined	Not determined	Not determined	Not determined	Not determined
3) Holding Times	Y - Minor violations	N - Samples sent to TL 10 days after collection	N - All samples exceeded HT & are qual. as estimated (J/UJ)	Y - Hg results are flagged for exceeding HT by 27–42 days (J/UJ)	Y	N - All samples exceeded HT & are qual. as estimated (J/UJ)	Y
4) Initial Calibration	Y	Y - Not consistent with CLP protocol	Y - Not consistent with CLP protocol	Y (validator recalc. Hg results)	Y	Y - Exceedance	Y - Exceedance
Curve (# of standards)	5 pt	5 pt	5 pt	Lin Reg	Lin Reg	5 pt	5 pt
5) Calibration Verification	20 %RSD	N - Correct concentration not used, certain analytes outside RT window	15 %D - Some exceedances qual. samples as estimated J/UJ	10 %D	10 %D	Y - 15%	Y - 15%
Secondary Column	NA	Not indicated	Not indicated	NA	NA	NA	NA
6) Laboratory Blanks	Y	Y	Y	Y	Y	Y	Y
7) Surrogate Recoveries (# required)	TCFD 25%–150%/TCDD 25%–150%	TCMX 55%–115%/DCB 70%–125%	8 required, 18% min–137% max	NA	NA	NA	NA
8) Matrix Spike (# required)	TCDD/TCDF 54–162	18/9 required, 29 min–152 max	11 required, 11% min–142% max	75%–125%	75%–125%	75%–125%	75%–125%
9) Lab Duplicate	Not mentioned	Not mentioned	Not mentioned	Y - 20%, Some exceedances qual. J/UJ	Y	Y	Y
Lab Control Sample (SRM results?)	Y	Y	Y - Acenapthene fell outside @ 53%	Y	Y	Y	Y
10) Gel Permeation/Forisil Cleanup	Not sure	Not sure	Not sure	NA	NA	NA	NA
11) Detection Limit	Elevated in some samples due to BC & noise	Elevated in some samples due to BC & noise	NA	NA	NA	NA	NA
12) Calc and Transposition Verification (Qualitative verification?)	Y - Sample IDs, sample quant. not reviewed	Not verifiable	Y	Y - Some calc. errors	Y	N	N
13) Field QC Results	Not identified	Not identified	Not identified	None	N	Y - FD	N
14) Usability Usable/ Supporting	Usable	Third-party validation considers it unusable	Usable	Usable - 1 data point rejected for Zn	Usable	Usable	Usable
Qualifiers	Y - Due to BC & elevated MSR sample results may be biased positive (J+)	Y - Major issues about overall quality of data, assoc. with RT drift, quality of work poor	Y - Minor quals. due to HT exceedances & low surr. & spike recoveries (J/UJ)	Y - Minor & major quals. due poor spike recoveries (J/UJ) & (R) on Zn	No quals.	Y - Minor J flags	Y - Minor UJ/J flags
15) Other IC Samples							
SAP							
QAPP							
Lab QAM							

Table 3-2 QC Elements for Data Sets Supporting the Fox River RI/FS and RA

	1994 GAS/SAIC Sediment Data (Continued)					1998 Fox River Group		
Parameters: Requirements	**Mercury Sediment**	**Mercury Sediment**	**Mercury Sediment**	**Mercury Sediment**	**Mercury Sediment**	**PCB Surface Water**	**Conventionals Surface Water**	**PCB Sediment**
SDG #s	Swanson WL12806	Swanson WL12812/ 12724/12718	Swanson WL12816/12882/ 12929/12922/ 12853/12852/12851	Swanson WL12688/ 12725/12783/ 12777	Swanson WL12693	Enchem Multiple SDGs	Enchem Multiple SDGs	Enchem Multiple SDGs
Data Review								
1) Third-party Validation Performed	Y - SAIC	Y - SAIC	Y - SAIC	Y - SAIC	Y - SAIC	Blasland Bouck & Lee	Blasland Bouck & Lee	Blasland Bouck & Lee
Deliverables								
1) Electronic Deliverables	Y	Y	Y	Y	Y	Y	Y	Y
2) Hardcopy	Y - but not easily accessed	Y - but not easily accessed	Y - but not easily accessed	Y - but not easily accessed	Y - but not easily accessed	Y	Y	Y
Data Review Details								
1) Package Completeness	Y	Y	Y	Y	Y	Y	Y	Y
2) Chain of Custody Procedures	Not determined	Not determined	Not determined	Not determined	Not determined	Acceptable	Acceptable	Acceptable
3) Holding Times	Y	Y	N - Quals. J/UJ	Y	Y	Y	Y - TSS samples J flagged	Y - Dilutions done out of HT, diluted Aroclors J
4) Initial Calibration	Y - Exceedance	Y (validator recalc. results)	Y (validator recalc. results)	Y (validator recalc. results)	Y (validator recalc. results)	Y	Y	Y
Curve (# of standards)	5 pt	5 pt	5 pt	5 pt	5 pt			
5) Calibration Verification	Y - 15%	Y - 15%	Y - 15%	Y - 15%	Y - 15%	20%	10%	20%
Secondary Column	NA	NA	NA	NA	NA	20% qualitative only	NA	20% qualitative only
6) Laboratory Blanks	Y	Y	Y	Y	Y	Y	Y	Y
7) Surrogate Recoveries (# required)	NA	NA	NA	NA	NA	Y - Control limits not provided	Y - Control limits not provided	Y/Control limits not provided
8) Matrix Spike (# required)	75%–125%	75%–125%	75%–125%	75%–125%	75%–125%	Y - Control limits not provided	Y - Control limits not provided	Y - Control limits not provided
9) Lab Duplicate	Y	Used MS/MSD	Y - Occ. used MS/MSD SDG 12922 >35%	Y - Used MS/MSD	Y	Y - MS/MSD control limits not provided	Y - Control limits not provided	Y - MS/MSD control limits not provided
Lab Control Sample (SRM results?)	Y	Y (not always performed) - CLs were 75%–125%	Used MS/MSD (75%–125%)	Used MS/MSD (80%–120%)	Y	Y	Y	Y - Not addressed
10) Gel Permeation/Forisil Cleanup	NA	NA	NA	NA	NA	Not mentioned	NA	Not mentioned
11) Detection Limit	NA	NA	NA	NA	NA	NA	NA	NA
12) Calc and Transposition Verification (Qualitative verification?)	N	Y	Y - Recalc.	Y - Recalc.	Y - Recalc.	No recals. provided; unable to determine if transcription checks were done	No recalcs. provided; unable to determine if transcription checks were done	No recalcs. provided; unable to determine if transcription checks were done
13) Field QC Results	N	Y - OK on rinsate, FD (12812) failed No Action	Y - OK on rinsate, <35% on FD	Y - OK on rinsate, <20% on FD	Y - OK on rinsate, OK on FD	FDs - OK, rinsates had cont.	FDs - OK, rinsates had cont.	FDs - OK
14) Usability Usable/ Supporting	Usable	Usable	Usable	Usable	Usable	Usable	Usable - Except some TOC/DOC rejected	Usable
Qualifiers	Y - Minor UJ/J flags	Y - Minor quals. due to incorrect ICB calc.	Y - Minor J/UJ flags due to HT exceedances, SDG 12853 also qualifed on poor FD values	No quals.	Not apparent if no or some minor quals.	Y - Aroclor 1242 ND based on rinsate cont., UJ extraction errors, J/UJ low surr. %R	Y - TOC/DOC R DOC > TOC, all parameters U rinsate, TSS J HT	Y - Aroclor 1242 & 1254 J spectral overlap, J dilutions out of HT, minor CCAL %D
15) Other IC Samples								
SAP								
QAPP								
Lab QAM								

Table 3-2 QC Elements for Data Sets Supporting the Fox River RI/FS and RA

Parameters: Requirements	1998 Fox River Group (Continued)					
	PCB Congeners Sediment	Pesticides Sediment	SVOC Sediment	Metals Sediment	TOC/Ammonia Sediment	PCB Fish Tissue
SDG #s	Enchem Multiple SDGs	Quanterra Multiple SDGs	Enchem Multiple SDGs	Enchem Multiple SDGs	Enchem Multiple SDGs	Enchem Multiple SDGs
Data Review						
1) Third-party Validation Performed	Blasland Bouck & Lee	Blasland Bouck & Lee	Blasland Bouck & Lee	Blasland Bouck & Lee	Blasland Bouck & Lee	Blasland Bouck & Lee
Deliverables						
1) Electronic Deliverables	Y	Y	Y	Y	Y	Y
2) Hardcopy	Y	Y	Y	Y	Y	Y
Data Review Details						
1) Package Completeness	Y	Y	Y	Y	Y	Y
2) Chain of Custody Procedures	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
3) Holding Times	Y	Y	Y - 1 missed HT sample J/UJ	Y	Y - Some TOC & ammonia samples J	Y
4) Initial Calibration	Y	Y	Y	Y	Y	Y
Curve (# of standards)	NA	NA	NA	NA	NA	NA
5) Calibration Verification	30% target analytes, 40% internal stds.	20%	20%	10%	10%	20%
Secondary Column	NA	20% qualitative only	NA	NA	NA	20% qualitative only
6) Laboratory Blanks	Y	Y	Y	Y	Y	Y
7) Surrogate Recoveries (# required)	Y - Control limits not provided	Y - Control limits not provided	Y - Control limits not provided	Y - Control limits not provided	Y - Control limits not provided	Y - Control limits not provided
8) Matrix Spike (# required)	Y - Control limits not provided	Y - Control limits not provided	Y - Control limits not provided	Y - Control limits not provided	Y - Control limits not provided	Y - Control limits not provided
9) Lab Duplicate	Y - MS/MSD control limits not provided	Y - MS/MSD control limits not provided	Y - MS/MSD control limits not provided	Y - Control limits not provided	Y - Control limits not provided	Y - MS/MSD control limits not provided
Lab Control Sample (SRM results?)	Y	Y	Y	Y	Y	Y
10) Gel Permeation/Forisil Cleanup	Not mentioned	Not mentioned	Not mentioned	NA	NA	Not mentioned
11) Detection Limit	NA	NA	NA	NA	NA	NA
12) Calc and Transposition Verification (Qualitative verification?)	No recalcs. provided; unable to determine if transcription checks were done	No recalcs. provided; unable to determine if transcription checks were done	No recalcs. provided; unable to determine if transcription checks were done	No recalcs. provided; unable to determine if transcription checks were done	No recalcs. provided; unable to determine if transcription checks were done	No recalcs. provided; unable to determine if transcription checks were done
13) Field QC Results	None identified	FDs - OK	FDs - OK	FDs - OK	FDs - OK	None identified
14) Usability Usable/ Supporting	Usable	Usable	Usable - Except hexachlorocyclopentadiene rejected	Usable	Usable	Usable
Qualifiers	Y - 1 compound J/UJ CCAL D, MS/MSD/LCS low %R, poor peak resolution	N	Y - HCCP R 0% MS/MSD, minor CCAL %D, low surr. %R, & missed HT	Y - BC, low MS %R, RPD	Y - HT	Y - Aroclor 1242 & 1254 J spectral overlap, J/UJ due to extraction error
15) Other IC Samples						
SAP						
QAPP						
Lab QAM						

Table 3-2 QC Elements for Data Sets Supporting the Fox River RI/FS and RA

Parameters: Requirements	1992–1993 BBL Deposit A Sediment Data					1998–1999 Deposit N Data		
	VOA Soil	**SVOC Soil**	**PCB Soil**	**Pesticides Soil**	**Metals/CN Soil**	**PCB Slurry, Soil, Liquid**	**PCB Congener Slurry, Soil, Liquid**	**TOC/DOC/TSS Slurry, Soil, Liquid**
SDG #s	Hazleton 104116 203257	Hazleton 104116 203242	Hazleton SDG-1, SDG-2, SDG-3, SDG-4, SDG-5	Hazleton 104135 203256	Hazleton BASD34 SD01 BASD08	Severn Trent VT. Fox9, Fox10, Fox11, Fox12, Fox13, Fox14, Fox16	Severn Trent VT. Fox9, Fox10, Fox11, Fox12, Fox13, Fox14, Fox16	WSLH
Data Review								
1) Third-party Validation Performed	EcoChem	EcoChem	EcoChem	EcoChem	EcoChem	M. A. Kuehl Co.	M. A. Kuehl Co.	M. A. Kuehl Co.
Deliverables								
1) Electronic Deliverables	Y	Y	Y	Y	Y	Y	Y	Y
2) Hardcopy	Y	Y	Y	Y	Y	Y	Y	Y
Data Review Details								
1) Package Completeness	Y	Y	Y	Y	Y	Y	Y	Y
2) Chain of Custody Procedures	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
3) Holding Times	Y	Y	Y	Y	Y	Y - Some exceedances	Y - Some results J/UJ, some results rejected (>14 days)	Y - Some exceedances
4) Initial Calibration	Y	Y	Y	Y	Y	Y	Y	Y
Curve (# of standards)	Y - As required by method	Y - As required by method	Y - As required by method	Y - As required by method	Y - As required by method	NA	NA	NA
5) Calibration Verification	20%	20%	20%	20%	10%	15%	Y	Y
Secondary Column	NA	NA	Y	Y	NA	Y - Some %D exceedances	Y	NA
6) Laboratory Blanks	Y - Tics rejected due to cont.	Y - Tics rejected due to cont.	Y	Y	Y	Y	Y - Some results U based on MB cont.	Y
7) Surrogate Recoveries (# required)	Y	Y	Y	Y	Y	Y	Y	Y
8) Matrix Spike (# required)	Y - No MS/MSD for SDG 203257 J/UJ	Y - No MS/MSD for SDG 203242 J/UJ	Y	Y	Y	Y	Y	Y
9) Lab Duplicate	Y - No MS/MSD for SDG 203257 J/UJ	Y - No MS/MSD for SDG 203242 J/UJ	Y	Y	Y	Y	Y	Y
Lab Control Sample (SRM results?)	Y - No LCS for SDG 203257 J/UJ	Y - No LCS for SDG 203242 J/UJ	Y	Y	Y	Y - Some %R outliers	Y - Some %R outliers	Y
10) Gel Permeation/Forisil Cleanup	NA	NA	NA	NA	NA	Not addressed	Not addressed	NA
11) Detection Limit	NA	NA	NA	NA	NA	NA	NA	NA
12) Calc and Transposition Verification (Qualitative verification?)	Y	Y	Y	Y	Y	Y	Y	Y
13) Field QC Results	None identified	None identified	Y	Y	None identified	Y	Y - Some outliers, no quals. assigned	Y - DOC RPD outlier
14) Usability Usable/ Supporting	Usable - Tics rejected due to cont.	Usable - Tics rejected due to cont.	Usable	Usable	Usable	Usable - Some results rejected due to possible cross cont.	Usable - Some results rejected due to exceeded HT	Usable
Qualifiers	Y - BC U, Ical RSD, CCAL %D, no LCS MS/MSD TICs rejected due to BC	Y - BC, CCAL %D, Internal std. %R, NO LCS MS/MSD, TICs rejected due to BC	Y - Surr. %R, LCS %R, FD RPD 1242	Y - RPD between main & confirmation columns NJ	Y - BC, ICV %R CN, MS %R, GFAA post-spike %R	Y - Cooler temps., CCAL %D, HT, LCS %R, dual column %D	Y - HT, cooler temps., CCAl %D, MB cont., LCS %R, over cal	Y - HT, cooler temps., FD RPD, DOC>TOC
15) Other IC Samples								
SAP								
QAPP								
Lab QAM								

Table 3-2 QC Elements for Data Sets Supporting the Fox River RI/FS and RA

Parameters: Requirements	1998–1999 Deposit N Data (Continued)					
	PCB Sludge	**PCB Congener Sludge**	**TOC Sludge**	**PCB Congener Surface Water**	**PCB Fish**	**PCB Congener Minnow**
SDG #s	Severn Trent VT. Fox17, Fox18	Severn Trent VT. Fox17, Fox18	Severn Trent VT. Fox17, Fox18	WSLH	Severn Trent VT. Fox7	WSLH
Data Review						
1) Third-party Validation Performed	M. A. Kuehl Co.	M. A. Kuehl Co.	M. A. Keuhl Co.	M. A. Keuhl Co.	M. A. Keuhl Co.	M. A. Keuhl Co.
Deliverables						
1) Electronic Deliverables	Y	Y	Y	Y	Y	Y
2) Hardcopy	Y	Y	Y	Y	Y	Y
Data Review Details						
1) Package Completeness	Y	Y	Y	Y	Y	Y
2) Chain of Custody Procedures	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
3) Holding Times	Y	Y	Y	Y	Y	Y
4) Initial Calibration	Y	Y	Y	Y	Y	Y
Curve (# of standards)	NA	NA	Y	Y	Y	Y
5) Calibration Verification	Y	Y	Y	Y	Y	Y
Secondary Column	Y - %D outliers	Y	NA	Y	Y	Y
6) Laboratory Blanks	Y	Y	Y	Y - Some results U because of MB cont.	Y	Y
7) Surrogate Recoveries (# required)	Y	Y	Y	Y	Y	Y
8) Matrix Spike (# required)	Y	Y - Some %R & RPD outliers	Y	N - Not enough sample	N	Y
9) Lab Duplicate	Y	Y	Y - Some RPD outliers	Y	Y	Y
Lab Control Sample (SRM results?)	Y - Some %R outliers	Y	Y - 1 outlier	Y	Y	Y
10) Gel Permeation/Forisil Cleanup	Not addressed	Not addressed	NA	Not addressed	Not addressed	Not addressed
11) Detection Limit	NA	NA	NA	NA	NA	NA
12) Calc and Transposition Verification (Qualitative verification?)	Y	Y	Y	Y	Y	Y
13) Field QC Results	Y	Y - Some outliers, no quals. assigned	Y - Some RPD outliers	Y - Some outliers, no quals. assigned	Y	Y
14) Usability Usable/ Supporting	Usable	Usable	Usable	Usable	Usable	Usable
Qualifiers	Y - Dual column %D outliers	Y - CCAL %D outliers, MS/MSD %R & RPD outliers, LCS %R, over cal	Y - LCS %R, dup. RPD, FD RPD	Y - BC, results <LOQ	N	Y - Reported results <LOQ
15) Other IC Samples						
SAP						
QAPP						
Lab QAM						

4 Analytical and Archive Databases

Electronic data have undergone reduction and standardization and currently reside in both a working database (designed for the internal support of the ongoing RA and RI/FS processes) and the FRDB, complete with user interface.

The development of the FRDB required the data management and manipulation of the source data as described previously. Data were acquired prior to design and development of an appropriate and complete underlying data structure. An outline of the data structure is included in Attachment 1.

The FRDB, designed in Microsoft Access©, includes available environmental analytical data as well as capacity to store bibliographical information for available reports, research studies, and other documents compiled on the Fox River. The basic structure of the database includes several tables that store the actual data and bibliographical information along with several other "lookup" tables (Attachment 2) and indices that will allow flexibility in searching for information included in the database. The basic table structure and relationships are depicted in Attachment 3. A summary of each table's function within the database is described as follows:

- **Analytical Table.** This table stores all of the analytical information including fields such as analyte, result, qualifier, etc. This is the core of the analytical data processed and validated by EcoChem. Searches of the database can run on several of the fields contained in this table. This table has relationships with the Analysis Type and Qualifier lookup tables.

- **Data Dictionary Table.** This table contains definitions of the fields used in the Fox River database.

- **Data Set Table.** This table, along with the QA Status Lookup Table listed below, is used to store information regarding the quality assurance or validation level of each of the overall data sets that encompass a sample grouping. A relationship exists with the Document Archive Table that enables reference to a document that exclusively describes a data set.

- **Document Archive Table.** This table contains document and bibliographical information related to Fox River sample data. This table includes information such as the main author's name, additional author names, year of publication or release, subject, title, publication type, keywords and, when available, an abstract of the document and/or a hyperlink to online or electronic copies of the document and associated analytical data. Complete bibliographies from several sources (some not directly related to this project) have been added to this table creating a reference library of over 2,000 sources.

- **Sample Attribute Table.** Information regarding each unique sample is stored in this table. This table has relationships with Data Set and Analytical tables, in addition to six lookup tables. The Deposit, Location, Matrix, Sample Area, Sample Type, and Species lookup tables enable fast and efficient searches of sample attributes.

- **Analysis Type Lookup Table.** This table contains the key data on the type of each analyte in the Analytical Table.

- **Deposit Lookup Table.** This table contains the key data on the named deposit from which a sample was extracted, if a deposit exists for a particular sample.

- **Location Lookup Table.** This table contains the key data on the general location of a sample's origin.

- **Matrix Lookup Table.** This table holds the key data for the matrix type of each sample.

- **QA Status Lookup Table.** The key data on the quality assurance level of each data set contained in the Data Set Table is stored in this table.

- **Qualifier Lookup Table.** This table holds key data on the data qualifier assigned to each analyte in the Analytical Table.

- **Sample Area Lookup Table.** This table contains the key data on more specific locations for sample origins than the Location Table.

- **Sample Type Lookup Table.** This table contains key data on the type or form of each sample that is more specific than that contained in the Matrix Table.

- **Species Lookup Table.** This table contains key data on the common or specific name for a sample and the risk pathway that the sample is associated with. For example, a sample originating from the fish carp is listed under benthic fish for an ecological risk pathway and under food fish for a human health risk pathway.

The FRDB has been customized to include various user interfaces and search capabilities that enable access to the stored data by those who are not familiar with retrieving data from a database application. Help capability and integral database definitions are included. In addition, the database is available via a web server, thus allowing access to the data contained in the database by anyone with Internet capability and a web browser.

Finally, the FRDB is designed with a basic relational structure that will allow data addition in the future as well as the easy migration of the data to other relational database systems. Instructions for importing additional data are included in Attachment 4.

Appendix A

Data Validation Report

Attachment 1

Data Structure Outline

Table	Fox River Database Field	EcoChem Field	Data Type	Length	Index
Data Set Table	DataSet_ID	Primary key	autonumber	---	yes, no dups
	DataSet	DATASET	text	50	yes, no dups
	Description	to be added	text	100	
	QA_Status_ID	foreign key from QA STATUS lookup	long integer	---	yes
	Validator	VALIDATOR	text	20	yes
QA Status Lookup	QA_Status_ID	Primary key	autonumber	---	yes, no dups
	QA_Status	QASTATUS	text	15	yes, no dups
	Description	to be added	text	100	
Sample Attribute Table	SampleAttribute_ID	Primary key	autonumber	---	yes, no dups
	Sample_ID	SAMPID	text	30	yes
	DataSet_ID	foreign key from DATASET table	long integer	---	yes
	Location_ID	foreign key from LOCATION table	long integer	---	yes
	Deposit_ID	foreign key from DEPOSIT table	long integer	---	yes
	SampleArea_ID	foreign key from SAMPLEAREA table	long integer	---	yes
	BlindID	BLIND_ID	text	12	
	Depth	DEPTH	text	14	
	StartDepth	DEPTHFROM	text	10	yes
	EndDepth	DEPTHTO	text	10	yes
	DepthUnits	DEPTHUNITS	text	5	
	CoreGrab	CORE_GRAB	text	20	yes
	Northing	NORTHING	text	15	yes
	Easting	EASTING	text	15	yes
	County	COUNTY	text	20	yes
	SampleDate	SAMPDATE	text	10	yes
	SampledBy	SAMPLER	text	10	yes
	CollectionCompany	COMPANY	text	30	yes
	DateLabReceived	DATE_RCV	text	10	
	DateLabExtracted	DATE_EXT	text	10	
	Matrix_ID	foreign key from MATRIX lookup	long integer	---	yes
	SampleType_ID	foreign key from SAMPLE TYPE lookup	long integer	---	yes
	Species_ID	foreign key from SPECIES lookup	long integer	---	yes
	DBTimeStamp	TIMESTAMP	date/time	---	
Sample Area Lookup	SampleArea_ID	Primary key	autonumber	---	yes, no dups
	SampleArea	LOC_DESC	text	100	yes, no dups

Table	Fox River Database Field	EcoChem Field	Data Type	Length	Index
Location Lookup	Location_ID	Primary key	autonumber	---	yes, no dups
	Location	LOCATION	text	50	yes, no dups
	Description	to be added	text	100	
Deposit Lookup	Deposit_ID	Primary key	autonumber	---	yes, no dups
	Deposit	DEPOSIT	text	15	yes, no dups
	Description	to be added	text	100	
Matrix Lookup	Matrix_ID	Primary key	autonumber	---	yes, no dups
	Matrix	MEDIA	text	25	yes, no dups
	Description	to be added	text	50	
Sample Type Lookup	SampleType_ID	Primary key	autonumber	---	yes, no dups
	SampleType	SAMPLETYPE	text	30	yes, no dups
	Description	to be added	text	50	
Species Lookup	Species_ID	Primary key	autonumber	---	yes
	CommonName	SPECIES	text	30	yes, no dups
	EcoRisk	GROUP	text	20	same index
	HHRisk	GROUP2	text	20	same index
	Species	TRUESPECIES	text	20	

Table	Fox River Database Field	EcoChem Field	Data Type	Length	Index
Analytical Table	Analytical_ID	Primary key	autonumber	---	yes
	SampleAttribute_ID	foreign key from SAMPLE ATTRIBUTE table	text	30	yes
	Analyte	ANALYTE	text	50	yes
	Result	RESULT	text	15	yes
	Qualifier	foreign key from QUALIFIER lookup	text	6	yes
	Units	UNITS	text	15	
	AnalysisType_ID	foreign key from ANALYSIS TYPE table	long integer	---	yes
	ReportingBasis	BASIS	text	20	
	SDG	SDG	text	10	
	DetectionLimit	DETLIMIT	text	15	
	Aliquot	ALIQUOT	text	10	
	Method	METHOD	text	20	yes
	LabID	LABID	text	15	
	AnalyteOld	ANALYTEOLD	text	50	
	ResultOld	RESULTOLD	text	50	
	QualifierOld	QUALOLD	text	6	
	Comments	COMMENT	text	110	
	Lab	LAB	text	20	yes
	ImportFile	IMPORTFILE	text	15	
	Source	SOURCE	text	100	yes
Qualifier Lookup	Qualifier	QUAL (primary key)	text	6	yes, no dups
	Description	to be added	text	50	

Table	Fox River Database Field	EcoChem Field	Data Type	Length	Index
Document Archive	Document_ID	Primary key	autonumber	---	yes, no dups
	DataSet_ID	foreign key from DATASET table	long integer	---	yes, no dups
	Author		text	200	
	Year		text	4	
	Title		text	255	
	SecondaryTitle		text	150	
	Journal		text	75	
	Volume		text	3	
	Issue		text	10	
	Pages		text	10	
	AlternateJournal		text	75	
	CallNumber		text	25	
	Label		text	20	
	Keywords		text	225	
	Abstract		memo	---	
	Notes		text	40	
	City		text	20	
	Institution		text	75	
	Date		text	20	
	Publisher		text	50	
	SeriesEditor		text	35	
	SeriesTitle		text	100	
	Edition		text	5	
	Newspaper		text	75	
	ConferenceLocation		text	50	
	ConferenceYear		text	4	
	ConferenceName		text	50	
	AcademicDepartment		text	50	
	University		text	30	
	Programmer		text	40	
	Cartographer		text	40	
	Scale		text	20	
	AccessYear		text	4	
	AccessDate		text	25	
Analysis Type Lookup	AnalysisType_ID	Primary key	autonumber	---	yes, no dups
	AnalysisType	METHODTYPE	text	15	yes, no dups
Data Dictionary	Field	Primary key	text	30	yes, no dups
	Description	to be added	text	150	

Attachment 2

Lookup Tables

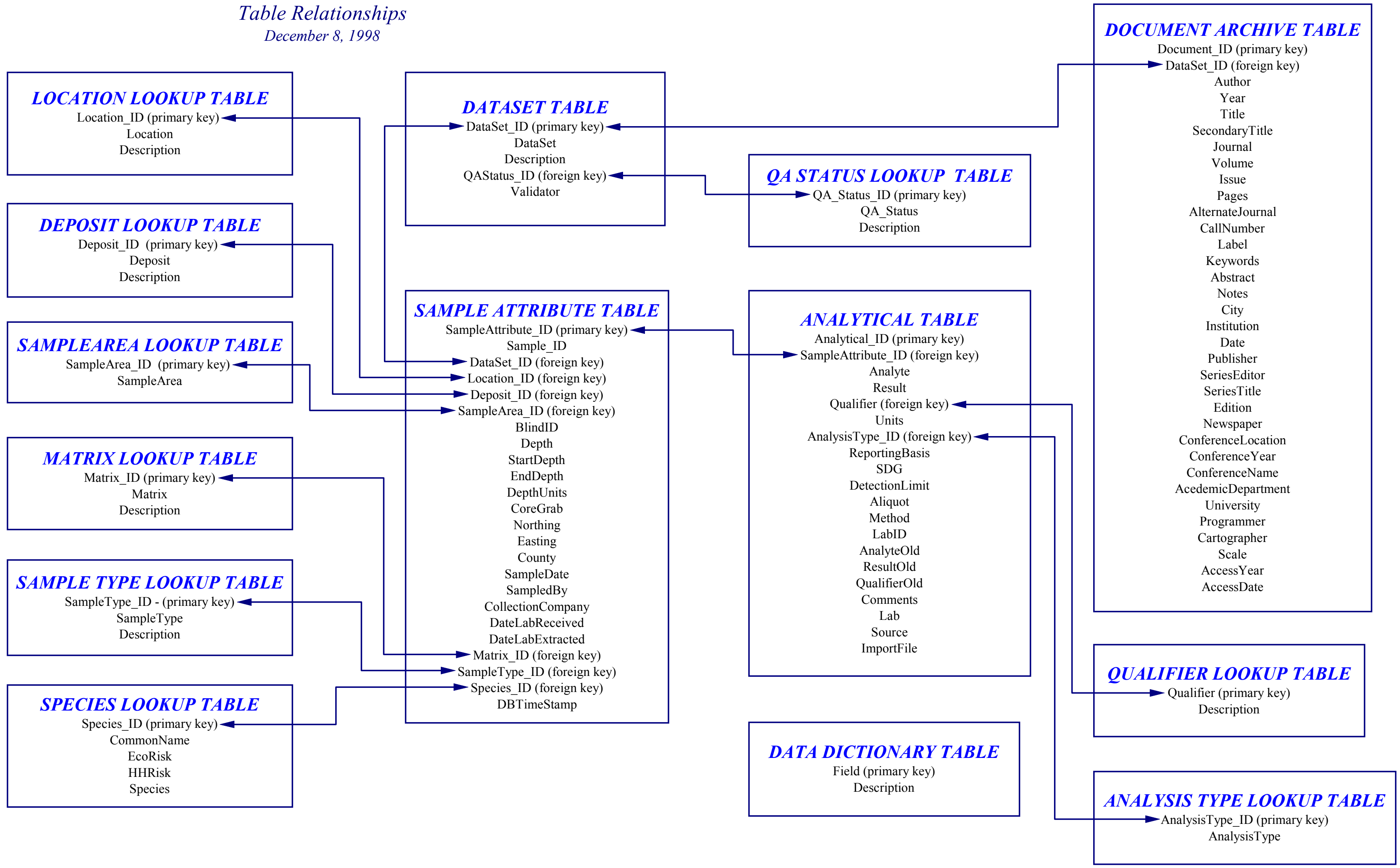
Local Lookup Tables and Queries for Fox River Database Forms.mdb File (Table 1)

Table Name	Query to Populate the Table	Forms Using the Table
tblLookup_CriteriaForLists	None – static table (DO NOT ALTER)	frmDataList
tblLookup_FieldsForLists	None – static table (DO NOT ALTER)	frmDataList
tblLookup_SortFieldsForSearches	None – static table (DO NOT ALTER)	frmDataSearch
tblLookup_Unique_AnalysisType	Append tblLookup_Unique_AnalysisType	frmDataList
tblLookup_Unique_Analyte	Append tblLookup_Unique_Analyte	frmDataList, frmDataSearch, frmStatistic
tblLookup_Unique_CollectionCompany	Append tblLookup_Unique_CollectionCompany	frmDataList
tblLookup_Unique_CommonName	Append tblLookup_Unique_CommonName	frmDataList
tblLookup_Unique_CoreGrab	Append tblLookup_Unique_CoreGrab	frmDataList
tblLookup_Unique_County	Append tblLookup_Unique_County	frmDataList
tblLookup_Unique_DataSet	Append tblLookup_Unique_DataSet	frmDataSearch
tblLookup_Unique_Deposit	Append tblLookup_Unique_Deposit	frmDataList
tblLookup_Unique_EcoRisk	Append tblLookup_Unique_EcoRisk	frmDataList
tblLookup_Unique_EcoRiskAndCommonName	Append tblLookup_Unique_EcoRiskAndCommonName	frmDataSearch
tblLookup_Unique_HHRisk	Append tblLookup_Unique_HHRisk	frmDataList
tblLookup_Unique_HHRiskAndCommonName	Append tblLookup_Unique_HHRiskAndCommonName	frmDataSearch
tblLookup_Unique_Lab	Append tblLookup_Unique_Lab	frmDataList
tblLookup_Unique_Location	Append tblLookup_Unique_Location	frmDataList
tblLookup_Unique_LocationAndDeposit	Append tblLookup_Unique_LocationAndDeposit	frmDataSearch
tblLookup_Unique_Matrix	Append tblLookup_Unique_Matrix	frmDataList
tblLookup_Unique_MatrixAndSampleType	Append tblLookup_Unique_MatrixAndSampleType	frmDataSearch
tblLookup_Unique_Method	Append tblLookup_Unique_Method	frmDataList
tblLookup_Unique_QAStatus	Append tblLookup_Unique_QAStatus	frmDataList
tblLookup_Unique_Qualifier	Append tblLookup_Unique_Qualifier	frmDataSearch
tblLookup_Unique_SampledBy	Append tblLookup_Unique_SampledBy	frmDataList
tblLookup_Unique_SampleID	Append tblLookup_Unique_SampleID	frmDataList
tblLookup_Unique_SampleType	Append tblLookup_Unique_SampleType	frmDataList
tblLookup_Unique_Source	Append tblLookup_Unique_Source	frmDataList
tblLookup_Unique_StatisticsChoices	Append tblLookup_Unique_StatisticsChoices	frmStatistic
tblLookup_Unique_Validator	Append tblLookup_Unique_Validator	frmDataList

FOX RIVER DATABASE

Table Relationships

December 8, 1998



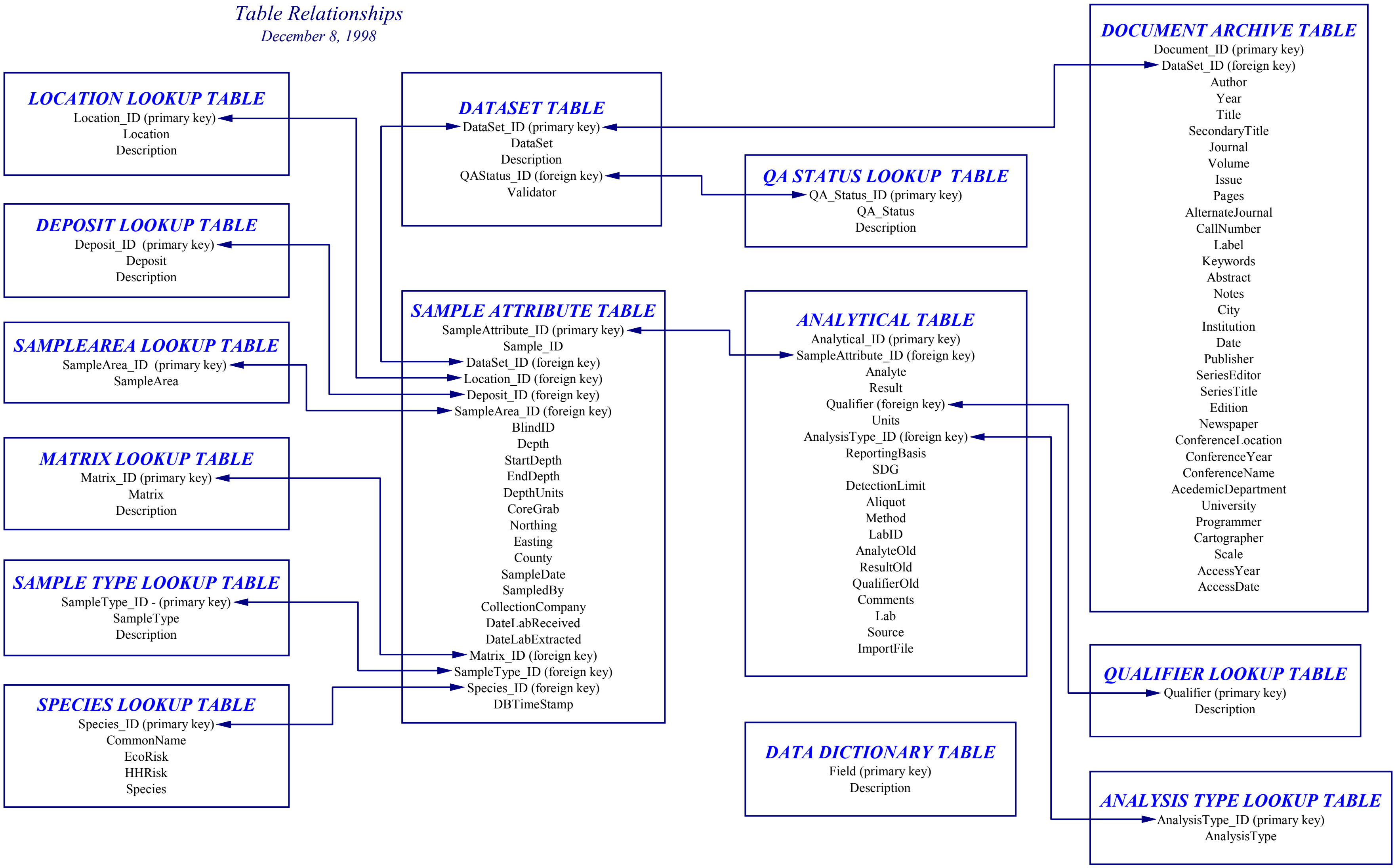
Attachment 3

Table Structure and Relationships

FOX RIVER DATABASE

Table Relationships

December 8, 1998



Attachment 4

Data Importing Instructions

I. Importing Data to the Fox River Database for the First Time (empty database):

Steps for the FoxRiverData.mdb Database File:

1. Import raw data to a new table called SAMPLES in the Fox River Data Tables database. Fields in this import table should be named as below (names in parentheses are the actual database field names). All fields should be of text data type except for TIMESTAMP, which should be of date/time type. TIMESTAMP should be left blank in the import file because a date/time value is added when the data is entered into the database.

    a. SAMPID (Sample_ID)
    b. ANALYTE (Analyte)
    c. RESULT (Result)
    d. QUAL (Qualifier)
    e. UNITS (Units)
    f. SAMPDATE (SampleDate)
    g. MEDIA (Matrix)
    h. LABID (LabID)
    i. DATE_RCV (DateLabReceived)
    j. DATE_EXT (DateLabExtracted)
    k. DETLIMIT (DetectionLimit)
    l. SDG (SDG)
    m. IMPORTFILE (ImportFile)
    n. SOURCE (Source)
    o. DATASET (DataSet)
    p. LAB (Lab)
    q. VALIDATOR (Validator)
    r. QASTATUS (QA_Status)
    s. LOCATION (Location)
    t. DEPTH (Depth)
    u. DEPTHFROM (StartDepth)
    v. DEPTHTO (EndDepth)
    w. DEPTHUNITS (DepthUnits)
    x. SPECIES (CommonName)
    y. ALIQUOT (Aliquot)
    z. METHODTYPE (AnalysisType)
    aa. METHOD (Method)
    bb. BLIND_ID (BlindID)
    cc. SAMPLER (SampledBy)
    dd. COMMENT (Comments)
    ee. DEPOSIT (Deposit)
    ff. NORTHING (Northing)
    gg. EASTING (Easting)
    hh. GROUP (EcoRisk)
    ii. GROUP2 (HHRisk)
    jj. COREGRAB (CoreGrab)
    kk. ANALYTEOLD (AnalyteOld)
    ll. LOC_DESC (SampleArea)
    mm. SAMPLETYPE (SampleType)
    nn. COUNTY (County)
    oo. RESULTOLD (ResultOld)
    pp. QUALOLD (QualifierOld)
    qq. TRUESPECIES (Species)
    rr. COMPANY (CollectionCompany)
    ss. BASIS (ReportingBasis)
    tt. TIMESTAMP (DBTimeStamp)

2. Run qryTimeStamp_ImportFile to date/time stamp the entry of new samples into the database. This allows for easier importing of new samples in the future as well as keeping a record of when samples were first entered into the database.

3. Populate lookup tables by running the these queries in the exact order listed below:
   a. qryPopulate_Unique_AnalysisType
   b. qryPopulate_Unique_QAStatus
   c. qryPopulate_Unique_DataSet
   d. qryPopulate_Unique_Deposit
   e. qryPopulate_Unique_Location
   f. qryPopulate_Unique_Matrix
   g. qryPopulate_Unique_Qualifier
   h. qryPopulate_Unique_SampleArea
   i. qryPopulate_Unique_SampleType
   j. qryPopulate_Unique_Species

4. Run qryPopulate_Unique_SampleAttribute to populate tblSampleAttribute.

5. Run qryPopulate_Unique_Analytical to populate tblAnalytical.

6. Run qryPopulate_tblDocumentArchive_WithDataSets to populate DataSet_ID field in tblDocumentArchive with DataSet_IDs from tblDataSet.

<u>Steps for the Fox River Database Forms.mdb Database File:</u>

1. Run the queries listed in Table 1 to populate the local lookup tables. The queries must be run in the order that they are listed in Table 1. The first three database tables listed in Table 1 are static tables and should never be altered.

II. Subsequent Importing of Data to the Fox River Database (populated database):

1. To import additional data to the Fox River Database after the database has been filled initially, follow the same steps as outlined above for entering data into the FoxRiverData.mdb file. The lookup tables have indexed fields to prevent entry of duplicate data. When the lookup queries are run and you are trying to enter duplicate data, Access© will show an error message that some data will not be added due to key violations. Choose the option to run the query anyway, and only the new data will be added to the database.

2. After the new data has been added, you must change the lookup tables in the Fox River Database Forms.mdb file. Open the database lookup tables listed in Table 1 and delete all records in each table. After all data has been deleted from all lookup tables, run the Table 1 queries in the order listed to repopulate the lookup tables with the updated database data.

3. The updated Fox River Database Forms.mdb must then be distributed to all users. Replace the old copy of the file with the updated version.

III. Populating the Fox River Web Database File (Fox River Web DB.mdb):

1. For first time populating of data to the web database file (empty database), import the following tables from the respective Access© database files created above:

FoxRiverData.mdb: tblAnalysisType
tblAnalytical
tblDataDictionary
tblDataSet
tblDeposit
tblDocumentArchive
tblLocation
tblMatrix
tblQA_Status
tblQualifier
tblSampleArea
tblSampleAttribute
tblSampleType
tblSpecies

Fox River Database Forms.mdb: tblLookup_CriteriaForLists
tblLookup_FieldsForLists
tblLookup_SortFieldsForSearches
tblLookup_Unique_AnalysisType
tblLookup_Unique_Analyte
tblLookup_Unique_CollectionCompany
tblLookup_Unique_CommonName
tblLookup_Unique_CoreGrab
tblLookup_Unique_County
tblLookup_Unique_DataSet
tblLookup_Unique_Deposit

tblLookup_Unique_EcoRisk
tblLookup_Unique_EcoRiskAndCommonName
tblLookup_Unique_HHRisk
tblLookup_Unique_HHRiskAndCommonName
tblLookup_Unique_Lab
tblLookup_Unique_Location
tblLookup_Unique_LocationAndDeposit
tblLookup_Unique_Matrix
tblLookup_Unique_MatrixAndSampleType
tblLookup_Unique_Method
tblLookup_Unique_QAStatus
tblLookup_Unique_Qualifier
tblLookup_Unique_SampledBy
tblLookup_Unique_SampleID
tblLookup_Unique_SampleType
tblLookup_Unique_Source
tblLookup_Unique_StatisticsChoices
tblLookup_Unique_Validator

2. When new data is imported into the Access database as above, you must repopulate the web database file to reflect the new data. To do this, delete all tables in the Fox River Web DB.mdb file except for the static tables listed below. After the tables have been deleted, compact the database file to clear the deleted tables file space. Then, import all tables as described in Step 1 above.

   tblLookup_CriteriaForLists
   tblLookup_FieldsForLists
   tblLookup_SortFieldsForSearches

Addendum 1 to the Data Management Summary Report
(EcoChem, 2002)

Data Management Summary Report, Addendum 1

Fox River Remedial Investigation/Feasibility Study

November 25, 2002

ADDENDUM 1 TO THE DATA MANAGEMENT SUMMARY REPORT

Note: As data are collected, reviewed (or validated), and appended to the Fox River Database (FRDB), the Data Management Summary Report will also be appended. A description of the data set, along with results of data review/validation and determination of usability will be discussed in consecutively numbered sections.

As supporting tables (Table 3-1: Data Set Analysis and Table 3-2: QC Elements for Data Sets Supporting the Fox River RI/FS and RA) are appended, the tables will be resubmitted (with each Addendum) in their entirety.

3.2.29 1999 DEMONSTRATION PROJECT DATA - SMU 56/57

This data set has now been appended to the Fox River Database (FRDB) and has been included in Tables 3-1, Data Set Analysis. All previous discussion remains valid, as presented in the DMR, October, 2000.

3.2.30 2000/2001 FRG/CH2M HILL SEDIMENT & WOOD CHIP DATA

CH_2M Hill collected soil/sediment (and one set of wood chip) samples in 2000 and 2001 for the Fox River Group (FRG). The samples were collected from the Little Lake Butte des Morts area. Samples were analyzed for polychlorinated biphenyl (PCB) Aroclors, metals, volatile organics, semivolatile organics, gasoline- and diesel-range organics, and cyanide. The data set consisted of 428 samples.

EcoChem performed a review of the FRG 2000 and 2001 data validation conducted by CH_2M Hill. EcoChem evaluated the validation results for completeness and technical agreement. The samples were analyzed by United States Environmental Protection Agency (EPA) SW-846 methodology and other miscellaneous EPA methods. The gasoline- and diesel-range analyses were conducted using the Wisconsin GRO and DRO methods. The validation protocols used by CH_2M Hill were not specified.

Overall the data are of acceptable quality. The samples appear to have analyzed as per the cited methods, and the validation worksheets generally follow the guidelines specified in *U.S. EPA National Functional Guidelines for Organic Data Review* (February 1994) and *U.S. EPA National Functional Guidelines for Inorganic Data Review* (February 1994). No validation reports were provided. The information reviewed consisted of data validation worksheets and annotated sample result summary forms. The validation worksheets were often not complete. However, there is sufficient information in the notes made by the validator (in the worksheet comments section) to indicate that the data were reviewed, and the issue is one of incomplete documentation, rather than an incomplete review. Most of the worksheets do not include the date that the validation was performed, or the name of the validator. Some of the sample result summary forms were also not dated.

Many of the data qualifiers issued by CH_2M Hill were due to interference caused by the natural overlap of some of the Aroclors (such as Aroclors 1242 and 1254). It is not possible to evaluate these findings without reviewing the raw data. A more detailed review of the data may result in the removal of some of these qualifiers. For the semivolatile analyses in data package 913426, the qualifiers on the sample result summary forms do not match those discussed in the validation worksheet. A more detailed review of the data for this package would result in additional qualifiers (estimated data). However, the above changes would not significantly impact the reported data. As determined by this review, the data, as qualified, are usable for the intended purpose.

3.2.31 2000 FRG/BBL SUPPLEMENTAL MONITORING PROGRAM DATA: SURFACE WATER

Blasland Bouck & Lee (BBL) collected surface water, particulate, and XAD filter samples in 2000 for the FRG. The samples were collected as part of the Supplemental Monitoring Program – Surface Water. Samples were analyzed for PCB Aroclors, PCB congeners, total suspended soils (TSS), total volatile suspended solids (TVSS), and total organic carbon (TOC). The data set consisted of 205 samples. Not all samples were analyzed for all tests.

EcoChem performed a review of the FRG 2000 data validation conducted by BBL. EcoChem evaluated the validation worksheets and reports for completeness and technical agreement. The samples were analyzed by EPA SW-846 methodology and other miscellaneous EPA methods. The validation report states that the qualifiers are "in accordance with National Functional Guidelines." The date of the version of Functional Guidelines used is not provided. The validation worksheets do not provide the name(s) of the validator(s), or the date that the validation was performed. The sample result summary forms are usually not initialed and dated.

The samples appear to have analyzed as per the cited methods, and the validation worksheets generally follow the guidelines specified in *U.S. EPA National Functional Guidelines for Organic Data Review* (February 1994) and *U.S. EPA National Functional Guidelines for Inorganic Data Review* (February 1994).

For one PCB congener data package, when qualifiers were recommended (in the validation worksheet) based on blank contamination, the sample result summary forms were not qualified. Rather, the reporting limits were elevated, but no "U" qualifier was added to the summary form. During a more detailed review, EcoChem would add the qualifiers. Although surrogate and laboratory control sample (LCS) recovery outliers were noted, no action was taken. A more detailed review of the data would most likely result in additional qualifiers (estimated data). Overall the data are of acceptable quality. The data, as qualified, are usable for the intended purpose.

3.2.32 2000/2001 FRG/BBL SUPPLEMENTAL MONITORING PROGRAM DATA: SEDIMENT DATA

BBL collected sediment samples in 2000 and 2001 for the FRG. The samples were collected as part of the Supplemental Monitoring Program. Samples were analyzed for PCB congeners (one data set), PCB Aroclors, TOC, and grain size. The data set consisted of 158 samples.

EcoChem performed a review of the FRG 2001 data validation conducted by BBL. EcoChem evaluated the validation worksheets and reports for completeness and technical agreement. The samples were analyzed by EPA SW-846 methodology and other miscellaneous EPA methods. The validation report states that the qualifiers are "in accordance with National Functional Guidelines." The date of the version of Functional Guidelines used is not provided. The validation worksheets do not provide the name(s) of the validator(s), or the date that the validation was performed. The sample result summary forms are usually not initialed and dated.

The samples appear to have analyzed as per the cited methods, and the validation worksheets generally follow the guidelines specified in *U.S. EPA National Functional Guidelines for Organic Data Review* (February 1994) and *U.S. EPA National Functional Guidelines for Inorganic Data Review* (February 1994). Only sample results were provided for the grain size analyses, so these were not validated.

Overall the data are of acceptable quality. Qualifiers were issued based on a matrix spike recovery outlier. However, the associated matrix spike duplicate and LCS were acceptable. A more detailed review of the data would most likely result in removal of the qualifiers. With this change, no data would be qualified. The data are usable for the intended purpose.

3.2.33 2001 FRG/BBL GREEN BAY SEDIMENT SAMPLING DATA

BBL collected sediment samples in 2001 for the FRG. The samples were collected as part of the Green Bay Sediment Sampling event. Samples were analyzed for PCB Aroclors, TOC, and grain size. The data set consisted of 30 samples.

EcoChem performed a review of the FRG 2001 data validation conducted by BBL. EcoChem evaluated the validation worksheets and reports for completeness and technical agreement. The samples were analyzed by EPA SW-846 methodology and other miscellaneous EPA methods. The validation report states that the qualifiers are "in accordance with National Functional Guidelines." The date of the version of Functional Guidelines used is not provided. The validation worksheets do not provide the name(s) of the validator(s), or the date that the validation was performed. The sample result summary forms are usually not initialed and dated.

Overall the data are of acceptable quality. The samples appear to have analyzed as per the cited methods, and the validation worksheets generally follow the guidelines specified in *U.S. EPA National Functional Guidelines for Organic Data Review* (February 1994) and *U.S. EPA National Functional Guidelines for Inorganic Data Review* (February 1994). Only sample results were provided for the grain size analyses, so these were not validated.

In addition to evaluating the validation reports and worksheets, EcoChem also performed a full validation of the data packages. The results of the validation by EcoChem were compared to the validation performed by BBL. The two validations were mostly in agreement; however, BBL estimated a few TOC results and EcoChem did not. The changes would not significantly impact the reported data. As determined by this review, the data, as qualified, is usable for the intended purpose.

3.2.34 2001 FRG/BBL WATER COLUMN-HIGH FLOW DATA

BBL collected surface water, particulate, and XAD filter samples in 2001 for the FRG. The samples were collected as part of the Fox River 2001 Water Column – High Flow study. Samples were analyzed for PCB Aroclors, PCB congeners, TSS, TVSS, and TOC. The data set consisted of 615 samples. Not all samples were analyzed for all tests.

EcoChem performed a review of the FRG 2001 data validation conducted by BBL. EcoChem evaluated the validation worksheets and reports for completeness and technical agreement. The samples were analyzed by EPA SW-846 methodology and other miscellaneous EPA methods. The validation report states that the qualifiers are "in accordance with National Functional Guidelines." The date of the version of Functional Guidelines used is not provided. The validation worksheets do not provide the name(s) of the validator(s), or the date that the validation was performed. The sample result summary forms are usually not initialed and dated.

The samples appear to have analyzed as per the cited methods, and the validation worksheets generally follow the guidelines specified in *U.S. EPA National Functional Guidelines for Organic Data Review* (February 1994) and *U.S. EPA National Functional Guidelines for Inorganic Data Review* (February 1994).

Many of the surrogate recovery values were less than the acceptance limit and less than 10 percent for the PCB Aroclor analyses. The validation reports state that this was caused by the Florisil cleanup. The reports further state that the Florisil had a negative impact on select peaks (typically Aroclor 1242), and that the results for the affected Aroclors were recalculated using non-impacted peaks. On the sample result summary forms, the reported value was lined out and a revised (elevated) concentration was hand entered.

It is not possible to evaluate the revisions without the raw data. Also, none of the calculations were provided, and so cannot be verified. During a more detailed review of the data, EcoChem would most likely estimate the data. If revised concentrations were appropriate, EcoChem would request that the laboratory recalculate the concentrations and issue a revised sample result summary form.

For the PCB congener analyses, no changes or additional qualifiers are recommended by EcoChem. However, when qualifiers were issued based on blank contamination, the sample result summary forms were not qualified as recommended. Rather, the reporting limits were elevated, but no "U" qualifier was added to the summary form. During a more detailed review, EcoChem would add the qualifiers. For the general chemistry parameters (TSS, TVSS, and TOC), no changes or additional qualifiers are recommended by EcoChem. A more detailed review of the data would most likely not result in additional qualifiers. The data, as qualified, are usable for the intended purpose.

3.3 DATA USABILITY

3.3.1 FULLY VALIDATED DATA

The following data sets have been validated by an independent party and are considered useable, as qualified:

- 1994 GAS/SAIC Sediment Collection
- 1994 Woodward-Clyde Deposit A Sediment Collection
- 1995 WDNR Sediment Data Collection
- 1996 USFWS NRDA Fish Tissue Data Collection
- 1996 WDNR Fish Tissue Data Collection
- 1998 Demonstration Project Data - SMU 56/57
- 1998 RETEC RI/FS Supplemental Data Collection
- 1996 FRG/BBL Sediment/Tissue Data Collection
- 1997 Demonstration Project Data - Deposit N
- 1992/93 BBL Deposit A Sediment Data Collection
- 1998 FRG/Exponent Data Collection
- 1998 FRG/Blasland, Bouck, and Lee, Inc. Sediment/Tissue Data Collection
- 1998 Deposit N Pilot Remediation-Pre-Dredge, Post-Dredge, Operation Monitoring, and Environmental Monitoring Data
- 1999 Demonstration Project Data- SMU 56/57
- State of Michigan Fish Consumption Advisory Data
- Lake Michigan Tributary Monitoring Data
- 1999 Demonstration Project Data - SMU 56/57
- Minergy EPA SITE Program Data
- 2000/2001 FRG/CH2M Hill Sediment & Wood Chip Data;

- 2000 FRG/BBL Supplemental Monitoring Program Data: Surface Water;
- 2000/2001 FRG/BBL Supplemental Monitoring Program Data: Sediment Data;
- 2001 FRG/BBL Green Bay Sediment Sampling Data; and
- 2001 FRG/BBL Water Column-High Flow Data.

Although the data sets (listed above) were found to be validated and useable, it must be stressed that there were individual data points that were rejected. These rejected data points have not been used in support of the RI/FS or RA.

3.3.2 SUPPORTING DATA

The following data sets have not been validated and, in general, should be used only as supporting data. The data have been collected within different programs and with different data quality objectives therefore, varying degrees of supporting documentation may be available.

- 1989/90 Fox River Mass Balance Study
- 1989/90 Green Bay Mass Balance Study (GLNPO)
- 1993 Triad Assessment
- 1993-1996 USFWS Tree Swallow Data Collection
- 1994-1995 Cormorant Data Collection
- 1997 USFWS NRDA Waterfowl Tissue Data Collection
- 1997 WDNR Caged Fish Bioaccumulation Study Data
- Fox River Fish Consumption Advisory Data
- Stromberg Eagle Data Collection
- USGS NAWQA Data
- WDNR Wildlife Tissue Data
- WPDES Permit Influent Data
- Lake Michigan Mass Balance Data
- Minergy Mineralogical Data
- Lower Fox River Background Metals Assessment
- FoxView Data

3.3.3 INDETERMINATE DATA

The following data sets have not been validated and have not been subjected to a data quality review. This is due to complete lack of supporting QA/QC documentation; or, EcoChem did not receive the hardcopy data and documents by the date of this report. At this time the overall quality of these data sets is unknown and the data should be used with that fact in mind.

- Ankley and Call

Table 3-1
Data Set Analysis

Data Source	Number of Samples	Matrices[1]	Analyses Conducted[2]	Number of Records	Number of Files in Delivery	File Type	Report Section	Earliest Year of Collection	Latest Year of Collection
1989 - 1990 Fox River Mass Balance Study	1967	S,W	PCB-A, PCB-C, W	25457	6	Spreadsheet	3.2.01	1989	1990
1989 - 1990 Green Bay Mass Balance Study (GLNPO)	2069	S,T,W	B, PCB-C, W	201701	92	Database	3.2.01	1987	1990
1992 - 1993 BBL Deposit A Sediment Data	117	S,W	M, P/H, PCB-A, SVOA, V, W	1094	1	Spreadsheet	3.2.02	1992	1993
1993 Triad Assessment	27	S	B, M, P/H, PCB-A, SVOA, W	631	11	Spreadsheet	3.2.03	1992	1993
1994 GAS/SAIC Sediment Collection	253	S	DXN, M, P/H, PCB-A, SVOA, V, W	5654	6	Spreadsheet	3.2.04	1994	1994
1995 WDNR Sediment Data	488	S	M, PCB-A, W	6433	8	Spreadsheet	3.2.05	1995	1995
1996 FRG/BBL Sediment/Tissue Data	25	S,T	B, PCB-C, W	2771	6	Spreadsheet	3.2.06	1996	1996
1995 - 1996 WDNR Tissue Data	200	T	B, PCB-A, W	1673	1	Spreadsheet	3.2.07	1995	1996
1996 - USFWS NRDA Tissue Data	376	T	DXN, P/H, PCB-A, PCB-C, W	16017	5	Spreadsheet	3.2.08	1996	1999
1993-1996 Tree Swallow Data	200	T	B, DXN, P/H, V, W	5429	2	Database	3.2.09	1993	1993
1994-1995 Cormorant Data	193	T	B, DXN, P/H, PCB-C, W	6178	2	Database	3.2.09	1994	1995
1997 USFWS NRDA Waterfowl Tissue Data	70	T	B, P/H, PCB, V, W	1680	2	Database	3.2.09	1997	1997
Fox River Fish Consumption Advisory Data: 1998 WDNR Fish Consumption Data	130	T	B,M, PCB-A, W	777	1	ASCII	3.2.10	1998	1998
Fox River Fish Consumption Advisory Data	1766	S,T	B, DXN, M, P/H, PCB-A, PCB-C, SVOA, V, W	11620	2	ASCII	3.2.10	1971	1996
WDNR Wildlife Tissue Data	417	T	B, M, P/H, PCB-A	2532	3	Database	3.2.11	1984	1996
Lake Michigan Tributary Monitoring Data	88	W	M, P/H, PCB-C, V	5722	5	Spreadsheet	3.2.12	1994	1995
Stromberg Eagle Data	31	T	B, DXN, P/H, PCB-A, PCB-C, SVOA, V, W	954	1	ASCII	3.2.13	1991	1996
USGS NAWQA Data	441	S,T,W	B, M, P/H, PCB, SVOA, V, W	11879	21	Spreadsheet	3.2.14	1992	1997
1994 Woodward-Clyde Deposit A Sediment Data	66	S	PCB-A, W	585	12	Spreadsheet	3.2.15	1994	1994
WPDES Permit Influent Data	8	W	B, DXN, M, P/H, PCB-A, RAD, SVOA, V, W	847	1	Spreadsheet	3.2.16	1993	1997
Lower Fox River Background Metals Assessment Data	14	W	M	78	1	Spreadsheet	3.2.17	1991	1993
1997 WDNR Caged Fish Bioaccumulation Study Data	25	S,T	B, PCB-C, W	1672	2	Spreadsheet	3.2.18	1997	1997
1997 Demonstration Project Data - Deposit N	10	S	M, PCB, W	83	1	Spreadsheet	3.2.19	1997	1997
1997 Demonstration Project Data - SMU 56/57	295	S,W	DXN, M, P/H, PCB-A, SVOA, V, W	3114	12	Spreadsheet	3.2.20	1997	1998
1998 RETEC RI/FS Supplemental Data	252	S,T	B, DXN, M, P/H, PCB-A, PCB-C, SVOA, V, W	10781	1	ASCII	3.2.21	1998	1998
Lake Michigan Mass Balance Data	6987	A,S,T,W	M, P/H,PCB-C, V, W	91621	211	Database	3.2.22	1993	1996
Minergy Mineralogical Data	15	S	W	219	1	Spreadsheet	3.2.23	1995	1999
1998 FRG/Exponent Data	225	T	B, M, P/H, PCB-A, PCB-C, W	17708	3	Database	3.2.24	1998	1998

Table 3-1
Data Set Analysis

Data Source	Number of Samples	Matrices[1]	Analyses Conducted[2]	Number of Records	Number of Files in Delivery	File Type	Report Section	Earliest Year of Collection	Latest Year of Collection
1998 FRG/BBL Sediment/Tissue Data	1315	S,T,W	B, M, P/H, PCB-A, PCB-C, RAD, SVOA, W	18824	1	Database	3.2.25	1998	1998
1998 - 1999 Deposit N Data: Post-Dredge	43	S	PCB-A, PCB-C, W	690	8	Spreadsheet	3.2.26	1999	1999
1998 - Deposit N Data: Pre-Dredge	53	S	PCB-A, PCB-C, W	1437	6	Spreadsheet	3.2.26	1998	1998
1998/1999 Deposit N Data: Remediation	197	T,W	PCB-C, W	10264	1	Spreadsheet	3.2.26	1998	1999
1998 - 1999 Deposit N Data: Operational Monitoring	12	S	M, PCB-A, W	123	1	Spreadsheet	3.2.26	1998	1998
Ankley and Call Data	62	PW,S,T,W	DXN, M, P/H, PCB, SVOA, W	1607	0	Hardcopy	3.2.27	1989	1989
State of Michigan Fish Consumption Advisory Data	434	T	B, DXN, M, P/H, PCB-A, W	6979	1	Database	3.2.28	1983	1999
1999 FRG Demonstration Project Data - Deposit N & SMU 56/57	2408	A,O,S,W	PCB-A, PCB-C, M, W, V, SVOA, P/H, DXN	46389	28	Database/ Spreadsheet	3.2.29	1999	1999
2000 - 2001 FRG/CH2M Hill Sediment/Wood Chip Data	428 [a]	S,WC	PCB-A, GRO, DRO, M, V, SVOA, CN	6428	1	Database	3.2.30	2000	2001
2000 FRG/BBL Supplemental Monitoring Program Data: Surface Water [b]	205	W, XAD	PCB-A, PCB-C, W				3.2.31	2000	2000
2000 - 2001 FRG/BBL Supplemental Monitoring Program Data: Sediment [b]	158	S	PCB-A, PCB-C, W				3.2.32	2000	2001
2001 FRG/BBL Green Bay Sediment Sampling Data [b]	30	S	PCB-A, W				3.2.33	2001	2001
2001 FRG/BBL Water Column - High Flow Data [b]	615	W, XAD	PCB-A, PCB-C, W				3.2.34	2001	2001
Minergy EPA SITE Data	90	A,O,S,W	PCB-C, M, W, V, SVOA, DXN	8053	5	Spreadsheet	na	2001	2001
Total: 41 Data Sets	**22377**			**535704**	**472**				

[1]Matrices
S = Sediment
T = Tissue
W = Water
PW = Sediment Pore Water
A = Ambiant Air
WC = Wood Chip
XAD = filters

[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)
GRO = gas range organics
DRO = diesel range organics
V = Volatiles
SVOA = Semi-volatiles
P/H = Pesticides/Herbicides
DXN = Dioxins
B = Biological
CN = Cyanide

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

			1989 - 1990 GREEN BAY MASS BALANCE STUDY	1995 - 1996 WDNR FISH TISSUE	1996 USFWS/ HAGLER BAILLY DATA	1995 WDNR BELOW DEPERE		
	Parameters:		PCBs	PCB	PCB	PCBs	TOC	Metals
Types	Requirements		Sediment	Fish Tissue	Fish Tissue	Sediment	Sediment	Sediment
SDG#'s			University of Minnesota - Data groups; IN0042, IN0047, IN0052, IN0057, IN0061, IN0070, IN0076, IN0078, IN0037, and IN0041	SLOH Fish SDG-1	Battelle Laboratory Multiple SDGs	Hazleton SDG #'s TBD2,10, 1 and 20	Hazleton SDG #'s TBD2,10, 1 and 20	Hazleton SDG #'s TBD2, and 20
Data Review	1)	Third Party Validation Performed	Verification Only Deborah Swackhamer, Ph. D.	MA Kuehl Co	EcoChem	Y/MAKuehl	Y/MAKuehl	Y/MAKuehl
Deliverables	1)	Electronic Deliverables	Yes	Yes	Yes	Yes	Yes	Yes
	2)	Hard copy	Some - Not sure if this is a complete set	Yes	Yes	Some	Some	Some
Data Review Details	1)	Package Completeness	Not determined	Yes	Yes	Yes	Yes	Yes
	2)	Chain of Custody Procedures	Not determined	Not determined	Yes/Minor issues	Not determined	Not determined	Not determined
	3)	Holding Times	Not summarized on the QA/QC Summary report Sheet	Yes	Yes	Yes	Yes	Yes
	4)	Initial Calibration	Not summarized on the QA/QC Summary report Sheet	Y (25%)	Y(35%)	25%	Yes	Yes
		Curve - # of standards	Not summarized on the QA/QC Summary report Sheet	5pt	5pt	5pt	Daily One Pt	1point/6 point for Hg
	5)	Calibration Verification	Not summarized on the QA/QC Summary report Sheet	15%D	Varies between GC/ECD and GC/MS. <25% for 75% analytes	15%	20%	10% for metals & 20% for Hg
		Secondary Column	Not summarized on the QA/QC Summary report Sheet	25%D	Y, data not used	25% D for CC on 2nd column	NA	NA
	6)	Laboratory Blanks	Not clear.	Yes	Yes	Yes	Yes	Yes
	7)	Surrogate Recoveries, # required	Y - 50-120%	Y - 70-120%	Y - 50-125%	60-150%	NA	NA
	8)	Matrix Spike, # required	Y - 50-120%	Y - 65-125%	Y- 50-125% tri and deca 30-125% for mono and dichloro	65-125%	75-125%	75-125%
	9)	Lab Duplicate	Yes/Not clear what limits are.	Y/26% Limit	Y/50%	26%	20%	20%
		Lab Control Sample (SRM results?)	None/QAPP says that a series of blindly coded QA samples will be analyzed.	N	SRM NRC %D Carp-1 <35%	NA	NA	Y/EPA
	10)	Gel Permeation/Forisil Cleanup	Not provided	Y	Not mentioned	Y	NA	NA
	11)	Detection Limit	Not provided	50 ug/kg	Results reported to zero	50 ppb	NA	CRDL
	12)	Calc and transposition verification. Qualitative verification?	Not able to determine if this was done.	Y/Recalc	Y/Recalc and Verification	Yes/Recalc performed > 10% frequency	NA	10%
	13)	Field QC Results	Not apparent	NA	None	None	None	None
	14)	Usability Usable/Supporting	Yes	Usable	Usable	Usable	Usable	Usable
		Qualifiers	Qualifiers mentioned but not defined.	Y/Minor J Quals due to detections below PQL.	Yes - Qualifiers due to CCV %D outliers, BS results, surrogate outliers, lab dups, SRM results and inteferences	Yes - Minor J Flags due to low surrogate recovery or below PQL and above MDL.	Yes - Minor J Flags due to poor lab RPD	None

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

		1989 - 1990 GREEN BAY MASS BALANCE STUDY	1995 - 1996 WDNR FISH TISSUE	1996 USFWS/ HAGLER BAILLY DATA	1995 WDNR BELOW DEPERE		
	Parameters:	PCBs	PCB	PCB	PCBs	TOC	Metals
Types	Requirements	Sediment	Fish Tissue	Fish Tissue	Sediment	Sediment	Sediment
SAP		N/Study Plan		N	Y		
QAPP		Y		Y/Tech Memo	Y		
Lab QAM		Answer Pending/U of M SOPs?	Y	Y/Tech Memo	Y - Hazleton SOPs		

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

			LOWER LAKE MICHIGAN MASS BALANCE	1998 FOX RIVER NRDA				
	Parameters:		Asst. Conventionals, Pest/PCB, Hg, Atrazine,DEA, DIA	PCB	PCB Congener	PCB Congener	Pesticide	Mercury
Types	Requirements		Water (Open Lake,Tributary), Air, Sediment, Phytoplankton	Fish Tissue	Fish Tissue	Fish Tissue	Fish Tissue	Fish Tissue
SDG#'s			BALN, GPLN, GRAN, GRLN, IUAA, IUAP, LHTL, LHTM, LHTN, LHTP, MDLH, MIAH, MNPH, RUAP, RULA, RUTA, SSSP, USTN, WSAA, WWTH, WWTN	Enchem Multiple SDGs	Michigan State University	Quanterra	Enchem Multiple SDGs	Enchem Multiple SDGs
Data Review	1)	Third Party Validation Performed	No- data reviewed by QC Coordinators	Exponent	Exponent	Exponent	Exponent	Exponent
Deliverables	1)	Electronic Deliverables	Yes	Yes	Yes	Yes	Yes	Yes
	2)	Hard copy	Unknown	Yes	Yes	Yes	Yes	Yes
Data Review Details	1)	Package Completeness	Not addressed	Y	Y	Y	Y	Y
	2)	Chain of Custody Procedures	Not addressed	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
	3)	Holding Times	NO DV reports provided	Y	Some exceedences Samples J/UJ	Y	Some exceedences Samples J/UJ	Y
	4)	Initial Calibration	NO DV reports provided	Y	Y	Y	Y	Y
		Curve - # of standards	NO DV reports provided	Y	Y	Y	Y	Y
	5)	Calibration Verification	NO DV reports provided	20%	20%	20%	20%	10%
		Secondary Column	NO DV reports provided	Y	Y	Y	Y	NA
	6)	Laboratory Blanks	NO DV reports provided	Y	Y- U based on blank contamination	Y	Y	Y
	7)	Surrogate Recoveries, # required	NO DV reports provided	Y	Y	Y	Y	Y
	8)	Matrix Spike, # required	NO DV reports provided	Y - no quals for %R outliers	Y - no quals for %R outliers	Y - no quals for %R outliers	Y	Y
	9)	Lab Duplicate	NO DV reports provided	Y - MS/MSD	Y - MS/MSD	Y - MS/MSD	Y - MS/MSD	Y
		Lab Control Sample (SRM results?)	NO DV reports provided	Y	Y	Y	Y	Y
	10)	Gel Permeation/Forisil Cleanup	NO DV reports provided	Not Mentioned	Not mentioned	Not mentioned	Not mentioned	NA
	11)	Detection Limit	NO DV reports provided	NA	NA	NA	NA	NA
	12)	Calc and transposition verification. Qualitative verification?	No recalculations were provided unable to determine if transcription checks were done	No recalculations were provided unable to determine if transcription checks were done	No recalculations were provided unable to determine if transcription checks were done	No recalculations were provided unable to determine if transcription checks were done	No recalculations were provided unable to determine if transcription checks were done	No recalculations were provided unable to determine if transcription checks were done
	13)	Field QC Results	Not addressed	None identified	None identified	None identified	None identified	None identified
	14)	Usability Usable/Supporting	Supporting	Usable	Usable - Some results rejected for low surrogate %R	Usable	Usable	Usable
		Qualifiers	Y - Specific LLMB 3 character Qual codes	Y/ holdtimes, surrogate %R, LCS %R	Y/ surr %R, blank contamination -U, coplanars- J/UJ diff between GC and HRGCMS, interference, coelutions	Y/ Coelutions, greater than calibration range	Y/ Holdtimes, MS/MSD %R, Surr %R, PCB interference - all + J	Y/ Duplicate RPD

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

		LOWER LAKE MICHIGAN MASS BALANCE	1998 FOX RIVER NRDA				
	Parameters:	Asst. Conventionals, Pest/PCB, Hg, Atrazine,DEA, DIA	PCB	PCB Congener	PCB Congener	Pesticide	Mercury
Types	Requirements	Water (Open Lake,Tributary), Air, Sediment, Phytoplankton	Fish Tissue	Fish Tissue	Fish Tissue	Fish Tissue	Fish Tissue
SAP							
QAPP							
Lab QAM							

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

			1994 SAIC/GAS REMEDIAL INVESTIGATION/FEASIBILITY STUDY DATA SETS							
	Parameters:		PCBs	PCBs	PCBs	PCBs	PCBs	PCBs	PCBs	PCBs
Types	Requirements		Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
SDG#'s			ARI M172	ARI M174	ARI M176	ARI M177	ARI M178/M179/M364	ARI M365	ARI M367/M368	ARI M370
Data Review	1)	Third Party Validation Performed	Y/SAIC	Y/SAIC	Y/SAIC	Y/SAIC	Y/SAIC	Y/SAIC	Y/SAIC	Y/SAIC
Deliverables	1)	Electronic Deliverables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	2)	Hard copy	Yes but not easily accessed	Yes but not easily accessed	Yes but not easily accessed	Yes but not easily accessed	Yes but not easily accessed	Yes but not easily accessed	Yes but not easily accessed	Yes but not easily accessed
Data Review Details	1)	Package Completeness	Y	Y	Y	Y	Y	Y	Y	Y
	2)	Chain of Custody Procedures	Not determined	Not determined	Not determined	Not determined	Not determined	Not determined	Not determined	Not determined
	3)	Holding Times	Y (Frozen)	Y/Some exceed	Y	Y	Y/some exceedances. one sample qualifed J for gross exceedances (M178)	Yes exceedances. several sample qualifed J for gross exceedances (M365)	Yes/Minor violations	Yes/Minor violations
	4)	Initial Calibration	Y	Y	Y	Y	Y	Y	Y	Y
		Curve - # of standards	3-5pt	3-5pt	5-pt	5-pt	5-pt	5-pt	5-pt	5-pt
	5)	Calibration Verification	15%D but Ave was higher. Results flagged (J/UJ).	15%D but Ave was higher. Results flagged (J/UJ).	15%D but Ave was higher. Results flagged (J/UJ).	15%D but Ave was higher. Results flagged (J/UJ).	15%D but Ave was higher. Results flagged (J/UJ).	15%D but Ave was higher. Results flagged (J/UJ).	15%D but Ave was higher. Results flagged (J/UJ).	15%
		Secondary Column	Not indicated	Not indicated	Not indicated	Not indicated	Not indicated	Not indicated	Not indicated	Not indicated
	6)	Laboratory Blanks	Y	Y	Y	Y	Y	Y	Y	Y
	7)	Surrogate Recoveries, # required	TCMX 55-115%/DCB 70-125%	TCMX 55-115%/DCB 70-125%	TCMX 55-115%/DCB 70-125%	TCMX 55-115%/DCB 70-125%	TCMX 55-115%/DCB 70-125%	TCMX 55-115%/DCB 70-125%	TCMX 55-115%/DCB 70-125%	TCMX 55-115%/DCB 70-125%
	8)	Matrix Spike, # required	5% min - 130% ma	35% min - 130% max	35% min - 130% max	35% min - 130% max	35% min - 130% max	35% min - 130% max	35 min% - 130% max	35 min% - 130% max
	9)	Lab Duplicate	N	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned	Not mentioned
		Lab Control Sample (SRM results?)	Y	Y	Y	Y	Y	Y	Y	Y
	10)	Gel Permeation/Forisil Cleanup	Y - If necess.	Y - If necess.	Not sure	Not sure	Not sure	Not sure	Not sure	Not sure
	11)	Detection Limit	50 ppb wet wt	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	12)	Calc and transposition verification. Qualitative verification?	Y / 10 % ?	N - No chros	ID and Quants Could not be verified. Raw data not provided	ID and Quants Could not be verified. Raw data not provided	ID and Quants Could not be verified. Raw data not provided	Data verified	N	Not verified
	13)	Field QC Results	None	None	None	Not identified	Not identified	Not identified	Not identified	Not identified
	14)	Usability Usable/Supporting	Usable	Usable	Usable	Usable	Usable	Usable	Usable	Usable
		Qualifiers	Yes - Minor quals assigned due to CCV (J/UJ)	Yes - Minor quals assigned due to CCV (J/UJ)	Yes - Minor quals assigned due to CCV, surrogate recoveries J/UJ	Yes - Minor quals assigned due to CCV, surrogate recoveries J/UJ	Yes - Minor quals assigned due to CCV, surrogate recoveries J/UJ	Yes - Minor quals assigned due to CCV, surrogate recoveries J/UJ	Yes - Minor quals assigned due to CCV, surrogate recoveries J/UJ	Yes - Minor quals assigned due to surrogate recoveries J/UJ

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

		1994 SAIC/GAS REMEDIAL INVESTIGATION/FEASIBILITY STUDY DATA SETS							
	Parameters:	PCBs	PCBs	PCBs	PCBs	PCBs	PCBs	PCBs	PCBs
Types	Requirements	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
SAP		Y							
QAPP		Y							
Lab QAM									

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

			1994 SAIC/GAS REMEDIAL INVESTIGATION/FEASIBILITY STUDY DATA SETS (cont.)						
	Parameters:		Dioxins	CLP Pest/PCBs	CLP SVOCs	CLP Metals	TCLP Metals	Mercury	Mercury
Types	Requirements		Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
SDG#'s			Triangle Lab SDG # 35589	Swanson/SDG 948521	Swanson/ SDG 948521	Swanson/SDGs 12718, 12724, 12745, 12806, 12816, 12941	Swanson/ SDGs 12718, 12724,12730, 12827, 12718, 12802, 12833, 12844	Swanson WL12941	Swanson WL12745
Data Review	1)	Third Party Validation Performed	Y/SAIC	Y/SAIC	Y/SAIC	Y/SAIC	Y/SAIC	Y/SAIC	Y/SAIC
Deliverables	1)	Electronic Deliverables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	2)	Hard copy	Yes but not easily accessed	Yes but not easily accessed	Yes but not easily accessed	Yes but not easily accessed	Yes but not easily accessed	Yes but not easily accessed	Yes but not easily accessed
Data Review Details	1)	Package Completeness	Y	Y	N/Forms 1 not supplied by lab	Y	Y	N/Forms 1 not supplied by lab	Y
	2)	Chain of Custody Procedures	Not determined	Not determined	Not determined	Not determined	Not determined	Not determined	Not determined
	3)	Holding Times	Yes/Minor violations	N/Samples sent to TL 10 days after collection	N/All samples exceeded HT and are qualifed as estimated (J, UJ).	Y/Hg results are flagged for exceeding HT by 27 to 42 days (J/UJ)	Y	N/All samples exceeded HT and are qualifed as estimated (J, UJ).	Y
	4)	Initial Calibration	Y	Y/Not consistent with CLP protocol	Y/Not consistent with CLP protocol	Y (Validator recalc HG results)	Y	Y/exceedance	Y/exceedance
		Curve - # of standards	5-pt	5-pt	5-pt	Lin Reg	Lin Reg	5pt	5pt
	5)	Calibration Verification	20%RSD	N/correct concentration not used. Certain analytes outside RT window	%15D/Some exceedances qualified samples as estimated J/UJ	10%D	10%D	Y/15%	Y/15%
		Secondary Column	NA	Not indicated	Not indicated	NA	NA	NA	NA
	6)	Laboratory Blanks	Y	Y	Y	Y	Y	Y	Y
	7)	Surrogate Recoveries, # required	TCFD 25-150%/TCDD 25-150%	TCMX 55-115%/DCB 70-125%	8 Required/ 18% min - 137% max	NA	NA	NA	NA
	8)	Matrix Spike, # required	TCDD/-TCDF 54-162	18/9 Required 29 min - 152 max	11 Required/11% min - 142% max	75-125%	75-125%	75-125%	75-125%
	9)	Lab Duplicate	Not mentioned	Not mentioned	Not mentioned	Y 20%/some exceedances qualified J/UJ	Y	Y	Y
		Lab Control Sample (SRM results?)	Y	Y	Y/acenapthene fell outside @53%	Y	Y	Y	Y
	10)	Gel Permeation/Forisil Cleanup	Not sure	Not sure	Not sure	N/A	N/A	N/A	N/A
	11)	Detection Limit	Elevated in some samples due to blank cont. and noise	Elevated in some samples due to blank cont. and noise	N/A	N/A	N/A	N/A	N/A
	12)	Calc and transposition verification. Qualitative verification?	Y - Sample Identifications. Sample Quant not reviewed.	Not Verifiable	Y	Y. Some calc errors.	Y	N	N
	13)	Field QC Results	Not identified	Not identified	Not identified	None	N	Y/Field Duplicate >	N
	14)	Usability Usable/Supporting	Usable	Third party validation considers it unusable.	Usable	Usable - 1 data point rejected for Zn	Usable	Usable	Usable
		Qualifiers	Yes/Due to blank cont, and elevated matrix spike recovery sample results may be biased positive (J+)	Yes/Major issues about overall quality of data. Associated with RT drift, quality of work poor.	Yes/Minor qualifications due to HT exceedances and low surr and spike recoveries (J/UJ)	Yes/Minor and Major qualifications due poor spike recoveries (J/UJ) and (R) on Zinc	No Qualifications	Yes - Minor J Flags	Yes - Minor UJ/J Flags

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

		1994 SAIC/GAS REMEDIAL INVESTIGATION/FEASIBILITY STUDY DATA SETS (cont.)						
	Parameters:	Dioxins	CLP Pest/PCBs	CLP SVOCs	CLP Metals	TCLP Metals	Mercury	Mercury
Types	Requirements	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment
SAP								
QAPP								
Lab QAM								

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

			1994 SAIC/GAS REMEDIAL INVESTIGATION/FEASIBILITY STUDY DATA SETS (cont.)				
	Parameters:		Mercury	Mercury	Mercury	Mercury	Mercury
Types	Requirements		Sediment	Sediment	Sediment	Sediment	Sediment
SDG#'s			Swanson WL12806	Swanson WL12812/12724/12718	Swanson WL12816/12882/12929/12922/12853/12852/12851	Swanson WL12688/12725/12783/12777	Swanson WL12693
Data Review	1)	Third Party Validation Performed	Y/SAIC	Y/SAIC	Y/SAIC	Y/SAIC	Y/SAIC
Deliverables	1)	Electronic Deliverables	Yes	Yes	Yes	Yes	Yes
	2)	Hard copy	Yes but not easily accessed	Yes but not easily accessed	Yes but not easily accessed	Yes but not easily accessed	Yes but not easily accessed
Data Review Details	1)	Package Completeness	Y	Y	Y	Y	Y
	2)	Chain of Custody Procedures	Not determined	Not determined	Not determined	Not determined	Not determined
	3)	Holding Times	Y	Y	N/Quals J/UJ	Y	Y
	4)	Initial Calibration	Y/exceedance	Y (Validator recalc results)	Y (Validator recalc results)	Y (Validator recalc results)	Y (Validator recalc results)
		Curve - # of standards	5pt	5pt	5pt	5pt	5pt
	5)	Calibration Verification	Y/15%	Y/15%	Y/15%	Y/15%	Y/15%
		Secondary Column	NA	NA	NA	NA	NA
	6)	Laboratory Blanks	Y	Y	Y	Y	Y
	7)	Surrogate Recoveries, # required	NA	NA	NA	NA	NA
	8)	Matrix Spike, # required	75-125%	75-125%	75-125%	75-125%	75-125%
	9)	Lab Duplicate	Y	Used MS/MSD	Y/Occ. Used MS/MSD SDG 12922 >35%	Y/Used MS/MSD	Y
		Lab Control Sample (SRM results?)	Y	Y (not always performed) CLs were 75-125%	Used MS/MSD (75-125%)	Used MS/MSD (80-120%)	Y
	10)	Gel Permeation/Forisil Cleanup	N/A	N/A	N/A	N/A	N/A
	11)	Detection Limit	N/A	N/A	N/A	N/A	N/A
	12)	Calc and transposition verification. Qualitative verification?	N	Y	Y/Recalc	Y/Recalc	Y/Recalc
	13)	Field QC Results	N	Y/Ok on rinsate/FD (12812) failed No Action	Y/Ok on rinsate/<35% on FD	Y/Ok on rinsate/<20?% on FD	Y/Ok on rinsate/OK on FD
	14)	Usability Usable/Supporting	Usable	Usable	Usable	Usable	Usable
		Qualifiers	Yes - Minor UJ/J Flags	Yes/Minor qualifications due to incorrect ICB calc.	Yes/Minor J/UJ Flags due to HT exceedances/SDG 12853 also qualifed on poor FD values.	No Qualifications	Not apparent if no or some minor qualifications

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

		1994 SAIC/GAS REMEDIAL INVESTIGATION/FEASIBILITY STUDY DATA SETS (cont.)				
	Parameters:	Mercury	Mercury	Mercury	Mercury	Mercury
Types	Requirements	Sediment	Sediment	Sediment	Sediment	Sediment
SAP						
QAPP						
Lab QAM						

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

			1998 FOX RIVER GROUP								
Types		Parameters: Requirements	PCB Surface Water	Conventionals Surface Water	PCB Sediment	PCB Congeners Sediment	Pesticides Sediment	SVOC Sediment	Metals Sediment	TOC/Ammonia Sediment	PCB Fish Tissue
SDG#'s			Enchem Multiple SDGs	Enchem Multiple SDGs	Enchem Multiple SDGs	Enchem Multiple SDGs	Quanterra Multiple SDGs	Enchem Multiple SDGs	Enchem Multiple SDGs	Enchem Multiple SDGs	Enchem Multiple SDGs
Data Review	1)	Third Party Validation Performed	Blasland Bouck & Lee	Blasland Bouck & Lee	Blasland Bouck & Lee	Blasland Bouck & Lee	Blasland Bouck & Lee	Blasland Bouck & Lee	Blasland Bouck & Lee	Blasland Bouck & Lee	Blasland Bouck & Lee
Deliverables	1)	Electronic Deliverables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	2)	Hard copy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Data Review Details	1)	Package Completeness	Y	Y	Y	Y	Y	Y	Y	Y	Y
	2)	Chain of Custody Procedures	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
	3)	Holding Times	Y	Y/TSS samples J flagged	Y/ Dilutions done out of hold, diluted Aroclors J	Y	Y	Y/ 1 missed hold time sample J/UJ	Y	Y/ Some TOC and ammonia samples J	Y
	4)	Initial Calibration	Y	Y	Y	Y	Y	Y	Y	Y	Y
		Curve - # of standards				NA	NA	NA	NA	NA	NA
	5)	Calibration Verification	20%	10%	20%	30% Target analytes 40% Internal stds	20%	20%	10%	10%	20%
		Secondary Column	20% qualitative only	NA	20% qualitative only	NA	20% qualitative only	NA	NA	NA	20% qualitative only
	6)	Laboratory Blanks	Y	Y	Y	Y	Y	Y	Y	Y	Y
	7)	Surrogate Recoveries, # required	Y/ Control limits not provided	Y/ Control limits not provided	Y/ Control limits not provided	Y/ Control limits not provided	Y/ Control limits not provided	Y/ Control limits not provided	Y/ Control limits not provided	Y/ Control limits not provided	Y/ Control limits not provided
	8)	Matrix Spike, # required	Y/ Control limits not provided	Y/ Control limits not provided	Y/ Control limits not provided	Y/ Control limits not provided	Y/ Control limits not provided	Y/ Control limits not provided	Y/ Control limits not provided	Y/ Control limits not provided	Y/ Control limits not provided
	9)	Lab Duplicate	Y - MS/MSD/ Control limits not provided	Y / Control limits not provided	Y - MS/MSD/ Control limits not provided	Y - MS/MSD/ Control limits not provided	Y - MS/MSD/ Control limits not provided	Y - MS/MSD/ Control limits not provided	Y/ Control limits not provided	Y / Control limits not provided	Y - MS/MSD/ Control limits not provided
		Lab Control Sample (SRM results?)	Y	Y	Y- not addressed	Y	Y	Y	Y	Y	Y
	10)	Gel Permeation/Forisil Cleanup	Not mentioned	NA	Not mentioned	Not mentioned	Not mentioned	Not mentioned	NA	NA	Not mentioned
	11)	Detection Limit	NA	NA	NA	NA	NA	NA	NA	NA	NA
	12)	Calc and transposition verification. Qualitative verification?	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done
	13)	Field QC Results	Field Duplicates -OK Rinsates had contamination	Field Duplicates -OK Rinsates had contamination	Field Duplicates -OK	None identified	Field Duplicates -OK	Field Duplicates -OK	Field Duplicates -OK	Field Duplicates -OK	None identified
	14)	Usability Usable/Supporting	Usable	Usable - except some TOC/DOC rejected	Usable	Usable	Usable	Usable - except hexachlorocyclopenta-diene rejected	Usable	Usable	Usable
		Qualifiers	Y/ Aroclor 1242 ND based on rinsate cont./ UJ extraction errors/ J/UJ low surrogate % R	Y/TOC/DOC R DOC > TOC, All parameters U rinsate, TSS J hold time	Y/ Aroclor 1242 & 1254 J spectral overlap/ J dilutions out of hold time/ minor CCAL %D	Y/1 compound J/UJ CCAL D, MS/MSD/LCS low %R, poor peak resolution	N	Y/HCCP R 0% MS/MSD, minor CCAL %d, low surr %R, and missed hold time	Y/Blank contamination, low MS %R, RPD	Y/ holdtimes	Y/Aroclor 1242 & 1254 J spectral overlap, J /UJ due to extraction error

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

		1998 FOX RIVER GROUP								
	Parameters:	PCB	Conventionals	PCB	PCB Congeners	Pesticides	SVOC	Metals	TOC/Ammonia	PCB
Types	Requirements	Surface Water	Surface Water	Sediment	Sediment	Sediment	Sediment	Sediment	Sediment	Fish Tissue
SAP										
QAPP										
Lab QAM										

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

			1992/1993 DEPOSIT A SEDIMENT DATA					DEPOSIT N DEMONSTRATION PROJECT 1998			
	Parameters:		VOA	SVOC	PCB	Pesticides	Metals/CN	PCB	PCB Congener	TOC/DOC/TSS	PCB
Types	Requirements		Soil	Soil	Soil	Soil	Soil	Slurry, Soil, Liquid	Slurry, Soil, Liquid	Slurry, Soil, Liquid	Sludge
SDG#'s			Hazleton 104116 203257	Hazleton 104116 203242	Hazleton SDG-1, SDG-2, SDG-3, SDG-4, SDG-5	Hazleton 104135 203256	Hazleton BASD34 SD01 BASD08	Severn Trent VT. Fox9, Fox10, Fox11, Fox12, Fox13, Fox14, Fox16	Severn Trent VT. Fox9, Fox10, Fox11, Fox12, Fox13, Fox14, Fox16	WSLH	Severn Trent VT. Fox17 and Fox18
Data Review	1)	Third Party Validation Performed	EcoChem	EcoChem	EcoChem	EcoChem	EcoChem	MA Kuehl Co	MA Kuehl Co	MA Kuehl Co	MA Kuehl Co
Deliverables	1)	Electronic Deliverables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	2)	Hard copy	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Data Review Details	1)	Package Completeness	Y	Y	Y	Y	Y	Yes	Yes	Yes	Yes
	2)	Chain of Custody Procedures	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
	3)	Holding Times	Y	Y	Y	Y	Y	Y - some exceedences	Y- some results J/UJ, Some results Rejected (greater than 14 days)	Y - some exceedences	Yes
	4)	Initial Calibration	Y	Y	Y	Y	Y	Y	Y	Y	Y
		Curve - # of standards	Y - As required by method	Y - As required by method	Y - As required by method	Y - As required by method	Y - As required by method	NA	NA	NA	NA
	5)	Calibration Verification	20%	20%	20%	20%	10%	15%	Y	Y	Y
		Secondary Column	NA	NA	Yes	Yes	NA	Y - some %D exceedences	Y	NA	Y - %D outliers
	6)	Laboratory Blanks	Y - Tics rejected due to contamination	Y - Tics rejected due to contamination	Y	Y	Y	Y	Y - some results U based on MB cont.	Y	Y
	7)	Surrogate Recoveries, # required	Y	Y	Y	Y	Y	Y	Y	Y	Y
	8)	Matrix Spike, # required	Y - No MS/MSD for SDG 203257 J/UJ	Y - No MS/MSD for SDG 203242 J/UJ	Y	Y	Y	Y	Y	Y	Y
	9)	Lab Duplicate	Y - No MS/MSD for SDG 203257 J/UJ	Y - No MS/MSD for SDG 203242 J/UJ	Y	Y	Y	Y	Y	Y	Y
		Lab Control Sample (SRM results?)	Y - No LCS for SDG 203257 J/UJ	Y - No LCS for SDG 203242 J/UJ	Y	Y	Y	Y- some %R outliers	Y- some %R outliers	Y	Y- some %R outliers
	10)	Gel Permeation/Forisil Cleanup	NA	NA	NA	NA	NA	Not addressed	Not Addressed	NA	Not Addressed
	11)	Detection Limit	NA	NA	NA	NA	NA	NA	NA	NA	NA
	12)	Calc and transposition verification. Qualitative verification?	Yes	Yes	Yes	Yes	Yes	Y	Y	Yes	Yes
	13)	Field QC Results	None identified	None identified	Yes	Yes	None identified	Y	Y - some outliers, no quals assigned	Y - DOC RPD outlier	Y
	14)	Usability Usable/Supporting	Usable - Tics rejected due to contamination	Usable- Tics rejected due to contamination	Usable	Usable	Usable	Usable - some results rejected due to possible cross contamination	Usable - some results rejected due to exceeded holding times	Usable	Usable
		Qualifiers	Y/ blank contamination U, Ical RSD, CCAL%D, no LCS MS/MSD TICs rejected due to blank contamination	Y/ blank contamination, CCAL %D, Internal std %R, NO LCS MS/MSD, TICs rejected due to blank contamination	Y/ surrogate %R, LCS %R, Field Dup RPD 1242	Y/ RPD between main and confirmation columns NJ	Y/ Blank contamination, ICV %R CN, MS %R, GFAA post spike %R	Y- cooler temps, CCAL %D, holding time, LCS%R, Dual Column % D	Y- hold times, cooler temps, CCAl %D, method blank contamination, LCS %R, over cal	Y - holding times, cooler temps, Field Dup RPD, DOC>TOC	Y - Dual column %D outliers

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

		1992/1993 DEPOSIT A SEDIMENT DATA					DEPOSIT N DEMONSTRATION PROJECT 1998			
	Parameters:	VOA	SVOC	PCB	Pesticides	Metals/CN	PCB	PCB Congener	TOC/DOC/TSS	PCB
Types	Requirements	Soil	Soil	Soil	Soil	Soil	Slurry, Soil, Liquid	Slurry, Soil, Liquid	Slurry, Soil, Liquid	Sludge
SAP										
QAPP										
Lab QAM										

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

Types	Parameters: Requirements		PCB Congener Sludge
SDG#'s			Severn Trent VT. Fox17 and Fox18
Data Review	1)	Third Party Validation Performed	MA Kuehl Co
Deliverables	1)	Electronic Deliverables	Yes
	2)	Hard copy	Yes
Data Review Details	1)	Package Completeness	Yes
	2)	Chain of Custody Procedures	Acceptable
	3)	Holding Times	Yes
	4)	Initial Calibration	Y
		Curve - # of standards	NA
	5)	Calibration Verification	Y
		Secondary Column	Y
	6)	Laboratory Blanks	Y
	7)	Surrogate Recoveries, # required	Y
	8)	Matrix Spike, # required	Y - some %R and RPD outliers
	9)	Lab Duplicate	Y
		Lab Control Sample (SRM results?)	Y
	10)	Gel Permeation/Forisil Cleanup	Not addressed
	11)	Detection Limit	NA
	12)	Calc and transposition verification. Qualitative verification?	Yes
	13)	Field QC Results	Y - some outliers, no quals assigned
	14)	Usability Usable/Supporting	Usable
		Qualifiers	Y - CCAL %D outliers, MS/MSD %R and RPD outliers, LCS %R, over cal

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

	Parameters:	PCB Congener
Types	Requirements	Sludge
SAP		
QAPP		
Lab QAM		

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

Types		Parameters: / Requirements	DEPOSIT N DEMONSTRATION PROJECT 1998 (cont.)				2000/2001 FOX RIVER GROUP-LITTLE LAKE BUTTE DES MORTS				
		Parameters:	TOC	PCB Congener	PCB	PCB Congener	VOC	Cyanide	PCB Aroclors	Metals	Semivolatiles
Types		Requirements	Sludge	Surface Water	Fish	Minnow	Wood Chips	Sediment	Sediment	Sediment	Sediment
SDG#'s			Severn Trent VT. Fox17 and Fox18	WSLH	Severn Trent VT. Fox7	WSLH	Enchem 913915	Enchem 913915	Enchem Multiple SDGs	Enchem 913426/913915	Enchem 913426/913904
Data Review	1)	Third Party Validation Performed	MA Keuhl Co	MA Keuhl Co	MA Keuhl Co	MA Keuhl Co	CH2M Hill	CH2M Hill	CH2M Hill	CH2M Hill	CH2M Hill
Deliverables	1)	Electronic Deliverables	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	2)	Hard copy	Yes	Yes	Yes	Yes	Yes-but only Form 1s reviewed by EcoChem	Yes-but only Form 1s reviewed by EcoChem	Yes-but only Form 1s reviewed by EcoChem	Yes-but only Form 1s reviewed by EcoChem	Yes-but only Form 1s reviewed by EcoChem
Data Review Details	1)	Package Completeness	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	2)	Chain of Custody Procedures	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
	3)	Holding Times	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	4)	Initial Calibration	Y	Y	Yes	Yes	Yes	Yes	Yes	Yes	Yes
		Curve - # of standards	Y	Y	Yes	Yes	5 pt	Yes-criteria met	Yes-criteria met	Lin Reg	5 pt
	5)	Calibration Verification	Y	Y	Yes	Yes	unknown	Yes	Yes	Yes	Yes
		Secondary Column	NA	Y	Yes	Yes	NA	NA	qualitative only	NA	NA
	6)	Laboratory Blanks	Y	Y - some results U because of MB cont.	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	7)	Surrogate Recoveries, # required	Y	Y	Yes	Yes	Y/ Low recoveries	NA	Yes	NA	Y/ 2 samples J/UJ for low %R.
	8)	Matrix Spike, # required	Y	N- not enough sample	No	Y	No	Y/ Lab limits	Yes/MS/MSD	Yes	Yes-MS/MSD - 1 sample J for high %R
	9)	Lab Duplicate	Y - some RPD outliers	Y	Yes	Yes	No	Yes-criteria met	No	Yes	No
		Lab Control Sample (SRM results?)	Y - one outlier	Y	Yes	Yes	Yes-some low recoveries	Yes-criteria met	Yes-acceptable	Yes-acceptable	Yes-acceptable
	10)	Gel Permeation/Forisil Cleanup	NA	Not addressed	Not Adressed	Not Addressed	NA	NA	Not mentioned	NA	Not mentioned
	11)	Detection Limit	NA	NA	NA	NA	ppb-varies by sample and compound	ppm-varies by sample	ppb-varies by sample	ppm-varies by sample and analyte	ppb-varies by sample and compound
	12)	Calc and transposition verification. Qualitative verification?	Yes	Yes	Yes	Yes	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done
	13)	Field QC Results	Y - some RPD outliers	Y - some outliers, no quals assigned	Yes	Yes	Field Dups & Trip Blanks -OK	Field Duplicates -OK	Field Duplicates -some high RPD with no qualifiers	Field Dup for Hg only	Field Duplicates -OK
	14)	Usability Usable/Supporting	Usable	Usable	Usable	Usable	Usable	Usable	Usable	Usable	Usable
		Qualifiers	Y- LCS %R, Dup RPD, Field Dup RPD	Y- blank contamination, results < LOQ,	No	Y- reported results < LOQ	Yes-All results U/UJ for low surrogate %R	No	Yes/ Many Aroclor 1254 & some 1260 qualified J due to spectral overlap	No	Yes/due to surrogate and MS %R outliers

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

		DEPOSIT N DEMONSTRATION PROJECT 1998 (cont.)				2000/2001 FOX RIVER GROUP-LITTLE LAKE BUTTE DES MORTS				
	Parameters:	TOC	PCB Congener	PCB	PCB Congener	VOC	Cyanide	PCB Aroclors	Metals	Semivolatiles
Types	Requirements	Sludge	Surface Water	Fish	Minnow	Wood Chips	Sediment	Sediment	Sediment	Sediment
SAP						Not provided	Not provided	Not provided	Not provided	Not provided
QAPP						Not provided	Not provided	Not provided	Not provided	Not provided
Lab QAM						Not provided	Not provided	Not provided	Not provided	Not provided

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

			2000 FOX RIVER GROUP-SUPPLEMENTAL MONITORING PROGRAM-SURFACE WATER			2000/2001 FOX RIVER GROUP-SUPPLEMENTAL MONITORING PROGRAM-SEDIMENTS		
	Parameters:	Fuels (GRO/DRO)	Conventionals	PCB Aroclors	PCB Congeners	Conventionals	PCB Aroclors	PCB Congeners
Types	Requirements	Sediment	Water & XAD Resins	Water & XAD Resins	Water & XAD Resins	Sediment	Sediment	Sediment
SDG#'s		Enchem 913426/913904	Enchem Multiple SDGs	Enchem Multiple SDGs	Enchem & STL Multiple SDGs	Enchem & CQM Multiple SDGs	Enchem Multiple SDGs	STL GOL020161
Data Review	1) Third Party Validation Performed	CH2M Hill	BBL	BBL	BBL	BBL	BBL	BBL
Deliverables	1) Electronic Deliverables	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	2) Hard copy	Yes-but only Form 1s reviewed by EcoChem	Yes-but only Form 1s reviewed by EcoChem	Yes-but only Form 1s reviewed by EcoChem	Yes-but only Form 1s reviewed by EcoChem	Yes-but only Form 1s reviewed by EcoChem	Yes-but only Form 1s reviewed by EcoChem	Yes-but only Form 1s reviewed by EcoChem
Data Review Details	1) Package Completeness	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	2) Chain of Custody Procedures	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
	3) Holding Times	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	4) Initial Calibration	Yes	Yes	Yes	Yes	Yes	Yes	Yes
	Curve - # of standards	Lin Reg	Per method	Lin Reg	5 pt	Per method	Lin Reg	5 pt
	5) Calibration Verification	Yes	Yes	Yes	Yes-all samples in 3 SDG qualified 1+ congeners J/UJ	Per method	Yes	Yes
	Secondary Column	NA	NA	qualitative only	NA	NA	qualitative only	NA
	6) Laboratory Blanks	Yes	Yes	Yes	Yes-several congeners in several samples qualified U	Yes-TOC only	Yes	Yes
	7) Surrogate Recoveries, # required	Yes	NA	Yes	Yes	NA	Yes	Yes
	8) Matrix Spike, # required	No	Yes- TOC only	Yes-MS/MSD	No	Yes-TOC only; 20 samples J for high %R	Yes-MS/MSD	No
	9) Lab Duplicate	No	Yes-criteria met	No	No	No duplicates for grain size & %moisture	No	No
	Lab Control Sample (SRM results?)	Yes-acceptable	Yes-criteria met	Yes-acceptable	Yes-acceptable	Yes-TOC only	Yes-acceptable	No
	10) Gel Permeation/Forisil Cleanup	Not mentioned	NA	Not mentioned	NA	NA	Not mentioned	NA
	11) Detection Limit	ppm-varies by sample	ppm-varies by sample	ppb-varies by sample	ppb-varies by sample & congener	TOC-ppm-varies by sample	ppb-varies by sample	ppt-varies by sample & congener
	12) Calc and transposition verification. Qualitative verification?	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done
	13) Field QC Results	Field Duplicates -all DRO results J due to high RPD	Field Duplicates -OK	Field Duplicates -some high RPD with no qualifiers	Field Dup for Hg only	Field Duplicates TOC only	Field Duplicates -acceptable	No
	14) Usability Usable/Supporting	Usable	Usable	Usable	Usable	Usable	Usable	Usable
	Qualifiers	Yes/all DRO results J due to high RPD	No	No	Yes-due to blank cont., ccal, IS %R, & linear range exceed.	Yes-TOC 20 samples J for high % R	No	No

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

			2000 FOX RIVER GROUP-SUPPLEMENTAL MONITORING PROGRAM-SURFACE WATER			2000/2001 FOX RIVER GROUP-SUPPLEMENTAL MONITORING PROGRAM-SEDIMENTS		
	Parameters:	Fuels (GRO/DRO)	Conventionals	PCB Aroclors	PCB Congeners	Conventionals	PCB Aroclors	PCB Congeners
Types	Requirements	Sediment	Water & XAD Resins	Water & XAD Resins	Water & XAD Resins	Sediment	Sediment	Sediment
SAP		Not provided	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided
QAPP		Not provided	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided
Lab QAM		Not provided	Not provided	Not provided	Not provided	Not provided	Not provided	Not provided

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

		2001 FOX RIVER GROUP-GREEN BAY SEDIMENT SAMPLING		2001 FOX RIVER GROUP-WATER COLUMN - HIGH FLOW STUDY		
	Parameters:	Conventionals	PCB Aroclors	Conventionals	PCB Aroclors	PCB Congeners
Types	Requirements	Sediment	Sediment	Water & XAD Resins	Water & XAD Resins	Water & XAD Resins
SDG#'s		Enchem & CQM 914351, 914390	Enchem 914351, 914390	Enchem Multiple SDGs	Enchem Multiple SDGs	Enchem & STL Multiple SDGs
Data Review	1) Third Party Validation Performed	EcoChem & BBL	EcoChem & BBL	BBL	BBL	BBL
Deliverables	1) Electronic Deliverables	Yes	Yes	Yes	Yes	Yes
	2) Hard copy	Yes	Yes	Yes-but only Form 1s reviewed by EcoChem	Yes-but only Form 1s reviewed by EcoChem	Yes-but only Form 1s reviewed by EcoChem
Data Review Details	1) Package Completeness	Yes	Yes	Yes	Yes	Yes
	2) Chain of Custody Procedures	Acceptable	Acceptable	Acceptable	Acceptable	Acceptable
	3) Holding Times	Yes	Yes	Yes-several TVS samples J/UJ	Yes	Yes
	4) Initial Calibration	Yes	Yes	Yes	Yes	Yes
	Curve - # of standards	Per method	Lin Reg	Per method	Lin Reg	5 pt
	5) Calibration Verification	Per method	Yes	Per method	Yes	Yes-all samples in 1 SDG qualified 1+ congeners J/UJ
	Secondary Column	NA	qualitative only	NA	qualitative only	NA
	6) Laboratory Blanks	Yes-TOC only	Yes	Yes-TOC only	Yes	Yes-10 SDG had mult. congeners qualified U
	7) Surrogate Recoveries, # required	NA	Yes-1 sample J due to high % R	NA	Yes-1 sample J/UJ & 1 sample J/R due to low %R	Yes-several results R due to low %R; several SDG J/UJ due to low % R
	8) Matrix Spike, # required	Yes-TOC only MS/MSD	Yes-MS/MSD	Yes-TOC only; 20 samples J for high %R	Yes-MS/MSD	No
	9) Lab Duplicate	No duplicates for grain size & %moisture	No	No duplicates for grain size & %moisture	No	No
	Lab Control Sample (SRM results?)	Yes-TOC only	Yes-acceptable	Yes-TOC only	Yes-acceptable	Yes-results in 16 samples J/UJ due to low %R
	10) Gel Permeation/Forisil Cleanup	NA	Not mentioned	NA	Not mentioned	NA
	11) Detection Limit	TOC-ppm-varies by sample	ppb-varies by sample	TOC-ppm-varies by sample	ppb-varies by sample	ppt-varies by sample & congener
	12) Calc and transposition verification. Qualitative verification?	EcoChem performed recalcs and transcription checks	EcoChem performed recalcs and transcription checks	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done	No recalculations were provided; unable to determine if transcription checks were done
	13) Field QC Results	No	No	Field Duplicates-acceptable; Rinse blank (TOC only)-contamination	Field Duplicates -acceptable	Yes-high RPD, no action taken
	14) Usability Usable/Supporting	Usable	Usable	Usable	Usable	Rejected (R) data not usable; all other data usable
	Qualifiers	Yes-TOC data estimated due to high RSD between injections	No	Yes-Several TOC samples U due to rinse blank contamination. Several TVS samples J/UJ due to HT exceedance.	Yes-1 sample J/UJ & 1 sample J/R due to low %R	Yes-several results R due to low %R. Results J/UJ due to surrogate, LCS, CCAL, co-elution & ion ratio outliers. Results U due to blank contamination.

TABLE 3-2
QC Elements for Data Sets
Supporting the Fox River RI/FS and RA

		2001 FOX RIVER GROUP-GREEN BAY SEDIMENT SAMPLING		2001 FOX RIVER GROUP-WATER COLUMN - HIGH FLOW STUDY		
	Parameters:	Conventionals	PCB Aroclors	Conventionals	PCB Aroclors	PCB Congeners
Types	Requirements	Sediment	Sediment	Water & XAD Resins	Water & XAD Resins	Water & XAD Resins
SAP		Not provided	Not provided	Not provided	Not provided	Not provided
QAPP		Not provided	Not provided	Not provided	Not provided	Not provided
Lab QAM		Not provided	Not provided	Not provided	Not provided	Not provided

APPENDIX B

TIME TRENDS ANALYSIS (MOUNTAIN-WHISPER-LIGHT, 2002)

Time Trends in PCB Concentrations in Sediment and Fish

Lower Fox River and Green Bay, Wisconsin

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Prepared for:

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December 2002

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December 2002

Executive Summary

Introduction

PCBs were introduced into the Fox River, Wisconsin, from the manufacture and recycling of carbonless, multi-copy paper. PCBs were deposited in river sediments and were also passed along the food chain to fish and other wildlife. The fate of the PCBs is an important issue. This report presents rates of change of PCB concentrations in sediment and fish over time.

Methods

Sediment

Sediment samples were grouped into 23 newly designated geographic deposits that were spatially relatively compact within each river reach (see Figure 5 through Figure 8). Depth strata within each deposit were defined consistent with earlier studies: 0 to 10, 10 to 30, 30 to 50, 50 to 100, and 100+ cm. A total of 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 ppb) due to the approximately lognormal distribution of these values.

Samples were determined to be spatially correlated, and a method was used which spatially clusters observations into groups that are then approximately independent, and the statistical significance of time trends can be appropriately calculated (Lumley and Heagerty, 1999; Heagerty and Lumley, 2000).

Regression models for log PCB concentration in sediment versus time, depth, and spatial coordinates were fitted using the method of maximum likelihood, which readily incorporates the observations below detection limit. A meta-analysis was performed to yield an average time trend of PCB concentrations in surface deposits (0 to 10 cm) in each reach.

Fish

There were 19 combinations of reach, species, and sample type (whole body or fillet with skin) that had a sufficient sample size and a sufficient time spread for analysis of time trends. These 19 combinations included 867 samples. Carp and walleye provided the largest number of observations of any species.

Regression models for log 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 a "breakpoint" and different rates of change in PCB concentrations during earlier versus later periods. The maximum likelihood method was used to accommodate observations below detection limit.

The differences in fish PCB concentrations between De Pere to Green Bay Reach and Green Bay Zone 2 were analyzed using cross-sectional data (1989–1991, five analyses) and data over time (1989–1998, four time trends analyses).

Results and Conclusions

Concentrations of PCBs in fish tissue and surface sediments have generally declined following the elimination of PCB point source discharges. However, there are statistically significant breakpoints in the decline for most of the fish species examined, suggesting that the decline has slowed down or, in some cases, that tissue concentrations of PCBs have increased. The time trends appear to be quite changeable and confidence intervals for rates are quite wide so that it is not possible to project PCB concentrations into the future for fish or sediment with much confidence.

Data on PCBs in surface sediment samples suggest that PCB concentrations have generally declined over time. Trends in concentrations of PCBs in subsurface sediments are mixed—some deposits show declining trends, while others show trends either close to zero or not significantly different from zero and yet others show increasing trends.

Specific conclusions of the time trends analysis include:

- **Fish tissue concentrations have generally declined over the period of time for which there are data in the Lower Fox River and Green Bay Zone 2.** Fish tissue PCB concentrations generally showed a slow rate of decline throughout the Lower Fox River and Green Bay Zone 2. Most time trend slopes were negative, and all statistically significant slopes for the most recent period were negative except one.

- **Significant "breakpoints" in the decline were identified for some of the fish species examined, suggesting that rates of decline in PCB tissue concentrations are changeable and may be slowing and, in some cases, tissue concentrations may be increasing.** Fish tissue concentrations have not declined at a constant rate since the 1970s. Among fish time trends analyzed, seven out of 19 combinations of reach, species, and sample type showed a statistically significant change in trend between earlier and later periods. In Little Lake Butte des Morts, De Pere Reach, and in Green Bay Zone 2, there were steep declines in fish tissue PCB concentrations from the 1970s, but with significant breakpoints in declines for some species beginning around 1980. A meta-analysis of the most recent time trends was carried out for three reaches, yielding 5 to 7 percent rates of decline per year averaged across species. Six species showed an increasing rate in their final slope, but only two of these rates were statistically significant. The existence of breakpoints and an additional analysis showing non-constant rates suggests that rates of change are not stable and could be different in the future.

- **PCBs in surface sediment samples have generally declined over the period of time for which there are data for the Lower Fox River.** Surface sediment PCB concentrations combined within each reach by meta-analysis showed statistically significant decreasing trends in all reaches (10 to 15 percent decline per year) except Appleton to Little Rapids (1 percent increase per year). Surface sediments of individual deposits within the reaches included a mixture of positive and negative slopes. Among the 16 negative slopes, six were statistically significant; and neither of the two positive slopes was statistically significant. There were wide confidence intervals for rates of change, both for individual deposits and combined deposits, indicating that rate estimates are not precise. This imprecision and other uncertainties associated with the data prevent truly accurate future projections of sediment PCB concentrations.

- **Time trends in PCB concentrations in sediments below the surface sediment are quite varied—some indicate a decline, others indicate no change, others indicate an increase.** There is a strong trend toward fewer and weaker negative slopes at increasing depths. For Little Lake Butte des Morts, subsurface trends are mixed. The only statistically significant subsurface trend shows an increase and the other trends are a mixture of positive and negative trends. In the Appleton and De Pere reaches, there are both positive and negative trends that, taken together, are not clearly distinguishable from an overall zero trend. For Little Rapids to De Pere, there are consistently negative trends in the 10- to 30-cm strata, but in the lower strata, the data are consistent with either a zero trend (30 to 50 cm), or an increasing trend (50 to 100 cm and 100+ cm).

- **Projection of PCB concentrations into the future for fish or sediments are speculative because of imprecision and other uncertainties identified in the analysis.** The analyses carried out cannot assure a continued decline in PCB concentrations in fish and sediments over time. Even though there are a number of negative time trends that suggest PCB declines, future projection is speculative. Increases in PCB concentrations in some deeper sediments and breakpoints and other indications of changing rates in fish PCB time trends suggest that the river, its sediment, and its fish species could experience an arrest or reversal of such a decline at some time in the future.

- **PCB concentrations may increase or decrease in the future.** Some, perhaps all, of the changes in slope from before to after a breakpoint in the fish time trends may be genuine, due to unpredictable events, such as floods accompanied by scouring and deposition. As discussed in the RI, sediment bed elevations have been altered historically and may also undergo changes in the future due to scouring and redistribution of sediments. The occurrence of these breakpoints in the past suggests that the river may change again in the future. The presence of non-constant rates of change in the post-breakpoint period also suggests unpredictability. These findings support the notion of a dynamic process, liable to change, rather than a steady state with future constant rates of change. Thus, the data do not provide assurance of a continuing future decline in PCB concentrations.

- **PCB concentrations in fish in the De Pere Reach differ from concentrations from the same species in Green Bay Zone 2.** Comparison of samples from the De Pere to Green Bay Reach (Green Bay Zone 1) and Green Bay Zone 2 showed statistically significant differences between alewife, carp, gizzard shad, and walleye in the two reaches in seven out of eight analyses. A given species and sample type differed between the reaches in one or more ways: 1) average PCB concentration differed, 2) time trend in PCB concentration differed, or 3) the relationship of PCB concentration to lipid content differed.

Discussion

Some of the considerable 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 during the period of data collection. Changes in sediment bed elevations have been documented and are discussed in Technical Memorandum 2g (WDNR, 1999a) and in the Remedial Investigation (ThermoRetec, 2001a). These potential mechanisms could not be introduced into the statistical analysis and could not be controlled. The time trends analysis is dependent upon the existing hydraulic conditions in the Lower Fox River. Any changes in those conditions might result in exposure of underlying PCB-laden sediments or burying of such sediments, and lead to new trends that may not be similar to the trends from the present analysis.

The conclusions of a general decrease in PCB burdens in sediments and fish of the Lower Fox River and in Zone 2 of Green Bay are consistent with findings from other research on PCBs in the Great Lakes (Offenberg and Baker, 2000; DeVault *et al.*, 1996; Lamon *et al.*, 1998; Gobas *et al.*, 1995; Smith, 2000). Some of these reports have also noted slowing of trends. Based on the present and previous studies, there may continue to be slow, gradual declines, or a steady state in PCB concentrations in fish and sediment in the future. The possibility of some increases cannot be ruled out.

Controlling for lipid content of fish samples distinctly helped in calculating more accurate time trends. The lipid content is best used as an independent variable in regression analysis rather than as the denominator of a ratio (*PCB concentration ÷ percent lipid content*) used in traditional "lipid normalization."

Some strengths of the study include the methods used to handle data below a detection limit, methods used to detect and handle spatial correlation of sediment samples, approaches to quantifying and testing for non-constant rates of change in fish time trends, data-driven modeling of lipid content as a factor in PCB concentrations, and meta-analysis of rates to increase precision and power. The inherent very great variability of the PCB concentrations has been thoroughly described quantitatively and graphically, and clear statements about confidence in and statistical significance of the various quantitative trends have been provided to guide the reader in the use of the trends.

Sources of Uncertainty

The data used for both sediment and fish time trends analyses are inherently quite variable. Of the 46 sediment deposit group analyses and four surface sediment meta-analyses, only 16 of the analyses can offer us a reasonably firm conclusion that PCB concentrations are changing. Two of the 16 analyses indicate increasing trends and 14 indicate decreasing trends. The remaining 34 analyses show trends with wide confidence intervals. Among the 19 analyses of individual fish species and three meta-analyses, 17 clearly demonstrate a non-zero trend. The other five analyses or meta-analyses do not support a solid "no change," zero-slope conclusion, but yield an uncertain rate, consistent with a fairly wide range of plausible increasing or decreasing trends.

Relative depth was used rather than absolute depth. Depth of sediment is closely related to PCB concentration. We used depth defined as the distance of a sample to the sediment-water interface. Some of the time trends noted here may possibly be due to a change in the depth due to deposition or scouring over time, so that different parcels of sediment are identified with the same depth label at different times. Some changes that have occurred in sediment or fish tissue concentrations may be due to flooding, ice scouring, propeller wash, or other mechanisms that would have caused changes to the hydraulic conditions in the river or may have changed the relative depth of a deposit or a sample.

Age of fish may be related to their PCB concentrations, due to different feeding habits and locations during the lifecycle. Incorporating age proxy variables (either length or mass, unavailable in this study) might reduce unexplained variance and increase power to detect trends.

A "laboratory effect," whereby different laboratories would produce a different mean PCB concentration on split samples, is possible. In addition, analytical techniques may have changed over the 1989-through-1998 period of sediment sample collection and both the laboratory and analytical variation may have introduced spurious positive or negative trends, or masked real trends.

Table of Contents

1 Introduction 1-1

2 Methods for Sediment Analysis 2-1
2.1 Sediment Data 2-1
2.1.1 Variables of Interest 2-1
2.1.2 Preliminary Data Handling 2-1
2.1.3 Logarithmic Transformation 2-2
2.1.4 Core Averaging 2-6
2.1.5 Observations Below Detection Limit 2-7
2.2 Maximum Likelihood Method 2-7
2.3 Spatial Dependence 2-10
2.4 Addressing Spatial Dependence Using the WSEV Method 2-13
2.5 Geographic Grouping of Data 2-15
2.6 Models for Variation in PCB Concentration in Space and Time 2-25

3 Methods for Fish Analysis 3-1
3.1 Lipid Normalization 3-1
3.2 Seasonality 3-2
3.3 Time Trend Models 3-3
3.4 Model Fitting and Hypothesis Testing 3-4
3.5 Testing for a Constant versus a Changing Final Slope 3-6
3.6 Meta Analyses—Combining Data on All Species Within a Reach 3-6
3.7 Projecting into the Future 3-7

4 Sediment Results 4-1
4.1 Number of Observations 4-1
4.2 Geographic Groups for Time Trend Analysis 4-4
4.3 Time Trends in Sediment Concentrations 4-5
4.4 Time Trends by Reach 4-17
4.4.1 Little Lake Butte des Morts 4-17
4.4.2 Appleton Reach 4-20
4.4.3 Little Rapids to De Pere Reach 4-21
4.4.4 De Pere to Green Bay Reach 4-22
4.5 Comments on Combined Reaches 4-26

5 Fish Results 5-1
5.1 Number of Observations 5-1
5.2 Time Trends in PCB Concentrations in Fish 5-4
5.2.1 Testing Spline Model versus Simple Linear Model 5-4
Reach 1 — Little Lake Butte des Morts 5-5
Reach 2 — Appleton to Little Rapids 5-9
Reach 3 — Little Rapids to De Pere 5-9
Reach 4 — De Pere to Green Bay 5-10

Table of Contents

Reach 5 — Green Bay Zone 2 5-12
Impact of Seasonality and Lipid Content on Best-fitting Model 5-15
5.2.2 Best-fitting Model, Meta-analysis, Sensitivity Analysis, and Future Projections 5-19
Reach 1 — Little Lake Butte des Morts 5-27
Reach 2 — Appleton to Little Rapids 5-29
Reach 4 — De Pere to Green Bay 5-30
Reach 5 — Green Bay Zone 2 5-31
5.2.3 Additional Analysis of Alternative Models 5-32
Results for Fitting Models with Breakpoint at 1985 5-32
Testing for a Non-constant Final Slope 5-32
5.3 Conclusions about Trends over Time in PCB Concentration in Fish 5-36
5.4 Comparison of De Pere Reach to Green Bay Zone 2 5-36
5.4.1 De Pere Reach versus Green Bay Zone 2: "Snapshot" Analysis 5-38
5.4.2 De Pere Reach versus Green Bay Zone 2: Time Trends Analysis 5-43
5.4.3 De Pere Reach versus Green Bay Zone 2: Without Adjustment for Lipid Concentrations 5-46
5.4.4 De Pere Reach versus Green Bay Zone 2: Summary 5-47
5.4.5 Lipid Normalization 5-47

6 Conclusions and Discussion 6-1
6.1 Conclusions 6-1
6.2 Time Trends Discussion 6-4
6.2.1 General Issues 6-4
6.2.2 Fish Lipids 6-6
6.2.3 Strengths of the Study 6-6
6.3 Sources of Uncertainty in the Time Trends Analysis 6-7
6.3.1 Statistical Uncertainty — Statistical Significance and Confidence Intervals 6-7
6.3.2 Physical Sources of Uncertainty 6-11
Depth of Sediments 6-11
Hydraulic Conditions 6-12
6.3.3 Sources of Biological Uncertainty 6-12
Age and Gender of Fish 6-12
Spatial Dependence 6-13
6.3.4 Uncertainty Due to Laboratory and Analytical Factors 6-13

7 References 7-1

List of Figures

Figure 1 Example of PCB Concentration Distribution on Natural and Logarithmic Scales 2-4

Figure 2 Comparison of Cum-cum Plots Based on Untransformed and Log-transformed Data 2-5

Figure 3 Semivariogram Plot of Appleton Deposit Group N Pre-dredge, 10+–30 cm Depth 2-12

Figure 4 Semivariogram Plot of De Pere to Green Bay Deposit Group 2025, 10–30 cm Depth 2-13

Figure 5 Sample Point Groups for Sediment Time Trends Analysis: Little Lake Butte des Morts 2-19

Figure 6 Sample Point Groups for Sediment Time Trends Analysis: Appleton to Little Rapids 2-20

Figure 7 Sample Point Groups for Sediment Time Trends Analysis: Little Rapids to De Pere 2-21

Figure 8 Sample Point Groups for Sediment Time Trends Analysis: De Pere to Green Bay 2-22

Figure 9 Locations of Deposit Groups in Little Lake Butte des Morts Reach 2-23

Figure 10 Locations of Deposit Groups in Appleton Reach 2-24

Figure 11 Locations of Deposit Groups in Little Rapids Reach 2-24

Figure 12 Locations of Deposit Groups in De Pere Reach 2-25

Figure 13 Log_{10} PCB Concentration versus Time, Depth, Northing and Easting for Little Lake Butte des Morts Deposit Group C (0 to 10 cm) Including Fitted Smoothed Line 2-29

Figure 14 Log_{10} PCB Concentration versus Time, Depth, Northing and Easting for Little Lake Butte des Morts Deposit Group C (10 to 30 cm) Including Fitted Smoothed Line 2-30

Figure 15 Log_{10} PCB Concentration versus Time, Depth, Northing and Easting for De Pere SMU Group 5067 (0 to 10 cm) Including Fitted Smoothed Line 2-31

List of Figures

Figure 16 Log$_{10}$ PCB Concentration versus Time, Depth, Northing and Easting for De Pere SMU Group 5067 (10 to 30 cm) Including Fitted Smoothed Line 2-32

Figure 17 Log$_{10}$ PCB Concentration versus Time, Depth, Northing and Easting for De Pere SMU Group 5067 (50 to 100 cm) Including Fitted Smoothed Line 2-33

Figure 18 Northing/Easting Plot Key 2-36

Figure 19 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Lake Butte des Morts Deposit Group AB 2-37

Figure 20 95 Percent Confidence Intervals Showing Annual Percent Rate of Change (Left Vertical Axis) in PCB Concentration for Little Lake Butte des Morts Deposit Group and Depth Strata 4-9

Figure 21 95 Percent Confidence Intervals Showing Annual Percent Rate of Change (Left Vertical Axis) in PCB Concentration for Appleton Deposit Group and Depth Strata 4-10

Figure 22 95 Percent Confidence Intervals Showing Annual Percent Rate of Change (Left Vertical Axis) in PCB Concentration for Little Rapids Deposit Groups and Depth Strata 4-11

Figure 23 95 Percent Confidence Intervals Showing Annual Percent Rate of Change (Left Vertical Axis) in PCB Concentration for De Pere SMU Groups and Depth Strata 4-12

Figure 24 95 Percent Confidence Intervals for Annual Percent Rate of Change at Depth 0 to 10 cm 4-13

Figure 25 95 Percent Confidence Intervals for Annual Percent Rate of Change at Depth 10+ to 30 cm 4-14

Figure 26 95 Percent Confidence Intervals for Annual Percent Rate of Change at Depth 30+ to 50 cm 4-15

Figure 27 95 Percent Confidence Intervals for Annual Percent Rate of Change at Depth 50+ to 100 cm 4-16

Figure 28 95 Percent Confidence Intervals for Annual Percent Rate of Change at Depth 100+ cm 4-17

List of Figures

Figure 29 De Pere SMU Group 5067: Location of 0 to 10 cm Core-averaged Samples with Sample A3_0-4 Identified 4-23

Figure 30 Sample Locations for SMU Group 5067, 0 to 10 cm Depth, Samples Closest to Sample A3_0-4 (Less than 208 meters Distance) 4-24

Figure 31 Log_{10} PCB Concentration (ppb) in Little Lake Butte des Morts Carp, Skin-on Fillet, versus Time 5-6

Figure 32 Log_{10} PCB Concentration (ppb) in Little Lake Butte des Morts Carp, Whole Body, versus Time 5-7

Figure 33 Log_{10} PCB Concentration (ppb) in Little Lake Butte des Morts Walleye, Whole Body, versus Time 5-8

Figure 34 Log_{10} PCB Concentration (ppb) in De Pere to Green Bay Walleye, Whole Body, versus Time 5-10

Figure 35 Log_{10} PCB Concentration (ppb) in De Pere to Green Bay Carp, Whole Body, versus Time 5-11

Figure 36 Rejected Spline Model for Green Bay Zone 2 Yellow Perch, Skin-on Fillet 5-13

Figure 37 Log_{10} PCB Concentration in Green Bay Zone 2 Yellow Perch, Skin-on Fillet, versus Time 5-14

Figure 38 95 Percent Confidence Intervals Showing Annual Percent Rate of Change (Left Vertical Axis) in PCB Concentrations by Reach, Species, and Sample Type 5-23

Figure 39 Log_{10} PCB Concentration (ppb) in Little Lake Butte des Morts Carp, Whole Body, versus Time 5-28

Figure 40 Log PCB Concentration versus Log Percent Lipid for De Pere Reach and Green Bay Zone 2 for Alewife, Whole Body, 1989 5-40

Figure 41 Log PCB Concentration versus Log Percent Lipid for De Pere Reach and Green Bay Zone 2 for Carp, Whole Body, 1989 5-41

Figure 42 Log PCB Concentration versus Log Percent Lipid for De Pere Reach and Green Bay Zone 2 for Gizzard Shad, Whole Body, 1989 5-41

Figure 43 Log PCB Concentration versus Log Percent Lipid for De Pere Reach and Green Bay Zone 2 for Walleye, Skin-on Fillet, 1989–1991 5-42

List of Figures

Figure 44 Log PCB Concentration versus Log Percent Lipid for De Pere Reach and Green Bay Zone 2 for Walleye, Whole Body, 1989 5-42

Figure 45 1989–1998 Time Profile Comparison of PCBs Between De Pere Reach and Green Bay Zone 2 for Alewife, Whole Body 5-44

Figure 46 1989–1998 Time Profile Comparison of PCBs Between De Pere Reach and Green Bay Zone 2 for Carp, Whole Body Samples 5-45

Figure 47 1989–1998 Time Profile Comparison of PCBs Between De Pere Reach and Green Bay Zone 2 for Gizzard Shad, Whole Body Samples 5-45

Figure 48 Log_{10} PCB Concentration (ppb) versus Log_{10} Percent Lipid Content for Walleye, Skin-on Fillet, De Pere to Green Bay Reach 5-50

List of Tables

Table 1 Little Lake Butte des Morts Deposit Groups Defined for Time Trends Analysis 2-16

Table 2 Appleton Deposit Groups Defined for Time Trends Analysis 2-17

Table 3 Little Rapids Deposit Groups Defined for Time Trends Analysis 2-18

Table 4 De Pere SMU Groups Defined for Time Trends Analysis 2-18

Table 5 Sample Removed from Time Trends Analysis 2-28

Table 6 Sample Size by Deposit Group and Depth after Core Averaging 4-2

Table 7 Sample Size by Deposit Group and Depth Included in Time Trends Analysis, after Core Averaging 4-3

Table 8 Deposit Groups Analyzed, Or Reasons for No Analysis 4-4

Table 9 Sediment Time Trend Parameters by Depth and Deposit Group 4-7

Table 10 Mass-weighted Combined Time Trend for 0 to 10 cm Depth by Reach 4-19

Table 11 PCB Concentrations at Various Depths and Distances from Sample A3_0-4 4-25

Table 12 Sample Sizes for Total PCB Time Trend Analyses by Reach, Species, and Sample Type 5-2

Table 13 Testing the Null Hypothesis that a Straight Line Fits As Well As a Spline Model with a Breakpoint 5-5

Table 14 PCB Time Trend Results for Fish Samples in Little Lake Butte des Morts Reach 5-9

Table 15 PCB Time Trend Results for Fish Samples in Appleton to Little Rapids Reach 5-9

Table 16 PCB Time Trend Results for Fish Samples in De Pere to Green Bay Reach 5-12

Table 17 PCB Time Trend Results for Fish Samples in Green Bay Zone 2 5-15

Table 18 Model Parameters and Other Statistics for the Best-fitting Model 5-17

List of Tables

Table 19 Meta-analysis of Fish Time Trends 5-20

Table 20 Final Slope and Percent Change per Year for Best-fitting Model and Sensitivity Analysis 5-22

Table 21 Projecting into the Future—Predicted Mean PCB Concentration (ppb) in 1999 and 2020 and Time When Specified PCB Concentrations Will Be Reached 5-24

Table 22 Mean Log_{10} Percent Lipid in Fish Tissue 5-26

Table 23 Details of Fitting Models with a Breakpoint at 1985 for Every Fish Category 5-33

Table 24 Test for Curvature in Final Slopes 5-34

Table 25 De Pere Reach and Green Bay Zone 2: Fish Types and Sample Types with Sufficient Data for PCB Comparisons 5-37

Table 26 Outlier from Analysis of De Pere Reach versus Green Bay Zone 2 5-38

Table 27 Fitted Models for Log_{10} (PCB Concentration) versus Log_{10} (Percent Lipid) in De Pere Reach and Green Bay Zone 2 for Species with Sufficient Data During 1989 5-39

Table 28 Log_{10} (PCB Concentration) versus Time in De Pere Reach and Green Bay Zone 2 for Species with Sufficient Data During 1989–1998 5-44

Table 29 Comparison of Geometric Mean Concentrations of PCB Concentrations in De Pere Reach and Green Bay Zone 2, With and Without an Adjustment for Lipid Content, Samples from 1989–1991 (“snapshot” analysis) 5-48

Table 30 Models Comparing Log (PCB Concentration) versus Time in De Pere Reach and Green Bay Zone 2, Without Adjustment for Lipid Content 5-49

Table 31 Sediment Time Trends: Analyses with Clear Outcomes and Good Precision 6-8

Table 32 Fish Time Trends: Analyses with Clear Outcomes and Good Precision 6-11

1 Introduction

PCBs are toxic chemicals that may pass through the food chain via fish, birds, and other wildlife to ultimately reach humans. PCBs were introduced into the Fox River, Wisconsin, from the manufacture and recycling of carbonless, multi-copy paper between 1954 and 1971. A number of studies have been carried out on the burden of PCBs in sediment, wildlife, water, and other media. The issue of time trends in PCB concentrations motivates our analysis. Carbonless paper manufacturing no longer introduces PCBs into the river, and other sources negligibly add to the PCB burden. Therefore, one can determine the rate at which the original store of PCBs is changing over time in fish and sediments.

In this report, therefore, we analyze the trends of PCB concentrations in sediment and fish over time. We provide quantitative estimates of rates of change of PCBs concentrations in sediments for:

- River reaches,
- Deposits within those reaches,
- Depth strata within the deposits, and
- Surface sediments combined within each reach.

We also provide quantitative estimates of time trends of PCBs in fish tissue for:

- Individual species, by reach, and
- Estimates combined across species, by reach.

In addition, we compare time trends in PCB concentrations in fish between the De Pere to Green Bay Reach and Green Bay Zone 2.

The analysis proves challenging due to the following features of the data:

- Concentrations below detection limits (both in sediment and fish),
- Spatial correlation of observations in sediment (due to the proximity of many of the samples in space),
- Potentially confounding spatial trends in sediment concentrations,
- A decline in fish PCB concentrations that, for several cases, is neither linear on the original scale of concentration per unit mass nor on a logarithmic scale,
- A limited number of sampling episodes for sediment and fish, typically leading to just a few distinct points in time for each analysis,

- Limited sample sizes for some deposits and some fish species, and
- Generally wide confidence intervals for estimates of rates of change.

Our methodology attempts to address each of the issues noted above. Despite the somewhat daunting methodology (a discussion of our methodology occupies more space in this report than our findings), the key results boil down to some fairly simple values: slope coefficients that represent the rate of change of the logarithm of PCB concentrations in sediment or fish over time. From the slope coefficients we calculated the following items of interest:

- The annual percent rate of decrease (or increase) of PCB concentrations in fish and sediments, and
- The statistical significance of the rate of change over time compared to a zero rate of change over time.

The last item refers to a "hypothesis test." Specifically, we test the null hypothesis that a given rate of change (of sediment or fish) is zero (no change over time) versus the alternative hypothesis that the PCB concentration is either decreasing or increasing over time.

2 Methods for Sediment Analysis

2.1 Sediment Data

Sediment data were obtained from EcoChem, the contractor responsible for maintaining the Fox River database. An initial selection from the Fox River Database (FRDB) yielded 2,776 observations for the following restrictions: analyte = total PCBs; matrix = sediment; and location = Little Lake Butte des Morts, Appleton, Little Rapids, or De Pere reaches.

2.1.1 Variables of Interest

Each sediment sample was described by a number of variables, of which the following variables were used in this study:

- Sample ID (used to identify records in case of unusual values or problems),
- Location (reach designation),
- Deposit (traditional deposit designations supplied with each record within the FRDB and used in other reports on the Fox River),
- “Depth from” and “depth to” (minimum and maximum depth of a sample),
- Sample date (date sample was obtained),
- Analyte (we used only total PCB concentration),
- Qualifier (indicates whether PCBs were detected or were below detection limits, and, also, data quality),
- Northing and easting (geographic location in meters), and
- “Result,” which, in this case, gives the PCB concentration or the detection limit in μg/kg (or parts per billion, ppb).

2.1.2 Preliminary Data Handling

We excluded the following types of data:

- Ninety-four (94) samples with northing and easting coordinates outside the river boundaries, or with no northing or easting coordinates. These were typically side samples from creeks and tributaries, unusual samples such as bottled samples collected by divers with no exact location specified, or samples with sediment type indicated as coal composite, coarse-screened material, sand, stockpile, or non-TSCA pile;

- Thirty-four (34) samples from Appleton Deposit N, collected after January 1, 1999 (after dredging operations, which would have disturbed the natural action of the river); and

- Thirty (30) duplicated records, samples the data from which were present in more than one record in the database.

After these initial exclusions, a total of 2,618 observations were available. Any samples with a quality qualifier of R (rejected value—do not use) were ineligible for inclusion, but no samples were excluded on this basis alone.

Some data were missing the month and day, or just the day of the sample acquisition. Samples missing the day, but including month and year, were assigned to the midpoint of the month (i.e., day set to 15). Samples missing both day and month were set to the midpoint of the year (July 1). Because the time trends span data covering several years, these date imputations have a minor impact on the trend analysis.

To handle the fairly dramatic differences in concentrations and potential trends by depth, we incorporated the framework for stratifying observations by depth used in many other Fox River studies. The depth strata were right-endpoint inclusive (e.g., the interval 10 to 30 cm includes all samples with a depth greater than 10 cm and less than or equal to 30 cm): 0 to 10 cm, 10 to 30 cm, 30 to 50 cm, 50 to 100 cm, and 100+ cm). Samples were placed into a stratum based on their average depth (the mean of the minimum and maximum depth of the sample).

2.1.3 Logarithmic Transformation

We analyzed sediment and fish concentrations of PCBs after a logarithmic transformation. We implemented the $\log_{10}$ transform for two main reasons. First, plotting the logarithm of the concentrations generated a far more normally distributed (bell-shaped) curve than plotting values on the original scale.

Second, an analysis on the log scale corresponds to modeling percent change. Expressing the rate of change as percent change per year rather than absolute change in concentration is generally more meaningful. Percentages are a common way to express rates of change (e.g., "3 percent per year"). A fixed percentage rate of change per year (analogous to compound interest) corresponds to an exponentially increasing or decreasing curve. Such a curve on the natural scale transforms to an easily modeled straight line on the logarithmic scale.

Stated another way, fixed multiplicative increments on the natural scale (as in compound interest) become fixed additive increments on the log scale.

We note, also, that the logarithmic transform is consistent with the analysis of halving and doubling times for a PCB concentration. Like the percentage rate of change, the halving (or doubling) time can readily be calculated from a model for the logarithm of PCB concentration versus time. However, throughout this report, we favor the use of the percentage rate of change over halving and doubling times. The reported percentage estimates the actual rate of change during the period when the data were collected. The halving and doubling times, however, refer to a halving or doubling of concentration that would occur only if the rate of change of log concentration remains constant over the stated halving or doubling period. For example, suppose the coefficient of time (in years) for a model of $\log_{10}$ PCB concentration versus time is –0.01 per year during the period 1989 through 1998. The average rate of change of the PCB concentration during that period is, then, –2.3 percent per year $\left[=100\%\left(10^{-0.01}-1\right)\right]$ and the calculated halving time is 30.1 years $\left[=\left(\log_{10}0.5\right)\div\left(-0.01\right)\right]$. On the one hand, the –2.3 percent per year is a confident statement about a real period of time, 1989 through 1998. On the other hand, the 30.1 years for halving assumes a steady state that may not occur in a changeable river during a speculative 30.1 years. There is a one-to-one correspondence between the percentage rate of change, P, and the halving time, T ($-T$ for doubling): $P=100\left(0.5^{1/T}-1\right)$. Both bear the same information. We avoid, however, the connotation of possible long-term stability implied by the "doubling" and "halving" terms.

Figure 1 provides an example of a distribution of PCB concentrations plotted on the original scale (ppb, left plot), which can be compared to a plot on a logarithmic scale ($\log_{10}$ ppb, right plot). The *X*-axis is an arbitrary scale for each plot, expressed as positive or negative deviations from the mean. The *Y*-axis shows the number of cases in each bin. A bell-shaped curve has been superimposed on each plot. The logarithmic plot shows a more symmetrical distribution and no outliers, compared to the plot on the natural scale. Generally speaking, for the hypothesis tests used in this study, such as those used to detect non-zero time trends, a more normal or "bell-shaped" distribution is less likely to lead to biased results. An exact or approximate normal distribution is desirable because the hypothesis tests used in our study assume a normal distribution. Moderate departures from this assumption are acceptable.

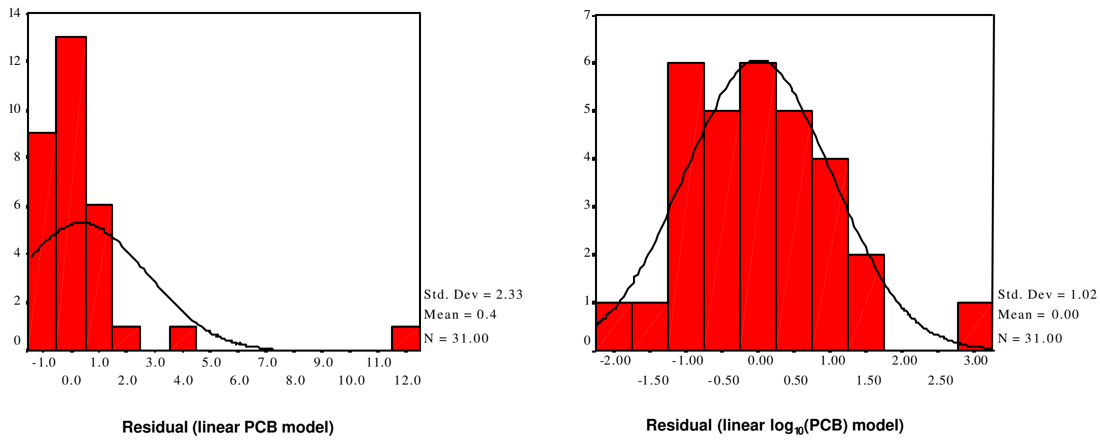


Figure 1 Example of PCB Concentration Distribution on Natural and Logarithmic Scales

Time trend estimates based on less skewed, more normal distributions are less likely to be influenced by extreme observations. A measure of skewness is the classical skewness coefficient, which is zero for symmetrical distributions and increasingly positive or negative for distributions that are increasingly stretched toward large values or small values, respectively. The normal distribution has a skewness coefficient of zero. The Appendix contains the skewness coefficients for the PCB concentrations and $\log_{10}$ (PCB concentration). Almost all distributions of sediment PCB concentrations had smaller skewness coefficients (closer to zero) on the logarithmic scale than on the natural scale. In addition, use of the logarithmic transformation passed an important visual test for the bell-shaped normality, based on "residuals." A residual here is defined as an observed value of log PCB concentration minus the corresponding predicted value from the fitted regression model. If the residuals have a bell-shaped distribution, then estimates from the fitted model are more likely to be correct. To check the bell shape, we commonly use a visual display called the QQ, or "cum-cum" plot. One plots the cumulative distribution of residuals against the corresponding cumulative normal distribution. If the residuals are normally distributed, the points will all huddle along the 45 degree line. If the residuals are not normally distributed, the points will stray therefrom.

Figure 2 shows an example of a cum-cum plot. The log PCB data (right plot) lie closer to the straight line representing the normal distribution than the PCB data on the original scale (left plot).

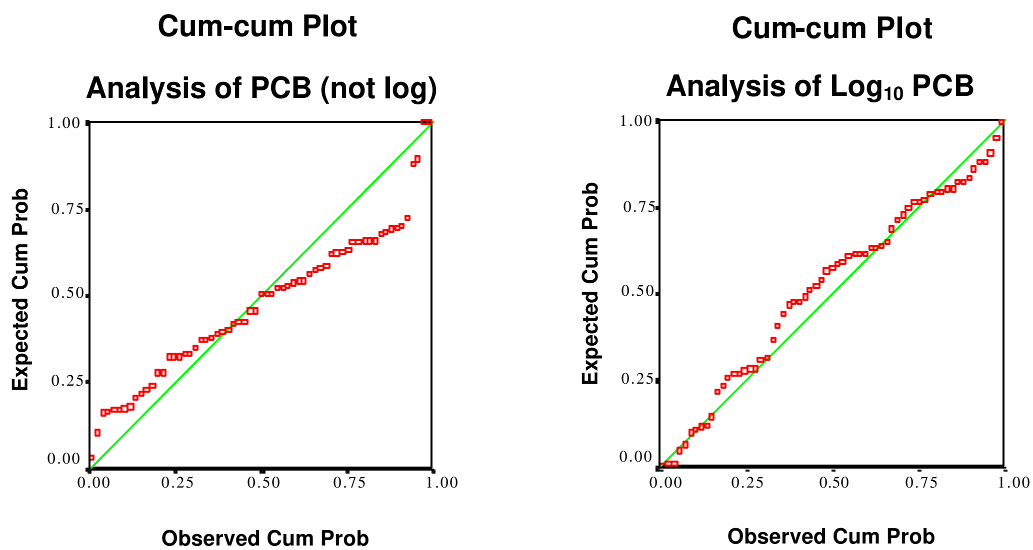


Figure 2 Comparison of Cum-cum Plots Based on Untransformed and Log-transformed Data

We have not carried out a formal hypothesis test that the distributions of $\log_{10}$ PCB concentrations are normal. With the sample sizes used in this study (both for sediment and fish), the visual checks noted here are adequate and consistent with good statistical practice. Formal tests for normality, such as that of Kolmogorov and Smirnov, have low power for these sample sizes. In addition, regression and other procedures used in this study are robust, even if distributions are only approximately normal.

Given the good fit of the lognormal distribution to most of the observed distributions of PCB concentrations, we analyzed PCBs as the logarithm to base 10 of the PCB concentration in parts per billion. Throughout the report, our reference to PCB concentrations denotes this logarithm, unless stated otherwise. In plots and tables, the log carries the usual, easily interpreted quantification: a log value equal to 0 means an untransformed value of 1, a value of 1 represents 10, 2 represents 100, and so on.

Later, we develop models for log PCB concentration over time, i.e., "time trends" models. Given a correct model for time trend in a particular deposit, the predicted value of log PCB concentration at a specific time from the model is an unbiased estimate of the corresponding true mean log concentration at that time. The anti-logarithm of this predicted mean is an unbiased estimate of the geometric mean (GM_{est}) of PCB concentrations on the natural scale at the specified time. Because of the skewness toward large values on the natural scale, however, the geometric mean underestimates the arithmetic mean at the specified time. The arithmetic mean PCB concentration is a value of particular interest. Equation 1 provides an estimate of the arithmetic mean (AM_{est}) that can be calculated from the geometric mean.

Equation 1

$$AM_{est} = GM_{est} \ \exp(s^2 \cdot 5.302/2) .$$

where *GM* is the geometric mean and s^2 is the estimated variance on the $\log_{10}$ scale, calculated from a regression model. The quantity 5.302 comes from use of a $\log_{10}$ scale rather than a $\log_e$ scale. If a $\log_e$ scale is used, the 5.302 can be dropped.

2.1.4 Core Averaging

We refer to the combination of some samples from the same vertical core sample as "core averaging." As described below, proximate samples were correlated (showed similar PCB values). Thus, we replaced the log PCB concentrations of multiple samples from the same core in a given depth range with their mean (on the log scale), yielding one core-averaged sample per core per depth stratum. Twenty-five (25) percent of the sediment observations included in the analysis resulted from core averaging. A mean of 2.4 single observations contributed to a core-averaged observation. After core averaging, there were 1,980 observations.

Core averaging offers several advantages. Samples taken from exactly the same location constitute a distinct spatial sampling pattern with, possibly, different correlations than may be found among samples taken at distinct locations. Spatial correlation typically varies inversely with distance, so that samples taken close together possess stronger correlations than samples taken far apart. A distance of zero, and its infinite inverse, arising from samples taken at exactly the same location may not fit into the spatial correlation pattern present among samples collected from dispersed locations. Specifically, if $r(d)$ is the correlation between samples separated by distance d, the value of $r(0)$ may not equal the limit of $r(d)$ as d approaches zero; i.e., $r(0)$ may be an isolated discrete value. Taking the average of multiple samples from a single location will likely yield a concentration that fits better with the spatial correlation pattern from other, spatially dispersed samples. Also, multiple samples from a single location would weight that location more heavily in subsequent analyses than locations represented by a single sample. Core averaging equally weights each location.

Other than addressing an unusual correlation scenario and a statistical weighting issue, core averaging probably has little influence on the calculated time trends. A scatter plot of $\log_{10}$ PCB concentration (Y-axis) versus time (X-axis) would spread the multiple PCB concentrations from the single location vertically around the core-averaged value at the same value for time, $X = t_0$. If the individual sample concentrations are given the same total statistical weight as the single core-averaged value, then a least-squares regression analysis of log PCB concentration versus time would yield identical slopes for either representation of the samples—core-averaged or individual. This simplified example ignores the spatial variables that we used in our regression analysis. However, the point is that core averaging is unlikely to influence the slope of a time trend.

Core averaging probably does not affect statistical significance because of two offsetting factors:

1. Heightened precision of a core-averaged log PCB concentration (compared to the less precise individual concentrations) would tend to add power to detect a non-zero slope and designate it as statistically significant.

2. Reduced sample size from core averaging would tend to subtract power to detect non-zero slopes, and would then be less likely to designate a real non-zero slope as statistically significant.

These two factors may balance out.

Core averaging imputes the mean log PCB concentration to the mean depth of the samples (all within the same stratum). Thus, core averaging reduces the information available to determine and control spatial trends. This is probably a small effect, because 75 percent of $\log_{10}$ PCB concentrations used in the time trends analysis did not result from core averaging.

In summary, core averaging protects against a mixture of two possibly distinct spatial correlation patterns, offers equal statistical weight to each location sampled, and likely will have little influence on both estimated time trend slopes and statistical significance. It may result in slightly less precise estimates of spatial trends.

In subsequent calculations, a core-averaged value counted as one observation, on par with other single observations that had not been core averaged.

2.1.5 Observations Below Detection Limit

A number of observations dropped below detection limits. We used the maximum likelihood method (see next section) to handle these observations. In statistical parlance, observations below detection limits are designated as “censored,” which simply refers to truncated observations. Note that “censored” does not mean that observations have been excluded from the analysis. Observations both above and below detection limits contribute to the analysis. By using the maximum likelihood methodology, an observation below the detection limit brings all the information that it contains to the analysis—namely, a concentration observed as not exceeding a certain limit—and obviates the need to impute a replacement value, such as half the detection limit.

2.2 Maximum Likelihood Method

Maximum likelihood (ML) is a method very commonly used in statistics to estimate parameters such as coefficients in a regression model or in other types of models (Lawless, 1982). The precision of an estimated parameter depends on the size of the dataset, the complexity of the model, and other factors. One expresses the precision as the standard error. In many situations, adding and subtracting twice the standard error to the estimated parameter value, as obtained from the sample, provide a 95 percent confidence interval for the true population value. That is, we are 95 percent confident that the interval includes the true population parameter. Like other estimation methods, including normal-based least-squares, ML yields: 1) an estimate of the parameter; 2) a standard error of the parameter, which indicates the precision of the estimate; and 3) a statement of statistical significant (*p*-value), which tells us the strength of evidence that the true parameter is not zero. One can conduct tests for statistical significance using either: 1) the parameter compared to its standard error (the ratio would be approximately normally distributed with an expected mean of zero if the true value of the parameter, such as a slope, is zero), or 2) a likelihood ratio test (LRT).

Specifying some distribution for the data is integral to the ML method. This assumption of a particular distribution is part of our model for the observed data. The models used in the current study, both for sediment and fish PCB concentrations, assume that the PCB concentration depends on some known variables. For PCB in sediments, the variables are spatial dimensions and time. For PCB concentrations in fish tissue, the variables are time, position within the annual seasonal cycle, and lipid content of the tissue. For specified values of these other variables (e.g., specified time, sediment depth, and northing and easting coordinates), the observations are assumed to occur randomly above or below an expected value. This random variation constitutes "noise." As part of the maximum likelihood approach, one must specify the distribution of this "noise." In our analysis, we have assumed a normal distribution for log PCB concentrations and, equivalently, a lognormal distribution for the original data. As noted earlier (Section 2.1.3), this assumption fit the distribution of log-transformed sediment concentrations exceptionally well. The normal distribution then was assumed when using the ML method with log PCB concentrations.

Data analysis customarily assumes a model, such as that noted here, for generating observations: random variation generates observations scattered around the "truth." In this study, "the truth" of sediment time trends has been modeled as a straight line (logarithm of PCB concentration versus time) corresponding to an exponential decay of the actual PCB concentration, with appropriate adjustment for spatial coordinates. The "noise" has been modeled as the normal distribution—a bell-shaped curve.

The idea behind maximum likelihood estimation for the coefficients in a model can be illustrated by a simple example. We can visualize a scatter plot of a dependent variable (y) versus time (t) with some apparent linear trend to the scatter of points. When attempting to fit a straight line to the data, we can imagine taking the line and shifting it around the plot until we see a "best fit." We can get residuals from this line of predicted values to the observed data points. For a given point, the residual is the observed value minus the predicted value. Generally large residuals imply a poorer fit than generally small residuals. Given the assumption of a normal distribution of points around the line (a bell-shaped curve) at each time *t* and an estimate of the "width" or variance of the normal distribution around the straight line, we then can calculate the probability of getting a particular collection of residuals around the line. (The reader should note that this simplified example of PCB concentration versus time does not include spatial coordinates. The actual models developed later do include spatial coordinates.)

A straight line that does not pass through most of the data would produce a very unlikely collection of residuals. As such, the probability of such a line being a good fit would be low. Similarly, a straight line driving right through the data would produce a far more likely collection of residuals. The "best fit" line is the one with the most probable collection of residuals.

The maximum likelihood method lets us actually calculate the probability, given a particular straight line, that we would get a certain set of residuals scattered around the straight line. Each residual would contribute to that probability. For a concentration below the detection limit, we can calculate the probability, given the line, that an observation would occur at or below the specified detection limit. By multiplying together the probabilities for all residuals, we would calculate one overall probability that the given configuration of residuals would occur around this line.

We can think of the maximum likelihood method as calculating probabilities for infinitely many lines, with infinitely many values of noise around the line. The method allows one to identify the line and the value of the noise around the line with the maximum probability for the data. (The maximizing and probability concepts lead to the name "maximum likelihood.")

One can then find the statistical significance of the slope of the line—the probability that the non-zero slope could have arisen randomly when the "truth" is a zero, or horizontal, slope. The statistical significance (or of lack thereof) of the departure of a fitted line from zero slope involves comparing a model with that slope set to zero (in this simple example a horizontal, straight line) to the model with a sloping straight line. A small change in the likelihood from the horizontal, straight line to the sloping line suggests a non-statistically significant difference, and, similarly, a non-statistically significant non-zero slope. That is, random variation could easily generate a line with this magnitude of slope.

Conversely, if we have to tilt the line quite a bit in order to get a better representation of the data, and the likelihood of that fit increases dramatically compared to the horizontal, zero-slope line, then we would probably declare the slope "statistically significant." Such an impressively sloping line probably could not have arisen by chance if "the truth" had a zero slope. So, we would reject the hypothesis of zero slope.

The typical output from the maximum likelihood method includes:

- The estimate for each parameter,
- The standard error of the parameter estimate, and
- The statistical significance (*p*-value) for the null hypothesis that the true parameter is zero.

One can extend the ML method to more complex models including spatial coordinates with relative ease. Either simple or complex models will have residuals. As in the simple linear case, the more complex models also involve multiplying probabilities together and adjusting parameters in the model to get the largest overall probability of producing the observed set of residuals.

Throughout the report, significance levels of $p < 0.05$, from regression analysis or from any other analyses, have been designated as "statistically significant." "$p < 0.05$" means that there is less than 5 percent probability that an observed non-zero slope could arise randomly and differ from zero to the extent observed, if the true slope were zero.

2.3 Spatial Dependence

Analysis of sediment PCB concentrations for the Fox River data revealed a close-range spatial dependence. As will be shown later, measured total PCB concentration from samples obtained within a few centimeters or meters of one another tended to have similar values. Samples located hundreds of meters apart were more dissimilar. Thus, PCB concentrations appear to be spatially correlated.

Standard statistical methods typically assume independent observations. When data show spatial correlation, standard statistical methods may provide an unbiased parameter estimate, but they will also underestimate the standard error of the estimate, generate anticonservative *p*-values and confidence intervals, and overstate claims of statistical significance. This occurs because two observations that show spatial correlation do not produce as much information as two independent observations. Hence, standard statistical methods overestimate effective sample size.

Consider the following illustration of dependence, polling voters on their choice of a presidential candidate: asking five people in each of two households to choose the next president will yield 10 answers, but the true sample size will be closer to two, not 10, as people within households tend to vote more similarly than people in separate households. Asking the same question of 10 individuals from separate households in different neighborhoods across the country will yield much more information than asking five individuals within two households. As an extreme example, we cannot obtain a precise percentage estimate of the popular vote by asking one person repeatedly 10,000 times how they expect to vote.

We investigated spatial correlation using semivariogram analysis (Cressie, 1993), a method developed in the field of mining geostatistics for assessing close-range correlation of mineral concentrations in soil samples. In our context, the semivariogram vertical axis shows the average squared difference in $\log_{10}$ (PCB concentration) between pairs of observations, and the horizontal axis shows the distance between the observation pairs. If the observed difference in PCB concentrations is smaller for pairs close together, this curve will rise from zero up to a "sill" level, where the curve flattens out, as in Figure 3. Beyond the sill level, the approximately constant difference in concentration indicates independence between data pairs at that level of separation. The semivariogram in Figure 3 also sports a smooth curve, added to aid in assessing the sill level; these smoothed curves do not always accurately show the initial rise to the sill (as in Figure 4), due to the particular algorithm used for smoothing. The leftmost data values help to visually assess the "rise to the sill." The leftmost point(s) are lower on the Y-axis than other points, indicating that points close together have more similar PCB concentrations than the concentrations of points farther apart. Around any trend, however, one finds considerable scatter.

The log of core-averaged concentrations was used in calculating and plotting the semivariograms. Because most observations (75 percent) did not arise from core averaging, semivariogram plots based on the original concentrations (not core averaged) would be expected to differ little from plots based on core averaging. Without core averaging, points on the plot would tend to shift upward (toward larger variances).

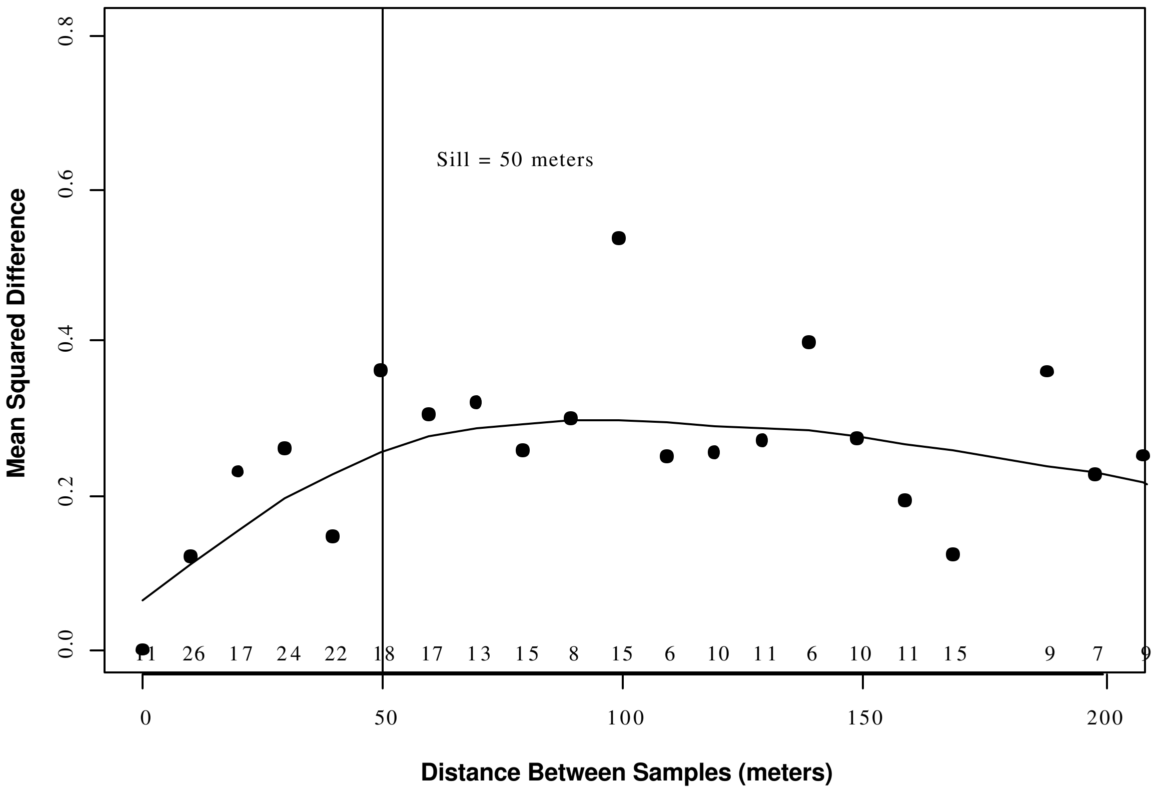


Figure 3 Semivariogram Plot of Appleton Deposit Group N Pre-dredge, 10+–30 cm Depth

The semivariogram considers all possible pairs of n samples. That is, sample #1 and sample #2 are a pair, sample #1 and sample #3 are a pair, and so on, up to the last pair, sample #n and #(n – 1). There are n (n – 1) ÷ 2 total pairs. The vertical axis shows the mean squared difference in $\log_{10}$ (PCB concentration) between a pair of samples, and the horizontal axis shows the distance between the pair. The distance between pairs of samples binned (i.e., all pairs of samples closer than about 10 meters are pooled into one bin). For each sample pair in this bin, the squared difference of their $\log_{10}$ PCB concentration is calculated and the mean of the squared values is plotted above the bin location on the *X*-axis. The next bin represents pairs of samples separated by about 10 to 20 meters. Again, the mean squared difference is calculated and plotted. A similar process of calculation and plotting is carried out for all possible pairs of samples. Note that a given sample will appear in (n – 1) pairs (once with each other sample). Moreover, it may occur in multiple bins as a member of some pairs that are close together and other pairs that are far apart. A smooth curve has been added to represent the trend of increasing mean squared difference with increasing distance between pairs of samples. The number of sample pairs in each bin shows just above the horizontal axis, directly beneath the estimated mean squared difference point for that bin. Samples obtained very close together show small differences, as their measured PCB values tend to be quite similar; i.e., samples obtained close together are not statistically independent. The average squared difference rises from zero as distance between points increases, up to the "sill" value (marked as 50 meters in the plot), where the average squared difference levels off and reflects the distance beyond which points are effectively independent. Semivariogram plots were used to detect spatial dependence, but no quantitative results from the semivariograms entered calculation of time trends.

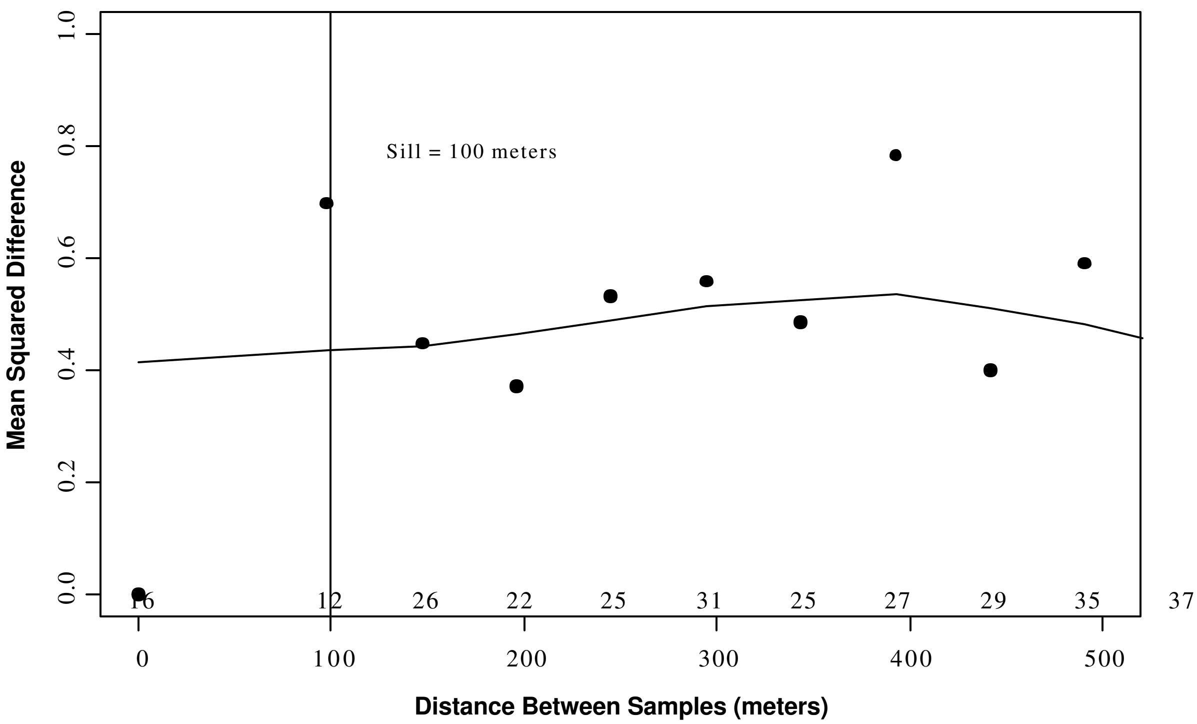


Figure 4 Semivariogram Plot of De Pere to Green Bay Deposit Group 2025, 10–30 cm Depth

(See explanation in legend of Figure 3.) Semivariogram plot portraying a case where smoother curve shows the "sill" level adequately, but does not curve up from zero due to lack of sample pairs close together. The leftmost data point indicates a very low mean squared difference for sample pairs located closer than about 25 meters. Beyond 100 meters, the average squared difference is fairly constant, indicating that samples separated by at least 100 meters are effectively independent.

Semivariograms were plotted for each of the many combinations of deposit and depth that were ultimately analyzed. The plots showed that short-range spatial dependence was pervasive in these data. Semivariogram analysis was used only to visually display spatial dependence. No quantitative results from the semivariogram analysis were used in subsequent time trends calculations. Spatial dependence was handled through the WSEV estimate, discussed below.

2.4 Addressing Spatial Dependence Using the WSEV Method

Lumley and Heagerty (1999) and Heagerty and Lumley (2000) have developed a method for more accurately assessing variability in the presence of spatial correlation using Window Subsampling Empirical Variance (WSEV) estimation. The problem being addressed is that the effective sample size is smaller than the total sample size because correlated observations do not contain as much total information as totally independent, uncorrelated observations. The WSEV method tends to lump correlated observations together into groups that are then approximately uncorrelated. In the WSEV method, one divides up the geographic region over which the data values are obtained into a collection of windows, or subregions. We can think of the subregions being defined by a rectangular grid (with rectangular grid cells) placed over the map of sample locations. With a grid of the right spacing, the observations in different subregions of the grid will tend to be independent. The mean of the observations in a subregion can represent that subregion. The WSEV method works with means of regions, though one actually uses a more complex function than the mean. The WSEV method is analogous to using a sample size that is more closely related to the number of independent regions, rather than the number of samples available. This smaller effective sample size yields a more accurate estimate of the standard error of a parameter, more accurate confidence intervals, and a more accurate statement of statistical significance.

The ML method discussed earlier provides estimates of regression coefficients, such as a time trend slope, that do not need any adjustment. Only the standard error of these regression coefficients is adjusted by the WSEV method. In turn, the standard error is used to calculate statistical significance (a *p*-value).

Implementing Lumley's WSEV method involves dividing the spatial region using a coarse mesh grid, then averaging particular functions of the data within grid cells and using the averages to obtain standard error estimates for the regression model parameters. One repeats the procedure with decreasing grid mesh sizes (i.e., decreasing size of subregions), typically investigating five to ten mesh sizes. As the mesh size decreases, parameter standard errors initially increase and then decrease.

Inordinately large grid sizes result in too much averaging and subregions exhibit too little variation among themselves. As the grid size initially decreases, the estimated standard error will increase. As the grid size continues to decrease, at some point the estimated standard error will now stop increasing and begin to decrease. This occurs because neighboring cells will show too little variation due to their correlation with one another. The WSEV method uses the standard error of the regression model intercept as an aid in determining the proper grid size. We fit all of our regression models with an intercept (constant term). The WSEV standard error of the intercept will show the increasing-then-decreasing magnitude with increasing grid size as just described. In the WSEV method, the grid size that yields the largest standard error for the intercept term of the regression model is selected. From this grid size, we then calculate the WSEV standard error for the coefficient of time (the time trend slope). This standard error fully accounts for spatial dependence and is selected in an objective way.

In each analysis, we used ML estimation S-PLUS functions "SurvReg" and "CensorReg" to fit regression models and calculate the time trend slope coefficients. (The two S-PLUS functions SurvReg and CensorReg provide the same estimates of slope, but each generates different quantities used in the WSEV analyses.) Using the WSEV method, we then calculated the standard error of the time trend slope coefficient. We wrote our own software routines (in S-PLUS) to calculate the WSEV estimates of standard error, based on output from SurvReg and CensorReg (S-PLUS 2000, Release 2, MathSoft, Seattle).

We calculated the statistical significance (*p*-value) of each time trend slope using the *t*-distribution; i.e., a "*t*-test." The *t*-statistic was calculated as the ratio of: 1) the time trend slope coefficient (the coefficient of time, *t*, in Equation 1); and 2) the WSEV standard error. The degrees of freedom for the *t*-statistic was the number of grid cells, at the chosen grid mesh size, which contained at least one sample. This is analogous to the number of independent groups of observations. The Appendix includes this number of non-empty grid cells.

2.5 Geographic Grouping of Data

Our need for geographically grouping samples for statistical analysis led to the creation of new "deposit groups." The sample deposit designations in the FRDB were unsuited to defining spatially cohesive subsets, as many samples fell outside the original deposits (and had no deposit designation). Furthermore, some deposit designations spanned stretches of a river reach too long to allow adequate control of spatial variation in PCB concentration. We examined the spatial layout of all samples in each river reach. Based on this plotting and mapping exercise, we defined new "Deposit Groups," forming data subsets with spatial variation far more amenable to statistical analysis. We named the deposit groups to reflect, to some extent, the original deposit designations already in place, with the added benefit that these groups designated non-overlapping spatial sets that included all samples. The geographic size of deposit groups is a compromise between a desire for large sample sizes in each group and a desire for tiny areas with homogeneity (i.e., relatively similar PCB concentrations within each depth stratum).

There was an isolated sample, labeled as "POG," located by Wrightstown in the Appleton to Little Rapids Reach. The sample was located at least 2 miles from upstream samples and at least 3 miles from downstream samples. The sample was excluded.

Table 1 through Table 4 show how the original sample designations (identified in table rows) correspond to our "deposit group" designations (positioned in table columns). For example, the new "Little Lake Butte des Morts Deposit **Group** E" primarily contains samples from the original Little Lake Butte des Morts Deposit E (40 samples), but also includes four samples from the original Little Lake Butte des Morts Deposit D and nine from Deposit POG. Samples with no deposit designation in the FRDB constitute from 5 to 70 percent of samples within each of the four reaches (Table 1 through Table 4). Little Lake Butte des Morts had 5 percent of samples with no deposit designation (presumably samples located spatially outside the original deposit designations). The corresponding percentages of samples without designations in other reaches were 7 percent for Appleton Reach, 12 percent for Little Rapids Reach, and 72 percent for the De

Pere Reach. The large percentage for De Pere Reach arises because the original deposit designations were noted only for SMU Deposits 50–67. Our new "deposit group" designation includes all samples and thus increases sample sizes available for trend estimates and hypothesis tests. In any case, having an original deposit designation became irrelevant with the formation of our new deposit groups. Furthermore, the lack of an original deposit designation had no role in disqualifying a sample from inclusion in our time trends analysis. Finally, not having an original deposit designation does not suggest poor data quality.

Table 1 Little Lake Butte des Morts Deposit Groups Defined for Time Trends Analysis

Original Deposit Designation	Time Trends Analysis: Deposit Group Designation							Total
	LLBdM Deposit Group AB	LLBdM Deposit Group C	LLBdM Deposit Group POG	LLBdM Deposit Group D	LLBdM Deposit Group E	LLBdM Deposit Group F	LLBdM Deposit Group GH	
Deposit A	281	0	0	0	0	0	0	281
Deposit B	5	0	0	0	0	0	0	5
Deposit C	0	52	0	0	0	0	0	52
Deposit D	0	0	1	49	4	8	0	62
Deposit E	0	0	2	1	40	68	32	143
Deposit F	0	0	0	0	0	12	0	12
Deposit G	0	0	0	0	0	0	3	3
Deposit H	0	0	0	0	0	0	3	3
Deposit POG	0	0	27	0	9	0	0	36
No Designation	13	2	4	5	0	10	0	34
Total:	**299**	**54**	**34**	**55**	**53**	**98**	**38**	**631**

Note:

Column entries show number of samples from original deposits included in each time trends deposit group.

Table 2 Appleton Deposit Groups Defined for Time Trends Analysis

Original Deposit Designation	Time Trends Analysis: Deposit Group Designation					Total
	Appleton Deposit Group IMOR	Appleton Deposit Group N	Appleton Deposit Group VCC	Appleton Deposit Group SU	Appleton Deposit Group DD	
Deposit AA	0	0	1	0	0	1
Deposit BB	0	0	3	0	0	3
Deposit CC	0	0	9	0	0	9
Deposit DD	0	0	0	0	20	20
Deposit I	4	0	0	0	0	4
Deposit J	2	0	0	0	0	2
Deposit K	3	0	0	0	0	3
Deposit L	3	0	0	0	0	3
Deposit M	2	0	0	0	0	2
Deposit N	0	136	0	0	0	136
Deposit O	7	0	0	0	0	7
Deposit P	12	0	0	0	0	12
Deposit Q	12	0	0	0	0	12
Deposit R	2	0	0	0	0	2
Deposit S	0	0	0	7	0	7
Deposit T	0	0	0	15	0	15
Deposit U	0	0	0	3	0	3
Deposit V	0	0	7	0	0	7
Deposit W	0	0	39	0	0	39
Deposit X	0	0	46	0	0	46
Deposit Y	0	0	3	0	0	3
Deposit Z	0	0	2	0	0	2
No Designation	9	0	15	0	0	24
Total:	**56**	**136**	**125**	**25**	**20**	**362**

Note:

Column entries show number of samples from original deposits included in each time trend deposit group.

Table 3 Little Rapids Deposit Groups Defined for Time Trends Analysis

Original Deposit Designation	Time Trends Analysis: Deposit Group Designation				Total
	Little Rapids Deposit Group Upper EE	Little Rapids Deposit Group Lower EE	Little Rapids Deposit Group FF	Little Rapids Deposit Group GGHH	
Deposit EE	100	96	94	145	435
Deposit FF	0	0	3	5	8
Deposit GG	0	0	0	75	75
Deposit HH	0	0	0	49	49
No Designation	4	22	0	52	78
Total:	**104**	**118**	**97**	**326**	**645**

Note:

Column entries show number of samples from original deposits included in each time trend deposit group.

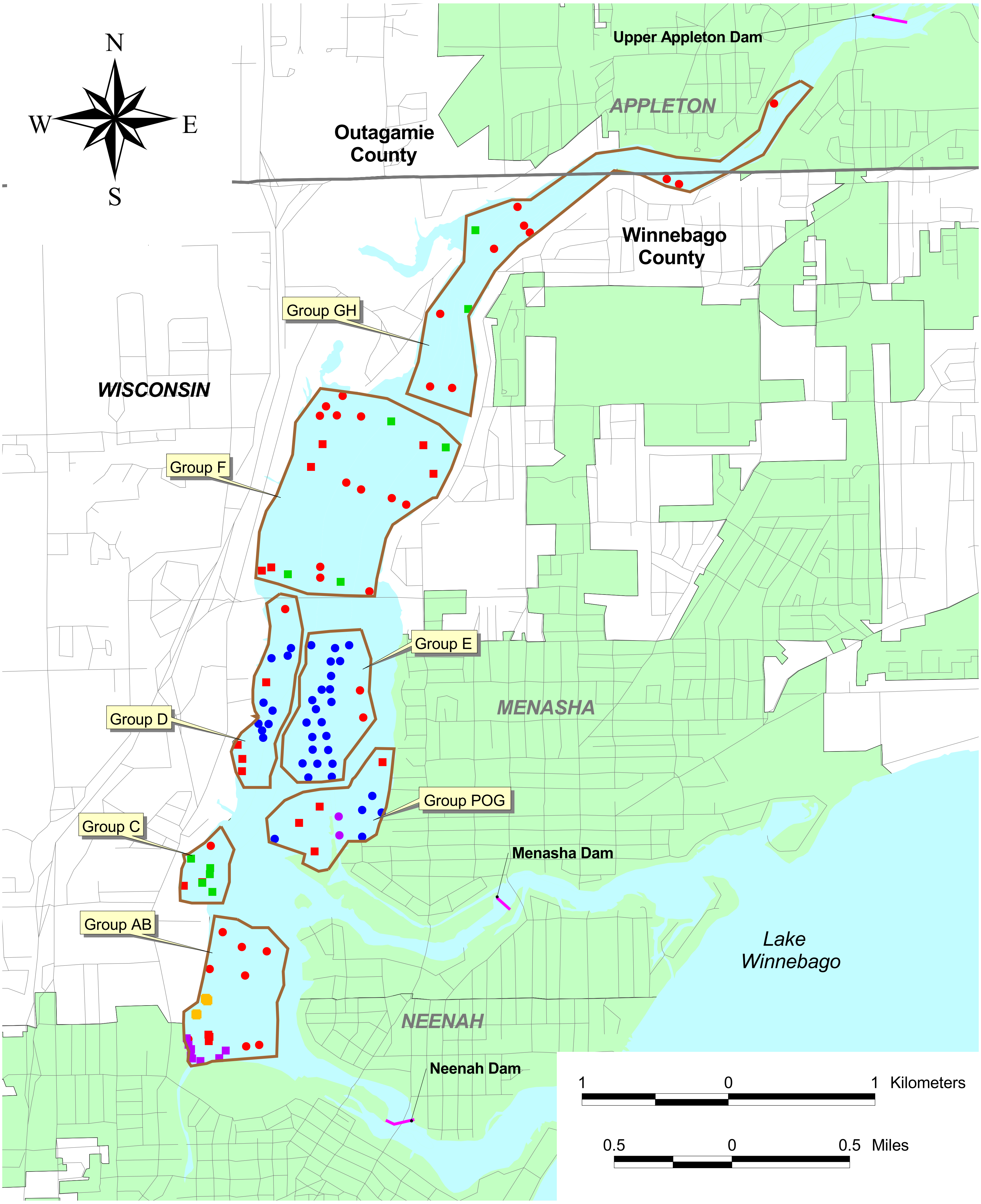
Table 4 De Pere SMU Groups Defined for Time Trends Analysis

Original Deposit Designation	Time Trends Analysis: Deposit Group Designation					Total
	De Pere SMU Group 2025	De Pere SMU Group 2649	De Pere SMU Group 5067	De Pere SMU Group 6891	De Pere SMU Group 92115	
SMU56/57	0	0	282	0	0	282
No Designation	201	284	97	88	61	731
Total:	**201**	**284**	**379**	**88**	**61**	**1,013**

Note:

Column entries show number of samples from original deposits included in the time trends SMU group.

Figure 5 through Figure 8 map the location of samples and our deposit groups in the four river reaches. The boundaries separating the deposits were approximations drawn by eye, as formal definitions were unnecessary. Figure 8 breaks our SMU groups into smaller units than actually used, showing some of the original SMU designations. Our SMU Group 2025 aggregated (approximately) the original SMU designations 20–25; our SMU Group 2649 aggregated the original SMU designations 26–49; and so on for our SMU groups 5067 (aggregating 50–67), 6891 (aggregating 68–91), and 92115 (aggregating 92–115).



Revised Deposit Outlines

Sediment Sample Data Collection Points

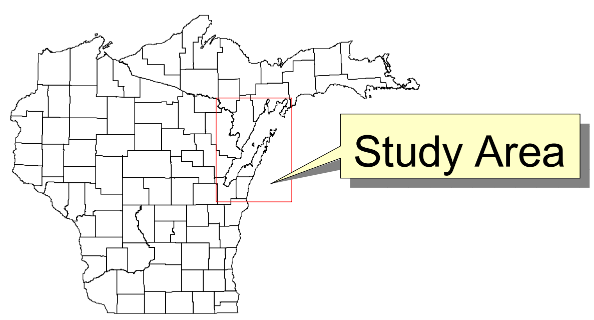
- 1989/90 Mass Balance sediment data study
- 1994 SAIC and GAS study
- 1995 WDNR
- 1996 BBL data study
- 1997 SMU 56/57 Demonstration Project
- 1998 BBL data study
- 1998 Deposit N Post-Dredge sediment Demonstration Project
- 1998 RI/FS Supplemental data
- 1992/1993 LLBDM RI/FS Deposit A
- 1994 Woodward Clyde Deposit A sediment sample

Dam Locations

Roads

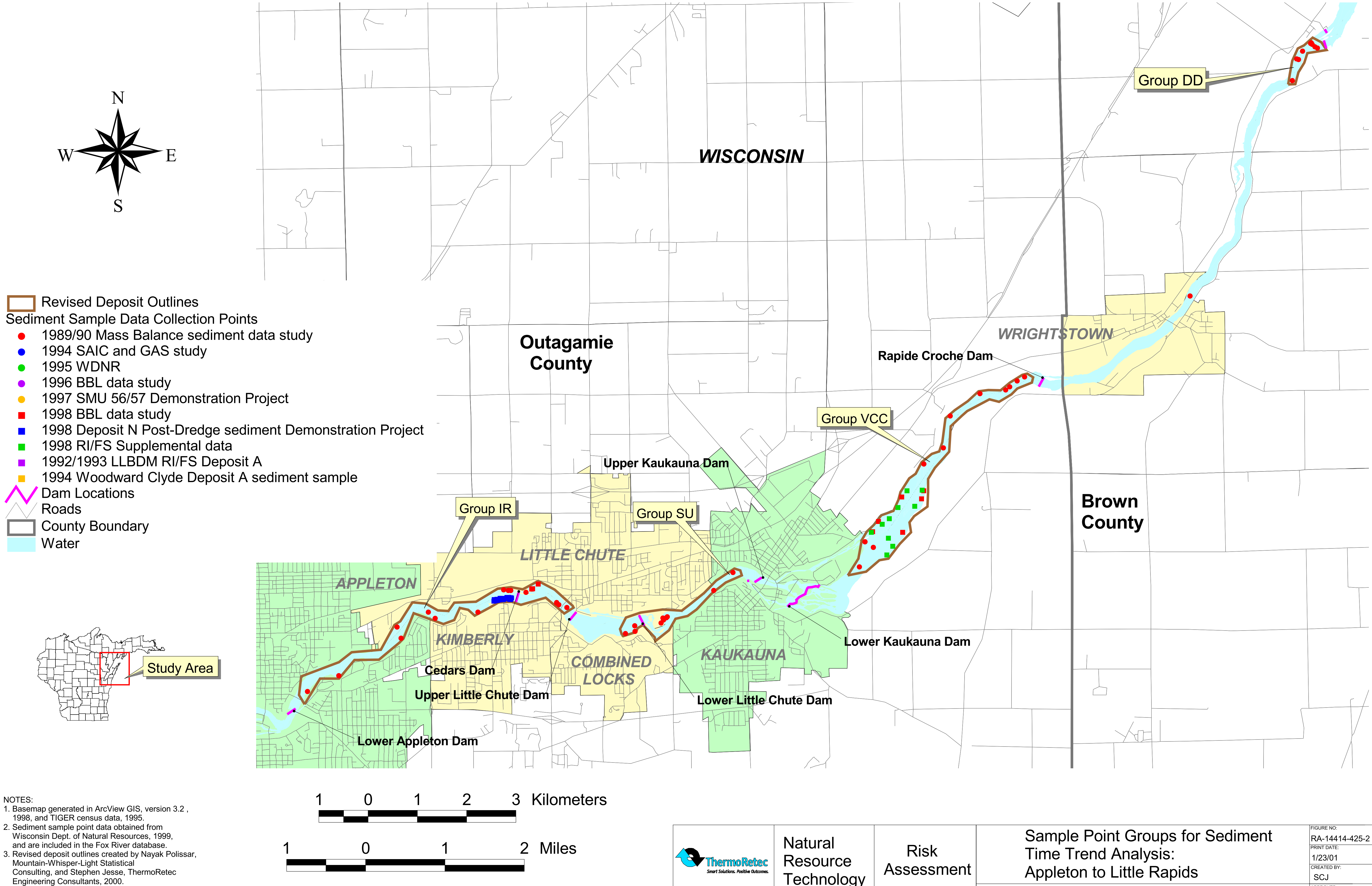
County Boundary

Water



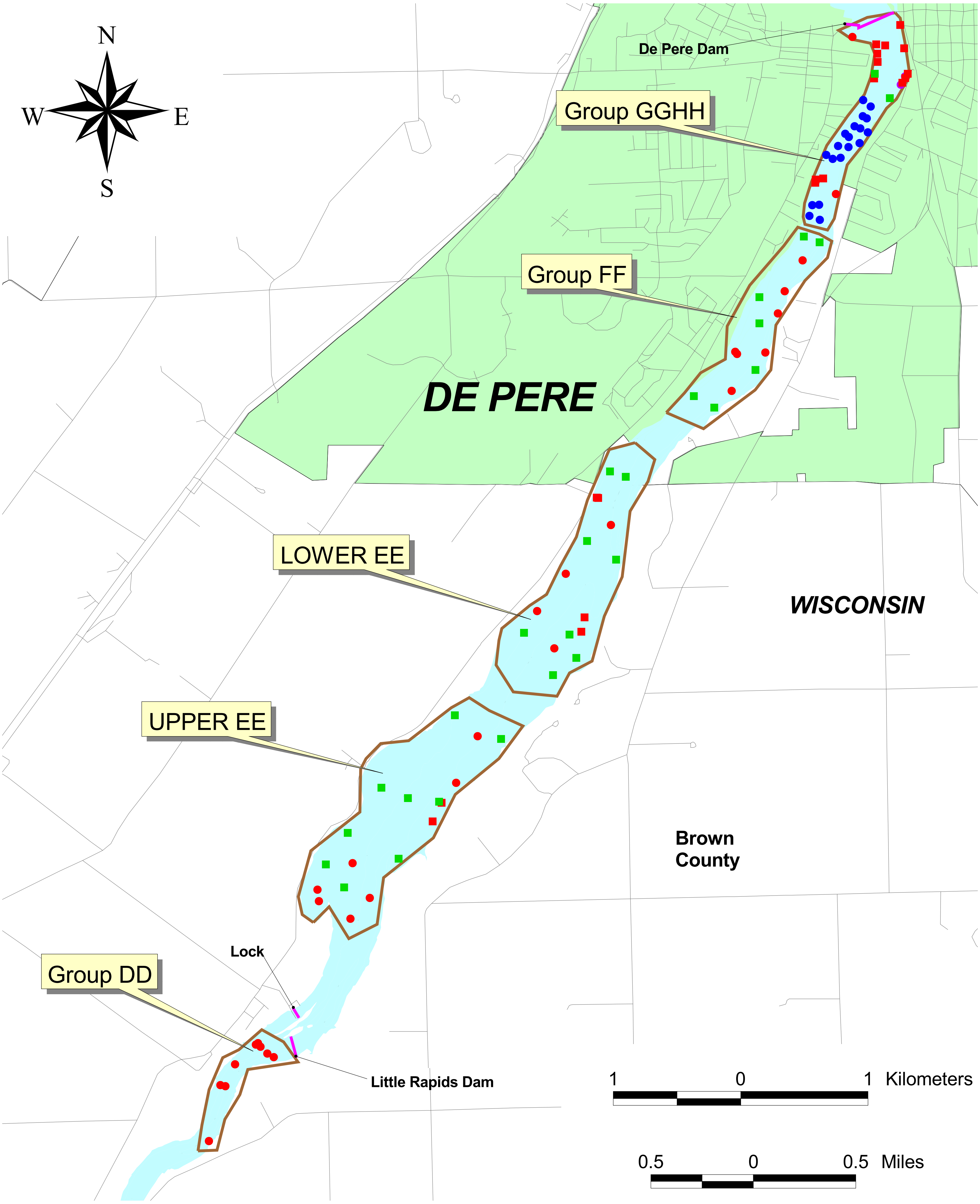
NOTES:
1. Basemap generated in ArcView GIS, version 3.2 , 1998, and TIGER census data, 1995.
2. Sediment sample point data obtained from Wisconsin Dept. of Natural Resources, 1999. and are included in the Fox River database.
3. Revised deposit outlines created by Nayak Polissar, Mountain-Whisper-Light Statistical Consulting, and Stephen Jesse, ThermoRetec Engineering Consultants, 2000.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Sample Point Groups for Sediment Time Trend Analysis: Little Lake Butte des Morts	FIGURE NO: RA-14414-425-1
				PRINT DATE: 1/23/01
				CREATED BY: SCJ
			FIGURE 5	APPROVED: AGF



NOTES:
1. Basemap generated in ArcView GIS, version 3.2 , 1998, and TIGER census data, 1995.
2. Sediment sample point data obtained from Wisconsin Dept. of Natural Resources, 1999, and are included in the Fox River database.
3. Revised deposit outlines created by Nayak Polissar, Mountain-Whisper-Light Statistical Consulting, and Stephen Jesse, ThermoRetec Engineering Consultants, 2000.

ThermoRetec	Natural Resource Technology	Risk Assessment	Sample Point Groups for Sediment Time Trend Analysis: Appleton to Little Rapids	FIGURE NO: RA-14414-425-2
			FIGURE 6	PRINT DATE: 1/23/01
				CREATED BY: SCJ
				APPROVED: AGF



Revised Deposit Outlines

Sediment Sample Data Collection Points

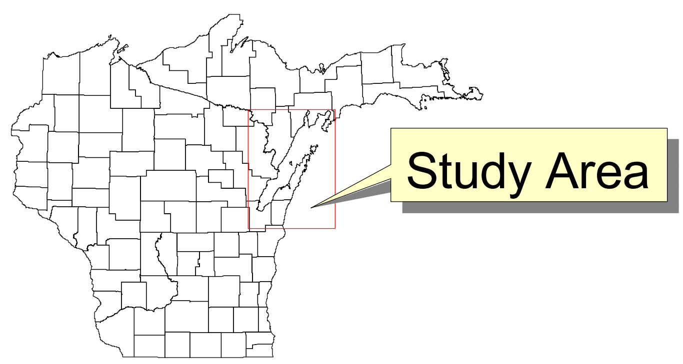
- 1989/90 Mass Balance sediment data study
- 1994 SAIC and GAS study
- 1995 WDNR
- 1996 BBL data study
- 1997 SMU 56/57 Demonstration Project
- 1998 BBL data study
- 1998 Deposit N Post-Dredge sediment Demonstration Project
- 1998 RI/FS Supplemental data
- 1992/1993 LLBDM RI/FS Deposit A
- 1994 Woodward Clyde Deposit A sediment sample

Dam Locations

Roads

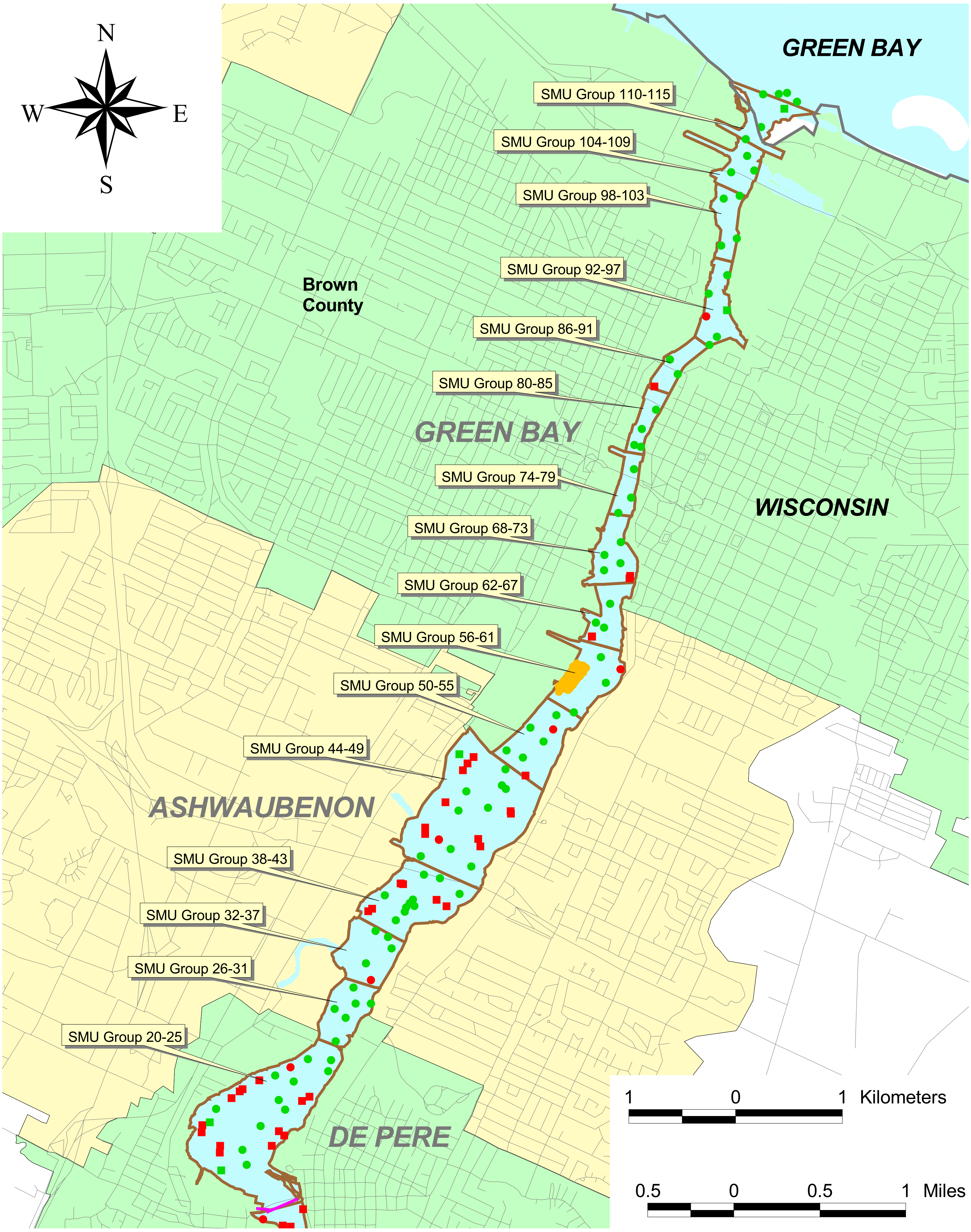
County Boundary

Water



NOTES:
1. Basemap generated in ArcView GIS, version 3.2 , 1998, and TIGER census data, 1995.
2. Sediment sample point data obtained from Wisconsin Dept. of Natural Resources, 1999. and are included in the Fox River database.
3. Revised deposit outlines created by Nayak Polissar, Mountain-Whisper-Light Statistical Consulting, and Stephen Jesse, ThermoRetec Engineering Consultants, 2000.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Sample Point Groups for Sediment Time Trend Analysis: Little Rapids to De Pere **FIGURE 7**	FIGURE NO: RA-14414-425-3 PRINT DATE: 1/23/01 CREATED BY: SCJ APPROVED: AGF



SMU Deposits

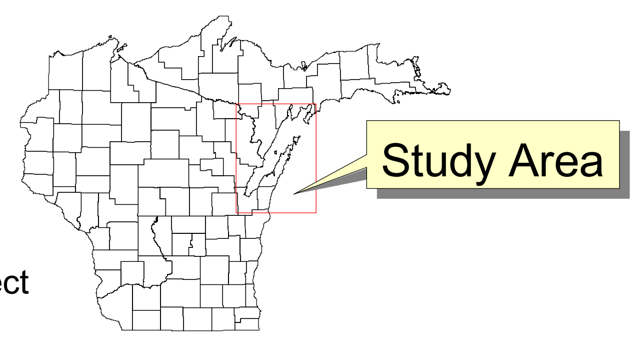
Sediment Sample Data Collection Points

- 1989/90 Mass Balance sediment data study
- 1994 SAIC and GAS study
- 1995 WDNR
- 1996 BBL data study
- 1997 SMU 56/57 Demonstration Project
- 1998 BBL data study
- 1998 Deposit N Post-Dredge sediment Demonstration Project
- 1998 RI/FS Supplemental data
- 1992/1993 LLBDM RI/FS Deposit A
- 1994 Woodward Clyde Deposit A sediment sample

Roads

County Boundary

Water



NOTES:
1. Basemap generated in ArcView GIS, version 3.2 , 1998, and TIGER census data, 1995.
2. Sediment sample point data obtained from Wisconsin Dept. of Natural Resources, 1999. and are included in the Fox River database.
3. Revised deposit outlines created by Nayak Polissar, Mountain-Whisper-Light Statistical Consulting, and Stephen Jesse, ThermoRetec Engineering Consultants, 2000.

ThermoRetec Smart Solutions. Positive Outcomes.	Natural Resource Technology	Risk Assessment	Sample Point Groups for Sediment Time Trend Analysis: De Pere to Green Bay	FIGURE NO: RA-14414-425-4
				PRINT DATE: 1/23/01
				CREATED BY: SCJ
			FIGURE 8	APPROVED: AGF

Figure 9 through Figure 12, show the location of each sample in a rectangular coordinate system devoid of map features. The "northing" and "easting" rectangular coordinates locate each sample along a north-south and east-west axis, respectively, based on a standard geographic coordinate system for Wisconsin State. Northing and easting are expressed in meters relative to an origin not shown on the plot.

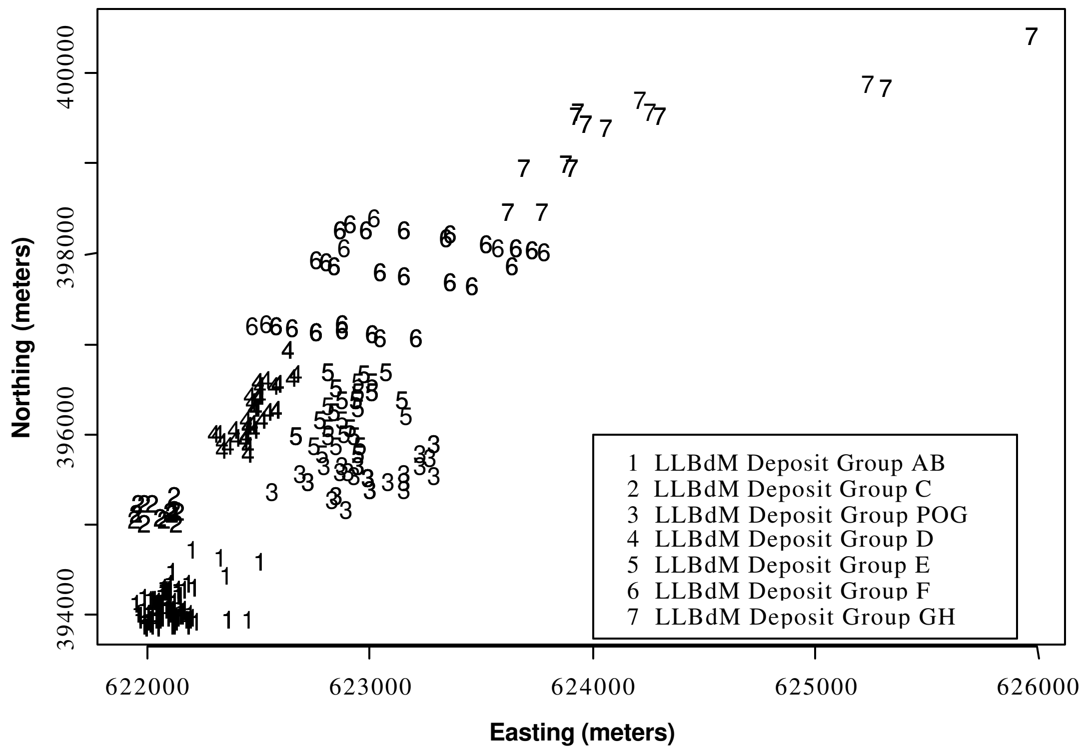


Figure 9 Locations of Deposit Groups in Little Lake Butte des Morts Reach

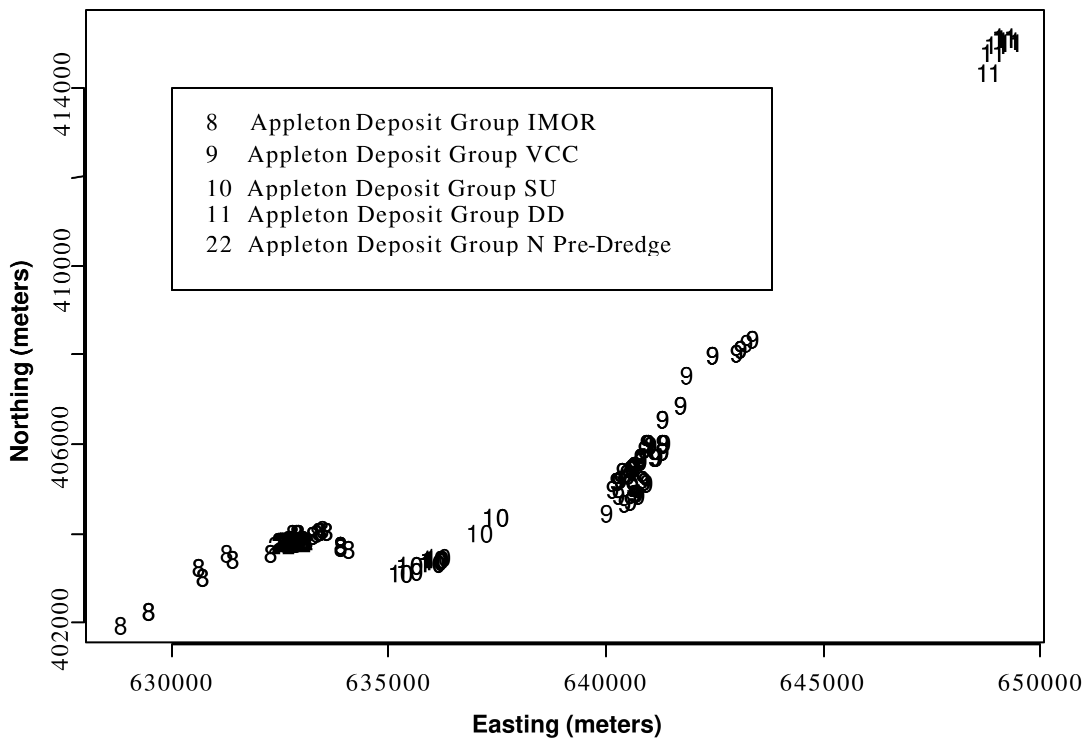


Figure 10 Locations of Deposit Groups in Appleton Reach

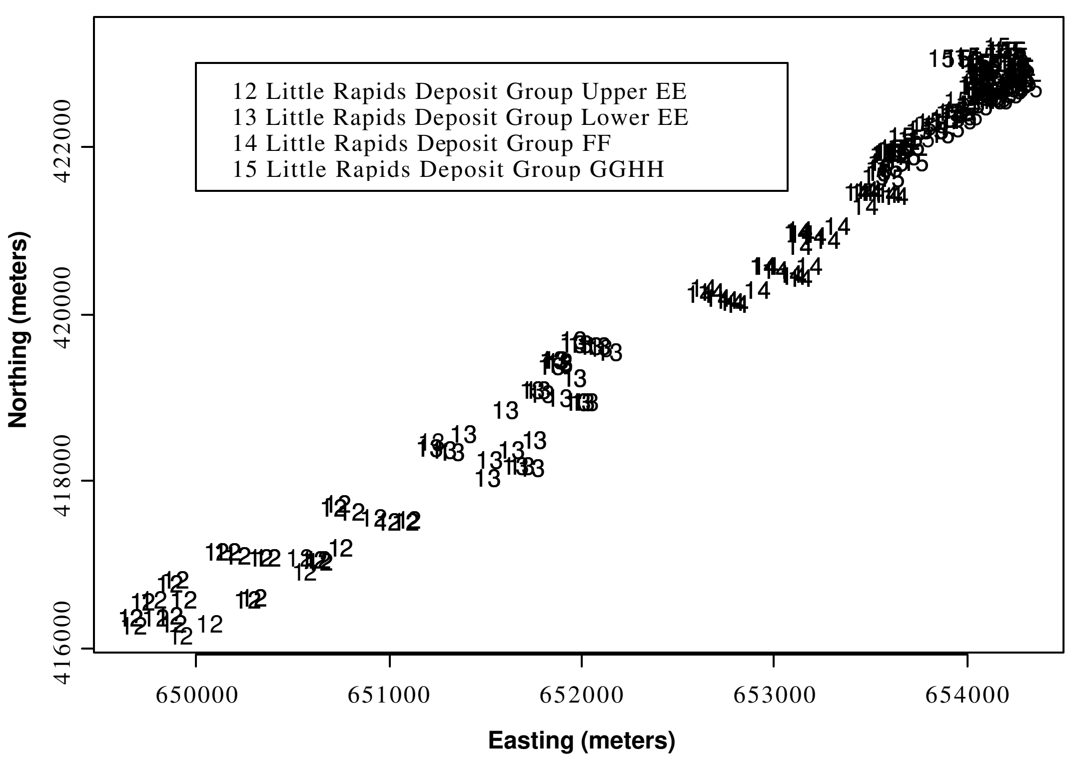


Figure 11 Locations of Deposit Groups in Little Rapids Reach

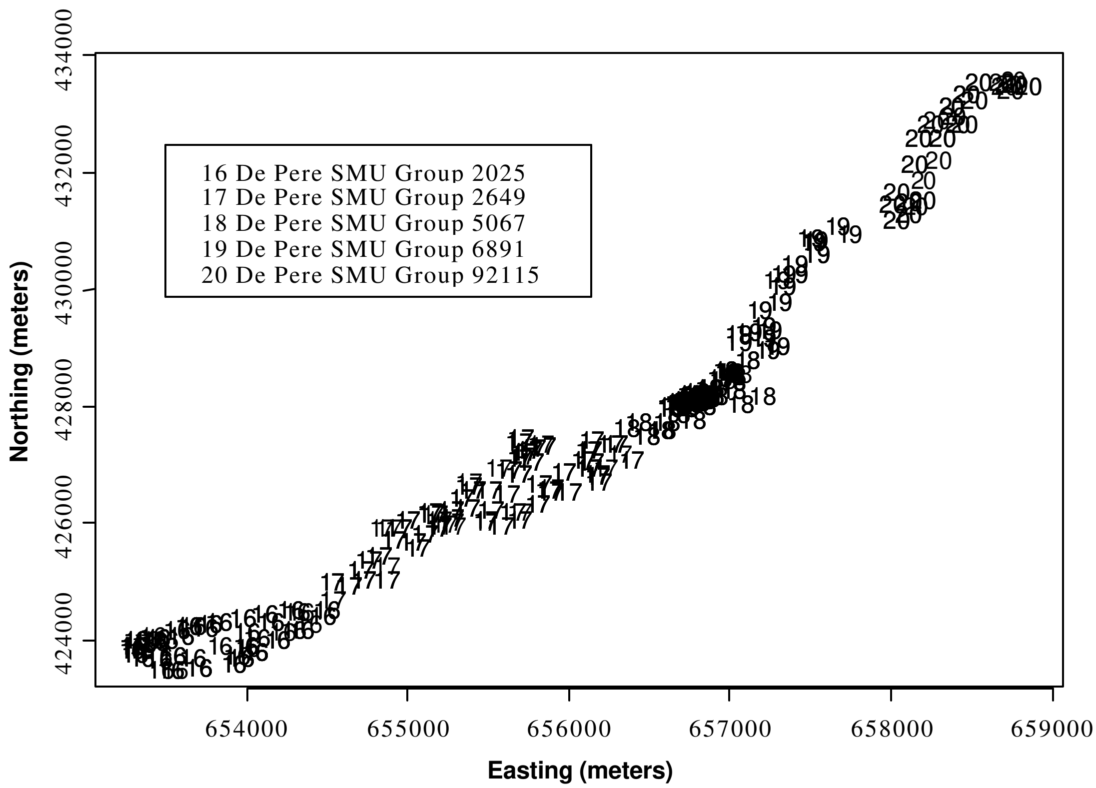


Figure 12 Locations of Deposit Groups in De Pere Reach

2.6 Models for Variation in PCB Concentration in Space and Time

Because PCB concentrations vary spatially as well as over time, we included spatial dimensions in our regression models. To characterize the spatial component in the models, we used linear and quadratic variables for "easting" and "northing" coordinates (east and north distances in meters) and a linear term for depth. For every stratum, depth was measured from a value of zero at the top of the 0- to 10-cm layer. Depth, thus, means simply distance from the surface of the river sediment at the time the sample was taken. We centered the northing and easting coordinates for each depth stratum in each deposit group. "Centering" involved finding the spatial centroid of the samples used in the regression analysis for the specific deposit group and depth stratum. Given a set of northing and easting coordinates, the sample centroid sits at the mean of the northing and easting coordinates. We produced the centered northing (N) and easting (E) coordinates by subtracting the centroid from the northing and easting coordinates of each sample.

Under this new coordinate system, the centroid of each deposit group at each depth stratum is the origin of a coordinate system with coordinates (0, 0). By centering, one avoids round-off problems when using the fitted regression models. Without centering, calculating a fitted concentration would involve subtracting a very large number from a second large number. The difference of interest (a log PCB concentration) is usually relatively close to zero. Thus, the later digits for the two large numbers must be tabulated accurately. A simple hypothetical example illustrates this point. Let us ignore time and consider only easting, where an equation

$$\log_{10} PCB = 2.24 + 0.016 E_c$$

indicates that $\log_{10}$ PCB concentration increases by 0.016 for each meter to the east of the centroid of a deposit group. At the centroid, the $\log_{10}$ PCB concentration is 2.24 (the value of the intercept). *E* is the centered easting coordinate. If E^* is the original (uncentered) easting coordinate and the deposit group centroid E^* mean = 622,347 meters (a realistic value for this study), then the equation for $\log_{10}$ PCB concentration with the original easting coordinate would be

$$\log_{10} PCB = -9955.312 + 0.016 E^* .$$

If this cumbersome second equation is used with E^* = 622,347 (the centroid), $\log_{10}$ PCB = 2.24 is calculated accurately for the centroid location. However, if –9955.312 is casually rounded to 9955, an estimate of 2.552 is obtained (instead of the correct 2.24), off by +0.312 units, which, on the natural scale (not log), corresponds to approximately a doubling of the concentration. Thus, centering helps computation and presentation. For the same reason, time was measured from January 1, 1989, taken as *time* = 0.

The specific regression model fitted to the PCB concentrations was:

Equation 2

$$\log_{10} PCB = b_0 + b_t \cdot t + b_D \cdot D + b_E \cdot E + b_N \cdot N + b_{E2} \cdot E^2 + b_{N2} \cdot N^2$$

where

$\log_{10}$ PCB	=	the logarithm (base 10) of the PCB concentration in µg/kg (ppb) by weight,
t	=	time in years since January 1, 1989,
D	=	depth in centimeters from the sediment-water interface,
E	=	the centered easting coordinate for the particular deposit group and depth stratum (meters), and
N	=	the centered northing coordinate (meters).

The intercept is b_0 and b_t, b_D, etc., are regression coefficients. E^2 and N^2 are the quadratic terms for centered easting and northing.

Based on scatter plots of PCB concentrations versus easting coordinate or northing coordinate, we included the quadratic terms (E^2 and N^2) for easting and northing in the regression models whenever we analyzed at least 20 samples. For sample sizes smaller than 20, we included the quadratic terms whenever we suspected a potential curvilinear trend of $\log_{10}$ PCB concentration versus northing or easting.

We note that we included up to five variables to describe spatial variation: *D*, *E*, *N*, E^2, and N^2. These five variables are sometimes needed to describe five unique kinds of spatial variation in concentrations of PCBs: linear trends in depth, easting and northing, and curvilinear trends in easting and northing. When there is a deposit group and stratum with little variation in one of these variables (e.g., little curvilinear trend in the easting direction), then the coefficient of that variable will be zero or close to zero, and it is virtually harmless to include it in a model. Because of widely varying sample sizes, we did not wish to tailor the spatial model to each deposit group and stratum; in some cases, the small sample sizes yield insufficient power to formally accept or reject a given type of spatial variation, such as curvilinearity. Due to low power to detect the need for variables for the spatial dimensions, one errs on the side of safety by including all, rather than erroneously excluding some. With fewer than 20 observations, however, we were concerned about over-fitting models to the data. (See discussion of over-fitting in the context of fish analysis, Section 5.2.1, subsection on Green Bay Zone 2.) Thus, we included the curvilinear terms (E^2 and N^2) only in the face of a visually apparent curvilinear trend in diagnostic plots (see below). We note that, regardless of their number, including appropriate spatial variables in a regression model increases the power to detect time trends notwithstanding a slight possibility that inappropriately including extra spatial terms could decrease power if there are correlations between space and time variables.

In addition to the spatial variables in the regression models, we introduced time as a simple linear term in all analyses. In each analysis, there was an insufficient number of distinct times of sampling to implement a curvilinear model for time. For this brief discussion, we considered a “distinct” time of sampling as a period of several months, or even a year, with at least two samples taken (see Figures A-44 through A-89, upper left panel). Of the 46 analyses ultimately carried out (specific combinations of deposit group and depth), 23 had observations at only two distinct points in time (e.g., 1989 and 1998), 20 had observations at three points in time, and 3 had observations at four points in time.

The dependent variable in all analyses was the $\log_{10}$ PCB concentration with a companion variable indicating whether the observation was below the detection limit or was a detected concentration. We examined residual plots for all regression analyses to detect outliers and assess the assumption of normality. Table 5 notes the removal of only one exceptional value from the formal sediment regression analysis. This sample is considered in the context of time trends in the results section.

Table 5 Sample Removed from Time Trends Analysis

Database ID	Reach	Original Deposit	Time Trends Deposit Group	Depth	Total PCBs (ppb)
A3_0-4	De Pere	SMU56/57	SMU Group 5067	0–10 cm	99,000

Note:
Other PCB values range from 400 to 7,800 in this depth stratum and SMU group.

Figure 13 through Figure 17 show examples of plots we used to determine choice of linear or quadratic terms for northing and easting in the regression models. The plots also show log PCB concentration versus time and log PCB concentration versus depth. We added a “smoother” line to the plots to depict the general trend for these variables taken one at a time. As can be noted in some of the plots, a common structure of the deposit groups shows PCB concentrations rising from minima at one or both sides of the deposit group to a maximum in the middle (e.g., see Figure 17). The quadratic terms (E^2 and N^2) for northing and easting in the regression models capture this curvilinear trend. Separate plots evaluate each variable (time, depth, easting, northing), though a single regression model uses them all.

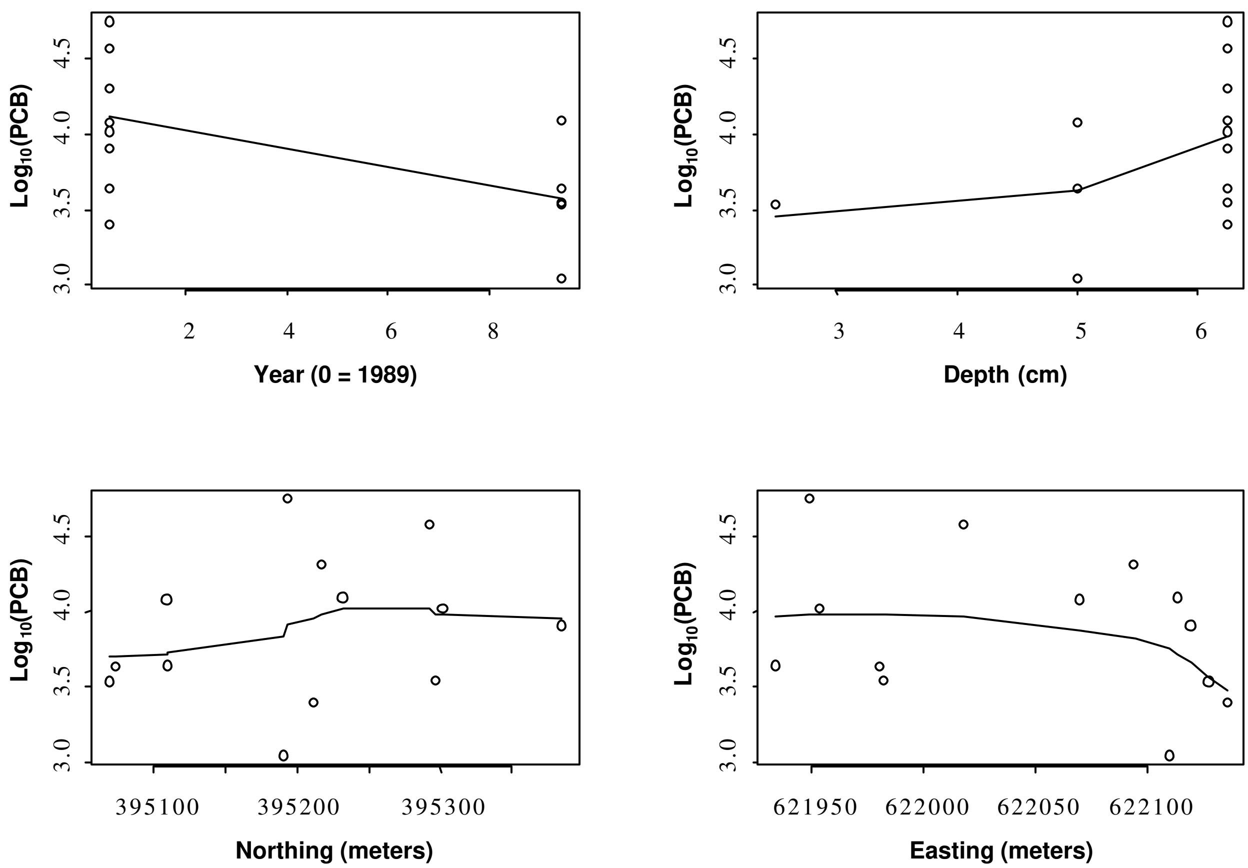


Figure 13 Log_{10} PCB Concentration versus Time, Depth, Northing and Easting for Little Lake Butte des Morts Deposit Group C (0 to 10 cm) Including Fitted Smoothed Line

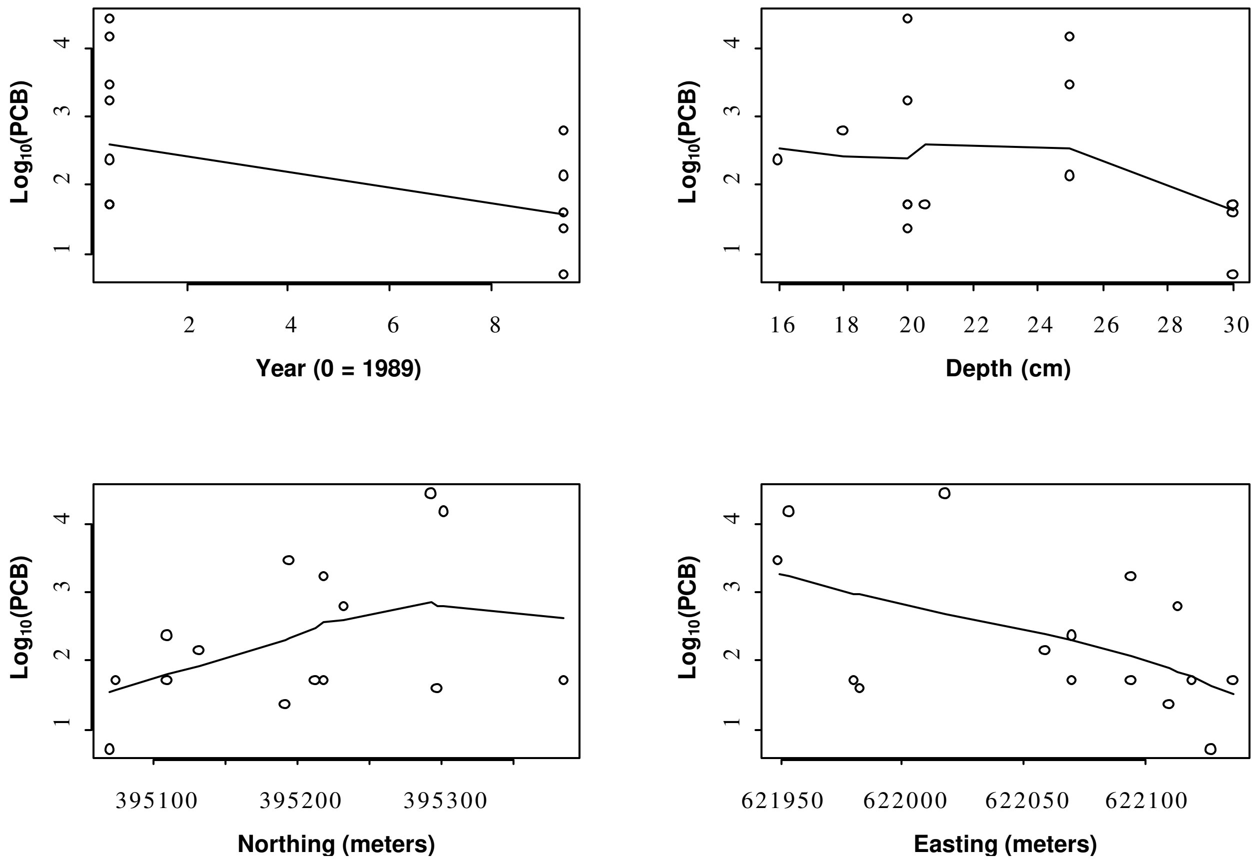


Figure 14 Log_{10} PCB Concentration versus Time, Depth, Northing and Easting for Little Lake Butte des Morts Deposit Group C (10 to 30 cm) Including Fitted Smoothed Line

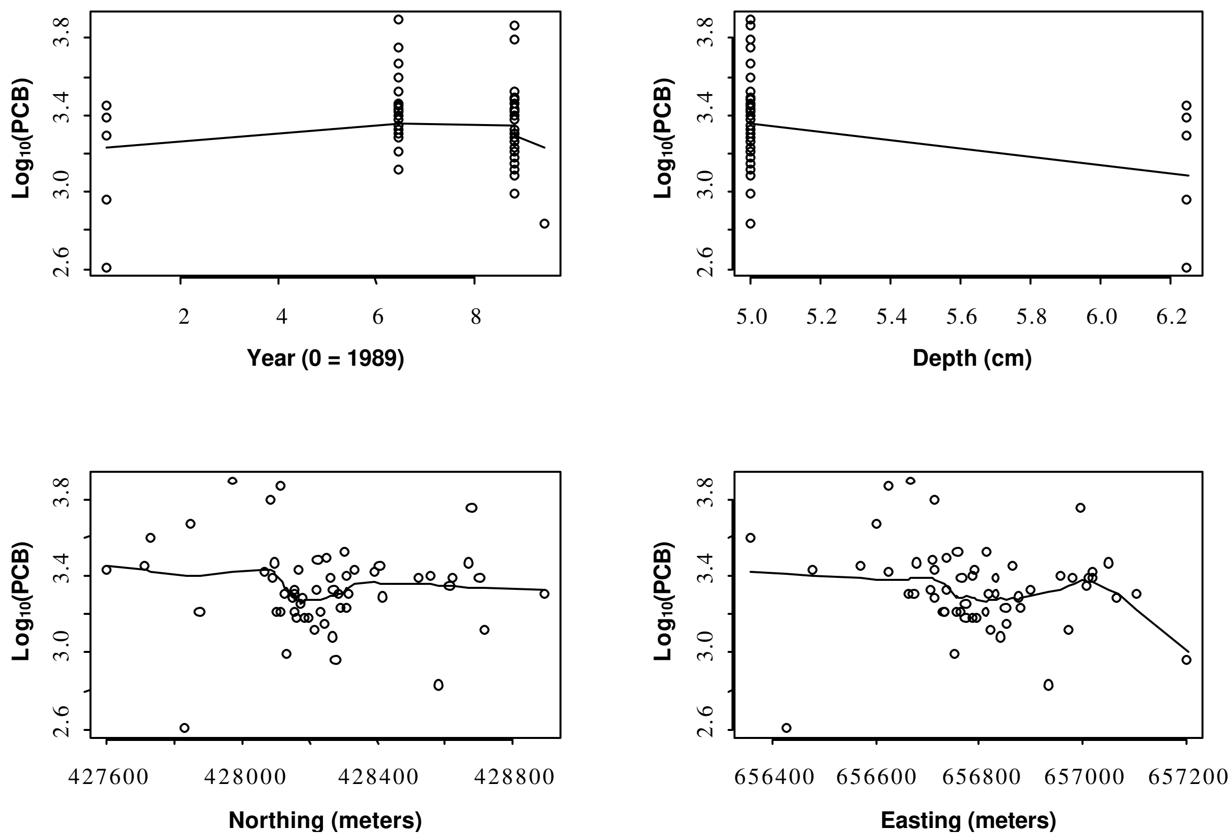


Figure 15 Log_{10} PCB Concentration versus Time, Depth, Northing and Easting for De Pere SMU Group 5067 (0 to 10 cm) Including Fitted Smoothed Line

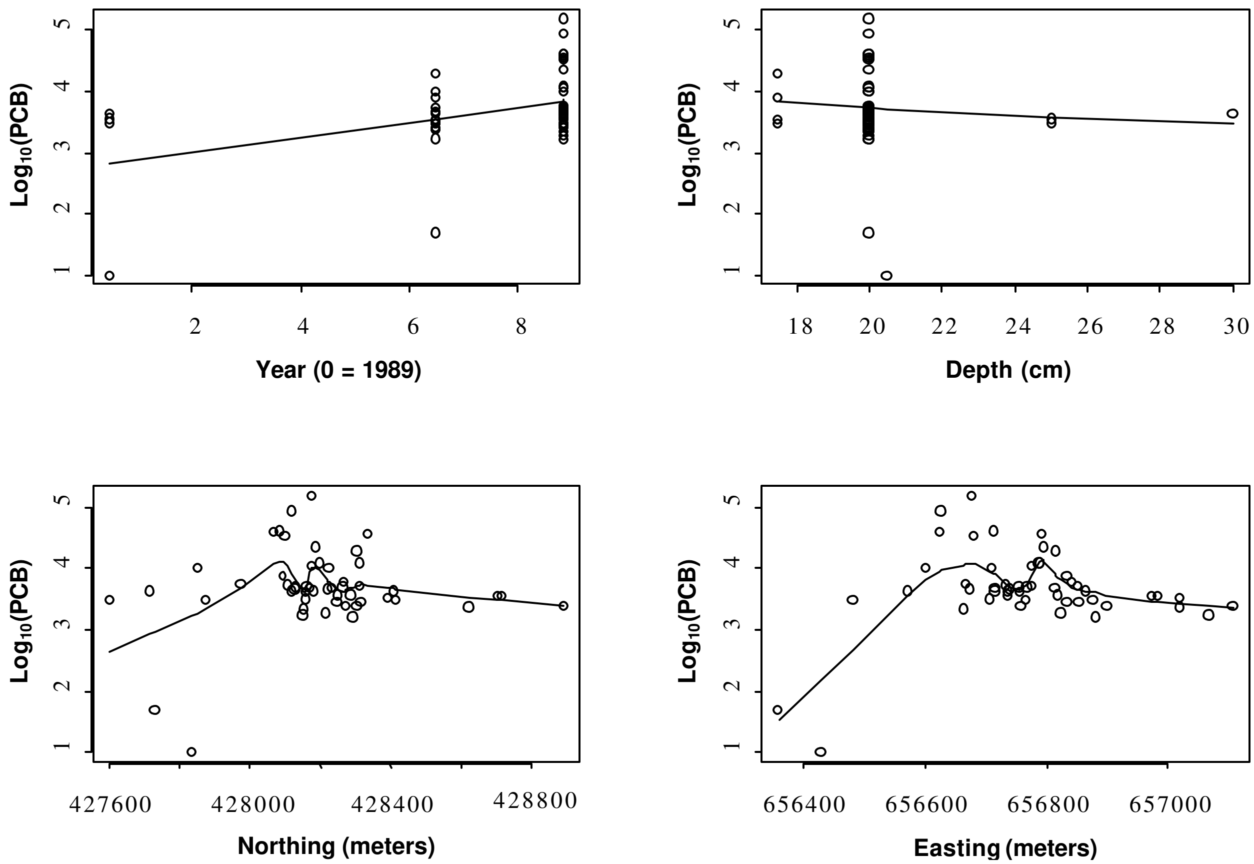


Figure 16 Log$_{10}$ PCB Concentration versus Time, Depth, Northing and Easting for De Pere SMU Group 5067 (10 to 30 cm) Including Fitted Smoothed Line

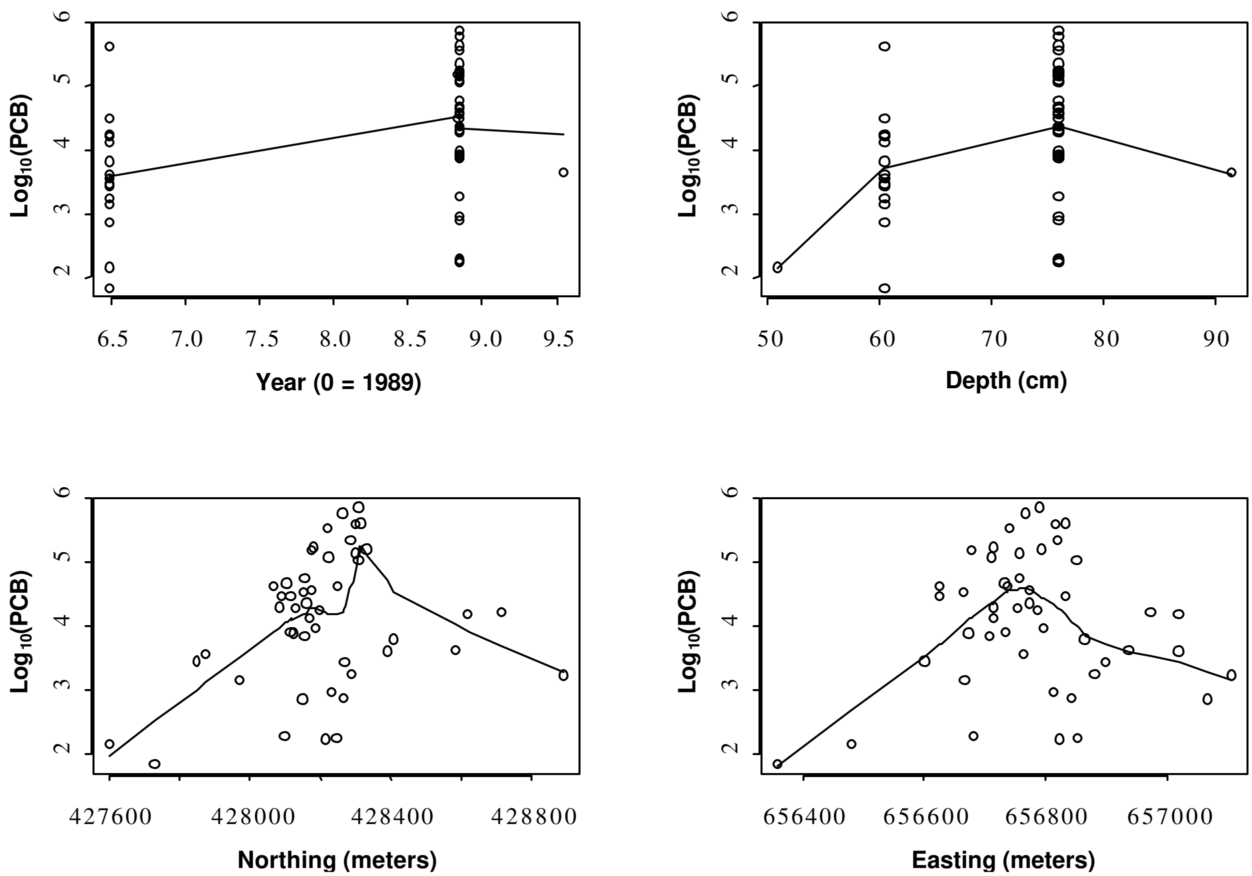


Figure 17 Log$_{10}$ PCB Concentration versus Time, Depth, Northing and Easting for De Pere SMU Group 5067 (50 to 100 cm) Including Fitted Smoothed Line

PCB concentration shows strong spatial variation, as shown on Figure 13 through Figure 17 and in the Appendix (i.e., space and PCBs are correlated). Controlling for spatial variation in the analysis allows for proper estimation of time trends in PCB concentrations. Similarly, the date and location of sampling may be correlated. These correlations can induce a spurious correlation between PCB concentration and time. This might happen, for example, if early samples were taken in the "hotter" location of a deposit (higher PCB concentrations) and later samples were drawn from a "cooler" location.

In order to determine the extent of the time-location correlation (which might create false time trends), we calculated the Pearson correlation coefficient between time and spatial variables. This correlation coefficient is +1.0 for perfect positive correlation, –1.0 for perfect negative correlation, and 0.0 (zero) if no correlation exists. We encountered a number of statistically significant correlations between the time that samples were drawn and either their depth within the stratum, their easting (centered) or easting-squared coordinates, or northing or northing-squared. Among the 46 combinations of deposit group and depth we analyzed, 22 had statistically significant correlation coefficients between time and depth, eight between time and easting or easting-squared, and nine between time and northing or northing-squared. Among all the correlations between time and spatial coordinates, one-quarter were of magnitude 0.3 or larger, and 10 percent of the correlations were of magnitude 0.5 or larger (corresponding to a moderate correlation or stronger), with a maximum observed correlation of 0.97. These numerous non-zero correlations between time and the spatial variables show the importance of controlling for spatial variables, lest spatial trends in the time of sampling combine with spatial trends in PCB concentrations to induce false time trends in PCB concentrations.

The values of $\log_{10}$ PCB also correlate with spatial coordinates. Again, among 46 analyzed combinations of deposit group and depth, six had statistically significant Pearson correlations between $\log_{10}$ PCB and depth within the stratum, 18 between $\log_{10}$ PCB and easting or easting-squared, and 10 between $\log_{10}$ PCB and northing or nothing-squared. The 75th and 90th percentile and maximum of all of the correlations of $\log_{10}$ PCB with spatial coordinates were of magnitude 0.3, 0.5 and 0.7, respectively. Peppered throughout these data are significant spatial trends either in time of sample acquisition or in PCB concentration. Thus, it behooves the analyst to include spatial variables in regression models for time trends of PCB concentrations in order to minimize the opportunity for a spatial trend in PCB concentration to masquerade as a time trend. (For purposes of exploring these correlations, concentrations below detection limits entered the analysis with the value of the detection limit. These limits and actual PCB concentrations were all log-transformed and used in the calculation of correlations.)

We also carried out an inspection of visual displays to detect glaring shifts over time in location of samples within a deposit group.

Figure 19 displays an example of these plots, showing northing and easting location of each sample, for each depth stratum, and for two time periods for Little Lake Butte des Morts Deposit Group AB. The key to interpretation of symbol size is included as Figure 18. Circles and squares indicate measured concentrations and concentrations below detection limits, respectively, and the size of the symbol indicates the magnitude of the PCB concentration. The upper row of the figure shows northing and easting location of each sample taken during 1989 through 1993 and the lower row corresponds to a later period, 1994 through 1999.

Working through the 0- to 10-cm plots (Figure 19, upper and lower left panels) as an example will help to clarify the role of space and its interaction with PCB concentrations and time. This is intended as a descriptive exploration. Note that in the 0- to 10-cm stratum, a larger fraction of early samples (upper panel, 1989–1993) occurs in the north of the deposit group than samples taken in the later period (lower panel, 1994–1999). Correlation coefficients can help to summarize such trends. The Pearson correlation coefficient ranges from $r = -1$ (perfect negative association) to $r = +1$ (perfect positive association). In a scatter plot, when $r = +1$, all points would fall on an upward sloping straight line. A correlation of $r = 0$ means no association between two variables. The correlation of the time of sampling and the northing coordinate is $r = -0.3$ ($p = 0.02$, statistically significant), indicating that sampling locations have a southward trend across the deposit over time. The correlation coefficient is negative because later ("larger") sampling times tend to occur with smaller northing coordinates. Smaller northing coordinates are farther south than larger ones. Also, earlier samples (upper plot) spread out more in the east and west directions than the samples from the later period (lower plot). The statistically significant correlation of –0.3 ($p = 0.03$) between time of sampling and the centered easting-squared term provides evidence for this. Over time, therefore, the sampling effort became more concentrated toward the south and west-center of this deposit group. This shift readily appears by comparing the upper and lower panels of Figure 19. In statistical parlance, time and spatial coordinates are confounded (and correlated). It is important to control for one when examining the role of the other.

We also found strong and highly significant spatial trends in $\log_{10}$ PCB concentrations. The correlation between $\log_{10}$ PCB concentration and easting is $r = -0.6$ ($p < 0.0001$). The negative correlation indicates that PCB concentration generally decreases from west to east. The correlation is $r = --0.5$ ($p < 0.0001$) for easting-squared, meaning that PCB concentrations decrease from the middle of the deposit to the east and west. The correlations of $r = -0.5$ ($p < 0.0001$) for northing, and $r = -0.6$ ($p < 0.0001$) for northing-squared, have similar interpretations to those just offered. The strong correlation of PCB concentration with linear and curvilinear (quadratic) spatial dimensions suggests a deposit group with a peak concentration near one edge of the area sampled. Concentrations taper off on all sides, but particularly to the east and north. In the upper plot for the 0- to 10-cm stratum (still Figure 19), the smaller circles toward the upper right corroborate this trend. Given that the PCB concentrations in the 0- to 10-cm stratum of Little Lake Butte des Morts Deposit Group AB have a distinct spatial structure, we have incorporated that structure in our model for a time trend in this deposit group. We also note that Figure 19 presents two time periods although time in the continuous form has been used in the analysis of time trends.

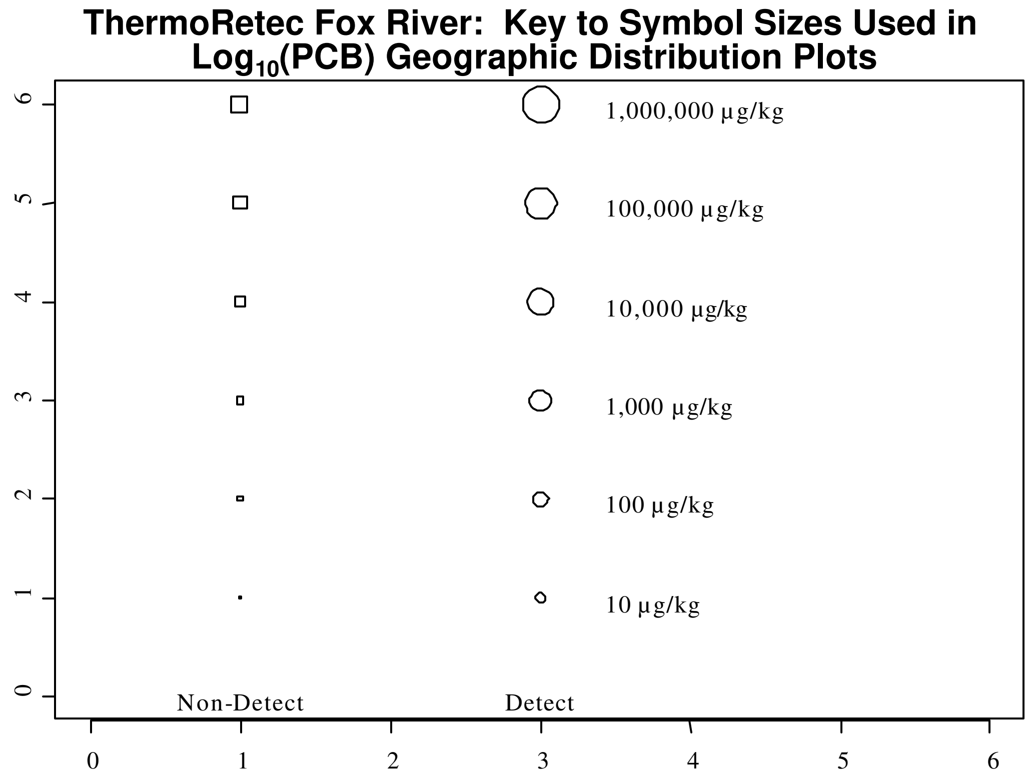


Figure 18 Northing/Easting Plot Key

Scale plot showing the size of circles (for samples with detected PCBs) and squares (for samples with PCBs below detection limit, the square conveys the level at which the PCBs would have been detected as reported by the various testing agencies) used to convey total PCB concentration in the northing/easting plots of sample locations.

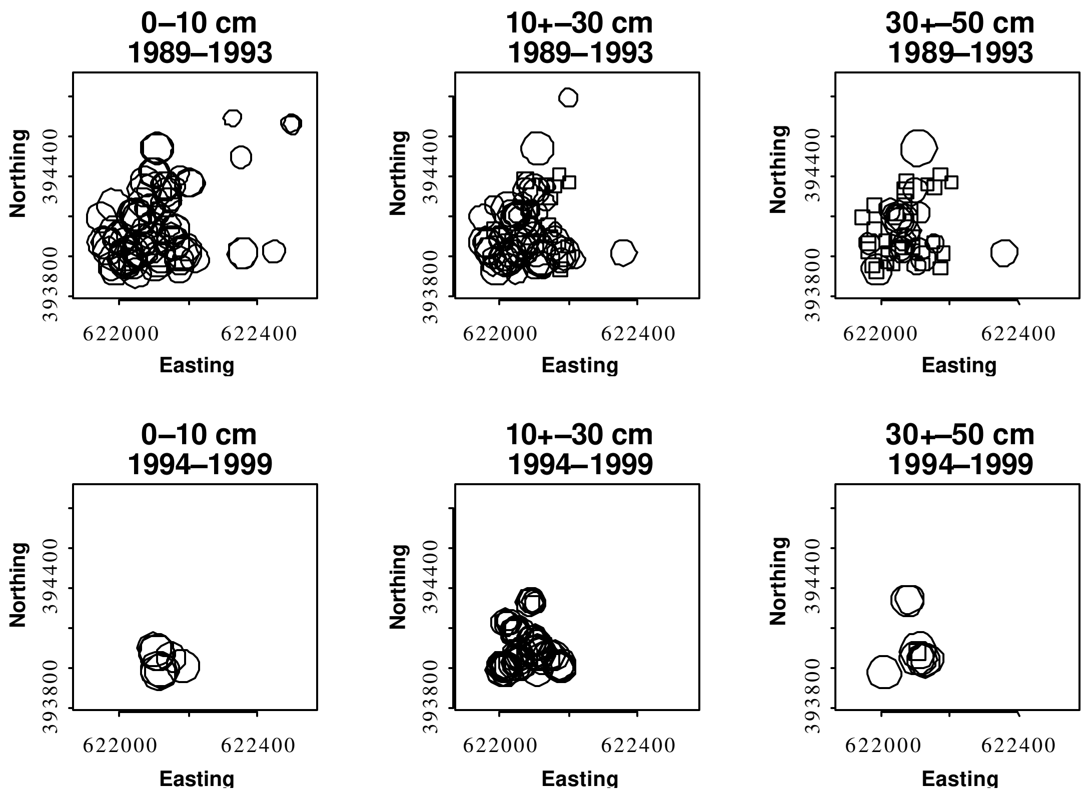


Figure 19 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Lake Butte des Morts Deposit Group AB

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

3 Methods for Fish Analysis

For the reasons discussed earlier ("Logarithmic Transformation," Section 2.1.3), we used the log of PCB concentration as the outcome variable in all the regression models fitted. There are good reasons for using the log transformation. Expressing rate of change as percent change per year has more meaning than absolute change in concentration, which can lead to absurd negative concentration predictions. An analysis on the $\log_{10}$ scale corresponds to modeling percent change. The data have an approximately normal distribution on the log scale, but a strongly skewed distribution on the original scale.

We included two potential confounding factors in all regression models for $\log_{10}$ PCB concentration versus time: percent lipid in the sample by weight and seasonality. As described below in the results section, both of these factors added significantly to prediction of PCB concentrations in most analyses. The following paragraphs describe how we incorporated these two factors into the models. We could not introduce any procedures to handle spatial dependence of fish data due to the lack of easting and northing coordinates for the fish samples in each reach. Not being able to model or investigate spatial dependence of fish samples does not imply the absence of such dependence. We simply have no means to study or address it. Because fish move more than sediments do, we expect that fish samples are closer to independent than sediment samples.

3.1 Lipid Normalization

Analyses of PCB concentration in fish often utilize "lipid normalization" in order to account for the relationship between PCB concentration and percent lipid in fish tissue. PCBs tend to concentrate in fat tissue so that, in general, fatter fish have higher concentrations of PCBs per total weight than leaner fish. The direct lipid normalization commonly used consists of dividing the PCB concentration by the percent lipid content (by weight) of the sample. This results in a variable showing PCB concentration per unit weight of lipid. We have chosen a somewhat different approach, similar to that of Larsson *et al.* (1993) and Herbert *et al.* (1995). We regard the lipid variable as an independent variable rather than a direct divisor of the PCB concentration. This approach allows the data itself to specify the relationship of PCBs to lipids. The model we use is:

Equation 3

$$\log(PCB) = b_0 + b_1 \log_{10}(lipid) + \ldots + e$$

where

- b_0 = the intercept term,
- b_1 = the regression coefficient on log of percent lipid,
- e = random error, and

additional variables such as time are included in the model as well (the time variable is considered below).

This model yields a predicted value for PCB concentration per unit tissue weight. Since the public consumes fish tissues (rather than just the lipid in the tissue), this offers a more useful prediction in many applications than the other normalization based on PCB per unit of lipid content.

An interesting fact should be noted about this model for PCB concentration (Equation 3). The model can be directly compared to the traditional "lipid normalization." Subtracting log(*lipid*) from both sides of Equation 3 gives the equivalent model:

Equation 4

$$\log_{10}\left(\frac{PCB}{lipid}\right) = b_0 + (b_1 - 1)\log_{10}(lipid) + \ldots + e$$

Comparing the two (Equation 3 and Equation 4), one clearly sees that as long as we treat log of percent lipid as a predictor, then it does not really matter whether we lipid-normalize the PCB concentration on the left-hand side of the equation or use PCB concentration without lipid normalization. Except for the coefficient for log of percent lipid differing by 1, all other coefficient and standard error estimates will remain unchanged. An analysis that has log of lipid-normalized PCB concentration on the left-hand side (such as in Equation 4), but does not include log of percent lipid on the right-hand side, amounts to forcing b_1 to be 1, so that $b_1 - 1$ will be zero. If direct lipid normalization represents the best model for the observed data, then we will estimate b_1 close to 1 in the regression approach. It is an advantage of the regression approach, model 3, that it will reduce to the direct lipid normalization if that is the correct model for the data considered in a given analysis. If PCB concentration and percent lipid do not have a directly proportional relationship, then we will estimate b_1 as something different than 1 (usually less than 1, as seen in the results below).

3.2 Seasonality

To account for the possibility that PCB concentration may vary by time of year, we incorporated into the model a sine curve as a function of the time of year.

Equation 5

$$\log_{10}(PCB) = b_0 + b_1 \log_{10}(lipid) + b_2 \sin(2\pi\, t^*) + b_3 \cos(2\pi\, t^*) + \ldots + e$$

where

t^* = time of year expressed as a fraction between 0 and 1.

Trigonometry shows that the weighted sum of the sine and cosine function in this equation gives a sine curve with a maximum at the time arctangent($-b_2/b_3$) and an amplitude equal to $(b_2^2 + b_3^2)^{0.5}$. We present these more meaningful quantities, time of maximum and amplitude, in our results tables rather than the more abstract b_1 and b_2. The time of maximum is coded to range from 1.0 (beginning of January) to 12.999... (end of December).

We note that the true seasonal cycle in PCB concentration may not be sinusoidal. Albeit likely, the presence of some average annual pattern of rise and fall of PCB concentration may not have the shape or smoothness of a sine curve. Nevertheless, the sine curve can serve as an approximation to seasonal variation. The statistical significance of the fitted sine curve (described later) strongly suggests that this simple function helps to capture and control seasonal variation in PCB concentration in fish.

Prior to model fitting, we centered the log of percent lipid variables. This step is analogous to the centering of northing and easting coordinates described earlier in the methodology section for sediment analysis. For each combination of reach, species, and sample type, we subtracted the mean $\log_{10}$ lipid percent within that reach/species/type from the $\log_{10}$ lipid value for each sample. Table 22 of the results displays these mean values. We also centered the sine and cosine terms by subtracting off the value of the sine and cosine variables at midyear (i.e., July 1). The advantage of the centering is that for forward projection we need only use the intercept and slope coefficient from the fitted models for PCB concentrations. Then, when using the intercept term and the coefficient on final slope to predict values of PCB at future time points, we are estimating the PCB concentration for a fish with average lipid content sampled on July 1. For numerical stability in estimating the slope coefficient for time, we centered time at the beginning of 1989 by subtracting January 1, 1989 from each sample date.

3.3 Time Trend Models

The simplest model for time trend in PCB concentration is a linear relationship between log of PCB concentration and time. A negative slope corresponds to an exponential decay in PCB concentration at a constant rate (for example, 5 percent per year). The first step in our analysis involved testing whether this simple model fit the data well, for each unique combination of reach, species and sample type (whole body, or fillet with skin). In statistical terms, this means testing the null hypothesis of a constant exponential rate of decay over all years versus the alternative of decay rate that is not constant over time. To perform such a hypothesis test, one must specify an alternative model, which we consider to be a competing model for the change in PCB concentration over time.

The simple linear model has the following equation:

Equation 6

$$\log_{10}(PCB) = b_0 + b_1 \log_{10}(lipid) + b_2 \sin(2\pi\, t^*) + b_3 \cos(2\pi\, t^*) + b_5\, time + e$$

We modeled the alternative nonlinear model as a two-slope model in the form of a linear spline, which appears as two straight lines joined at a kink, or breakpoint (Cressie, 1993). This is modeled in a linear regression equation as:

Equation 7

$$\log_{10}(PCB) = b_0 + b_1 \log_{10}(lipid) + b_2 \sin(2\pi\, t^*) + b_3 \cos(2\pi\, t^*) + b_4 early + b_5 time + e$$

The variable *early* equals (*time – breakpoint*) if time predates the breakpoint and 0 for time after the breakpoint. The coefficient of *time* (b_5) represents the slope of log PCB concentration versus time after the breakpoint, and the coefficient of *early* (b_4) measures how much the early slope differs from the late slope. That is, the early slope equals $b_4 + b_5$ and the late slope equals b_5.

This model offers simplicity and intuitive clarity: it means that PCBs were changing at two different constant rates of change—one before and one after the breakpoint. This model has been applied to PCB and DDT concentrations in fish in the Great Lakes (De Vault *et al.*, 1996). A visual inspection of scatter plots of log PCB versus time shows that, for many reach/species/type combinations, this model gives a good representation of the pattern apparent in the data. Since the model incorporates a constant rate of change after the breakpoint (coefficient b_5), it facilitates straightforward projections of concentrations into the future.

One could fit more complex models to the data. Given the fairly small number of distinct time points at which data were collected for each reach/species/type combination, however, one can not reliably fit models containing many parameters used to describe the time effect. The linear spline model, which includes a seasonal time effect, already uses five parameters explicitly modeling change with time: two seasonal terms (sine and cosine), early and late slope, and the location of the breakpoint.

3.4 Model Fitting and Hypothesis Testing

Fitting models and testing hypotheses involved several analyses. The first key steps were: 1) finding the best-fitting linear spline model, 2) determining if the spline model (Equation 7) offered a significant improvement over a simple linear model (Equation 6), and 3) choosing a spline or simple linear model accordingly.

If the breakpoint is specified, Equation 7 is a linear regression model that can be fitted using standard statistical software that accommodates concentrations below the detection limit. We used the S-PLUS procedure CensorReg for this analysis. As described earlier for sediment samples, CensorReg uses the maximum likelihood method to estimate parameters in the model while correctly accounting for the values below the detection limit. In order to find the optimal location of the breakpoint, we fit models using different possible breakpoint locations. To reduce the computation time required to a manageable level, we considered only one breakpoint per year, on January 1 for each year across the range of data. For all analyses, the 1-year span of uncertainty in the breakpoint is small compared to the total range of the observations over time. We considered only breakpoint locations that provided data extending at least 2 years on both sides of the breakpoint. This 2-year rule would provide at least a minimum of data needed to calculate slopes before and after the breakpoint. The best linear spline model, including the optimum breakpoint location was determined using the maximum likelihood method.

The best linear spline model (Equation 7) and the simple model (Equation 6) were compared and a choice between them was made, as follows:

In comparing the two models using the maximum likelihood method, a quantity called the "deviance" is calculated. The change in deviance relates to the change in probability (i.e., improvement in fit) when extra parameters are added to a model. For a given model, the deviance is $-2 * \log(L)$, where L is the likelihood of the model, given the data, as described in the sediment methods section.

The linear spline model (Equation 7) has two additional parameters compared to the simple linear model (Equation 6)—the location of the breakpoint and the early slope difference. Under the null hypothesis, the spline model would not be a true improvement over the simple linear model. The difference in deviance between the linear model and the best linear spline model should have a chi-square distribution with two degrees of freedom if the null hypothesis is true. If the chi-square test statistic is too large, we reject the null hypothesis and accept the spline model. The spline model, if selected, includes the parameter estimates in Equation 7 and their standard errors and *p*-values based on the likelihood method. A small chi-square value prompts selection of Equation 6.

If we know the true location of the breakpoint, the method behind the S-PLUS procedure CensorReg produces correct standard errors and *p*-values for slopes and other parameters in the spline model, which are reported in the tables. As the breakpoint is not known with absolute certainty, the data are used to estimate it. Thus, the reported standard errors and *p*-values for the intercept, time trend slopes, and other coefficients in a model based on Equation 7 do not account for the additional variance due to the estimated breakpoint location. Without compensating for the uncertainty in the breakpoint, the *p*-values and standard errors for other parameters are too small. Through bootstrapping, we could compute more accurate standard errors. We did not use the quite computer-intensive bootstrap given the resources available to the project. Instead, we used a more informal sensitivity analysis to determine the role of the breakpoint in slope estimates. This analysis tells us how sensitive the conclusions concerning time trend slopes are to shifts in the breakpoint.

As part of the breakpoint sensitivity analysis, we initially created a plausible range of breakpoints for those combinations of species, reach, and sample type where a spline model (Equation 7) fit significantly better than the simple linear model (Equation 6). We considered as plausible all breakpoints having a value of the likelihood that was close to the value of the likelihood at the best breakpoint, in that they fit the data almost as well as the best breakpoint. Formally, we settled on the plausible range of breakpoints as starting from the earliest and ending at the latest breakpoint year with a deviance within 3.84 of the best model. The value 3.84 corresponds to a *p*-value of 0.05 for a chi-square test with one degree of freedom and is analogous to testing whether the alternative breakpoint (and its associated early and late slopes and other parameters) fits the data significantly worse than the best breakpoint.

3.5 Testing for a Constant versus a Changing Final Slope

The fitted models assume that PCB decreases at a constant rate on the log scale (i.e., linear on the log scale) after the breakpoint, or for the entire range if there is no breakpoint. We tested the appropriateness of this assumption by fitting a model that includes a quadratic term in time for the interval after the breakpoint. This analysis simply adds a term to Equation 6 that is $b_6 \cdot (time^2)$ for time after breakpoint or $b_6 \cdot (0)$ for time before the breakpoint. This model allows for a curved rather than a linear relationship of log PCB concentration with time. A significant *p*-value for this quadratic term indicates that the curved model fits better than the model that assumes linearity after the breakpoint. Testing the quadratic model addresses the simple question: are the data consistent with a constant rate of change after the breakpoint (or entire range if there is no fitted breakpoint) or do the data imply a changing rate?

3.6 Meta Analyses—Combining Data on All Species Within a Reach

After completing all of the model fitting and hypothesis testing for each of the reach/species/type combinations, we performed analyses that combined results from all the species/type combinations within each reach. Three groups of hypothesis tests of interest emerged. The first group involved testing the null hypothesis that a simple linear model, without a breakpoint, for every species/type fits just as well as a spline model for all species/types within a reach. Formally, we accomplished this by summing up the chi-square statistics from the linear versus spline tests for each of the species/type combinations within the reach, and then comparing this sum to a chi-square distribution with degrees of freedom equal to twice the number of species/types combinations in the reach.

The second group of hypothesis tests is actually a single test. We tested the null hypothesis that the final slope is zero for all species/types in the reach versus the alternative that one or more species/types have a negative or positive slope. We accomplished this by first computing the directional or one-tailed *p*-value for each species/type. That is, *p* is close to 0 for large negative slopes and close to 1 for large positive slopes. Then, for each species/type within the reach we computed the statistic $X^2 = -2\log(p - value)$, where log is the natural log. Under the null hypothesis, X^2 has a chi-square distribution with two degrees of freedom.

Thus, summing up the X^2 values within a reach gives a quantity that should, under the null hypothesis that all final slopes are zero, have a chi-square distribution with degrees of freedom equal to twice the number of species/type combinations within the reach. We converted the statistic to a two-tailed p-value by counting either very large values or values very close to zero as rejecting the null hypothesis. These correspond to evidence for an overall negative or overall positive slope, respectively.

An average final slope estimate for the reach was defined as a weighted average of the final slope estimates for each species/type combination, where the weight was the inverse of the square of the standard error of the slope coefficient estimate. Thus, slope estimates with great precision (low standard error) have more weight than imprecise ones (high standard error). This weighting minimizes the variance of the resulting combined estimate and proves optimal if all of the true final slopes are in fact identical.

The third group of hypothesis tests examined the null hypothesis that the final slope is constant over time versus the curved alternative that the slope changes over time. We followed a similar procedure to that just described for testing for a zero final slope, since the null hypothesis corresponds to the coefficient on the quadratic term being zero. A positive coefficient on the quadratic term means the slope either curves upward or plateaus over time (on the log scale), while a negative coefficient means the slope curves downward or steepens over time.

3.7 Projecting into the Future

Predictions of concentration of PCBs in future years assumed that PCB concentration continues to decrease (or increase) at a constant rate, which is the final slope or the slope after the breakpoint. Based on this assumption, we can compute the estimate of the mean of log (PCB concentration) from the coefficients in Equation 6 or Equation 7as:

Equation 8

$$E\,[\log\ (PCB\ at\ time)] = b_0 + b_5\ time$$

where E indicates the expected value and time is years since 1989, the year at which time was centered prior to fitting the model. The formula predicts the mean of log (*PCB*) for a fish with average percent lipid content sampled on July 1 of the year, as long as the year follows the breakpoint. We obtain this formula from Equation 6 or Equation 7 by setting all other covariates in the model equal to zero. Since we centered log (*lipid*) at its mean, a zero value for the centered lipid variable is the same as setting log (*lipid*) equal to its mean. The seasonal variables and sine and cosine of time were centered at zero on July 1. The variable *early* in Equation 7 equals zero for all times after the breakpoint.

One computes the confidence interval for this predicted mean by first calculating the standard error:

Equation 9

$$SE\,(predicted\ \ mean\ at\ \ year\ t) = \sqrt{[SE\,(b_0)]^2 + t^2\,[SE(b_5)]^2 + 2t\,\mathrm{cov}(b_0, b_5)}$$

where cov(b_0, b_5) denotes the covariance between these two parameter estimates, b_0 and b_5 from Equation 6 or Equation 7. The predicted mean plus or minus twice the standard error gives the 95 percent confidence interval on the log scale.

One can convert the predicted mean on the log scale to an estimate of the mean on the original scale (i.e., ppb) by the formula:

Equation 10

$$E\,(PCB\ at\ time) = 10^{(E\,(\log(PCB\ at\ time)) + (MSE \div 2))}$$

where *MSE* is the mean squared error from the regression model on the natural log scale and is an estimate of the residual variance around the fitted regression model. This is just the formula for the mean of a lognormal distribution, based on the mean and variance on the log scale. We applied this formula to the predicted mean on the log scale and the lower and upper bounds of the confidence interval on the log scale in order to get the mean and confidence interval on the original (ppb) scale. This confidence interval does not consider the variance due to estimating the location of the breakpoint. A confidence interval that corrects for breakpoint estimation could be wider.

We also computed predicted time until mean PCB concentration reaches a specified concentration, *G*. The formula is:

Equation 11

$$time\ to\ specified\ \ concentration\,(G) = \frac{(\log_e(G) - b_0 - (MSE \div 2))}{b_5}$$

where

G	=	the specified level of PCB concentration in ppb,
time	=	time until that level is reached, in years since 1989,
MSE	=	mean squared error from a regression model fit to $\log_e$ of PCB concentration,
b_0	=	intercept from Equation 6 or Equation 7, and
b_5	=	coefficient of *time* from Equation 6 or Equation 7.

Computing confidence intervals for the predicted time to reach a specified level would seriously complicate our analysis, so we did not attempt to do so. A confidence interval based on the estimated standard errors would be wide and one that correctly accounted for the uncertainty due to estimating the breakpoint would be exceptionally wide. Therefore, we regard these “time to specified level” estimates as very uncertain.

In addition to the need to account for variance due to estimating the location of the breakpoint, the predictions are uncertain for yet another reason. Predictions of concentration of PCBs in future years assume that PCB concentration continues to decrease (or increase) at a constant rate. One cannot test this assumption except to continue collecting data in future years. Moreover, the assumption of a constant rate of change may not be very reasonable. A positive final slope, for example, implies that the PCB concentration continues to increase “forever” to higher and higher levels, an absurd conclusion. A negative final slope means that PCB concentration continues to decline to values near zero. But a scouring event that uncovered buried sediment more contaminated than surface sediment would likely lead to an increase in PCB concentration at the surface. Also, even a decreasing rate may level off well above a PCB concentration of zero. These future projections depend for their validity on an unverifiable future steady state.

4 Sediment Results

4.1 Number of Observations

A total of 1,980 observations (core-averaged) were initially available for analysis. Table 6 shows the distribution of these observations by our deposit group designation and depth. Due to the requirement of a sufficient number of observations and a sufficient time spread for an appropriate time trend analysis, only 1,618 samples qualified for the time trend analysis (Table 7). The reasons for dropping particular depth strata in specific deposit groups are explained in Table 8. Over one-third of the 1,618 usable observations occurred in the upper 10 cm of sediment, approximately one-third in the 10- to 30-cm stratum, about one-eighth in the 30- to 50-cm stratum, and the balance at greater depths. The greatest fraction of unusable data (due to lack of sufficient number of observations or lack of sufficient time spread) occurred at depths of 30 cm or lower, where approximately one-third of the core-averaged observations were unusable.

The fraction of observations below detection limit (BDL) varied widely by reach, deposit group, and depth, from a minimum of 0 percent (no BDL observations) to a maximum of 82 percent BDL observations. A majority of analyses included 20 percent or fewer BDL observations. The fraction of BDL observations, however, sufficiently requires the use of the maximum likelihood (ML) methods noted earlier. The number and percent of BDL observations by deposit group and depth is included in an appendix table. As noted in Section 2, all observations available for a given deposit group and depth stratum were included in the calculation of time trends. Due to the use of ML methods, BDL observations were neither modified nor excluded.

Table 6 Sample Size by Deposit Group and Depth after Core Averaging

TMWL Deposit Group	Sample Average Depth (cm)					Total
	0–10	10+–30	30+–50	50+–100	100+	
Little Lake Butte des Morts						
Deposit Group AB	67	105	54	12	2	240
Deposit Group C	13	15	8	2	0	38
Deposit Group POG	13	10	4	3	2	32
Deposit Group D	18	15	9	6	0	48
Deposit Group E	6	7	21	14	2	50
Deposit Group F	29	28	10	2	2	71
Deposit Group GH	15	12	3	0	0	30
Appleton						
Deposit Group IMOR	18	15	9	3	1	46
Deposit Group N Pre-dredge	51	40	18	4	0	113
Deposit Group VCC	41	34	17	9	3	104
Little Rapids						
Deposit Group Upper EE	31	25	13	3	1	73
Deposit Group Lower EE	30	33	13	5	3	84
Deposit Group FF	32	31	8	0	0	71
Deposit Group GGHH	49	45	75	54	36	259
De Pere						
SMU Group 2025	43	31	13	30	25	142
SMU Group 2649	66	48	10	46	45	215
SMU Group 5067	57*	51	34	48	50	240
SMU Group 6891	20	18	2	16	15	71
SMU Group 92115	27	15	3	7	1	53
Total:	**626**	**578**	**324**	**264**	**188**	**1,980**

Note:

* One additional sample, A3_0-4, not included in these sample sizes, had an exceptionally large PCB concentration and was considered separately.

Table 7 Sample Size by Deposit Group and Depth Included in Time Trends Analysis, after Core Averaging

TMWL Deposit Group	Sample Average Depth (cm)					Total
	0–10	10+–30	30+–50	50+–100	100+	
Little Lake Butte des Morts						
Deposit Group AB	67	105	54	—	—	226
Deposit Group C	13	15	—	—	—	28
Deposit Group POG	13	—	—	—	—	13
Deposit Group D	18	15	—	—	—	33
Deposit Group F	29	28	—	—	—	57
Deposit Group GH	15	—	—	—	—	15
Appleton						
Deposit Group IMOR	18	—	—	—	—	18
Deposit Group N Pre-dredge	32	27	17	—	—	76
Deposit Group VCC	41	34	17	—	—	92
Little Rapids						
Deposit Group Upper EE	31	25	13	—	—	69
Deposit Group Lower EE	30	33	13	—	—	76
Deposit Group FF	32	31	—	—	—	63
Deposit Group GGHH	49	45	75	54	36	259
De Pere						
SMU Group 2025	43	31	13	30	—	117
SMU Group 2649	66	48	—	46	45	205
SMU Group 5067	57*	51	—	48	50	206
SMU Group 6891	20	18	—	—	—	38
SMU Group 92115	27	—	—	—	—	27
Total:	**601**	**506**	**202**	**178**	**131**	**1,618**

Note:

* One additional sample, A3_0-4, not included in these sample sizes, had an exceptionally large PCB concentration and was considered separately.

A dash, "—," indicates that he particular cell could not be analyzed for time trends. An explanation is provided in Table 8.

Table 8 Deposit Groups Analyzed, Or Reasons for No Analysis

TMWL Deposit Group	Sample Average Depth (cm)					Total Yes
	0–10	10+–30	30+–50	50+–100	100+	
Little Lake Butte des Morts						
Deposit Group AB	Yes	Yes	Yes	I, T	I, T	3
Deposit Group C	Yes	Yes	I	I, T	N	2
Deposit Group POG	Yes	I, T	I, T	I, T	I, T	1
Deposit Group D	Yes	Yes	I, T	I, T	N	2
Deposit Group E	I, T	I	T	I, T	I, T	0
Deposit Group F	Yes	Yes	I, T	I, T	I, T	2
Deposit Group GH	Yes	I, T	I, T	N	N	1
Appleton						
Deposit Group IMOR	Yes	T	I, T	I, T	I, T	1
Deposit Group N Pre-dredge	Yes	Yes	Yes	I, T	N	3
Deposit Group SU	T	I, T	I, T	N	N	0
Deposit Group VCC	Yes	Yes	Yes	I, T	I, T	3
Deposit Sample POG	I, T	I, T	I, T	I, T	I, T	0
Deposit Group DD	I, T	I, T	I, T	N	N	0
Little Rapids						
Deposit Group Upper EE	Yes	Yes	Yes	I, T	I, T	3
Deposit Group Lower EE	Yes	Yes	Yes	I, T	I, T	3
Deposit Group FF	Yes	Yes	I	N	N	2
Deposit Group GGHH	Yes	Yes	Yes	Yes	Yes	5
De Pere						
SMU Group 2025	Yes	Yes	Yes	Yes	T	4
SMU Group 2649	Yes	Yes	T	Yes	Yes	4
SMU Group 5067	Yes	Yes	T	Yes	Yes	4
SMU Group 6891	Yes	Yes	I, T	I, T	I, T	2
SMU Group 92115	Yes	T	I, T	I, T	I, T	1
Total Yes:	**18**	**14**	**7**	**4**	**3**	**46**

Notes:

Yes - Deposit groups and depths with sufficient data to perform a time trend analysis.
I - Insufficient data (fewer than 10 observations).
N - No observations.
T - No time variation. Need at least two measured PCB concentrations (not below detection limits) at each of two distinct times.

4.2 Geographic Groups for Time Trend Analysis

As noted earlier, we regrouped the data into more compact geographic deposits (deposit groups, noted in Table 1 through Table 4). The majority of the original deposit designations transferred primarily, but not always wholly, into one of our time trend deposit groups. The exceptions, where a geographically extensive original deposit was broken into a number of separate groups for analysis, included Little Lake Butte des Morts Deposit E (which became our Little Lake Butte des Morts deposit groups E, F, and GH) and Little Rapids Deposit EE (which became our Little Rapids deposit groups Upper EE, Lower EE, FF and

GGHH). In addition, a number of observations in the database supplied to us had no deposit designation in the database supplied to us (e.g., noted as "No Designation," Table 1 through Table 4), and were allocated to one of our deposit groups based on location. As noted in Table 1 through Table 4, we were able to include a substantial number of observations in the time trends analysis by forming new deposit groups. For example, in the De Pere Reach, we analyzed 731 observations (Table 4) that had no deposit designation in the FRDB. The result of our grouping for time trend analysis is captured by Figure 5 through Figure 12. As can be seen from the plot, the deposit groups are fairly compact.

The data analyzed included diverse spatial configurations. An illustration of the variety of geographic configurations can be found on Figures A-1 through A-43 (see Appendix), an example of which can be found on Figure 19. The description and interpretation of the plot were presented earlier. The plot demonstrates how the geographic configuration is not necessarily the same for the two time periods, illustrating the importance of controlling for geography in analyzing time trends. By failing to control for sample geography, an apparent time trend could simply be due to sampling from, for example, a high concentration area in an earlier period and a lower concentration area in a later period without any real shift in concentration in either area over time. The figures show measured concentrations and concentrations below detection limits as circles and squares, respectively, with the magnitude of the PCB concentration indicated by the size of the square or circle.

4.3 Time Trends in Sediment Concentrations

Time trends in PCB concentrations differ both by depth and by deposit group. Appendix Table A-1 presents detailed numerical results, sections of which are reproduced here in Table 9 for 46 different analyses, representing different deposit groups and depths. The key results from the table are:

- Coefficient of the time term (this parameter represents the slope estimate on a $\log_{10}$ scale as rate of change in $\log_{10}$ PCB concentration per year),

- Standard error of the time coefficient based on the window subsampling empirical variance (WSEV) method,

- The annual percentage rate of change (compounded), and

- The *p*-value for the null hypothesis that the true slope is zero ($b_t = 0$ in Equation 2, Section 2.6). The "statistically significant" slopes are also designated by asterisk(s) in the table. The deposit group and depth combinations that are "statistically significant" will very likely have true non-zero rates of change over time.

Statistical significance plays an important role in interpreting Table 9 and other tables presenting rates of change. The *p*-value column in this and other tables shows the degree of statistical significance of the calculated rate of change of log PCB concentration versus time. The *p*-value, which constitutes the numeric statement of statistical significance, quantifies the strength of the evidence against the null hypothesis that the true rate of change is zero. The closer the *p*-value is to zero, the more confidence we have that the true rate of change is not zero. Formally, the *p*-value is defined of as the probability of observing a result as or more extreme than that actually observed if the null were, in fact, true. More explicitly, the *p*-value can be interpreted as the outcome of the following hypothetical experiment. We can imagine taking samples from a deposit group whose **true** rate of change is zero and repeating this operation many times. For example, Little Lake Butte des Morts Deposit Group AB has $n = 67$ samples at 0 to 10 cm depth. We would take many samples of size $n = 67$ from the deposit group and analyze them as we have here, yielding one slope for each set of 67 samples. Due to random variation in sampling, each calculated slope would differ to a greater or lesser extent from the true slope. If the true slope were really zero, then these random slopes would have some distribution around zero. For any slope value that we choose or observe, we can look at the distribution and determine what fraction of our random slopes are as large or larger than a given slope. Usually, we take the fraction of slopes that are larger in either the positive or negative direction from the value. For example, for the slope of –0.097, we would look at the fraction of random slopes smaller than –0.097 and larger than +0.097, because random variation can take us either in a positive or negative direction away from zero. The key concept is that if the true slope is really zero, the observed slope should not stray too far from zero. Traditionally (but with no other basis than that), $p < 0.05$ has been used to designate statistical significance. This *p*-value means that there are fewer than 5 chances in 100 that a slope as large or larger than that observed could have been generated by chance, if the **true** slope is zero. We adopt this definition and also designate $p < 0.05$ as "statistically significant." In the tables, we note this with one asterisk and also use the following conventions: ** $p < 0.01$, *** $p < 0.001$.

In reality, one need not compute the hypothetical experiment to get the *p*-value. In fact, the *p*-values computed in Table 9 use the very standard *t*-test. As a conservative measure, we have chosen the degrees of freedom for the *t*-test as the number of grid cells with at least one sample, determined in the WSEV method described earlier. The number of non-empty grid cells is included in an appendix table.

We have also included in Table 9 a 95 percent confidence interval for the percent rate of change of the PCB concentration over time (derived from the slope and its standard error using the *t*-distribution with the same degrees of freedom as in the calculation of the *p*-value). We can state with 95 percent confidence that the true rate of change lies in this interval. If this interval is especially narrow, we have a very precise idea of the true rate of change. A particularly wide interval casts much doubt on the true rate of change.

Appendix Table A-1 presents the form of the linear regression model—either linear or quadratic, fitted to the data. "Linear" indicates that depth, easting, and northing are used as linear terms in the regression model. "Quadratic" indicates that these terms plus squared terms for easting and northing are also used. Time is always introduced as a linear term, in years, and all models include an intercept.

Table 9 Sediment Time Trend Parameters by Depth and Deposit Group

Deposit Group	Depth Range (cm)	Log_{10}(PCB) Time Trend Slope Estimate	WSEV Standard Error	WSEV *p*-value	Statistically Significant Slopes	Est. Annual Compound Percent Increase in PCB Level	Estimated Annual Compound Percent Increase in PCB Level	
							95% Conf. Int. Lower-bound	95% Conf. Int. Upper-bound
Little Lake Butte des Morts								
AB	0–10	−0.0970	0.0348	0.0131	*	−20.0	−32.5	−5.2
	10–30	−0.0213	0.0647	0.7535		−4.8	−33.9	37.1
	30–50	−0.0144	0.1113	0.8995		−3.3	−45.0	70.0
C	0–10	−0.0612	0.0342	0.1481		−13.2	−30.2	8.1
	10–30	0.0317	0.0770	0.7018		7.6	−34.2	76.0
POG	0–10	−0.0893	0.0567	0.1900		−18.6	−43.3	16.9
D	0–10	−0.0755	0.0317	0.0307	*	−16.0	−28.1	−1.8
	10–30	0.3168	0.0454	0.0009	***	107.4	58.5	171.3
F	0–10	−0.0373	0.0136	0.0252	*	−8.2	−14.6	−1.4
	10–30	−0.0760	0.0749	0.3246		−16.1	−41.7	20.8
GH	0–10	−0.1244	0.0541	0.0443	*	−24.9	−43.1	−0.9
Appleton								
IMOR	0–10	0.0412	0.0255	0.1810		9.9	−6.6	29.4
N Pre-dredge	0–10	−0.0281	0.0065	0.0233	*	−6.3	−10.6	−1.7
	10–30	0.0572	0.0440	0.2061		14.1	−7.5	40.7
	30–50	0.0846	0.0932	0.3877		21.5	−25.2	97.4
VCC	0–10	−0.0582	0.0275	0.0878		−12.5	−25.7	2.9
	10–30	−0.1537	0.0164	0.0000	***	−29.8	−35.4	−23.7
	30–50	−0.0060	0.0151	0.6984		−1.4	−8.7	6.6
Little Rapids								
Upper EE	0–10	−0.0447	0.0435	0.3618		−9.8	−31.7	19.1
	10–30	−0.0944	0.0429	0.0554		−19.5	−35.6	0.6
	30–50	−0.0712	0.0536	0.2173		−15.1	−35.8	12.2
Lower EE	0–10	−0.0682	0.0193	0.0387	*	−14.5	−25.8	−1.5
	10–30	−0.0759	0.0390	0.0695		−16.0	−30.6	1.6
	30–50	0.0900	0.0330	0.0213	*	23.0	3.9	45.7
FF	0–10	−0.0549	0.0557	0.3400		−11.9	−32.9	15.8
	10–30	−0.0962	0.0390	0.0389	*	−19.9	−34.9	−1.4
GGHH	0–10	−0.0394	0.0231	0.1643		−8.7	−21.2	5.9
	10–30	−0.0182	0.0596	0.7631		−4.1	−27.7	27.3
	30–50	0.1762	0.1008	0.1188		50.0	−12.5	156.3
	50–100	0.1012	0.0700	0.1586		26.2	−9.2	75.4
	100+	0.0365	0.0249	0.1587		8.8	−3.5	22.6

Table 9 Sediment Time Trend Parameters by Depth and Deposit Group

Deposit Group	Depth Range (cm)	Log_{10}(PCB) Time Trend Slope Estimate	WSEV Standard Error	WSEV *p*-value	Statistically Significant Slopes	Est. Annual Compound Percent Increase in PCB Level	Estimated Annual Compound Percent Increase in PCB Level	
							95% Conf. Int. Lower-bound	95% Conf. Int. Upper-bound
De Pere								
SMU Group 2025	0–10	–0.0528	0.0231	0.0838		–11.4	–23.6	2.6
	10–30	–0.0556	0.0750	0.4796		–12.0	–40.9	31.0
	30–50	–0.0580	0.0322	0.1016		–12.5	–25.8	3.2
	50–100	–0.0847	0.1058	0.4306		–17.7	–50.2	35.9
2649	0–10	–0.0608	0.0109	<0.0001	***	–13.1	–17.4	–8.5
	10–30	–0.2882	0.1440	0.0764		–48.5	–75.7	9.0
	50–100	0.1957	0.1419	0.2399		56.9	–36.6	288.7
	100+	0.0177	0.1548	0.9146		4.2	–61.3	180.3
5067	0–10	–0.0998	0.0345	0.0136	*	–20.5	–33.2	–5.5
	10–30	0.0912	0.0649	0.1800		23.4	–10.3	69.6
	50–100	0.3677	0.0684	0.0030	**	133.2	55.5	249.5
	100+	–0.1963	0.2223	0.4112		–36.4	–81.8	122.6
6891	0–10	–0.2208	0.0944	0.1013		–39.9	–69.9	20.1
	10–30	–0.1685	0.0765	0.0550		–32.2	–54.4	1.0
92115	0–10	0.0413	0.0426	0.3493		10.0	–10.9	35.8

Notes:

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

The annual percentage rate of change corresponding to a given slope, b_t, is calculated as

Equation 12

$$Percentage = 100\% * (10^{b_t} - 1).$$

The halving time is $\frac{\log_{10}(0.5)}{b_t}$ if b_t is negative (decrease over time). If b_t is positive, the doubling time is $\frac{-\log_{10}(0.5)}{b_t}$. The 95 percent confidence interval for the slope, b_t, is given by:

Equation 13

$$[b_t - t_{0.025,df} * SE(b_t), b_t + t_{0.025,df} * SE(b_t)]$$

where

$SE(b_t)$ = the WSEV standard error of b_t, and

$t_{0.025,df}$ = from the t-distribution, 0.025 tail area, with degrees of freedom = df = number of non-empty grid cells, noted in Table A-1.

The 95 percent confidence interval for the percent rate of change is calculated by first deriving the confidence interval for the slope and then using Equation 12 to convert the upper and lower bounds for the slope to upper and lower bounds for the percentage.

The percent increase and the 95 percent confidence interval for the percent increase/decrease (along with the scale for the doubling time or halving time) are presented on Figure 20 through Figure 28. The figures show a number of statistically significant trends. Apparent from Table 9 and the figures is a tendency for more negative slopes to occur at shallower depths and more positive slopes to occur at greater depths. For example, in our Little Lake Butte des Morts Deposit Group D, the slope in the upper 10 cm of sediment is –0.0755 per year, implying a rate of decrease of 16 percent compounded per year; and in the 10- to 30-cm stratum, the slope is 0.317 per year, indicating a rate of increase of 107 percent, compounded annually with trends in both depths being statistically significant (p = 0.03 for 0 to 10 cm, p = 0.0009 for 10 to 30 cm).

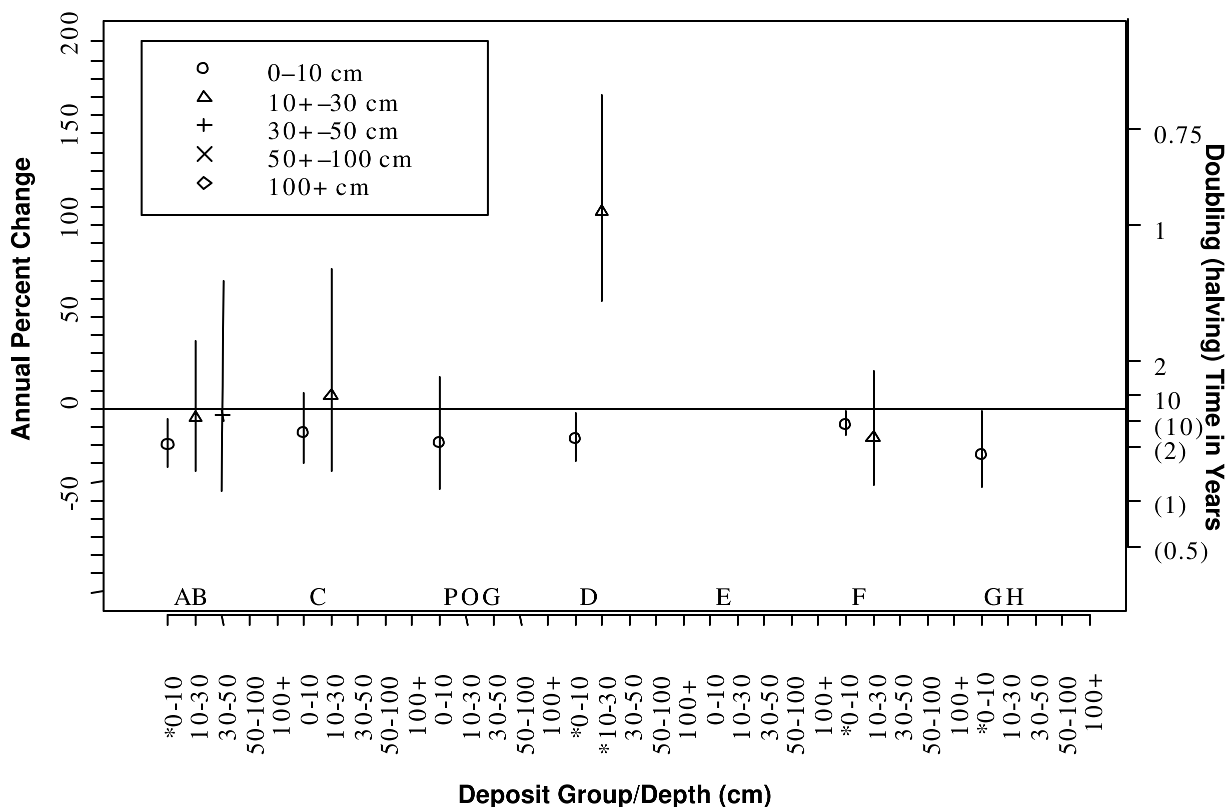


Figure 20 95 Percent Confidence Intervals Showing Annual Percent Rate of Change (Left Vertical Axis) in PCB Concentration

for Little Lake Butte des Morts Deposit Group and Depth Strata

An asterisk (*) below the depth label indicates that a rate of change differs significantly from zero. Right vertical axis expresses time trend change in terms of doubling and halving times. Confidence intervals are shown for all deposit groups and depths with sufficient data to perform an analysis of time trend.

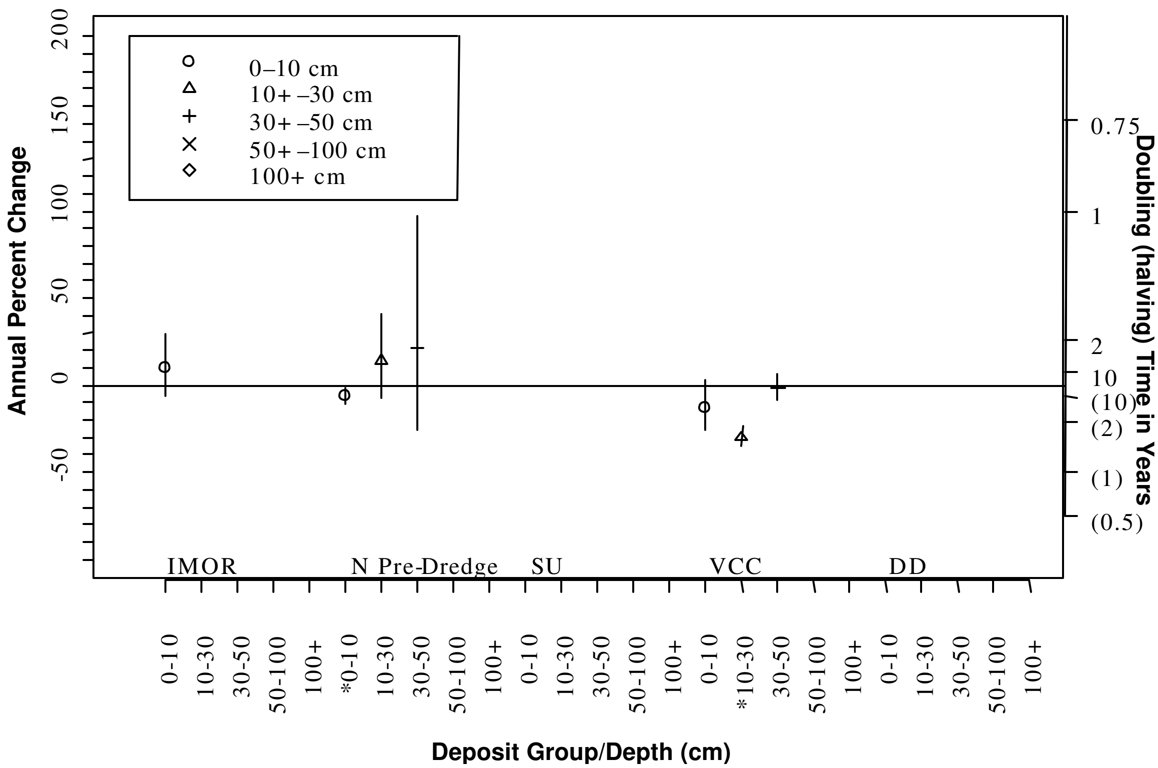


Figure 21 95 Percent Confidence Intervals Showing Annual Percent Rate of Change (Left Vertical Axis) in PCB Concentration for Appleton Deposit Group and Depth Strata

An asterisk (*) below the depth label indicates that a rate of change differs significantly from zero. Right vertical axis expresses time trend change in terms of doubling and halving times.

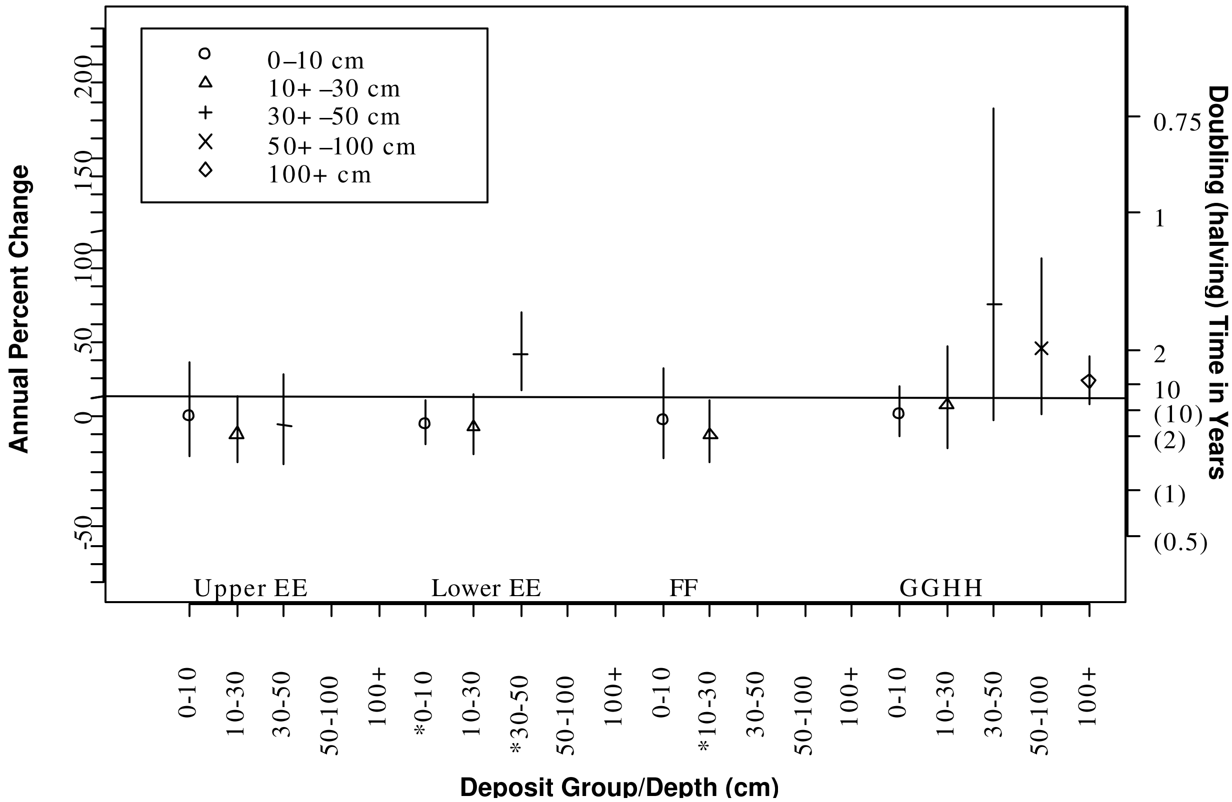


Figure 22 95 Percent Confidence Intervals Showing Annual Percent Rate of Change (Left Vertical Axis) in PCB Concentration for Little Rapids Deposit Groups and Depth Strata

An asterisk (*) below the depth label indicates that a rate of change differs significantly from zero. Right vertical axis expresses time trend change in terms of doubling and halving times.

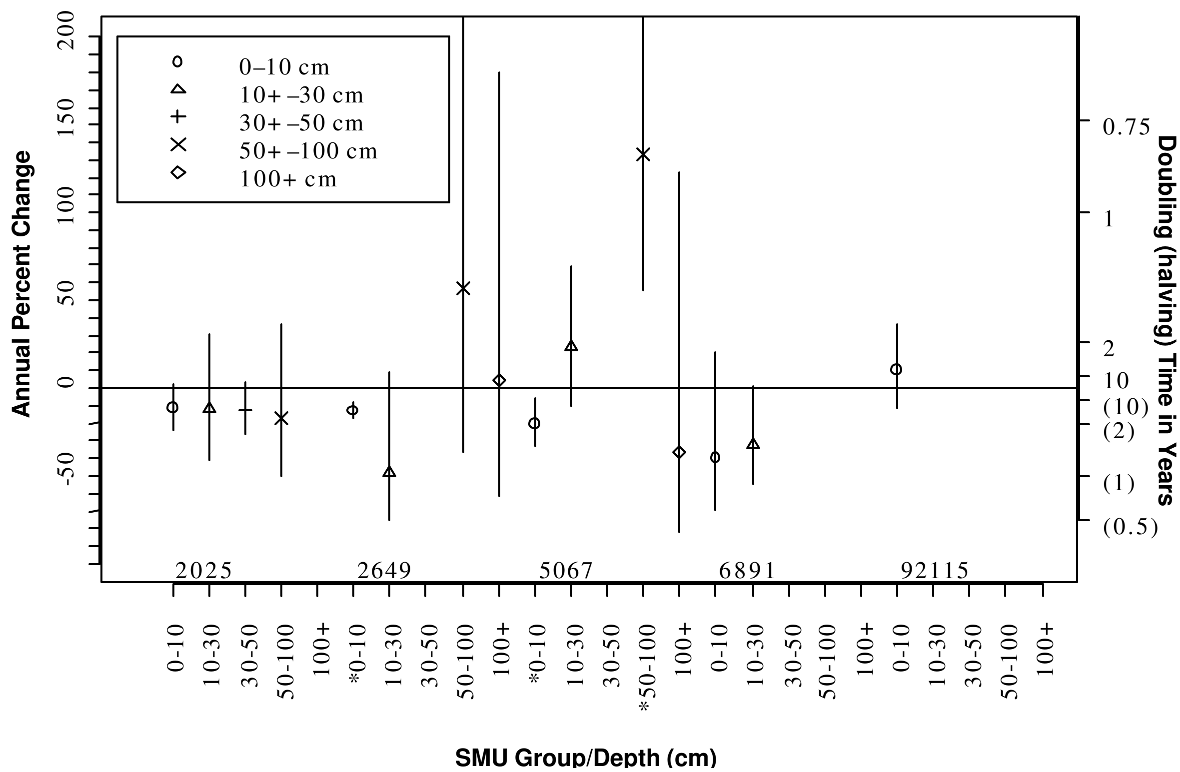


Figure 23 95 Percent Confidence Intervals Showing Annual Percent Rate of Change (Left Vertical Axis) in PCB Concentration for De Pere SMU Groups and Depth Strata

An asterisk (*) below the depth label indicates that a rate of change differs significantly from zero. Right vertical axis expresses time trend change in terms of doubling and halving times.

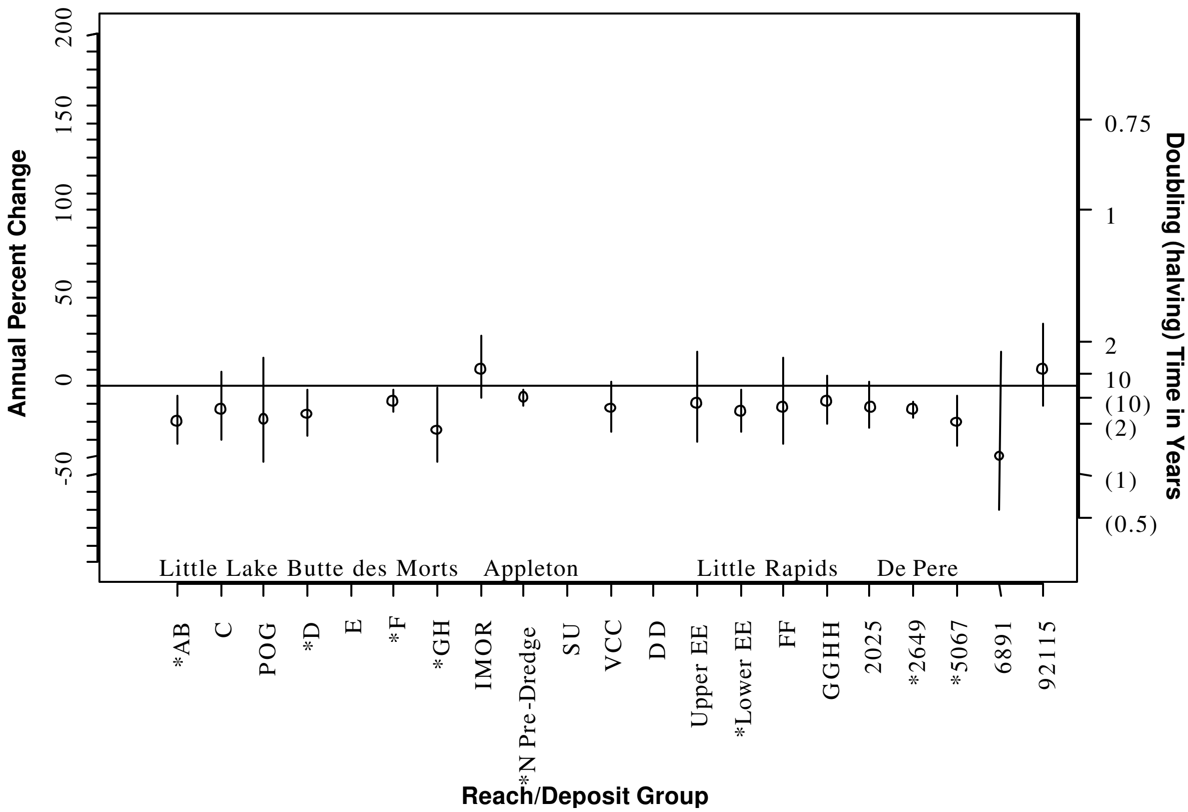


Figure 24 95 Percent Confidence Intervals for Annual Percent Rate of Change at Depth 0 to 10 cm

An asterisk (*) below the depth label indicates that a rate of change differs significantly from zero. Right vertical axis expresses time trend change in terms of doubling and halving times.

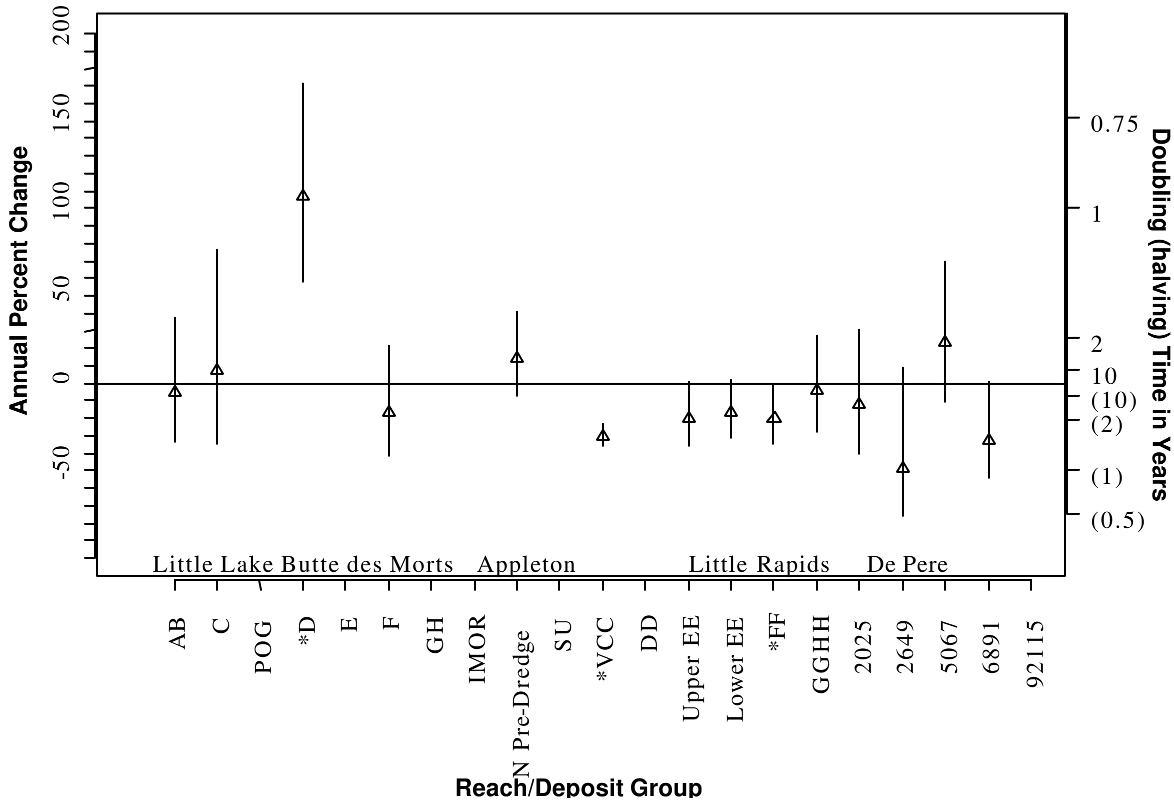


Figure 25 95 Percent Confidence Intervals for Annual Percent Rate of Change at Depth 10+ to 30 cm

An asterisk (*) below the depth label indicates that a rate of change differs significantly from zero. Right vertical axis expresses time trend change in term s of doubling and halving times.

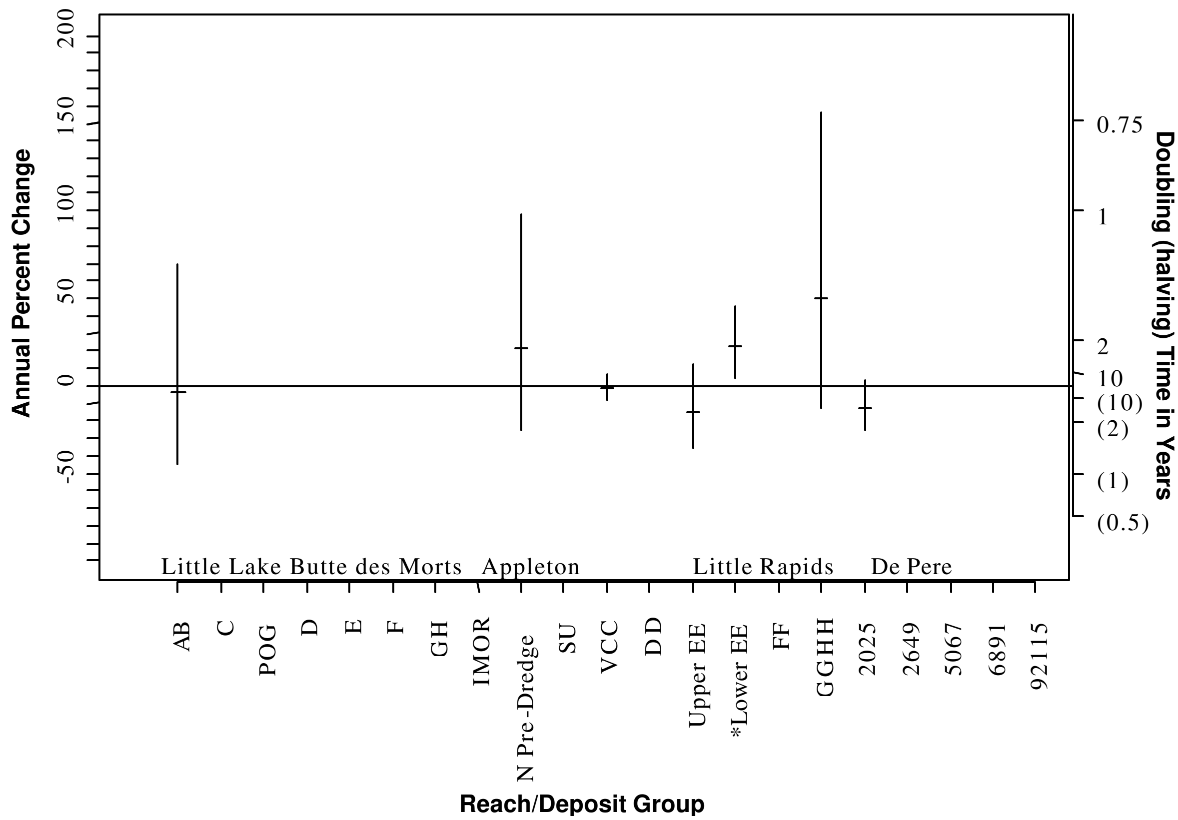


Figure 26 95 Percent Confidence Intervals for Annual Percent Rate of Change at Depth 30+ to 50 cm

An asterisk (*) below the depth label indicates that a rate of change differs significantly from zero. Right vertical axis expresses time trend change in terms of doubling and halving times.

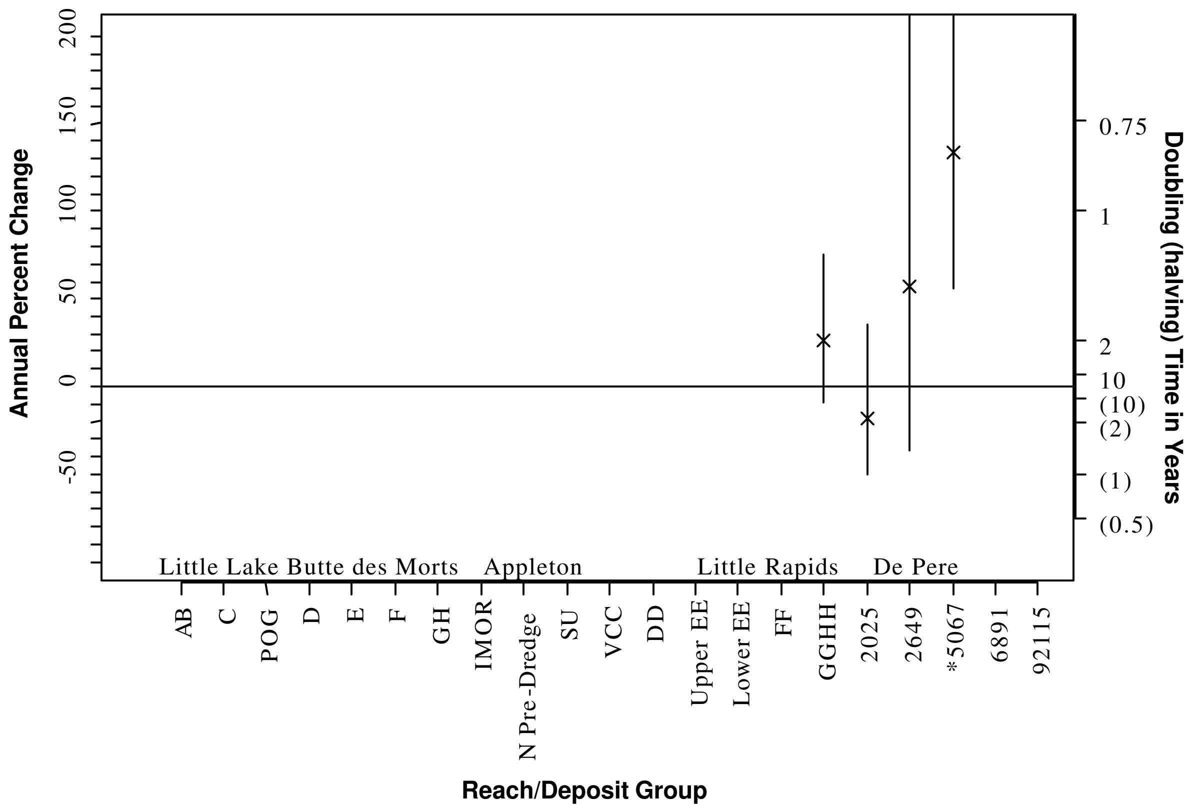


Figure 27 95 Percent Confidence Intervals for Annual Percent Rate of Change at Depth 50+ to 100 cm

An asterisk (*) below the depth label indicates that a rate of change differs significantly from zero. Right vertical axis expresses time trend change in terms of doubling and halving times.

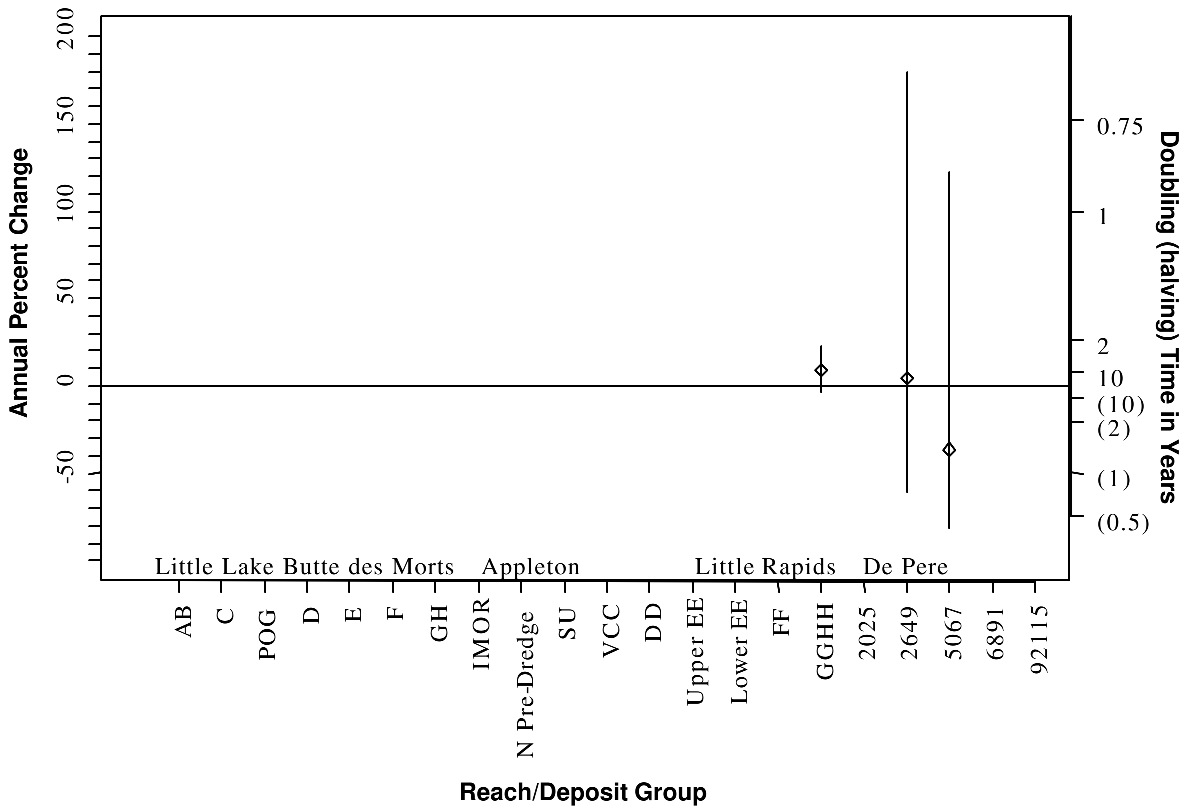


Figure 28 95 Percent Confidence Intervals for Annual Percent Rate of Change at Depth 100+ cm

Right vertical axis expresses time trend change in terms of doubling and halv ing times.

We note that negative slopes are 89 percent of the calculated slopes from 0 to 10 cm, 71 percent (10/14) of the slopes (16/18) at 10 to 30 cm, 57 percent (4/7) at 30 to 50 cm, 25 percent (1/4) at 50 to 100 cm, and 33 percent (l/3) at 100 cm and over. This indicates a powerful trend toward fewer or weaker negative slopes and more or stronger positive slopes at greater depths. This suggests either that some of the PCBs may transfer out of the river and into Green Bay, instead moving to greater depths, or that attrition of PCBs slows at greater depths, or even that both mechanisms are occurring. These findings can be compared with mass balance studies discussed in the Remedial Investigation for the Lower Fox River and Green Bay.

4.4 Time Trends by Reach

4.4.1 Little Lake Butte des Morts

With the exception of two strata at 10 to 30 cm in two separate deposit groups, slopes are negative (9 out of 11 analyses). Statistically significant negative slopes (decreasing PCB concentration over time) occur in surface sediments (0 to 10 cm) of four deposit groups (AB, D, F, GH) with estimated rates of decrease ranging from 8 to 24 percent per year (Table 9 and Figure 24). The only statistically significant increasing trend of PCB concentrations occurs at 10 to 30 cm in Deposit Group D, where the rate of increase is 108 percent per year. The confidence intervals for these rates of change are quite wide. For the significantly decreasing slopes in the surface 0- to 10-cm stratum, the confidence intervals indicate a rate of decrease of as little as 1 to 5 percent and as much as 15 to 43 percent per year. The confidence interval for the significantly increasing slope at 10 to 30 cm in Deposit Group D indicates a rate as low as 59 percent and as high as 171 percent per year. This must represent a temporary positive trend because a projection of the PCB concentration even at the minimum of 59 percent per year yields an absurd 10,000-fold increase in PCB concentration after 20 years. Again, the negative slopes also refer to the period of data collection, and one cannot guarantee that such negative slopes would continue indefinitely into the future.

An additional calculation for the surface strata of this reach yields an average slope. This average slope is a weighted mean, where the weights are estimated PCB masses for our deposit groups using mass estimation methods developed in other Fox River studies (WDNR, 1999b). The mass estimates for surface deposits (0 to 10 cm) refer to the boundaries noted on Figure 5 through Figure 8. Because new boundaries have been drawn for these deposit groups, the masses here differ from the masses quoted in other documents for the original deposit designations. Using the estimated PCB mass in the surface sediments (0 to 10 cm) as a relative weight, the weighted mean slope is –0.071 ± 0.018 $\log_{10}$ PCB concentration per year (*mean* ± *SE*, Table 11) with $p = 0.0001$ for the null hypothesis of zero slope (i.e., the weighted mean slope is significantly negative and corresponds to an 18 percent rate of decrease of PCB concentration per year). The weighted mean slope is calculated as:

Equation 14

$$b_{wt} = \frac{\left(\sum_{i=1}^{K} b_i \cdot w_i\right)}{\left(\sum_{i=1}^{K} w_i\right)}$$

where the b_i are the slopes of the individual deposit groups, $i = 1, \ldots, K$, from Table 9 and the w_i are the PCB masses in the strata (see Table 10). The standard error of b_{wt} is calculated as:

Equation 15

$$SE\,(b_{wt}) = \left[\sum_{i=1}^{K} (SE \cdot (b_i))^2\ (w_i^*)^2\right]^{0.5}$$

where the $SE(b_i)$ are the standard errors of the individual b values and $w_i^* = \frac{w_i}{\left(\sum_{i=1}^{K} w_i\right)}$. The statistical significance of the weighted slope is based on a two-sided, single-sample Z-test (twice the tail area of the normal distribution lying beyond $Z = \frac{b_{wt}}{SE(b_{wt})}$).

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

Deposit Group	Log_{10}(PCB) Time Trend Slope Est.	WSEV Standard Error	PCB Mass (kg)	*p*-value	Annual Percent Change in PCB Conc.	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	**0.0025**	**0.01469**	**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				
2649	−0.06078	0.010894	356.8				
5067	−0.09978	0.034549	92.4				
6891	−0.22081	0.094396	72.1				
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 10 provides the weighted slope of surface sediment for each reach. One should interpret the weighted mean slope carefully. This descriptive statistic shows how rapidly the PCB mass is changing at the particular reference date for the mass estimations (1989–1990), assuming that the rates of change in Table 9 correctly reflect the rates of change at the reference date. The weighted mean slope itself has a straightforward interpretation: it is the rate at which mass is decreasing from the 0- to 10-cm stratum of the collection of deposit groups in the reach. We caution readers when comparing the statistical significance of trends in individual deposit groups (Table 9) to the significance of the weighted mean pooled across all deposit groups in the reach (Table 10). One can calculate a non-significant weighted mean slope although one of the slopes shows, for example, a significant or even highly significant decrease in PCBs over time in the specific deposit group. This can arise where considerable uncertainty exists in some of the slopes being weighted, and when combined, overwhelms the relative certainty of one or two highly significant individual slopes. Thus, one can clearly interpret the value of the slope as representing the rate of decline of the PCB mass at the reference date used for total PCB mass evaluation. One must interpret statistical significance, however, as the likelihood that the observed weighted mean slope could arise, differing from zero, given *within-deposit* sampling variation. It could happen that one sees a significantly negative slope for an individual deposit group with a non-significant overall weighted mean slope. This could occur if, among other deposit groups, the slopes have values close to zero and large enough standard errors such that the mass could conceivably be increasing in these deposit groups. Hence, individual deposit groups with statistically significant slopes alongside a non-significant overall weighted slope should not alarm the reader. In fact, we face just such a contradiction in Appleton, the next reach considered.

The weighted mean slope should not be used for projection of PCB concentrations for the entire reach, because deposit groups with the lowest rate of decrease will in the future dominate the decay of PCB mass over time. The weighted mean slope serves as a summary descriptive value representing average change during the period of data collection and, also, as a statistic used to derive a significance level (*p*-value) for the hypothesis of no change. The PCB mass remaining in the future, w, can be estimated as:

Equation 16

$$w = \sum_{i=1}^{K} w_i * 10^{b_i t}$$

where time, t, is measured in decimal years since January 1, 1989, w_i are the PCB masses in the K strata, and b_i is the coefficient of time term in the model for the i^{th} stratum. The equation works for any collection of K strata.

4.4.2 Appleton Reach

Two strata have statistically significant slopes. The, 0 to 10 cm in the Deposit Group N (pre-dredge) has a statistically significant negative slope of b = --0.028 ($\log_{10}$ PCB concentration per year). This slope translates into a rate of decrease of 6 percent per year with a 95 percent confidence interval of 2 percent to 11 percent decrease per year (Table 9). The 10- to 30-cm stratum of Deposit Group VCC has a statistically significant decrease of −0.154 (log_{10} PCB concentration per year), implying a 30 percent rate of decrease per year with a 95 percent confidence interval of −35 to −24 percent (Table 9).

The weighted slope for surface strata is 0.003 per year, implying a rate of increase of 0.6 percent per year with a 95 percent confidence interval of −6 to +7 percent per year. This mass-weighted mean slope of −0.011 per year is not statistically significant (p = 0.4). Even though the N Pre-dredge Deposit Group has a significantly decreasing slope in the 0- to 10-cm stratum (equivalent to a 2.6% decrease per year), the total PCB mass in surface sediments in the entire Appleton Reach may be either increasing, decreasing, or remaining constant over time. The reach includes the one statistically significant negative slope for surface sediments, as well as an additional positive and negative slope. Thus, while it is likely that one surface deposit is, indeed, decreasing in PCB concentration, the combination of positive and negative slopes convey a state of uncertainty as to the trends in total PCB mass in the combined surface deposits in the reach.

4.4.3 Little Rapids to De Pere Reach

This reach has a majority of negative slopes (change in log_{10}[PCB concentration] per year). Two of the three significant slopes are negative and occur in the 0- to 10-cm and 10- to 30-cm depth strata. One large positive statistically significant slope occurs at the 30- to 50-cm depth (Table 9).

The surface sediment (0 to 10 cm) in the Lower EE Deposit Group has a significantly negative slope (−0.068 per year), 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 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 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, we still encounter notably wide confidence intervals.

Although only one surface sediment has a statistically significant decline, we nonetheless find 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.

4.4.4 De Pere to Green Bay Reach

This reach, again, has primarily negative slopes (Table 9). Statistically significant negative slopes occur in three combinations of deposit group and depth. Our SMU Group 2649 has a significantly negative slope in the surface deposit (0 to 10 cm), with a rate of decrease of 13 percent per year (95 percent confidence interval of 8 to 17 percent per year) and $p < 0.0001$. SMU Group 5067, 0 to 10 cm, also has a significantly negative slope implying an annual rate of decrease of 21 percent (95 percent confidence interval of 5 to 33 percent) and $p = 0.01$. In the same SMU group (5067), at a greater depth of 50 to 100 cm, we observe a statistically significant and large positive slope with a rate of increase of 133 percent per year (95 percent confidence interval of 56 to 250 percent) and $p = 0.003$.

We noted earlier (Section 2.6 and Table 5) an exceptional value of PCB concentration in SMU Group 5067. Sample A3_0-4 had a concentration of 99,000 ppb, whereas all other samples in the 0- to 10-cm 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. We have no reason to suspect invalidity of the concentration of 99,000 ppb for sample A3_0-4, especially given internal evidence in the deposit corroborating it (see below). However, the sample is a statistical outlier to the spatial relationships of PCB concentrations in the deposit, as we shall show. The spatial layout of the samples in the 0- to 10-cm stratum of SMU Group 5067 is shown on Figure 29. The samples occur in an intensively sampled area (see Figure 8). Sample A3_0-4 lies close to the shore of the river, and we have been informed that this sample was located in the vicinity of direct deposition of PCBs. The more immediate vicinity of the sample is shown on Figure 30, which includes 34 out of the 58 samples in the 0- to 10-cm layer of the deposit. Figure 30 also designates the exceptional sample A3_0-4 (#1 in the plot) and the six samples closest to it.

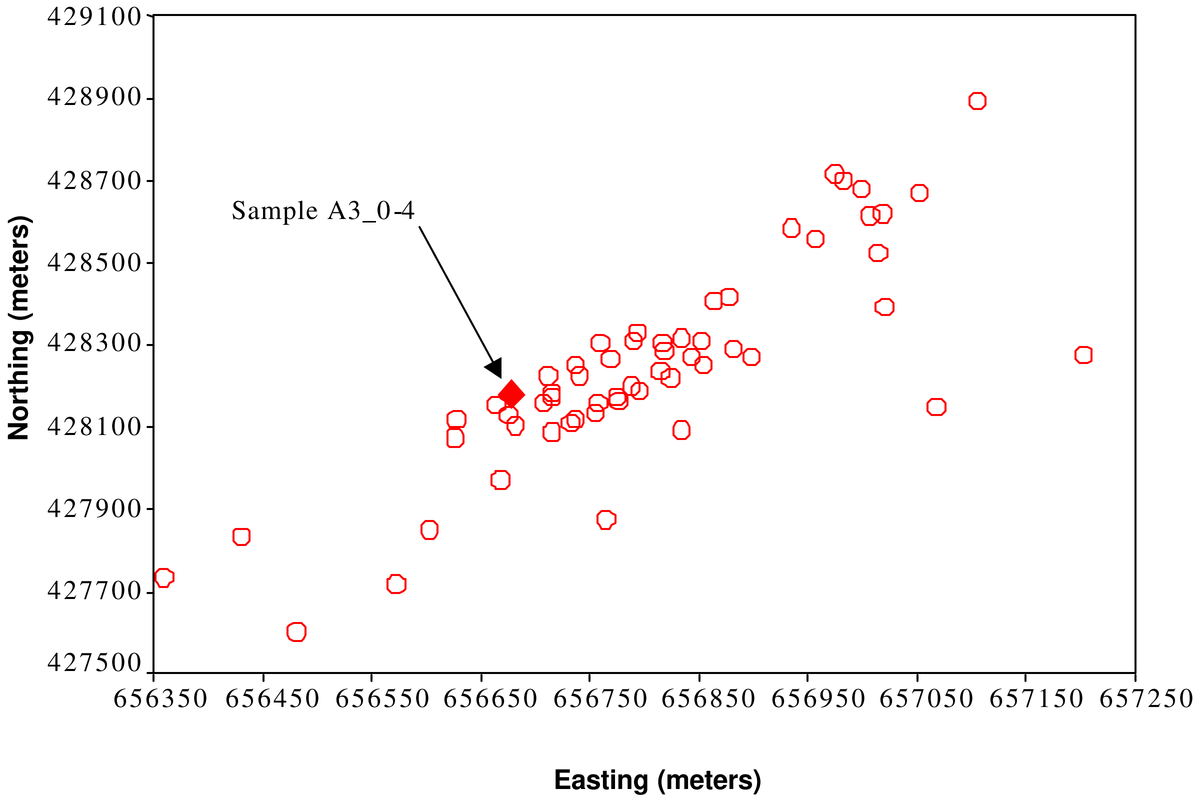


Figure 29 De Pere SMU Group 5067: Location of 0 to 10 cm Core-averaged Samples with Sample A3_0-4 Identified

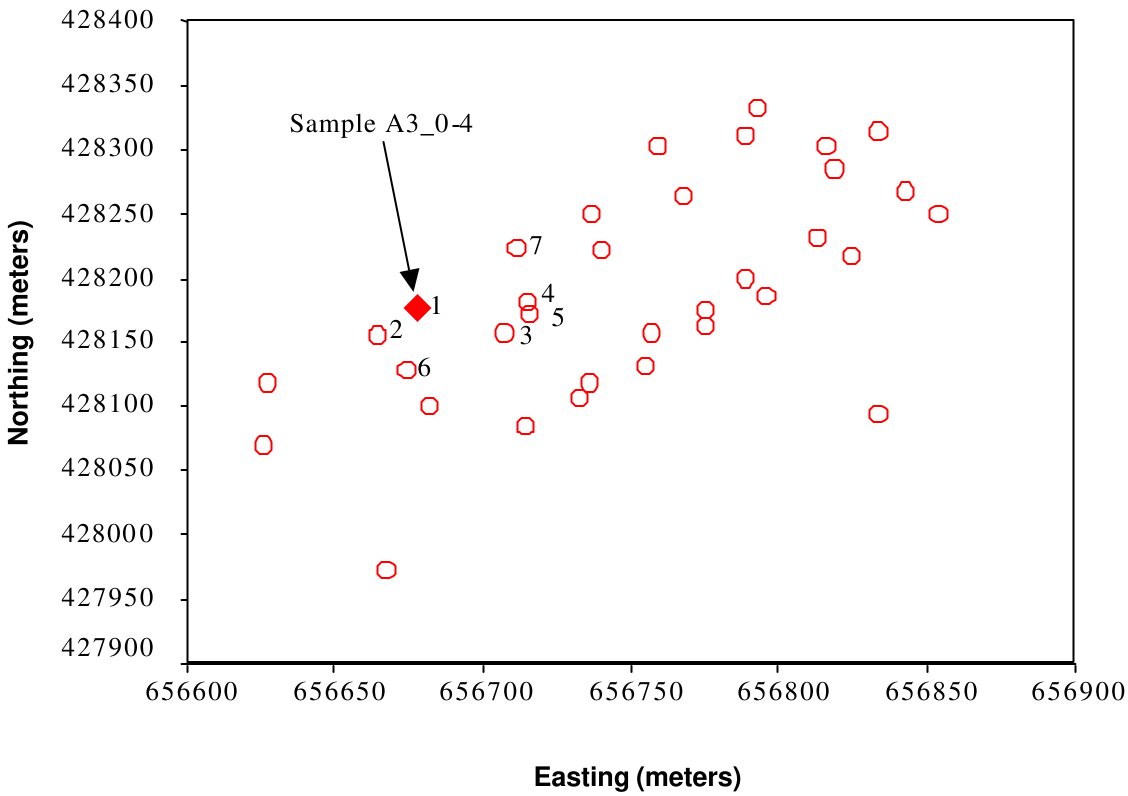


Figure 30 Sample Locations for SMU Group 5067, 0 to 10 cm Depth, Samples Closest to Sample A3_0-4 (Less than 208 meters Distance)

A3_0-4 and the six samples closest to it are labeled.

The specific concentrations of the samples near sample A3_0-4 are shown in Table 11, which includes not only concentrations for the 0- to 10-cm layer, but concentrations in lower sediment layers in precisely the same locations. (The samples have the same northing and easting coordinates down through the layers, presumably because multilayer samples were collected in a single coring operation.) These seven samples all occur within a radius of less than 60 meters from the location of A3_0-4. We note that in the 0- to 10-cm layer, all of these nearby samples are in the 2,000 to 3,000 ppb range, less than one-twentieth of the concentration of sample A3_0-4. In the next layer down, 10 to 30 cm, the highest concentration by a wide margin occurs at the same location as sample A3_0-4, suggesting that this sample location does, indeed, have a high concentration of PCBs and that the location differs from immediately neighboring sediment. We excluded the layer 30 to 50 cm from our time trends analysis (due to lack of time variation of samples) and, therefore, it does not appear in the table. The 50- to 100-cm layer shows a high concentration at the location of sample A3_0-4, but the other samples near it also show high concentrations. At 100+ cm, the PCB concentration no longer stands out at the location of sample A3_0-4.

Table 11 PCB Concentrations at Various Depths and Distances from Sample A3_0-4

Sample	0–10 cm	10–30 cm	50–100 cm	100+ cm	Year	Easting (meters)	Northing (meters)	Distance (meters)
1	99,000	150,000	150,000	53,122	1997	656678	428177	0
2	2,000	2,200	34,000	18,128	1997	656664	428155	26
3	2,100	3,100	7,000	61,094	1997	656707	428158	35
4	1,900	4,300	170,000	66,106	1997	656715	428182	37
5	2,700	4,800	13,000	30,948	1995	656716	428172	38
6	2,000	4,500	7,800	41,729	1997	656675	428128	49
7	3,000	9,900	120,000	6,665	1997	656711	428224	58

The value of 99,000 ppb stands out as considerably larger than nearby samples, which have quite uniform concentrations of PCBs and thereby heighten the contrast. We do not imply that the value of 99,000 is artificial, but it cannot readily be included in a regression analysis for the deposit. A valid regression analysis depends upon the included concentrations approximately following a normal (bell-shaped) distribution around the fitted regression model. A model fitted to the log concentrations in the 0- to 10-cm layer with sample A3_0-4 included shows that the sample is 5.5 standard deviations away from the model-fitted value, whereas all other samples are at most 2.6 standard deviations from their model-fitted values. With a sample of this size (n = 58, including A3_0-4), the occurrence of observations lying three or more standard deviations from the model questions the accuracy of the model. The deviation of 5.5 is exceptionally large. Even ignoring the modeling process, the log concentration of A3_0-4 is 7.4 standard deviations above the mean of the balance of observations, and the next largest observation is only 2.5 standard deviations above the same mean.

Thus, sample A3_0-4 appears to represent a real but exceptional concentration in the 0- to 10-cm layer. The regression model excluding it thus covers all of the 0- to 10-cm layer in the deposit except the immediate vicinity of this sample. The statistically significant decline in PCBs noted for this layer in Table 9 does not, then, necessarily apply to this small area. It is impossible to develop an estimate of the time trend for this "hotspot" alone. Of the nearby samples (Table 11), all except one occur at the same time as sample A3_0-4—1997. The lack of time variation of samples in the vicinity of A3_0-4 precludes a separate regression analysis for this sub-area.

The large concentration at the same location as A3_0-4, but one layer down—the 150,000 ppb concentration at 10 to 30 cm, is not an outlier to its layer. Its nearby samples vary considerably more among themselves relative to the variability observed in the corresponding samples from the 0- to 10-cm layer. Thus, the 150,000 value does not stand out with nearly as much contrast relative to the 99,000 value among its neighbors. The residuals from the regression analysis of the PCB concentrations in the 10- to 30-cm layer also show no statistical outliers. One reason that the concentration at this location in the 10- to 30-cm layer is so large may be that a hotspot extends from the 0- to 10-cm layer into at least part of the 10- to 30-cm layer.

In summary, the 0- to 10-cm layer of the deposit, outside of the vicinity of A3_0-4, shows a statistically significant decline in PCB concentration over time. The vicinity of A3_0-4 encompassed an area of exceptionally high concentrations with an unknown time trend. The exceptional vicinity of A3_0-4 is a small fraction of the total deposit area. A circle centered on A3_0-4 and bounded by the nearest sample (which has a typical concentration), 26 meters away, would have an area of 2,100 square meters, or approximately 0.3 percent of the 840,000-square meter total area covered by all samples of SMU Group 5067 in the 0- to 10-cm layer.

The mean slope for surface sediments in this reach, weighted by PCB mass, is --0.073 ± 0.013 and highly significant ($p < 0.0001$, Table 10). The negative slope implies a rate of decrease of 15 percent per year (95 percent confidence interval: –20 to –10 percent per year).

4.5 Comments on Combined Reaches

There may be some concern about the many analyses carried out and the possibility that some of the trends, both positive and negative, are statistically significantly different from zero by chance alone. We carried out a formal test for the hypothesis that the slopes, positive and negative, are simply randomly distributed around zero (i.e., the statistically significant differences from zero result from the large number of analyses carried out). Under the null hypothesis that the true slopes are all 0, the *p*-values should be uniformly distributed between 0 and 1.0, and minus twice the sum of the natural log of the *p*-values will yield a chi-squared variable with degrees of freedom equal to twice the total number of analyses (*p*-values) included. Carrying out this operation and obtaining a *p*-value for this null hypothesis of all zero true slopes yields $p < 0.0001$ for depth 0 to 10 cm, $p < 0.0001$ for depth 10 to 30 cm, $p = 0.07$ for 30 to 50 cm, $p = 0.01$ for 50 to 100 cm, and $p = 0.46$ for 100+ cm. Thus, it appears clear that there exist non-random changes in slope, both positive and negative, for all depths, except, possibly, 30 to 50 cm and 100+ cm. We conclude that real changes in concentrations are taking place over time in the Lower Fox River.

5 Fish Results

5.1 Number of Observations

A total of 1,742 fish samples were available for analysis, including sample types of fillet without skin, fillet with skin, and whole body. We excluded samples of eggs, stomach, carcass, and other miscellaneous sample types, as well as those for which percent lipid was unknown. As a criterion for analysis, we included only unique combinations of species and sample type for a given reach with at least 14 observations. In general, our largest model included seven parameters to be estimated. Thus, the minimum of 14 observations ensures at least twice as many observations as parameters. As some statistical "rules of thumb" require at least four or five times as many observations as parameters, our rule might strike many as rather generous. Nevertheless, we decided to err on the side of inclusiveness and to interpret with some caution analyses with a small number of observations. As an important additional condition, we required sufficient variation in time to provide a meaningful estimate of a time trend. The data provided 108 combinations of reach, species, and sample type with at least one observation, but only 19 of these had sufficient numbers of samples and an adequate time spread for analysis (see Table 12). In Little Lake Butte des Morts, 6 out of 23 combinations could be analyzed. For the other reaches, corresponding numbers are 1 of 20 for Appleton Reach, 0 of 16 for Little Rapids Reach, 7 of 24 for De Pere Reach, and 5 of 25 for Green Bay Zone 2. The 19 combinations that could be analyzed for time trends represent 868 samples—over half of all samples of whole body, fillet with skin, and fillet without skin. Carp and walleye provided the largest number of observations. None of the observations of fillet without skin would be analyzed due to either inadequate sample size or inadequate time variation. One outlier was detected and removed (see Appendix Table A-2).

Table 12 Sample Sizes for Total PCB Time Trend Analyses by Reach, Species, and Sample Type

	Fillet/Fillet No Skin	Skin-on Fillet	Whole Fish, Whole Body, Whole Body Composite	Eggs, Stomach, Carcass, Other	Total Sample Size: Fillet, Fillet No Skin, Skin-on Fillet, Whole Fish, Whole Body, Whole Body Composite
Little Lake Butte des Morts					
Brown Bullhead	4	8	6		18
Carp	20	55*	40*		115
Gizzard Shad			4		4
Northern Pike		19*	5		24
Smallmouth Bass		7	2		9
Walleye	7	63*	18*		88
White Bass		26		2	26
White Sucker	10	19	8		37
Yellow Perch		34*	7	1	41
Other	2	10	5	1	17
Appleton to Little Rapids					
Brown Bullhead	1	2			3
Carp		24	13		37
Channel Catfish	6				6
Northern Pike		7	4		11
Smallmouth Bass		5	4		9
Walleye		30*	4		34
White Bass		8	2		10
White Sucker		17	6		23
Yellow Perch		2	7		9
Other	1	10	3		14
Little Rapids to De Pere					
Carp		2	22		24
Channel Catfish	3				3
Gizzard Shad			3		3
Northern Pike		3	1		4
Smallmouth Bass		16	2		18
Walleye		48	4		52
White Bass		14			14
Yellow Perch		3	2		5
Other	4	6	8		18

Table 12 Sample Sizes for Total PCB Time Trend Analyses by Reach, Species, and Sample Type

	Fillet/Fillet No Skin	Skin-on Fillet	Whole Fish, Whole Body, Whole Body Composite	Eggs, Stomach, Carcass, Other	Total Sample Size: Fillet, Fillet No Skin, Skin-on Fillet, Whole Fish, Whole Body, Whole Body Composite
De Pere to Green Bay					
Alewife			15		15
Brown Bullhead			2		2
Carp		12	90*	13	102
Channel Catfish	17				17
Gizzard Shad		2	19*		21
Northern Pike		40*	6		46
Smallmouth Bass		15	4		19
Walleye	14	120*	58*	8	192
White Bass	3	58*	9	8	70
White Sucker		44*	22	2	66
Yellow Perch		11	9		20
Other	6	36	42	1	84
Green Bay Zone 2 (2A and 2B)					
Alewife		3	44*		47
Brown Bullhead	6	2	1		9
Carp		28*	57*	28	85
Channel Catfish	5				5
Gizzard Shad		1	32*		33
Northern Pike		7	1		8
Rainbow Smelt		2	33		35
Smallmouth Bass			2		2
Walleye		17	34		51
White Bass		3			3
White Sucker		7	1		8
Yellow Perch		19*	5		24
Other	3	33	2		38
Total (all reaches):					**1,678**

Note:
* Included in time trends analysis. Total *n* = 868.

While inadequate sample size for some species from some reaches presented the greatest obstacle to analysis, several cases with substantial numbers of observations suffered from inadequate spread over time, such as whole body white sucker in the De Pere to Green Bay Reach, with 22 observations. Notably, Little Rapids to De Pere Reach had no groups with both sufficient sample size and time spread.

Overall, only a small fraction of the observations had values below detection limit (BDL). Among the 19 combinations with a total of 868 samples, only *n* = 28 (3%)

were BDL. Several combinations had no BDL concentrations (0%), and BDL observations occurred mainly in four combinations, which had 13 to 29 percent BDL values. All observations, both above and below detection limits, in the selected combinations of reach, species, and sample type were used in the time trends analysis. Appendix Table A-3 indicates the number of observations below detection limits.

5.2 Time Trends in PCB Concentrations in Fish

We organize results in three major sections:

First, we introduce some ancillary results relevant to the process of model fitting, such as identifying the optimal location of the breakpoint and coefficients on percent lipids and seasonality (Section 5.2.1).

Then we turn to the main results, concerning rates of decline of PCB concentrations. The time trends for each species and sample type, within each reach, can be found in this section (Section 5.2.2).

Finally, we consider alternative models, such as those with a common breakpoint at 1985 for all fish categories and curvilinear (quadratic) models to test whether trends are constant or changing over time (Section 5.2.3).

5.2.1 Testing Spline Model versus Simple Linear Model

Table 13 shows results of testing the null hypothesis of a linear relationship between log of PCB concentration and time over the entire time period of the data versus the alternative hypothesis of a spline: two linear segments joined at a breakpoint. The year of the best-fitting spline model is shown in Table 13, and the *p*-value indicates whether the spline model significantly improves the fit to the data. With one exception (yellow perch, skin-on fillet in Green Bay Zone 2), the spline model has been used if $p < 0.05$ in Table 13; this means that a spline model fits significantly better than a simple, single-slope linear model.

Table 14 through Table 16 provide a description, reach by reach, of the final slopes from the fitted models (or the only slope, if there is no breakpoint) and Table 18 provides other model parameters discussed in this section. One can find the complete model in Appendix Table A-3 or A-6.

Table 13 Testing the Null Hypothesis that a Straight Line Fits As Well As a Spline Model with a Breakpoint

Reach and Species	Sample Type	Year of Best-fitting Breakpoint	Sample Size (*n*)	Breakpoint	
				p-value	Statistically Significant
Little Lake Butte des Morts					
Carp	skin-on fillet	1979	55	0.0347	*
Carp	whole fish[+]	1987	40	0.0263	*
Northern Pike	skin-on fillet	1996	19	0.2723	
Walleye	skin-on fillet	1990	63	0.0423	*
Walleye	whole fish[+]	1987	18	0.0088	**
Yellow Perch	skin-on fillet	1981	34	0.0062	**
Combined[++]			**229**	**<0.0001**	***
Appleton					
Walleye	skin-on fillet	1983	30	0.4526	
De Pere					
Carp	whole fish[+]	1995	90	0.0087	**
Gizzard Shad	whole fish[+]	1990	19	0.4672	
Northern Pike	skin-on fillet	1996	40	0.1421	
Walleye	skin-on fillet	1993	120	0.5680	
Walleye	whole fish[+]	1996	58	0.5550	
White Bass	skin-on fillet	1996	58	0.6059	
White Sucker	skin-on fillet	1990	44	0.1986	
Combined[++]			**429**	**0.0906**	
Green Bay Zone 2 (2A and 2B)					
Alewife	whole fish[+]	1986	44	0.0863	
Carp	skin-on fillet	1985	28	0.1811	
Carp	whole fish[+]	1983	57	0.0001	***
Gizzard Shad	whole fish[+]	1996	32	0.6655	
Yellow Perch	skin-on fillet[+++]	1986	19	0.0008	***
Combined[++]			**180**	**<0.0001**	***

Notes:

- * $p < 0.05$
- ** $p < 0.01$
- *** $p < 0.001$
- [+] Whole fish, or whole body, or whole body composite.
- [++] Indicates *p*-value for testing the null hypothesis that all fish categories in a reach do not have a breakpoint.
- [+++] A model with a breakpoint was rejected. See text.

Reach 1 — Little Lake Butte des Morts

In the first reach, for five of the six fish categories, the spline model fit significantly better than the linear model. In all cases, the initial slope decreased more steeply than the final slope, as seen by the negative coefficient for the slope difference. Figure 31 for carp fillet with skin in Little Lake Butte des Morts shows an example of an initial steep slope until 1979, followed by a continuing decline, but at a slower rate. Similar plots for all analyses are found in the Appendix. Figure 32 shows an example of initial decline until 1990, followed by a virtually flat line implying no further decline in PCBs. Figure 33 shows an example in which PCB concentration actually increases after the breakpoint in 1987. With only 18 data points and 9 distinct time points, one should interpret this result cautiously. Of note, the fitted line appears to fit poorly prior to 1987 because all of the observations lie above the fitted line. The fitted line, however, represents the prediction for fish with percent lipid equal to the mean, sampled on July 1. For this fish category, samples were taken prior to 1987 in late August and early September, and after 1987 mainly in July and some as early as April. This discrepancy, plus evidence for a significant seasonal effect for this fish category, explains the poor visual fit on the plot. The row at the bottom of the panel for Little Lake Butte des Morts in Table 14 reports the *p*-value from a meta-analysis for this reach. This meta-analysis combines the results from all species within this reach to test the global null hypothesis that a linear model fits well for **all** species/types versus the alternative that a spline model with a breakpoint gives a better fit for at least one species. The highly significant *p*-value provides strong evidence to reject the null hypothesis that every species has a constant rate of decline over the entire time frame in Little Lake Butte des Morts.

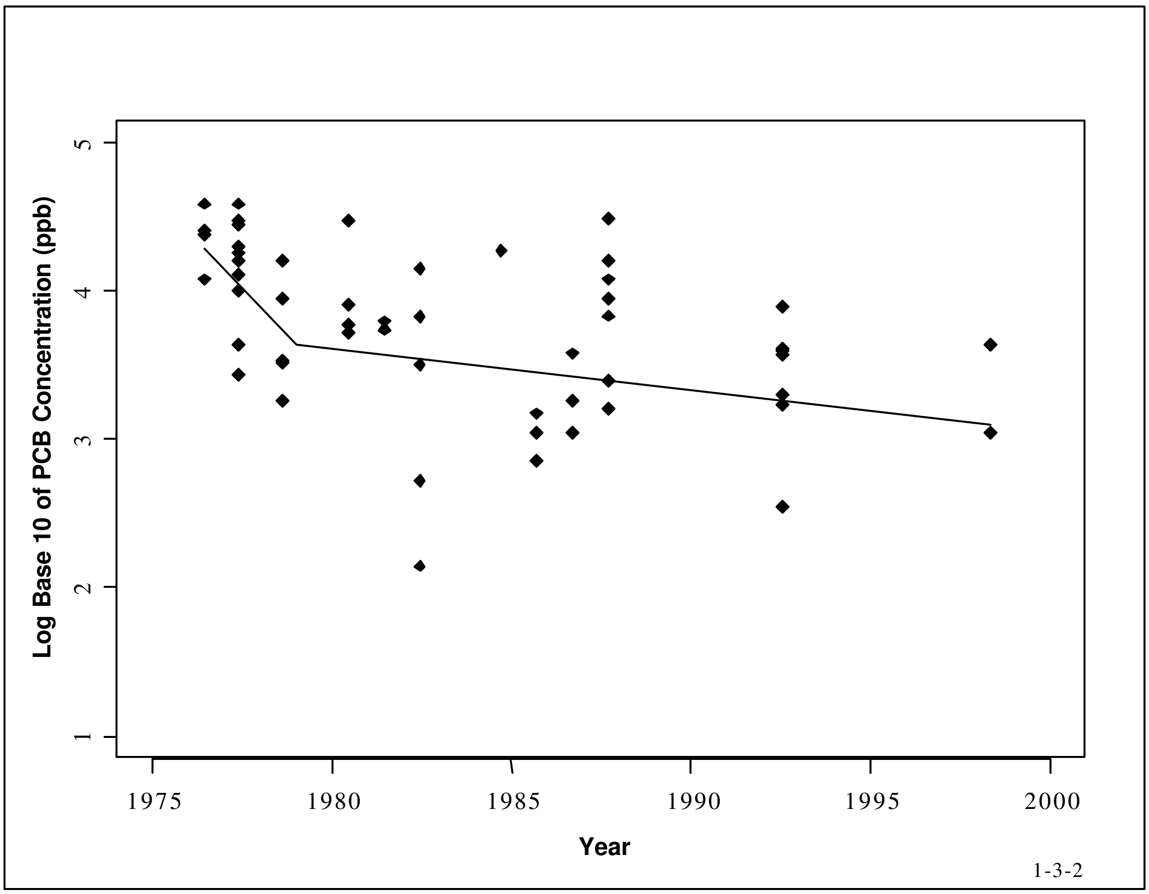


Figure 31 Log_{10} PCB Concentration (ppb) in Little Lake Butte des Morts Carp, Skin-on Fillet, versus Time

Breakpoint = 1979 (p = 0.03), Final Slope ($\log_{10}$ PCB versus time) = –0.028 (p = 0.02), Rate of Change of PCB Concentration During Period of Final Slope = --6.1% (95% confidence interval: –10.9% to –1.1%).

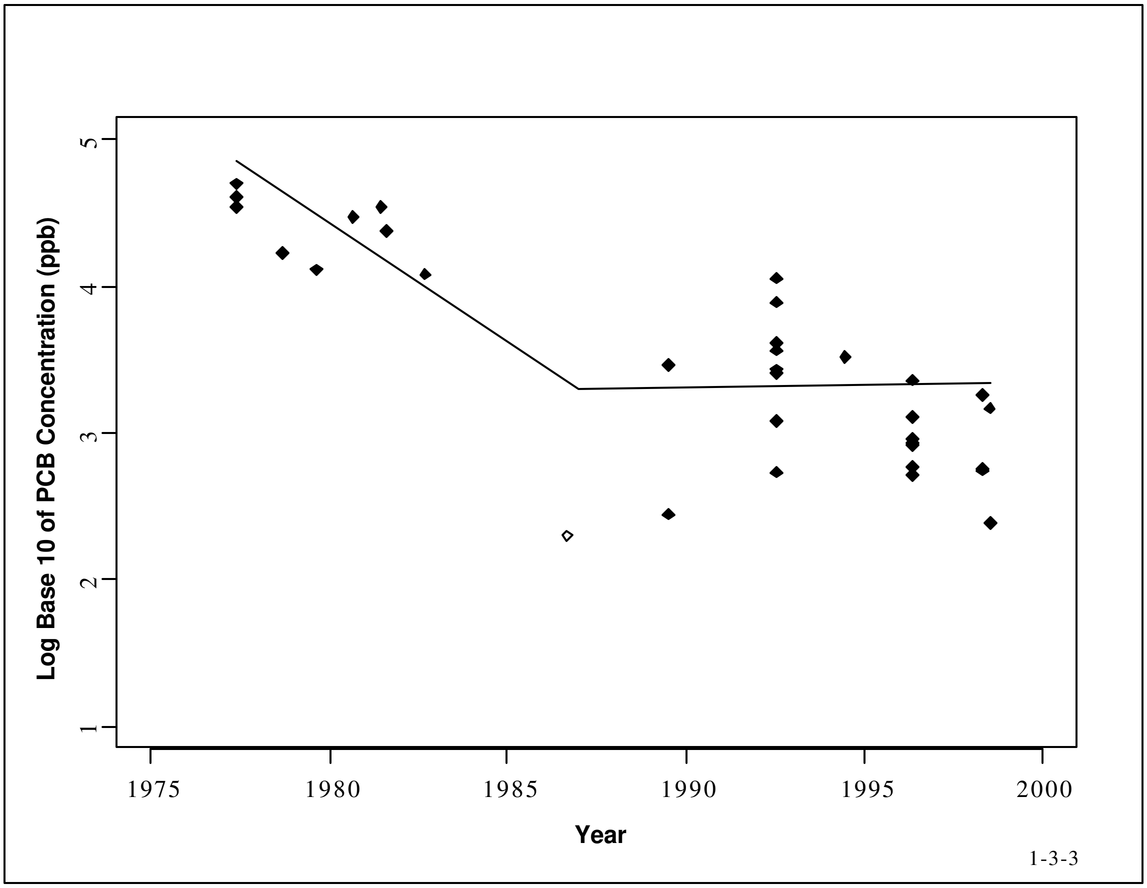


Figure 32 Log_{10} PCB Concentration (ppb) in Little Lake Butte des Morts Carp, Whole Body, versus Time

Breakpoint = 1987 (p = 0.03), Final Slope (log_{10} PCB versus time) = 0.003 (p = 0.9), Rate of Change of PCB Concentration During Period of Final Slope = 0.7% (95% confidence interval: –12.3% to 15.6%). Any values below detection limit are depicted as ◇.

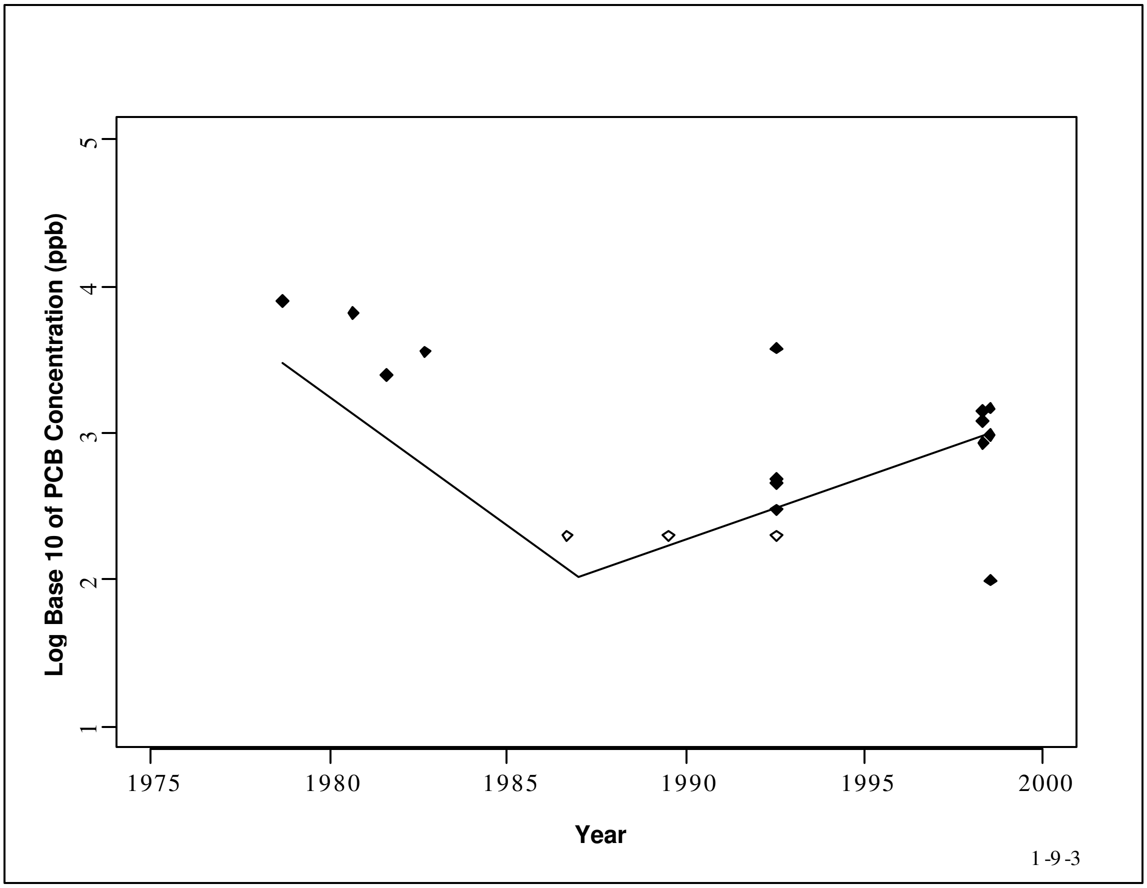


Figure 33 Log$_{10}$ PCB Concentration (ppb) in Little Lake Butte des Morts Walleye, Whole Body, versus Time

Breakpoint = 1987 (p = 0.009), Final Slope ($\log_{10}$ PCB versus time) = 0.084 (p = 0.09), Rate of Change of PCB Concentration During Period of Final Slope = 21.5% (95% confidence interval: –3.5% to 52.9%). Any values below detection limit are depicted as ◇.

Table 14 PCB Time Trend Results for Fish Samples in Little Lake Butte des Morts Reach

Species	Sample Type	Year of Break-point	*n*	Final (post-break) Slope				95% Confidence Interval	
				Final Slope	SE	*p*-value	% per Year	LCL	UCL
Carp	skin-on fillet	1979	55	–0.028	0.011	0.0177*	–6.1	–10.9	–1.1
	whole body	1987	40	0.003	0.030	0.9172	0.7	–12.3	15.6
Northern Pike	skin-on fillet	N/A	19	–0.055	0.011	0.0003***	–11.8	–16.7	–6.7
Walleye	skin-on fillet	1990	63	0.015	0.025	0.5576	3.4	–7.8	16.0
	whole body	1987	18	0.084	0.045	0.0874	21.5	–3.5	52.9
Yellow Perch	skin-on fillet	1981	34	0.003	0.012	0.8025	0.7	–5.0	6.8

Notes:

N/A – Not applicable; no breakpoint.
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

Reach 2 — Appleton to Little Rapids

Only data for walleye can be analyzed for this reach. The data provide no evidence to reject the null hypothesis of a constant rate of decline over the time span of observation. $P = 0.5$ for the spline model versus the simple linear model (Table 13).

Table 15 PCB Time Trend Results for Fish Samples in Appleton to Little Rapids Reach

Species	Sample Type	Year of Break-point	*n*	Final (post-break) Slope				95% Confidence Interval	
				Final Slope	SE	*p*-value	% per Year	LCL	UCL
Walleye	skin-on fillet	N/A	30	–0.046	0.014	0.0028**	–10.0	–15.7	–3.9

Notes:

N/A – Not applicable; no breakpoint.
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

Reach 3 — Little Rapids to De Pere

No fish species with both an adequate sample size and sufficient spread of samples over time for analysis occurred in this reach.

Reach 4 — De Pere to Green Bay

In this reach, six of the seven fish categories show no significant improvement in fit of the spline model over the linear model. Figure 34 shows an example where the linear model fits quite well. For one species, though, a model with a change point in 1995 fits significantly better than the linear model (De Pere to Green Bay, carp, whole body). As seen in Figure 35, this model shows a large increase in log PCB concentration between 1997 and 1999. The substantial number of samples at these two time points may in fact represent a real increase in PCB concentration.

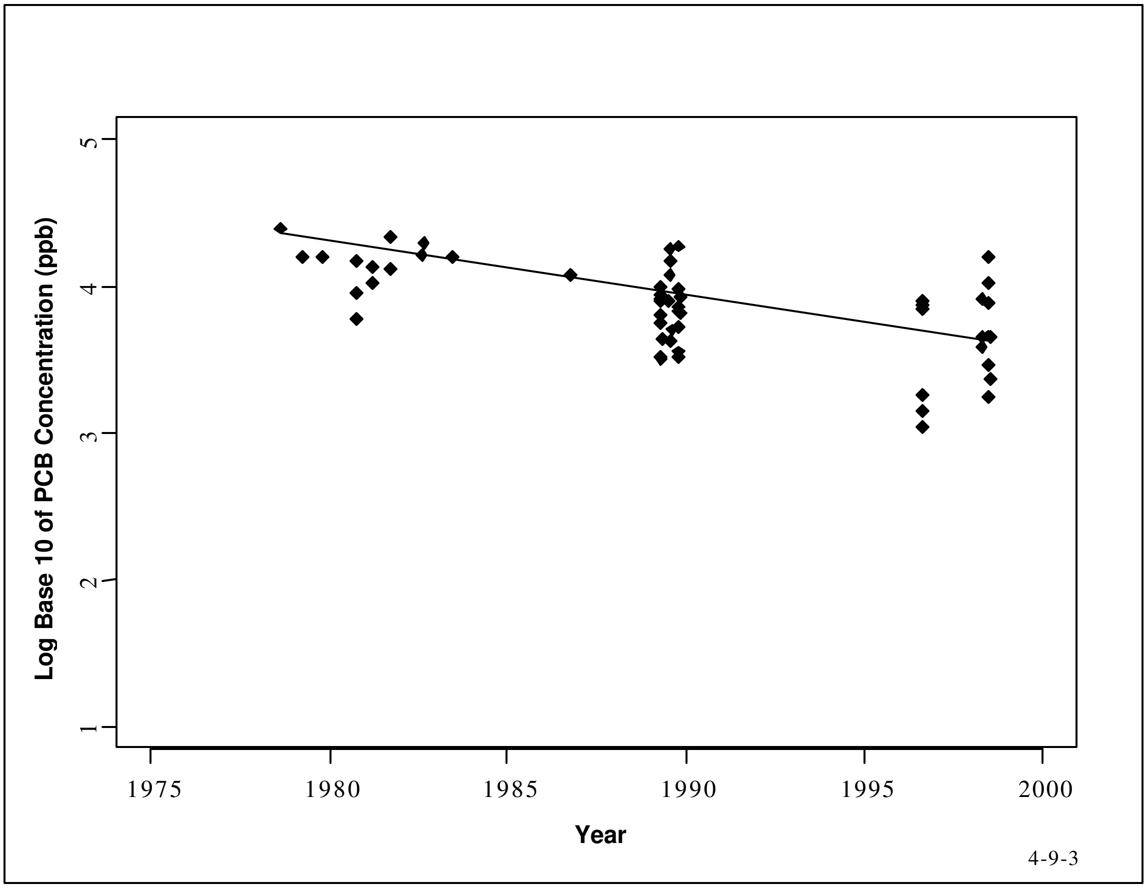


Figure 34 Log$_{10}$ PCB Concentration (ppb) in De Pere to Green Bay Walleye, Whole Body, versus Time

No Breakpoint, Final Slope ($\log_{10}$ PCB versus time) = –0.037 ($p < 0.0001$), Rate of Change of PCB Concentration During Period of Final Slope = –8.1% (95% confidence interval: –10.4% to –5.8%).

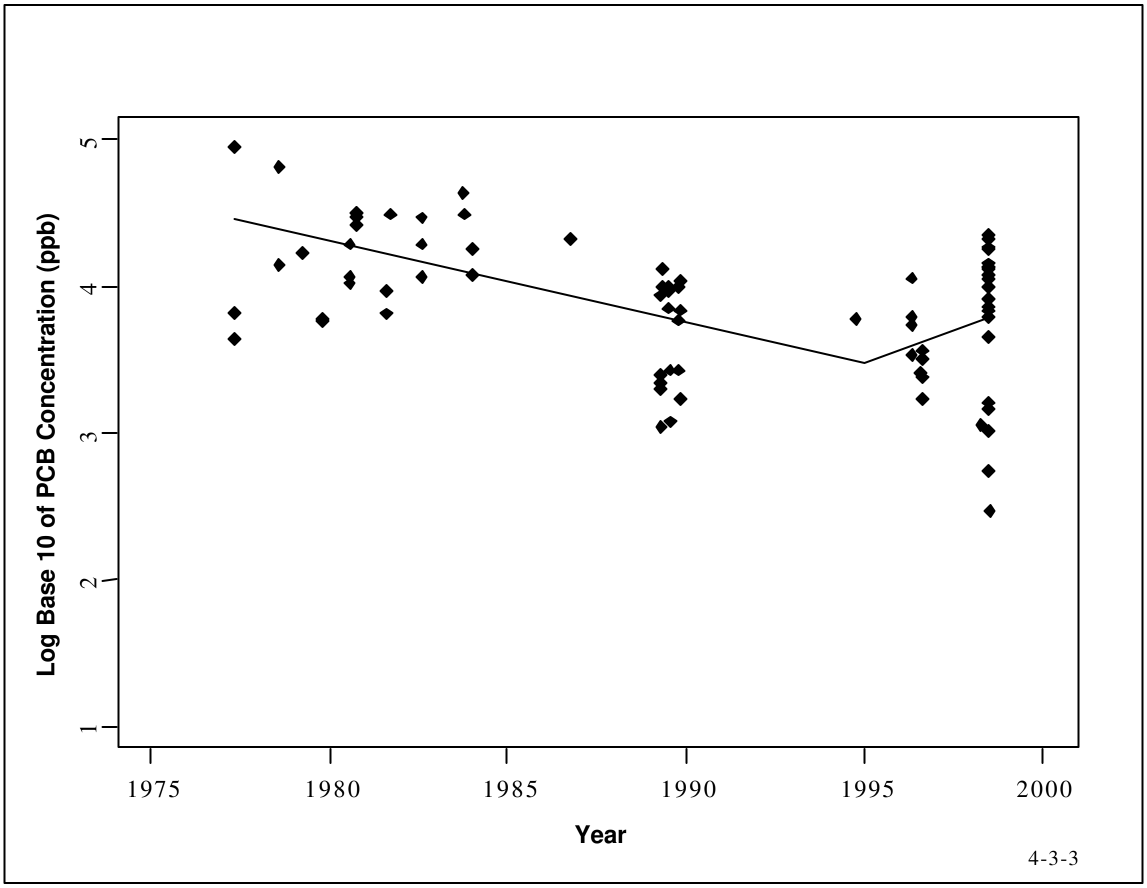


Figure 35 Log_{10} PCB Concentration (ppb) in De Pere to Green Bay Carp, Whole Body, versus Time

Breakpoint = 1995 (p = 0.009), Final Slope (log_{10} PCB versus time) = 0.086 (p = 0.03), Rate of Change of PCB Concentration During Period of Final Slope = 21.8% (95% confidence interval: 2.2% to 45.0%).

The non-significant (p = 0.09) meta-analysis for this reach indicates only weak evidence to reject the overall null hypothesis of a constant rate of change for all species within this reach over the time span of observation (Table 13). The meta-analysis partially remedies the problem of multiple comparisons. That is, if one conducts seven independent hypothesis tests and uses the standard criterion $p <$ 0.05 to designate statistical significance, the probability of finding at least one significant p-value out of these seven tests, when the null hypothesis is really true, approaches 30 percent. This considerably exceeds the 5 percent false positives behind "$p < 0.05$." Thus, the single significant breakpoint for this reach in Table 16 with p = 0.009 may have occurred by chance.

Table 16 PCB Time Trend Results for Fish Samples in De Pere to Green Bay Reach

Species	Sample Type	Year of Break-point	*n*	Final (post-break) Slope				95% Confidence Interval	
				Final Slope	SE	*p*-value	% per Year	LCL	UCL
Carp	whole body	1995	90	0.086	0.038	0.0277*	21.8	2.2	45.0
Gizzard Shad	whole body	N/A	19	–0.023	0.005	0.0002***	–5.1	–7.2	–2.9
Northern Pike	skin-on fillet	N/A	40	–0.046	0.007	<0.0001***	–10.0	–13.0	–6.8
Walleye	skin-on fillet	N/A	120	–0.032	0.004	<0.0001***	–7.2	–8.7	–5.6
	whole body	N/A	58	–0.037	0.005	<0.0001***	–8.1	–10.4	–5.8
White Bass	skin-on fillet	N/A	58	–0.021	0.006	0.0020**	–4.7	–7.5	–1.8
White Sucker	skin-on fillet	N/A	44	–0.036	0.006	<0.0001***	–7.9	–10.3	–5.5

Notes:

N/A – Not applicable; no breakpoint.
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

Reach 5 — Green Bay Zone 2

In the final reach considered, two of the fish categories show a highly significant improvement of the change point model over the linear model. For carp whole body samples, PCB concentration rises sharply until 1983 and then drops. Prior to 1983, there were samples for only five fish at two distinct time points. A similar pattern holds for carp fillet with skin samples, though the spline is statistically non-significant compared to the linear model.

For yellow perch skin-on fillet, we rejected the spline model, even though it formally provided a "better" fit, which can be seen in Figure 36. In this model, one finds a very steep fitted decrease until 1986, followed by a fitted steep increase. The huge amplitude of the estimated seasonal effect, however, exceeds by five- or ten-fold that for other fish categories. These strange results raised the concern that we may have over-fit the model for this species. The spline model for Figure 36 relied on 19 samples collected at seven distinct time points. There are six parameters in time (intercept, final slope, initial slope difference, location of breakpoint, sine and cosine of time of year) and only seven distinct time points. Introducing as many parameters in time as time points risks over-fitting and uncertain or erroneous estimates.

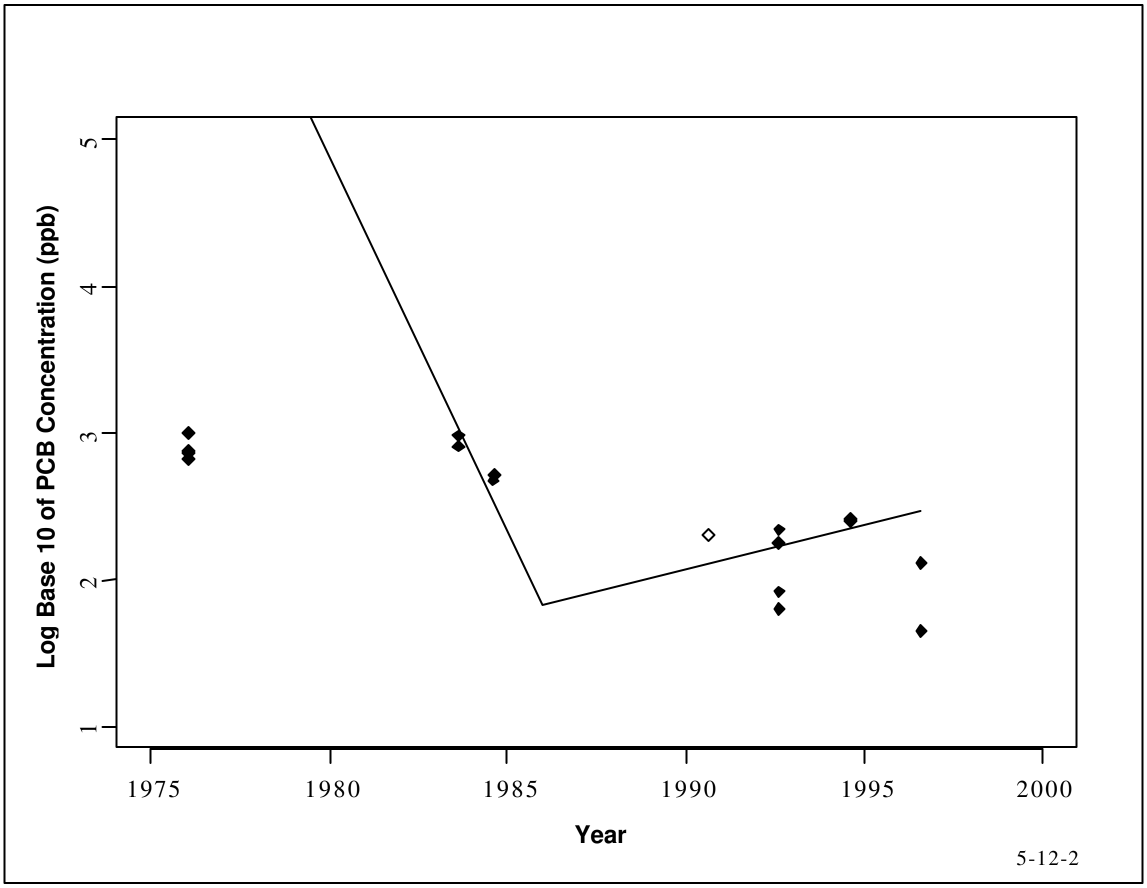


Figure 36 Rejected Spline Model for Green Bay Zone 2 Yellow Perch, Skin-on Fillet

Let us explain over-fitting by analogy. Suppose we choose six distinct time points. At each time point we randomly generate 10 values for log(*PCB*) as if 10 fish were sampled at that time point, for a total of 60 values. Then we fit a polynomial with six parameters (powers of time = X, from constant—X^0—through X^5) and plot the raw data and fitted line on a scatter plot. This polynomial will fit perfectly in time—it will go exactly through the mean value at each time point. Of course, it will probably generate an implausible curve that varies drastically, perhaps with extremely large peaks or valleys between time points. This hypothetical example speaks to our situation. Fitting our model with six parameters in time mirrors fitting a polynomial with six parameters and, therefore, may give ridiculous results. In the example of yellow perch fillet with skin, we encounter only one additional, distinct time point (seven time points instead of six), which reduces but does not eliminate the risk of over-fitting. We recommend discarding the fitted model with a breakpoint at 1986 for yellow perch fillet with skin in this reach, as it exemplifies over-fitting. Therefore, we will use the simple linear model as the best-fitting model for these data (Figure 37). The model provides not only a more plausible fit, but a visually acceptable fit as well.

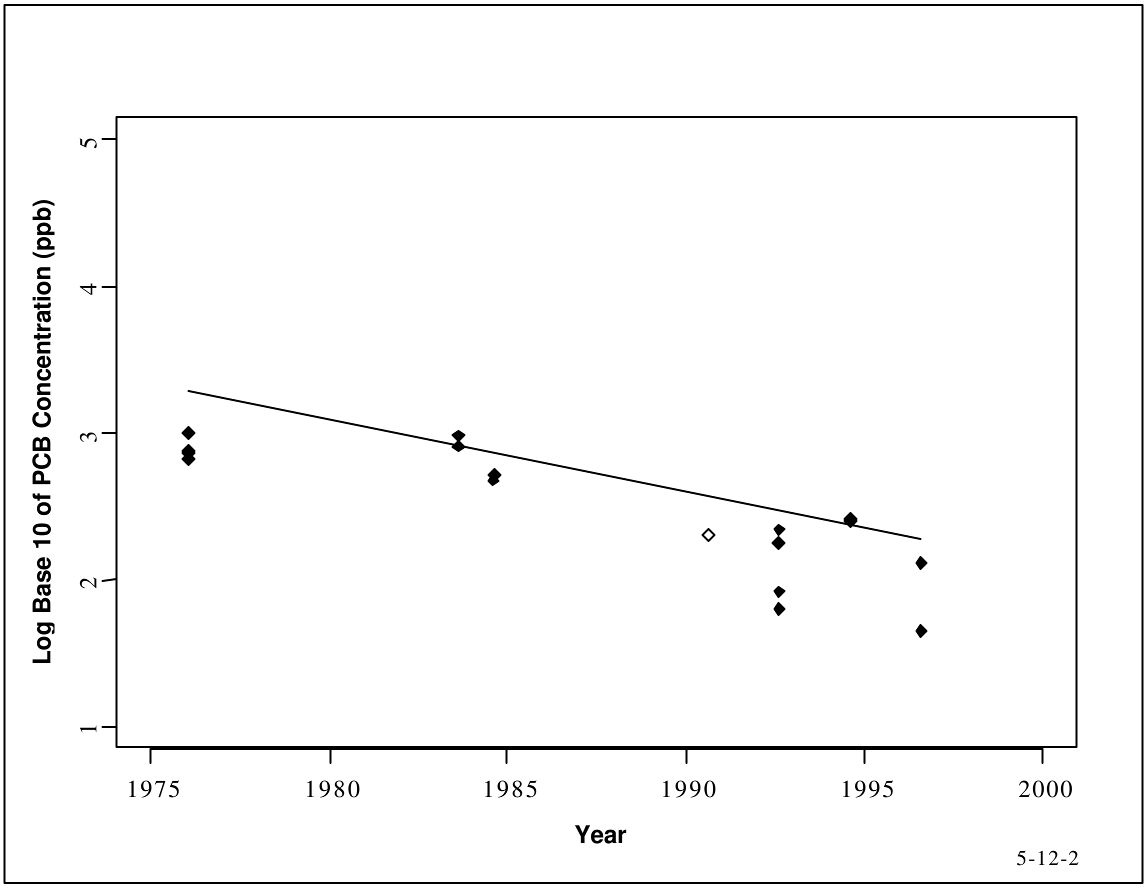


Figure 37 Log$_{10}$ PCB Concentration in Green Bay Zone 2 Yellow Perch, Skin-on Fillet, versus Time

No Breakpoint, Final Slope (log$_{10}$ PCB versus time) = –0.049 (p = 0.004), Rate of Change of PCB Concentration During Period of Final Slope = –10.7% (95% confidence interval: –16.8% to –4.2%). Any values below detection limit are depicted as ◇.

Table 17 PCB Time Trend Results for Fish Samples in Green Bay Zone 2

Species	Sample Type	Year of Break-point	*n*	Final (post-break) Slope				95% Confidence Interval	
				Final Slope	SE	*p*-value	% per Year	LCL	UCL
Alewife	whole body	N/A	44	–0.018	0.009	0.0497*	–4.0	–7.8	0.0
Carp	skin-on fillet	N/A	28	–0.023	0.015	0.1557	–5.1	–11.8	2.2
	whole body	1983	57	–0.073	0.010	<0.0001***	–15.5	–19.5	–11.4
Gizzard Shad	whole body	N/A	32	0.025	0.010	0.0144*	5.9	1.2	10.8
Yellow Perch	skin-on fillet	N/A	19	–0.049	0.014	0.0038**	–10.7	–16.8	–4.2

Notes:

N/A – Not applicable; no breakpoint.
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

Impact of Seasonality and Lipid Content on Best-fitting Model

For each fish category (reach/species/type combination), we determined the best-fitting model, either the linear model or the spline model with one breakpoint, if that showed a significantly better fit than the linear model. Table 18 shows details of the fitted models.

From left to right, Table 18 shows the year of the breakpoint or "N/A" for no breakpoint) in units of $\log_{10}$ (PCB concentration as ppb) per year and the standard error and *p*-value of the slope; the rate of change per year as a percentage along with a 95 percent confidence interval for the percentage; the difference between early and late slope, if applicable, in units of $\log_{10}$ (PCB concentration as ppb) per year, along with the standard error and *p*-value for the difference between early and late slope; the coefficient of $\log_{10}$ (lipid percent) and its standard error and *p*-value; and the month of the maximum amplitude of the seasonal effect and the amplitude (A) and the *p*-value for the seasonal effect. The quantities 10^{A} and 10^{-A} are multipliers that show the relative increase or decrease, respectively, of the seasonal maximum or minimum compared to the annual mean.

We note some interesting features about the covariates in Table 18. The coefficient of log of percent lipid departs significantly from zero for almost all fish categories. This coefficient approaches one for many fish categories, meaning that an analysis using the log of lipid-normalized PCB concentration as the outcome variable, without including percent lipids as a covariate, would be approximately correct. (As noted earlier, lipid normalization is usually calculated as PCB concentration divided by the percent lipid in the tissue.) Yet for several species the coefficient fails to reach 1. This suggests that traditional lipid normalization alone does not control the lipid contribution adequately. The amplitude of the seasonal effect is significantly non-zero for the majority of fish categories, falling mainly in the 0.2 to 0.6 range. We define the amplitude as the height of the seasonal sine curve from zero to the maximum on the log scale, so the range from minimum to maximum is twice this value. On the log scale, the majority of species would fall between 0.4 and 1.2. Calculating the antilog of 0.4 and 1.2 (i.e., 10 raised to that power) tells us that the ratio of maximum to minimum over a year ranges from 2.5 to 16 for the majority of species. This represents substantial seasonal variation. The month in which the peak PCB concentration occurs varies quite a bit across fish categories. A footnote to Appendix Table A-3 explains how to calculate estimated PCB concentration for any time of year, taking account of seasonal variation.

As seen in the plots, we observe quite a bit of variation in log of PCB concentration around the fitted line. Even fish samples taken at the same time vary greatly in PCB concentration. The residual standard deviation (SD), after fitting the model, measures the magnitude of this variation. Using the approximation of plus or minus two SDs allows us to estimate the range, which covers most of the data (from low to high end), at about four SDs. From an appendix table, most of the standard deviation values (calculated as the square root of the mean squared error) fall between 0.15 and 0.35. Four SDs is thus between 0.60 and 1.40 for most species. Taking the antilog of 0.60 and 1.40 gives 4.0 and 25, respectively. This implies very high variation in PCB concentration for a particular reach/species/type: for species with the least variation, the values differ from the low end to the high end by roughly a factor of four, corresponding to an SD of 0.15. That is, for the species with an SD of 0.15, it would not be uncommon to find different samples with a fourfold difference in PCB concentration when sampled at the same time of year and with the same lipid content (e.g., whole body alewife, in Green Bay Zone 2 has an SD = 0.17, similar to 0.15). For species with an SD of 0.35 (such as carp fillet with skin, Little Lake Butte des Morts), it would not be uncommon to find samples differing by a factor of 25 in PCB concentration. Figure 31 shows just such variation and supports the notion of highly variable PCB concentrations within species.

Table 18 Model Parameters and Other Statistics for the Best-fitting Model

Species	Sample Type	Year of Break-point	*n*	Final (post-break) Slope				95% Confidence Interval		Pre-break Slope Minus Final Slope	SE	*p*-value Slope Change	Coef-ficient of Log (% lipid)	SE	*p*-value for Log (% lipid)	Seasonal Peak		*p*-value for Seasonal Effect
				Final Slope	SE	*p*-value	% per Year	LCL	UCL							Mo.	Ampli-tude	
Little Lake Butte des Morts																		
Carp	skin-on fillet	1979	55	−0.028	0.011	0.0177*	−6.1	−10.9	−1.1	−0.228	0.085	0.0102	0.87	0.15	0.0000	12.9	0.39	0.0078
	whole body	1987	40	0.003	0.30	0.9172	0.7	−12.3	15.6	−0.165	0.059	0.0084	0.86	0.33	0.0131	7.0	0.83	0.0025
Northern Pike	skin-on fillet	N/A	19	−0.055	0.011	0.0003***	−11.8	−16.7	−6.7				0.45	0.30	0.1554	1.3	0.67	0.1594
Walleye	skin-on fillet	1990	63	0.015	0.025	0.5576	3.4	−7.8	16.0	−0.095	0.037	0.0140	0.50	0.15	0.0011	11.6	0.20	0.0273
	whole body	1987	18	0.084	0.045	0.0874	21.5	−3.5	52.9	−0.261	0.080	0.0069	0.99	0.36	0.0185	11.6	0.46	0.0040
Yellow Perch	skin-on fillet	1981	34	0.003	0.012	0.8025	0.7	−5.0	6.8	−0.247	0.077	0.0034	0.49	0.21	0.0236	7.0	0.22	0.0007
Appleton																		
Walleye	skin-on fillet	N/A	30	−0.046	0.014	0.0028**	−10.0	−15.7	−3.9				1.08	0.16	0.0000	8.1	0.43	0.0010
De Pere																		
Carp	whole body	1995	90	0.086	0.038	0.0277*	21.8	2.2	45.0	−0.141	0.044	0.0022	0.79	0.11	0.0000	6.7	0.06	0.0004
Gizzard Shad	whole body	N/A	19	−0.023	0.005	0.0002***	−5.1	−7.2	−2.9				0.51	0.09	0.001	8.6	0.58	0.0000
Northern Pike	skin-on fillet	N/A	40	−0.046	0.007	<0.0001***	−10.0	−13.0	−6.8				0.72	0.17	0.0001	10.1	0.17	0.3531
Walleye	skin-on fillet	N/A	120	−0.032	0.004	<0.0001***	−7.2	−8.7	−5.6				0.85	0.07	0.0000	9.5	0.02	0.7566
	whole body	N/A	58	−0.037	0.005	<0.0001***	−8.1	−10.4	−5.8				0.44	0.12	0.0007	7.0	0.12	0.2038
White Bass	skin-on fillet	N/A	58	−0.021	0.006	0.0020**	−4.7	−7.5	−1.8				0.82	0.11	0.0000	6.7	0.33	0.1043
White Sucker	skin-on fillet	N/A	44	−0.036	0.006	<0.0001***	−7.9	−10.3	−5.5				0.43	0.15	0.0071	6.9	0.08	0.5528
Green Bay Zone 2																		
Alewife	whole body	N/A	44	−0.018	0.009	0.0497*	−4.0	−7.8	0.0				0.91	0.14	0.0000	6.1	0.17	0.0335
Carp	skin-on fillet	N/A	28	−0.023	0.015	0.1557	−5.1	−11.8	2.2				0.76	0.15	0.0000	3.9	0.24	0.0288
	whole body	1983	57	−0.073	0.010	<0.0001***	−15.5	−19.5	−11.4	0.266	0.059	0.0000	0.90	0.10	0.0000	6.9	0.24	0.0000
Gizzard Shad	whole body	N/A	32	0.025	0.010	0.0144*	5.9	1.2	10.8				−0.13	0.12	0.2811	2.6	0.34	0.0300

Table 18 Model Parameters and Other Statistics for the Best-fitting Model

Species	Sample Type	Year of Break-point	*n*	Final (post-break) Slope				95% Confidence Interval		Pre-break Slope Minus Final Slope	SE	*p*-value Slope Change	Coef-ficient of Log (% lipid)	SE	*p*-value for Log (% lipid)	Seasonal Peak		*p*-value for Seasonal Effect
				Final Slope	SE	*p*-value	% per Year	LCL	UCL							Mo.	Ampli-tude	
Yellow Perch	skin-on fillet	N/A	19	−0.049	0.014	0.0038**	−10.7	−16.8	−4.2				1.09	0.47	0.353	4.7	0.45	0.5489

Notes:

N/A – Not applicable; no breakpoint.
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

5.2.2 Best-fitting Model, Meta-analysis, Sensitivity Analysis, and Future Projections

In the preceding section, Table 13 and the related discussion presented decisions for each reach, species, and sample type on the choice between a model including a breakpoint in the time trend and a model without a time trend. Accepting that decision, Table 14 through Table 17 presented the final slopes for the best-fitted models. Table 18 presented additional parameters for each best-fitted model. The Appendix includes the full set of parameters for each model.

Table 19 shows the results of meta-analyses for each reach. The final row in each reach gives a combined species analysis. The combined post-breakpoint slope is a weighted average of all the slopes within this reach, weighted by the inverse of the standard error squared. The inverse standard error squared provides weights leading to a minimum variance of the weighted mean estimate in many common sampling situations. Unlike the meta-analysis of surface sediments introduced in Section 4.4.1 (Table 10), where PCB mass provided a natural set of weights, there is no *a priori* set of weights available to use with fish. Thus, weights with good statistical properties have been chosen for the fish meta-analysis. This weighting gives high weights to more precise estimates, usually based on a large sample size, and low weights to imprecise estimates, usually derived from small sample sizes. The *p*-value (based on the normal distribution) tests whether this summary slope differs significantly from zero.

The fish species included in the meta-analysis have diverse habitats, lifecycles, and feeding patterns. Nevertheless, the PCB concentration in each species serves as a sentinel of PCBs in their environment. Just as the economic growth rate of each unique industrial sector of a nation can combine into a single growth rate for a national economy, the time trends of diverse species can combine into a meaningful descriptive statistical time trend for fish species in a reach. This summary rate of change cannot replace the individual species' rates of change. It means only what its definition implies: weighting more heavily on species with more precise slope estimates and less heavily on species with less precise slope estimates provides a reach mean slope which can be compared to zero. An individual species may possibly have a real slope that differs substantially from the combined reach slope. While the combined slope is a summary, the individual slopes cannot be ignored. Also, as noted in Section 4.4.1 in reference to sediment, the combined slope should not be used to project PCB concentrations for all species in the reach.

In addition to the combined reach slope in Table 19, the percent rate of change of PCB concentration implied by the combined slope, b, is also presented, using the following equation:

Equation 17

$$\textit{percent change} = 100 * \left(10^{b} - 1\right)$$

The 95 percent confidence interval for the percent change is also shown in the table (calculated by deriving the 95 percent confidence interval for the slope of log PCB concentration versus time—using the normal distribution and converting the upper and lower confidence bounds to percentages by Equation 17).

In this section, we also address an issue of uncertainty associated with the breakpoint. As mentioned in the methods section, the standard errors for time trend slopes and *p*-values for the best-fitting model do not incorporate the variation due to estimating the location of the breakpoint. They therefore underestimate the uncertainty in the time trend slope. The standard errors shown in the table are too small for those species where the model has a breakpoint. We addressed this problem by performing a sensitivity analysis for each of the seven reach/species/type combinations with a breakpoint model. We identified the earliest and the latest breakpoints that were “plausible,” as described in the methods section. Table 20 shows results for these “earliest” and “latest” models, when there is a breakpoint.

Table 19 Meta-analysis of Fish Time Trends

Species	Sample Type	Log_{10} (PCB) Time Trend Final Slope Estimate	Standard Error	Statistical Weight+	*p*-value	Annual % Change in PCB Concentration	% Change 95% Lower Bound	% Change 95% Upper Bound
Little Lake Butte des Morts								
Carp	skin-on fillet	–0.028	0.011	0.31				
	whole body	0.003	0.30	0.05				
Northern Pike	skin-on fillet	–0.055	0.011	0.30				
Walleye	skin-on fillet	0.015	0.025	0.06				
	whole body	0.084	0.045	0.02				
Yellow Perch	skin-on fillet	0.003	0.012	0.26				
Combined		**–0.022**	**0.006**	**1.00**	**0.0006**	**–4.9**	**–7.5**	**–2.1**
Appleton								
Walleye	skin-on fillet	–0.056	0.016		0.003	–10.0	–17.9	–5.6
De Pere								
Carp	whole body	0.086	0.038	0.00				
Gizzard Shad	whole body	–0.023	0.005	0.21				
Northern Pike	skin-on fillet	–0.046	0.007	0.08				
Walleye	skin-on fillet	–0.032	0.004	0.32				
	whole body	–0.037	0.005	0.15				
White Bass	skin-on fillet	–0.021	0.006	0.10				
White Sucker	skin-on fillet	–0.036	0.006	0.14				
Combined		**–0.031**	**0.002**	**1.00**	**<0.0001**	**–6.9**	**–7.8**	**–6.0**

Table 19 Meta-analysis of Fish Time Trends

Species	Sample Type	Log_{10} (PCB) Time Trend Final Slope Estimate	Standard Error	Statistical Weight+	*p*-value	Annual % Change in PCB Concentration	% Change 95% Lower Bound	% Change 95% Upper Bound
Green Bay Zone 2								
Alewife	whole body	−0.018	0.009	0.31				
Carp	skin-on fillet	−0.023	0.015	0.10				
	whole body	−0.073	0.010	0.22				
Gizzard Shad	whole body	0.025	0.010	0.26				
Yellow Perch	skin-on fillet	−0.049	0.014	0.12				
Combined		**−0.033**	**0.007**	**1.00**	**<0.0001**	**−5.1**	**−7.2**	**−3.0**

Note:

\+ Statistical weight is proportional to the inverse of the squared standard error. Weights sum to 1.0 within each reach.

Figure 38 captures the estimated percent change per year for the best-fitting model for each fish category. The confidence intervals shown in these plots obtain from the results of the best-fitting model and do not incorporate the extra uncertainty due to estimating the location of the breakpoint. Therefore, the reader must remember that the plotted confidence intervals are too narrow for the seven analyses with a breakpoint.

Table 20 Final Slope and Percent Change per Year for Best-fitting Model and Sensitivity Analysis

Species	Sample		Best-fitting Model			Earliest Breakpoint			Latest Breakpoint		
	Type	*n*	Break point Year	% Change per Year	*p*-value (% = 0)	Year	Final Slope: % Change per Year	*p*-value (% = 0)	Year	Final Slope: % Change per Year	*p*-value (% = 0)
Little Lake Butte des Morts											
Carp	skin-on fillet	55	1979	–6.15	0.0177	1979	–6.15	0.0177	1985	–1.56	0.7419
	whole body	40	1987	0.71	0.9172	1985	–4.04	0.5264	1990	–0.25	0.9765
Northern Pike	skin-on fillet	19	N/A	–11.83	0.0003						
Walleye	skin-on fillet	63	1990	3.44	0.5576	1979	–8.37	0.0000	1994	8.82	0.4482
	whole body	18	1987	21.47	0.0874	1984	15.10	0.2024	1990	21.11	0.1324
Yellow Perch	skin-on fillet	34	1981	0.73	0.8025	1979	0.27	0.9252	1996	333.61	0.0122
Appleton											
Walleye	skin-on fillet	30	N/A	–9.97	0.0028						
De Pere											
Carp	whole body	90	1995	21.76	0.0277	1990	–0.69	0.8232	1996	29.80	0.0191
Gizzard Shad	whole body	19	N/A	–5.07	0.0002						
Northern Pike	skin-on fillet	40	N/A	–9.95	0.0000						
Walleye	skin-on fillet	120	N/A	–7.19	0.0000						
	whole body	58	N/A	–8.11	0.0000						
White Bass	skin-on fillet	58	N/A	–4.72	0.0020						
White Sucker	skin-on fillet	44	N/A	–7.90	0.0000						
Green Bay Zone 2											
Alewife	whole body	44	N/A	–3.96	0.0497						
Carp	skin-on fillet	28	N/A	–5.06	0.1557						
	whole body	57	1983	–15.54	0.0000	1983	–15.54	0.0000	1984	–16.15	0.0000
Gizzard Shad	whole body	32	N/A	5.91	0.0144						
Yellow Perch	skin-on fillet	19	N/A	–10.75	0.0038						

Note:

N/A – Not applicable; no breakpoint.

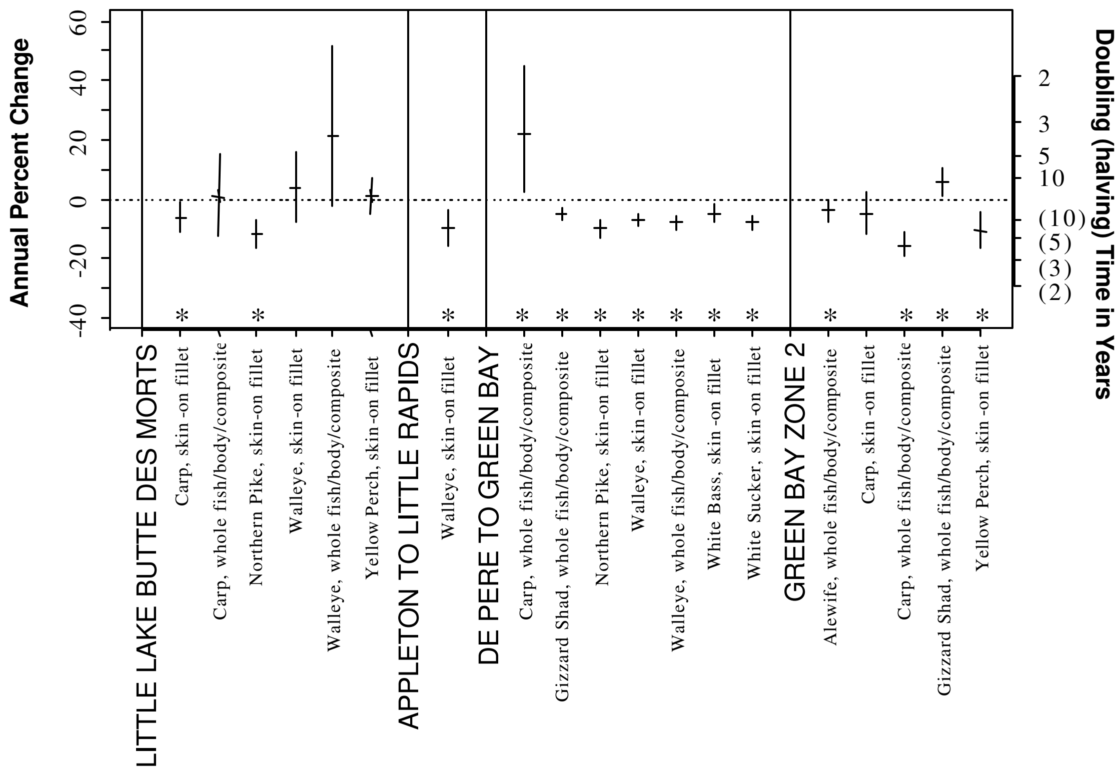


Figure 38 95 Percent Confidence Intervals Showing Annual Percent Rate of Change (Left Vertical Axis) in PCB Concentrations by Reach, Species, and Sample Type

An asterisk (*) indicates a rate of change that differs significantly from zero. Right vertical axis expresses time trend change in terms of doubling and halving times.

Table 21 shows projections into the future based on the best-fitting model, spline, or simple linear trend. We present the estimated mean PCB concentration in the years 1999 and 2020, with 95 percent confidence intervals for the concentration at each year. For fish categories with a negative final slope (the post-breakpoint slope for the spline models), the table also shows estimated times until PCB concentration drops below specified concentrations. The methods section provided the formulae for computing these quantities.

Table 21 Projecting into the Future—Predicted Mean PCB Concentration (ppb) in 1999 and 2020 and Time When Specified PCB Concentrations Will Be Reached

Species	Sample Type	Year of Break point	Estimate of Mean PCB Concentration in 1999			Estimate of Mean PCB Concentration in 2020			Year in Which Specified PCB Concentration (ppb) Is Reached								
			Mean PCB (ppb)	Lower 95% CI	Upper 95% CI	Mean PCB (ppb)	Lower 95% CI	Upper 95% CI	1,400	240	220	140	63	38	20	5	0.5
Little Lake Butte des Morts																	
Carp	skin-on fillet	1979	1,399	589	3,319	369	56	2,429	1999	2027	2028	2035	2048	2056	2066	2088	2124
	whole body	1987	2,506	1,055	5,954	2,910	78	109,080									
Northern Pike	skin-on fillet	N/A	149	59	375	11	2	73	1981	1995	1996	1999	2006	2010	2015	2026	2044
Walleye	skin-on fillet	1990	251	131	483	511	27	9,824									
	whole body	1987	1,266	515	3,113	75,208	534	10,591,388									
Yellow Perch	skin-on fillet	1981	255	110	590	296	40	2,173									
Appleton																	
Walleye	skin-on fillet	N/A	376	117	1,212	41	3	496	1986	2003	2004	2008	2016	2021	2027	2040	2062
De Pere																	
Carp	whole body	1995	7,526	5,439	10,414	470,285	9,207	24,021,513									
Gizzard Shad	whole body	N/A	1,709	1,463	1,995	573	329	1,000	2003	2037	2038	2047	2062	2072	2085	2111	2156
Northern Pike	skin-on fillet	N/A	542	364	807	60	25	145	1990	2007	2008	2012	2020	2024	2030	2044	2066
Walleye	skin-on fillet	N/A	781	647	941	163	103	257	1991	2015	2016	2022	2033	2039	2048	2067	2098
	whole body	N/A	4,343	3,384	5,575	736	374	1,449	2012	2033	2034	2040	2049	2055	2063	2079	2106
White Bass	skin-on fillet	N/A	2,693	1,659	4,370	975	342	2,781	2013	2049	2051	2060	2077	2087	2100	2129	2177
White Sucker	skin-on fillet	N/A	637	414	981	113	48	268	1989	2011	2012	2017	2027	2033	2041	2058	2086
Green Bay Zone 2																	
Alewife	whole body	N/A	2,106	1,378	3,219	901	269	3,022	2009	2053	2055	2066	2086	2098	2114	2148	2205

Table 21 Projecting into the Future—Predicted Mean PCB Concentration (ppb) in 1999 and 2020 and Time When Specified PCB Concentrations Will Be Reached

Species	Sample Type	Year of Break point	Estimate of Mean PCB Concentration in 1999			Estimate of Mean PCB Concentration in 2020			Year in Which Specified PCB Concentration (ppb) Is Reached								
			Mean PCB (ppb)	Lower 95% CI	Upper 95% CI	Mean PCB (ppb)	Lower 95% CI	Upper 95% CI	1,400	240	220	140	63	38	20	5	0.5
Carp	skin-on fillet	N/A	4,852	2,224	10,587	1,630	180	14,784	2023	2057	2059	2067	2083	2092	2105	2131	2176
	whole body	1983	1,468	935	2,305	42	10	175	1999	2010	2010	2013	2018	2021	2024	2033	2046
Gizzard Shad	whole body	N/A	3,159	2,129	4,687	10,549	2,965	37,524									
Yellow Perch	skin-on fillet	N/A	150	23	997	14	1	143	1979	1995	1996	2000	2007	2011	2017	2029	2049

Note:

N/A – Not applicable; no breakpoint.

All of the estimated times to reach specified concentrations in Table 21, as well as the estimated concentrations for 1999 and 2020, require extremely careful interpretation. We have based all of these estimates on the untestable assumption that the PCB concentration will continue to change in the future at the same rate as during the post-breakpoint period. In addition, as noted repeatedly, the confidence intervals for models that include a breakpoint do not incorporate the extra uncertainty related to breakpoint estimation and are too narrow.

A striking feature of the table is that most of the confidence intervals are very wide. For instance, for carp whole body in Little Lake Butte des Morts, the expected mean concentration in the year 2020 is 2,910 ppb, but the range is huge: 78 to 109,080 ppb. For those cases with a wide confidence interval in 2020 (or 1999), the time to reach specified concentrations (in the right half of the table) can also be expected to have a wide confidence interval.

We now discuss these tables for each reach. The appendix contains plots of observed values and fitted time trends for every fish category referred to below. Remember that the fitted values represent fish sampled on July 1 of the given year and with mean log lipid content as observed in the samples used to build the model. The values of mean log percent lipid are shown in Table 22. Thus, the fitted trend lines may differ from a best visual fit that does not account for lipids or season. This apparent lack of correspondence occurs in several plots.

Table 22 Mean Log_{10} Percent Lipid in Fish Tissue

Reach	Species	Type	Mean Log Percent Lipid
Little Lake Butte des Morts	Carp	skin-on fillet	0.68
		whole body	0.90
	Northern Pike	skin-on fillet	0.00
	Walleye	skin-on fillet	0.11
		whole body	0.73
	Yellow Perch	skin-on fillet	–0.01
Appleton	Walleye	skin-on fillet	–0.03
De Pere	Carp	whole body	0.88
	Gizzard Shad	whole body	0.82
	Northern Pike	skin-on fillet	0.07
	Walleye	skin-on fillet	0.31
		whole body	0.97
	White Bass	skin-on fillet	0.60
	White Sucker	skin-on fillet	0.23
Green Bay Zone 2	Alewife	whole body	0.97
	Carp	skin-on fillet	0.82
		whole body	0.98
	Gizzard Shad	whole body	0.77
	Yellow Perch	skin-on fillet	–0.29

Reach 1 — Little Lake Butte des Morts

Carp, Skin-on Fillet

After the breakpoint in 1979, PCP concentration declines at a rate of 6 percent per year ($p = 0.02$, Table 14) down to about 1,400 ppb by 1999. Projecting the same rate of decline out to the year 2020 gives an estimated mean PCB concentration of 370 ppb (Table 21), but with a very wide 95 percent confidence interval. Note in particular that the 2,400 ppb upper-bound on the confidence interval for the concentration in 2020 is higher than the estimated concentration 21 years earlier in 1999. Sensitivity analysis (Table 20) shows that a later breakpoint, at 1985, agrees with the data and gives a lower estimate of the post-breakpoint rate of decline, namely, 1.6 percent per year.

The significant negative slope from the best model (Table 14) and the negative slopes from both the earliest and latest breakpoints in the sensitivity analysis (Table 20) consistently suggest that PCBs are decreasing in this species/type in Little Lake Butte des Morts.

Carp, Whole Body

After the breakpoint at 1987, PCB concentration stays almost constant at a level of about 2,500 ppb (0.7% per year, $p = 0.9$). Figure 39 identifies two rather low values in 1987 and 1990. These values do not warrant rejection from the analysis, and the slope calculated with them is appropriate. As a learning exercise, on the other hand, one can illustrate the strong influence of individual observations by omitting these values. A calculation of slope without these two samples would show a continuing decline in PCB concentration to less than 1,000 ppb by 1999.

The barely positive and non-significant slope from the best model versus the negative and barely negative slopes from the earliest and latest breakpoint models, respectively, show no clear evidence of a slope differing from zero for carp whole body samples in Little Lake Butte des Morts.

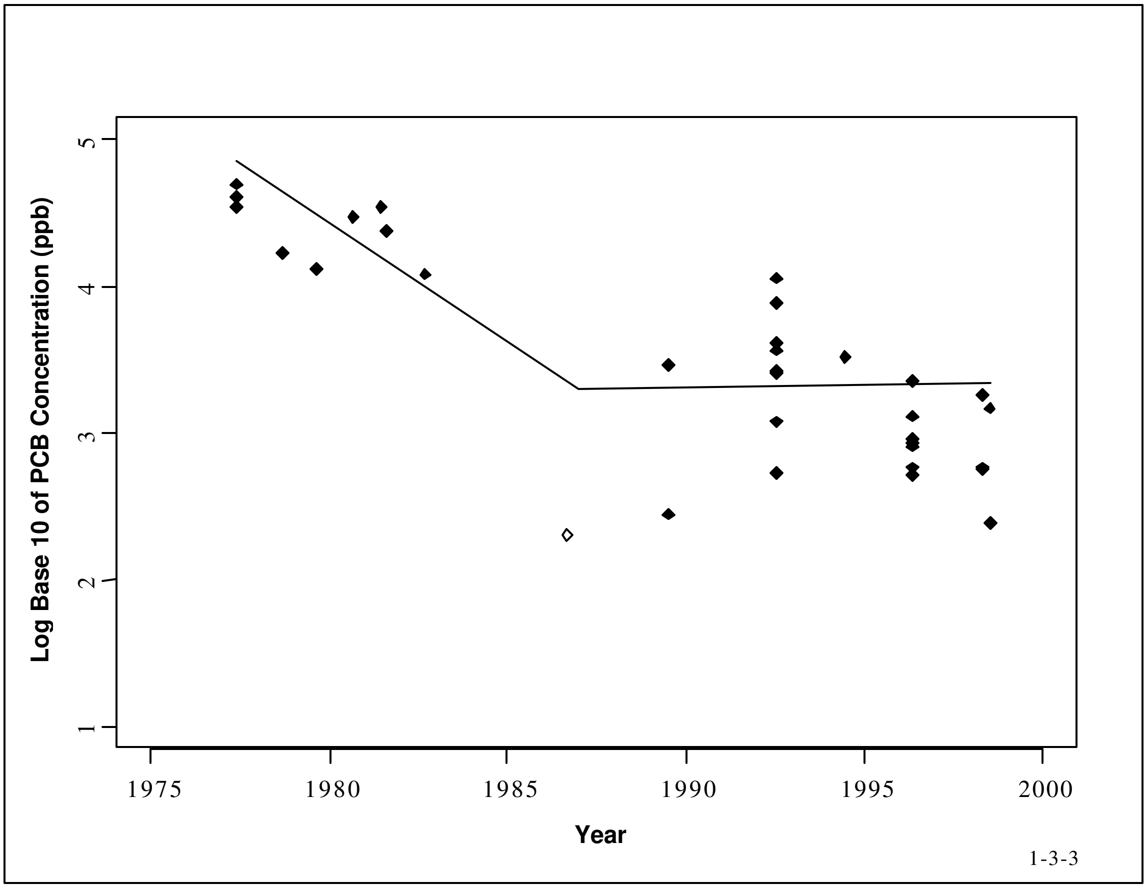


Figure 39 Log$_{10}$ PCB Concentration (ppb) in Little Lake Butte des Morts Carp, Whole Body, versus Time

Breakpoint = 1987 (p = 0.03), Final Slope (log$_{10}$ PCB versus time) = 0.003 (p = 0.09), Rate of Change of PCB Concentration During Period of Final Slope = 0.7% (95% confidence interval: –12.3% to 15.6%). Any values below detection limit are depicted by ◇.

Northern Pike, Skin-on Fillet

The best-fitting model has no breakpoint, but rather a constant rate of decline of 12 percent per year (p = 0.0003) yielding a concentration of about 150 ppb by 1999, with a projected mean in the year 2020 of 10 ppb. This is a case of a clear decline during the observation period.

Walleye, Skin-on Fillet

After the breakpoint in 1990, we view a barely increasing PCB concentration hovering around 250 ppb (3.4% per year, p = 0.6). The sensitivity analysis (Table 20) shows that a model with an earlier breakpoint, in 1979, also suits the data, producing a post-breakpoint decline of 8 percent per year, and the late 1994 breakpoint produces an increase of 9 percent per year. There is no strong evidence of a slope differing from zero.

Walleye, Whole Fish

The best-fitting model shows a decline in PCB concentration to about 100 ppb in 1987, then a sharp increase at 21 percent per year up to a level of 1,300 ppb by 1999. These parameter estimates are rather imprecise since this model relied upon only 18 samples. The estimated final slope of a 21 percent increase per year is not significantly different from zero, and its confidence interval is very wide: –4 to 53 percent.

Yellow Perch, Skin-on Fillet

PCB concentration declines sharply until 1981 at 43 percent per year and stays fairly constant thereafter at a level of about 250 ppb (+0.7% per year, $p = 0.8$). There is no evidence of a decreasing late trend.

Summary of Results for Reach 1 — Little Lake Butte des Morts

For most of the fish categories in this reach, we observe an early rapid decline followed by either a slower decline or a flattening without further decline. We find strong evidence against the rate of decline being constant over the whole time range.

On Figure 38, we notice narrow confidence intervals for three fish categories (carp, skin-on fillet; northern pike, skin-on fillet; yellow perch, skin-on fillet). The confidence intervals are much wider for the other three categories, which indicates that the data from these categories do not provide sufficient information to accurately estimate the final slope. The meta-analysis that combines all six results assigns almost all the weight to the three with narrow confidence intervals. Two of these show a negative final slope while one shows a final slope of virtually zero. The combined analysis gives an estimated post-breakpoint rate of decline of 4.9 percent per year—significantly different from zero ($p = 0.0006$). This combined analysis leads us to conclude that PCB concentrations were declining, on the average, at a slow rate during the data collection period. During future periods, species with lower rates of decline would gradually dominate the average rate of decline across species. As noted earlier, the combined rate of change cannot be used for forward projection.

Reach 2 — Appleton to Little Rapids

Walleye, Skin-on Fillet

PCB concentration declines at a constant rate of 10 percent per year over the whole time period ($p = 0.003$), down to an estimated mean of 380 ppb in 1999 and a projected mean of 40 ppb by the year 2020. The sensitivity analysis also shows a negative slope for both the earliest (1982) and latest (1994) breakpoints.

Reach 4 — De Pere to Green Bay

Carp, Whole Fish

This model shows decline in PCB concentration to a minimum of about 3,200 ppb in 1995 (the breakpoint), followed by a sharp increase of 22 percent per year ($p = 0.03$) up to a mean of 7,500 ppb by 1999. We find a rather wide confidence interval for this rate of increase, but it does not quite include zero. The sensitivity analysis, on the other hand, shows that the data are also consistent with an earlier breakpoint in 1990, followed by a slightly negative slope, close to zero. Thus, despite the *p*-value of 0.03 for the post-breakpoint negative slope, when we add in the uncertainty due to the breakpoint, the final slope is not convincingly different than zero.

Gizzard Shad, Whole Fish

PCB concentration declines at a constant rate of 5 percent per year ($p = 0.0002$) to a mean of 1,700 ppb in 1999 and a projected mean of 570 ppb in 2020.

Northern Pike, Skin-on Fillet

PCB concentration declines at a constant rate of 10 percent per year ($p < 0.0001$) to a mean of 540 ppb in 1999 and projected mean of 60 ppb in 2020.

Walleye, Skin-on Fillet

PCB concentration declines at a constant rate of 7 percent per year ($p < 0.0001$) to a mean of 780 ppb in 1999 and projected mean of 160 ppb in 2020. The spread of observations (more than 20 years) in this analysis, and in the preceding analysis for northern pike, helps to considerably improve the precision of the combined slope estimates for this reach (see below).

Walleye, Whole Fish

PCB concentration declines at a constant rate of 8 percent per year ($p < 0.0001$) to a mean of 4,300 ppb in 1999 and projected mean of 740 ppb in 2020.

White Bass, Skin-on Fillet

PCB concentration declines at a constant rate of 5 percent per year ($p = 0.002$), to a mean of 2,700 ppb in 1999 and projected mean of 980 ppb in 2020. Sensitivity analysis shows the data are consistent with a late breakpoint at 1996 followed by a slope that slightly increases.

White Sucker, Skin-on Fillet

PCB concentration declines at a constant rate of 8 percent per year ($p < 0.0001$), to a mean of 640 ppb in 1999 and projected mean of 110 ppb in 2020.

Summary of Results for Reach 4 — De Pere to Green Bay

All but one of the fish categories show a decline in PCB concentration at a constant rate. The meta-analysis results reflect this, with an estimated rate of decline of 7 percent per year, highly significantly different from zero

($p < 0.0001$). Whole body carp, with a breakpoint in 1995, emerges as the only exception to this pattern of monotonically decreasing PCB concentration, occurring in six out of seven of the analyses. These slopes have relatively tight confidence intervals. One can explain the large increase after 1995 in carp due to high PCB concentrations observed in a large number of fish sampled on July 2 and July 6, 1998. Such a phenomenon might reflect a scouring event that exposed buried sediment with a high PCB concentration. Or the large positive slope for the carp may be random, given that the sensitivity analysis accords with a slightly negative to a large positive slope for this reach/species/type combination, as discussed earlier.

Reach 5 — Green Bay Zone 2

Alewife, Whole Body

PCB concentration declined at a constant rate of 4 percent per year ($p = 0.05$) to a mean of 2,100 ppb in 1999 and a projected mean of 900 ppb in 2020.

Carp, Skin-on Fillet

PCB concentration declines at a constant rate of 5 percent per year ($p = 0.16$, not significantly different from zero) to a mean of 4,900 ppb in 1999 and projected mean of 1,630 ppb in 2020.

Carp, Whole Fish

PCB concentration increases to a maximum of about 25,000 ppb in 1983, and then declines at a rate of 16 percent per year ($p < 0.0001$) down to a mean of 1,500 ppb in 1999 and projected mean of 40 ppb in 2020. An informal sensitivity analysis does not alter the combination of an initially positive and final negative slope. However, we are concerned about having potentially over-fit the model. We have only 5 years during which data were collected over a period covering about 20 years. Given that five parameters in the model relate to time (breakpoint, final slope, slope difference [early minus late], and two season parameters), it is possible to fit a spline model "too well" to the limited number of years with observations. In any case, the final slope does appear firmly negative, though it may be less negative than the 16 percent. A model fitted without a breakpoint yields a single negative slope with a rate of decline of 9 percent per year.

Gizzard Shad, Whole Fish

Samples were only taken over a relatively short time period from 1989 to 1999. PCB concentration appears to increase over this time period at a rate of 6 percent per year ($p = 0.01$) to a mean of 3,200 in 1999.

Yellow Perch, Skin-on Fillet

PCB concentration declines at a constant rate of 11 percent per year ($p = 0.004$) to a mean of 150 ppb in 1999 and projected mean of 14 ppb in 2020.

We have rejected a model with a breakpoint at 1986, even though the breakpoint is, formally, highly significant ($p = 0.0008$). The breakpoint model yields a final rate of change of plus 15 percent per year and a pre-break rate of minus 69 percent per year. We regard this implausible combination as due to over-fitting (mentioned earlier) and accept, instead, the single-slope model noted in the figure and table.

Summary of Results for Reach 5 — Green Bay Zone 2

Four out of the five fish categories for this reach show a continuing decline in PCB concentration. The meta-analysis results reflect this, yielding a combined estimate of final rate of decline of 5 percent per year ($p < 0.0001$).

5.2.3 Additional Analysis of Alternative Models

Results for Fitting Models with Breakpoint at 1985

In addition to showing results for the best-fitting model, we fit models to the 19 fish categories using a single common breakpoint. The best year for this breakpoint is 1985. A breakpoint at 1985 fits nearly as well as the optimal breakpoint for almost all fish categories. Table 23 shows results of fitting this model to every fish category.

Testing for a Non-constant Final Slope

Projection of PCB concentrations presumes some kind of steady or predictable state. In this section, we consider the "steadiness" of time trends. In order to test the assumption of a constant linear slope in the time period after the breakpoint, we fit models including a quadratic term for that time period. Table 24 shows the results of these analyses for the best-fitting model.

Table 23 Details of Fitting Models with a Breakpoint at 1985 for Every Fish Category

Species	Type	Model	Break-point Year	*n*	Inter-cept	SE Int	Estimate of Final (post-1985) Slope			Early Slope Difference			Coefficient of Log of Percent Lipids			Peak of Seasonal Variation		
							Slope	SE	*p*-value	Dif-ference	SE	*p*-value	Log_{10}	SE	*p*-value	Mo.	Amp.	*p*-value
Little Lake Butte des Morts																		
Carp	skin-on fillet	2	1985	55	3.23	0.12	−0.007	0.021	0.7419	−0.090	0.043	0.0403	0.86	0.16	0.0000	12.9	0.59	0.0268
	whole body	2	1985	40	3.41	0.16	−0.018	0.028	0.5264	−0.158	0.072	0.0360	0.87	0.34	0.0148	7.0	0.69	0.0099
Northern Pike	skin-on fillet	2	1985	19	2.84	0.19	−0.079	0.024	0.0053	0.071	0.061	0.2663	0.57	0.31	0.0854	1.8	0.56	0.0829
Walleye	skin-on fillet	2	1985	63	2.46	0.09	−0.026	0.012	0.0379	−0.061	0.032	0.0570	0.43	0.14	0.0038	12.7	0.25	0.1026
	whole body	2	1985	18	2.22	0.39	0.074	0.045	0.1285	−0.310	0.103	0.0106	0.97	0.36	0.0206	11.9	0.66	0.0077
Yellow Perch	skin-on fillet	2	1985	34	2.10	0.10	0.018	0.019	0.3297	−0.133	0.049	0.0110	0.34	0.21	0.1144	10.7	0.11	0.0025
Appleton																		
Walleye	skin-on fillet	2	1985	30	3.20	0.20	−0.065	0.022	0.0059	0.103	0.089	0.2574	1.23	0.20	0.0000	7.4	0.56	0.0005
De Pere																		
Carp	whole body	2	1985	90	3.94	0.09	−0.025	0.011	0.0238	−0.031	0.033	0.3508	0.82	0.12	0.0000	6.9	0.15	0.0304
Northern Pike	skin-on fillet	2	1985	40	3.13	0.11	−0.039	0.010	0.0005	−0.020	0.024	0.4111	0.71	0.17	0.0002	9.0	0.13	0.2505
Walleye	skin-on fillet	2	1985	120	3.21	0.05	−0.035	0.005	0.0000	0.011	0.018	0.5282	0.86	0.07	0.0000	8.7	0.02	0.6196
	whole body	2	1985	58	4.00	0.07	−0.039	0.009	0.0000	0.009	0.028	0.7440	0.45	0.12	0.0007	7.0	0.12	0.1931
White Bass	skin-on fillet	2	1985	58	3.61	0.07	−0.019	0.007	0.0065	−0.117	0.109	0.2897	0.83	0.11	0.0000	6.8	0.32	0.0592
White Sucker	skin-on fillet	2	1985	44	3.12	0.08	−0.032	0.010	0.0020	−0.013	0.025	0.6010	0.43	0.15	0.0065	7.3	0.08	0.4813
Green Bay Zone 2																		
Alewife	whole body	2	1985	44	3.42	0.06	−0.002	0.011	0.8200	−0.087	0.040	0.0341	0.90	0.13	0.0000	5.4	0.09	0.0034
Carp	skin-on fillet	2	1985	28	3.84	0.08	−0.063	0.026	0.0226	0.105	0.055	0.0698	0.74	0.14	0.0000	3.0	0.41	0.0052
	whole body	2	1985	57	3.89	0.06	−0.075	0.013	0.0000	0.135	0.040	0.0013	0.87	0.10	0.0000	6.6	0.23	0.0013
Yellow Perch	skin-on fillet	2	1985	19	2.60	0.35	0.015	0.018	0.4061	−0.745	0.170	0.0007	1.54	0.35	0.0008	7.2	2.99	0.0008

Table 24 Test for Curvature in Final Slopes

Species	Type	Coefficient of *t*-squared	SE of *t*-squared Coefficient	Tests for Curvature		
				p-value+ (2-sided)	*p*-value+ (1-sided, plus)	*p*-value+ (1-sided, minus)
Little Lake Butte des Morts						
Carp	skin-on fillet	−0.0014	0.0024	0.56	0.718	0.564
	whole body	−0.0144	0.0067	0.04*	0.981	0.039*
Northern Pike	skin-on fillet	−0.0033	0.0024	0.19	0.905	0.190
Walleye	skin-on fillet	−0.0095	0.0094	0.32	0.842	0.317
	whole body	−0.0202	0.0101	0.07	0.965	0.070
Yellow Perch	skin-on fillet	−0.0021	0.0059	0.72	0.639	0.722
Appleton to Little Rapids						
Walleye	skin-on fillet	−0.0047	0.0041	0.26	0.872	0.255
De Pere to Green Bay						
Carp	whole body	0.0168	0.0362	0.64	0.644	0.678
Gizzard Shad	whole body	0.0032	0.0029	0.29	0.290	0.855
Northern Pike	skin-on fillet	0.0009	0.0008	0.25	0.249	0.876
Walleye	skin-on fillet	−0.0005	0.0006	0.42	0.791	0.418
	whole body	0.0000	0.0008	0.97	0.514	0.971
White Bass	skin-on fillet	0.0015	0.0018	0.41	0.410	0.795
White Sucker	skin-on fillet	0.0011	0.0010	0.30	0.300	0.850
Green Bay Zone 2						
Alewife	whole body	0.0019	0.0011	0.10	0.099	0.950
Carp	skin-on fillet	−0.0061	0.0035	0.10	0.952	0.096
	whole body	0.0034	0.0018	0.06	0.062	0.969
Gizzard Shad	whole body	−0.0007	0.0032	0.82	0.591	0.818
Yellow Perch	skin-on fillet	0.0126	0.0034	0.003**	0.003**	0.999
All				**0.008****	**0.4**	**0.2**

Notes:

+ The three *p*-values indicate the statistical significance of the *t*-squared (curvature) term in the regression model for time trends. In all three columns, the null hypothesis is no curvature (i.e., there is a straight-line constant slope after the breakpoint—or the whole period, if there is no breakpoint). In the first *p*-value column, the alternative hypothesis is that the final time period has some curvature (i.e., the slope is shifting **either** toward more positive **or** more negative values). In the second *p*-value column, the alternative hypothesis is that the slope is shifting toward more positive values (less decline in PCB concentrations). In the third column, the alternative hypothesis is that the slope is shifting toward more negative values (greater decline in PCB concentrations).

* $p < 0.05$

** $p < 0.01$

*** $p < 0.001$

This model introduces a time-squared term for the final period. It is an implausible model for projection of PCB concentration, but readily works to detect a non-constant rate of decline of PCBs during the final period. We refer to this as "curvature." A positive sign for the time-squared term indicates a shifting slope over time toward either less reduction in PCBs or more accrual of PCBs. A negative sign indicates a shift toward more reduction or less accrual.

The results (Table 24) show two categories with significant curvature, discussed below. Overall, curvature may be a general phenomenon. A meta-analysis using chi-squared calculated from the 19 *p*-values for curvature yields $X^2 = 61.3$, with 38 degrees of freedom and $p = 0.008$. Thus, we reject the null hypothesis that **all** of the final periods, after the breakpoints (including the entire period, if there is no breakpoint), have a simple linear trend (on the log scale). We note, also, that 6 out of the 19 *p*-values for curvature are less than 0.10, whereas only 2 would be expected by chance. This excess of small *p*-values suggests that "curvature," or changing slopes over time, is common and not a feature confined to one or two of the categories analyzed here. Further, it appears that the curvature is a mixture of positive and negative changes (i.e., there are slopes that may shift toward either more negative or more positive rates of change as time passes). The evidence for a mixture of positive and negative changes is two-fold. First, there is both a positive and a negative curvature result among the two fish categories with $p < 0.05$ on the curvature test. In Green Bay Zone 2, yellow perch samples of skin-on fillet evidence that their rate of decline is decreasing (toward less reduction of PCBs) with $p = 0.002$, and in Little Lake Butte des Morts carp whole body samples evidence that their recent barely positive slope is changing toward an either flat or negative trend with more reduction of PCBs ($p = 0.04$). Among the six fish categories with $p < 0.10$ for curvature (marginally significant results) we again find quite an even mixture of positive and negative curvature—three of each. Overall, 9 categories with fitted curvature with a positive coefficient (rates of decline shifting toward slower reduction of PCBs over time) and 10 have negative curvature (rates of decline shifting toward faster reduction of PCBs over time).

There is a second reason we feel that slopes are shifting both positively and negatively. A meta-analysis using a one-sided test to detect an excess of fish categories with positive curvature (toward less reduction of PCBs) yields $p = 0.4$, and the *p*-value for an excess of negative curvature (toward more reduction of PCBs) yields $p = 0.2$. These two *p*-values indicate no significant excess of either only positively or only negatively curving slopes, but there is a significant excess of curving slopes in general (either positive or negative). Thus, we find evidence for changing slopes ($p = 0.008$, noted above), but of mixed direction among the fish categories. We can only be confident that there is change.

The generally non-significant *p*-values in the two-sided *p*-value column of Table 24, and in other *p*-value columns inspire confidence of curvature in very few cases. Except for the four *p*-values noted with asterisks (not including "All"), it is difficult to ascribe curvature to the specific combinations of species, reach, and sample type. However, the excess of relatively small two-sided *p*-values overall (even if individual *p*-values are not significant) does allow us to conclude with some confidence that there is changeability in the final slopes ($p = 0.008$). That is, we reject the notion that, during the period of final slopes, rates of changes were utterly constant for every combination of reach, species, and sample type. We accept the alternative that rates of change were shifting over time, both in a negative and positive direction for at least some combinations.

5.3 Conclusions about Trends over Time in PCB Concentration in Fish

The meta-analyses within three reaches with more than one fish category available for analysis show that PCB concentration was declining at a rate of 5 to 7 percent per year (Table 19, Little Lake Butte des Morts, De Pere, Green Bay Zone 2). The single fish category that could be analyzed for the Appleton Reach also shows a decline of 10 percent per year. Reach 1, Little Lake Butte des Morts, calls attention to a steeper decline in earlier years. All analyses with a breakpoint in this reach show a steeper decline before than after the breakpoint. But in the other reaches, except for 2 out of 13 categories, the data for each fish category considered individually are consistent with a constant rate of decline over the whole time period.

The majority of fish categories have data consistent with only a simple linear trend, and the balance of categories (with breakpoints) have post-break data fit well by a linear trend. Nevertheless, the collective evidence is that slopes (on the log scale) tend to be non-constant, as evidenced by the rejection of the hypothesis of no curvature in the final slopes based on the meta-analysis (Table 24).

We cannot project into the future with precision for several reasons. Many species suffer from rather sparse data with observations occurring at only a few time points. Models based on these data do not provide highly precise estimates. Incorporating the extra uncertainty due to estimating the breakpoint presents a challenge. We have done so in an informal fashion using a sensitivity analysis. The uncertainty in future projections would be greater if the uncertainty in the breakpoint were formally incorporated into calculations. Finally, some of the unusual changes in slope from before to after a breakpoint may be genuine, due to unpredictable events such as floods accompanied by scouring and deposition. If so, such events will continue adding variability to PCB concentration over time, making predictions based on the assumption of a future decline at a constant rate questionable. The presence of curvature (non-constant slopes) is consistent with the more dramatic changes represented by breakpoints and suggests a dynamic process, liable to change, rather than a steady state with constant rates of change.

5.4 Comparison of De Pere Reach to Green Bay Zone 2

We compared species and sample types between the De Pere to Green Bay Reach (equivalent to "Green Bay Zone 1" and so labeled in some reports) and Green Bay Zone 2. The two sets of observations from the two bodies of water are usually significantly different; either in the mean PCB concentration, the time trend of PCB concentration, or in the relationship of PCB concentration to lipid content of tissue.

We were able to carry out these analyses for some additional species and sample type combinations for which time trends could not be calculated by using a snapshot during a single year or short span of years. Table 25 shows which comparisons could be made. We carried out five analyses comparing De Pere Reach and Green Bay Zone 2 during a short "snapshot" cross-sectional period of years, and there were three analyses where time trends could be compared between reaches. In order to have a consistent period of years for the time trend comparison and to avoid differences between reaches arising from different sampling patterns over time, we limited the time trend analyses to a common period of years, 1989 through 1998.

We note that we limited our analysis and discussion to the data provided to us. A discussion of the biological and physical comparisons between the two bodies of water can be found in Technical Memorandum 7c (WDNR, 2001), the Remedial Investigation, and the Baseline Risk Assessment for the Lower Fox River and Green Bay (ThermoRetec, 2001a; ThermoRetec, 2001b).

Table 25 De Pere Reach and Green Bay Zone 2: Fish Types and Sample Types with Sufficient Data for PCB Comparisons

Sample Type	Species	Type of Analysis	
		Single Time Snapshot PCB Comparison - Years	Time Trend Analysis Across Years
Whole Fish/Whole Body/Composite	alewife	1989	1989–1998
Whole Fish/Whole Body/Composite	carp	1989	1989–1998
Whole Fish/Whole Body/Composite	gizzard shad	1989	1989–1998
Skin On Fillet	walleye	1989–1991	
Whole Fish/Whole Body/Composite	walleye	1989	

The equation used to analyze the De Pere and Zone 2 reaches based on the snapshot data is:

Equation 18

$$\log_{10}(PCB) = b_0 + b_1 L + b_2 R + b_3 L \cdot R + e$$

where

- *PCB* = PCB concentration in units of ppb,
- *L* = $\log_{10}$(percent lipid content),
- *R* = dichotomous indicator of Zone 2 versus De Pere Reach, and
- *e* = random error.

For the comparison of time trends in the De Pere and Zone 2 reaches, the equation is extended to:

Equation 19

$$\log_{10}(PCB) = b_0 + b_1 L + b_2 R + b_3 L \cdot R + b_4 t + b_5 t \cdot R + e$$

where

t = time in years since January 1, 1989.

In both the snapshot and time trends equations, all coefficients of terms involving *R* (reach) should be zero or close to zero if a given fish species takes in PCBs at a similar level and processes PCBs in a similar way in the two reaches. For example, in the snapshot equation if b_3 (the coefficient of $L \cdot R$) is zero, the increase in PCB concentration for a specified increase in fat content is the same in the two reaches. In addition, if b_2 (the coefficient of *R*) is also zero, then the mean PCB concentration is the same in the two reaches, given equal lipid content. As another example, if b_5 (coefficient of $t \cdot R$) is zero in the time trends model, then the rate of change of $\log_{10}$ (*PCB*) is the same in the two reaches. Thus, comparing the two reaches involves testing whether certain coefficients in regression models are significantly different from zero.

We detected one outlier, which was removed from the De Pere Reach versus Green Bay Zone 2 analysis. The outlier is noted in Table 27.

Table 26 Outlier from Analysis of De Pere Reach versus Green Bay Zone 2

Database ID	Reach	Fish Type	Sample Type	Total PCBs
WDF209006BC1	Green Bay Zone 2	alewife	whole body	19,000

Reason:

Large outlier. Other PCB values range from 990 to 4,500.

5.4.1 De Pere Reach versus Green Bay Zone 2: "Snapshot" Analysis

Four out of five snapshot analyses (Figure 40 through Figure 44) showed statistically significant differences between the two reaches (Table 27). In two of the analyses, PCB concentrations varied with percent lipid in a different way in the two reaches, and in two analyses the mean log PCB concentration differed between the two reaches, controlling for lipid content.

The two species with different PCB-lipid relationships were carp and gizzard shad, both whole body samples. For carp (whole body) the coefficient of the log lipid term *L*, in the snapshot equation above, when, combined with the coefficient of $L \cdot R$, yields different rates of change of log PCB with changes in log lipid content (p = 0.02). The slope of log PCB versus log lipid is 0.68 and 1.01 in De Pere and Green Bay Zone 2 reaches, respectively. (In all De Pere versus Zone 2 analyses, reach was coded as "1" for De Pere to Green Bay and "2" for Green Bay Zone 2. Thus, based on the snapshot equation, the slope of log PCB versus log lipid in the De Pere Reach, coded as "1," is $0.3426 + 0.3346 \times 1 = 0.6772$, and, in Green Bay Zone 2, coded as "2," the slope is $0.3426 + 0.3346 \times 2 = 1.0118$.)

Table 27 Fitted Models for Log_{10} (PCB Concentration) versus Log_{10} (Percent Lipid) in De Pere Reach and Green Bay Zone 2 for Species with Sufficient Data During 1989

Sample Type	Species	Single Time Snapshot PCB Comp: Years	De Pere Reach		Green Bay Zone 2		Equal Slopes Likelihood Ratio *p*-value	Equal Intercepts Likelihood Ratio *p*-value
			Intercept	Slope	Intercept	Slope		
Whole Fish/ Whole Body/ Composite	alewife+	1989	2.943	0.663	2.668	0.663	0.32	0.00006***
Whole Fish/ Whole Body/ Composite	carp+	1989	3.092	0.677	2.675	1.012	0.016*	
Whole Fish/ Whole Body/ Composite	gizzard shad+	1989	3.559	–0.204	2.846	0.496	0.0009***	
Skin On Fillet	walleye	1989–1991	3.040	0.348	3.040	0.348	0.69	0.66
Whole Fish/ Whole Body/ Composite	walleye+	1989	3.390	0.501	3.269	0.501	0.17	0.0058**

Notes:

+ Fish types significantly different between reaches at 5 percent significance level or better.
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

To illustrate the implication of these coefficients, consider a doubling of lipid content (e.g., from 5 to 10 percent). It can be derived from Equation 18 that an increase in lipid content by any multiplicative factor F, such as $F = 2$, leads to an increase in PCB concentration by a multiplicative factor of $F^{b_1 + R \cdot b_3}$. Thus, a doubling of lipid content leads to an increase in PCB concentration (ppb, not log) by a factor of $2^{0.6772} = 1.60$ in the De Pere Reach, and in Green Bay Zone 2, by a factor of $2^{1.0118} = 2.02$. The increase in Green Bay Zone 2 is larger by 26 percent.

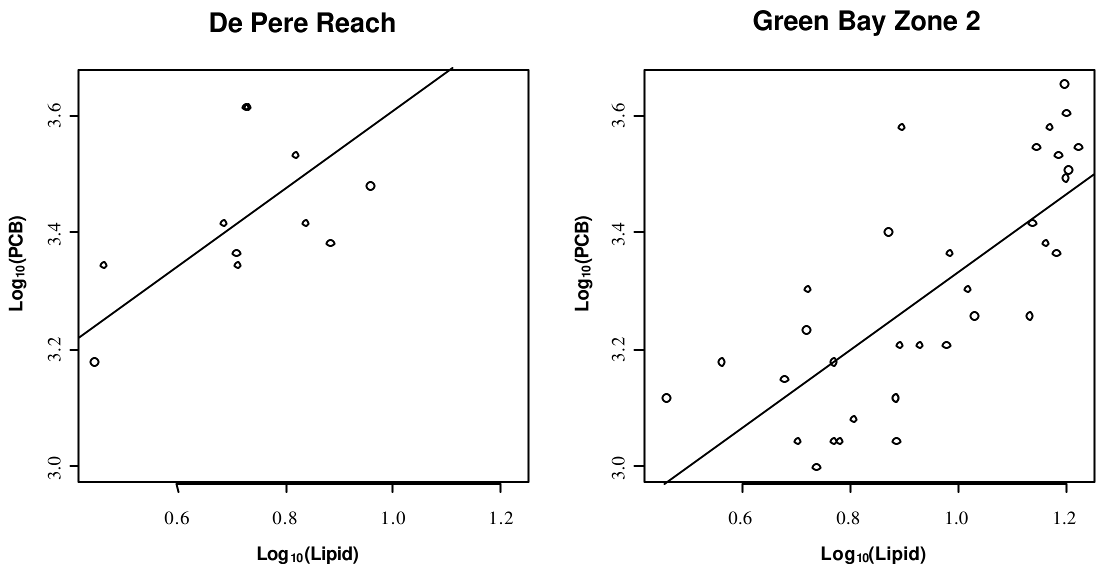


Figure 40 Log PCB Concentration versus Log Percent Lipid for De Pere Reach and Green Bay Zone 2 for Alewife, Whole Body, 1989

For the alewife species, there was no apparent difference in the slope of the relationship between $\log_{10}$ (PCB) and $\log_{10}$ (percent lipid) (p = 0.3, likelihood ratio test for slope differences). The intercepts were significantly different (p = 0.00006, likelihood ratio test). Thus, the mean PCB concentrations for alewife fish in the two zones are significantly different. Figure 40 shows that alewife in the De Pere Reach tend to have a higher PCB content at all lipid levels.

The carp whole body samples (Table 27, Figure 42) in Green Bay Zone 2 showed a greater rate of increase of PCBs with increasing lipid content than samples from the De Pere Reach. (See the steeper slope in Figure 42, right, than in the left panel.) The difference is statistically significant (p = 0.02).

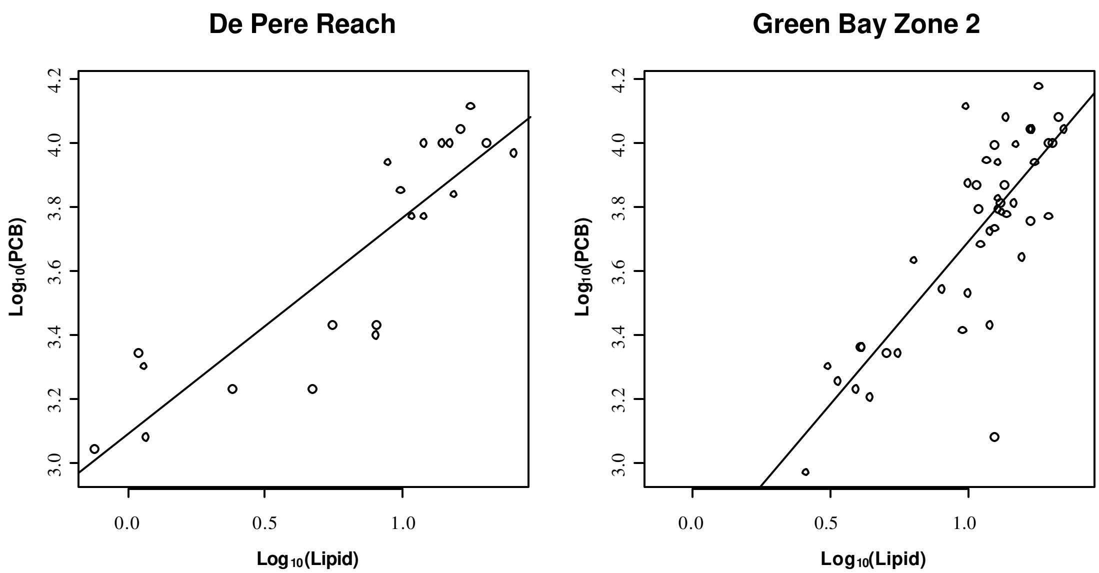


Figure 41 Log PCB Concentration versus Log Percent Lipid for De Pere Reach and Green Bay Zone 2 for Carp, Whole Body, 1989

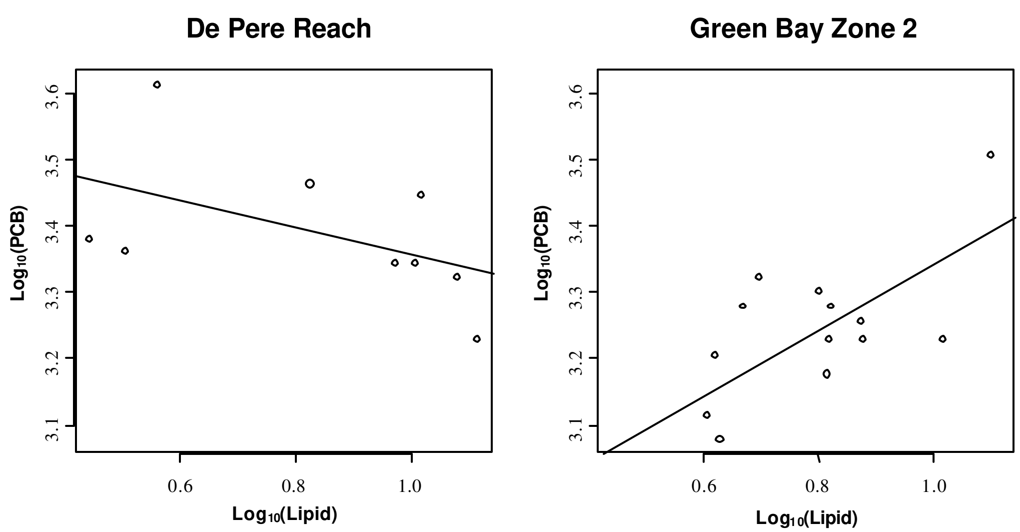


Figure 42 Log PCB Concentration versus Log Percent Lipid for De Pere Reach and Green Bay Zone 2 for Gizzard Shad, Whole Body, 1989

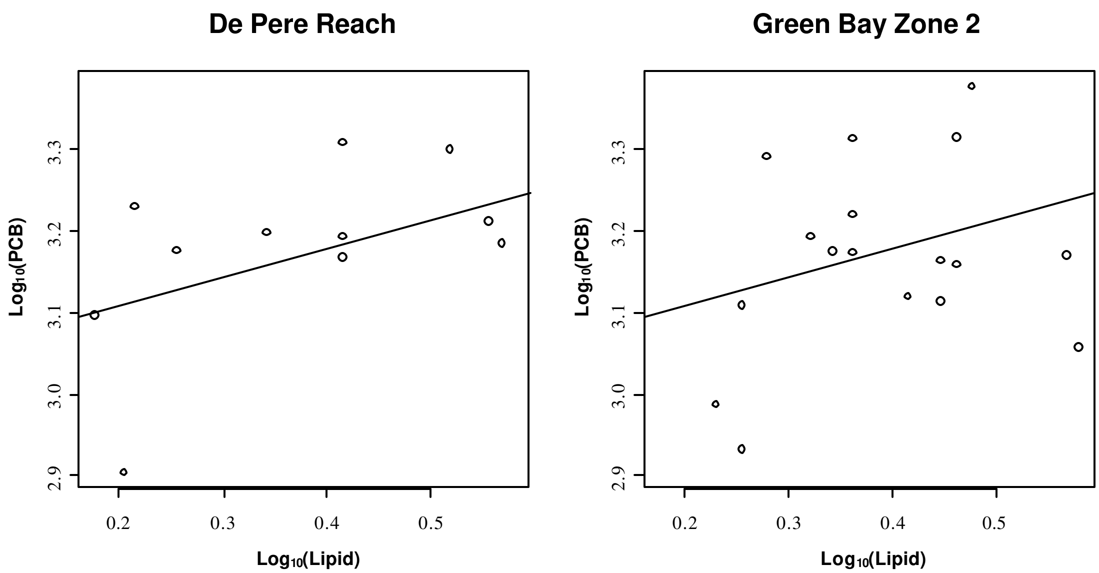


Figure 43 Log PCB Concentration versus Log Percent Lipid for De Pere Reach and Green Bay Zone 2 for Walleye, Skin-on Fillet, 1989–1991

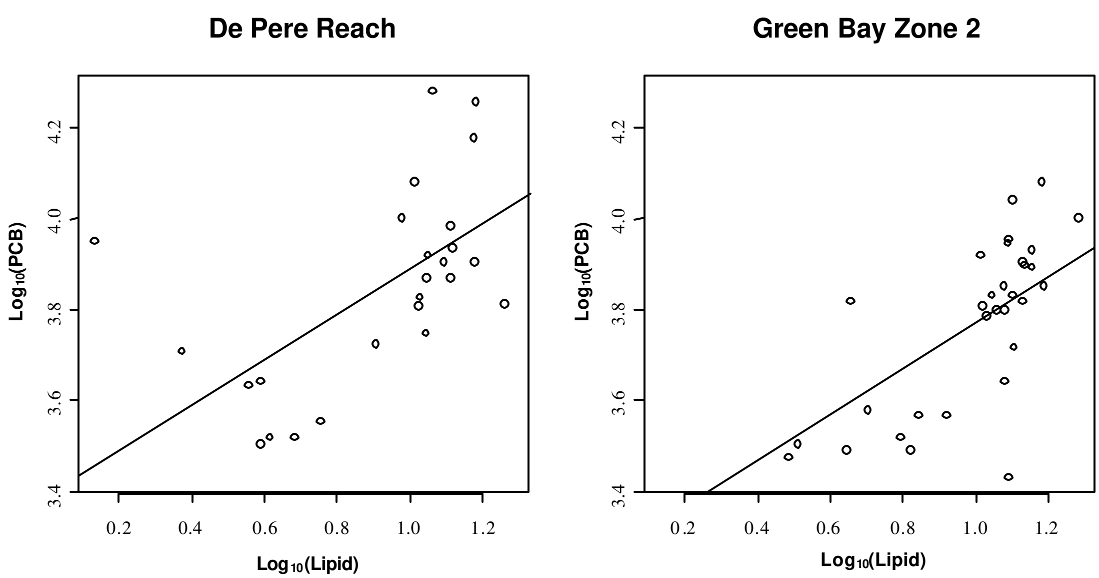


Figure 44 Log PCB Concentration versus Log Percent Lipid for De Pere Reach and Green Bay Zone 2 for Walleye, Whole Body, 1989

In the gizzard shad samples, the slope of log PCB versus log lipid in the De Pere Reach is –0.20 (Table 27, Figure 42). That slope is negative in the De Pere Reach is biologically implausible and probably randomly different from zero or a slightly positive value. The negative slope is significantly different ($p = 0.0009$) from the positive coefficient of 0.50 in Green Bay Zone 2. In Green Bay Zone 2, a doubling of percent lipid in the gizzard shad species would yield an expected 41 percent increase in PCB concentration, while in the De Pere Reach, if one takes the fitted model at face value, the PCB concentration would decrease. If zero or a small positive value is the true slope for log PCB concentration versus log percent lipid in the De Pere Reach, a doubling of lipid content in this reach would cause only a slight change in PCB concentration.

For these two species, carp and gizzard shad, the plots (Figure 41 and Figure 42) indicate that the PCB concentrations differ most at low lipid levels and tend to converge at higher lipid levels. Thus, for each of the two species, the fish samples in the two reaches will have similar PCB concentrations at higher lipid levels and dissimilar PCB concentrations at lower lipid levels.

In two of the three other snapshot analyses (alewife and walleye, both "whole body"), slopes of log PCB versus log lipid were not significantly different between the reaches ($p = 0.3$ and 0.2, respectively), but the mean PCB concentration differed, controlling for lipid level ($p = 0.0001$ and 0.006, respectively). The plots (Figure 40 and Figure 44) clearly convey this offset between the PCB-lipid relationship.

The difference between reaches in mean log PCB concentration for a specified lipid content is the coefficient b_2 in the snapshot equation with, in these two analyses, b_3 set equal to zero and the $L \cdot R$ term excluded from the model. The De Pere Reach minus Green Bay Zone 2 difference in expected log PCB is $2.943 - 2.668 = 0.275$ for alewife and 0.121 for walleye. These differences correspond to a geometric mean PCB concentration that is $10^{0.275} = 1.9$ times higher (90 percent higher) for alewife in De Pere Reach than in Green Bay Zone 2, and $10^{0.121} = 1.3$ times higher (30 percent higher), correspondingly, for walleye.

5.4.2 De Pere Reach versus Green Bay Zone 2: Time Trends Analysis

All three analyses comparing alewife, carp, and gizzard shad between De Pere Reach and Green Bay Zone 2 yield statistically significant differences in time trends between the reaches, as shown in Table 28. The trends are also plotted on Figure 45 through Figure 47. All results here are based on analyses of whole body samples. The slopes for alewife (log PCB versus time in years) are –0.023 for the De Pere Reach and 0.004 for Green Bay Zone 2. They imply that the PCB concentration in De Pere Reach alewife has been decreasing by 5 percent per year and increasing by 1 percent per year in Green Bay Zone 2, a difference in rates of 6 percent per year. Similar comparisons for the other species, based on the slopes in the table, yield, for carp, a 14 percent per year greater rate of decrease in

Green Bay Zone 2 than in the De Pere Reach. For gizzard shad, De Pere Reach concentrations have been decreasing 10 percent per year faster than the Green Bay Zone 2 concentrations.

Table 28 Log_{10} (PCB Concentration) versus Time in De Pere Reach and Green Bay Zone 2 for Species with Sufficient Data During 1989–1998

Sample Type	Species	Time Trend PCB Comp: Years	De Pere Reach		Green Bay Zone 2		Equal Slopes Likelihood Ratio *p*-value
			Intercept	Slope	Intercept	Slope	
Whole Fish/Whole Body/Composite	alewife	1989–1998	49.743	−0.0232	−4.336	0.00382	0.045*
Whole Fish/Whole Body/Composite	carp	1989–1998	−6.218	0.005	105.89	−0.05131	0.0099**
Whole Fish/Whole Body/Composite	gizzard shad	1989–1998	55.954	−0.0264	−24.037	0.01368	0.0031**

Notes:

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

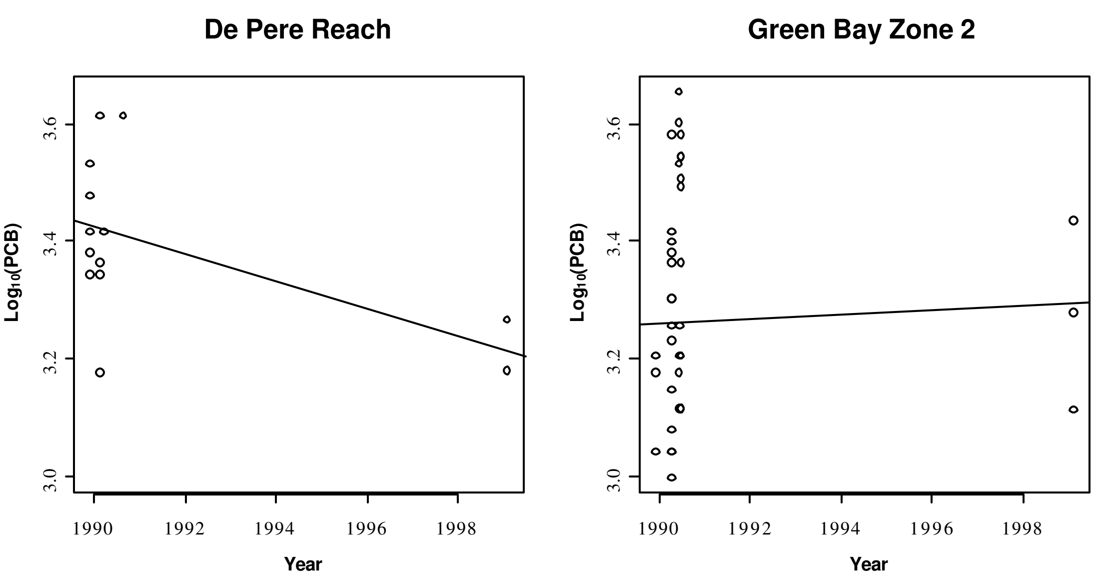


Figure 45 1989–1998 Time Profile Comparison of PCBs Between De Pere Reach and Green Bay Zone 2 for Alewife, Whole Body

Alewife whole body samples from the De Pere Reach show higher levels of PCBs around 1989–1990 than alewife in Green Bay Zone 2. By 1998, the PCB levels in the De Pere Reach appear to have dropped to levels comparable to those of Green Bay Zone 2.

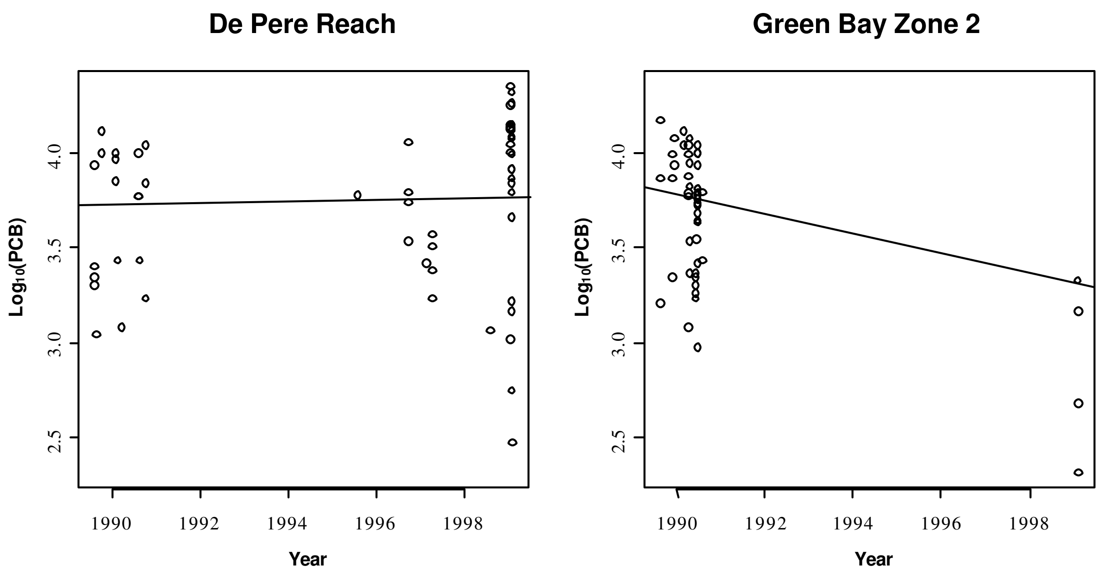


Figure 46 1989–1998 Time Profile Comparison of PCBs Between De Pere Reach and Green Bay Zone 2 for Carp, Whole Body Samples

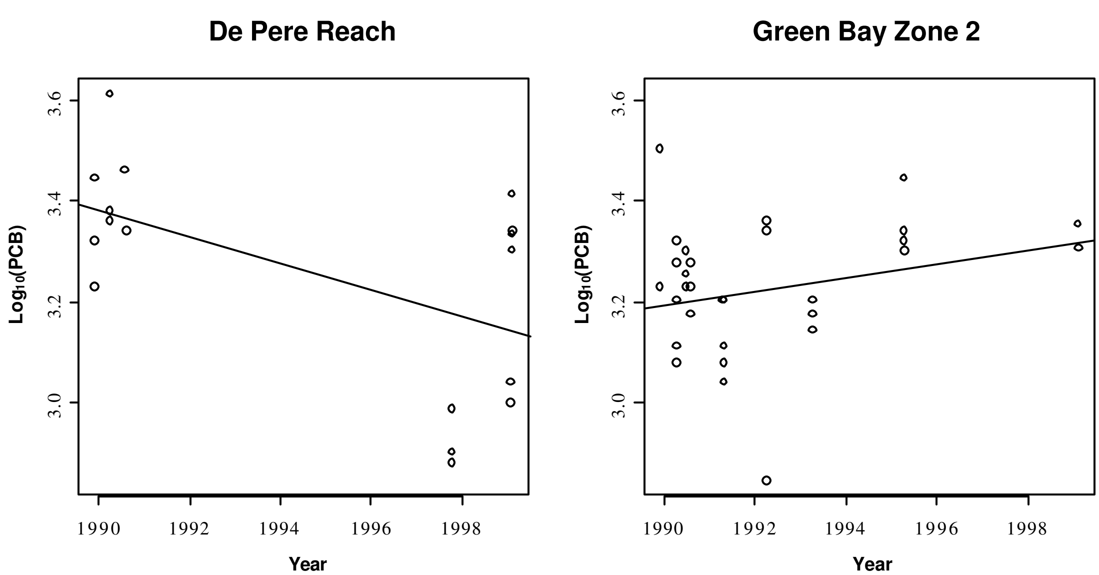


Figure 47 1989–1998 Time Profile Comparison of PCBs Between De Pere Reach and Green Bay Zone 2 for Gizzard Shad, Whole Body Samples

The majority of the analyses of species comparing De Pere Reach and Green Bay Zone 2 show statistically significant differences. Although no solid barriers separate the two zones, the fishes sampled exhibit enough differences to suggest that the fish in the two zones are heterogeneous in either exposure to PCBs or processing of PCBs or both.

5.4.3 De Pere Reach versus Green Bay Zone 2: Without Adjustment for Lipid Concentrations

We carried out a second comparison of De Pere Reach and Green Bay Zone 2 in terms of PCB concentrations in fish. In this second analysis, the lipid weight as a percentage of tissue weight was excluded from the analysis. Analyses of PCB concentrations in fish often proceed without lipid normalization. Results presented here can then be compared to such "lipid-less" analyses. Lipid-based analyses are preferred when available, however, due to the occurrence of many highly significant associations of PCB concentration and lipid content.

The statistical model used for comparing the PCB concentration between De Pere Reach and Green Bay Zone 2 for samples collected during a short time period (snapshot analysis) is:

Equation 20

$$\log_{10}(PCB) = b_0 + b_2 R + e$$

where log PCB parameters and variables have the same definition as for the lipid-based analysis. We defined R = 1 for De Pere Reach and R = 2 for Green Bay Zone 2.

Fish sampled from De Pere Reach have an expected log concentration $b_0 + b_2$; those sampled from Green Bay Zone 2 have an expected log concentration is $b_0 + 2b_2$. Thus, if the coefficient b_2 is zero or if its difference from zero is small and not statistically significant, we would accept the hypothesis that the mean PCB concentrations in the given species and sample type are equal in the two reaches.

The model for comparing De Pere Reach and Green Bay Zone 2 when data on PCB concentrations have been collected over a longer period expands on the previous model by inserting terms involving time. The model is:

Equation 21

$$\log_{10}(PCB) = b_0 + b_2 R + b_4 t + b_5 t \cdot R + e$$

where the parameters and variables are as defined earlier (with R = 1 or 2). The time trend slope for De Pere Reach in this model is ($b_4 + b_5$) and ($b_4 + 2b_5$) for Green Bay Zone 2.

For the comparison of fish PCB concentrations in the De Pere Reach versus those in Green Bay Zone 2, we would accept the hypothesis that a given fish species and sample type has an equal mean PCB concentration in the two reaches at any specified time if the coefficients b_2 and b_5 are small and not significantly different from zero. When these two coefficients are zero, then the rate of change (slope) of log PCB concentrations versus time in the two reaches is the same (b_5 = 0), and there is no difference in the expected mean log concentration (b_2 = 0) at any given time.

The results of the lipid-less snapshot analysis can be presented readily as a comparison of geometric means of PCB concentrations (see Table 29). For reference, we include the corresponding results for a lipid-based analysis, using 6 percent lipid content as a "plug-in" for the lipid-based snapshot equation (3 percent for walleye). We note, in general, the weaker contrast in geometric mean PCB concentration between the two reaches without the lipid variable (compare "percent increase" columns of the table). Also, only two, rather than four, of the differences are statistically significant.

The time trend lipid-less analysis is presented in Table 30. There, three out of the four analyses show statistically significant differences between the reaches with, in each case, quite striking disparities in the annual percent change in PCB concentration. (See the top row for each species/type to find the difference in rates of change in the two reaches—parameter b_5—and the row with "+" to view the final model after all non-significant terms have been dropped.) As noted earlier, we prefer models based on lipid content, a key variable, the absence of which may mislead.

5.4.4 De Pere Reach versus Green Bay Zone 2: Summary

The De Pere and Green Bay Zone 2 reaches do not have an equivalent relationship to PCBs based on the comparisons presented here. The same species and sample types generally differ between reaches either in the slope of time trends, the relationship of PCBs to lipid content, or in the mean PCB concentration, controlling for lipid content. As can be seen from the plots associated with this analysis, the De Pere Reach generally has higher PCB concentrations than Green Bay Zone 2.

5.4.5 Lipid Normalization

The lipid content of samples strongly predicts PCB concentrations in most of our analyses, and, therefore, is an important variable to include in the time trends models. Its association with PCB concentrations is statistically significant—and often highly significant—in 17 out of the 19 analyses of individual sample types (see Table 18). Also, 7 out of the 19 analyses have coefficients of the log lipid variable that differ significantly from 1.0, the value that yields results equivalent to the traditional lipid normalization calculated as (*PCB concentration*)/(*percent lipid content*). Only one such significant difference—rather than seven—would be expected by chance if 1.0 were the true value for all species and sample types. Thus, the traditional lipid normalization does not always control for the lipid effect.

Table 29 Comparison of Geometric Mean Concentrations of PCB Concentrations in De Pere Reach and Green Bay Zone 2, With and Without an Adjustment for Lipid Content, Samples from 1989–1991 (“snapshot” analysis)

Species	Sample Type	Lipids				No Lipids				Years	Sample Size: Total (DP/Z2)
		De Pere Geometric Mean Conc. (µg/kg)*	Zone 2 Geometric Mean Conc. (µg/kg)*	Zone 2 GM Percent Increase over De Pere	Reaches differ? *p*-value	Zone 2 Geometric Mean Conc.	Zone 2 Geometric Mean Conc.	Zone 2 Percent Increase over De Pere*	Reaches differ? *p*-value		
Alewife	Whole Fish/ Whole Body/ Composite	2,799	1,504	86	**0.00006**	2,654	1,963	35	**0.04**	1989	45 (11/34)
Carp	Whole Fish/ Whole Body/ Composite	4,158	2,896	44	**0.02**	4,528	5,116	–11	0.5	1989	66 (21/45)
Gizzard Shad	Whole Fish/ Whole Body/ Composite	2,514	1,706	47	**0.0009**	2,450	1,717	43	**0.002**	1989	23 (9/14)
Walleye	Skin-on Fillet	1,672	1,562	7	0.7	1,511	1,476	2	0.8	1989–1991	28 (11/17)
Walleye	Whole Fish/ Whole Body/ Composite	6,201	4,242	46	**0.006**	6,995	5,835	20	0.1	1989	56 (25/31)

Note:

* Based on a fitted model and a lipid percentage of 6 percent of weight except for walleye fillet with skin, where 3 percent was used.

Table 30 Models Comparing Log (PCB Concentration) versus Time in De Pere Reach and Green Bay Zone 2, Without Adjustment for Lipid Content

Sample Type	Species	Model	Regression Model Parameter Statistics: Constant Parameter (b_0)	Std. Err. (b_0)	Time Para-meter (b_4)	Std. Err. (b_4)	Reach Para-meter (b_2)	Std. Err. (b_2)	Time × Reach Inter-action Para-meter (b_5)	Std. Err. (b_5)	Likelihood Ratio Tests: III vs. II Equal Slopes: Time × Reach Effect *p*-value	II vs. I Equal Inter-cepts: Reach Effect *p*-value	III vs. I Equal Slopes and Intercepts: Full Reach Effect *p*-value	Sample Size: De Pere Reach	Green Bay Zone 2	Total
Whole Fish/Whole Body / Composite	alewife	III	89.7407	63.163	−0.0433	0.0317	−42.95	37.59	0.0215	0.0189	0.26		0.10	13	37	50
		II	20.8587	18.597	−0.0087	0.0093	−0.105	0.057	0	0		0.068				
		I(+)	18.2357	19.169	−0.0075	0.0096	0	0	0	0						
Whole Fish/Whole Body/ Composite	carp	III(+)	−242.08	64.123	0.1230	0.0322	219.60	49.47	−0.1100	0.0248	0.00002***		0.00005***	64	49	113
		II	27.37	22.514	−0.0118	0.0113	−0.1161	0.0926	0	0		NA				
		I	11.30	18.635	−0.0038	0.0094	0	0	0	0						
Whole Fish/Whole Body/ Composite	gizzard shad	III(+)	143.151	37.016	−0.0701	0.0186	−85.6	25.41	0.0429	0.013	0.0014**		0.0028**	18	32	50
		II	25.6608	13.639	−0.0112	0.0068	−0.06	0.048	0	0		NA				
		I	20.0254	13.061	−0.0084	0.0066	0	0	0	0						
Whole Fish/Whole Body/ Composite	walleye	III(+)	−24.0765	49.96	0.0141	0.0251	70.136	38.47	−0.0353	0.019	0.0707		0.0319*	44	34	78
		II	62.2372	16.529	−0.0293	0.0083	−0.119	0.062	0	0		0.0569				
		I	51.1061	15.85	−0.0238	0.008	0	0	0	0						

Notes:

(+) Model indicated by likelihood ratio test. Coefficients appear in Equation 21.
* $p < 0.05$
** $p < 0.01$
*** $p < 0.001$

The statistically significant coefficients of the log percent lipid term in the models range from 0.43 up to 1.09. We noted earlier that a change in the lipid content by a multiplicative factor of *F* (e.g., *F* = 2, doubling the percent) leads to a change in PCB concentration by a multiplicative factor of F^{b_1}, where b_1 is the coefficient of $\log_{10}$ lipid percentage in a regression model. The percentage change corresponding to *F* is $100\% * (F^{b_1} - 1)$. The observed range of significant lipid coefficients of 0.43 to 1.09 in the 19 analyses implies that a doubling of lipid percentage, for example, leads to a range of 34 to 113 percent increase in PCB concentration. The strong association between lipids and PCB concentration is illustrated by an example, Figure 48, where the positive association between log (PCB concentration) and log (percent lipid) is evident from the sparseness of points in the upper left and lower right of the plot.

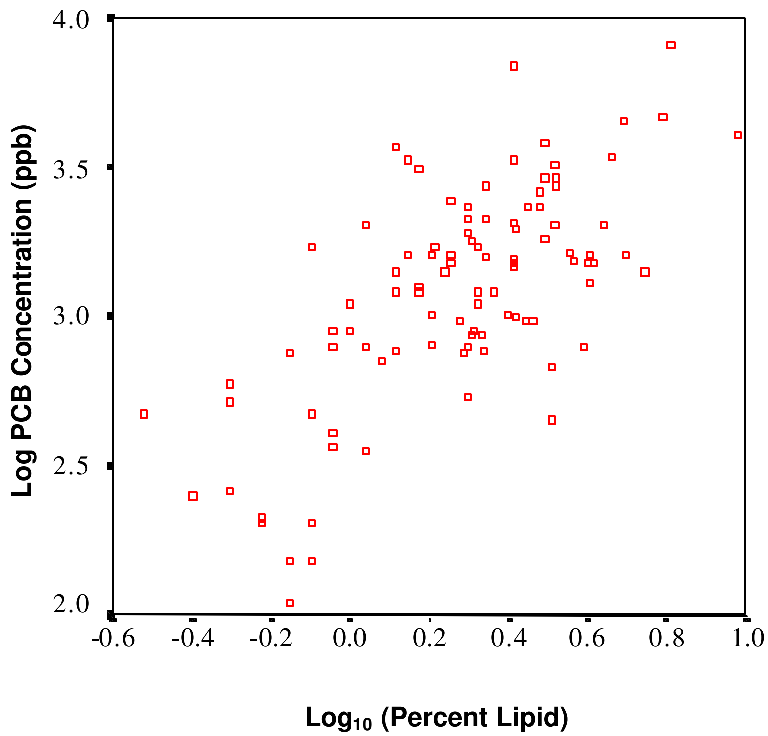


Figure 48 $\log_{10}$ PCB Concentration (ppb) versus $\log_{10}$ Percent Lipid Content for Walleye, Skin-on Fillet, De Pere to Green Bay Reach

The relationship between total PCBs and percent lipids (a measure of body fat) is strong. To adjust for this relationship, $\log_{10}$ (percent lipids) must be included as an independent covariate in regression analyses.

6 Conclusions and Discussion

The analysis of trends in fish tissue and sediment over time in the Lower Fox River has led us to several significant conclusions. These conclusions, supporting statements, and discussion are included in Section 6.1. In addition, Section 6.3 identifies uncertainties associated with this trends analysis.

6.1 Conclusions

Data collected in the Lower Fox River and Green Bay show that concentrations of PCBs in fish tissue and surface sediments declined following the elimination of PCB point source discharges. However, further analysis of that data has identified statistically significant breakpoints in the decline for most of the fish species examined, suggesting that the decline has slowed down or, in some cases, that tissue concentrations of PCBs have increased. Furthermore, the analysis shows that it is not possible to project PCB concentrations into the future for fish or sediment with confidence because time trends appear to be quite changeable and confidence intervals for rates are quite wide.

Data on PCBs in sediment samples taken from surface sediments suggest that PCB concentrations have generally declined over time. Trends in concentrations of PCBs in subsurface sediments are less clear—some deposits show declining trends, while others show trends either close to zero or not significantly different from zero and yet others show increasing trends.

Specific conclusions of the time trends analysis include:

- **Fish tissue concentrations have generally declined over the period of time for which there are data in the Lower Fox River and Green Bay Zone 2.** Fish tissue PCB concentrations generally showed a slow rate of decline throughout the Lower Fox River and Green Bay Zone 2. Most time trend slopes were negative, and all statistically significant slopes were negative except one.

- **Significant "breakpoints" in the decline were identified for most of the fish species examined, suggesting that rates of decline in PCB tissue concentrations are changeable and slowing and, in some cases, tissue concentrations may be increasing.** Fish tissue concentrations have not declined at a constant rate since the 1970s. Among fish time trends analyzed, 7 out of 19 combinations of reach, species, and sample type showed a statistically significant change in slope (log scale) between earlier and later periods. In Little Lake Butte des Morts, De Pere Reach, and in Green Bay Zone 2, there were steep declines in fish tissue PCB concentrations from the 1970s, but with significant breakpoints in declines for some species beginning around

1980. A meta-analysis of time trends showed that the most recent slopes averaged across species showed a 5 to 7 percent decline per year for three of the reaches. Six species showed an increasing rate in their final slope, but only two of these rates were statistically significant (carp, whole body, in De Pere Reach and in Green Bay Zone 2). The existence of breakpoints plus a meta-analysis to detect non-constant trends suggest that rates of change are changeable and not constant.

- **PCBs in surface sediment samples have generally declined over the period of time for which there are data for the Lower Fox River.** Surface sediment PCB concentrations combined within each reach showed statistically significant decreasing trends in all reaches except Appleton to Little Rapids. There were wide confidence intervals for rates of change, both for individual deposits and combined deposits, indicating that rate estimates are not precise. This imprecision and other uncertainties associated with the data do not support accurate future projections. Surface sediments of individual deposits within the reaches included a mixture of positive and negative slopes. Among the 16 negative slopes, 6 were statistically significant; neither of the 2 positive slopes were statistically significant.

- **Time trends in PCB concentrations in sediments below the surface sediment are less clear—some indicate a decline, others indicate no change or increases, others are unchanging or even increasing.** There is a strong trend toward fewer and weaker negative slopes at increasing depths. For Little Lake Butte des Morts, subsurface trends are mixed. The only statistically significant subsurface trend shows an increase and the other trends are a mixture of positive and negative trends. In the Appleton and De Pere reaches, there is a mixture of positive and negative trends that is not clearly distinguishable from a zero overall trend. For Little Rapids to De Pere, there are consistently negative trends in the 10- to 30-cm strata, but in the lower strata, the data are consistent with either a zero trend (30 to 50 cm), or an increasing trend (50 to 100 cm and 100+ cm).

- **Projection of PCB concentrations into the future for fish or sediments is questionable because of imprecision and other uncertainties identified in the analysis.** The analyses carried out cannot assure a continued decline in PCB concentrations over time. Even though there are a number of negative time trends that suggest PCB declines, future projection is questionable. Increases in PCB concentrations in some deeper sediments and breakpoints, and other non-linear phenomena in fish PCB time trends (on the log scale) suggest that the river, its sediment, and its fish species could experience an arrest or reversal of such a decline.

- **PCB concentrations may increase or decrease in the future.** Some, perhaps all, of the changes in slope from before to after a breakpoint in the fish analysis may be genuine, due to unpredictable events, such as floods accompanied by scouring and deposition. As discussed in the Remedial Investigation, sediment bed elevations have been altered historically and may also undergo changes in the future due to scouring and redistribution of sediments. The occurrence of these breakpoints in the past suggests that the river may change again in the future. The presence of non-constant slopes (which we refer to as "curvature") in the post-breakpoint period also suggests change. If so, such events will continue adding variability to PCB concentration over time, making predictions based on the assumption of a future decline at a constant rate questionable. The presence of curvature is consistent with the more dramatic changes represented by breakpoints and supports the notion of a dynamic process, liable to change, rather than a steady state with future constant linear rates of change.

The last two bullets are especially germane to use of the time trends analysis in other elements of the Lower Fox River Risk Assessment and Feasibility Study. The time trends were estimated only for the period of time for which data exist. These analyses are not suitable for accurately projecting trends into the future. Of particular importance, the data do not provide assurance of a continuing future decline in PCB concentrations.

The time trends analysis has dealt strictly with the testing of changes in PCB concentrations over time in the Lower Fox River, and not with the mechanisms that could control changes in sediment and tissue loads. The apparent decline of PCBs observed in surface sediments and fish from the Lower Fox River are consistent with the continued observed transport of PCBs from the river to Green Bay, as discussed in detail in the Remedial Investigation. Changes in sediment bed elevations have been documented and are discussed in Technical Memorandum 2g (WDNR, 1999a) and in the Remedial Investigation. 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 in the Lower Fox River and Zone 2 of Green Bay, these potential mechanisms were not introduced into the analysis and thus could not be controlled. What is important to note, however, is that the trends analysis is dependent upon the existing hydraulic conditions in the Lower Fox River. Any changes in those conditions might result in exposure of underlying PCB-laden sediments or burying of sediments, and lead to new trends that may not be similar to the trends from this analysis.

The conclusions of a general historical decrease in PCB burdens in sediments and fish of the Lower Fox River and in Zone 2 of Green Bay are similar to those reported by other Great Lakes researchers. Decreases 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), Lake Superior (Smith, 2000; DeVault *et al.*, 1996) and lakes Huron and Erie (DeVault *et al.*, 1996). The yearly rate of decline for PCBs in biota and sediment of Lake Superior has been estimated at 3 to 8 percent per year and is expected to continue 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. PCB concentrations in lake trout and smelt are reported to have been relatively constant in Lake Ontario since 1985 (Gobas *et al.*, 1995) while concentrations in other fish and in sediments show a decline during the period of observed data (to about 1990) and a projected continuing decline (see Gobas *et al.*, 1995, Figures 2 and 3). PCB body burdens in Lake Erie walleye were shown to be declining during the period of 1977 through 1982, but after that period remained constant through 1990 (DeVault *et al.*, 1996). Time tends analysis for salmonids and trout in Lake Michigan showed generally decreasing tissue concentrations (Lamon *et al.*, 1998). The uncertainty in rates is often large, and some trends are not significantly different from a zero rate or have confidence intervals that include positive rates of increase (e.g., lake trout, see DeVault *et al.*, 1996, Figure 3). 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 a steady state in PCB concentrations in fish and sediment in the future. The possibility of some increases cannot be ruled out.

6.2 Time Trends Discussion

6.2.1 General Issues

The time trends analysis has shown that PCB concentrations in surface sediments (0 to 10 cm) and fish are generally decreasing over time. In both sediment and fish analyses, the magnitude and level of statistical significance of time trends varies widely. All except one statistically significant fish time trend indicated decreasing concentrations. The time trends in subsurface (10+ cm) sediments contain a mixture of positive and negative rates of change, and it is difficult to reach a firm conclusion about the subsurface PCB time trends. The time trends in sediment generally exceed in magnitude (positive or negative) those in fish. Most significant and non-significant sediment trends were negative, but there were some statistically significant positive trends for deeper strata. More is known about the trends in surface deposits because a larger fraction of the surface deposit groups than subsurface deposits were analyzed.

Sediment samples taken from the surface sediments have more negative than positive slopes. However, there was a trend toward fewer negative and more positive slopes as depth increased. In sediments sampled from the surface, 89 percent of slopes were negative. Below 50 cm, 71 percent of slopes were positive. The time trend analysis has shown that rates of change of PCB concentrations in fish are themselves liable to change, calling into question the value of projecting concentrations under an assumed but unverifiable steady-state model. By implication, sediment—particularly surface sediment—as the primary source of PCBs in fish, is also likely to be changeable in its time trends of PCB concentrations.

The meta-analysis (pooled results from all surface sediment deposits) for trends in surface sediments showed an average rate of decrease in PCB concentrations of 18 percent per year in Little Lake Butte des Morts, 0.6 percent per year increase in the Appleton Reach, 10 percent per year decrease in the Little Rapids Reach, and 15 percent per year decrease in the De Pere Reach. These meta-analysis trends were statistically significant except for the small trend in the Appleton Reach. Thus, surface sediments show decreasing PCB concentrations over time, and at a fairly rapid average rate during the period covered by the data, except for the Appleton Reach.

It is important to emphasize that it is the average rate of change over a period of time that is strikingly negative in three out of the four reaches, and not necessarily the individual deposit rates or even the rates at each point in time covered by the data. Given the findings of fish time trends that seem to vary over time, as evidenced by both breakpoints and curvature, it is likely that the sediment time trends may also be volatile over time, perhaps due to scouring and deposition, which are described in a companion document (WDNR, 1999a). There are simply too few distinct time points of measurement of sediment concentrations to support a breakpoint and curvature analysis such as that carried out for fish. Since the ultimate source of PCBs in fish is sediment, however, it is difficult to imagine that fish have volatile time trends with sediment volatility.

The fish meta-analyses within the three out of four reaches with more than one fish category available for analysis show that PCB concentration was most recently declining at a rate of 5 to 7 percent per year (Little Lake Butte des Morts, De Pere, Green Bay Zone 2). The single fish category that could be analyzed for the Appleton Reach also shows a decline of 10 percent per year.

However, the fish time trends are changeable. Little Lake Butte des Morts had a steeper decline in PCB concentrations in earlier years. All analyses with a breakpoint in this reach show a steeper decline before the breakpoint. In the other reaches, the data for each fish category considered individually are consistent with a constant rate of decline over the whole time period, except for 2 out of 12 combinations of species and sample type. Nevertheless, the collective evidence demonstrates that slopes (on the log scale) tend to be non-constant. Based on a meta-analysis, the hypothesis of constant final slopes for all species was rejected and we must accept the concept of non-constant time trends for the post-breakpoint period for at least some species. In this regard, we note that it is possible to not detect curvature for analysis of individual species and yet to detect the presence of curvature from a global meta-analysis (and accept changing slopes for some individual species), because the meta-analysis has more power.

A practical dilemma in estimating future concentrations of PCBs is the choice of a statistical model to use in projecting concentrations forward in time, both for sediment and fish. For sediment, there are insufficient data to test for "curvature" (a non-constant slope over time), though the fish analysis implies curvature and changeability of slopes. Using the fitted time trends as presented in this report for projection and ignoring the possibility of non-constant sediment time trend slopes assumes a steady state in the river and, consequently, could lead to erroneous future projections. Such error in the projection is likely to be smaller, when one aggregates the results of projections of individual deposits into larger geographic units, such as a reach or the entire river. There is disagreement between fish and sediment time trends. The average rates of decrease of PCB concentration in the meta-analysis of surface sediments generally exceed those observed in the meta-analysis of fish PCB trends. Biologically, fish rates should have to be linked with and similar to those for sediment. One possible explanation for the mismatch is that the sediment rate of decrease may have slowed down recently. There are too few time points with sediment data, per deposit group and depth, to detect such a slowing, and the calculated rate of change for sediment PCB concentration may be an average of a faster earlier rate and a slower recent rate.

6.2.2 Fish Lipids

Lipid content of samples distinctly assisted in reducing unexplained variance for most analyses of fish PCB time trends. Since it is so helpful, efforts should be taken in the future to explore ways to more powerfully incorporate lipids into the analysis. The time trend analysis used lipid content as a linear independent variable. We prefer this approach to the alternative of dividing PCB concentration by the percent lipid content, which is equivalent to using lipids as an independent variable but forcing its coefficient to be unity.

Only two analyses of time trends in gizzard shad (for two different reaches) showed no significant relationship between lipids and PCBs, suggesting that some species may handle PCBs in a different fashion. The variety of coefficients relating PCBs to lipid content among the various species and sample types suggests that species are not identical in their PCB-lipid relationships.

6.2.3 Strengths of the Study

There are a number of strengths of the study. The maximum likelihood method used to handle data below a detection limit allowed these values to contribute to the analysis without having to impute a proxy value. The methods used to detect and handle spatial correlation of sediment samples have allowed us to avoid overstating statistical significance of time trends. In fact, statements of statistical significance should be quite conservative. Our approaches to quantifying and testing for non-constant rates of change in fish time trends (breakpoints and curvature) have allowed us to assess the changeability of time trends. Our use of regression analysis of lipid content as a factor in PCB concentrations makes good use of the lipid data and does not impose a pre-specified coefficient relating PCBs to lipid content. The use of meta-analysis of rates has increased precision and power in time trend estimates. The remarkable agreement of the data with the lognormal distribution and the need to address only two outliers in over 2,000 observations, support the overall validity of the PCB concentrations used in the time trends analysis. The inherent very great variability of the PCB concentrations has been thoroughly described quantitatively, through confidence intervals of slopes, and graphically, by scatter plots of concentrations versus time. Finally, clear statements about confidence in and statistical significance of the various quantitative trends have been provided to guide the reader in the use of the trends.

6.3 Sources of Uncertainty in the Time Trends Analysis

The conclusions and discussion presented above are based upon the statistical analyses of the data as received by us. However, there are areas of uncertainty that may have played a role in this analysis. By "uncertainty," we mean either random variation (such as fish-to-fish variation in PCB concentration) or systematic variation due to unmeasured factors, such as age and gender of fish or changes in the absolute elevation of the sediment-water interface. While statisticians use terms such as "variation" and "sources of unexplained variation" for these two effects, we will use the term "uncertainty," a term more familiar to readers, to specifically designate the combination of these two effects. While there is no uncertainty about the methodology, the results should be considered as possibly influenced by unmeasured factors, hence uncertain to that extent.

In addition to the uncertainty arising from sheer randomness, there are sources of uncertainty associated with laboratory and analytical variation and other factors that could not be included in the analysis. The various sources of uncertainty are discussed below.

6.3.1 Statistical Uncertainty — Statistical Significance and Confidence Intervals

The data used for both sediment and fish time trends analyses are inherently quite variable. A wide scatter of points typically surrounds the regression lines for fitted models. This variability has led to some wide confidence intervals around estimated values. The lack of statistical significance of a time trend does not imply the absence of a real trend, even a strong one. Some attention to confidence intervals shows the possibility of strong trends that may not have been detected due to the large random component in the data.

We suggest that the reader take note of the statistically significant trends and use the confidence intervals for these and other trends as statements ruling out (with high confidence) certain slopes outside the confidence intervals. Slopes within the confidence intervals (usually quite wide) are all quite plausible and consistent with the data. These confidence intervals are usually quite wide. Because the confidence intervals are generally wide, they cannot usually be used to state that a trend is close to zero. Within the intervals, there are differing rates of change.

By examining the standard errors of slope estimates of $\log_{10}$ PCB concentration versus time, a quantitative notion of the statistical uncertainty in the time trend estimates can be expressed. A standard error (SE) of 0.0054 for a slope estimate on the $\log_{10}$ scale would indicate "excellent" precision because, for example, a slope of zero (zero percent change per year) with an SE of 0.0054 would lead to a 95 percent confidence interval (CI) for the rate of change of --2.5 to +2.5 percent, a tight range of 5 percentage points. None of the 46 sediment trends and only 3 out of the 19 fish trends have this precision (Table 9 and Table 18).

"Good" or "fair" precision would be an SE of 0.01 or less, which, for a zero slope, would have a 95 percent CI of ±5 percent, a range of 10 percentage points. Two sediment and nine fish time trends have this precision. Among the meta-analyses, all of the fish combined time trend slopes have good-to-excellent precision (Table 19), but none of the combined surface sediment time trends has this precision (Table 10). Even "good" or "fair" precision of ±5 percent provides room for very different future scenarios. A rate of 5 percent decrease per year for 10 years leads to a 40 percent loss in PCB concentration, while a 5 percent increase per year for 10 years leads to a 63 percent increase in PCB concentration. The range –40 to +63 percent is a wide zone of uncertainty.

Indeed, one of the firm conclusions of this study must be that, in some cases, a firm conclusion cannot be reached. An increasing or decreasing time trend that is statistically significant, or a trend that is not significantly different from zero but with a tight confidence interval around zero, provides a clear outcome. Non-significant trends with wide confidence intervals impart little information and do not provide a clear outcome. Thus, Table 31 and Table 32 show which calculated time trends provide a "clear outcome" and which trends have "good" or "fair" precision.

Table 31 Sediment Time Trends: Analyses with Clear Outcomes and Good Precision

Type of Analysis			Clear Outcome: Significant Increase or Decrease, or Confidently Close to Zero?[+]	Is Precision Good or Fair?[++]
Sediment				
Little Lake Butte des Morts				
Deposit Group	AB	0–10 cm	Decrease	—
		10–30 cm	—	—
		30–50 cm	—	—
	C	0–10 cm	—	—
		10–30 cm	—	—
	POG	0–10 cm	—	—

Table 31 Sediment Time Trends: Analyses with Clear Outcomes and Good Precision

Type of Analysis			Clear Outcome: Significant Increase or Decrease, or Confidently Close to Zero?+	Is Precision Good or Fair?++
	D	0–10 cm	Decrease	—
		10–30 cm	Increase	—
	F	0–10 cm	Decrease	—
		10–30 cm	—	—
	GH	0–10 cm	Decrease	—
Little Lake Butte des Morts Surface Meta-analysis			**Decrease**	**—**
Appleton Reach				
Deposit Group	IMOR	0–10 cm	—	—
	N Pre-dredge	0–10 cm	Decrease	Yes
		10–30 cm	—	—
		30–50 cm	—	—
	VCC	0–10 cm	—	—
		10–30 cm	Decrease	—
		30–50 cm	—	—
Appleton Reach Surface Meta-analysis			**—**	**—**
Little Rapids Reach				
Deposit Group	Upper EE	0–10 cm	—	—
		10–30 cm	—	—
		30–50 cm	—	—
	Lower EE	0–10 cm	Decrease	—
		10–30 cm	—	—
		30–50 cm	Increase	—
	FF	0–10 cm	—	—
		10–30 cm	Decrease	—
	GGHH	0–10 cm	—	—
		10–30 cm	—	—
		30–50 cm	—	—
		50–100 cm	—	—
		100+ cm	—	—
Little Rapids Reach Surface Meta-analysis			**Decrease**	**—**

Table 31 Sediment Time Trends: Analyses with Clear Outcomes and Good Precision

Type of Analysis			Clear Outcome: Significant Increase or Decrease, or Confidently Close to Zero?+	Is Precision Good or Fair?++
De Pere Reach				
SMU Group	2025	0–10 cm	—	—
		10–30 cm	—	—
		30–50 cm	—	—
		50–100 cm	—	—
	2649	0–10 cm	Decrease	Yes
		10–30 cm	—	—
		50–100 cm	—	—
		100+ cm	—	—
	5067	0–10 cm	Decrease	—
		10–30 cm	—	—
		50–100 cm	Increase	—
		100+ cm	—	—
	6891	0–10 cm	—	—
		10–30 cm	—	—
	92115	0–10 cm	—	—
De Pere Reach Surface Meta-analysis			**Decrease**	**—**

Notes:

\+ 1. "Yes" indicates increase or decrease is statistically significant compared to zero rate of change ($p < 0.05$), **or** 95 percent confidence interval for percent change is within ±5 percent of zero.

\+ 2. Uncertain outcome noted by "—" (not "Yes" to above).

++ Standard error of slope ≤ 0.1.

Of the 46 deposit group analyses in Table 31 and 4 surface sediment analyses, only 16 cases can offer us a reasonably firm conclusion on time trends. Two indicate increasing, and 14 indicate decreasing, trends. The remaining 34 analyses have uncertain trends. All cases noted with a dash ("—") in the "Clear Outcome" column may have trends that deviate more than ±5 percent per year from a constant, 0 percent rate of change, and the rate may plausibly be either positive or negative. In these cases, a zero rate is just one among a wide range of possible rates bracketing zero. As noted in the "Precision" column of Table 31, only two analyses provide good or fair precision for their time trends.

The fish analyses provide a firmer set of conclusions (Table 32). Among the 19 primary analyses and 3 meta-analyses, 17 clearly demonstrate an "increase" or "decrease." The other five analyses do not support a solid "no change," zero-slope conclusion, but instead leave us with a fairly wide range of plausible increasing or decreasing slopes. As far as precision goes, 14 out of the 22 analyses provide "good" or "fair" precision for fish trend estimates.

Table 32 Fish Time Trends: Analyses with Clear Outcomes and Good Precision

Type of Analysis	Clear Outcome: Significant Increase or Decrease, or Confidently Close to Zero?+	Is Precision Good or Fair?++
Fish		
Little Lake Butte des Morts		
Carp, skin-on fillet	Decrease	Yes
Carp, whole body	—	—
Northern Pike, skin-on fillet	Decrease	Yes
Walleye, skin-on fillet	—	—
Walleye, whole body	—	—
Yellow Perch, skin-on fillet	—	—
Little Lake Butte des Morts Meta-analysis	**Decrease**	**Yes**
Appleton Reach		
Walleye, skin-on fillet	Decrease	—
De Pere Reach		
Carp, whole body	Increase	—
Gizzard Shad, whole body	Decrease	Yes
Northern Pike, skin-on fillet	Decrease	Yes
Walleye, skin-on fillet	Decrease	Yes
Walleye, whole body	Decrease	Yes
White Bass, skin-on fillet	Decrease	Yes
White Sucker, skin-on fillet	Decrease	Yes
De Pere Reach Meta-analysis	**Decrease**	**Yes**
Green Bay Zone 2		
Alewife, whole body	Decrease	Yes
Carp, skin-on fillet	—	—
Carp, whole body	Decrease	Yes
Gizzard Shad, whole body	Increase	Yes
Yellow Perch, skin-on fillet	Decrease	Yes
Green Bay Zone 2 Meta-analysis	**Decrease**	**Yes**

Notes:

\+ 1. "Yes" indicates increase or decrease is statistically significant compared to zero rate of change ($p < 0.05$), **or** 95 percent confidence interval for percent change is within ±5 percent of zero.
2. Uncertain outcome noted by "—" (not "Yes" to above).

++ Standard error of slope ≤ 0.1.

6.3.2 Physical Sources of Uncertainty

Depth of Sediments

The time trend analysis has shown that shallower sediment layers tend to have greater rates of decrease than deeper layers, where PCB concentrations may even be increasing. In Little Lake Butte des Morts, for example, Deposit Group D bears a strong and statistically significant decreasing trend at 0 to 10 cm and a strong and highly significant increasing tend at 10 to 30 cm. Deposits with these trend patterns may be experiencing either burying of more contaminated surface sediments over time into deeper strata, or some mechanism whereby PCBs migrate downward.

Depth of sediment is closely related to PCB concentration. We used depth defined as the distance to the sediment-water interface. The Fox River database (the source of our data) does not include the absolute depth of deposits (in relation to fixed points and elevations on land). Such data would undoubtedly help in the analysis. The data available now do not allow us to track a given parcel of sediment over time. The interface may change over time due to scouring or deposition. Some of the time trends noted here may be due to a change in the depth from the sediment-water interface, where that boundary has shifted up or down due to deposition or scouring over time, so that different parcels of sediment are identified with the same depth label at different times. Time trends based on an absolute definition of depth would more accurately track what happens to PCBs in a specific volume of sediment over time.

Hydraulic Conditions

As noted above, there was no way to control in the time trends analysis for changes that may have occurred in sediment or fish tissue concentrations that could be attributed to flooding, ice scouring, propeller wash, or other mechanisms that would have caused changes to the hydraulic conditions in the river. Changes in bed elevations have been previously documented (WDNR, 1999a). While in one sense, the analysis of trends over time is concerned only with change, and not necessarily the underlying mechanism(s), an understanding of episodic events that may have influenced observed upward or downward trends would have facilitated the overall understanding of those results.

The trends reported here pertain to hydraulic conditions in the river at the time the data were collected. The system of locks and dams on the Lower Fox River currently control to a large degree where deposition and scouring occur. In the future, should those conditions change, any comparison of rates of change of PCB concentrations to the rates presented in this report, for the purpose of determining slowing or quickening of rates over time, would have to be done very cautiously.

6.3.3 Sources of Biological Uncertainty

Age and Gender of Fish

Age of fish may relate to PCB concentrations, due to different feeding habits and locations during the lifecycle. Incorporating age proxy variables (either length or mass) might reduce unexplained variance and increase power to detect trends. The relation of age to PCB concentration could be explored as either linear, curvilinear, or some type of step function (e.g., representing juveniles versus adults). (Length data have recently become available for some samples as this analysis was completed.) Similarly, the gender of the fish and whether or not it recently spawned may be factors in PCB uptake and retention, and these factors can easily be incorporated into the analysis when data become available.

Spatial Dependence

The time trend analysis was not adjusted for and cannot, with present data, adjust for potential spatial dependence of data from fish samples. While individual fish do not have specific geographic coordinates, fish caught at about the same time and location may exhibit some dependence due to similar feeding sources.

6.3.4 Uncertainty Due to Laboratory and Analytical Factors

Our time trends analysis did not incorporate potential laboratory variation into the study. Multiple laboratories engaged in the analysis of sediments and fish tissues for the Lower Fox River and Green Bay, which is not uncommon for large environmental projects. Analytical variability amongst those laboratories is discussed in the Data Management Report (EcoChem, 2000). A "laboratory effect," whereby different laboratories would produce a different mean PCB concentration on split samples, is possible. In addition, analytical techniques may have changed over the 1989-through-1998 period of sediment sample collection. Similarly, the 1976-through-1998 period of the fish samples included in the analysis may well have seen changes and refinements in laboratory equipment and techniques. Both the "laboratory effect" and changes in technique may have influenced the time trends.

7 References

Cressie, N. A., 1993. *Statistics for Spatial Data*. John Wiley and Sons, New York.

DeVault, D. S., R. Hesselberg, P. W. Rodgers, and T. J. Feist, 1996. Contaminant trends in lake trout and walleye from the Laurentian Great Lakes. *Journal of Great Lakes Research*. 22:884–895.

EcoChem, 2000. *Data Management Summary Report: Fox River Remedial Investigation and Feasibility Study*. Prepared for Wisconsin Department of Natural Resources. October 3.

Gobas, F. A. P. C., M. N. Z'Graggen and X. Zhang, 1995. Time response of the Lake Ontario Ecosystem to virtual elimination of PCBs. *Environmental Science and Technology*. 29(8):2038–2046.

Heagerty, P., and T. Lumley, 2000. Window subsampling of estimating functions with application to regression models. *Journal of the American Statistical Association*. 95:197–211.

Herbert, C., and K. Keenleyside, 1995. To normalize or not to normalize? Fat is the question. *Environment Toxicology and Chemistry*. 14:801–807.

Lamon III, E. C. and S. R. Carpenter *et al*., 1998. Forecasting PCB concentrations in Lake Michigan salmonids: A dynamic linear model approach. *Ecological Applications*. 8(3):659–668.

Larsson, P., L. Lennart Okla, and L. Collvin, 1993. Reproductive status and lipid content as factors in PCB, DDT and HCH contamination of a population of pike (*Esox lucius* l.). *Environment Toxicology and Chemistry*. 12:855–861.

Lawless, J., 1982. *Statistical Models and Methods for Lifetime Data*. John Wiley and Sons, New York.

Lumley, T., and P. Heagerty, 1999. Weighted empirical adaptive variance estimators for correlated data regression. *Journal of the Royal Statistical Society B*. 61(2)459–477.

Offenberg, J. H. and J. E. Baker, 2000. PCBs and PAHs in southern Lake Michigan in 1994 and 1995: Urban atmospheric influences and long-term declines. *Journal of Great Lakes Research*. 26(2):196–208.

Smith, D. W., 2000. Analysis of rates of decline of PCBs in different Lake Superior media. *Journal of Great Lakes Research*. 26(2):152–163.

ThermoRetec, 2001a. *Remedial Investigation: Lower Fox River, Wisconsin.* Prepared by ThermoRetec Consulting Corporation, St. Paul, Minnesota. Prepared for Wisconsin Department of Natural Resources, Madison, Wisconsin.

ThermoRetec, 2001b. *Draft Baseline Human Health and Ecological Risk Assessment: Lower Fox River, Wisconsin Remedial Investigation and Feasibility Study*. Prepared by ThermoRetec Consulting Corporation, Seattle, Washington and Pittsburgh, Pennsylvania. Prepared for Wisconsin Department of Natural Resources, Madison, Wisconsin.

WDNR, 1999a. *Model Evaluation Workgroup Technical Memorandum 2g: Quantification of Lower Fox River Sediment Bed Elevation Dynamics through Direct Observations*. Prepared by Wisconsin Department of Natural Resources. July 23.

WDNR, 1999b. *Model Evaluation Workgroup Technical Memorandum 2e: Estimation of Lower Fox River Sediment Bed Properties*. Prepared by Wisconsin Department of Natural Resources. March 31.

WDNR, 2001. *Technical Memorandum 7c: Recommended Approach for a Food Web/Bioaccumulation Assessment of the Lower Fox River/Green Bay Ecosystem*. Prepared by Wisconsin Department of Natural Resources. January.

Appendix

Additional Data and Plots

APPENDIX B-1
TIME TRENDS IN PCB CONCENTRATIONS IN SEDIMENT AND FISH

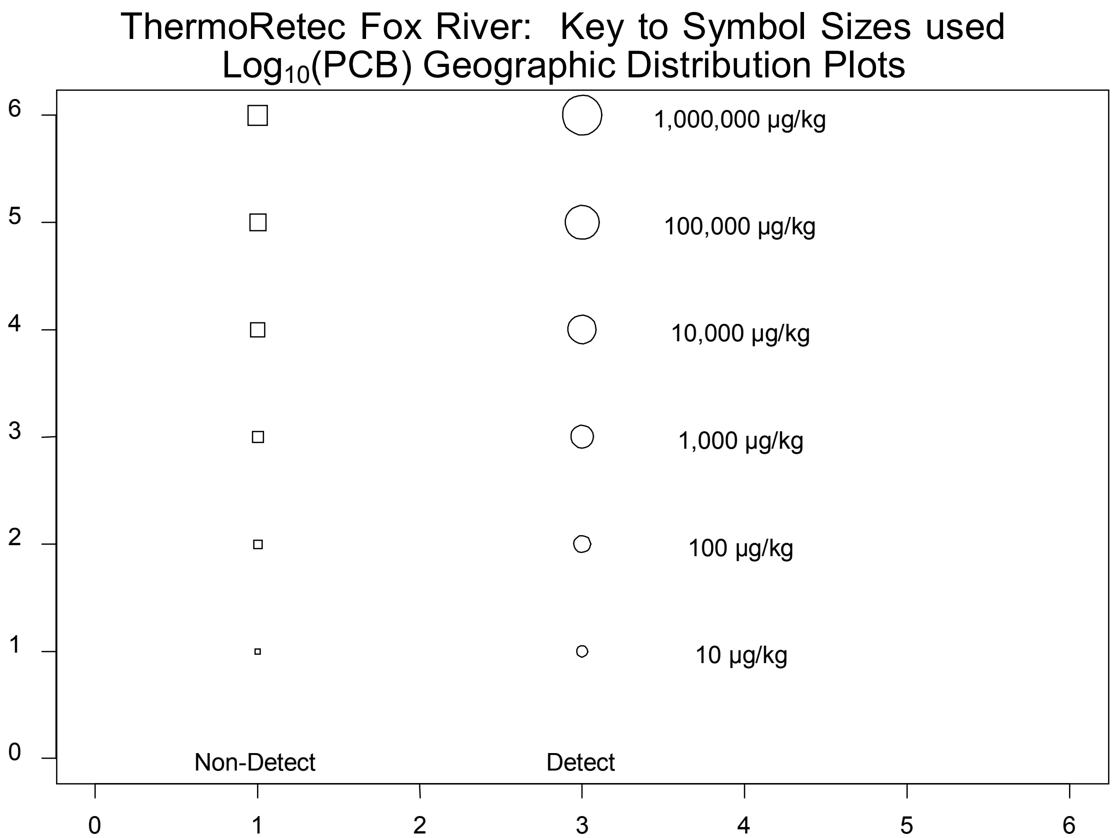


Figure A-1 Northing/Easting Plot Key

Scale plot showing the size of circles (for samples with detected PCBS) and squares (for samples with PCBs below detection limit, the square conveys the level at which the PCBs would have been detected as reported by the various testing agencies) used to convey total PCB level in the northing/easting plots of sample locations.

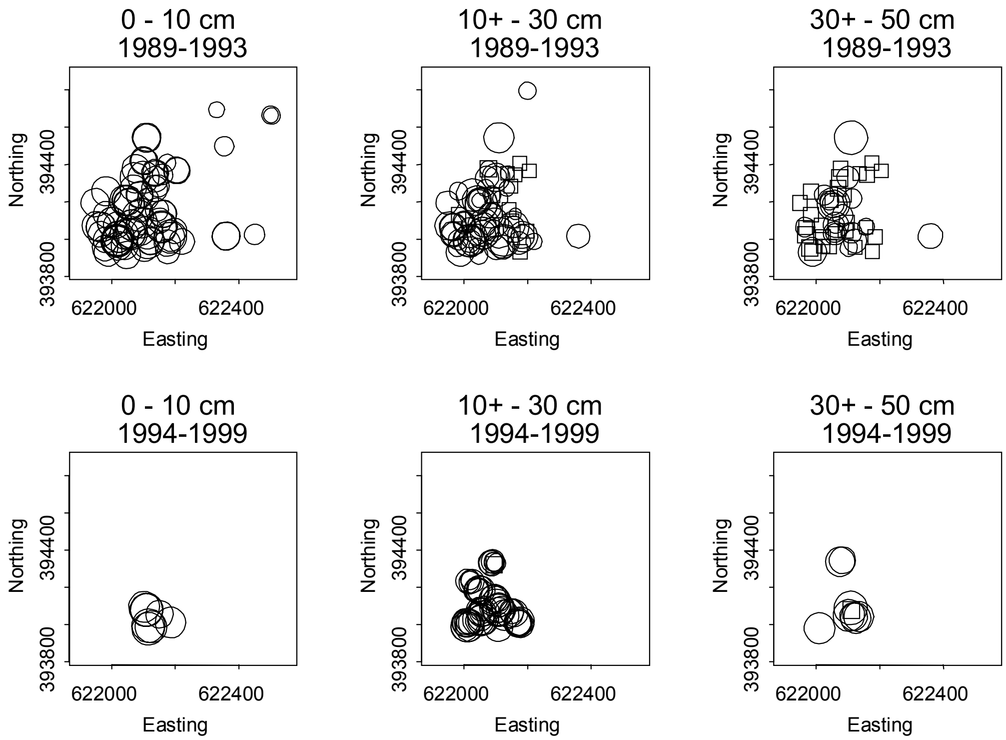


Figure A-2 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Lake Butte des Morts Deposit Group AB (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

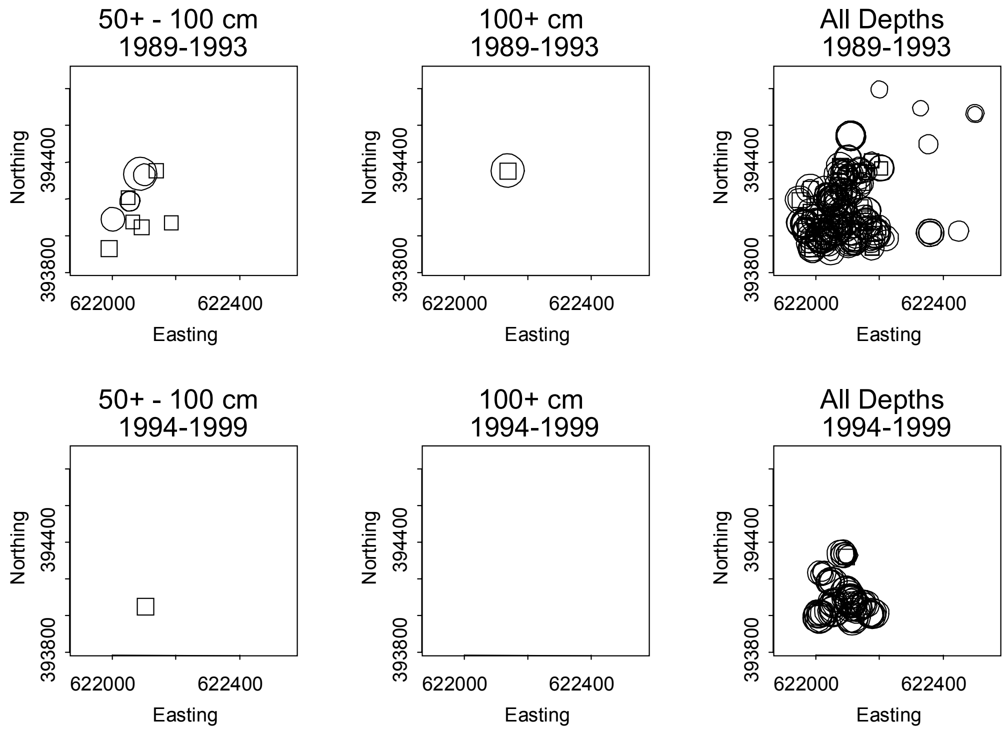


Figure A-3 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Lake Butte des Morts Deposit Group AB (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

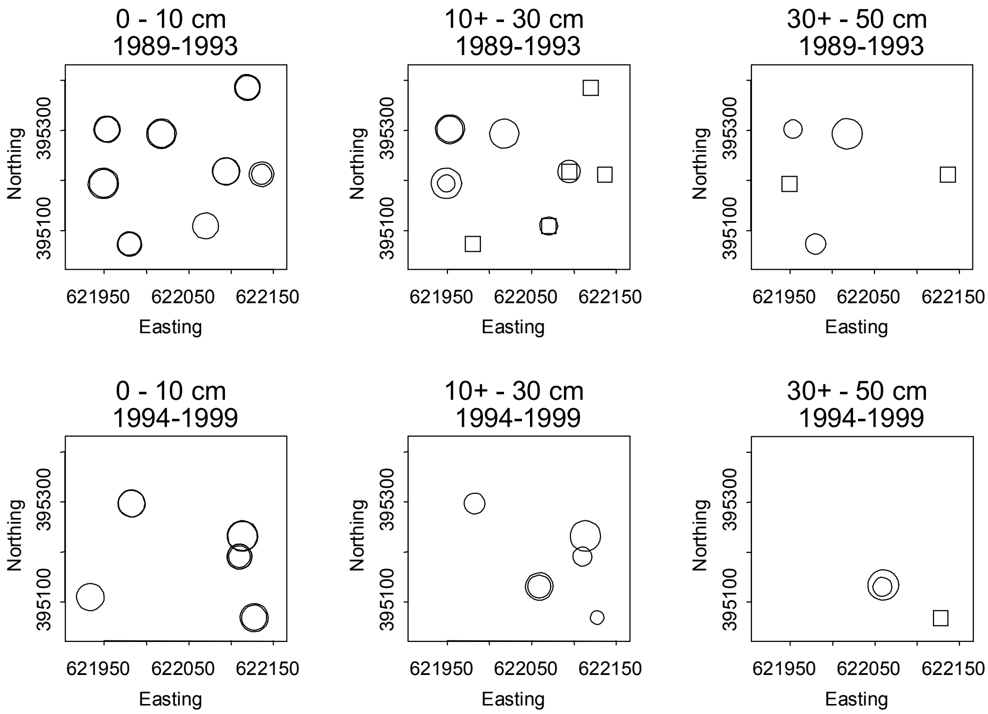


Figure A-4 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Lake Butte des Morts Deposit Group C (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

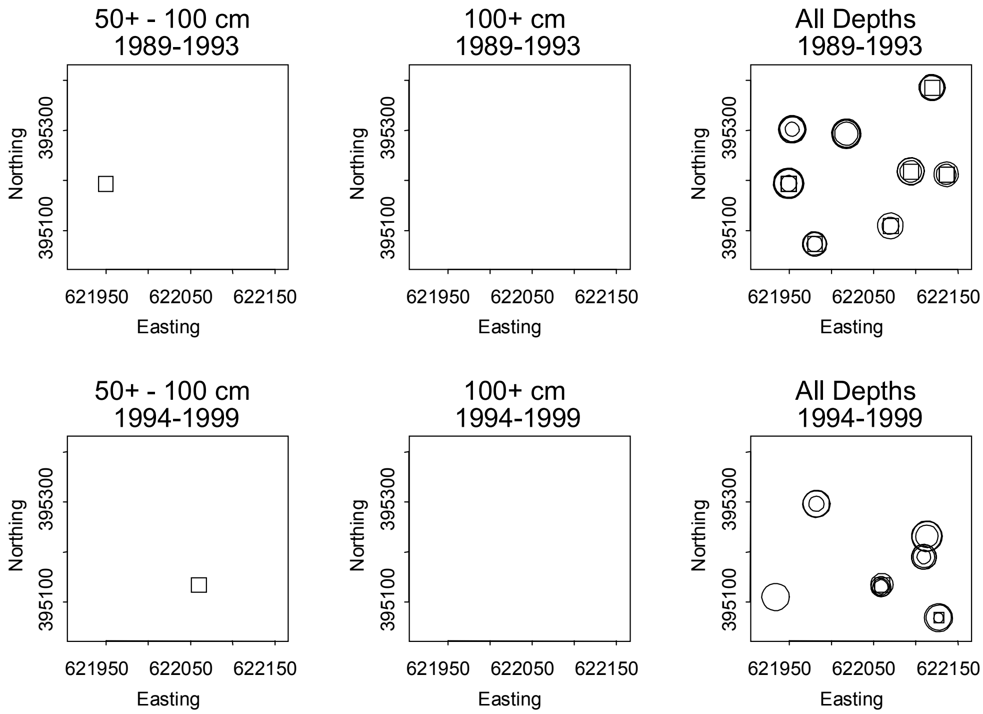


Figure A-5 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Lake Butte des Morts Deposit Group C (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

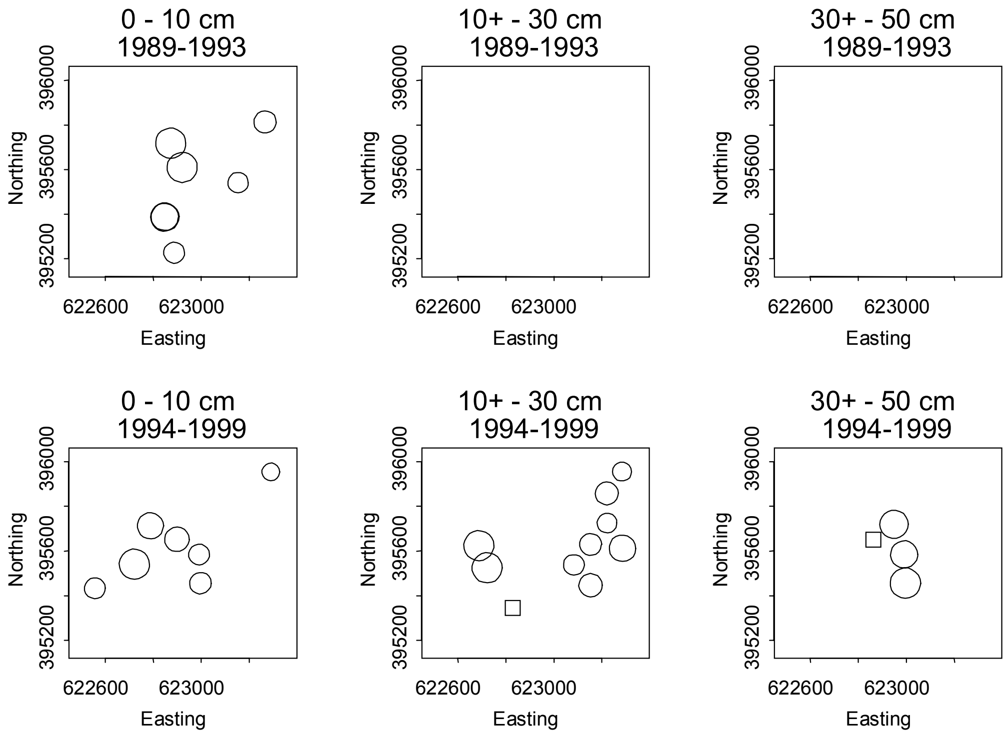


Figure A-6 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Lake Butte des Morts Deposit Group POG (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

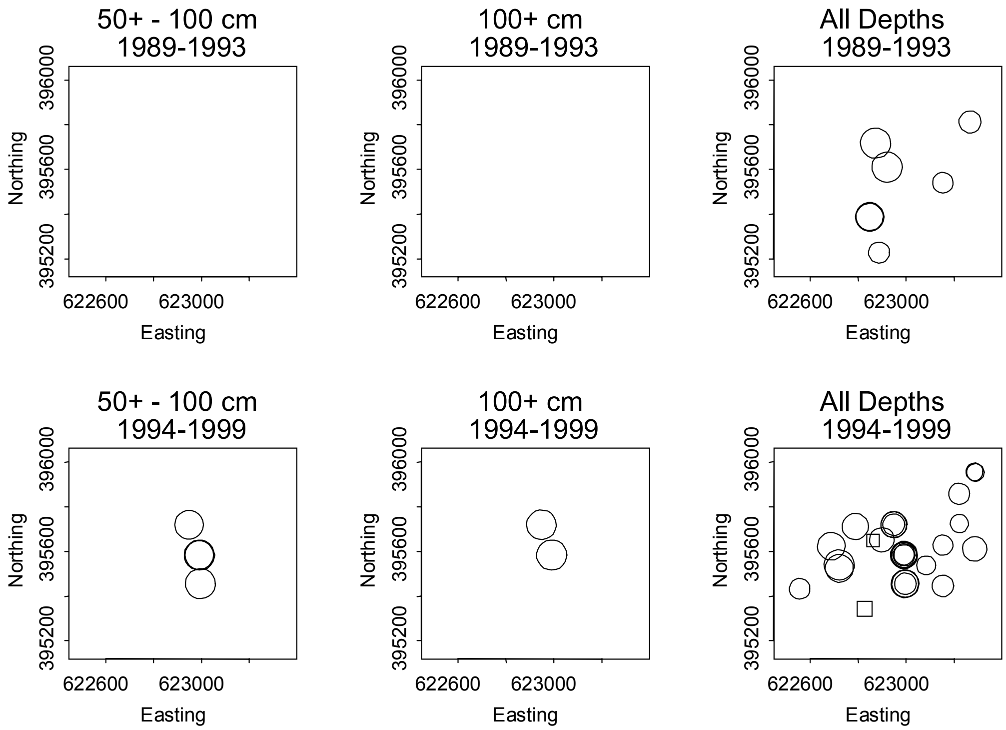


Figure A-7 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Lake Butte des Morts Deposit Group POG (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

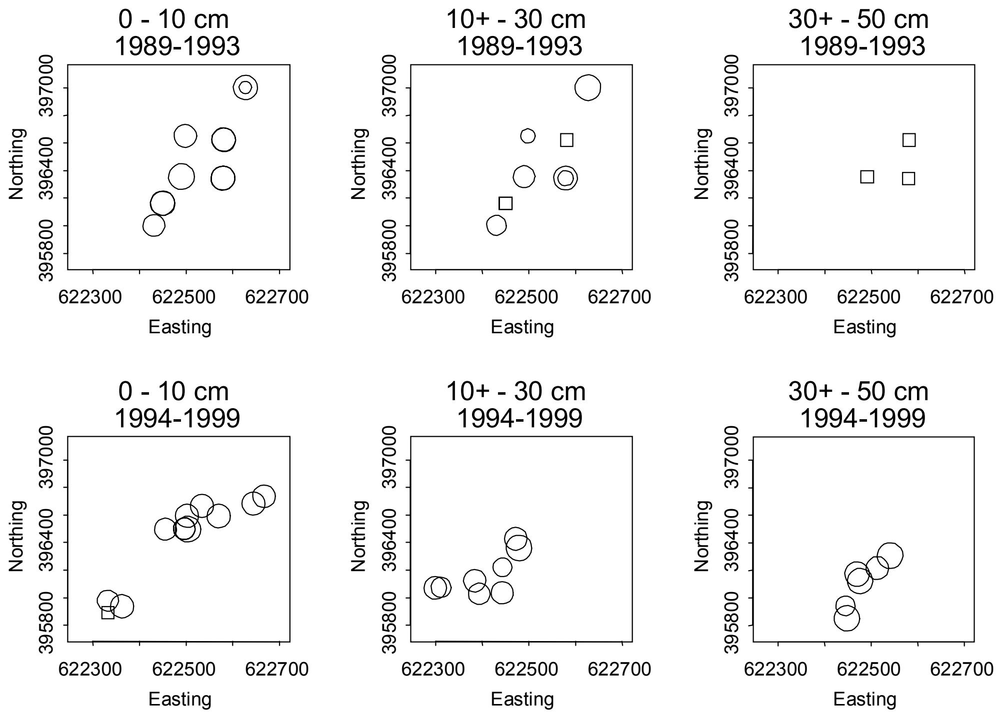


Figure A-8 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Lake Butte des Morts Deposit Group D (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

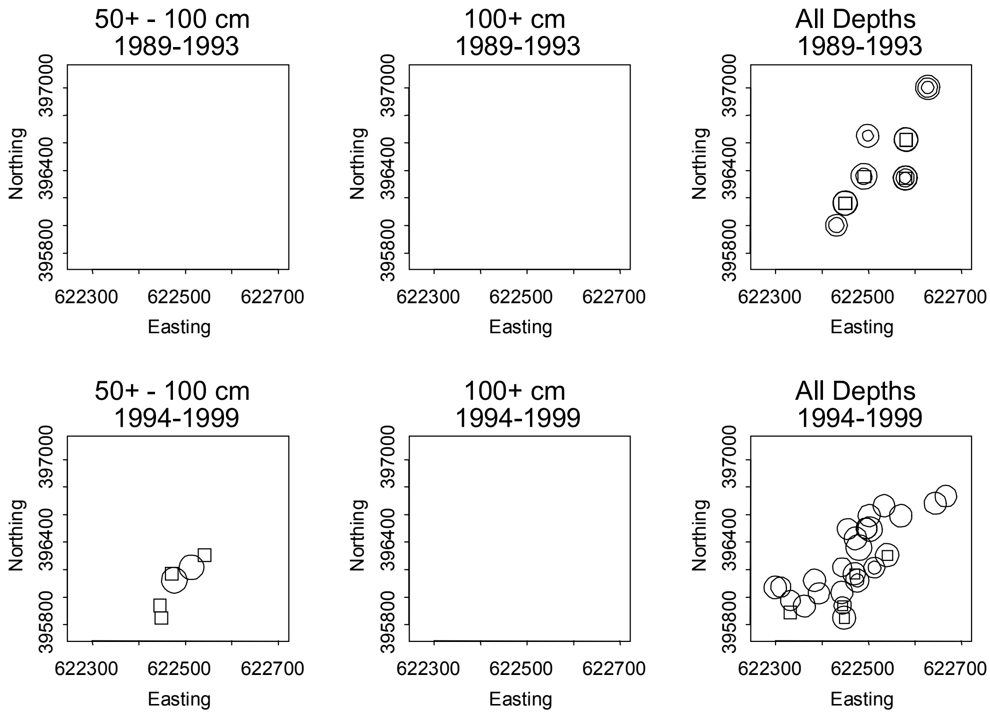


Figure A-9 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Lake Butte des Morts Deposit Group D (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

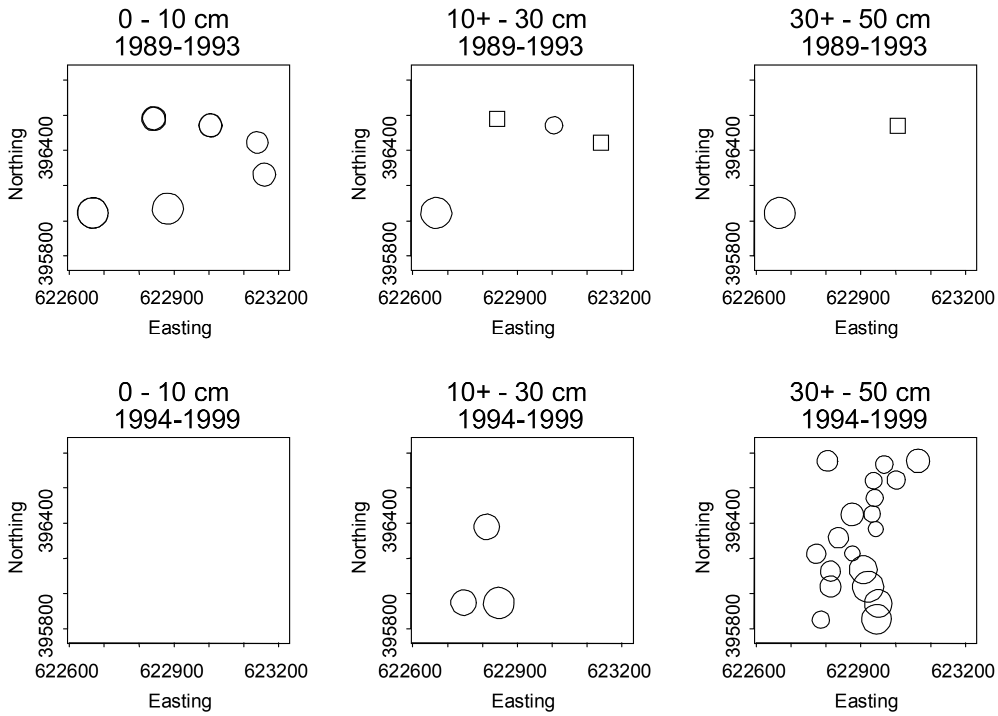


Figure A-10 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Lake Butte des Morts Deposit Group E (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

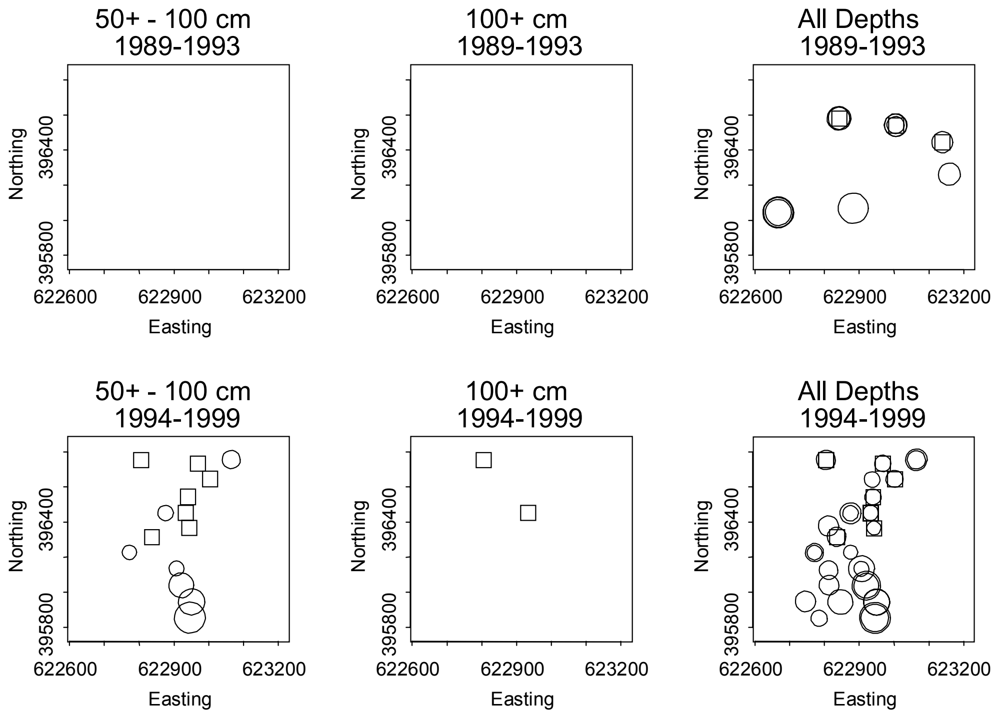


Figure A-11 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Lake Butte des Morts Deposit Group E (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

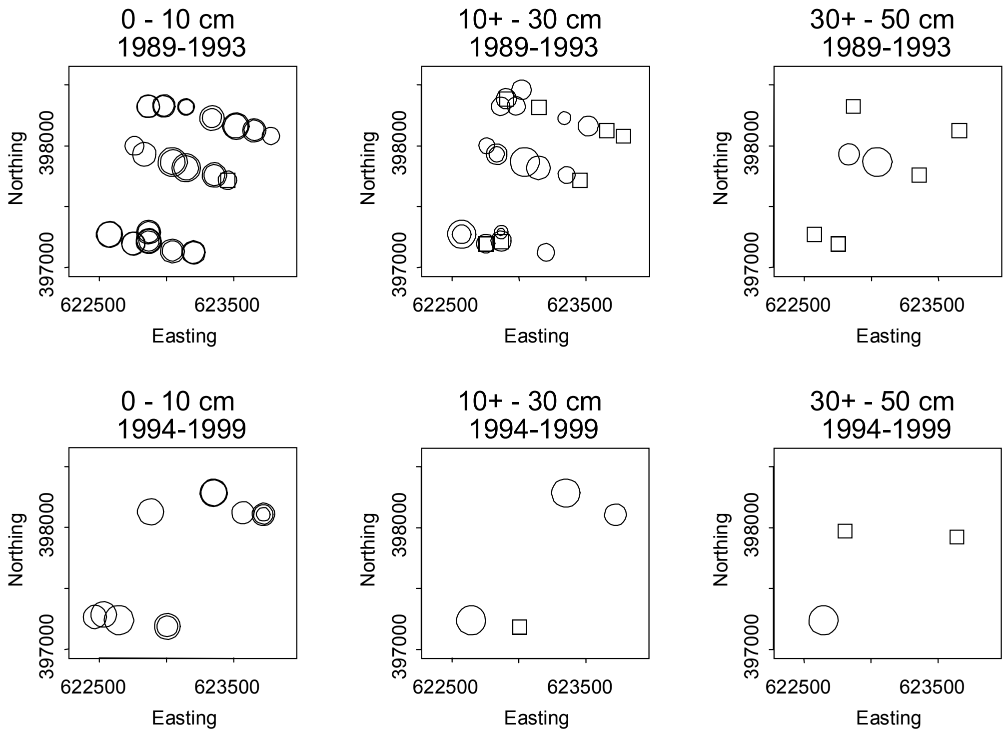


Figure A-12 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Lake Butte des Morts Deposit Group F (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

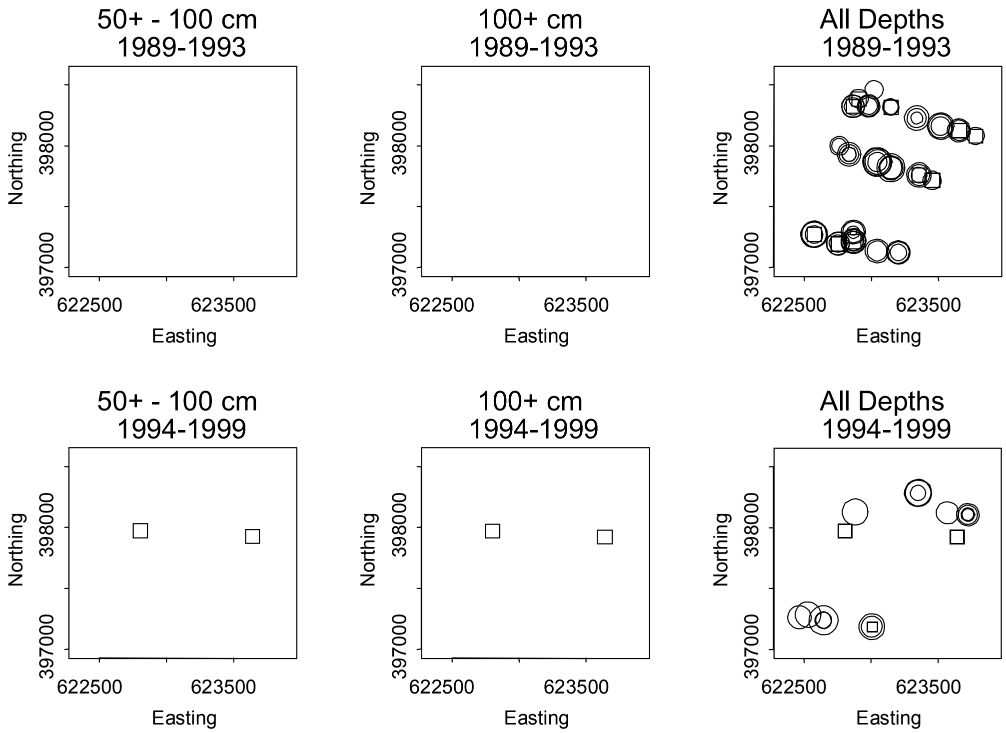


Figure A-13 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Lake Butte des Morts Deposit Group F (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

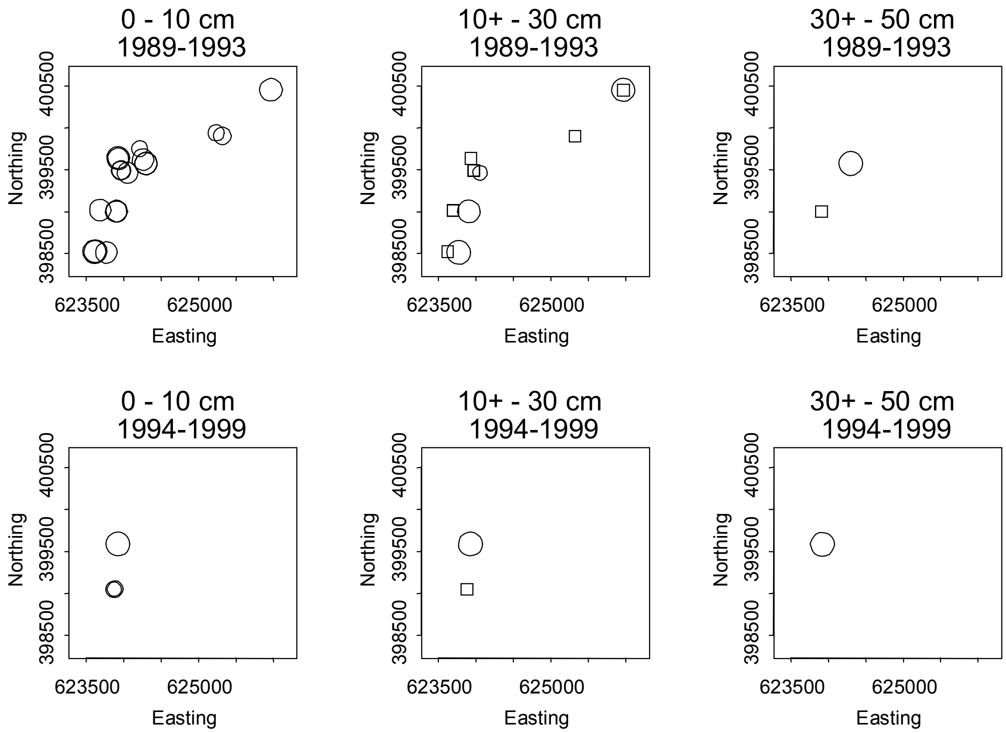


Figure A-14 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Lake Butte des Morts Deposit Group GH (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (O) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

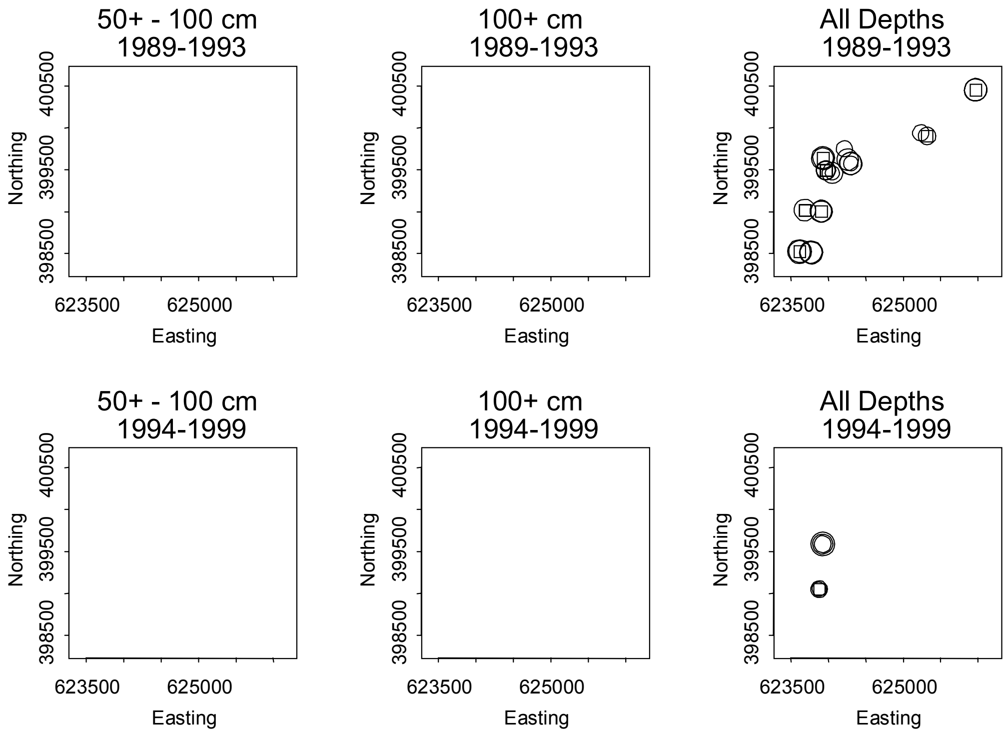


Figure A-15 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Lake Butte des Morts Deposit GH (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

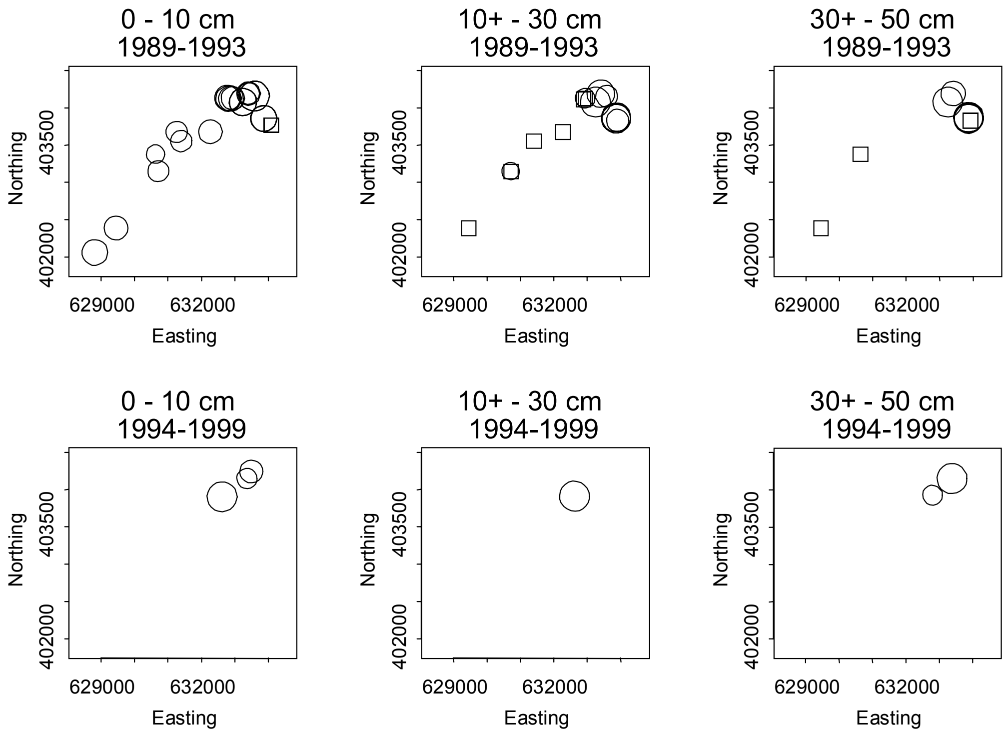


Figure A-16 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Appleton Deposit Group IMOR (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

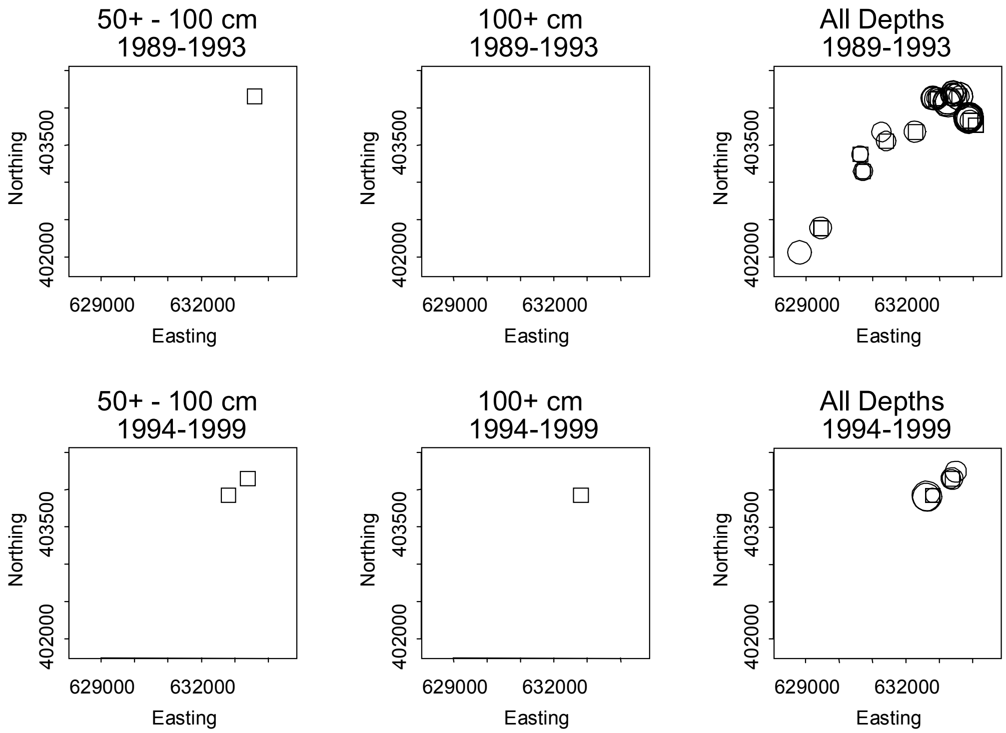


Figure A-17 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Appleton Deposit Group IMOR (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

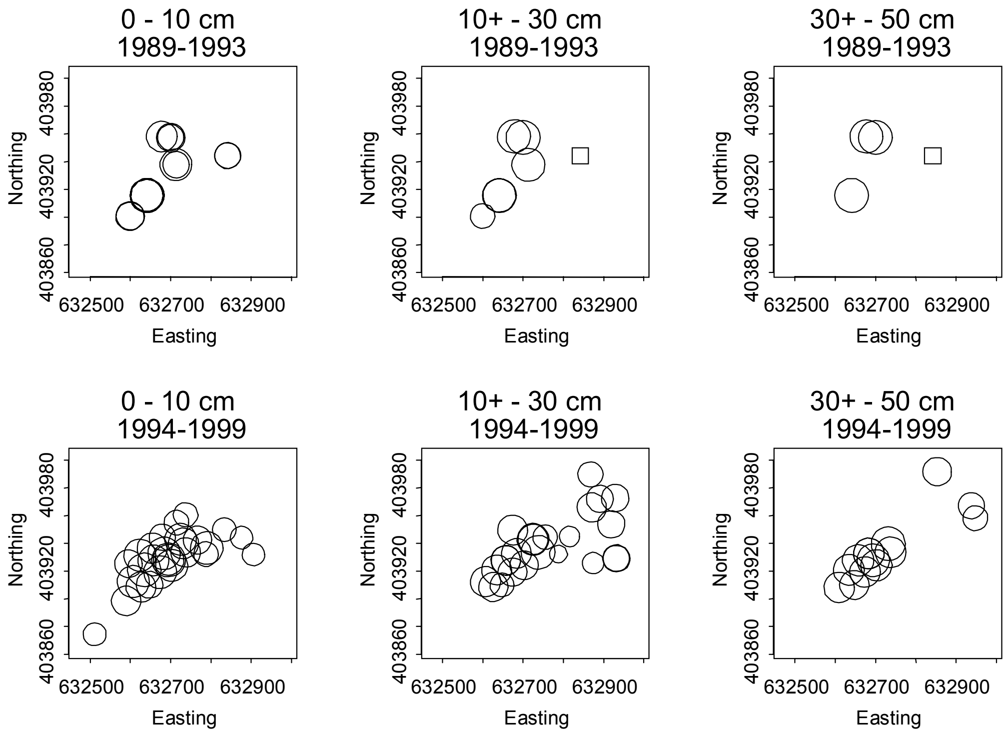


Figure A-18 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Appleton Deposit Group N Before Demonstration Project (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

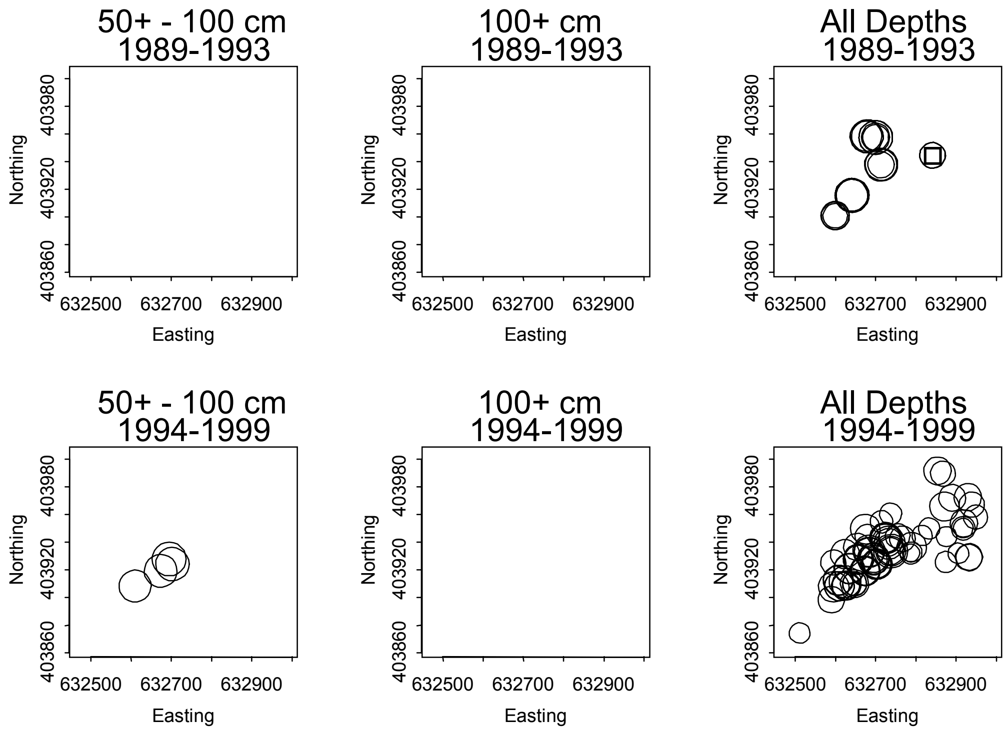


Figure A-19 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Appleton Deposit Group N Before Demonstration Project (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

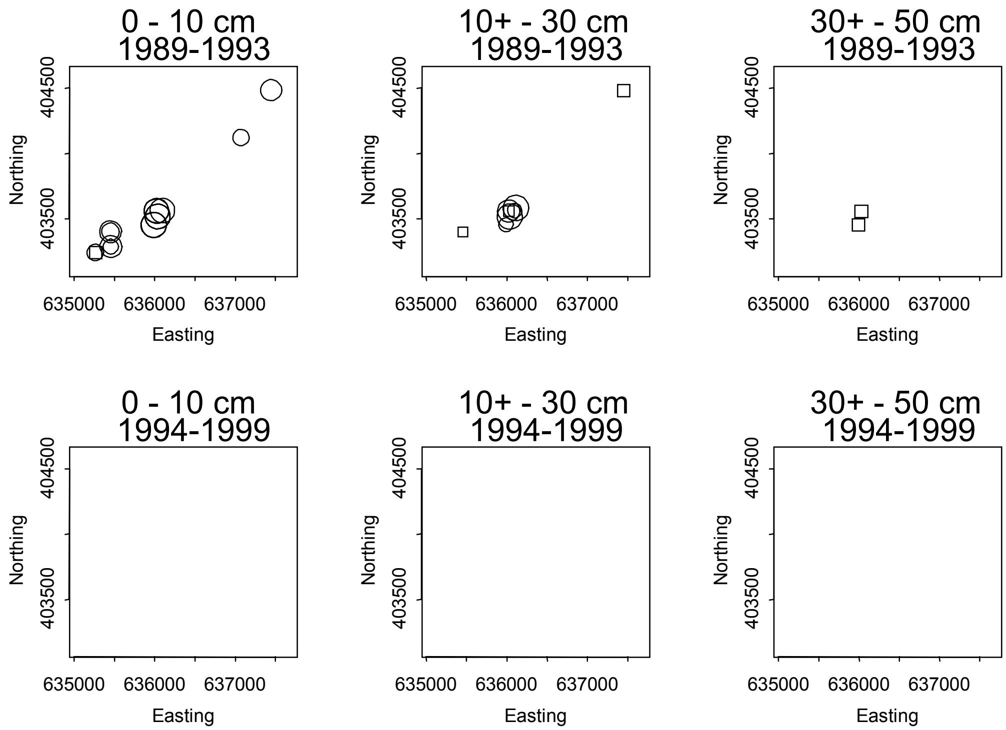


Figure A-20 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Appleton Deposit Group SU (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

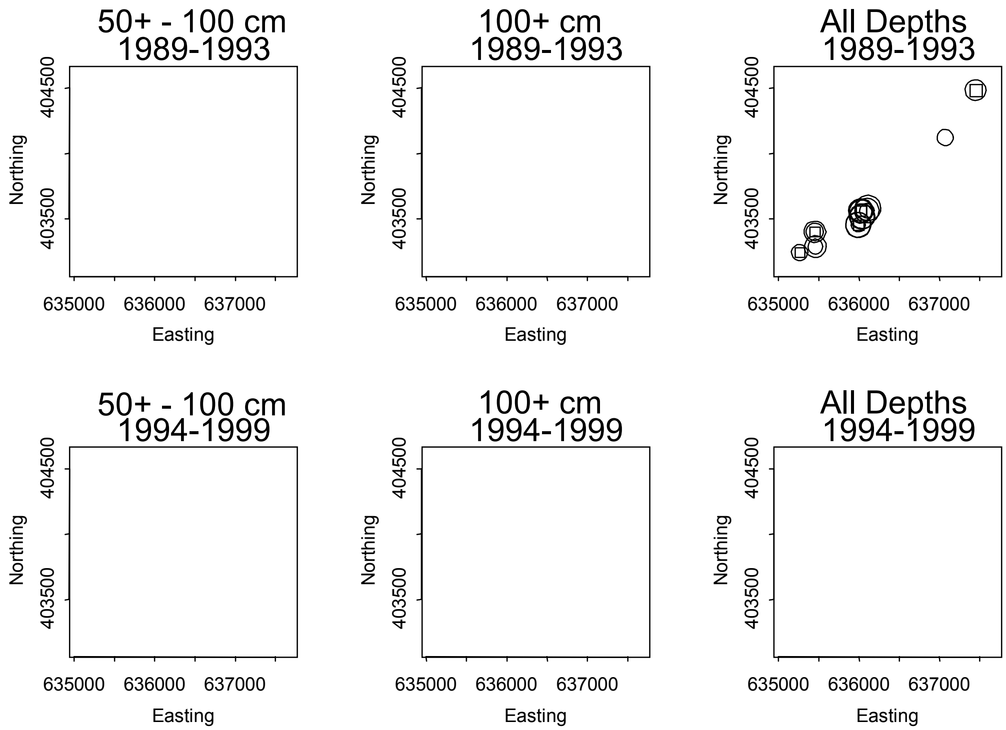


Figure A-21 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Appleton Deposit Group SU (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

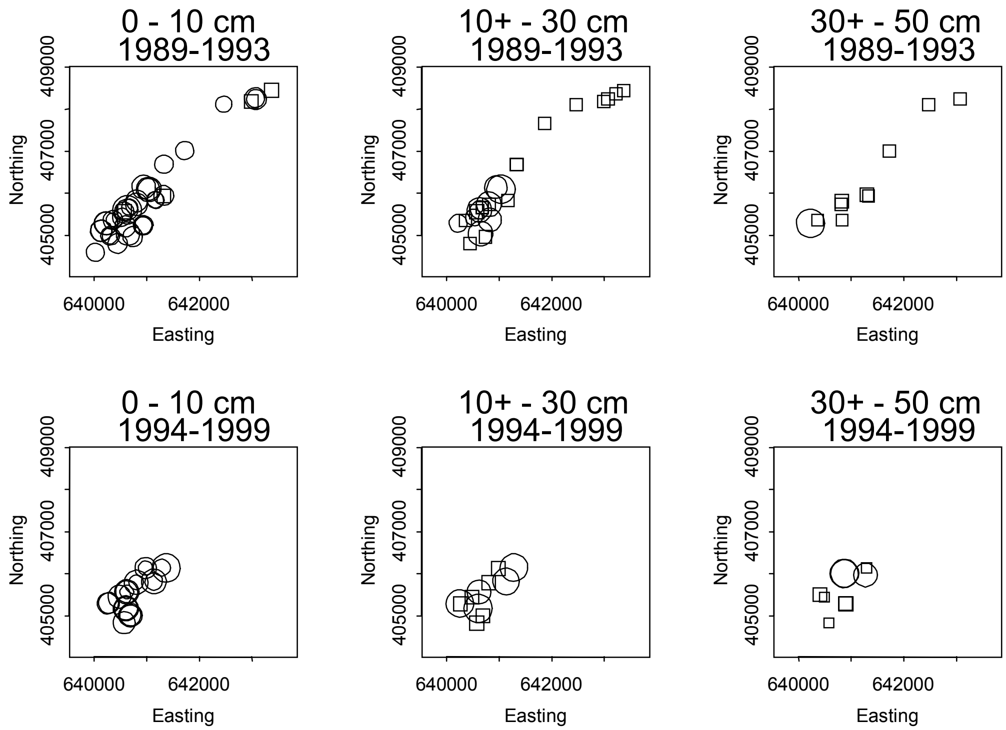


Figure A-22 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Appleton Deposit Group VCC (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

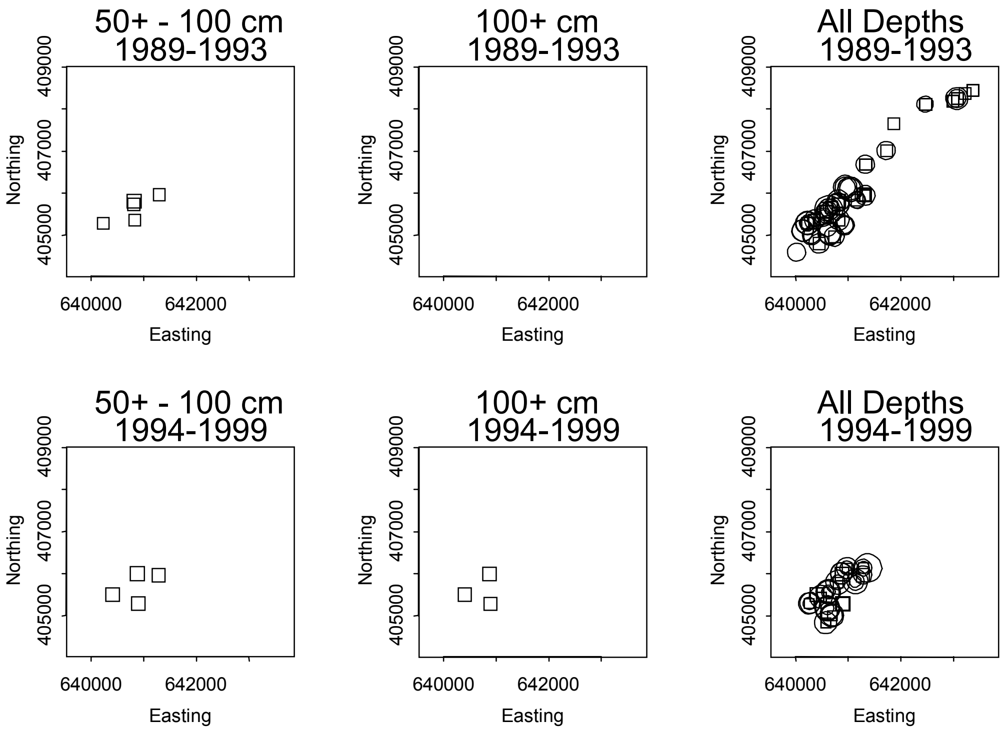


Figure A-23 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Appleton Deposit Group VCC (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

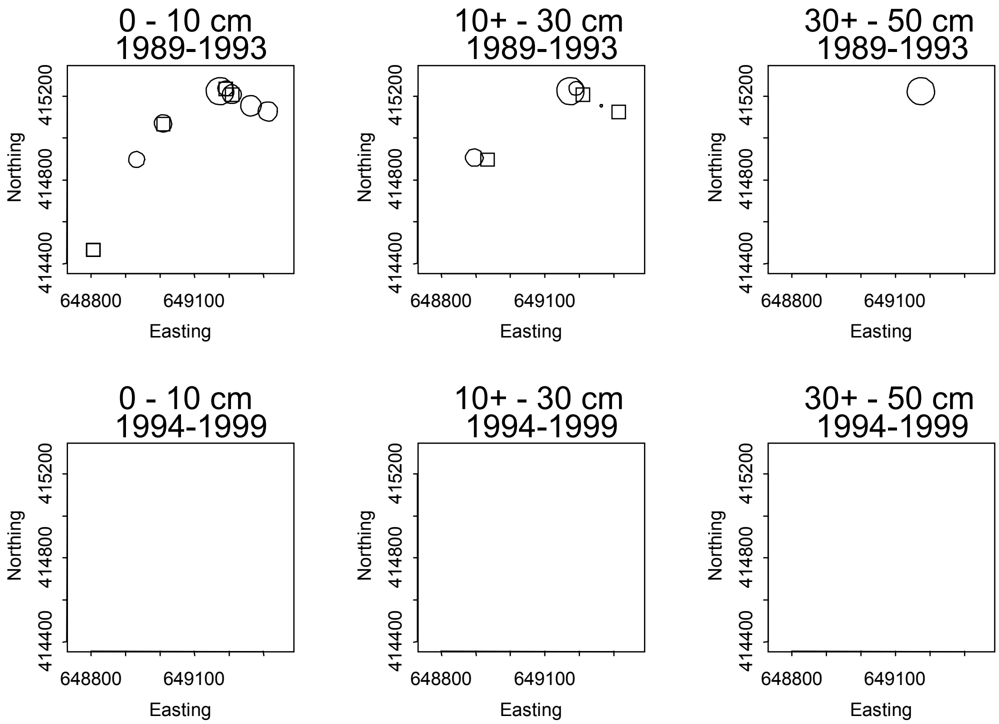


Figure A-24 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Appleton Deposit Group DD (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

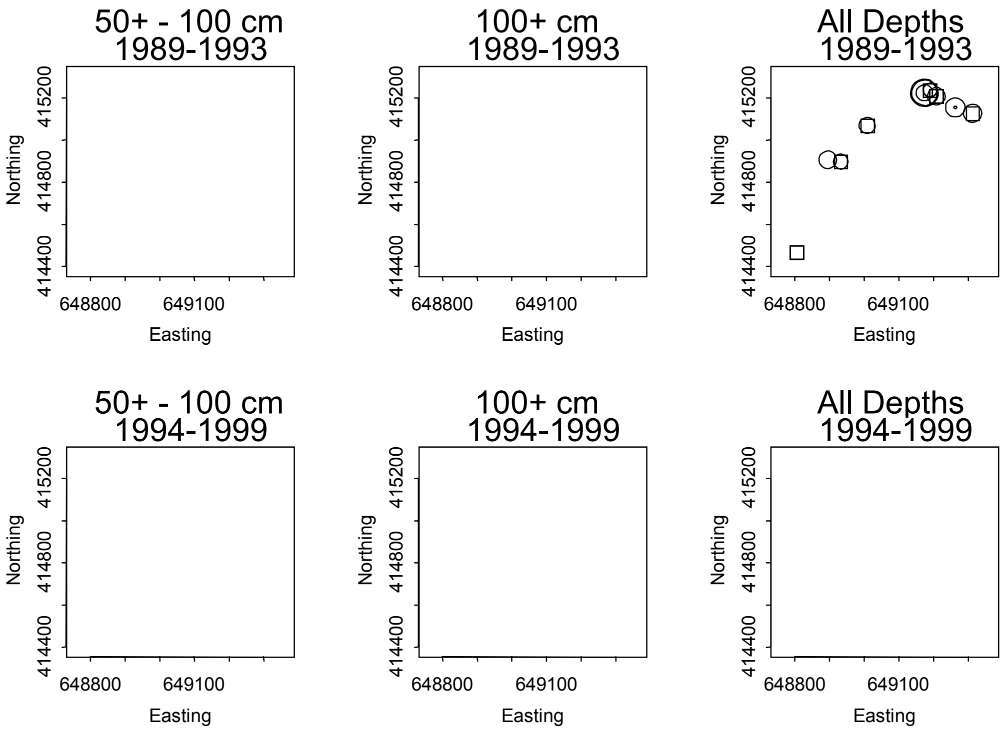


Figure A-25 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Appleton Deposit Group DD (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (O) indicate measured concentrations and squares (☐) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

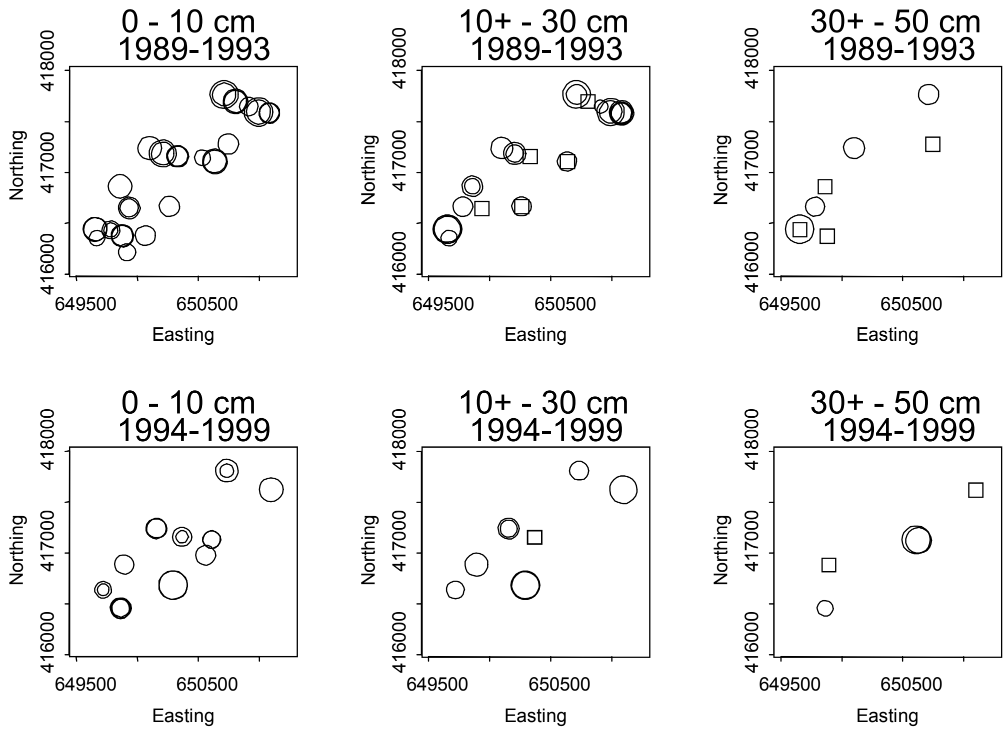


Figure A-26 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Rapids Deposit Group Upper EE (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

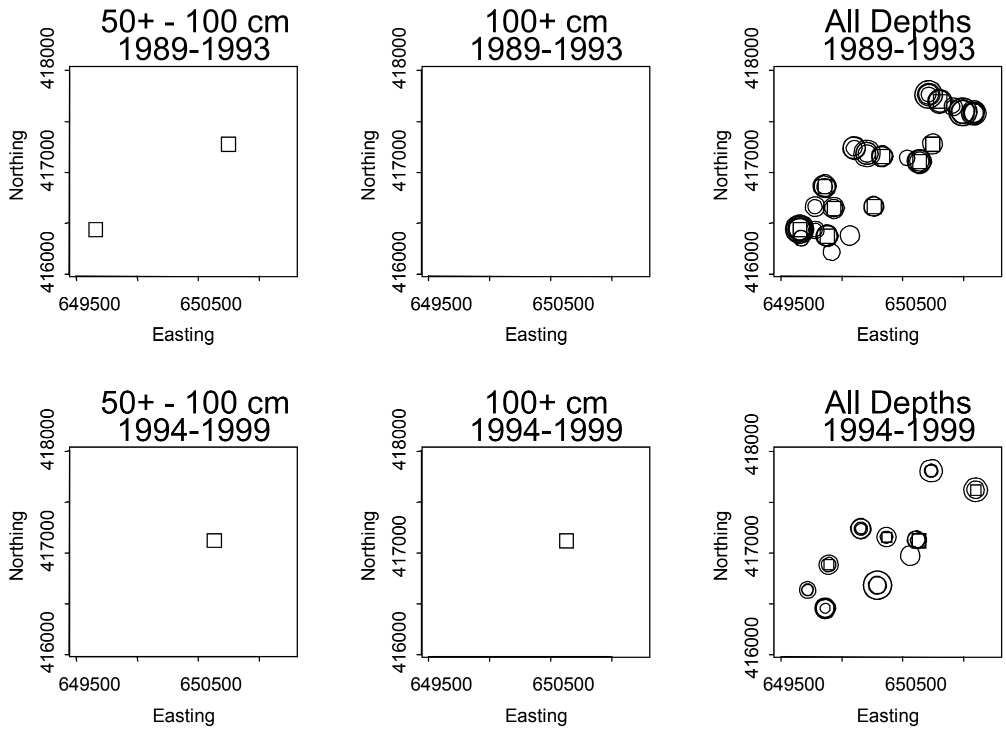


Figure A-27 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Rapids Deposit Group Upper EE (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

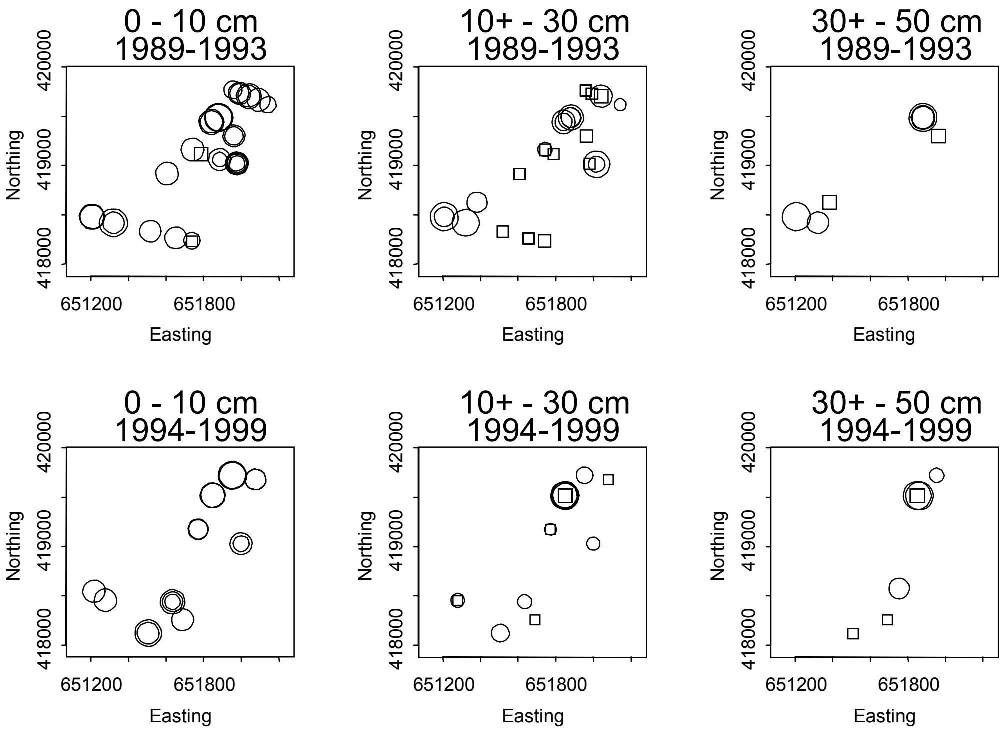


Figure A-28 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Rapids Deposit Group Lower EE (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

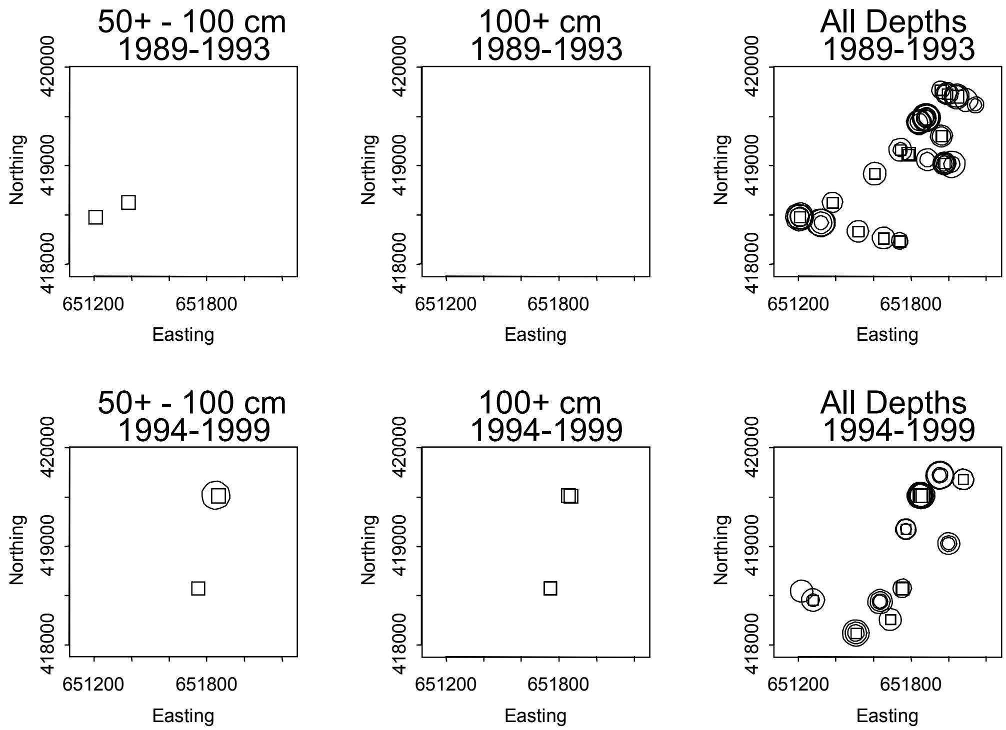


Figure A-29 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Rapids Deposit Group Lower EE (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

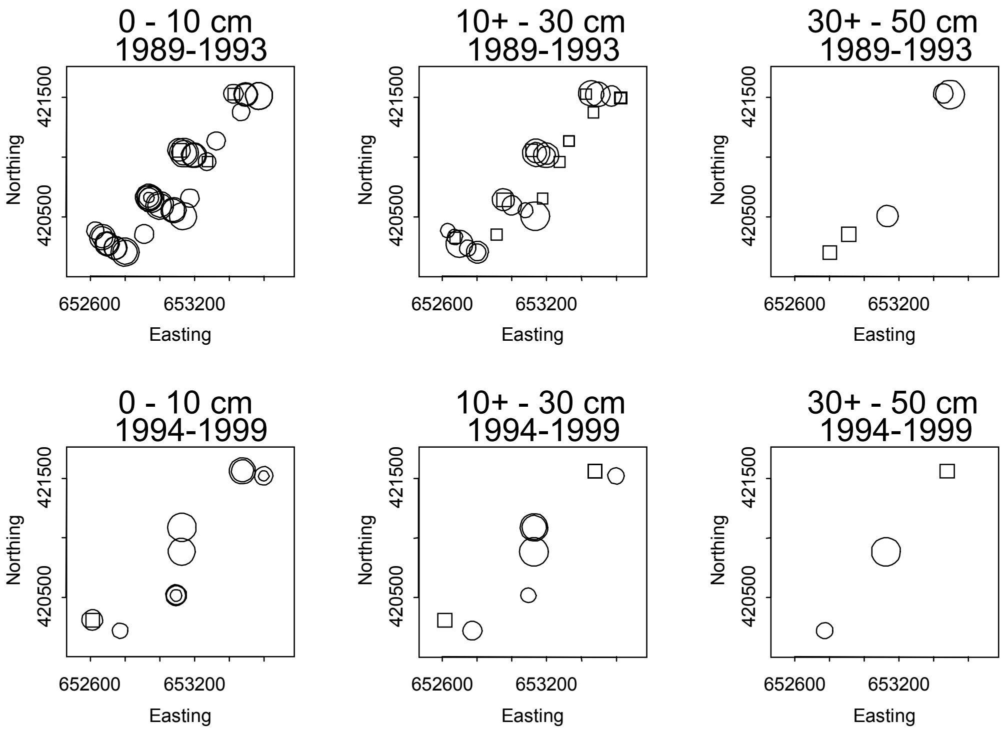


Figure A-30 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Rapids Deposit Group FF (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

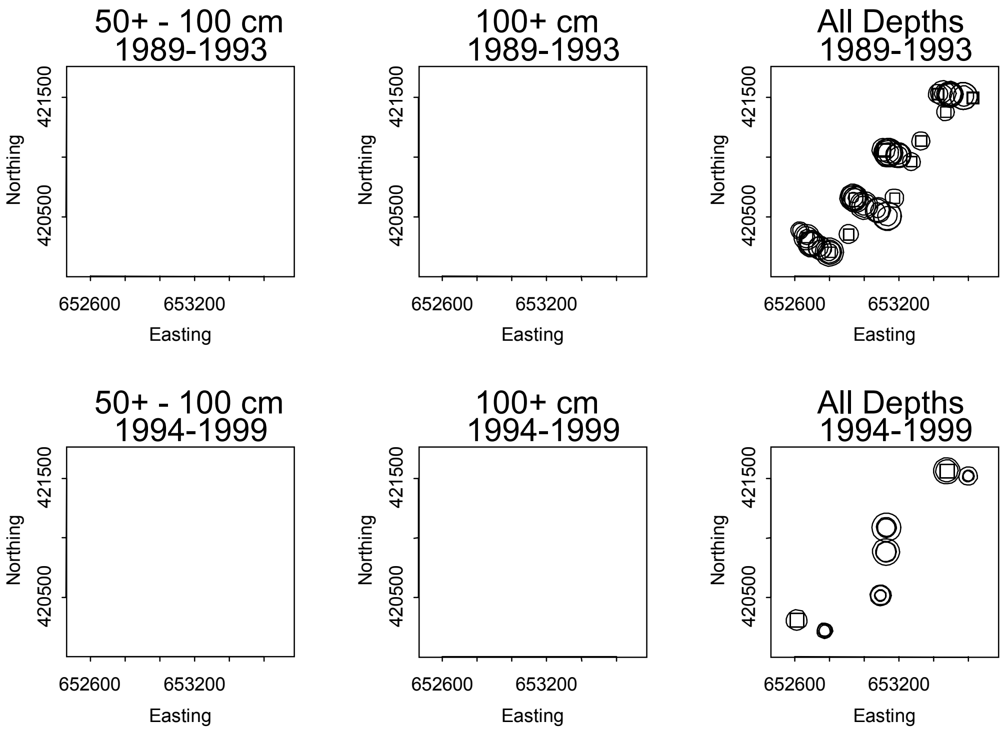


Figure A-31 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Rapids Deposit Group FF (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

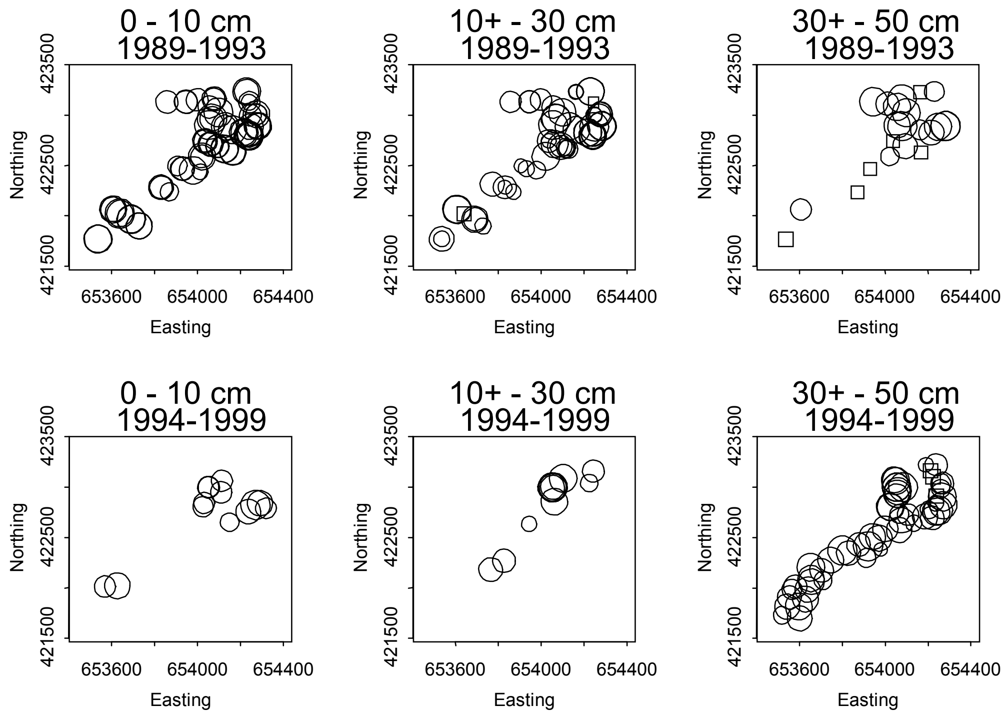


Figure A-32 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Rapids Deposit Group GGHH (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

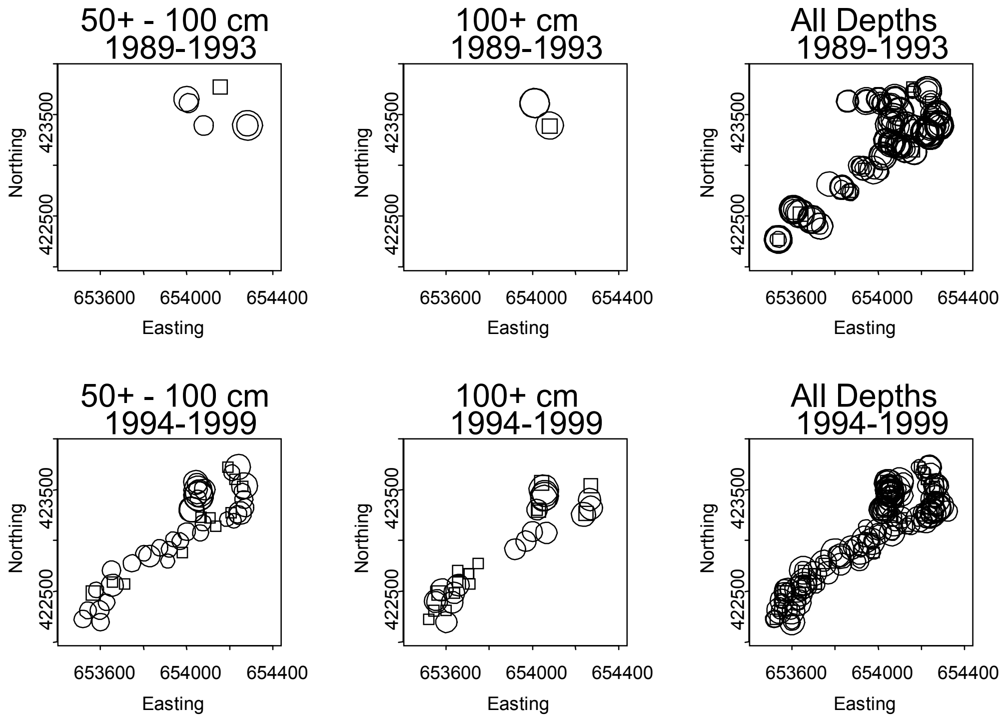


Figure A-33 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of Little Rapids Deposit Group GGHH (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

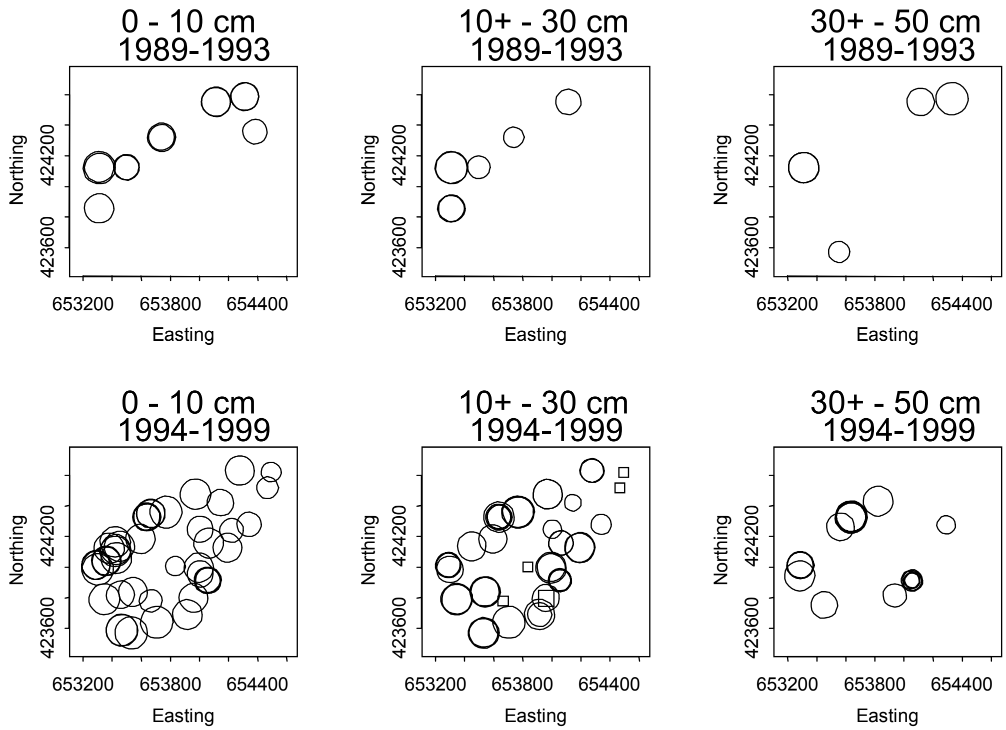


Figure A-34 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of De Pere SMU Group 2025 (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

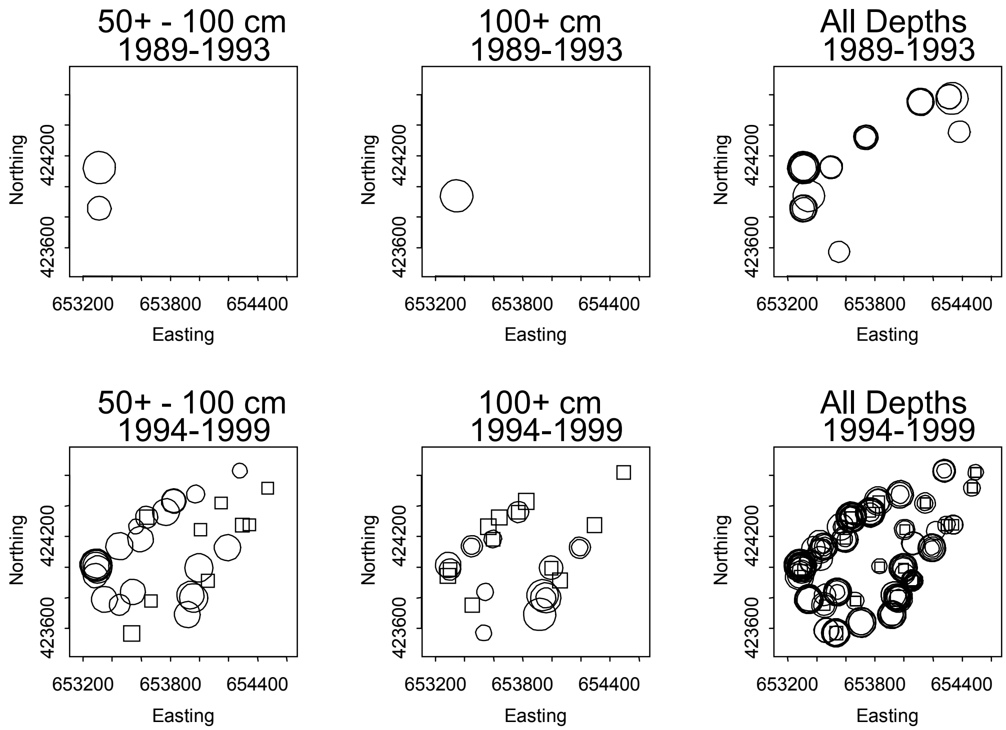


Figure A-35 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of De Pere SMU Group 2025 (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

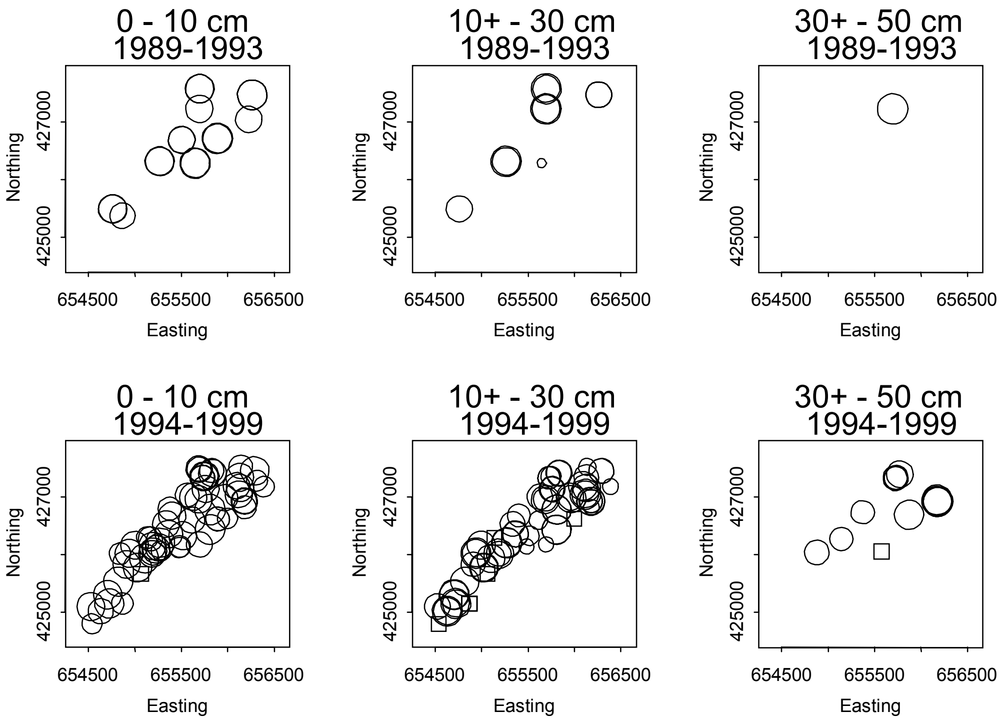


Figure A-36 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of De Pere SMU Group 2649 (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

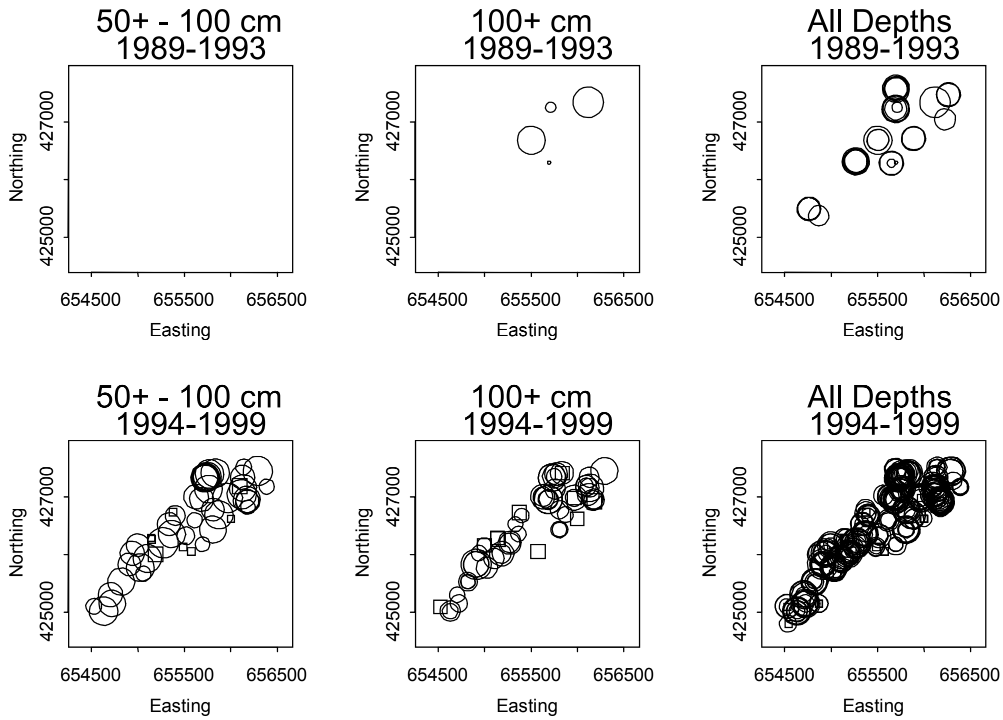


Figure A-37 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of De Pere SMU Group 2649 (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

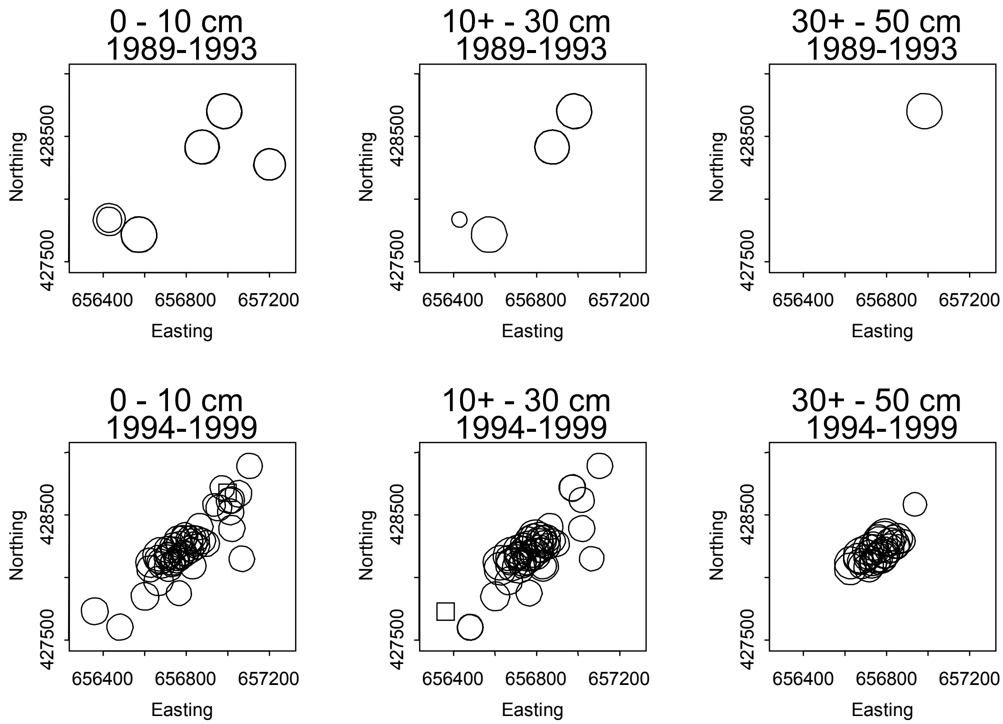


Figure A-38 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of De Pere SMU Group 5067 (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

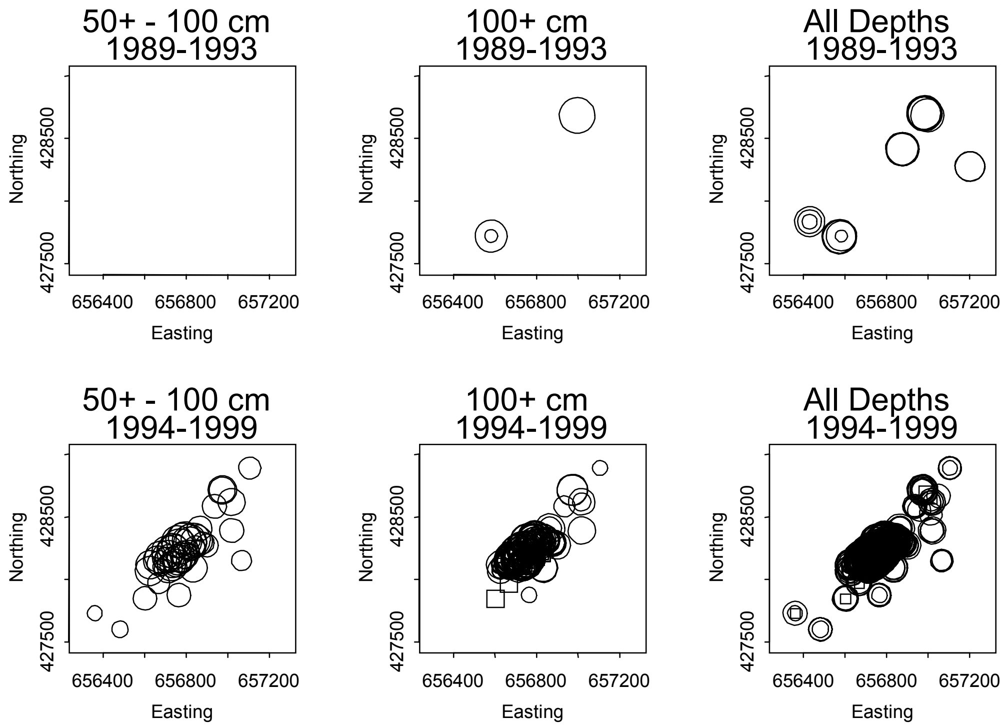


Figure A-39 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of De Pere SMU Group 5067 (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

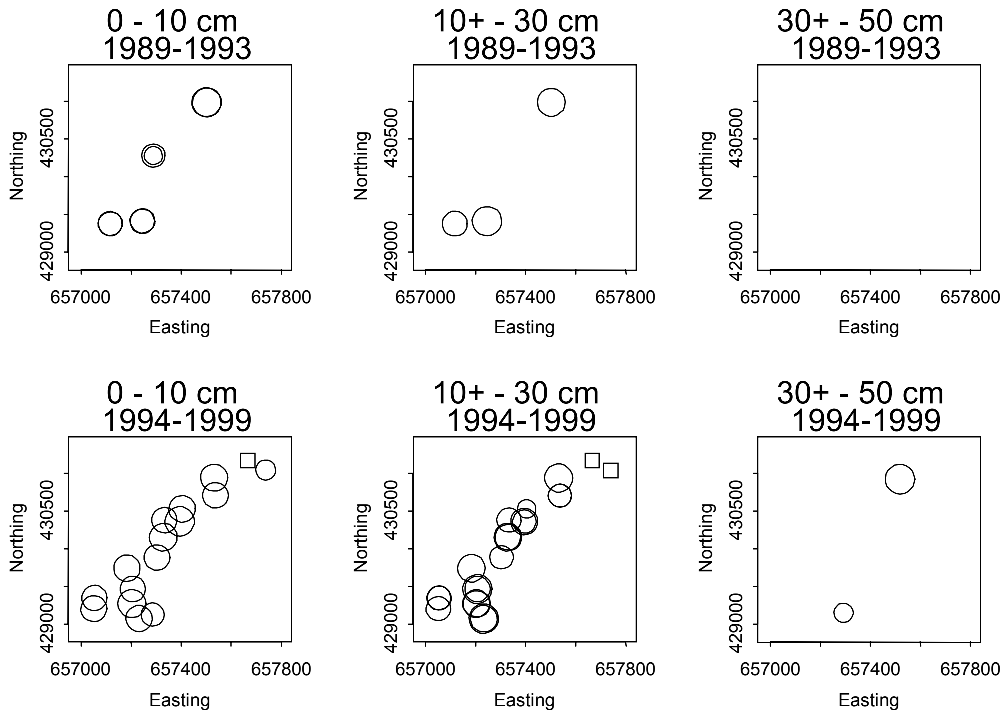


Figure A-40 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of De Pere SMU Group 6891 (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

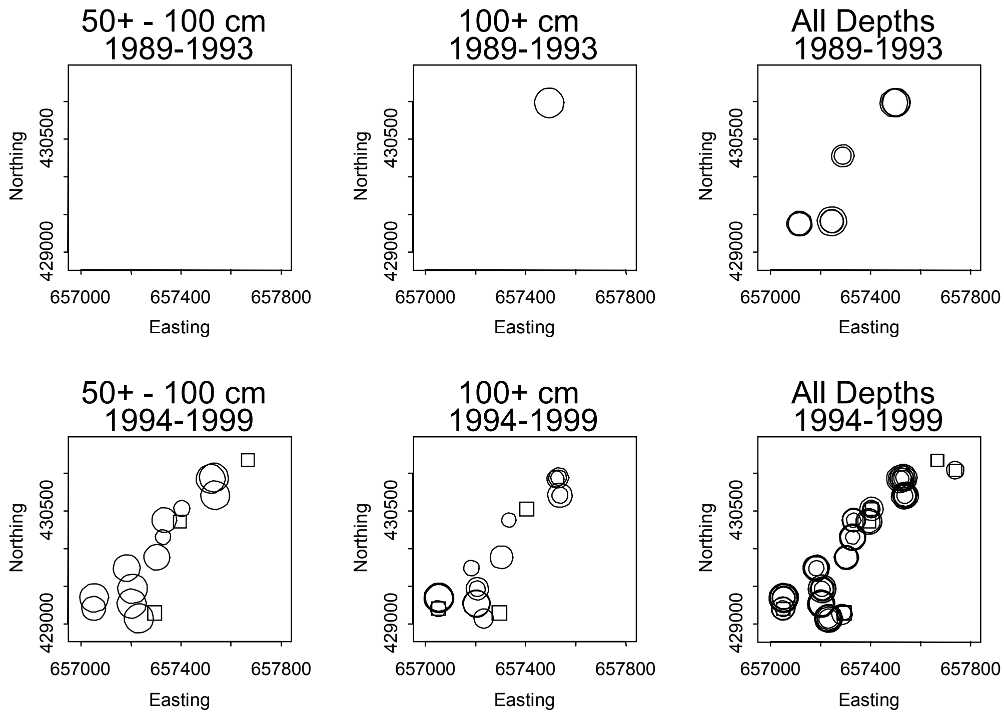


Figure A-41 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of De Pere SMU Group 6891 (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

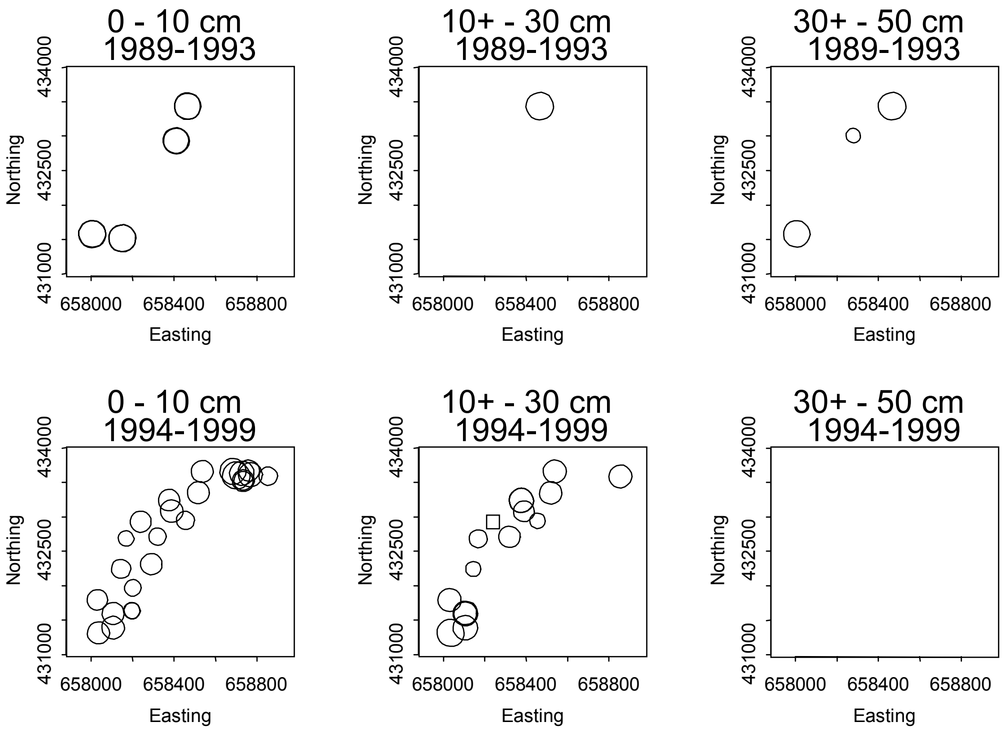


Figure A-42 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of De Pere SMU Group 92115 (0 to 50 cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

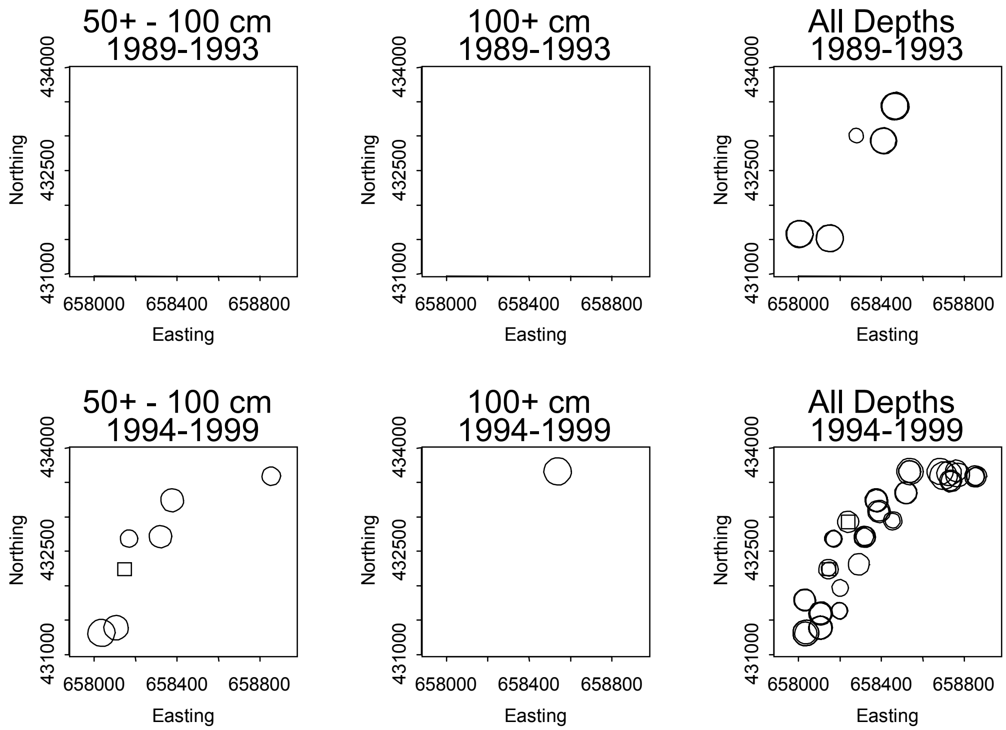


Figure A-43 Sample Locations by Northing and Easting Coordinates During 1989–1993 and 1994–1999, Depth Strata of De Pere SMU Group 92115 (50 to 100+ cm)

Larger symbols indicate higher concentrations. Circles (○) indicate measured concentrations and squares (□) indicate the detection limit of concentrations below the detection limit. Coordinates are in meters.

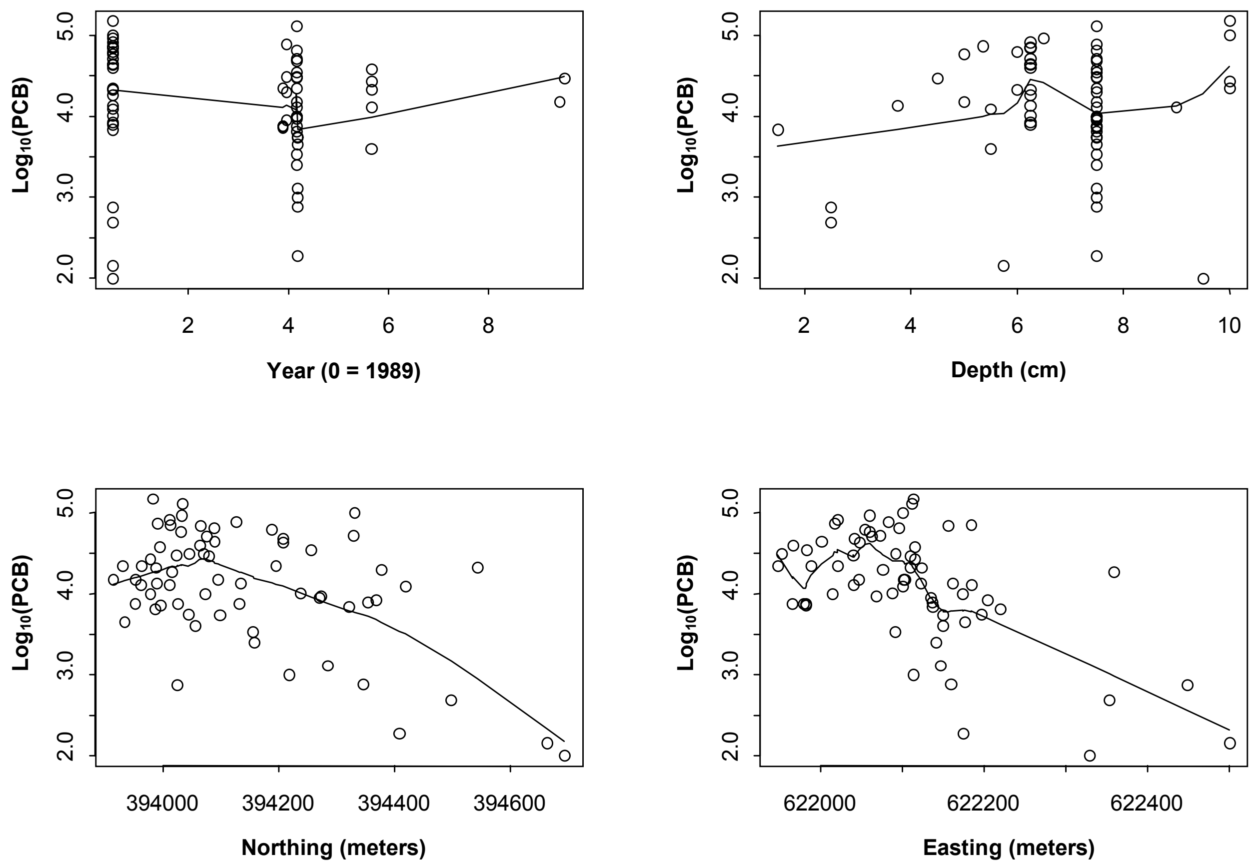


Figure A-44 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for Little Lake Butte des Morts Deposit Group AB (0 to 10 cm) Including Fitted Smoothed Line

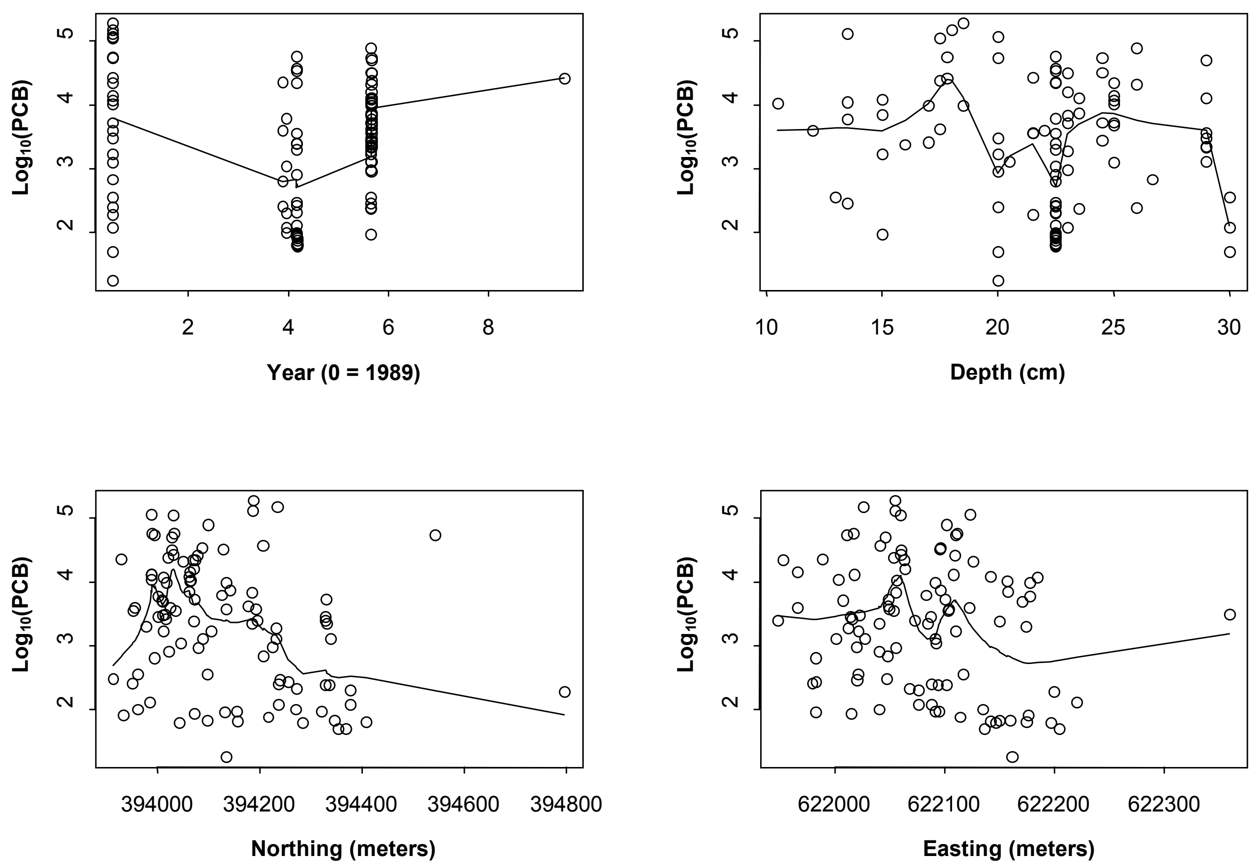


Figure A-45 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for Little Lake Butte des Morts Deposit Group AB (10 to 30 cm) Including Fitted Smoothed Line

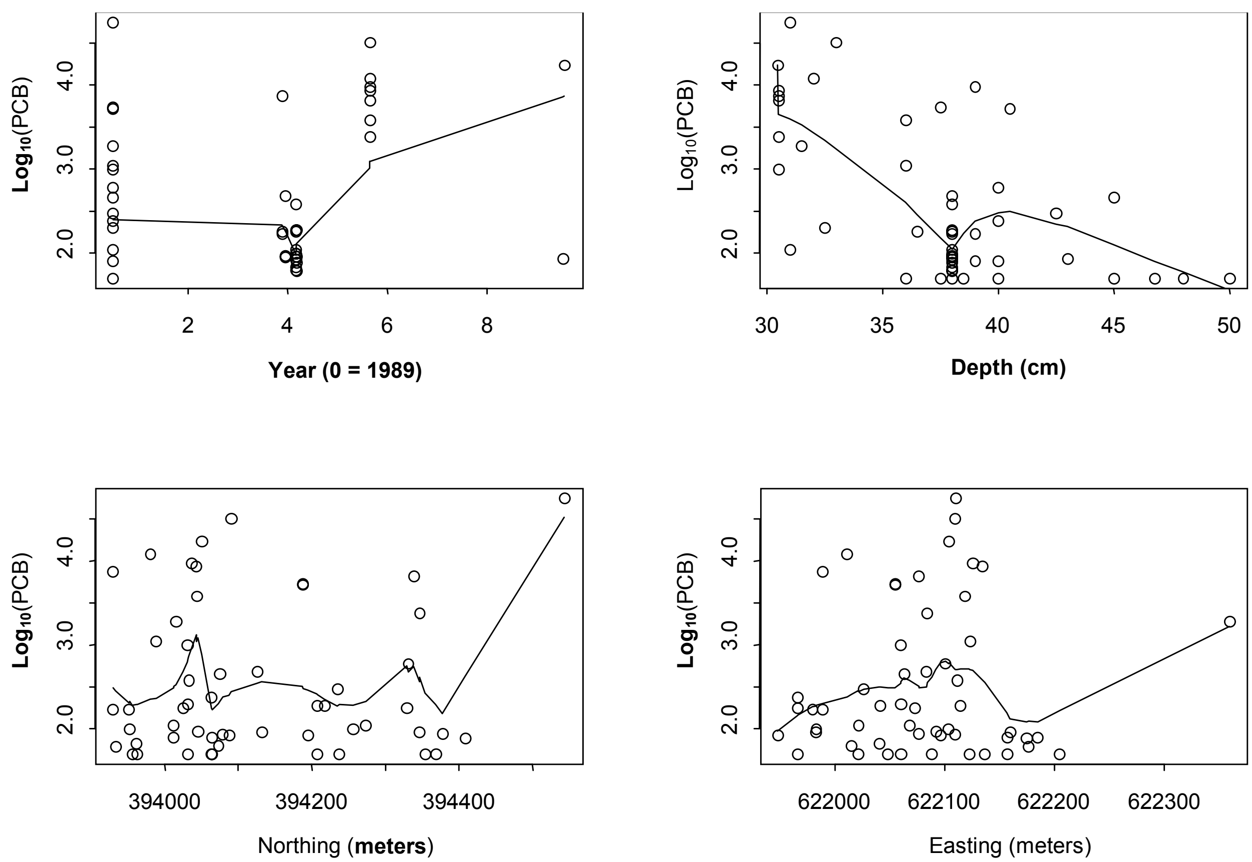


Figure A-46 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for Little Lake Butte des Morts Deposit Group AB (30 to 50 cm) Including Fitted Smoothed Line

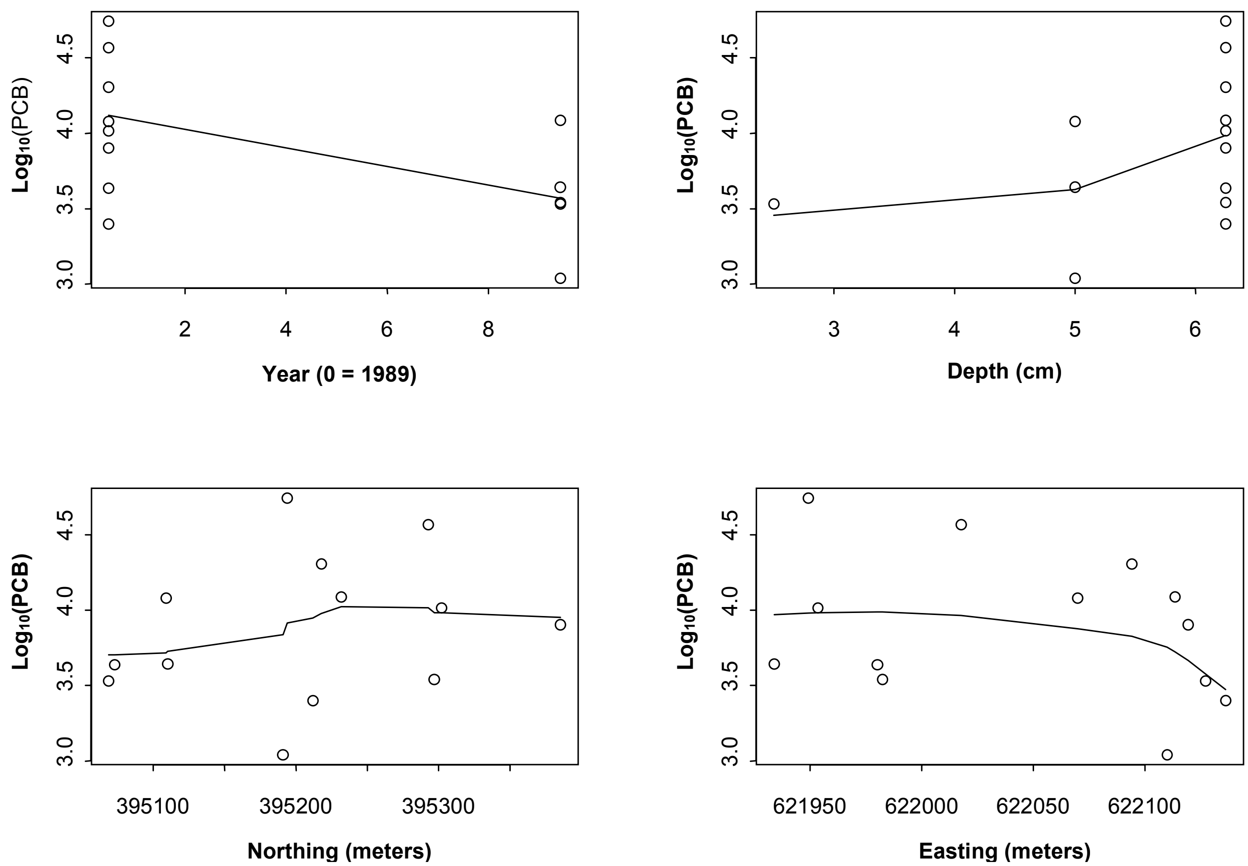


Figure A-47 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for Little Lake Butte des Morts Deposit Group C (0 to 10 cm) Including Fitted Smoothed Line

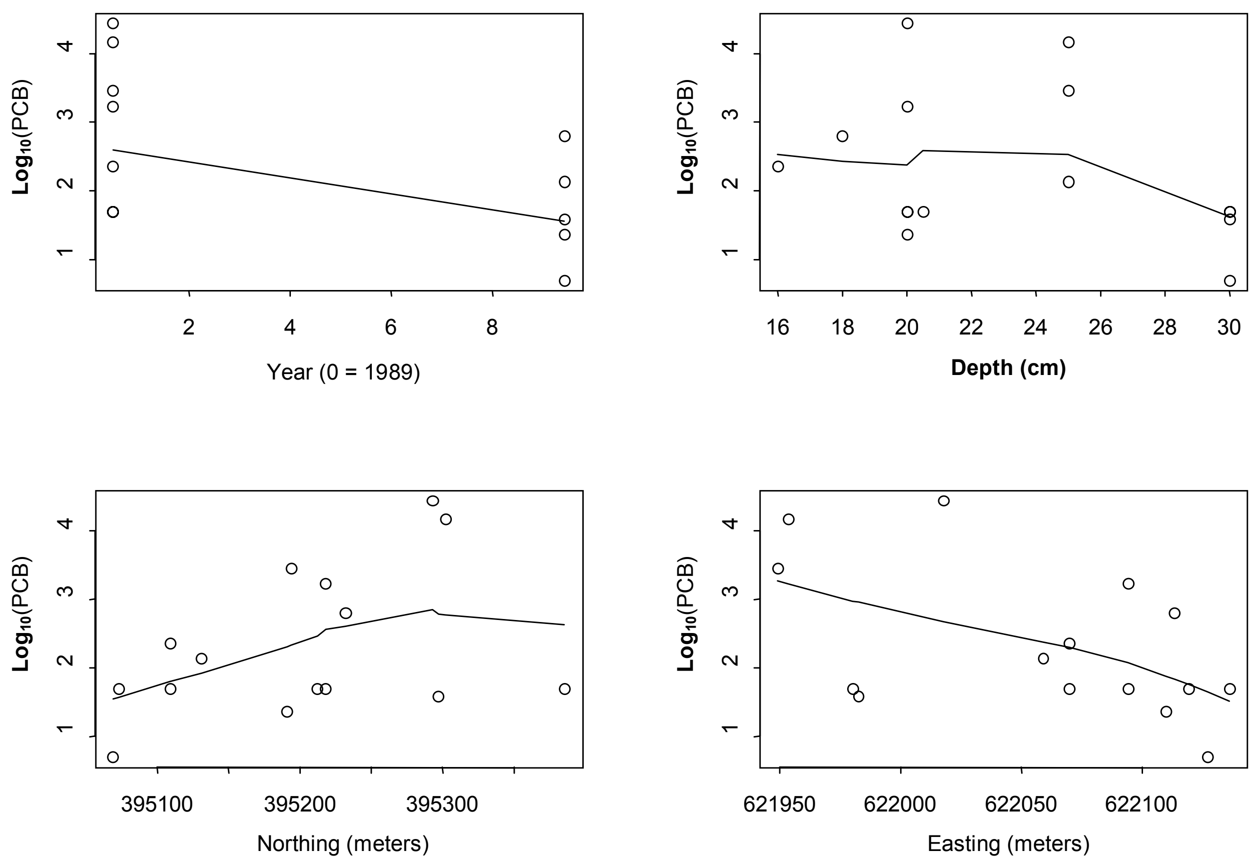


Figure A-48 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for Little Lake Butte des Morts Deposit Group C (10 to 30 cm) Including Fitted Smoothed Line

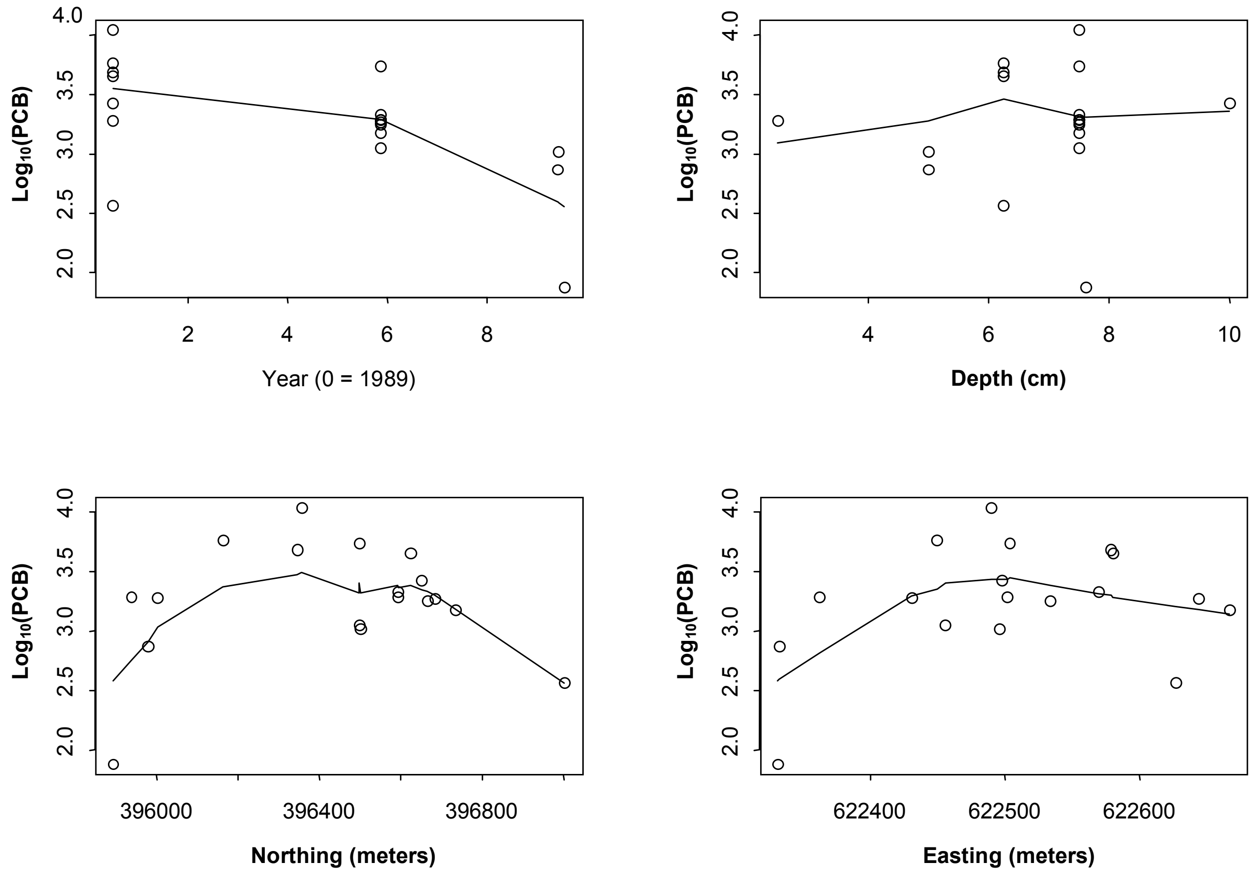


Figure A-49 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for Little Lake Butte des Morts Deposit Group D (0 to 10 cm) Including Fitted Smoothed Line

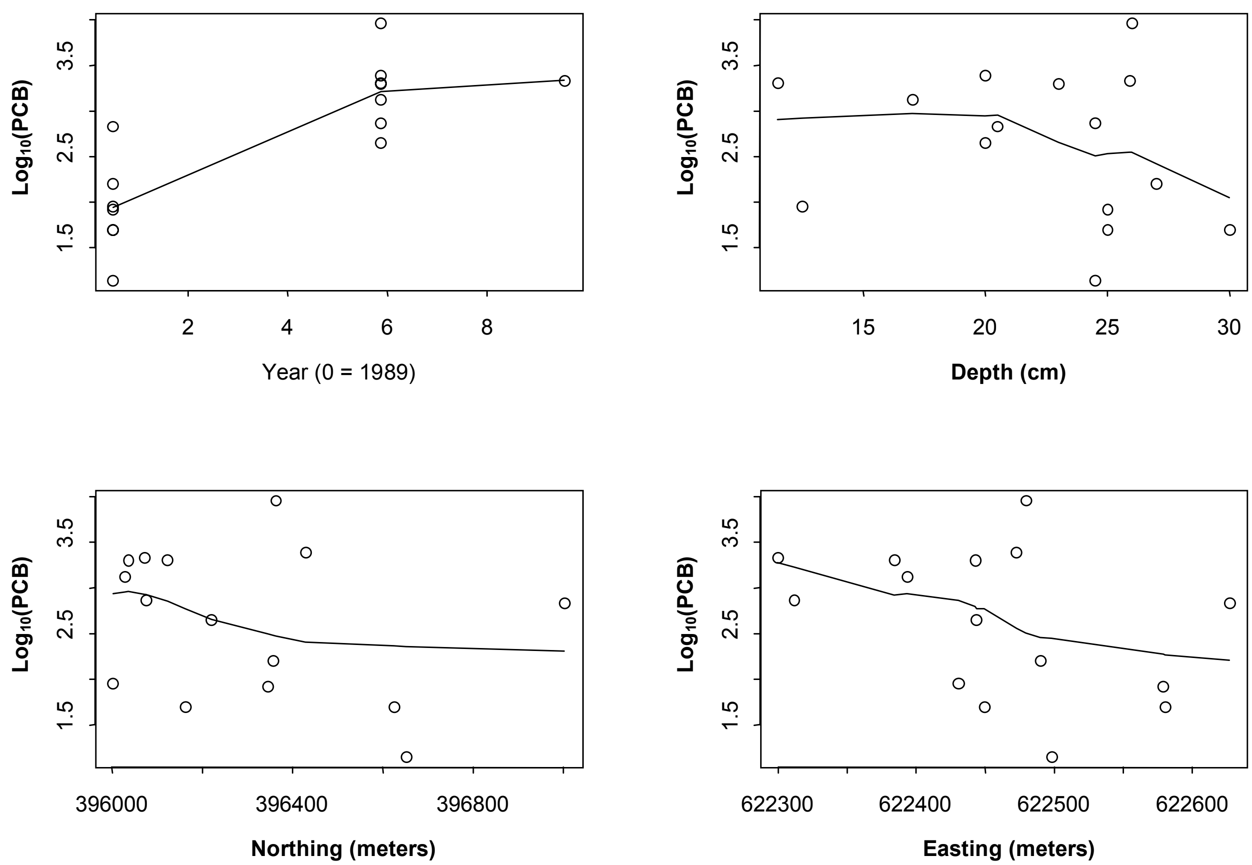


Figure A-50 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for Little Lake Butte des Morts Deposit Group D (10 to 30 cm) Including Fitted Smoothed Line

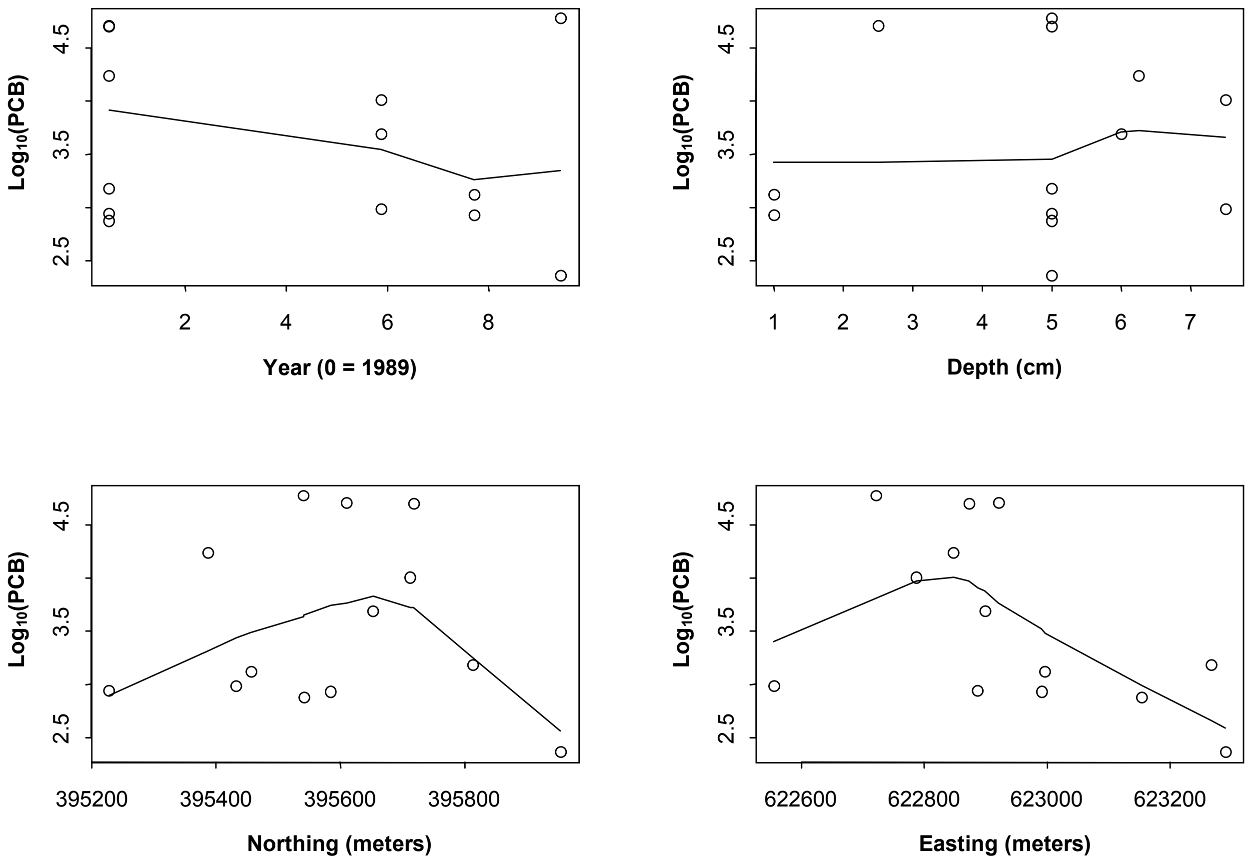


Figure A-51 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for Little Lake Butte des Morts Deposit Group POG (0 to 10 cm) Including Fitted Smoothed Line

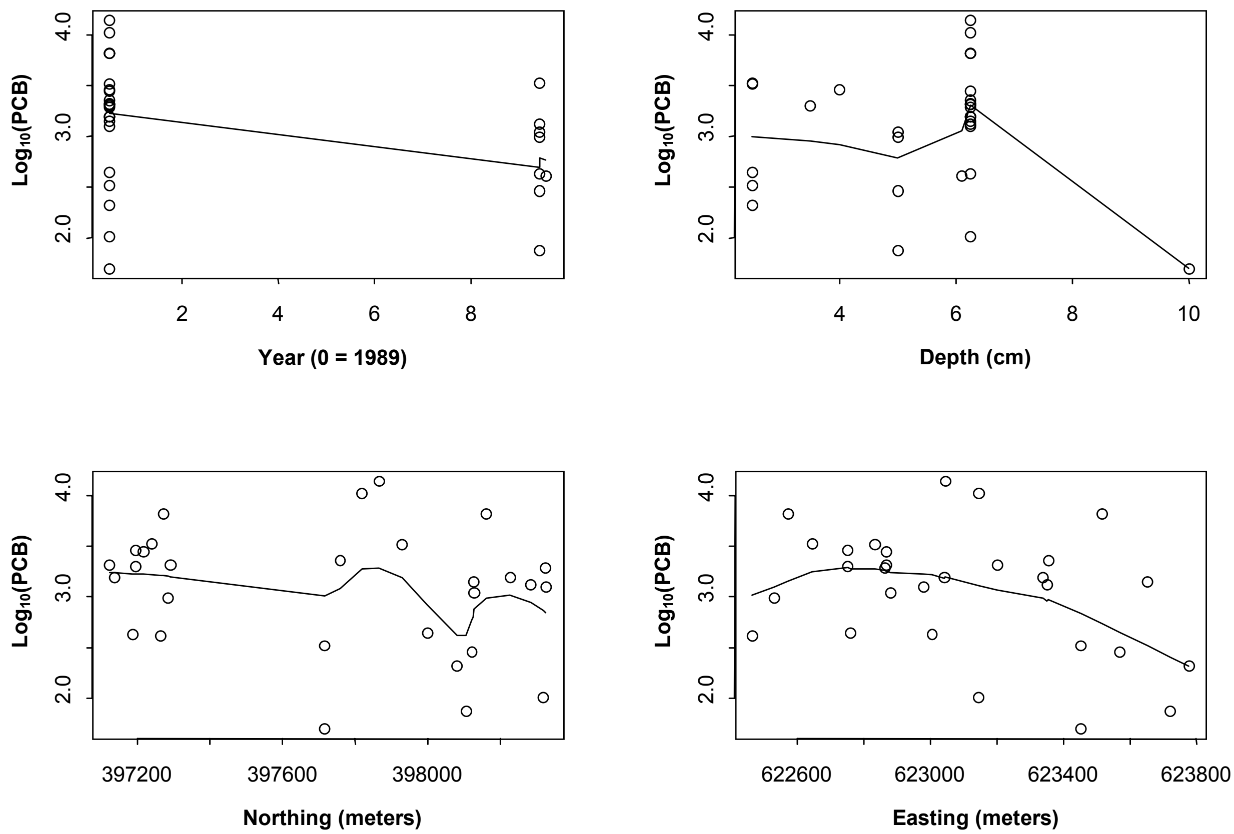


Figure A-52 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for Little Lake Butte des Morts Deposit Group F (0 to 10 cm) Including Fitted Smoothed Line

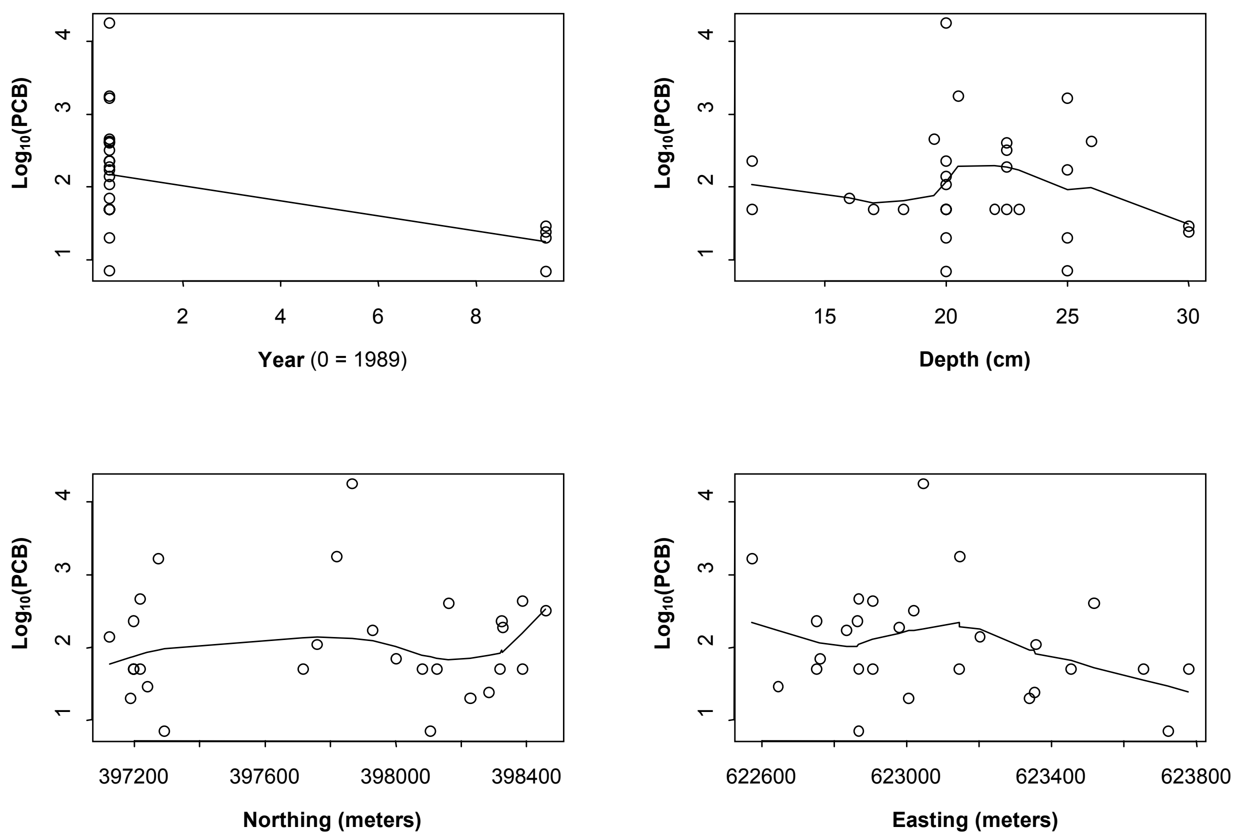


Figure A-53 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for Little Lake Butte des Morts Deposit Group F (10 to 30 cm) Including Fitted Smoothed Line

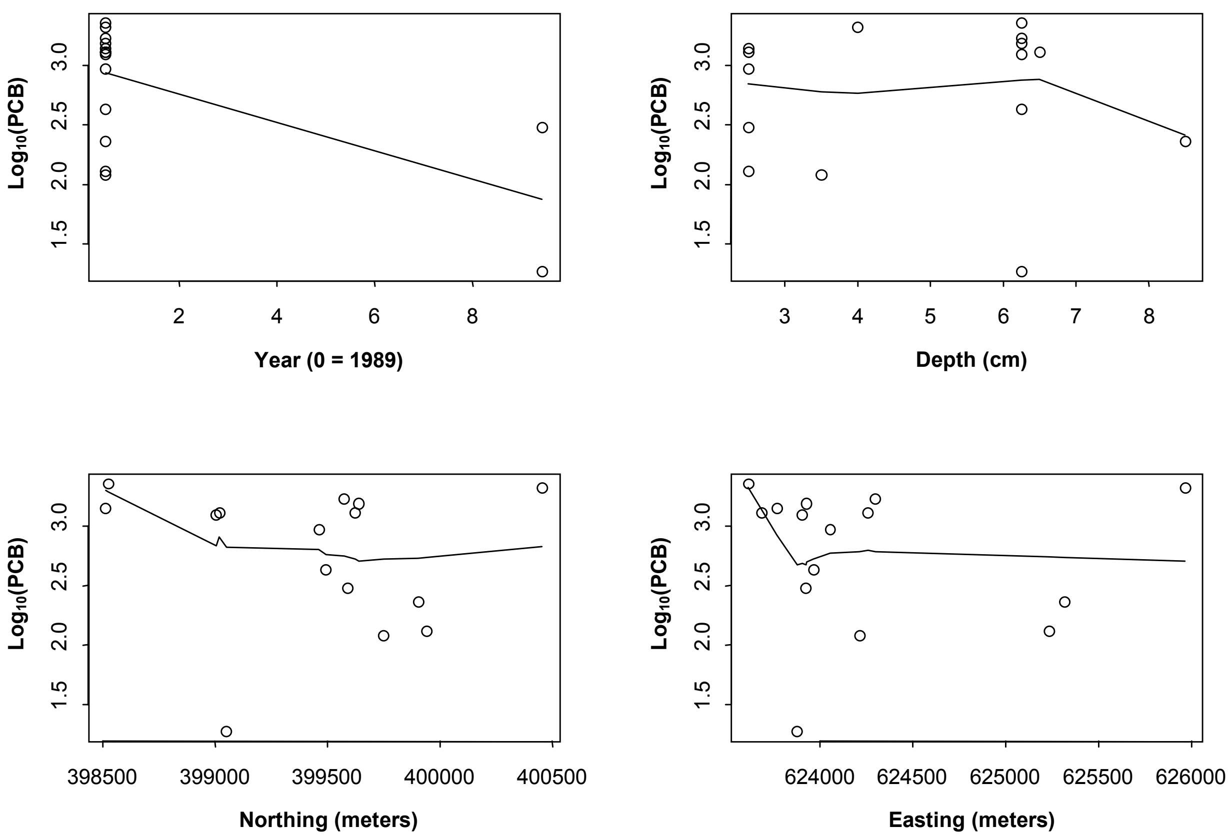


Figure A-54 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for Little Lake Butte des Morts Deposit Group GH (0 to 10 cm) Including Fitted Smoothed Line

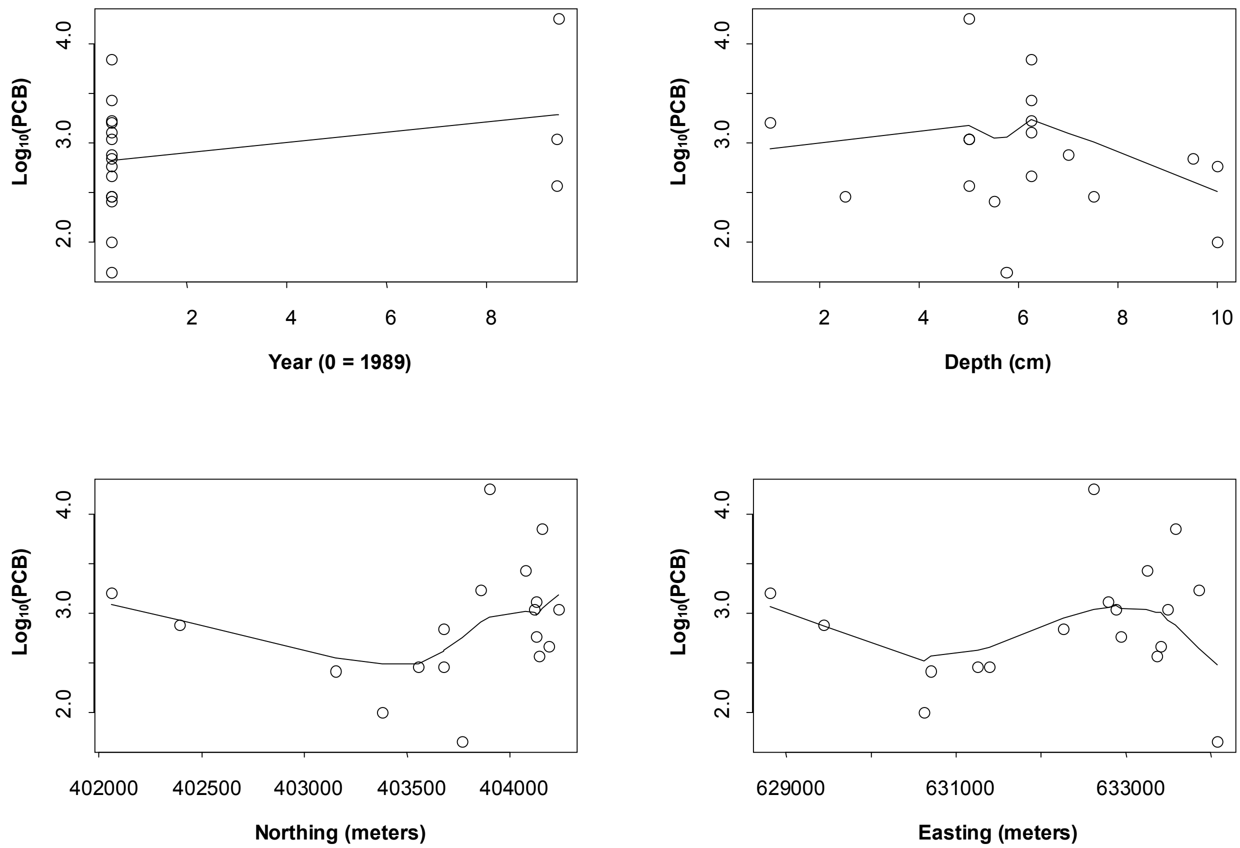


Figure A-55 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for Appleton Deposit Group IMOR (0 to 10 cm) Including Fitted Smoothed Line

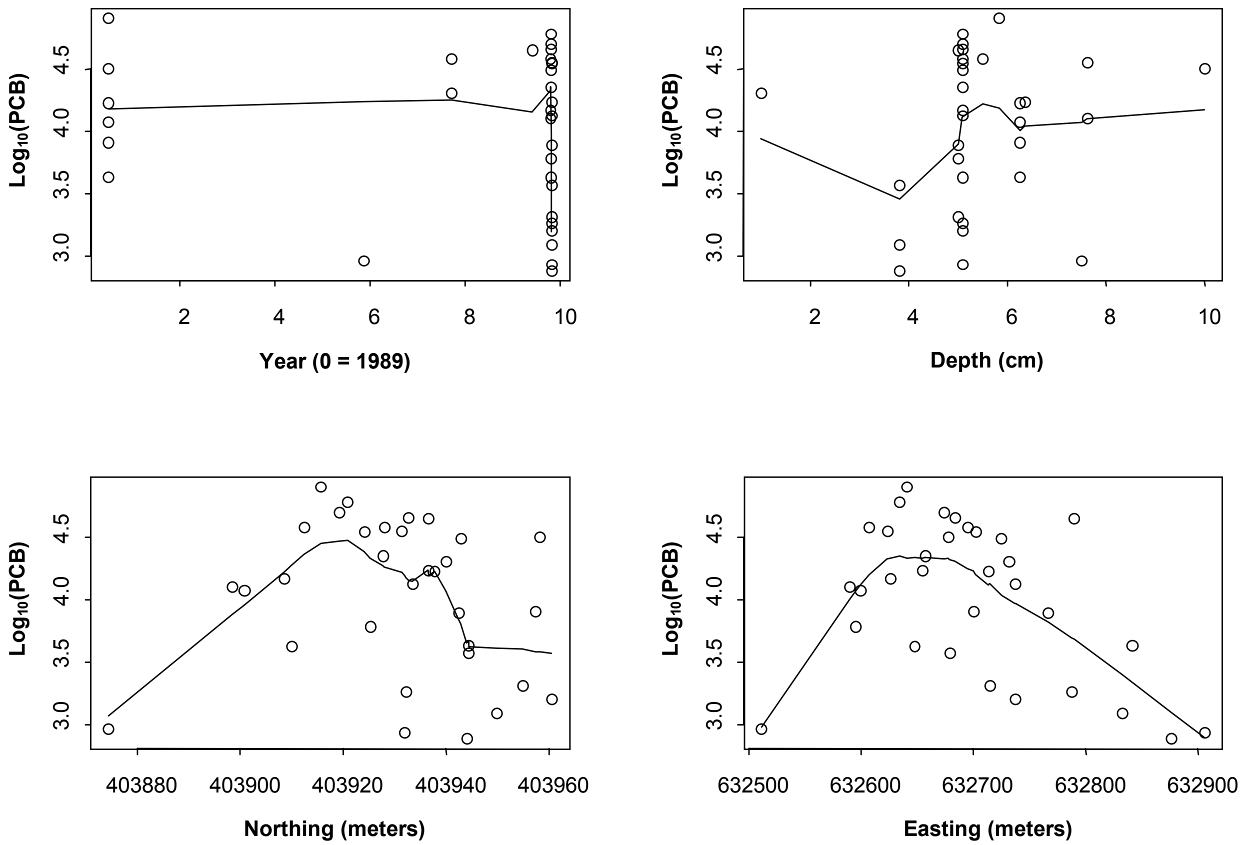


Figure A-56 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for Appleton Deposit Group N Before Demonstration Project (0 to 10 cm) Including Fitted Smoothed Line

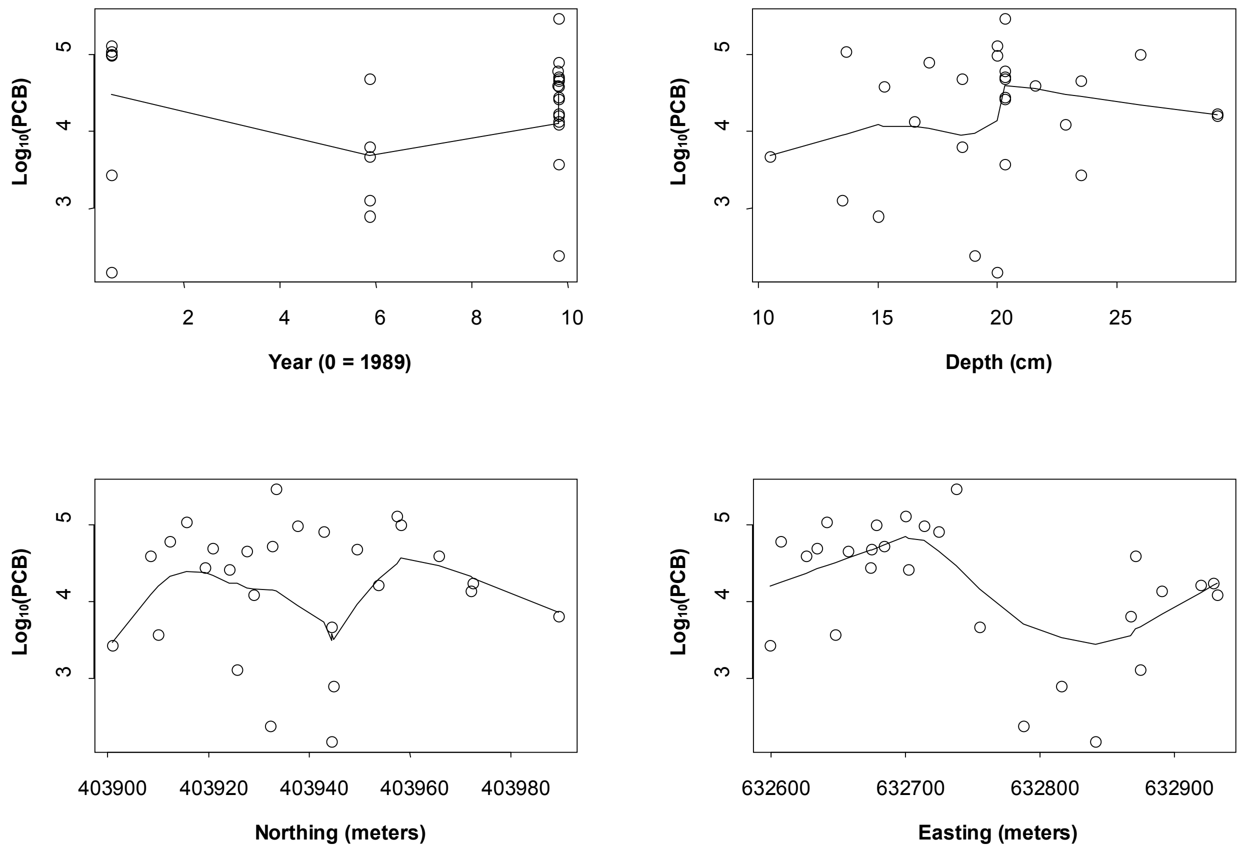


Figure A-57 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for Appleton Deposit Group N Before Demonstration Project (10 to 30 cm) Including Fitted Smoothed Line

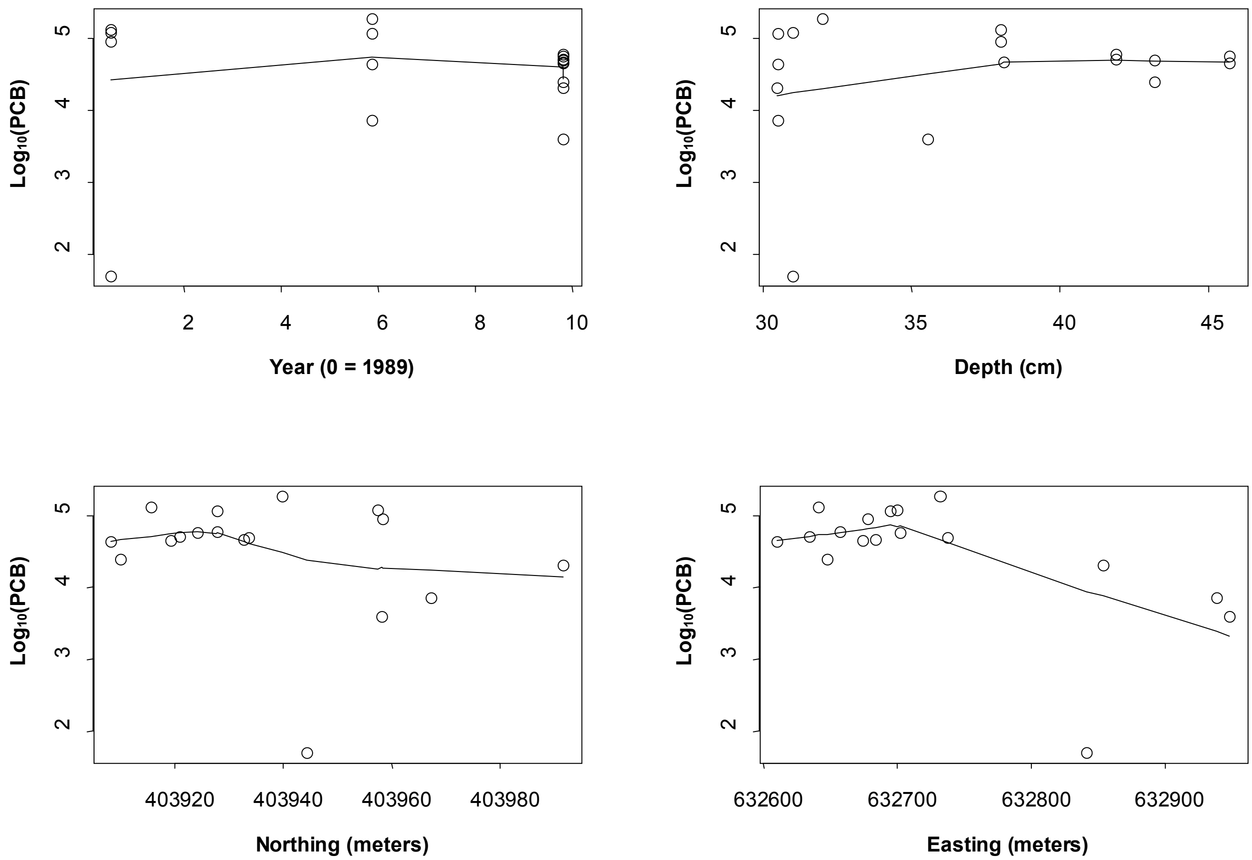


Figure A-58 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for Appleton Deposit Group N Before Demonstration Project (30 to 50 cm) Including Fitted Smoothed Line

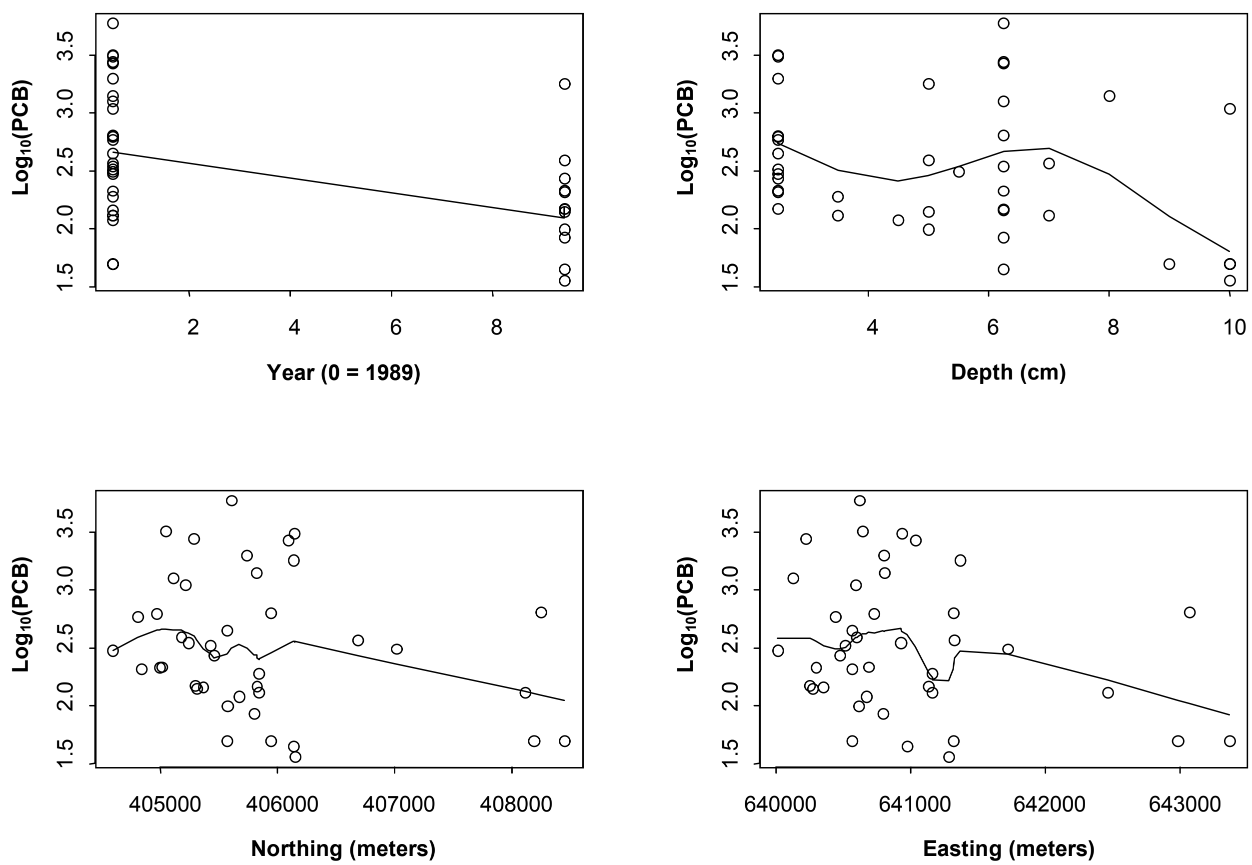


Figure A-59 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for Appleton Deposit Group VCC (0 to 10 cm) Including Fitted Smoothed Line

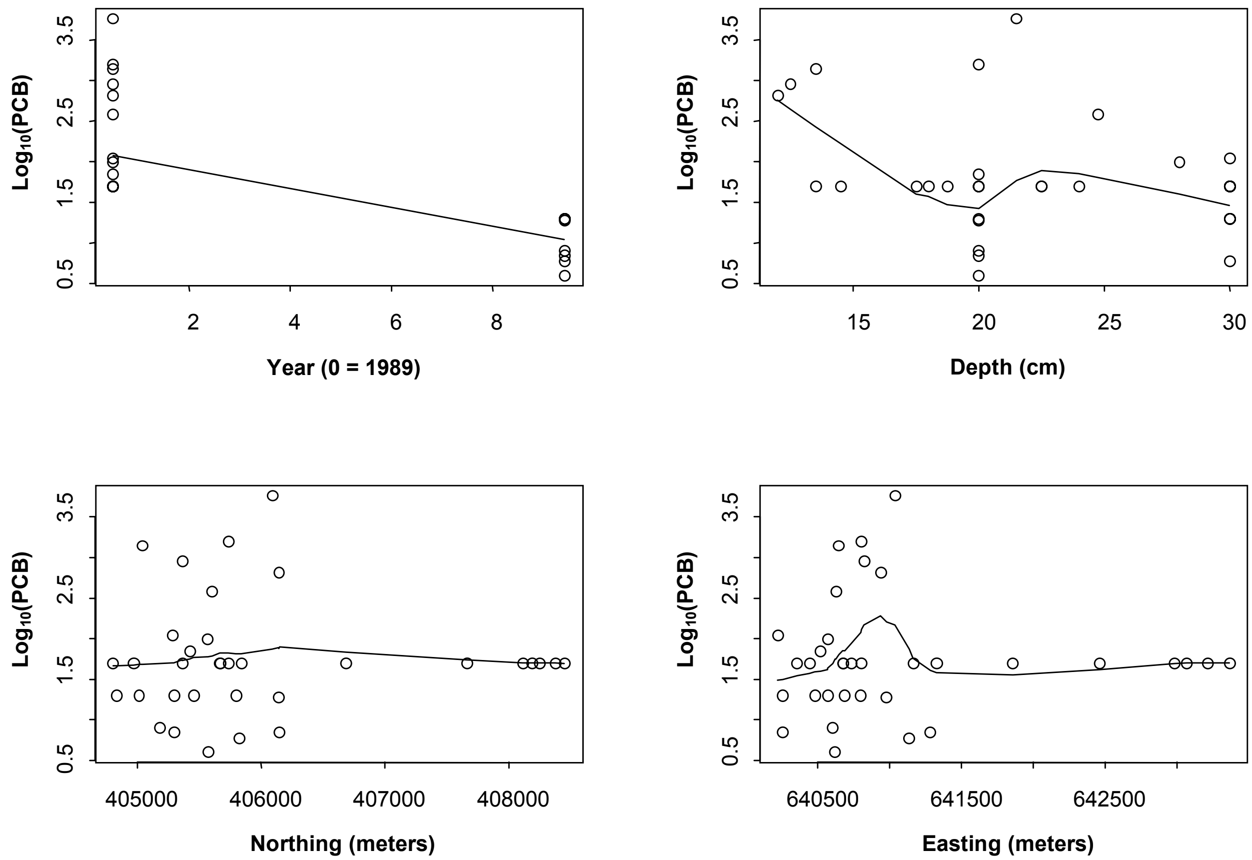


Figure A-60 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for Appleton Deposit Group VCC (10 to 30 cm) Including Fitted Smoothed Line

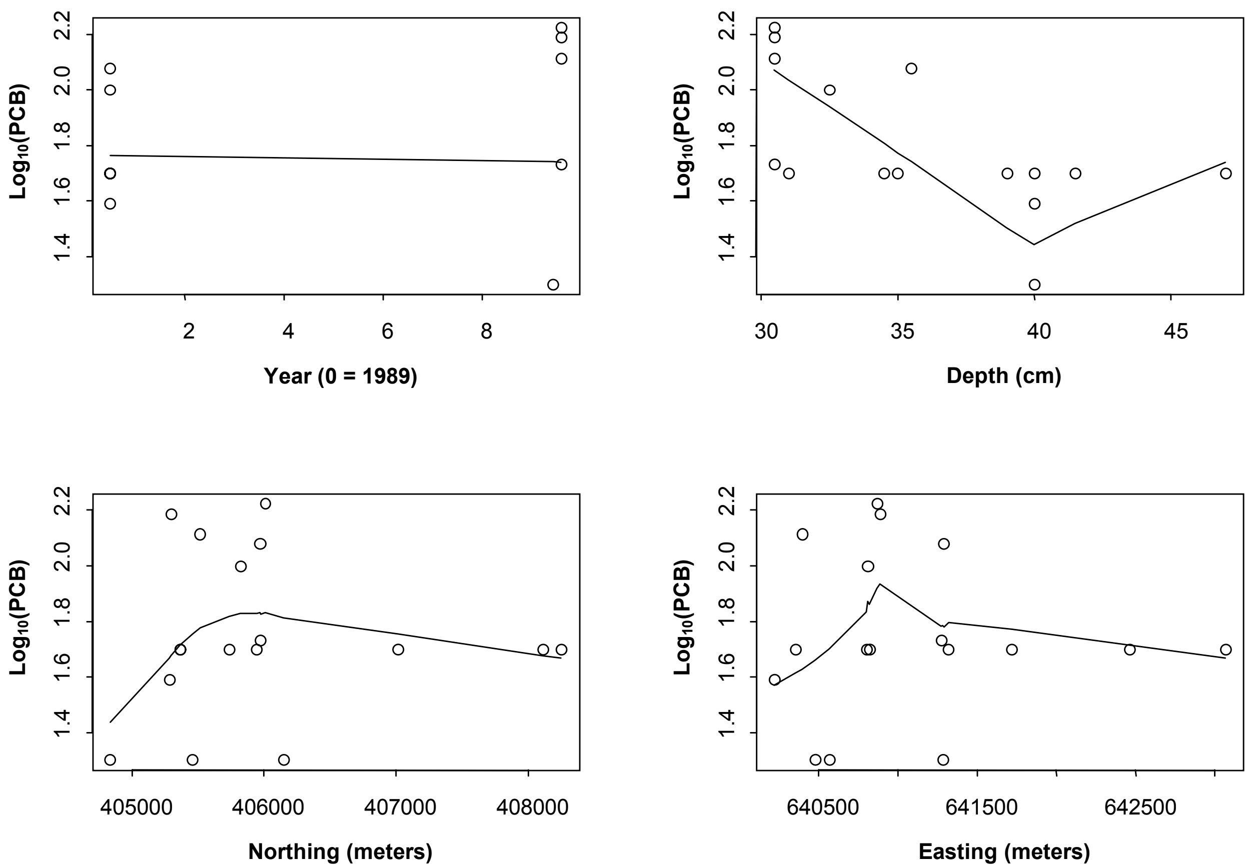


Figure A-61 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for Appleton Deposit Group VCC (30 to 50 cm) Including Fitted Smoothed Line

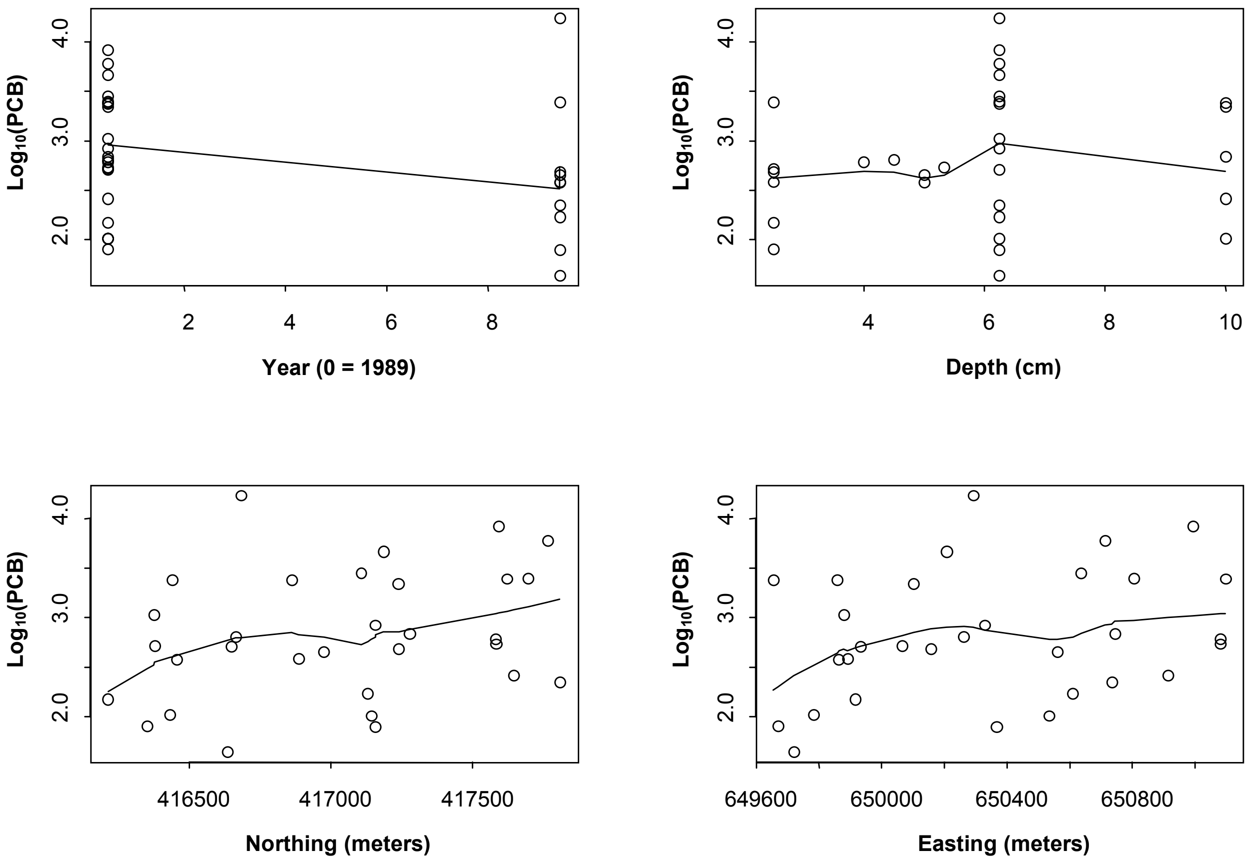


Figure A-62 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for Little Rapids Deposit Group Upper EE (0 to 10 cm) Including Fitted Smoothed Line

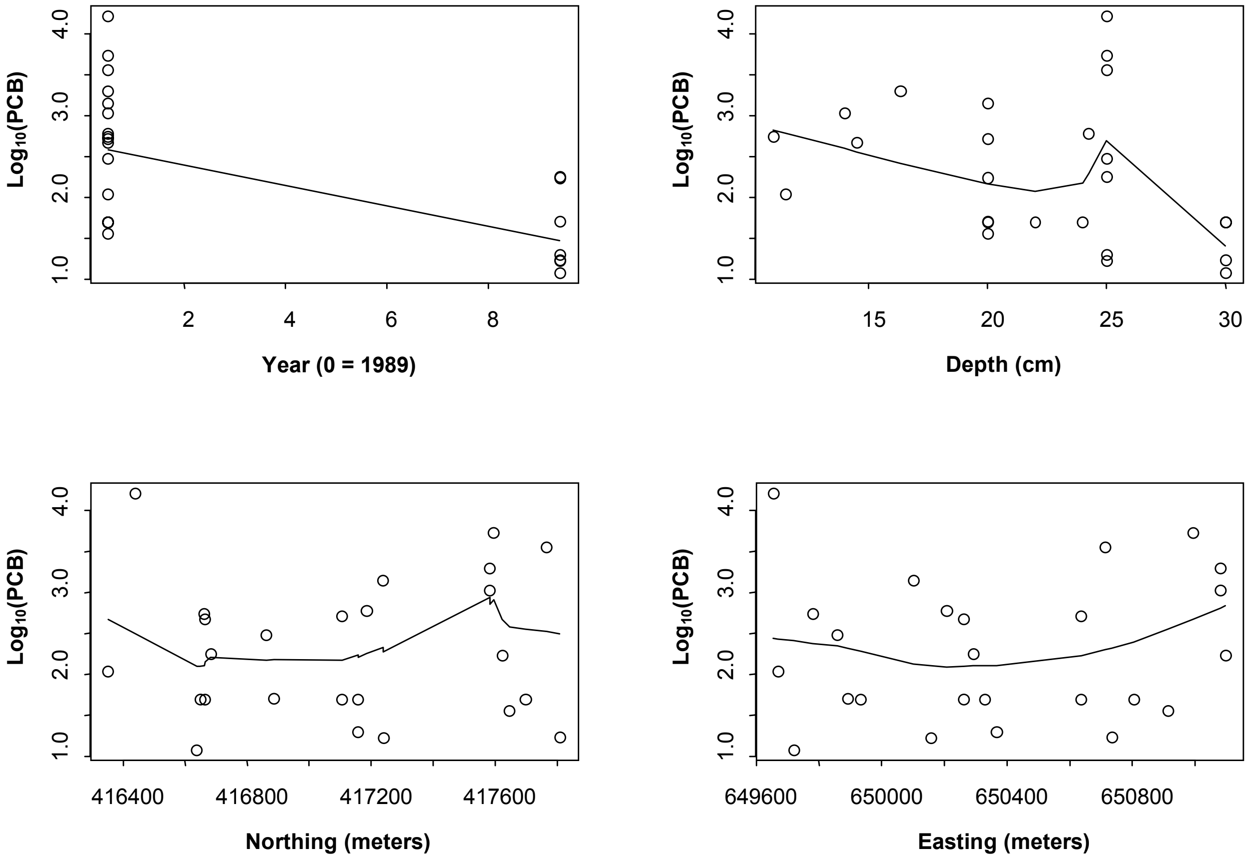


Figure A-63 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for Little Rapids Deposit Group Upper EE (10 to 30 cm) Including Fitted Smoothed Line

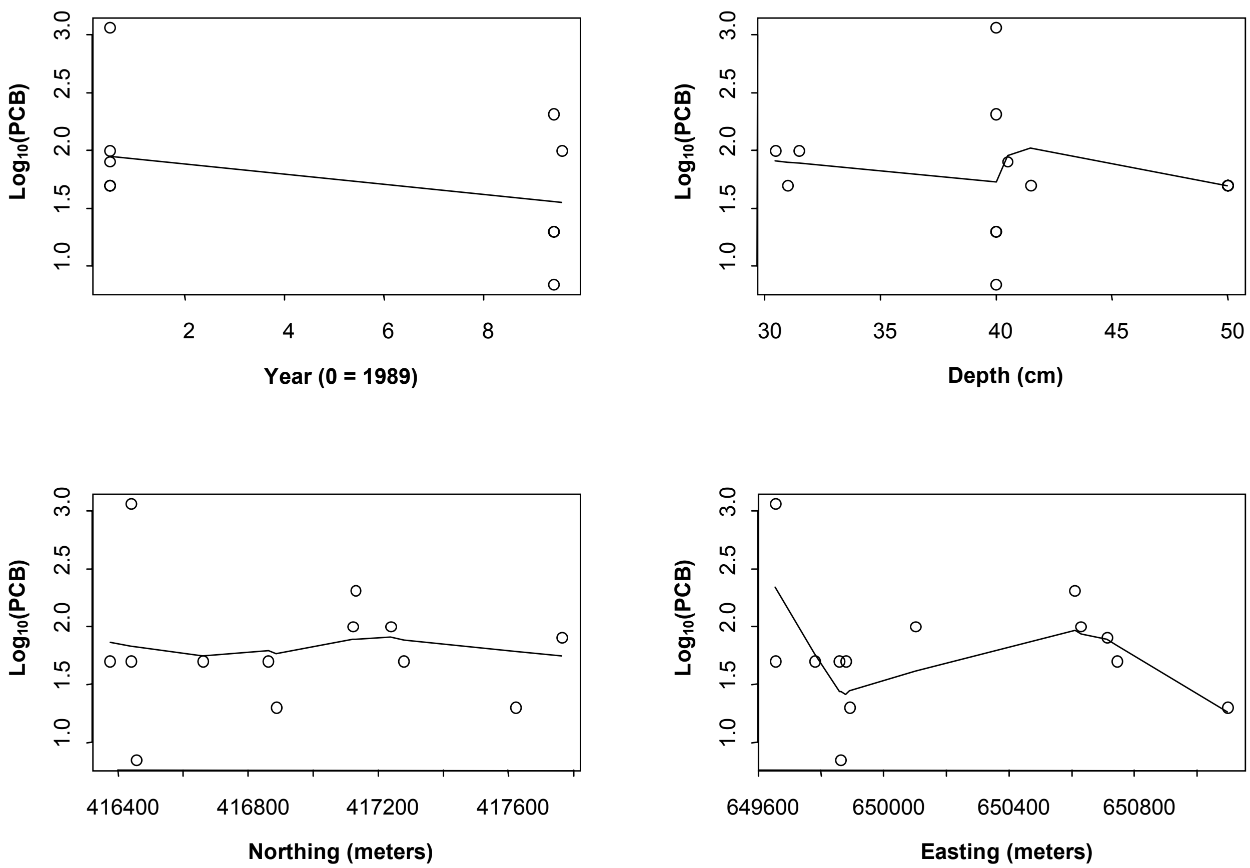


Figure A-64 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for Little Rapids Deposit Group Upper EE (30 to 50 cm) Including Fitted Smoothed Line

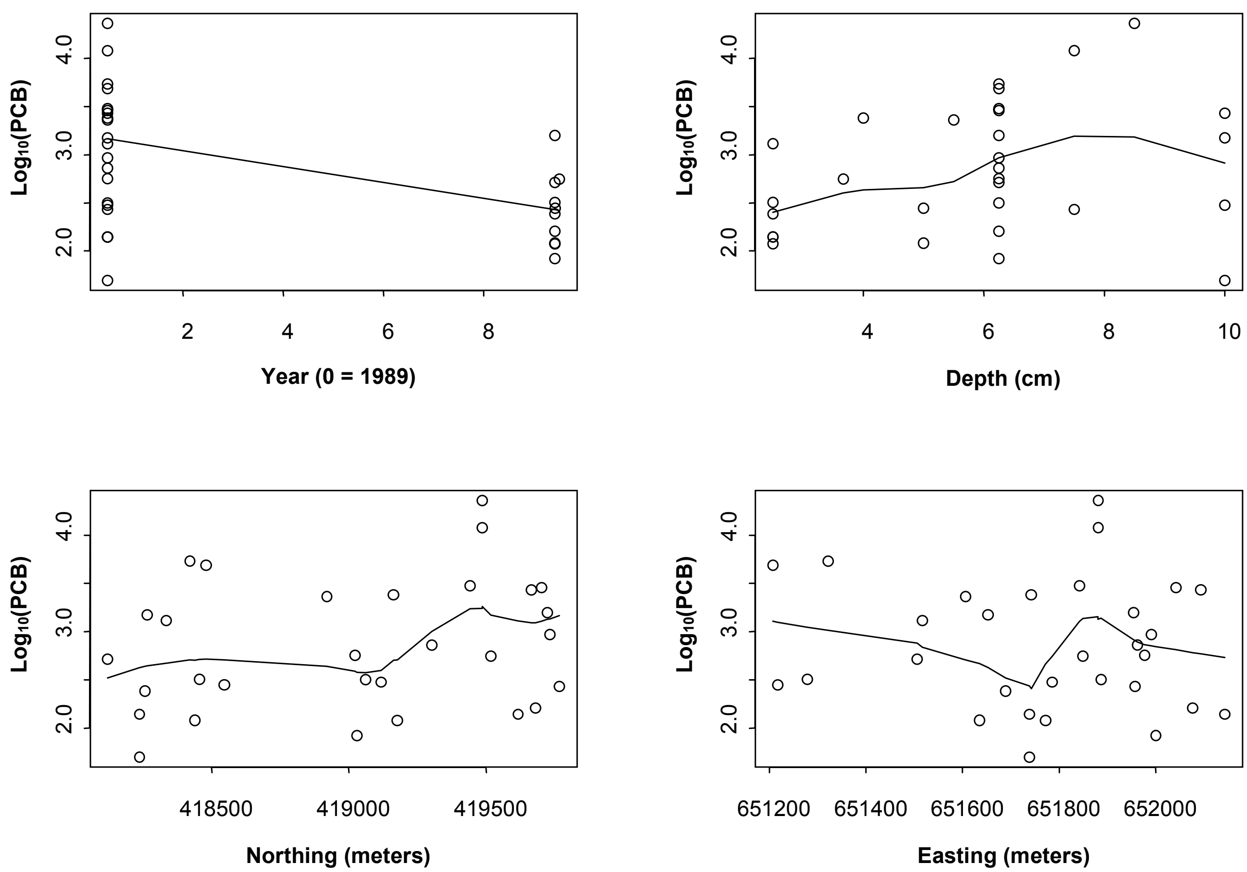


Figure A-65 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for Little Rapids Deposit Group Lower EE (0 to 10 cm) Including Fitted Smoothed Line

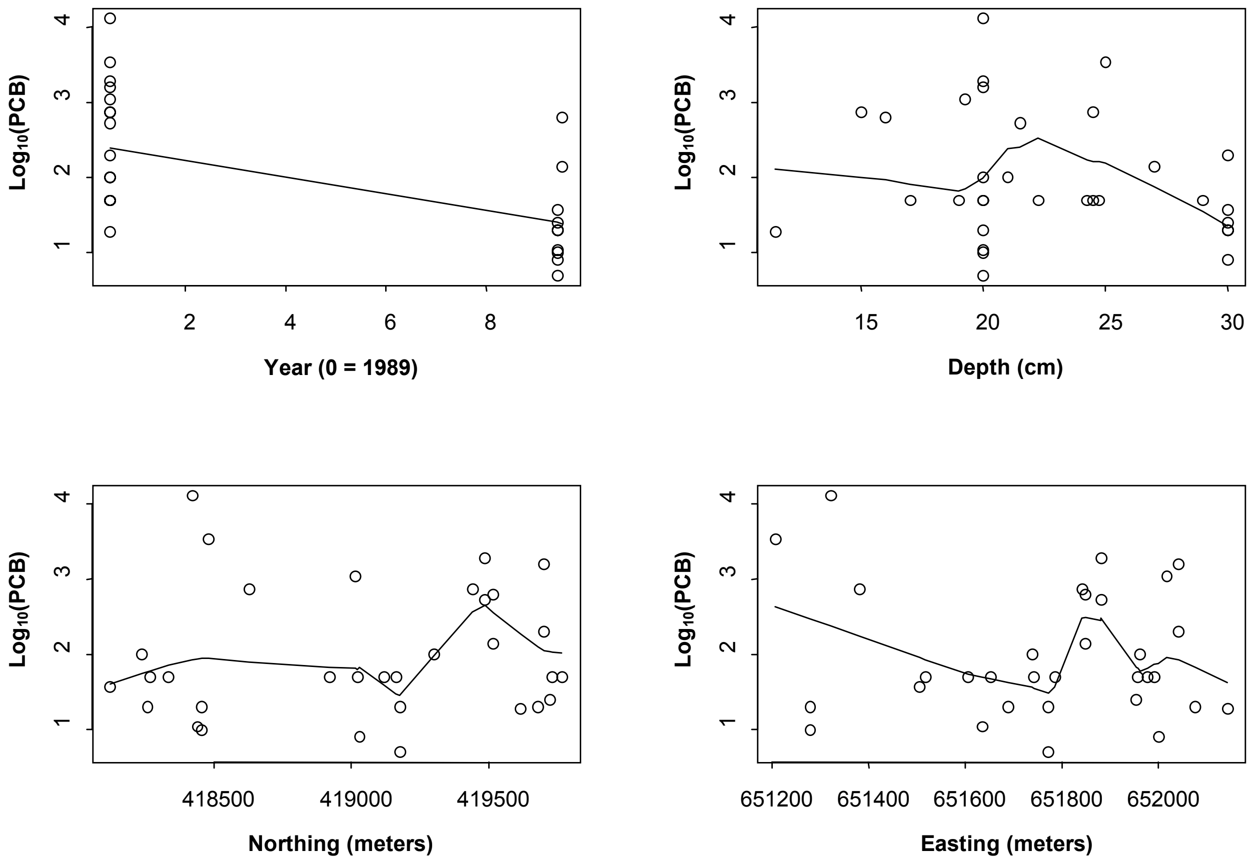


Figure A-66 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for Little Rapids Deposit Group Lower EE (10 to 30 cm) Including Fitted Smoothed Line

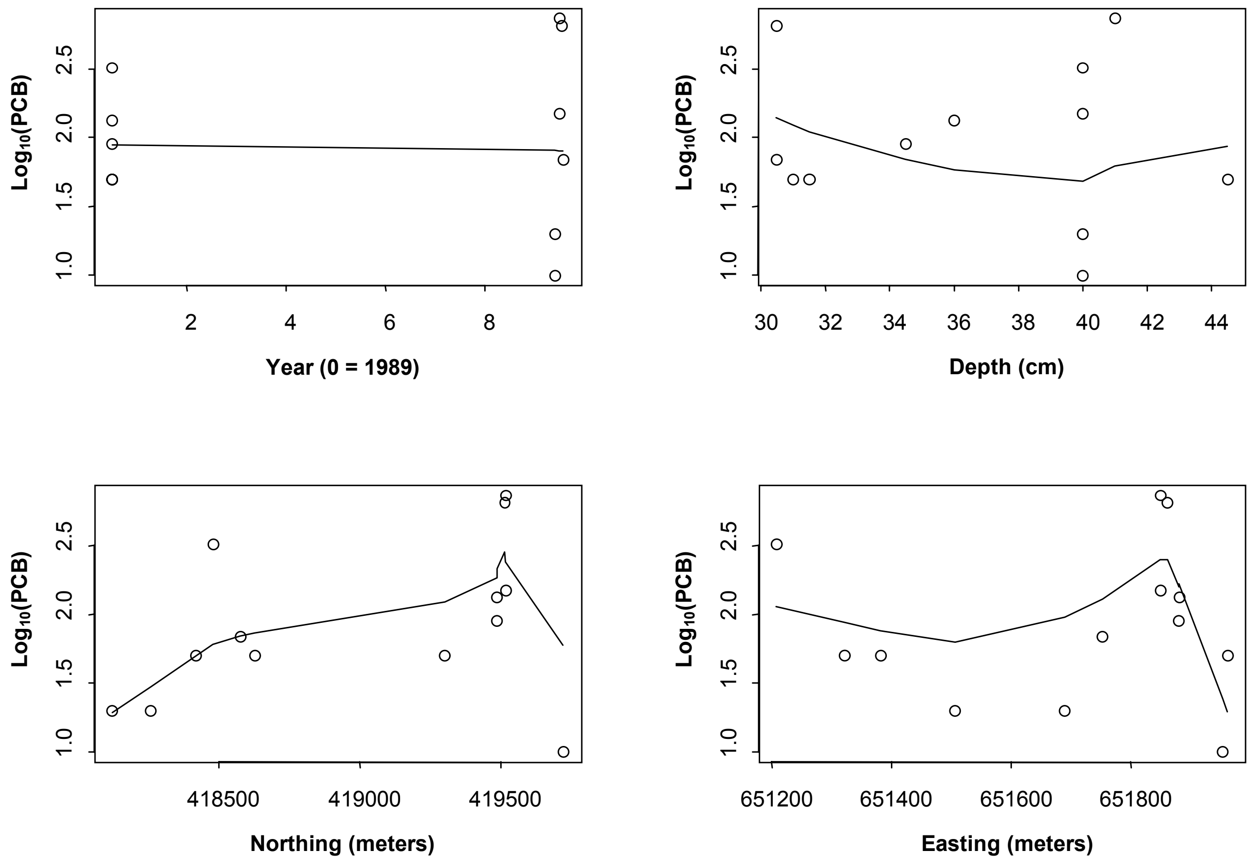


Figure A-67 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for Little Rapids Deposit Group Lower EE (30 to 50 cm) Including Fitted Smoothed Line

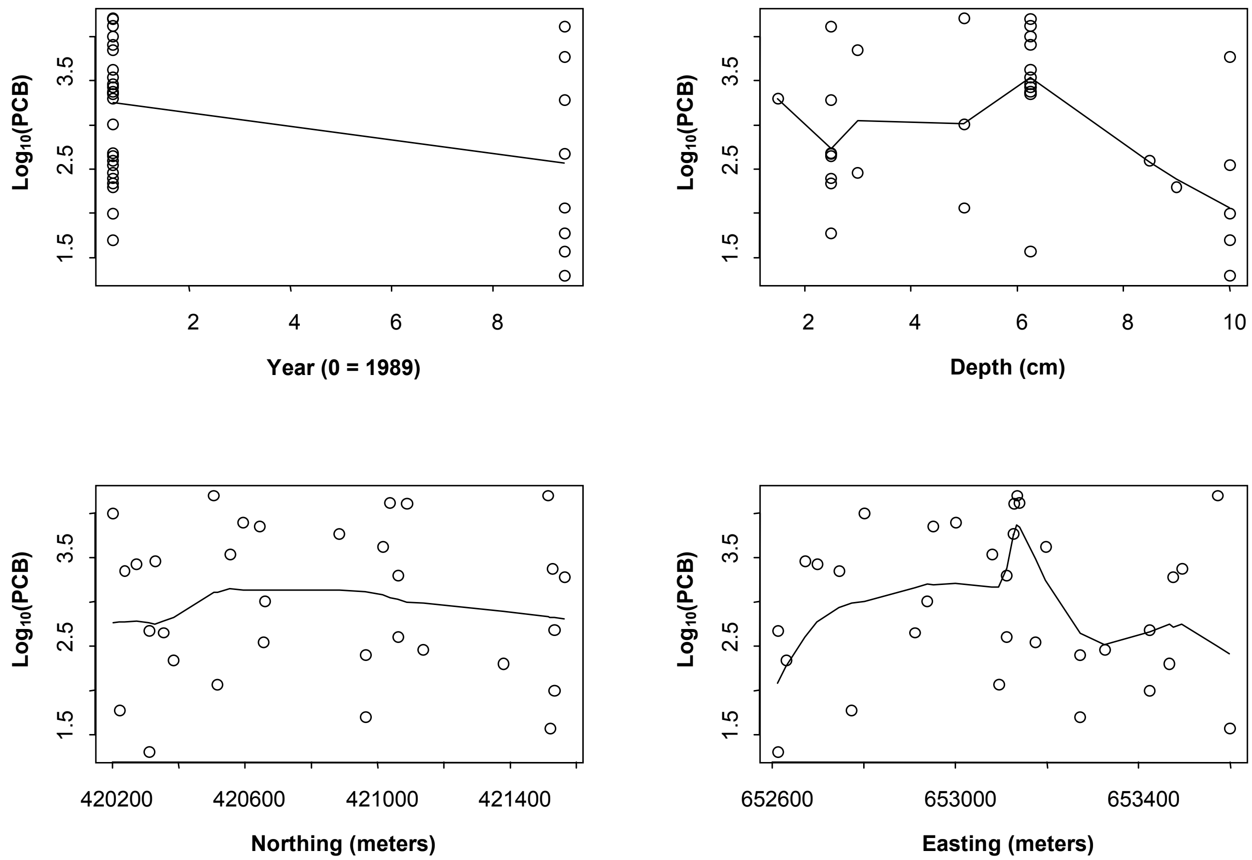


Figure A-68 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for Little Rapids Deposit Group FF (0 to 10 cm) Including Fitted Smoothed Line

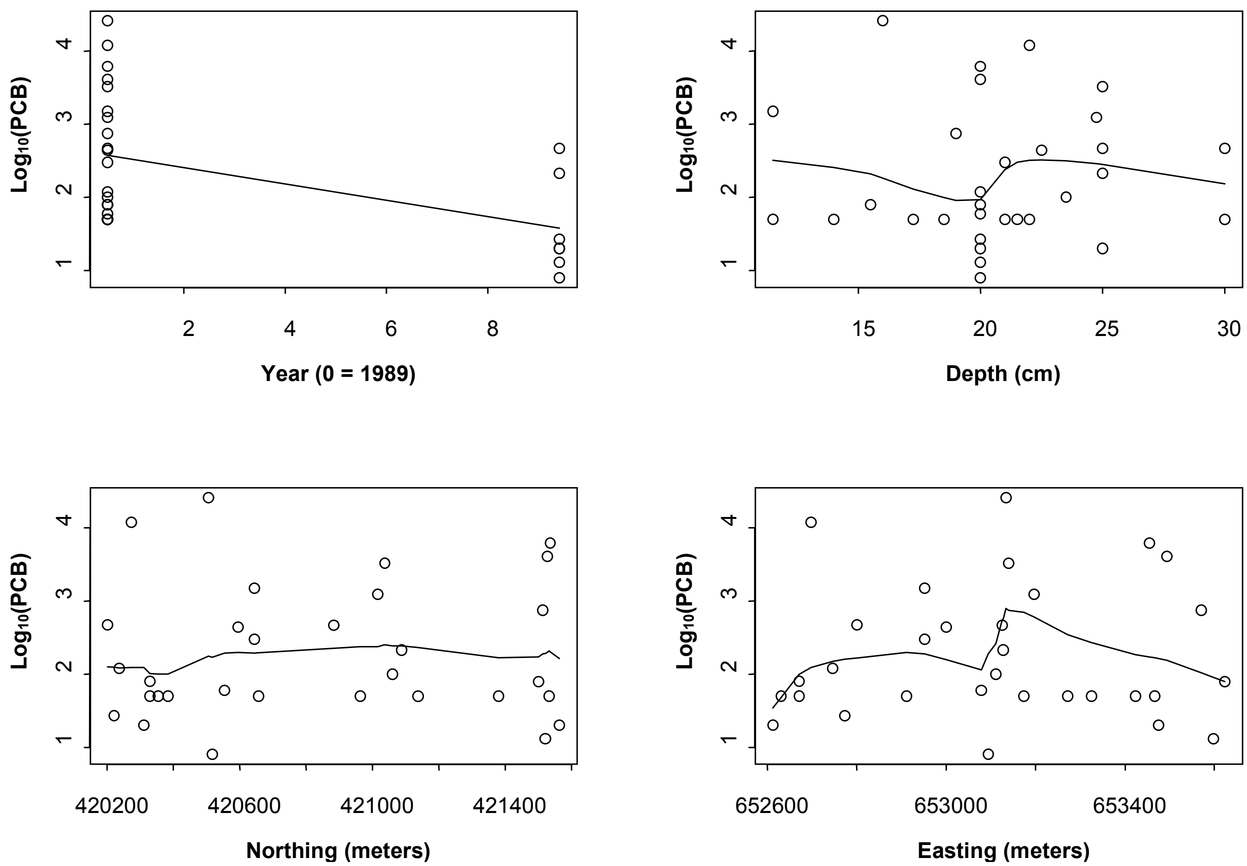


Figure A-69 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for Little Rapids Deposit Group FF (10 to 30 cm) Including Fitted Smoothed Line

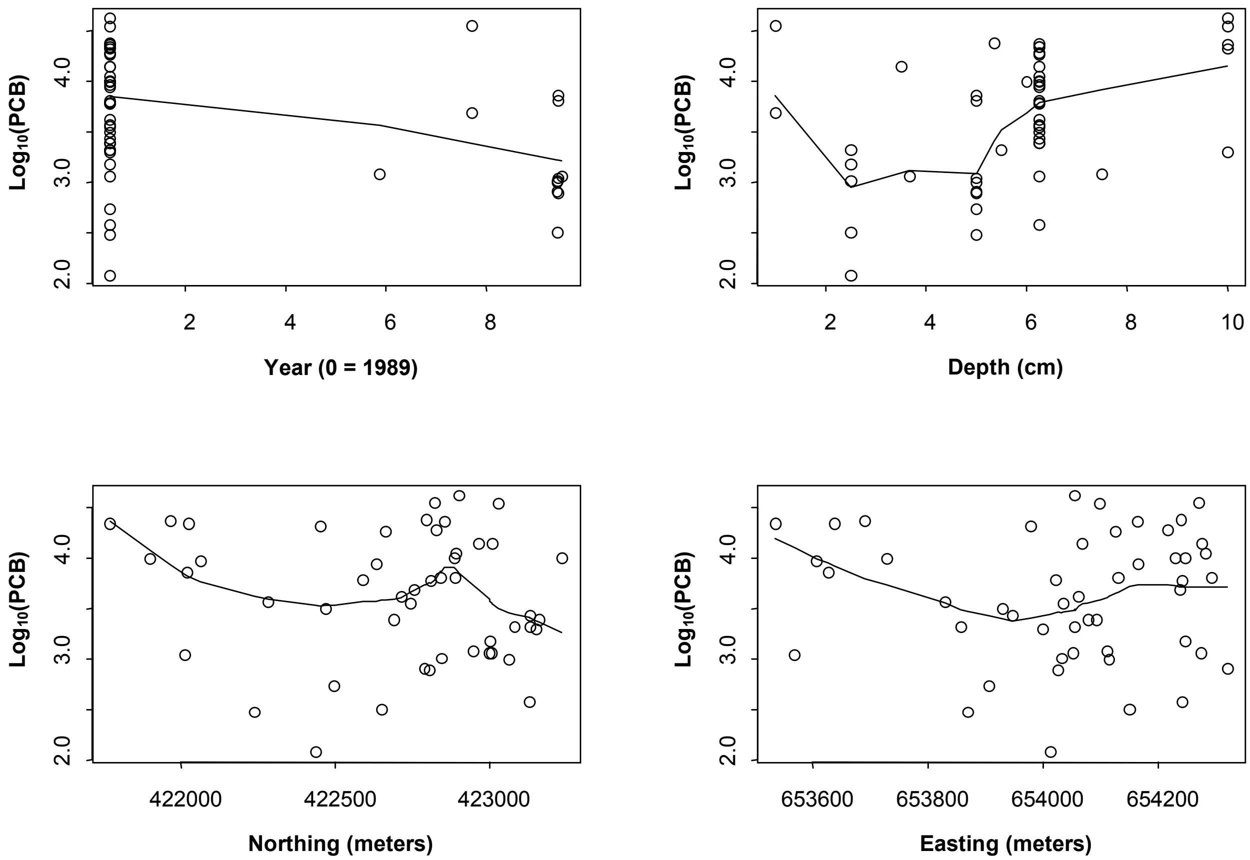


Figure A-70 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for Little Rapids Deposit Group GGHH (0 to 10 cm) Including Fitted Smoothed Line

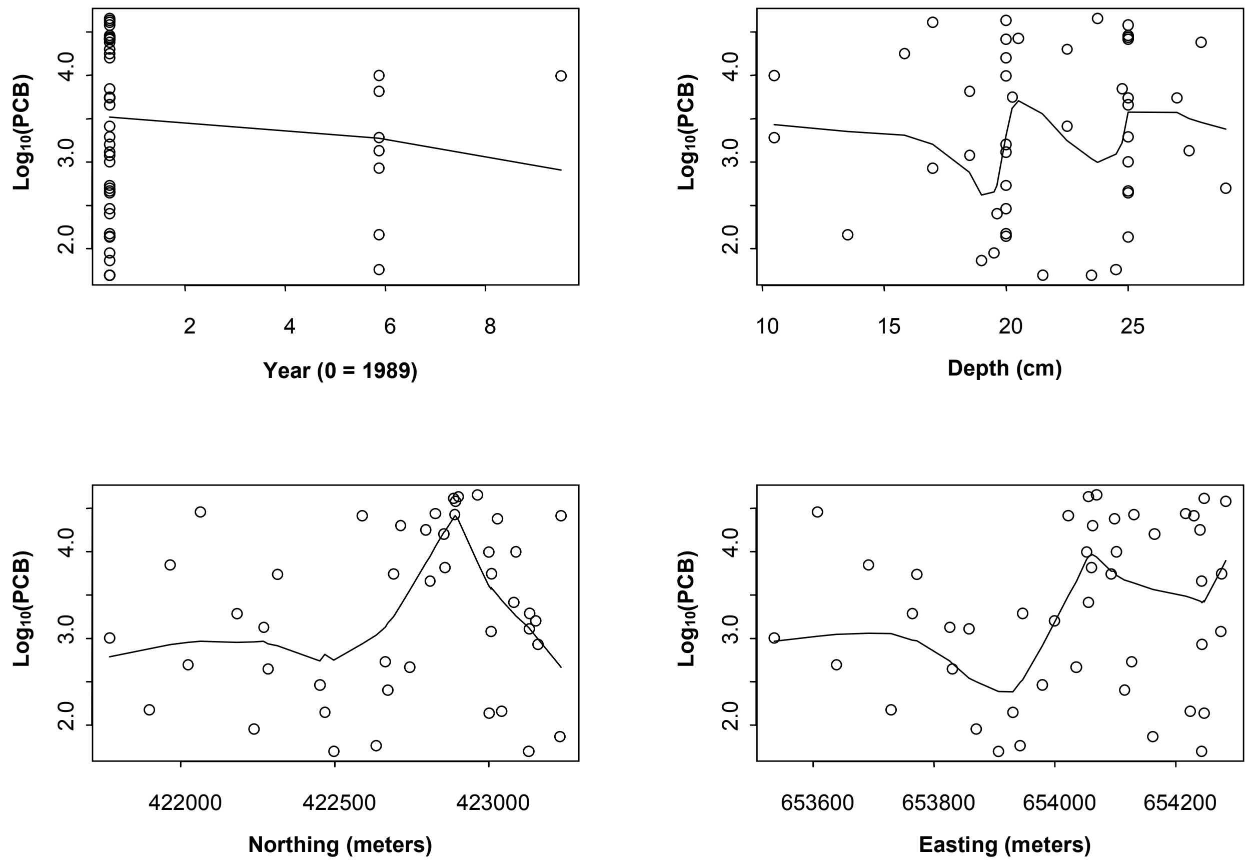


Figure A-71 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for Little Rapids Deposit Group GGHH (10 to 30 cm) Including Fitted Smoothed Line

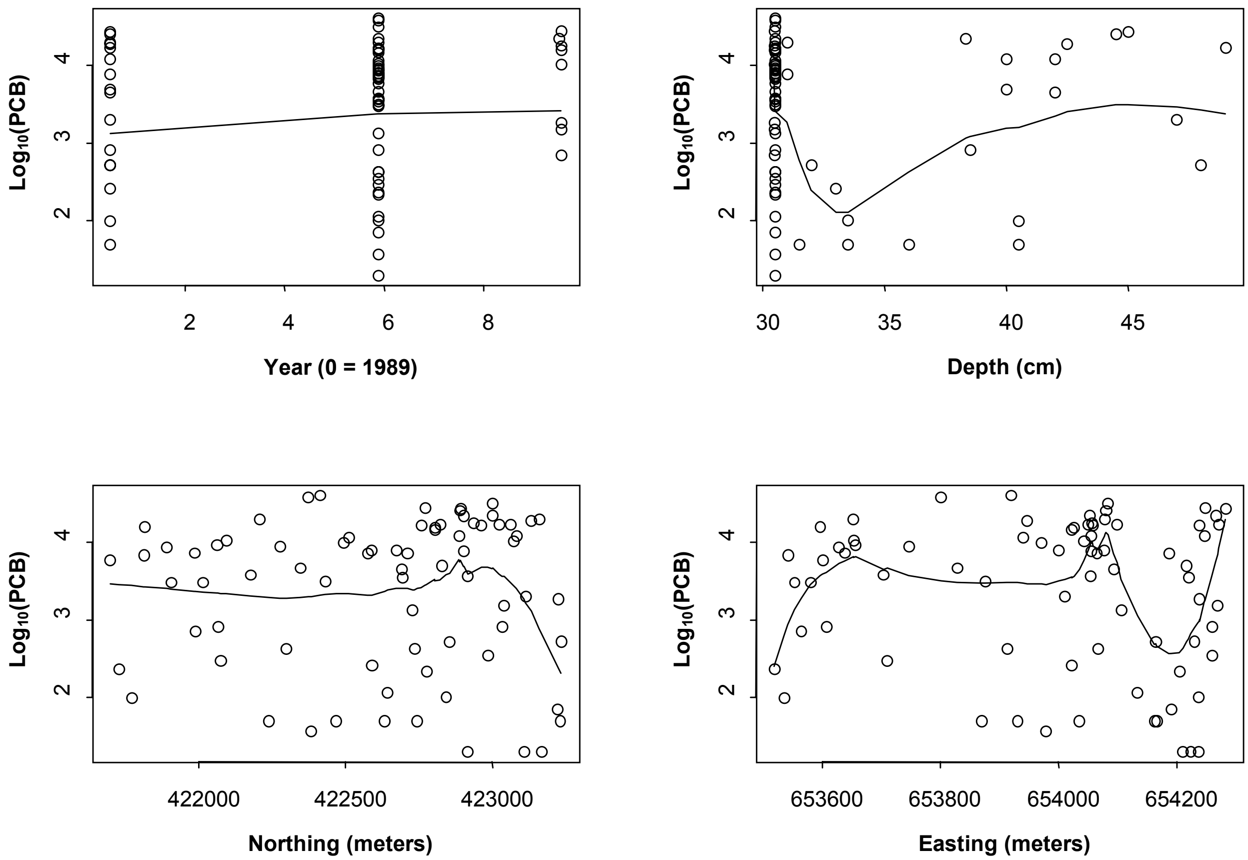


Figure A-72 $\mathbf{Log_{10}}$ PCB Concentration versus Time, Depth, Northing, and Easting for Little Rapids Deposit Group GGHH (30 to 50 cm) Including Fitted Smoothed Line

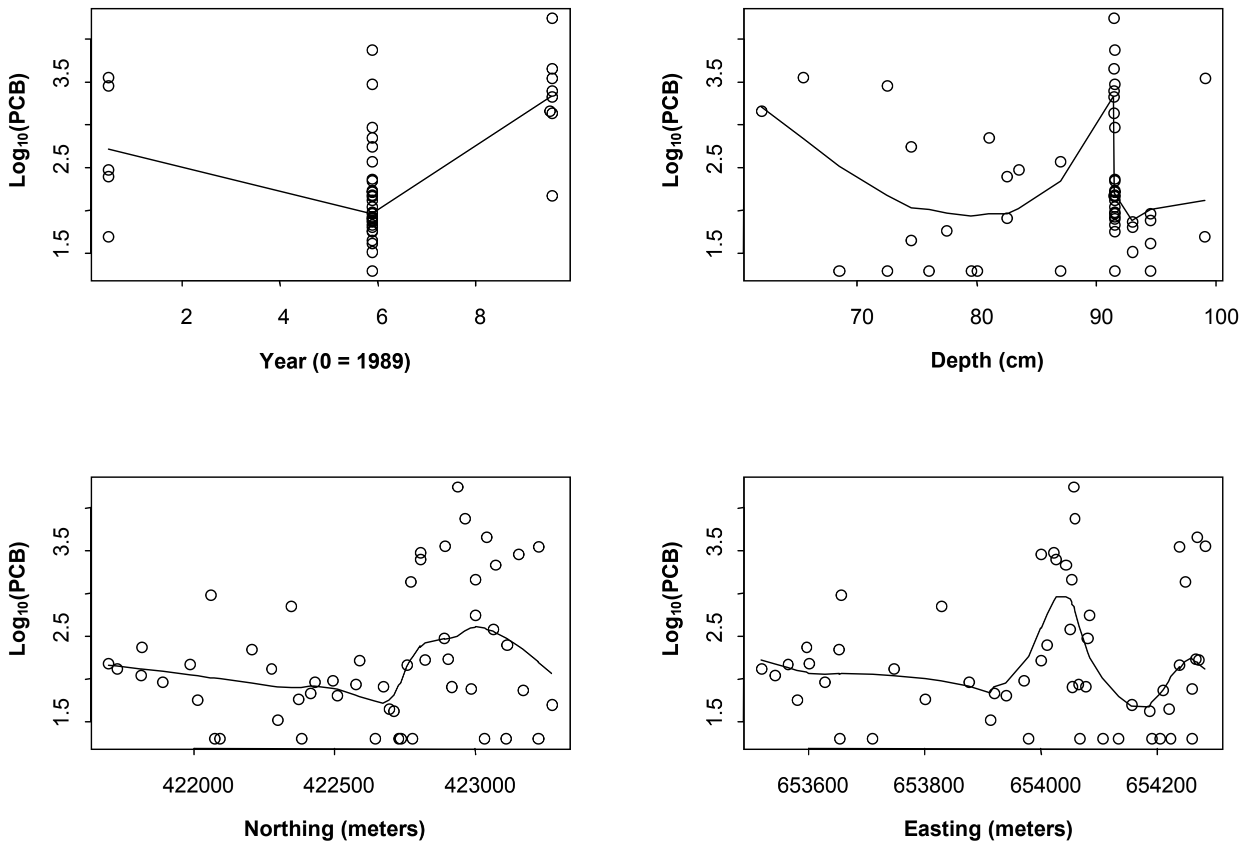


Figure A-73 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for Little Rapids Deposit Group GGHH (50 to 100 cm) Including Fitted Smoothed Line

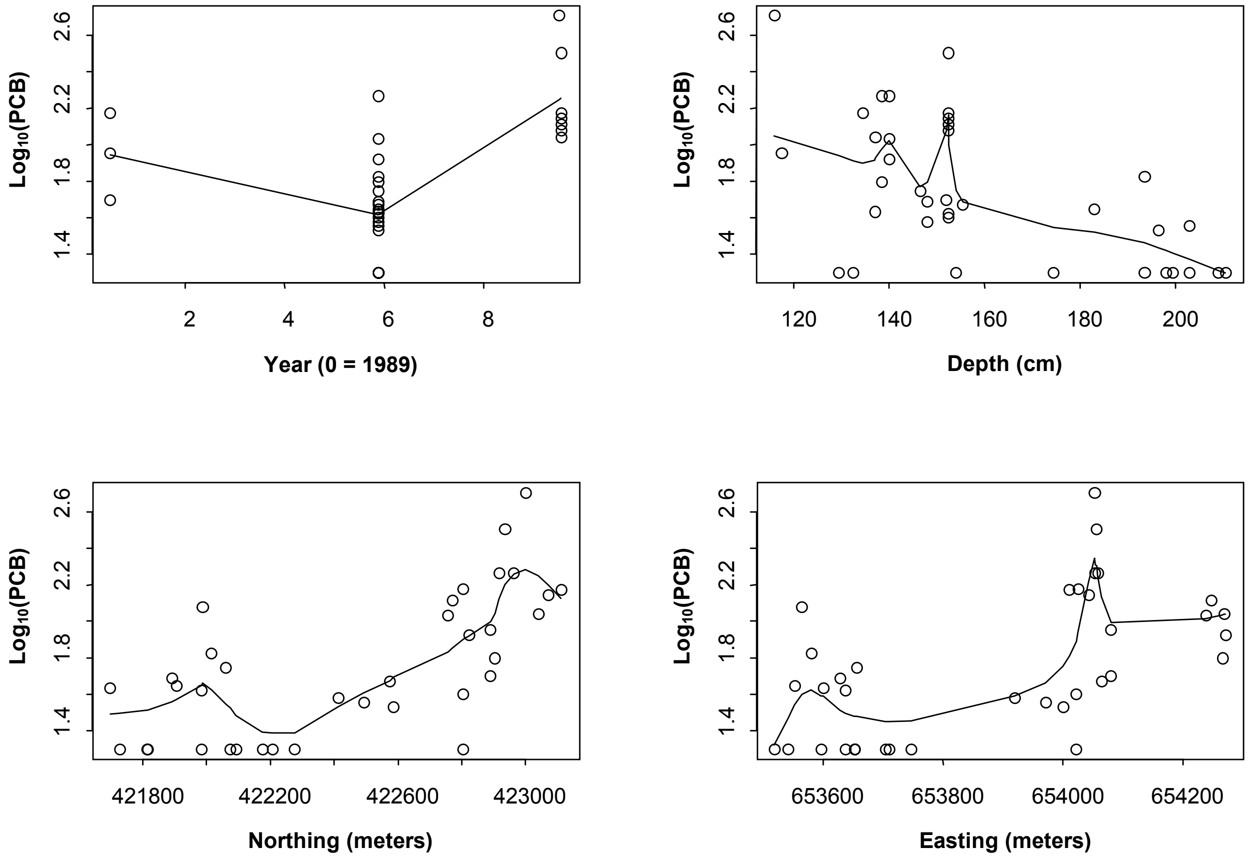


Figure A-74 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for Little Rapids Deposit Group GGHH (100+ cm) Including Fitted Smoothed Line

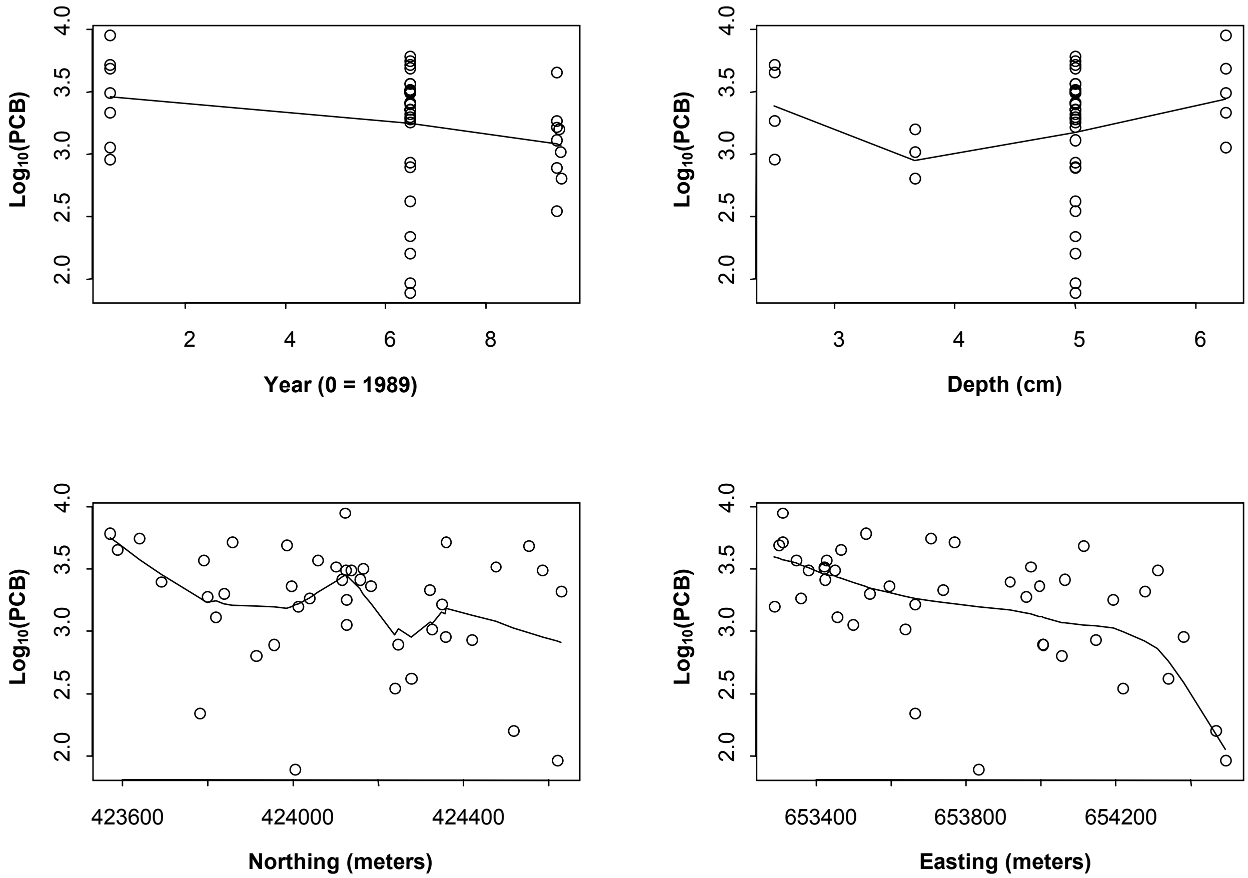


Figure A-75 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for De Pere SMU Group 2025 (0 to 10 cm) Including Fitted Smoothed Line

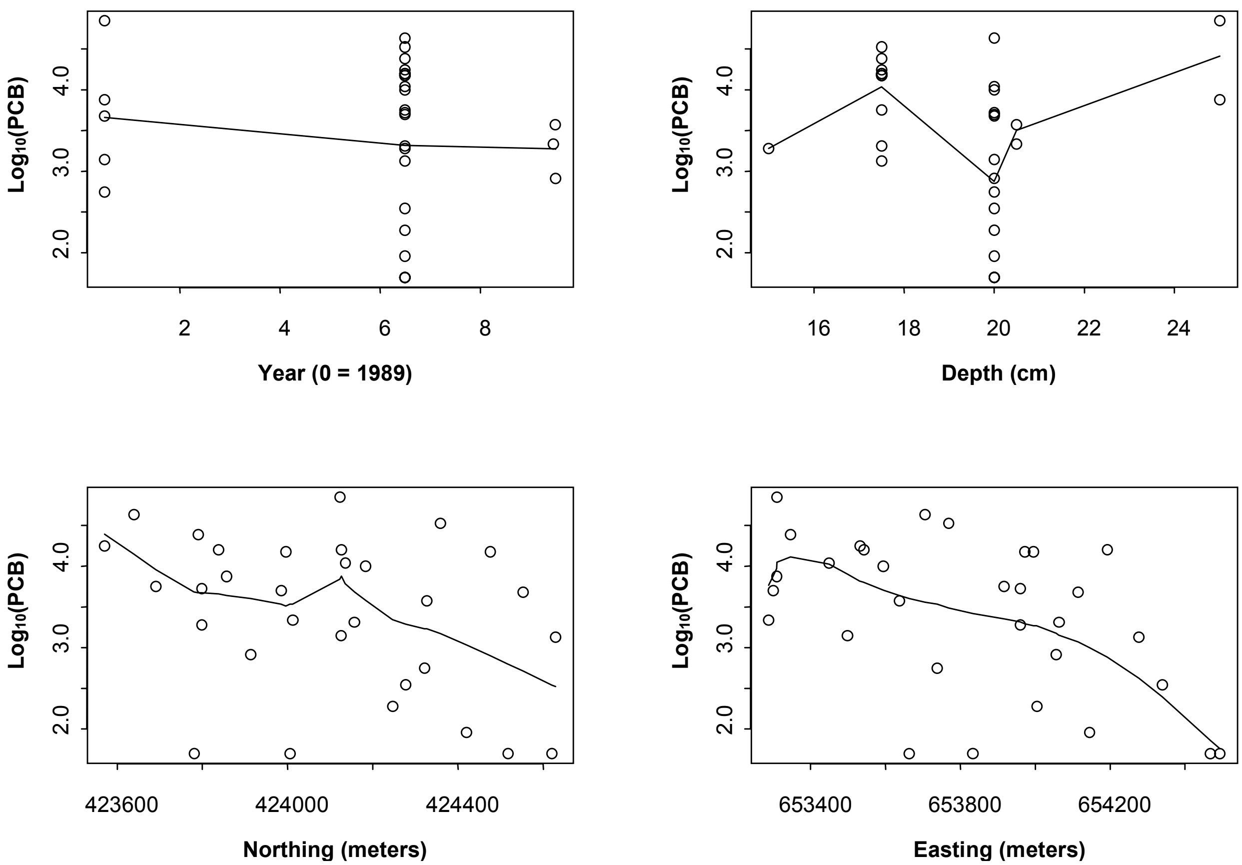


Figure A-76 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for De Pere SMU Group 2025 (10 to 30 cm) Including Fitted Smoothed Line

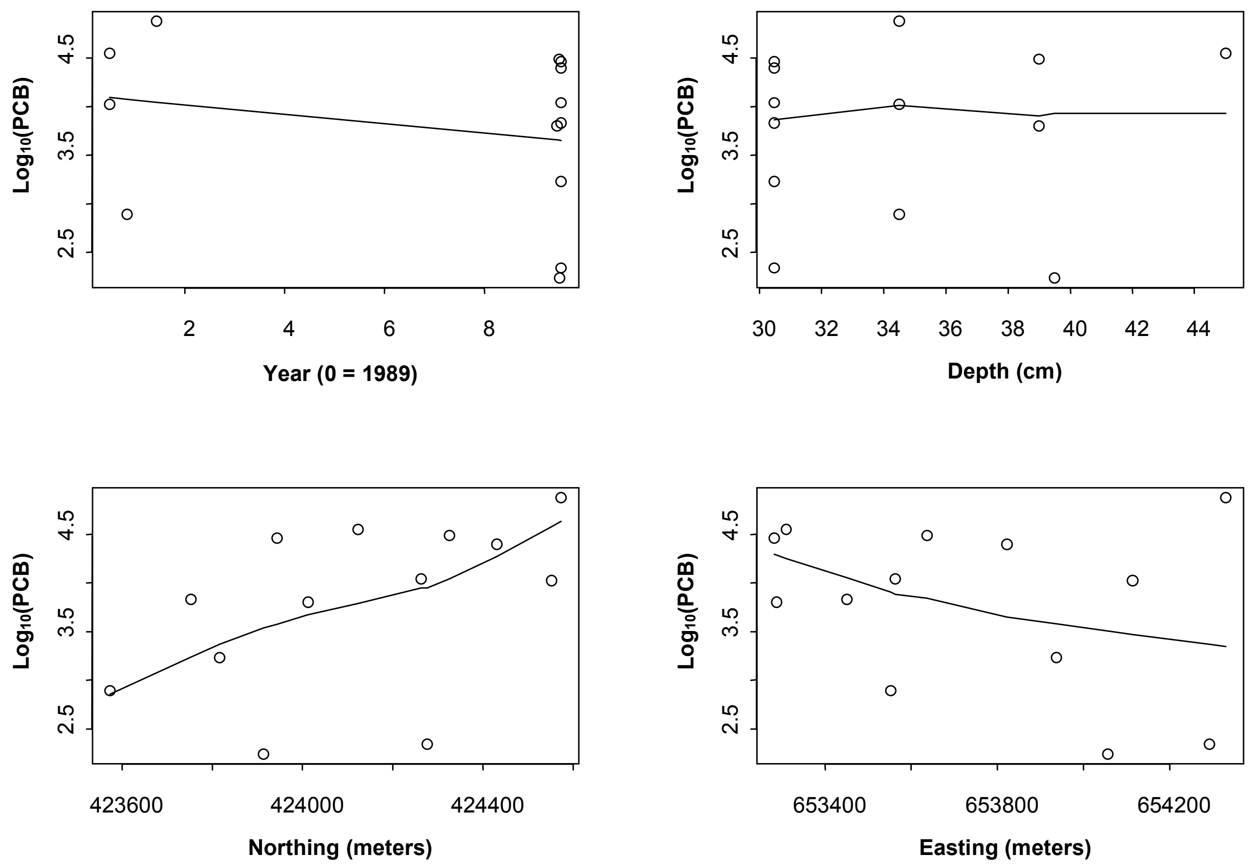


Figure A-77 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for De Pere SMU Group 2025 (30 to 50 cm) Including Fitted Smoothed Line

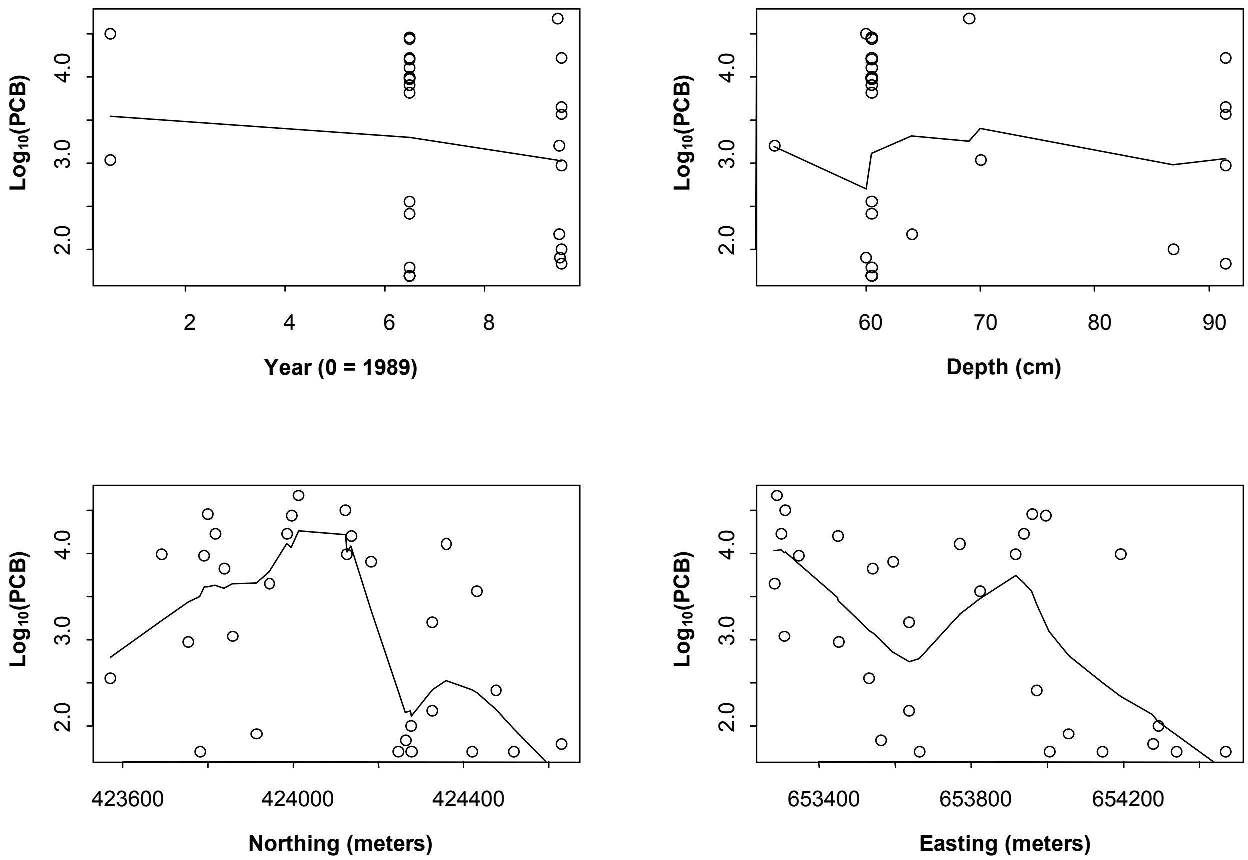


Figure A-78 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for De Pere SMU Group 2025 (50 to 100 cm) Including Fitted Smoothed Line

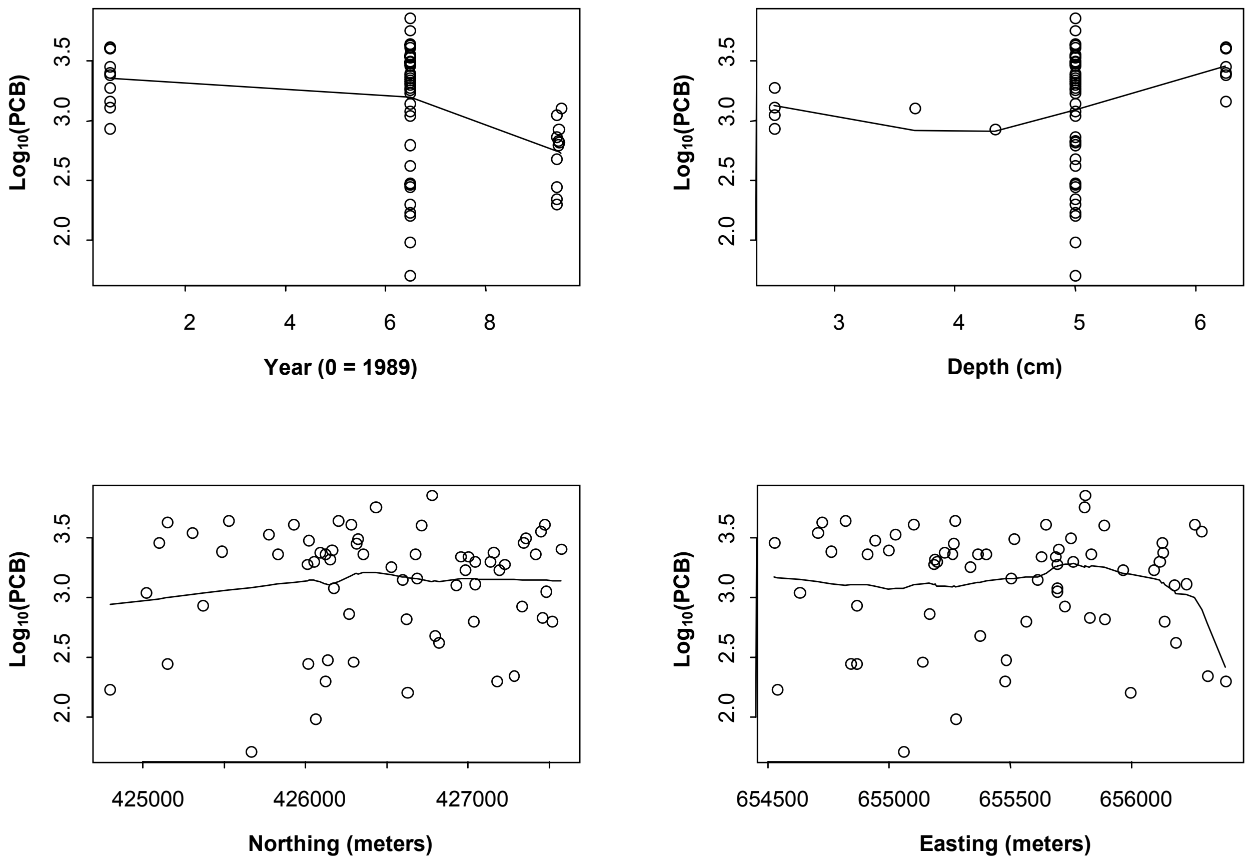


Figure A-79 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for De Pere SMU Group 2649 (0 to 10 cm) Including Fitted Smoothed Line

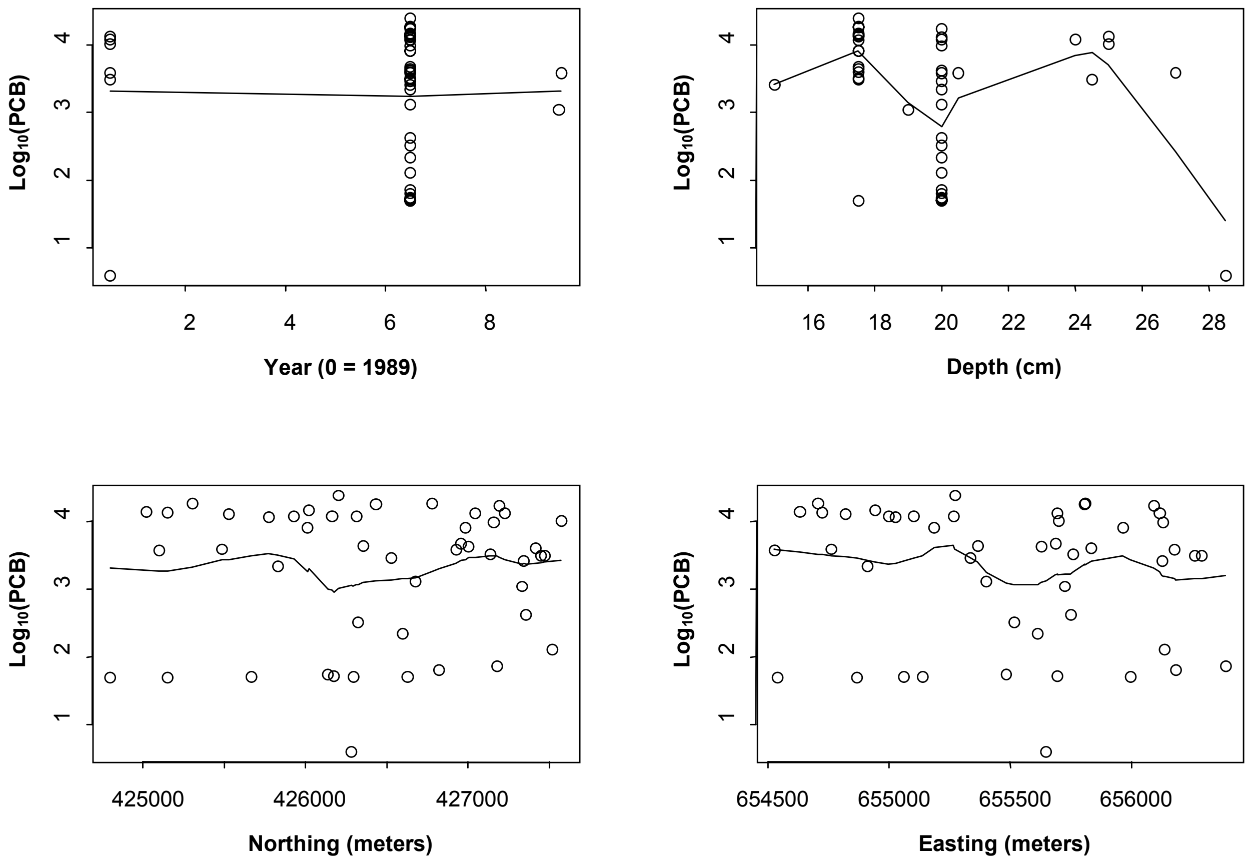


Figure A-80 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for De Pere SMU Group 2649 (10 to 30 cm) Including Fitted Smoothed Line

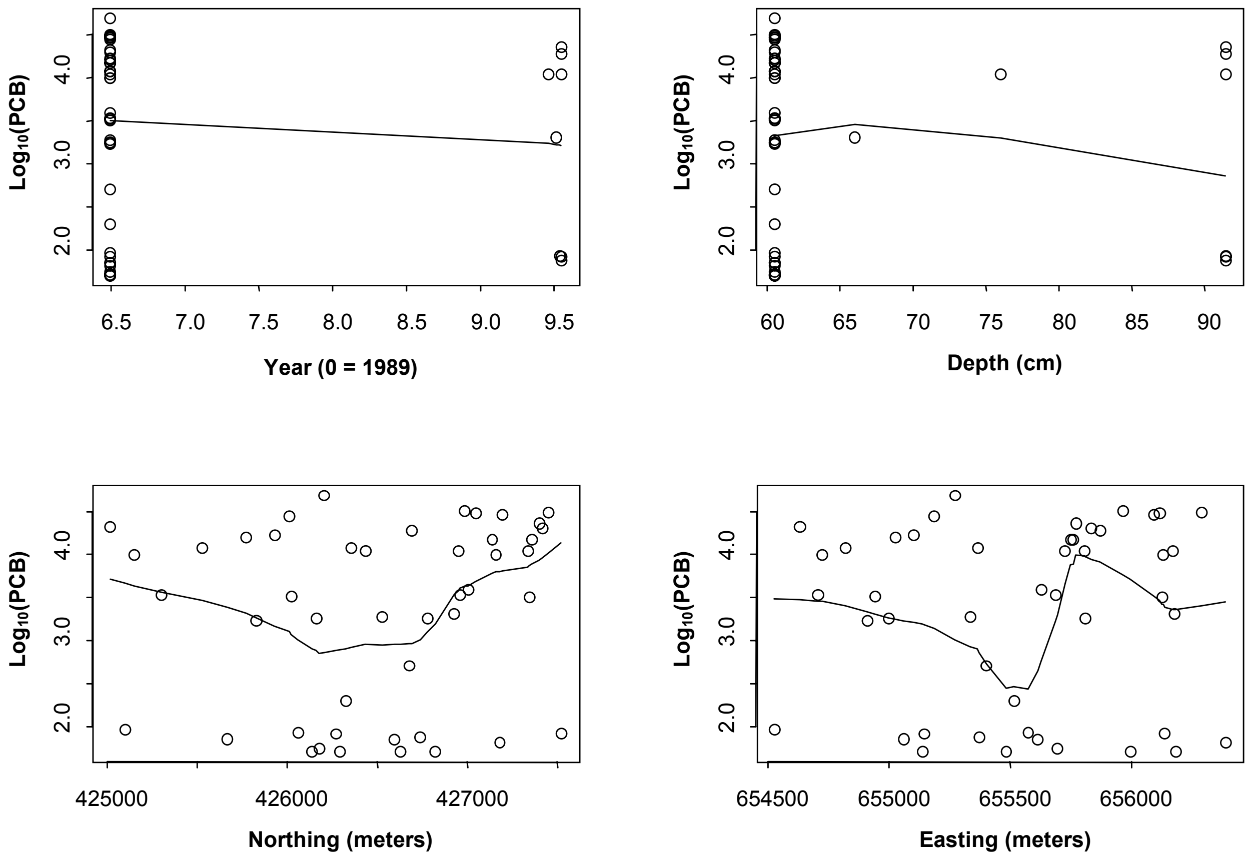


Figure A-81 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for De Pere SMU Group 2649 (50 to 100 cm) Including Fitted Smoothed Line

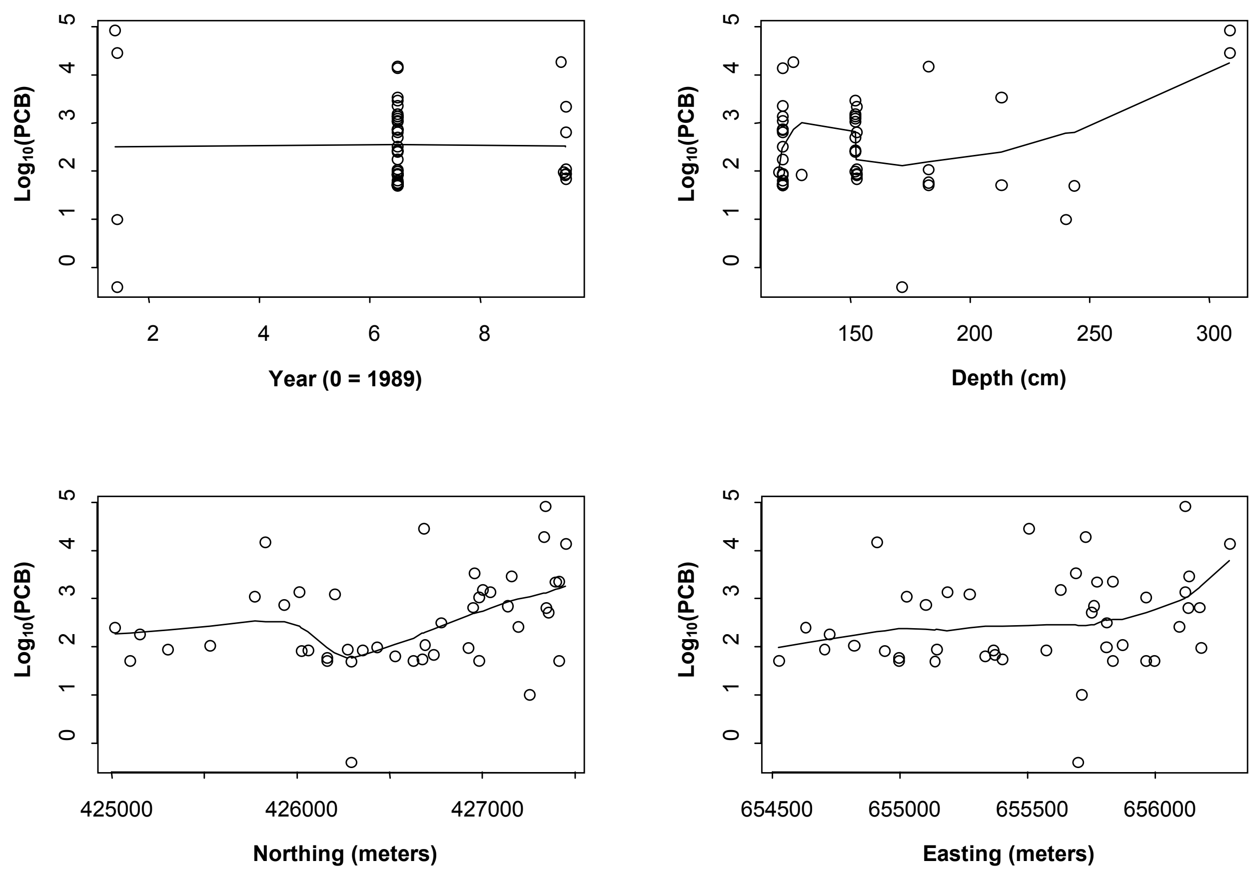


Figure A-82 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for De Pere SMU Group 2649 (100+ cm) Including Fitted Smoothed Line

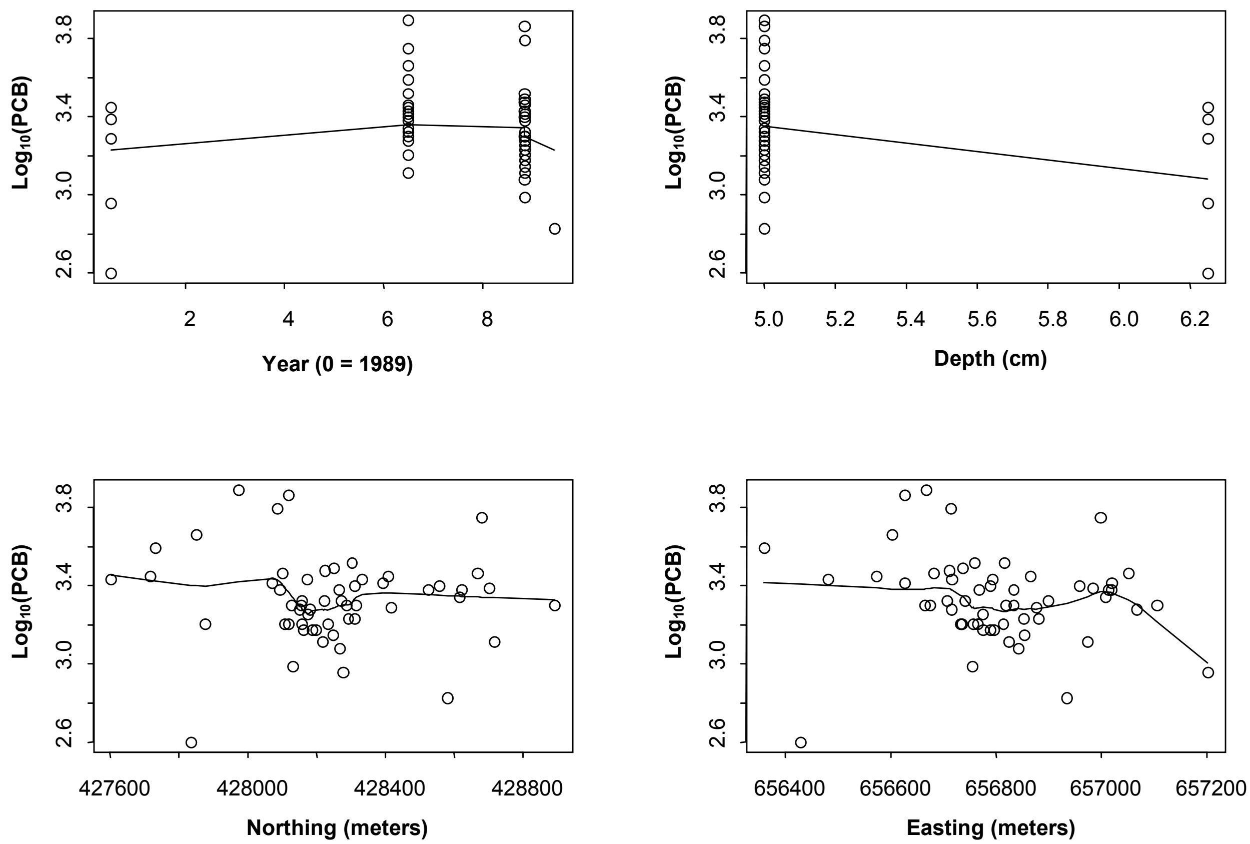


Figure A-83 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for De Pere SMU Group 5067 (0 to 10 cm) Including Fitted Smoothed Line

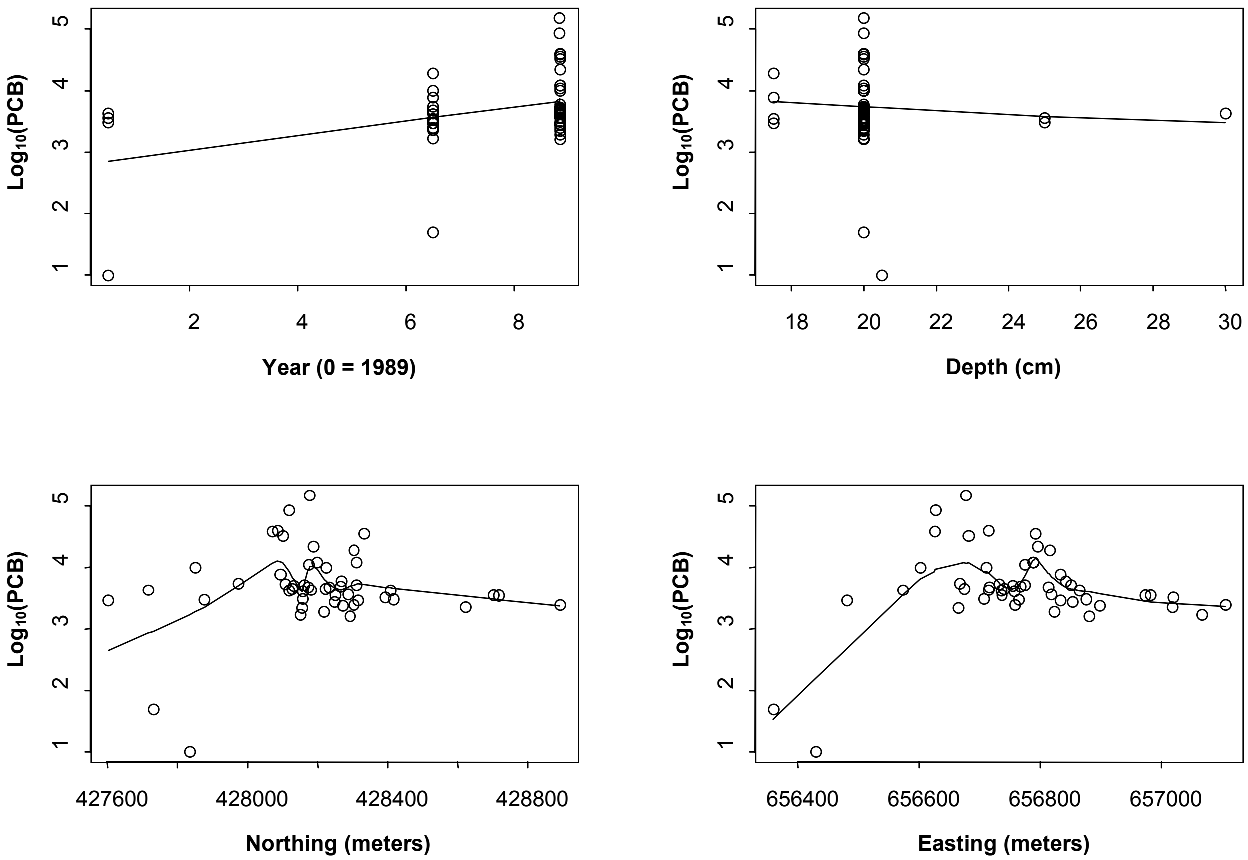


Figure A-84 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for De Pere SMU Group 5067 (10 to 30 cm) Including Fitted Smoothed Line

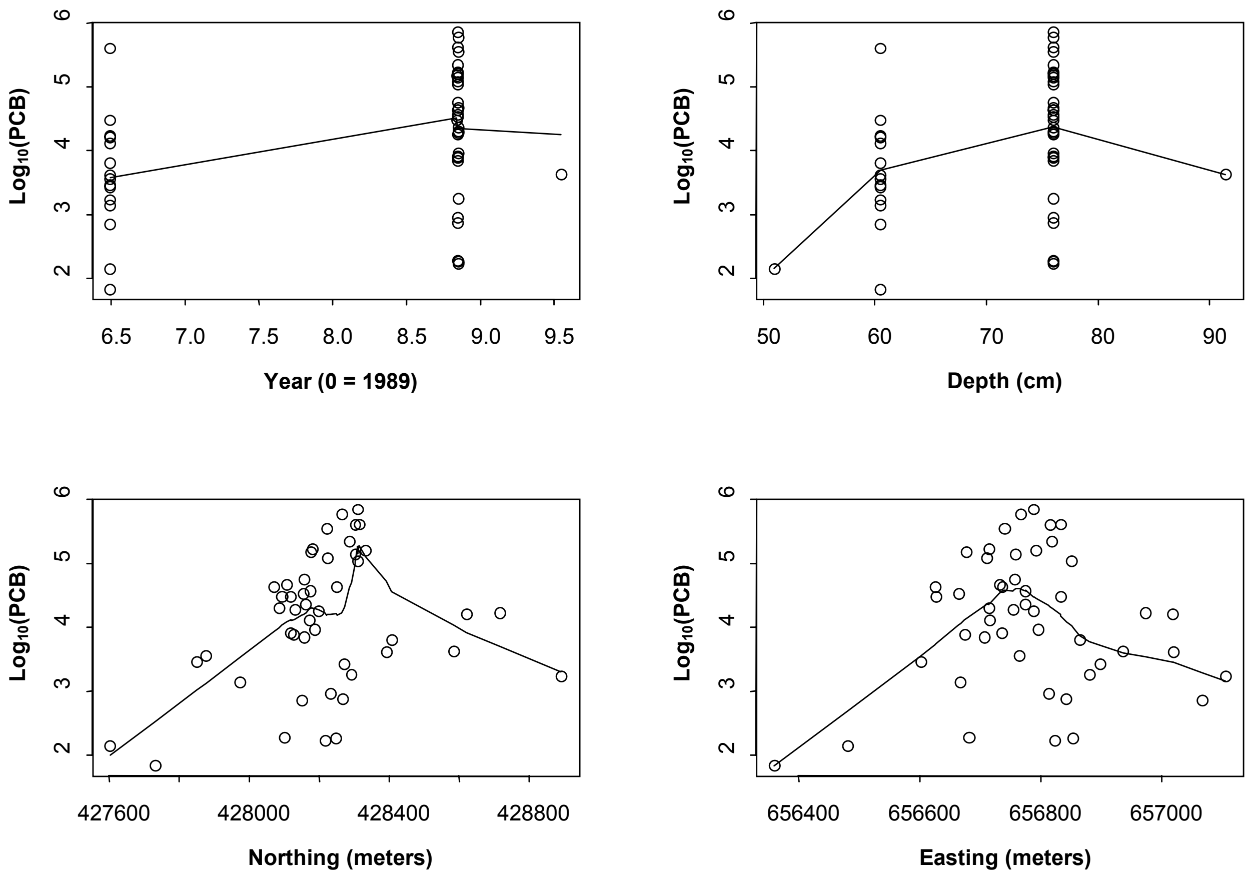


Figure A-85 Log_{10} PCB Concentration versus Time, Depth, Northing, and Easting for De Pere SMU Group 5067 (50 to 100 cm) Including Fitted Smoothed Line

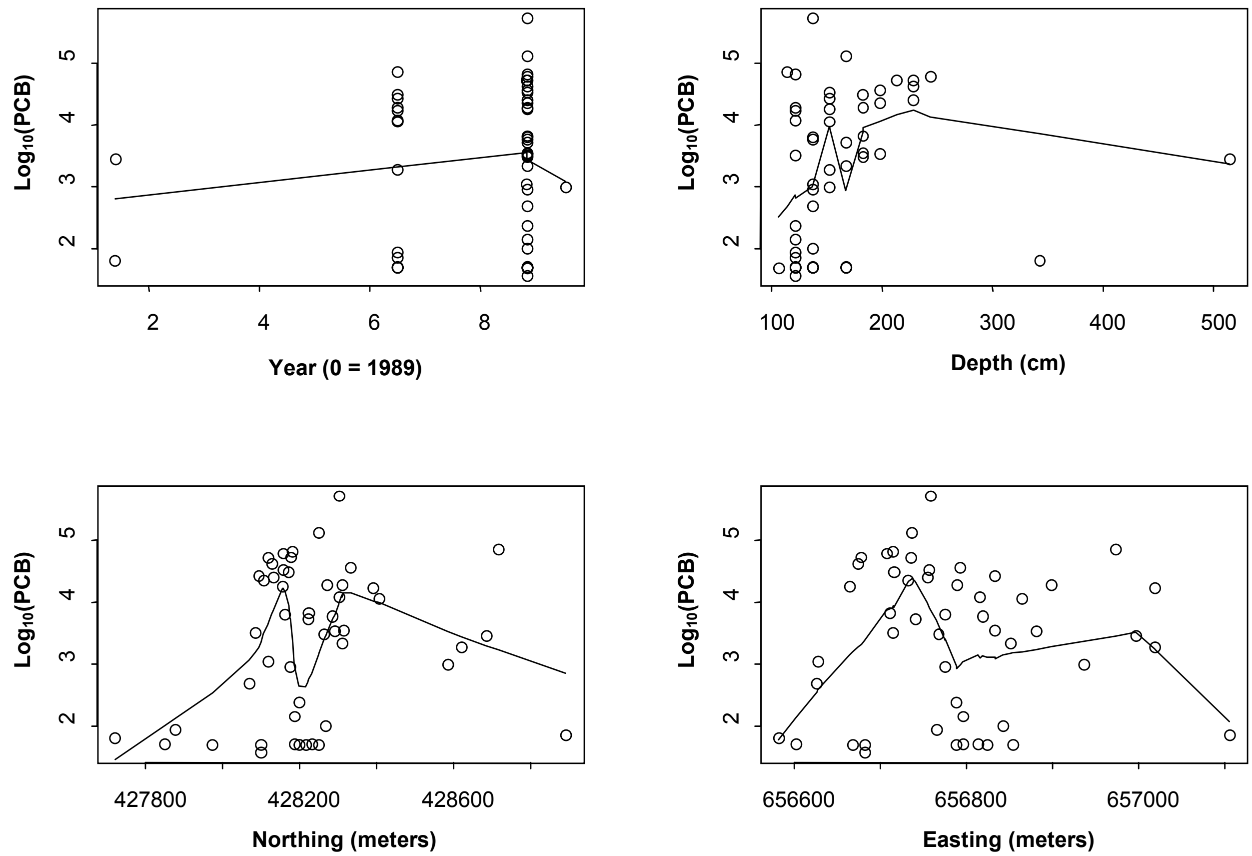


Figure A-86 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for De Pere SMU Group 5067 (100+ cm) Including Fitted Smoothed Line

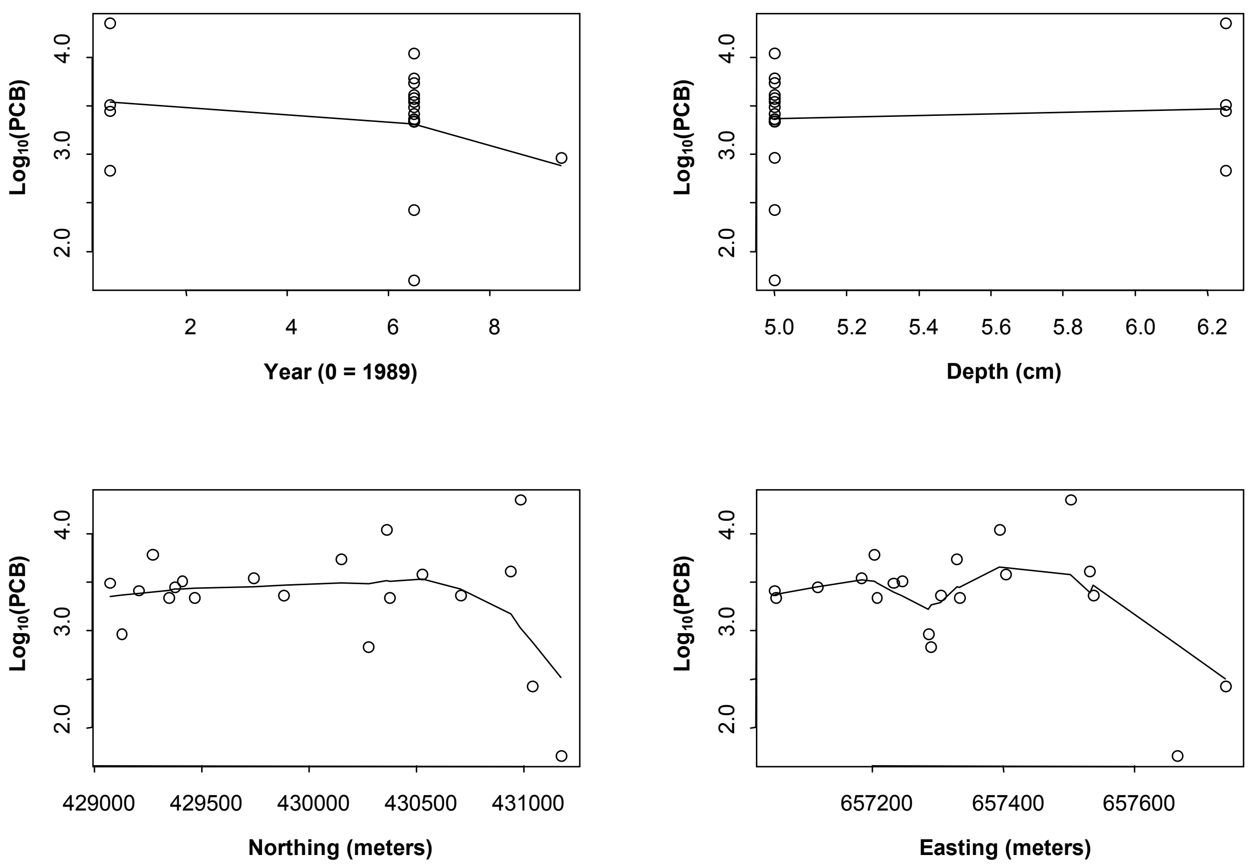


Figure A-87 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for De Pere SMU Group 6891 (0 to 10 cm) Including Fitted Smoothed Line

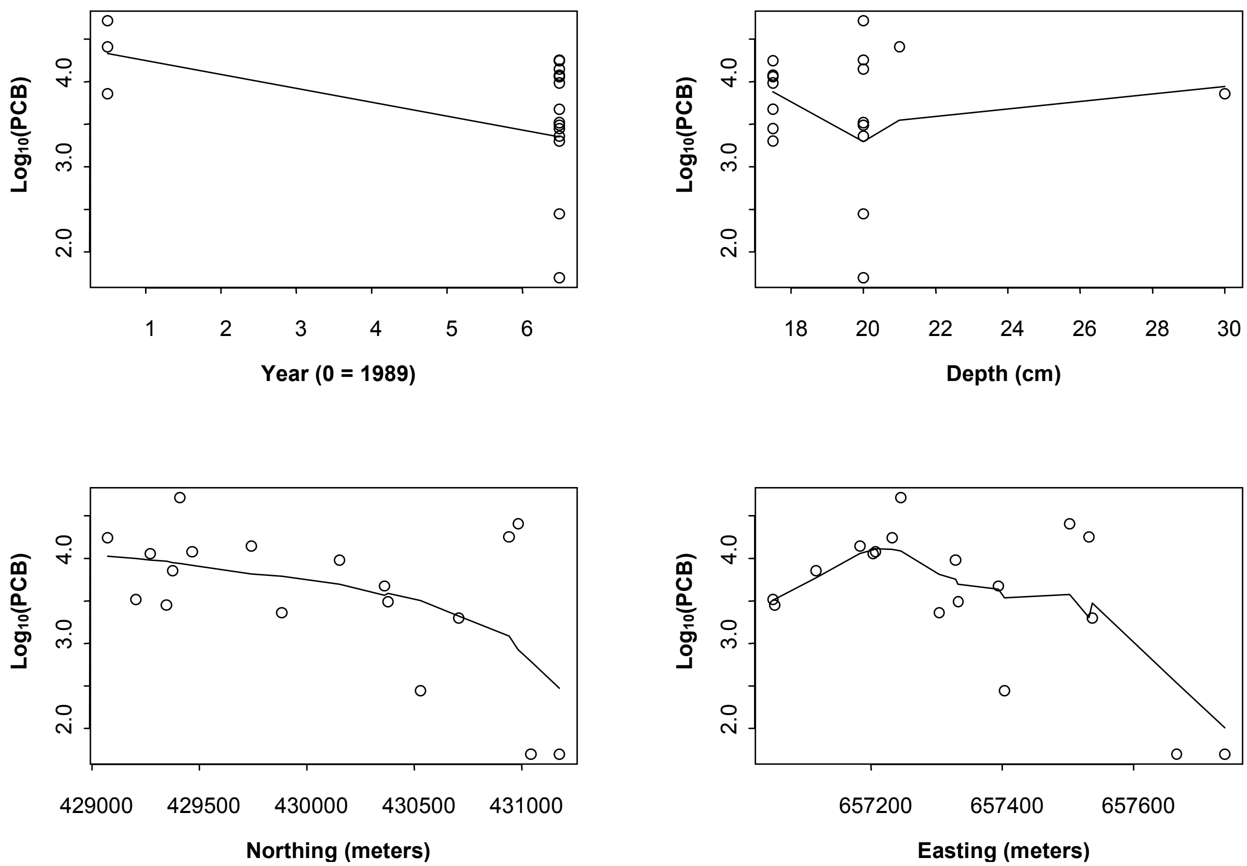


Figure A-88 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for De Pere SMU Group 6891 (10 to 30 cm) Including Fitted Smoothed Line

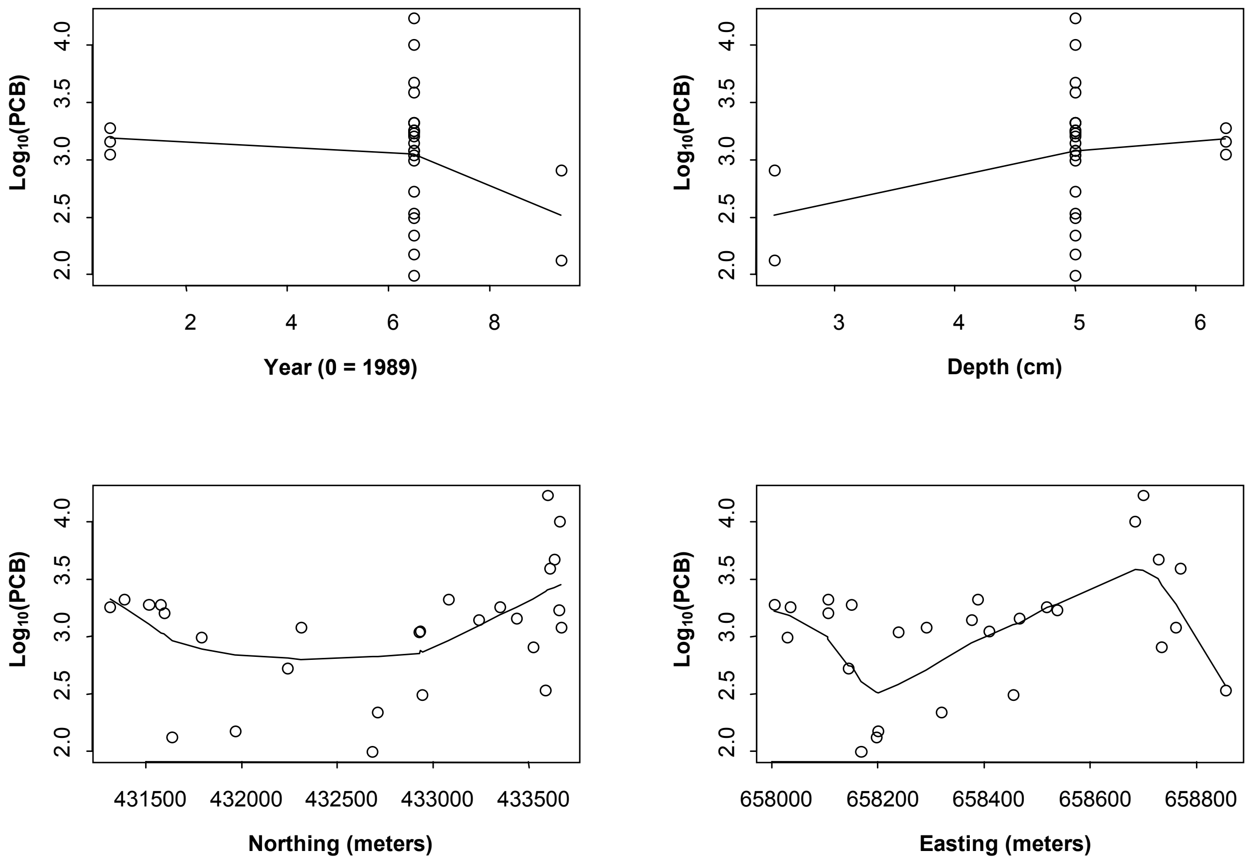


Figure A-89 Log$_{10}$ PCB Concentration versus Time, Depth, Northing, and Easting for De Pere SMU Group 92115 (0 to 10 cm) Including Fitted Smoothed Line

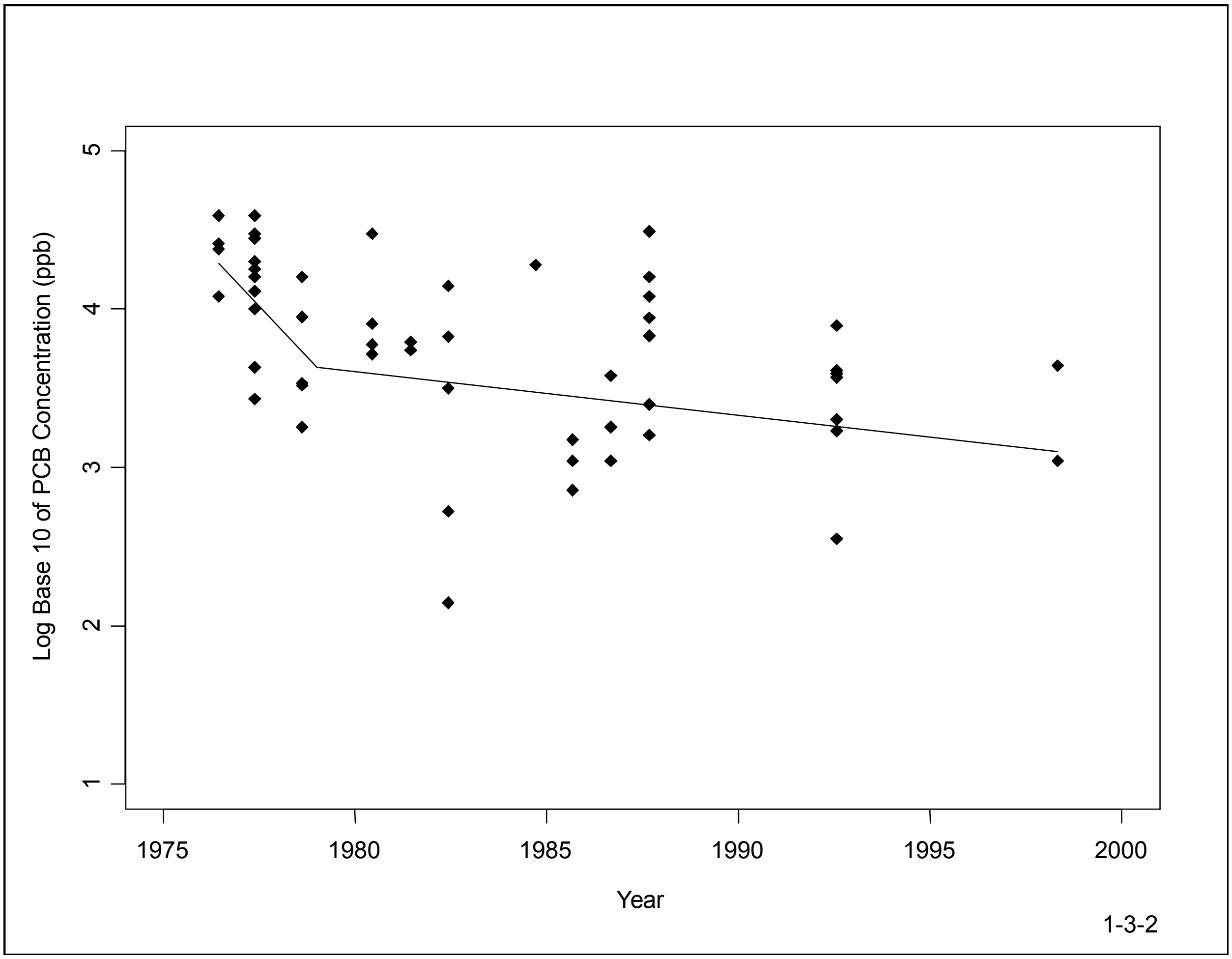


Figure A-90 Log_{10} PCB Concentration (ppb) in Little Lake Butte des Morts Carp, Skin-on Fillet, versus Time

Values at or above the detection limit are depicted as ◆.

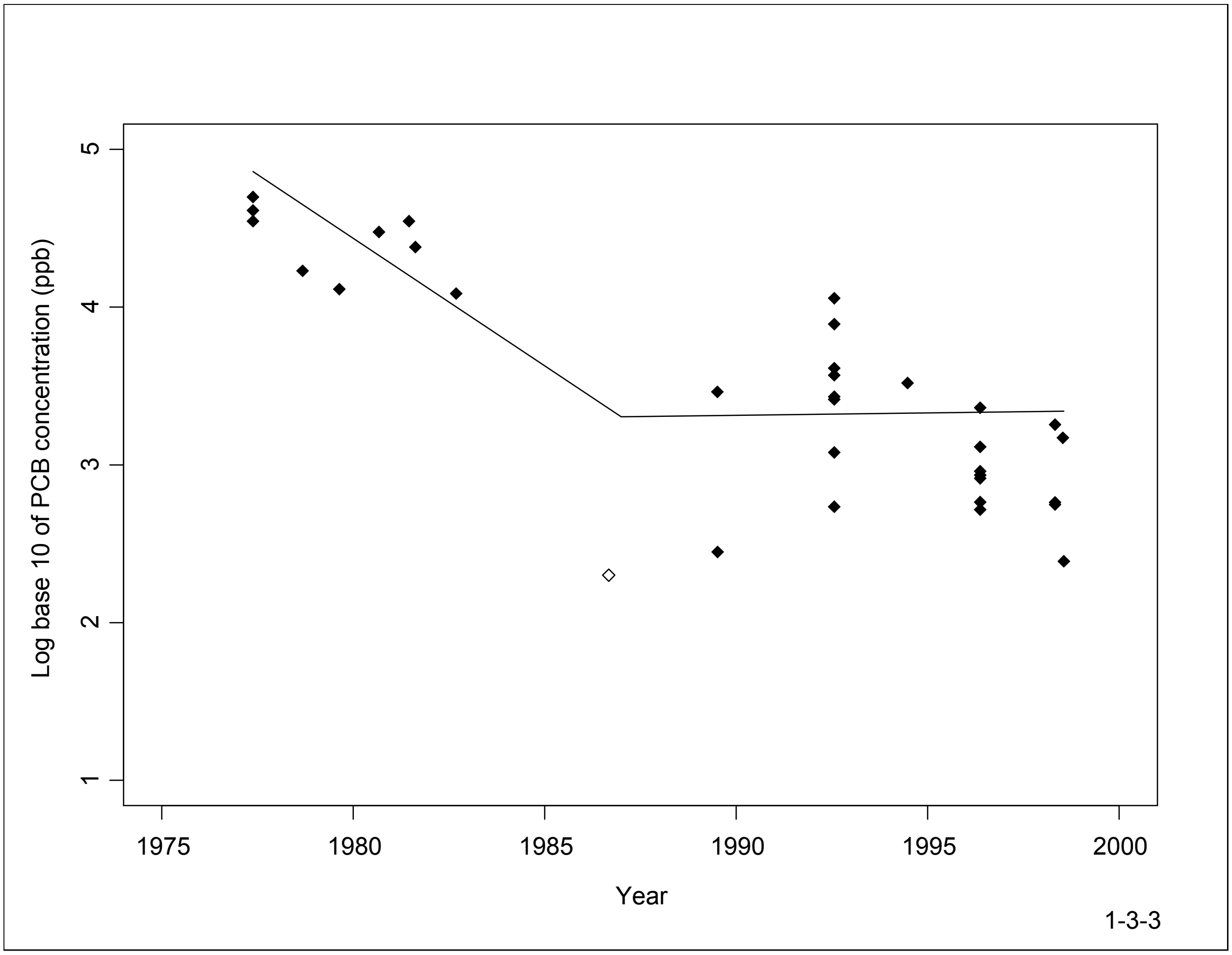


Figure A-91 Log_{10} PCB Concentration (ppb) in Little Lake Butte des Morts Carp, Whole Body, versus Time

Values at or above the detection limit are depicted as ◆. Any values below detection limit are depicted as ◇.

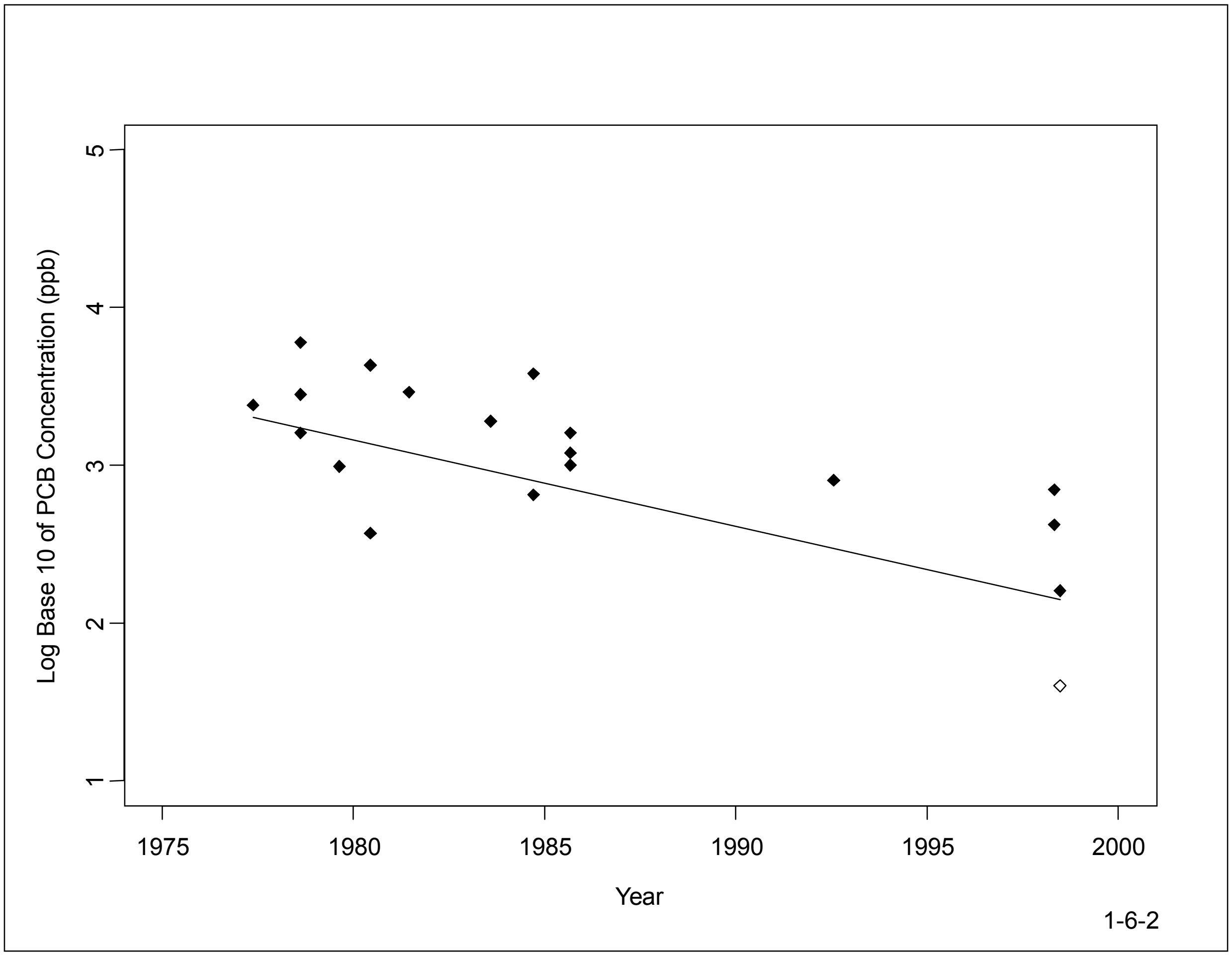


Figure A-92 Log$_{10}$ PCB Concentration (ppb) in Little Lake Butte des Morts Northern Pike, Skin-on Fillet, versus Time

Values at or above the detection limit are depicted as ◆. Any values below detection limit are depicted as ◇.

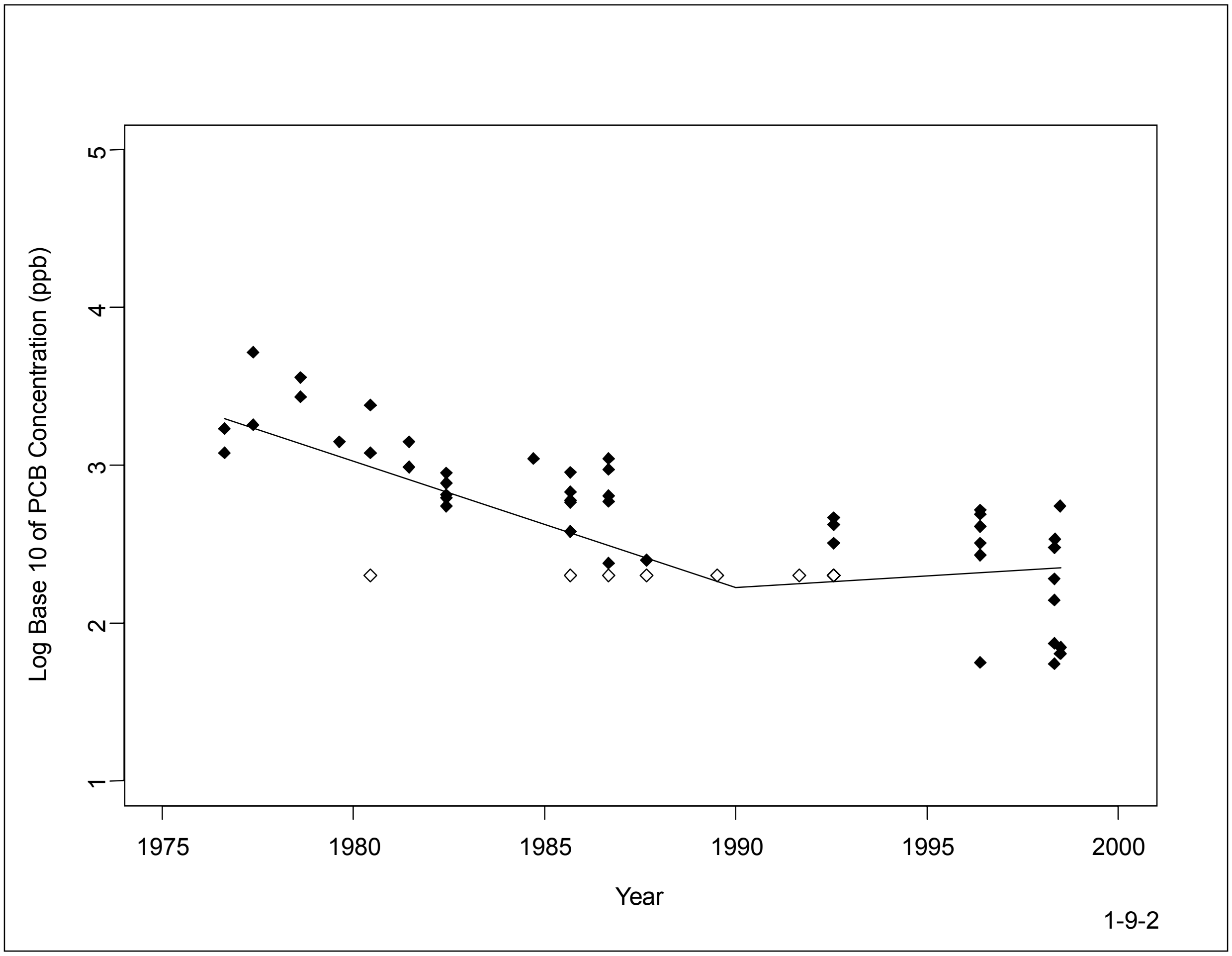


Figure A-93 Log$_{10}$ PCB Concentration (ppb) in Little Lake Butte des Morts Walleye, Skin-on Fillet, versus Time

Values at or above the detection limit are depicted as ◆. Any values below detection limit are depicted as ◇.

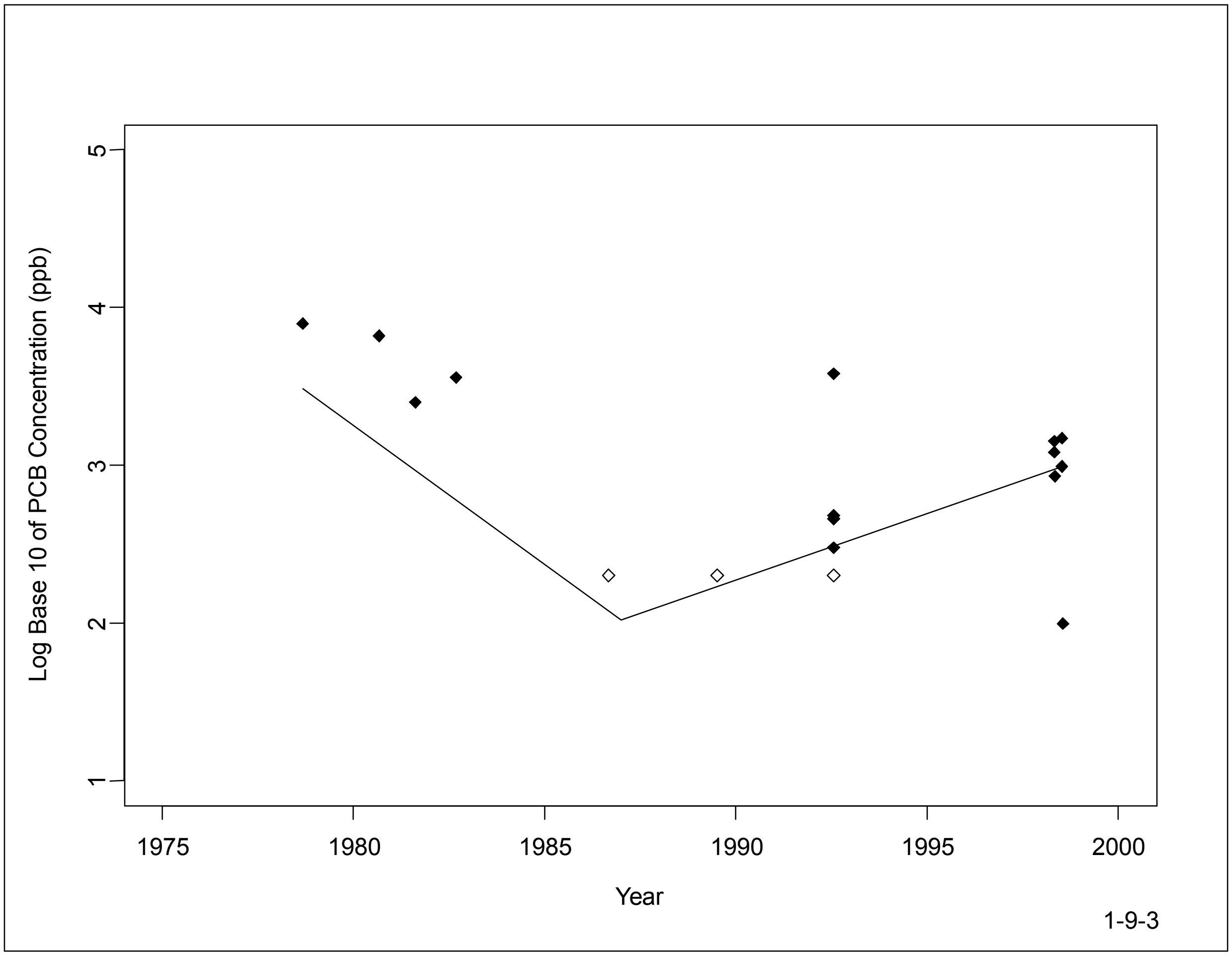


Figure A-94 Log$_{10}$ PCB Concentration (ppb) in Little Lake Butte des Morts Walleye, Whole Body, versus Time

Values at or above the detection limit are depicted as ◆. Any values below detection limit are depicted as ◇.

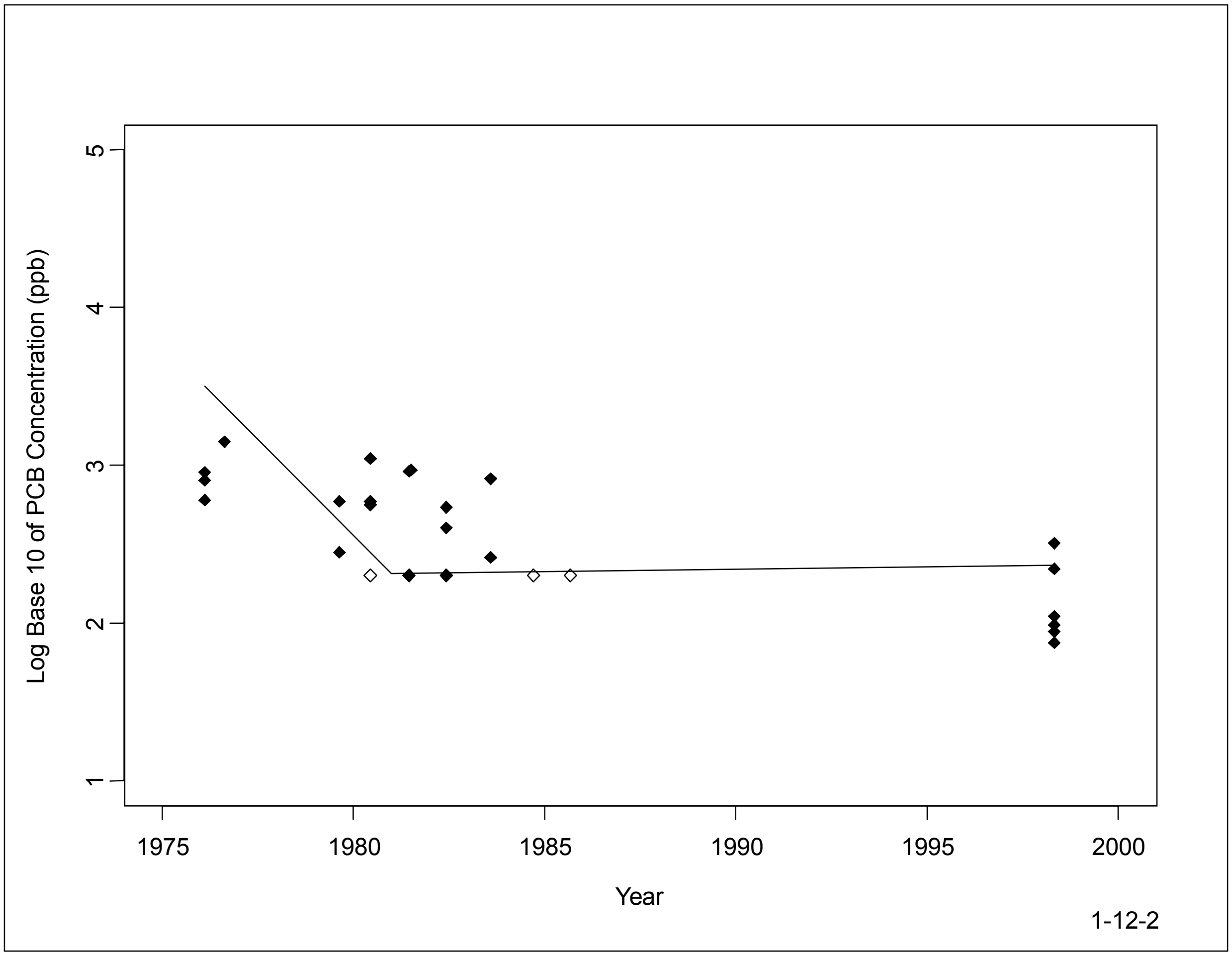


Figure A-95 Log$_{10}$ PCB Concentration (ppb) in Little Lake Butte des Morts Yellow Perch, Skin-on Fillet, versus Time

Values at or above the detection limit are depicted as ◆. Any values below detection limit are depicted as ◇.

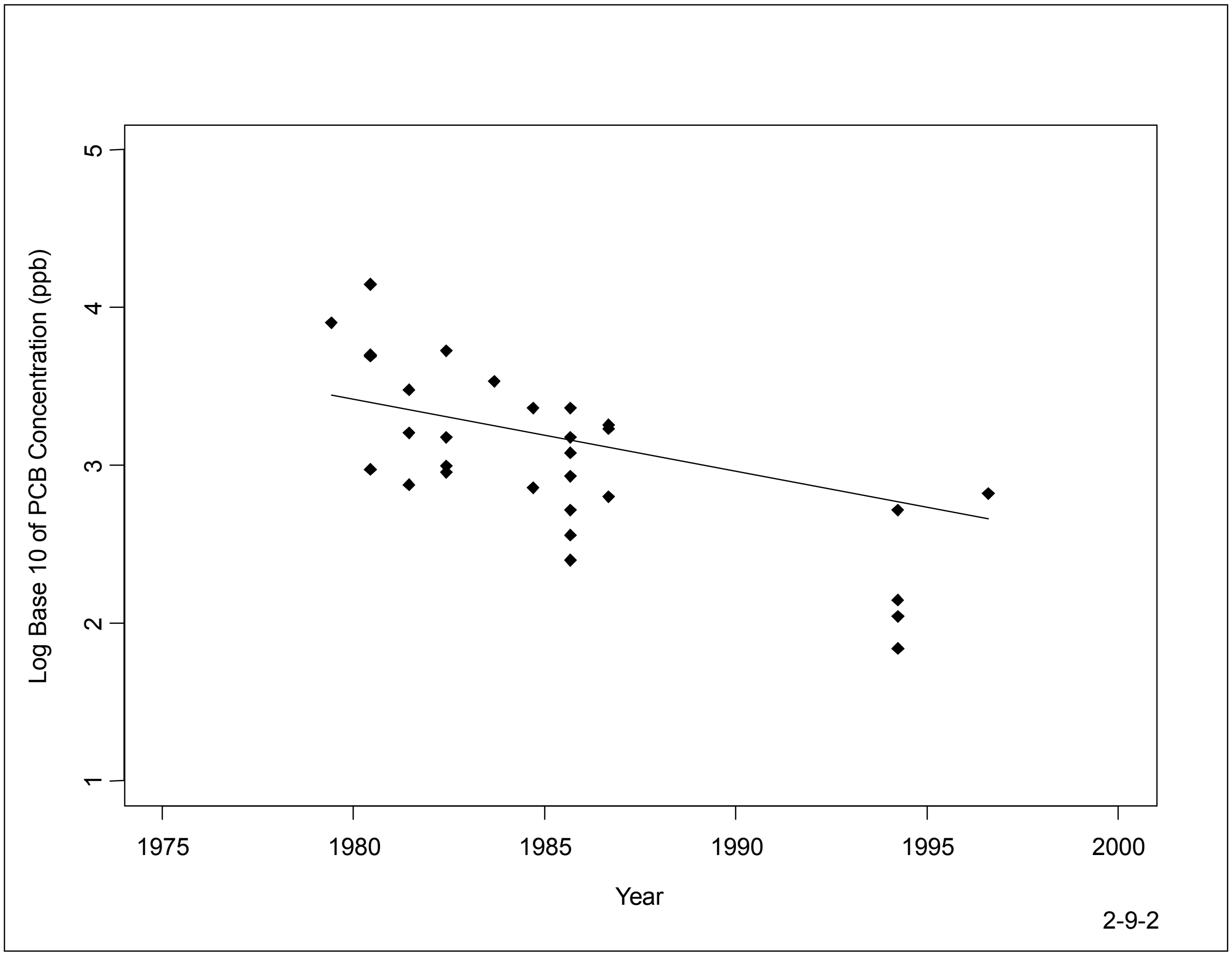


Figure A-96 Log$_{10}$ PCB Concentration (ppb) in Appleton to Little Rapids Walleye, Skin-on Fillet, versus Time

Values at or above the detection limit are depicted as ◆.

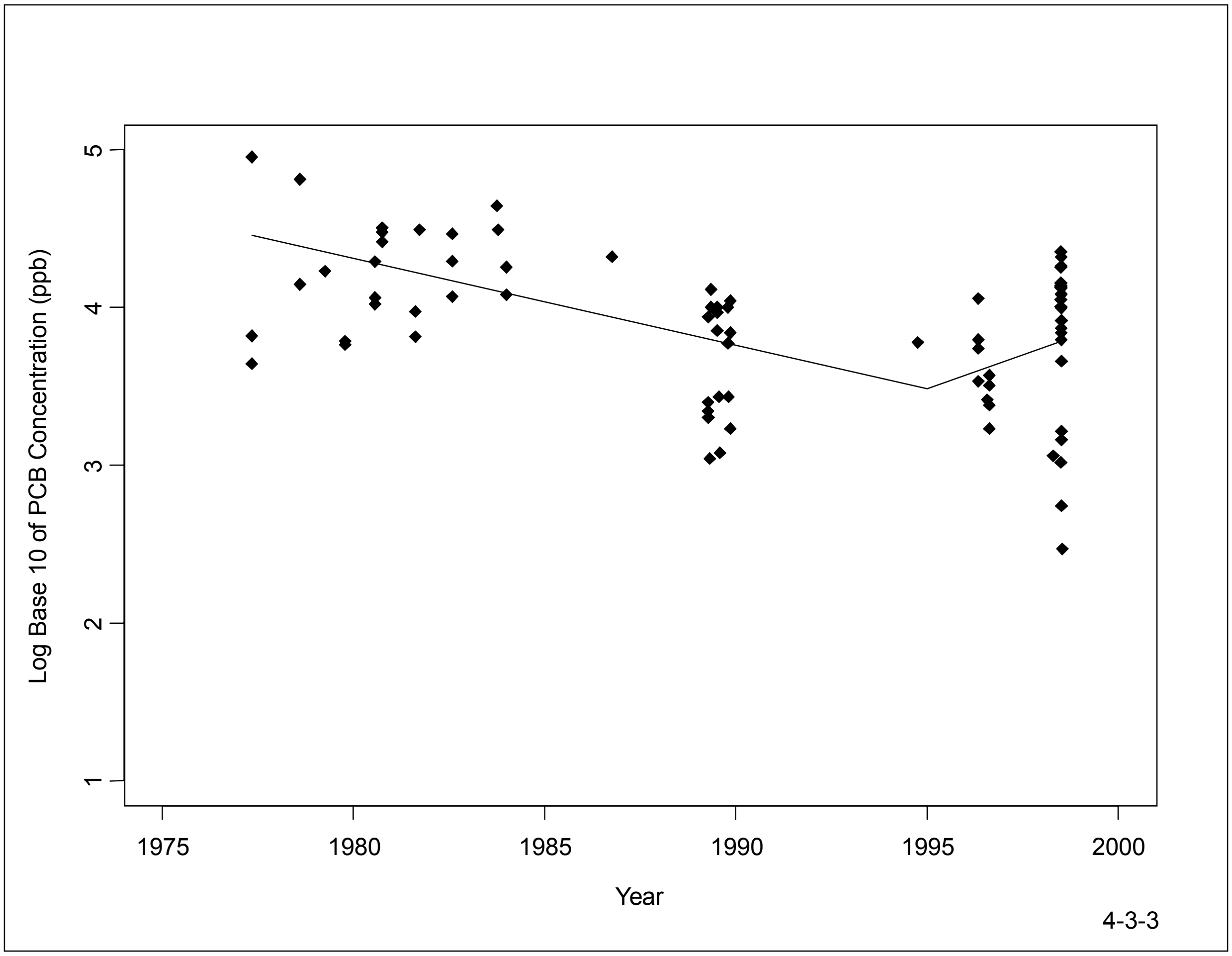


Figure A-97 Log$_{10}$ PCB Concentration (ppb) in De Pere to Green Bay Carp, Whole Body, versus Time

Values at or above the detection limit are depicted as ◆.

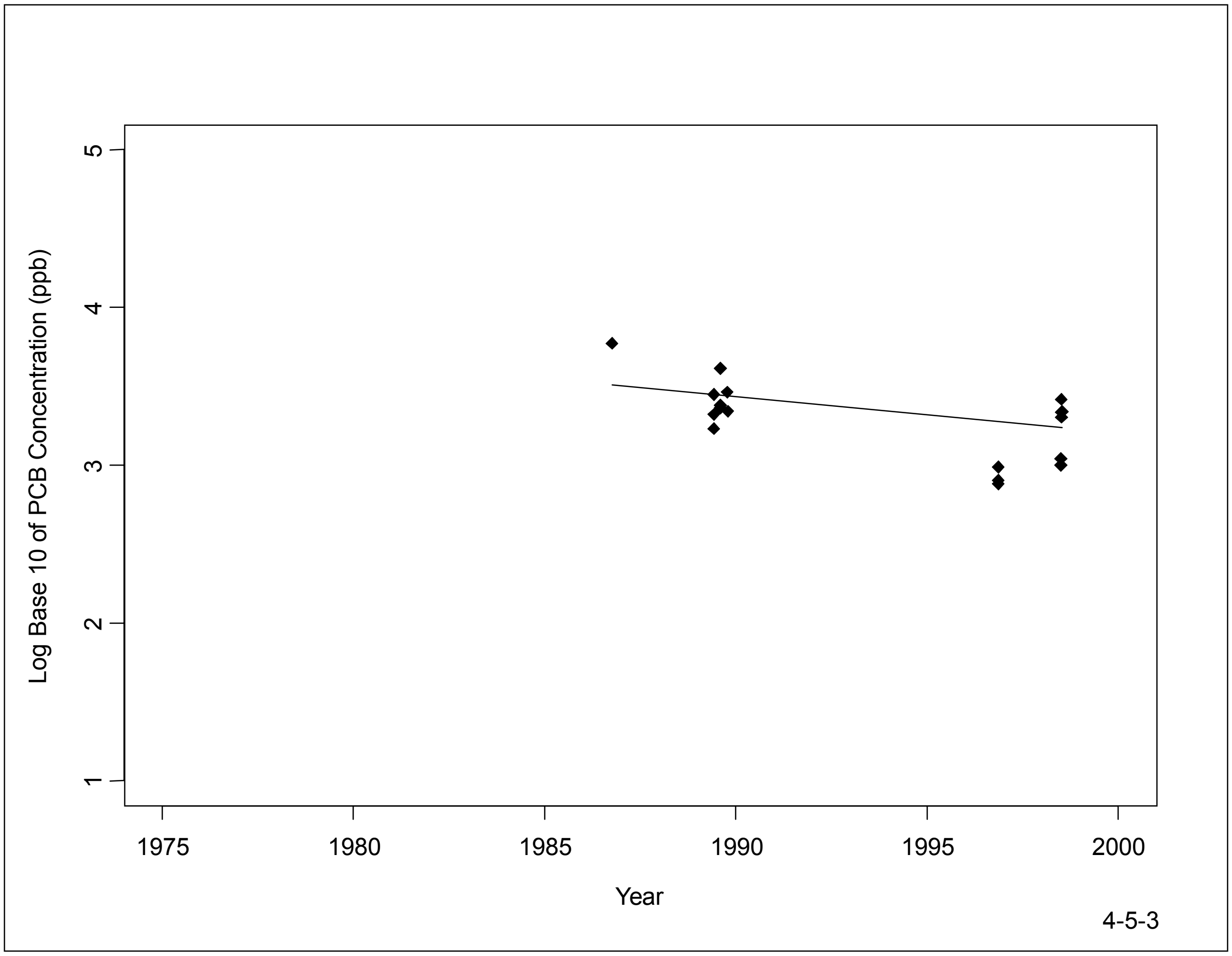


Figure A-98 Log$_{10}$ PCB Concentration (ppb) in De Pere to Green Bay Gizzard Shad, Whole Body, versus Time

Values at or above the detection limit are depicted as ◆.

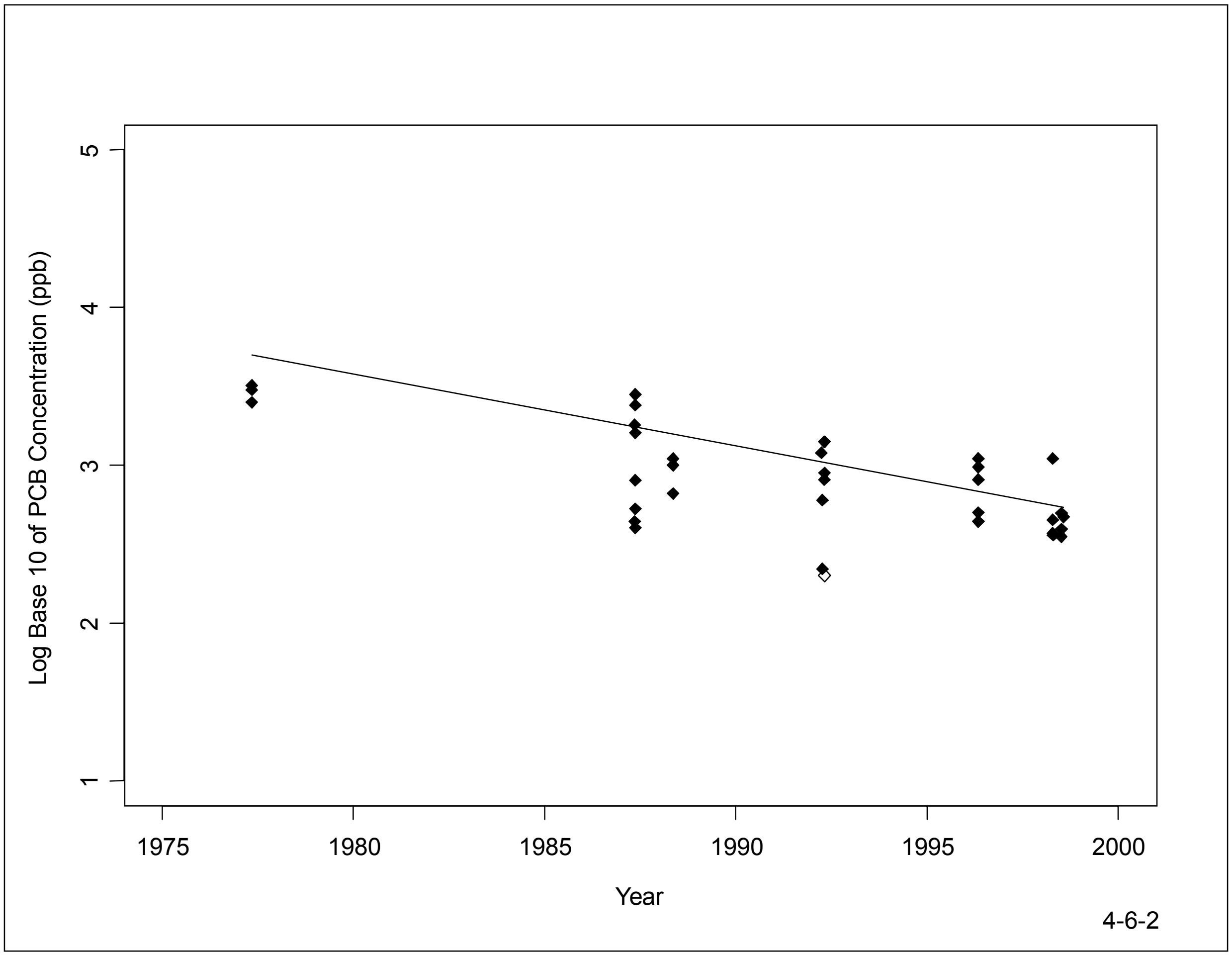


Figure A-99 Log$_{10}$ PCB Concentration (ppb) in De Pere to Green Bay Northern Pike, Skin-on Fillet, versus Time

Values at or above the detection limit are depicted as ◆. Any values below detection limit are depicted as ◇.

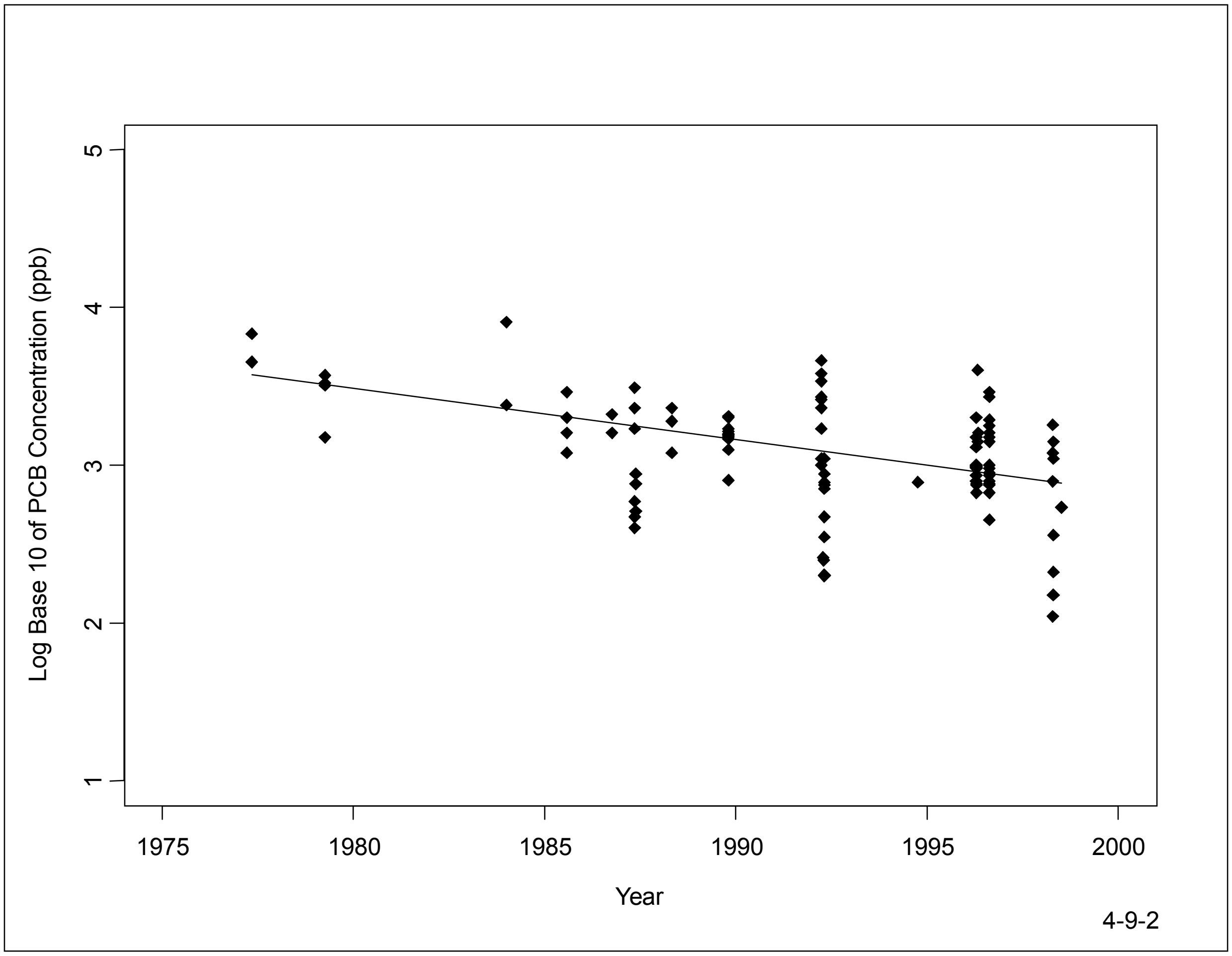


Figure A-100 Log_{10} PCB Concentration (ppb) in De Pere to Green Bay Walleye, Skin-on Fillet, versus Time

Values at or above the detection limit are depicted as ◆.

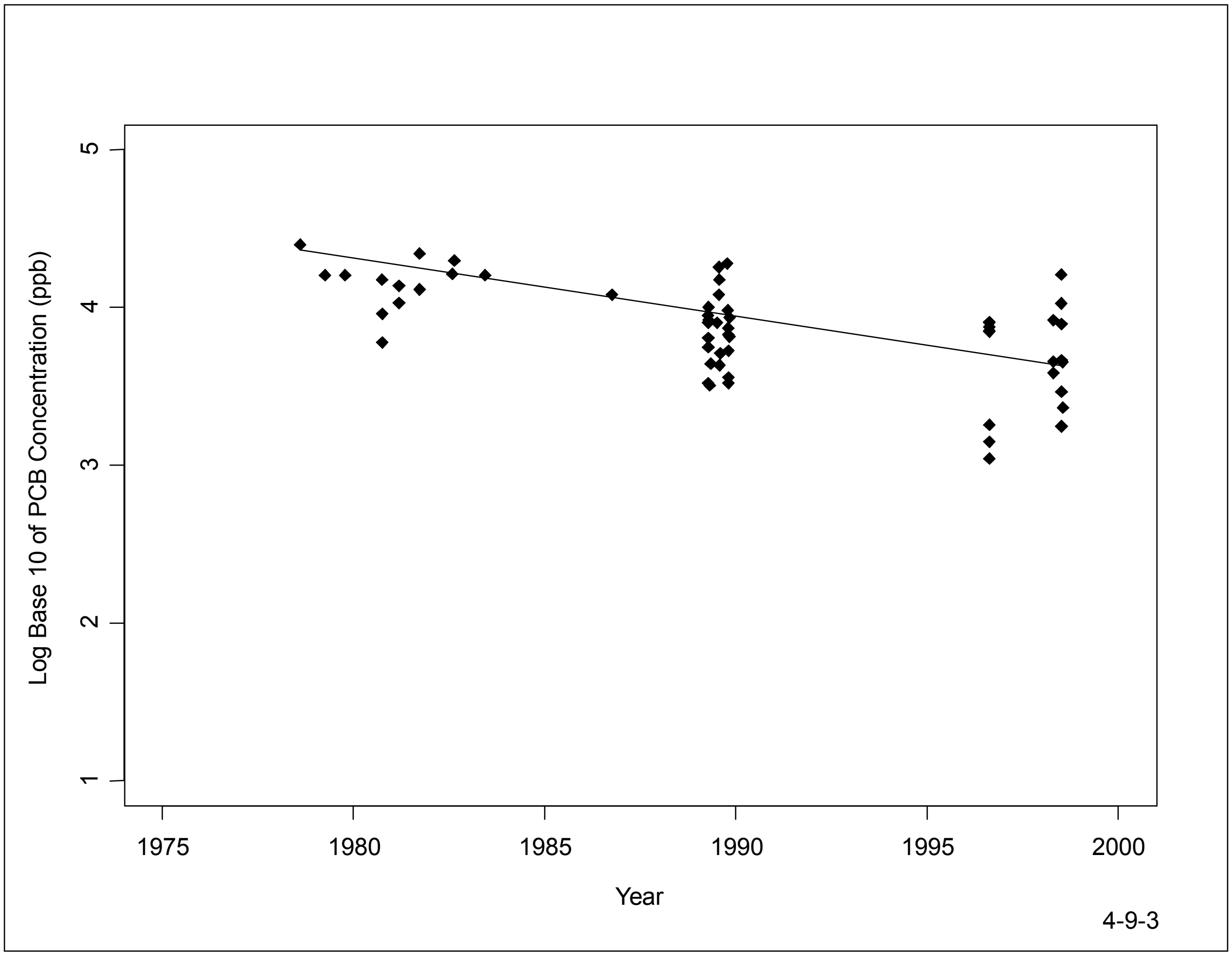


Figure A-101 Log$_{10}$ PCB Concentration (ppb) in De Pere to Green Bay Walleye, Whole Body, versus Time

Values at or above the detection limit are depicted as ◆.

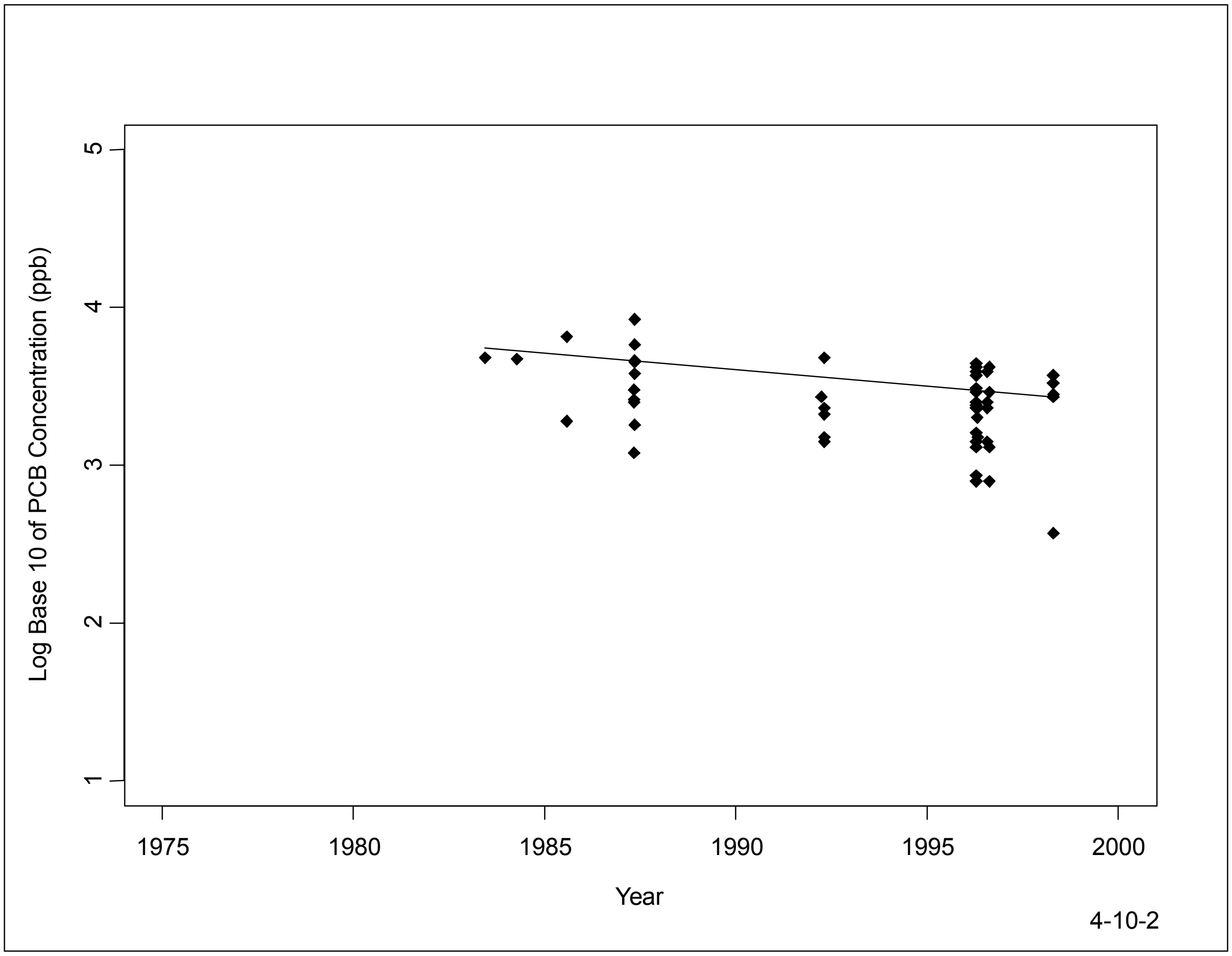


Figure A-102 Log_{10} PCB Concentration (ppb) in De Pere to Green Bay White Bass, Skin-on Fillet, versus Time

Values at or above the detection limit are depicted as ◆.

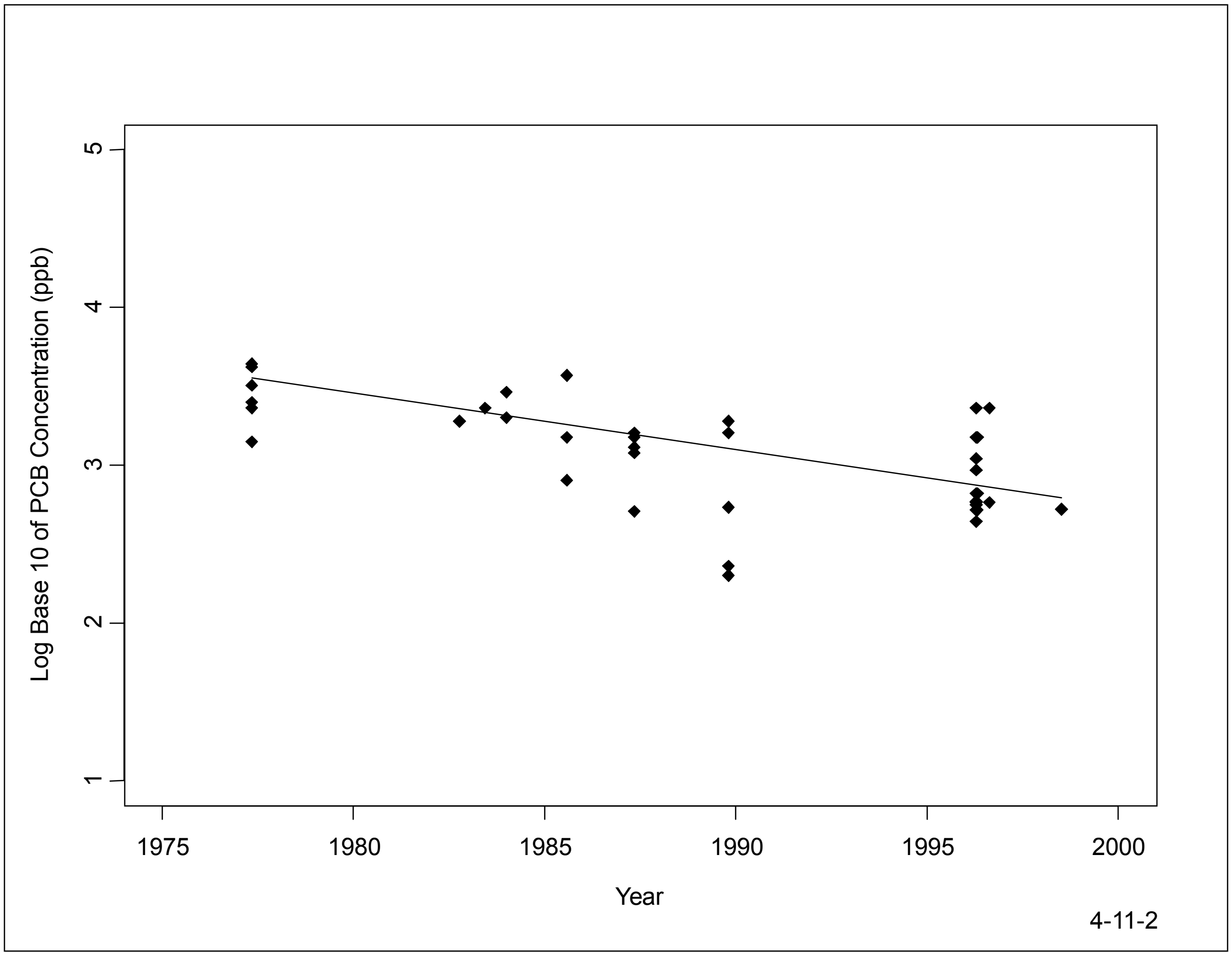


Figure A-103 Log_{10} PCB Concentration (ppb) in De Pere to Green Bay White Sucker, Skin-on Fillet, versus Time

Values at or above the detection limit are depicted as ◆.

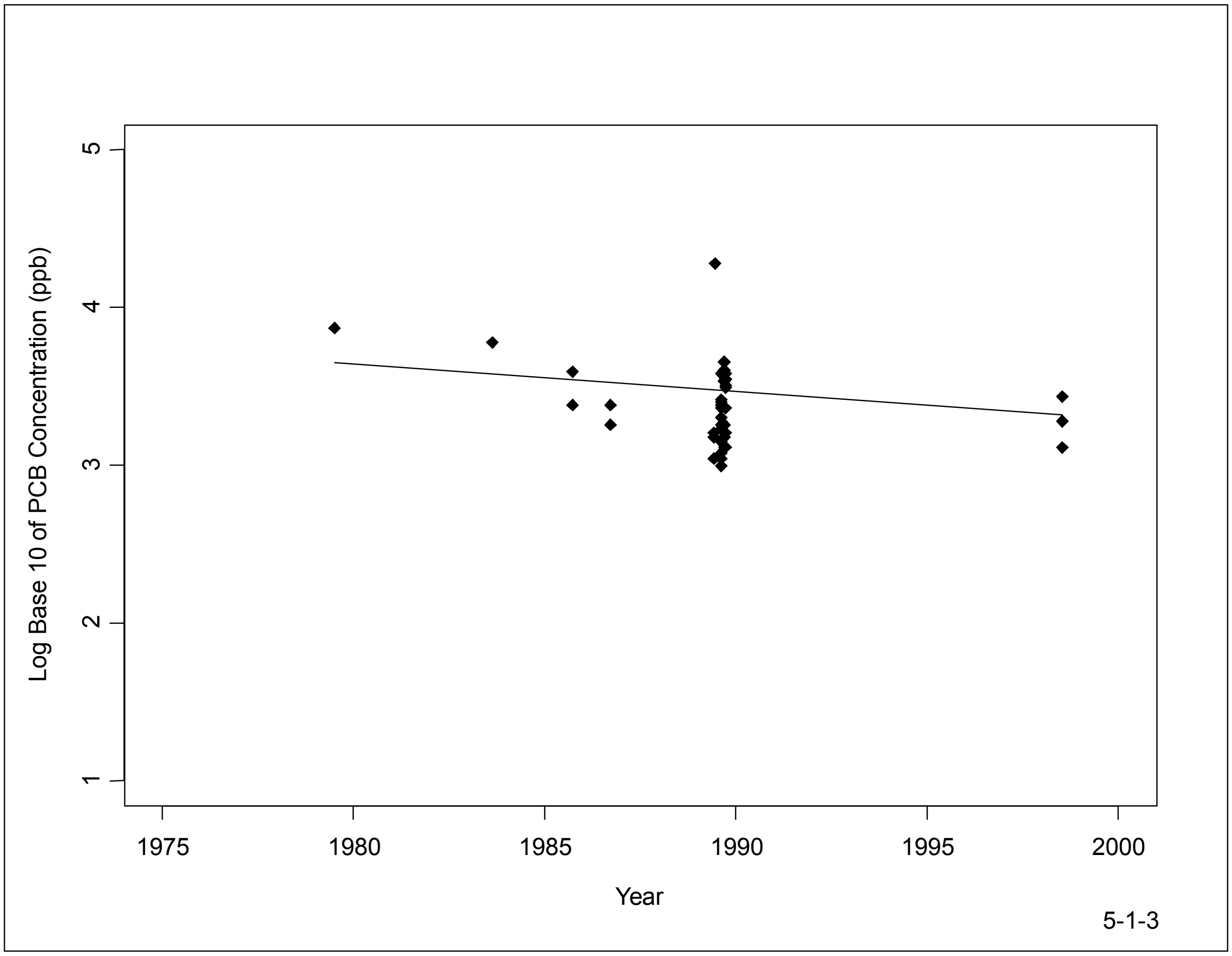


Figure A-104 Log_{10} PCB Concentration (ppb) in Green Bay Zone 2 (2A and 2B) Alewife, Skin-on Fillet, versus Time

Values at or above the detection limit are depicted as ◆.

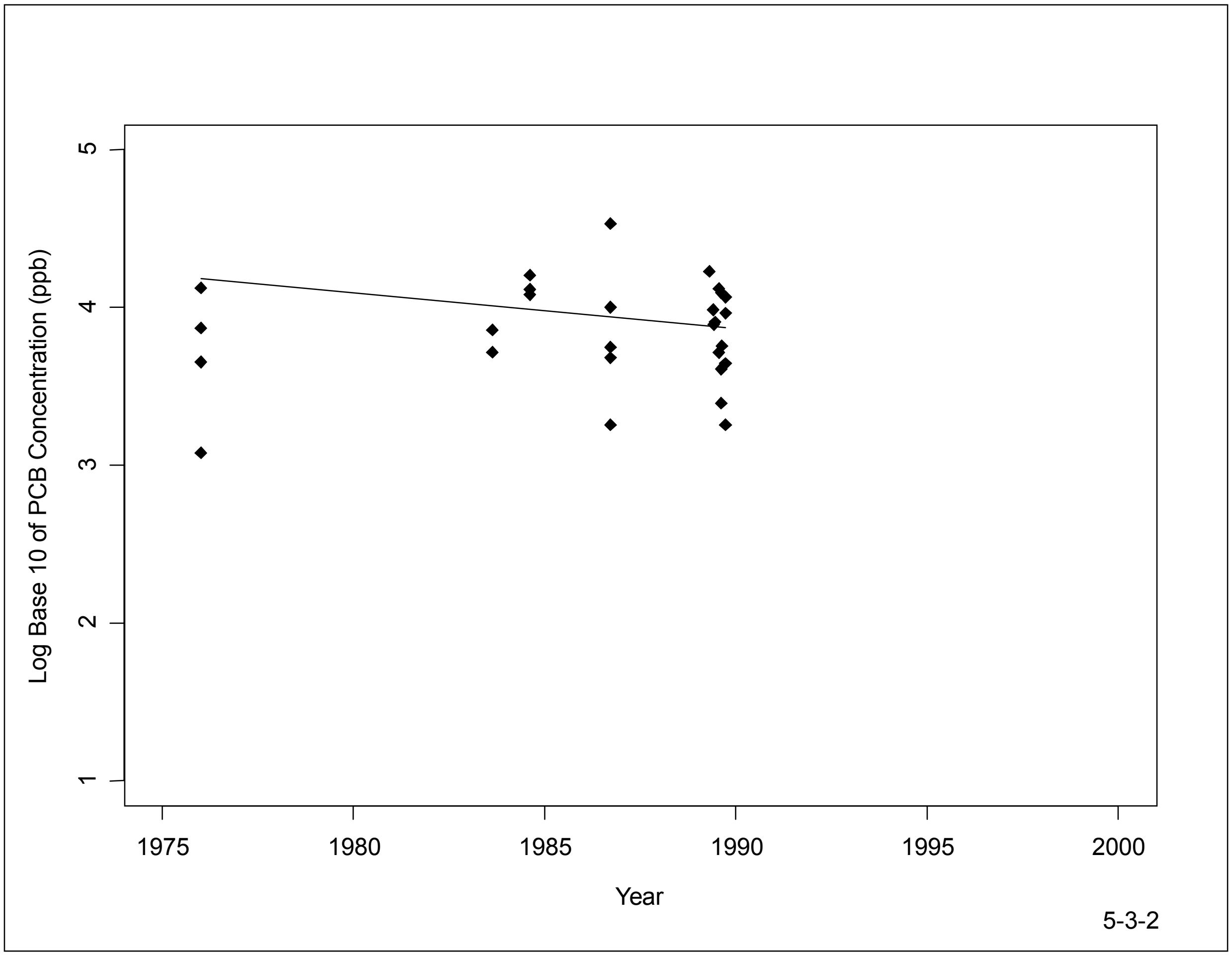


Figure A-105 Log_{10} PCB Concentration (ppb) in Green Bay Zone 2 (2A and 2B) Carp, Skin-on Fillet, versus Time

Values at or above the detection limit are depicted as ◆.

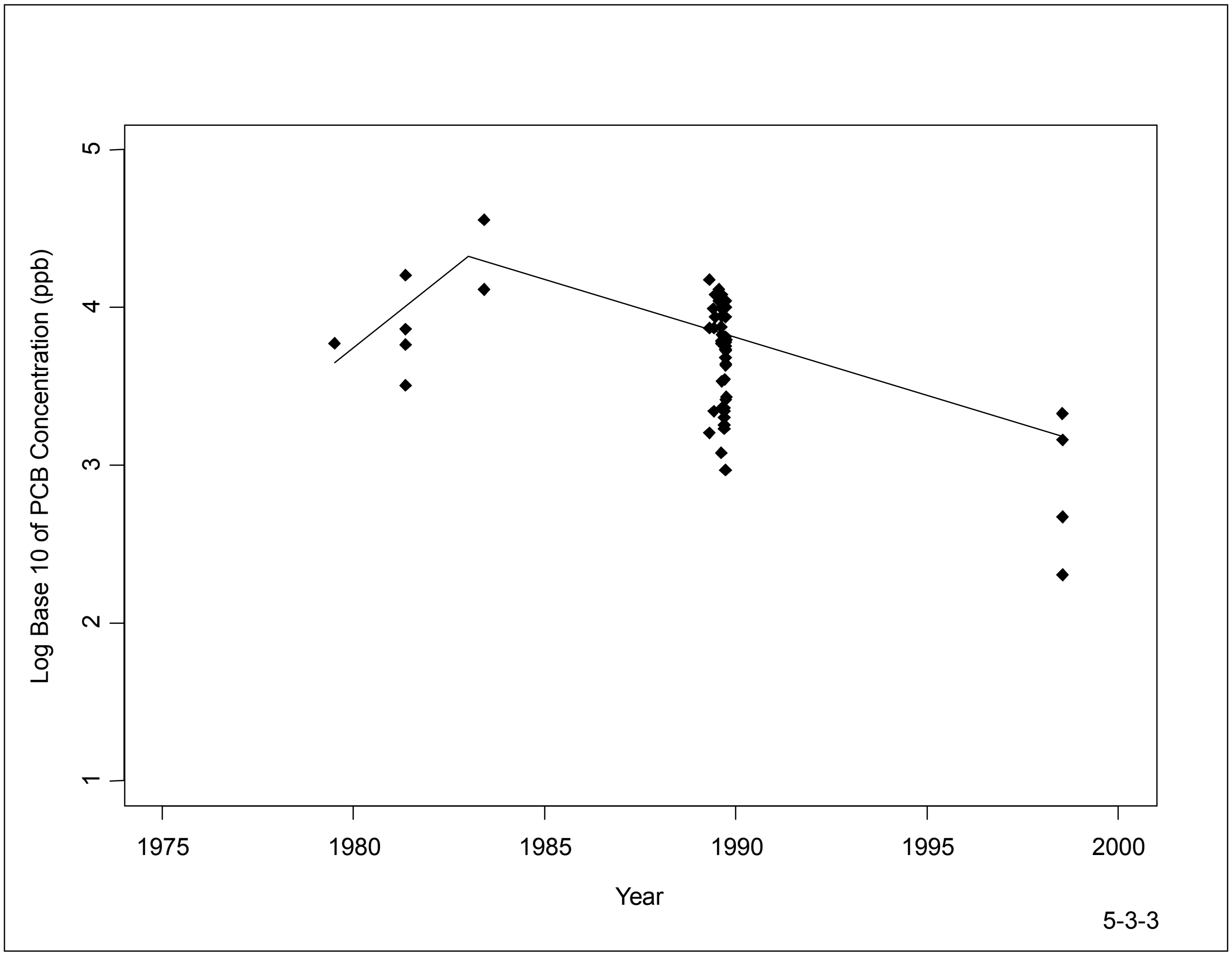


Figure A-106 Log_{10} PCB Concentration (ppb) in Green Bay Zone 2 (2A and 2B) Carp, Whole Body, versus Time

Values at or above the detection limit are depicted as ◆.

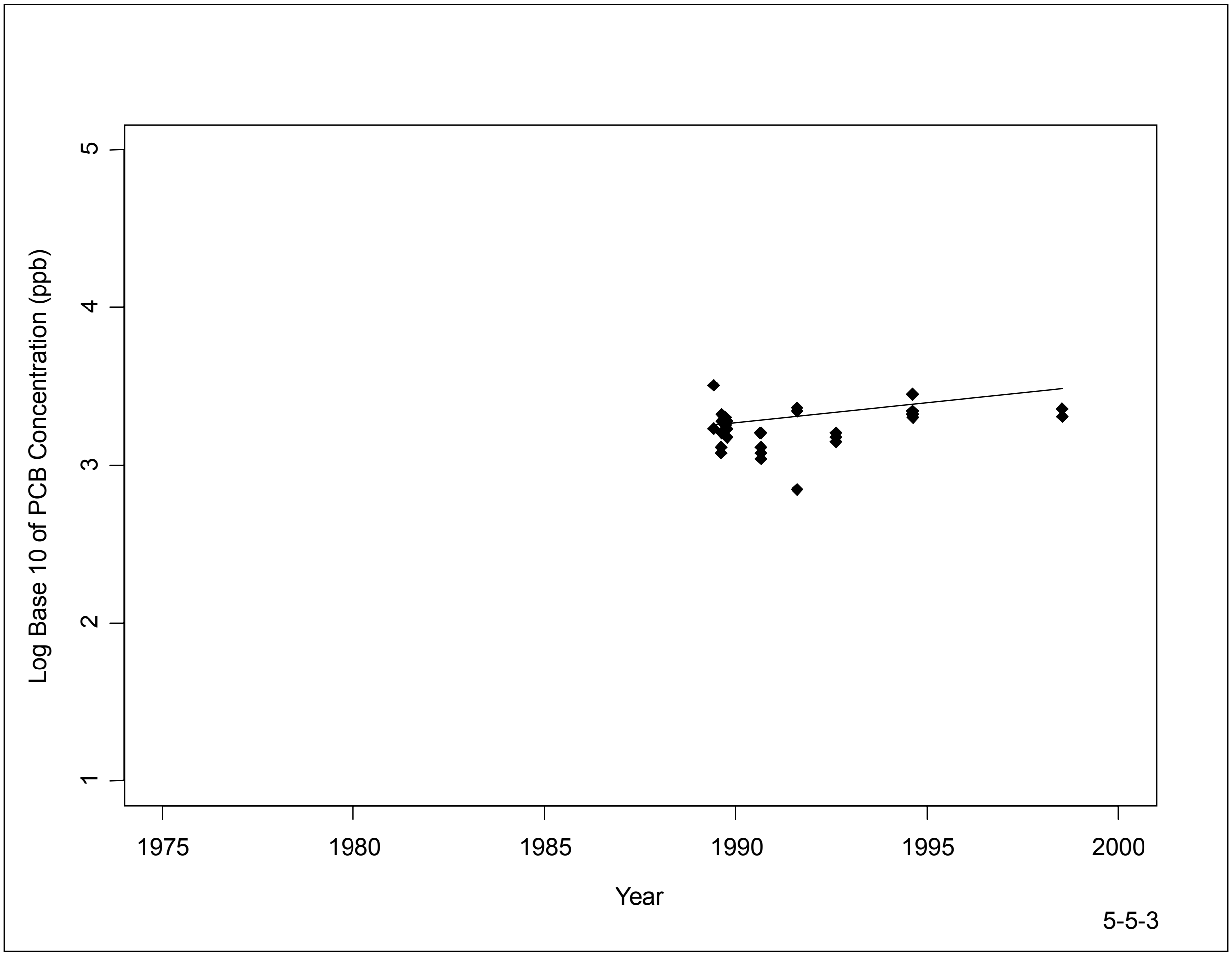


Figure A-107 Log_{10} PCB Concentration (ppb) in Green Bay Zone 2 (2A and 2B) Gizzard Shad, Whole Body, versus Time

Values at or above the detection limit are depicted as ◆.

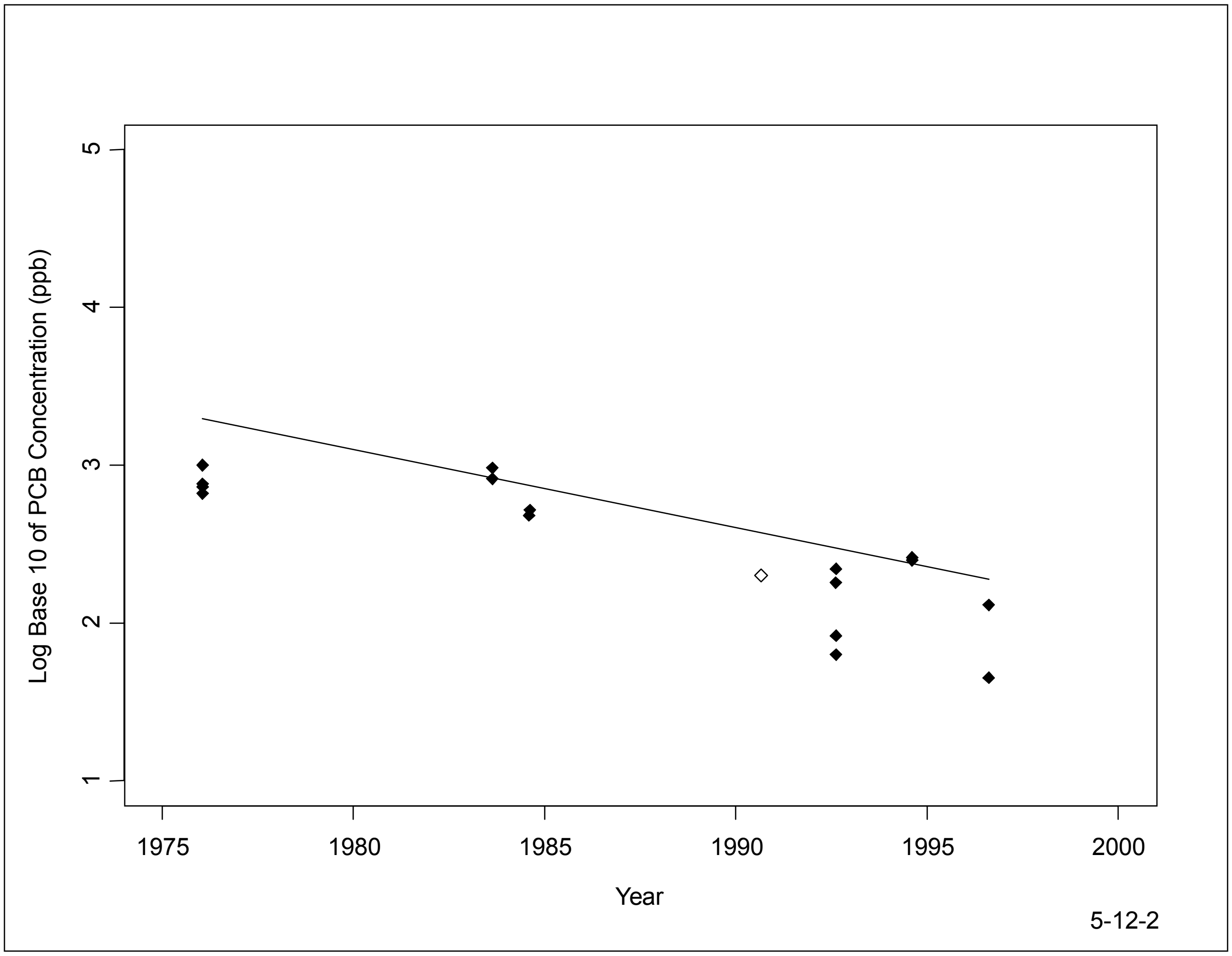


Figure A-108 Log$_{10}$ PCB Concentration (ppb) in Green Bay Zone 2 (2A and 2B) Yellow Perch, Skin-on Fillet, versus Time

Values at or above the detection limit are depicted as ◆. Any values below detection limit are depicted as ◇.

Table A-1 Details of Models Fitted to Time Trends in Sediment PCB Concentrations

Reach and Deposit Group	Depth Range (cm)	Coefficient of Log_{10}(PCB) Slope of Time Trend, Log Scale	WSEV Std. Err. of Slope	WSEV 95% Confidence Interval for Slope		WSEV *p*-value	*p* < 0.05	Core-averaged			Est. Ann. % Change in PCB Conc.	Est. Ann. % Change in PCB Conc.		WSEV				Fitted Model Form
				Lower Limit	Upper Limit			Sample Size	# Censored	% Censored		95% CI Lower-bound	95% CI Upper-bound	Grid Size Minimum (meters)	Grid Size Northing (meters)	Grid Size Easting (meters)	# Non-empty Grid Cells	
Little Lake Butte des Morts																		
AB	0–10	-0.0970	0.0348	-0.1708	-0.0233	0.0131	*	67	0	0	-20.0	-32.5	-5.2	110	156	110	16	quadratic
	10–30	-0.0213	0.0647	-0.1795	0.1370	0.7535		105	13	12	-4.8	-33.9	37.1	137	294	137	6	quadratic
	30–50	-0.0144	0.1113	-0.2593	0.2305	0.8995		54	28	52	-3.3	-45.0	70.0	103	153	103	11	quadratic
C	0–10	-0.0612	0.0342	-0.1563	0.0338	0.1481		13	0	0	-13.2	-30.2	8.1	101	158	101	4	quadratic
	10–30	0.0317	0.0770	-0.1820	0.2454	0.7018		15	5	33	7.6	-34.2	76.0	94	158	94	4	linear
POG	0–10	-0.0893	0.0567	-0.2467	0.0680	0.1900		13	0	0	-18.6	-43.3	16.9	363	363	367	4	quadratic
D	0–10	-0.0755	0.0317	-0.1430	-0.0080	0.0307	*	18	1	6	-16.0	-28.1	-1.8	34	111	34	15	quadratic
	10–30	0.3168	0.0454	0.2001	0.4335	0.0009	*	15	2	13	107.4	58.5	171.3	109	333	109	5	linear
F	0–10	-0.0373	0.0136	-0.0686	-0.0060	0.0252	*	29	1	3	-8.2	-14.6	-1.4	401	401	437	8	quadratic
	10–30	-0.0760	0.0749	-0.2341	0.0821	0.3246		28	9	32	-16.1	-41.7	20.8	172	191	172	17	quadratic
GH	0–10	-0.1244	0.0541	-0.2450	-0.0038	0.0443	*	15	0	0	-24.9	-43.1	-0.9	277	277	336	10	linear
Appleton																		
IMOR	0–10	0.0412	0.0255	-0.0295	0.1119	0.1810		18	1	6	9.9	-6.6	29.4	726	726	1,754	4	linear
N Pre-dredge	0–10	-0.0281	0.0065	-0.0489	-0.0072	0.0233	*	32	0	0	-6.3	-10.6	-1.7	43	43	197	3	quadratic
	10–30	0.0572	0.0440	-0.0338	0.1482	0.2061		27	1	4	14.1	-7.5	40.7	9	9	33	23	quadratic
	30–50	0.0846	0.0932	-0.1262	0.2954	0.3877		17	1	6	21.5	-25.2	97.4	17	17	68	9	quadratic
VCC	0–10	-0.0582	0.0275	-0.1287	0.0124	0.0878		41	4	10	-12.5	-25.7	2.9	1,116	1,286	1,116	5	quadratic
	10–30	-0.1537	0.0164	-0.1899	-0.1176	0.0000	*	34	21	62	-29.8	-35.4	-23.7	393	456	393	11	quadratic
	30–50	-0.0060	0.0151	-0.0396	0.0276	0.6984		17	14	82	-1.4	-8.7	6.6	285	341	285	10	linear
Little Rapids																		
Upper EE	0–10	-0.0447	0.0435	-0.1655	0.0760	0.3618		31	0	0	-9.8	-31.7	19.1	721	798	721	4	quadratic
	10–30	-0.0944	0.0429	-0.1914	0.0027	0.0554		25	6	24	-19.5	-35.6	0.6	288	291	288	9	quadratic
	30–50	-0.0712	0.0536	-0.1925	0.0502	0.2173		13	6	46	-15.1	-35.8	12.2	199	199	206	9	linear
Lower EE	0–10	-0.0682	0.0193	-0.1297	-0.0067	0.0387	*	30	2	7	-14.5	-25.8	-1.5	468	823	468	3	quadratic
	10–30	-0.0759	0.0390	-0.1585	0.0068	0.0695		33	16	48	-16.0	-30.6	1.6	104	183	104	16	quadratic
	30–50	0.0900	0.0330	0.0164	0.1635	0.0213	*	13	5	38	23.0	3.9	45.7	94	200	94	10	quadratic
FF	0–10	-0.0549	0.0557	-0.1735	0.0638	0.3400		32	4	13	-11.9	-32.9	15.8	110	151	110	15	quadratic
	10–30	-0.0962	0.0390	-0.1861	-0.0063	0.0389	*	31	12	39	-19.9	-34.9	-1.4	253	340	253	8	quadratic
GGHH	0–10	-0.0394	0.0231	-0.1036	0.0249	0.1643		49	0	0	-8.7	-21.2	5.9	392	732	392	4	quadratic
	10–30	-0.0182	0.0596	-0.1410	0.1047	0.7631		45	2	4	-4.1	-27.7	27.3	83	163	83	25	quadratic
	30–50	0.1762	0.1008	-0.0564	0.4087	0.1188		75	9	12	50.0	-12.2	156.3	191	384	191	8	quadratic
	50–100	0.1012	0.0700	-0.0417	0.2441	0.1586		54	12	22	26.2	-9.2	75.4	76	157	76	30	quadratic
	100+	0.0365	0.0249	-0.0155	0.0884	0.1587		36	16	44	8.8	-3.5	22.6	84	157	84	20	quadratic
De Pere																		
SMU Group 2025	0–10	-0.0528	0.0231	-0.1168	0.0112	0.0838		43	0	0	-11.4	-23.6	2.6	529	529	602	4	quadratic
	10–30	-0.0556	0.0750	-0.2285	0.1173	0.4796		31	5	16	-12.0	-40.9	31.0	353	353	402	8	quadratic
	30–50	-0.0580	0.0322	-0.1296	0.0137	0.1016		13	0	0	-12.5	-25.8	3.2	200	200	209	10	linear
	50–100	-0.0847	0.1058	-0.3025	0.1331	0.4306		30	9	30	-17.7	-50.2	35.9	118	118	132	25	quadratic
2649	0–10	-0.0608	0.0109	-0.0831	-0.0385	0.0000	*	66	1	2	-13.1	-17.4	-8.5	207	308	207	29	quadratic
	10–30	-0.2882	0.1440	-0.6140	0.0376	0.0764		48	5	10	-48.5	-75.7	9.0	466	694	466	9	quadratic
	50–100	0.1957	0.1419	-0.1982	0.5896	0.2399		46	8	17	56.9	-36.6	288.7	931	1,251	931	4	quadratic
	100+	0.0177	0.1548	-0.4122	0.4476	0.9146		45	10	22	4.2	-61.3	180.3	882	1,217	882	4	quadratic
5067	0–10	-0.0998	0.0345	-0.1751	-0.0245	0.0136	*	57	1	2	-20.5	-33.2	-5.5	168	258	168	12	quadratic
	10–30	0.0912	0.0649	-0.0470	0.2295	0.1800		51	1	2	23.4	-10.3	69.6	124	215	124	15	quadratic
	50–100	0.3677	0.0684	0.1918	0.5435	0.0030	*	48	0	0	133.2	55.5	249.5	248	430	248	5	quadratic
	100+	-0.1963	0.2223	-0.7402	0.3476	0.4112		50	7	14	-36.4	-81.8	122.6	174	390	174	6	quadratic
6891	0–10	-0.2208	0.0944	-0.5212	0.0796	0.1013		20	1	5	-39.9	-69.9	20.1	344	1,051	344	3	quadratic
	10–30	-0.1685	0.0765	-0.3415	0.0044	0.0550		18	2	11	-32.2	-54.4	1.0	138	420	138	9	quadratic
92115	0–10	0.0413	0.0426	-0.0502	0.1327	0.3493		27	0	0	10.0	-10.9	35.8	142	393	142	14	quadratic

Table A-1 Details of Models Fitted to Time Trends in Sediment PCB Concentrations

Reach and Deposit Group	Depth Range (cm)	R-squared			Sill Distance	Intercept Parameter Est.	WSEV Std. Err. of Intercept	Std. Err. of Intercept Based on Independence	Skewness of Untransformed PCB Conc.	Skewness of Log_{10}(PCB) Conc.	PCB Mass (kg)	Normal Scale (Std. Dev.) Est.
		Geographic Variables Only	Geographic + Time	Change Due to Time								
Little Lake Butte des Morts												
AB	0–10	0.47	0.55	0.08	25	4.4461	0.3237	0.2788	1.74	-1.13	71.7	0.465933
	10–30	0.17	0.17	0.00	25	4.0797	0.8357	0.6054	3.37	-0.09	217.7	1.02534
	30–50	0.36	0.37	0.01	0	10.4324	2.8100	2.1917	4.52	1.03	328.3	1.1568
C	0–10	0.27	0.47	0.21	25	5.2096	1.2084	1.0586	1.97	0.19	25.4	0.336235
	10–30	0.55	0.69	0.14	25	5.0070	1.4441	1.3930	2.80	0.76	14.6	0.897603
POG	0–10	0.61	0.71	0.10	75	4.4765	0.5067	0.4769	1.33	0.34	113.5	0.425786
D	0–10	0.67	0.78	0.10	0	3.8807	0.6868	0.3776	1.92	-1.18	32.1	0.2376
	10–30	0.19	0.80	0.61	0	2.2285	0.5288	0.5202	2.96	-0.25	55.5	0.397127
F	0–10	0.24	0.30	0.05	50	3.5528	0.3827	0.4099	2.40	-0.52	142.5	0.520421
	10–30	0.23	0.31	0.08	50	2.2040	1.3533	1.0844	5.15	0.97	180.1	0.789297
GH	0–10	0.02	0.61	0.59	0	3.1032	0.3153	0.3176	0.14	-1.27	15.7	0.439535
Appleton												
IMOR	0–10	0.09	0.41	0.32	0	3.1269	0.4735	0.4747	3.44	0.31	6.9	0.583018
N Pre-dredge	0–10	0.68	0.70	0.02	0	4.2292	0.4199	0.3549	1.14	-0.52	6.9	0.326511
	10–30	0.43	0.48	0.05	50	3.7450	0.6539	0.6366	2.66	-0.98	11.5	0.615759
	30–50	0.49	0.56	0.07	10	4.4070	1.5119	1.2267	1.00	-2.56	4.9	0.570745
VCC	0–10	0.14	0.31	0.17	0	3.2202	0.3490	0.2537	2.55	0.34	5.2	0.524406
	10–30	0.12	0.56	0.44	0	4.1303	0.6783	0.7806	4.76	0.99	2.9	0.734058
	30–50	0.46	0.52	0.06	0	4.4304	0.5727	0.5713	1.05	0.06	0.9	0.11942
Little Rapids												
Upper EE	0–10	0.09	0.16	0.06	0	3.2722	0.7469	0.4948	3.43	0.21	85.0	0.58418
	10–30	0.17	0.38	0.22	0	2.5703	1.1521	0.8651	4.06	0.51	46.4	0.822143
	30–50	0.03	0.24	0.22	200	4.7214	1.3448	1.7186	3.44	0.77	4.3	0.678349
Lower EE	0–10	0.36	0.52	0.16	0	2.9308	0.2663	0.3268	3.68	0.37	25.4	0.486326
	10–30	0.17	0.40	0.23	0	2.8576	0.7657	0.9180	4.97	0.80	13.2	0.96465
	30–50	0.47	0.56	0.09	0	5.0328	0.9549	1.1745	1.76	0.26	4.6	0.357574
FF	0–10	0.15	0.20	0.05	0	3.7208	0.3852	0.4231	1.52	-0.24	36.7	0.83476
	10–30	0.07	0.25	0.18	0	2.1741	1.3609	1.2502	4.02	0.77	14.6	1.12086
GGHH	0–10	0.29	0.33	0.04	0	2.8846	0.7084	0.2893	1.47	-0.38	131.6	0.50908
	10–30	0.12	0.12	0.00	0	3.3231	0.8171	0.9167	1.33	-0.22	289.6	0.91031
	30–50	0.10	0.19	0.09	0	0.0821	2.8431	1.3045	1.33	-0.74	271.4	0.964739
	50–100	0.16	0.23	0.07	0	1.4499	1.9204	1.2885	4.82	0.74	195.7	0.8449
	100+	0.62	0.72	0.09	0	2.3137	0.5420	0.4451	2.86	0.53	21.4	0.295787
De Pere												
SMU Group 2025	0–10	0.38	0.46	0.07	0	3.6631	0.4655	0.4255	1.11	-1.18	225.6	0.350891
	10–30	0.35	0.37	0.02	100	6.3342	3.4691	2.2114	2.58	-0.59	813.6	0.855251
	30–50	0.66	0.76	0.10	150	5.5480	0.9776	1.1642	1.76	-0.76	950.3	0.430459
	50–100	0.35	0.36	0.01	50	4.0031	1.1675	1.2707	1.76	-0.18	1569.3	1.13947
2649	0–10	0.06	0.17	0.11	0	3.2501	0.2065	0.4161	0.89	-1.01	356.8	0.434768
	10–30	0.31	0.43	0.12	0	10.6240	3.2452	1.9813	0.80	-0.90	1556.5	0.816451
	50–100	0.13	0.13	0.00	100	3.6653	2.3249	1.1267	1.32	-0.47	3135.5	1.07814
	100+	0.20	0.22	0.02	0	1.2186	1.9141	1.2818	5.18	0.10	1717.6	1.05288
5067	0–10	0.13	0.27	0.14	0	7.6178	1.2394	1.1333	7.47	2.40	92.4	0.186359
	10–30	0.42	0.47	0.05	0	2.4000	1.4903	1.2775	4.35	-1.43	353.7	0.472972
	50–100	0.42	0.43	0.01	0	6.5635	2.1819	1.5704	2.61	-0.36	2764.9	0.778337
	100+	0.26	0.29	0.02	0	4.9240	2.3655	1.8648	5.97	-0.22	4426.0	1.13022
6891	0–10	0.42	0.46	0.04	100	10.2963	4.2471	5.8601	3.04	-1.34	72.1	0.422776
	10–30	0.63	0.74	0.11	100	6.4202	1.3240	1.3665	2.29	-1.22	246.7	0.447153
92115	0–10	0.52	0.52	0.01	0	0.8839	0.9748	1.1169	3.37	-0.12	37.1	0.359379

Table A-1 Details of Models Fitted to Time Trends in Sediment PCB Concentrations

Reach and Deposit Group	Depth Range (cm)	Number of Samples					Mean of Within-core-avg. Sample Variances	Variance of Singleton Samples in Core-avg. Data Set	Parameter Estimates and Standard Errors					
		Single Used in Core-averaged Analyses	Core-avg. Used in Core-avg. Analyses	Total Original Single	Total in Core-avg. Analyses (mixed, single, & core-avg.)	Avg. that Ended up in a Core-avg. Sample			Intercept Estimate	WSEV Std. Err. Intercept	Independence Std. Err. Intercept	Time Estimate	WSEV Std. Err. Time	Independence Std. Err. Time
Little Lake Butte des Morts														
AB	0–10	47	20	94	67	2.4	0.0632	0.4984	4.4461	0.3237	0.2788	-0.0970	0.0348	0.0279
	10–30	87	18	134	105	2.6	0.4082	1.0782	4.0797	0.8357	0.6054	-0.0213	0.0647	0.0501
	30–50	52	2	56	54	2.0	1.4924	0.7630	10.4324	2.8100	2.1917	-0.0144	0.1113	0.0831
C	0–10	2	11	25	13	2.1	0.1032	0.0949	5.2096	1.2084	1.0586	-0.0612	0.0342	0.0272
	10–30	12	3	18	15	2.0	1.1476	0.9889	5.0070	1.4441	1.3930	0.0317	0.0770	0.0709
POG	0–10	12	1	14	13	2.0	0.0311	0.6958	4.4765	0.5067	0.4769	-0.0893	0.0567	0.0417
D	0–10	13	5	23	18	2.0	0.5476	0.2467	3.8807	0.6868	0.3776	-0.0755	0.0317	0.0267
	10–30	13	2	17	15	2.0	0.3832	0.6341	2.2285	0.5288	0.5202	0.3168	0.0454	0.0526
F	0–10	12	17	49	29	2.2	0.1923	0.3178	3.5528	0.3827	0.4099	-0.0373	0.0136	0.0266
	10–30	22	6	34	28	2.0	0.4242	0.5408	2.2040	1.3533	1.0844	-0.0760	0.0749	0.0674
GH	0–10	9	6	21	15	2.0	0.0492	0.2345	3.1032	0.3153	0.3176	-0.1244	0.0541	0.0389
Appleton														
IMOR	0–10	12	6	24	18	2.0	0.0184	0.3153	3.1269	0.4735	0.4747	0.0412	0.0255	0.0458
N Pre-dredge	0–10	26	6	42	32	2.7	0.1282	0.4005	4.2292	0.4199	0.3549	-0.0281	0.0065	0.0185
	10–30	23	4	32	27	2.3	0.0186	0.7645	3.7450	0.6539	0.6366	0.0572	0.0440	0.0334
	30–50	16	1	18	17	2.0	0.0006	0.7463	4.4070	1.5119	1.2267	0.0846	0.0932	0.0504
VCC	0–10	27	14	57	41	2.1	0.3692	0.3242	3.2202	0.3490	0.2537	-0.0582	0.0275	0.0209
	10–30	31	3	37	34	2.0	0.1965	0.5572	4.1303	0.6783	0.7806	-0.1537	0.0164	0.0420
	30–50	15	2	19	17	2.0	0.0041	0.0638	4.4304	0.5727	0.5713	-0.0060	0.0151	0.0135
Little Rapids														
Upper EE	0–10	13	18	51	31	2.1	0.2516	0.2396	3.2722	0.7469	0.4948	-0.0447	0.0435	0.0291
	10–30	15	10	36	25	2.1	0.2717	0.3608	2.5703	1.1521	0.8651	-0.0944	0.0429	0.0460
	30–50	13	0	13	13	0.0		0.2834	4.7214	1.3448	1.7186	-0.0712	0.0536	0.0659
Lower EE	0–10	15	15	49	30	2.3	0.2781	0.5693	2.9308	0.2663	0.3268	-0.0682	0.0193	0.0232
	10–30	23	10	45	33	2.2	0.4506	0.6548	2.8576	0.7657	0.9180	-0.0759	0.0390	0.0495
	30–50	11	2	15	13	2.0	0.1221	0.3792	5.0328	0.9549	1.1745	0.0900	0.0330	0.0364
FF	0–10	18	14	50	32	2.3	0.3690	0.6980	3.7208	0.3852	0.4231	-0.0549	0.0557	0.0401
	10–30	24	7	39	31	2.1	0.3304	0.9190	2.1741	1.3609	1.2502	-0.0962	0.0390	0.0606
GGHH	0–10	24	25	80	49	2.2	0.1169	0.5300	2.8846	0.7084	0.2893	-0.0394	0.0231	0.0235
	10–30	27	18	71	45	2.4	0.3074	0.9414	3.3231	0.8171	0.9167	-0.0182	0.0596	0.0665
	30–50	73	2	78	75	2.5	0.0008	0.9359	0.0821	2.8431	1.3045	0.1762	0.1008	0.0560
	50–100	51	3	57	54	2.0	0.8083	0.5186	1.4499	1.9204	1.2885	0.1012	0.0700	0.0572
	100+	33	3	39	36	2.0	0.0367	0.1512	2.3137	0.5420	0.4451	0.0365	0.0249	0.0259
De Pere														
SMU Group 2025	0–10	32	11	57	43	2.3	0.0271	0.2709	3.6631	0.4655	0.4255	-0.0528	0.0231	0.0217
	10–30	16	15	54	31	2.5	0.0886	0.9893	6.3342	3.4691	2.2114	-0.0556	0.0750	0.0726
	30–50	9	4	23	13	3.5	0.0925	0.6680	5.5480	0.9776	1.1642	-0.0580	0.0322	0.0335
	50–100	28	2	34	30	3.0	0.1551	1.1742	4.0031	1.1675	1.2707	-0.0847	0.1058	0.1163
2649	0–10	54	12	80	66	2.2	0.0153	0.2503	3.2501	0.2065	0.4161	-0.0608	0.0109	0.0211
	10–30	25	23	73	48	2.1	0.1028	1.0853	10.6240	3.2452	1.9813	-0.2882	0.1440	0.0956
	50–100	44	2	51	46	3.5	0.0433	1.1505	3.6653	2.3249	1.1267	0.1957	0.1419	0.3961
	100+	31	14	63	45	2.3	0.5315	1.0783	1.2186	1.9141	1.2818	0.0177	0.1548	0.1046
5067	0–10	53	5	63	58	2.0	0.0736	0.0919	7.6178	1.2394	1.1333	-0.0998	0.0345	0.0307
	10–30	45	6	57	51	2.0	0.2006	0.4654	2.4000	1.4903	1.2775	0.0912	0.0649	0.0465
	50–100	47	1	49	48	2.0	0.1247	1.0992	6.5635	2.1819	1.5704	0.3677	0.0684	0.4775
	100+	13	37	176	50	4.4	0.6534	1.1959	4.9240	2.3655	1.8648	-0.1963	0.2223	0.1720
6891	0–10	16	4	24	20	2.0	0.1259	0.3116	10.2963	4.2471	5.8601	-0.2208	0.0944	0.1858
	10–30	11	7	25	18	2.0	0.0973	1.0964	6.4202	1.3240	1.3665	-0.1685	0.0765	0.0689
92115	0–10	21	6	33	27	2.0	0.0284	0.3161	0.8839	0.9748	1.1169	0.0413	0.0426	0.0574

Table A-1 Details of Models Fitted to Time Trends in Sediment PCB Concentrations

Reach and Deposit Group	Depth Range (cm)	Parameter Estimates and Standard Errors														
		Depth Estimate	WSEV Std. Err. Depth	Independence Std. Err. Depth	Northing Estimate	WSEV Std. Err. Northing	Independence Std. Err. Northing	Easting Estimate	WSEV Std. Err. Easting	Independence Std. Err. Easting	Northing-squared Estimate	WSEV Std. Err. Northing-squared	Independence Std. Err. Northing-squared	Easting-squared Estimate	WSEV Std. Err. Easting-squared	Independence Std. Err. Easting-squared
Little Lake Butte des Morts																
AB	0–10	0.0127	0.0633	0.0409	-1.0975	0.4992	0.4595	-2.0095	0.9635	0.7386	-2.4494	2.1658	1.8061	-5.3925	3.5417	3.2507
	10–30	-0.0338	0.0211	0.0250	-2.9471	1.5897	0.8840	-3.2882	2.0674	1.6795	2.3822	4.8087	2.7630	-12.7711	21.9423	13.4218
	30–50	-0.2185	0.0674	0.0545	0.7990	1.5402	1.6161	3.0474	2.0452	3.0465	-6.3672	11.0640	8.3931	-20.7443	12.1952	18.3243
C	0–10	-0.1412	0.1936	0.1599	1.6869	1.2250	1.4496	-2.6324	2.2086	1.5222	-14.4039	13.6209	11.8569	-28.8072	27.5631	31.7216
	10–30	-0.1328	0.0599	0.0655	3.9183	3.9217	2.8835	-12.5252	4.3174	4.5834						
POG	0–10	-0.0434	0.1158	0.0909	2.9932	0.3684	1.0207	-3.4068	0.7446	1.1297	-1.3834	2.5588	3.4422	-6.7243	3.8221	3.0709
D	0–10	0.0016	0.0822	0.0475	-0.5055	0.9173	0.5734	0.7551	2.5966	1.9171	-3.4413	1.9010	1.1846	1.4114	15.7548	12.9109
	10–30	-0.0357	0.0227	0.0221	-0.0334	0.7334	0.6602	4.8278	2.6055	2.5146						
F	0–10	-0.0345	0.0831	0.0630	-0.0750	0.2812	0.2673	-0.5557	0.2385	0.3464	-0.2749	1.5113	0.8837	-1.0831	0.5661	0.8540
	10–30	0.0178	0.0593	0.0488	0.1980	0.3974	0.3964	-0.9190	0.7543	0.7001	-2.0705	1.5904	1.2523	-1.4047	2.0686	1.7550
GH	0–10	-0.0264	0.0497	0.0587	-0.0852	0.3564	0.3934	-0.1385	0.3700	0.3075						
Appleton																
IMOR	0–10	-0.0552	0.0659	0.0681	0.2432	1.0106	0.5859	-0.0513	0.3799	0.2284						
N Pre-dredge	0–10	0.0783	0.0842	0.0505	-13.0001	8.6265	5.7496	-1.0311	2.4778	1.5680	-576.7283	75.1630	150.1163	-28.0271	15.7291	9.8662
	10–30	-0.0098	0.0365	0.0349	38.4878	10.3435	10.4052	-10.3445	2.9457	2.3469	-633.9268	204.1228	287.0263	49.1326	30.5758	22.6896
	30–50	-0.0146	0.0374	0.0357	33.2158	21.9749	14.3060	-12.3383	7.8129	3.8360	-307.2611	243.4987	301.2426	18.4344	30.9885	18.8647
VCC	0–10	-0.0908	0.0616	0.0388	0.1753	0.2540	0.2933	-0.2587	0.3273	0.3816	-0.0144	0.1154	0.1920	-0.1078	0.1094	0.2578
	10–30	-0.0882	0.0265	0.0352	-1.0040	1.0156	1.2013	0.9931	1.0793	1.4751	-1.3033	0.7249	1.0073	0.9072	1.0233	1.3690
	30–50	-0.0829	0.0152	0.0161	0.6032	0.1695	0.2156	-0.9142	0.2435	0.2556						
Little Rapids																
Upper EE	0–10	-0.0258	0.1220	0.0572	0.3850	0.6189	0.4675	0.0762	0.5422	0.4773	-0.2680	0.0899	0.6390	-0.3970	0.3091	0.6846
	10–30	-0.0229	0.0489	0.0365	0.4099	0.6506	0.7961	-0.2514	0.5624	0.7467	-0.0198	0.7059	1.2080	1.7720	1.1293	1.1117
	30–50	-0.0745	0.0307	0.0427	-0.5189	0.9981	1.1966	0.6193	0.9395	1.2762						
Lower EE	0–10	0.0251	0.0532	0.0433	1.1109	0.2728	0.2937	-2.6603	0.4376	0.7436	0.3520	0.3646	0.4311	-1.7459	0.8458	1.4421
	10–30	-0.0552	0.0270	0.0426	0.8874	0.8233	0.6482	-1.8815	2.0380	1.4465	0.1246	1.0613	0.9360	2.6939	4.4128	3.0731
	30–50	-0.0734	0.0307	0.0313	2.4176	0.4448	0.7119	-5.1517	1.3718	1.7193	-4.0206	1.2678	1.5058	-0.6923	4.3874	4.0097
FF	0–10	-0.0864	0.0634	0.0601	0.0232	0.7702	0.9493	-0.2189	1.4350	1.5524	0.8106	1.3806	1.4371	-3.9307	3.0655	3.1191
	10–30	0.0048	0.0663	0.0572	0.5910	1.5431	1.4340	-1.2403	2.3865	2.3065	2.1896	1.1179	2.1191	-6.1569	3.0884	4.5264
GGHH	0–10	0.1141	0.0748	0.0403	-0.2046	0.3480	0.3619	1.0979	1.0084	0.7402	-0.2429	1.5891	0.8907	5.0351	2.0031	2.5160
	10–30	0.0025	0.0346	0.0387	0.7336	0.5032	0.6972	-0.7336	1.3691	1.5452	-2.6015	1.4440	1.5777	9.1624	5.6538	5.4674
	30–50	0.0818	0.0734	0.0340	0.8932	1.6858	0.7687	-3.0753	2.3031	1.3481	-2.1752	2.4315	1.1141	1.4384	7.1742	4.0281
	50–100	0.0005	0.0205	0.0153	1.7920	0.7295	0.7362	-2.4967	1.2953	1.3551	-0.1966	1.2491	1.0857	1.6211	4.4325	4.0758
	100+	-0.0063	0.0032	0.0025	0.6162	0.4661	0.4185	-0.2224	1.0309	0.8222	0.5376	0.6100	0.5136	-0.2400	2.0933	1.7928
De Pere																
SMU Group 2025	0–10	-0.0218	0.0247	0.0673	0.2322	0.1954	0.2727	-0.8168	0.2670	0.1952	1.4369	0.6614	0.6721	-0.9296	0.9774	0.5463
	10–30	-0.1353	0.1674	0.1039	0.1168	0.5505	0.7072	-1.8758	0.6483	0.6353	0.7551	2.1870	2.0435	-1.1481	2.0442	1.5719
	30–50	-0.0396	0.0231	0.0301	2.3369	0.3537	0.4625	-1.8970	0.3919	0.4047						
	50–100	0.0016	0.0198	0.0209	-0.7090	0.9904	0.9190	-1.3836	0.9355	0.8003	-4.3505	3.6551	3.2428	-2.3768	2.3783	2.3032
2649	0–10	0.0528	0.0366	0.0725	0.3481	0.1918	0.1900	-0.4861	0.2934	0.2805	-0.1224	0.1295	0.1457	0.1794	0.4357	0.3553
	10–30	-0.2963	0.1275	0.0753	1.7553	0.4476	0.4437	-2.6073	0.7299	0.6432	-0.8618	0.3015	0.3349	2.2571	0.6432	0.8075
	50–100	-0.0329	0.0535	0.0438	0.8507	1.0310	0.6052	-0.6367	1.4451	0.8173	0.8211	0.6382	0.5198	-0.4678	1.6001	1.1621
	100+	0.0044	0.0056	0.0046	0.9871	1.0713	0.6428	-0.3836	1.2383	0.8749	0.4507	0.4532	0.5315	0.5980	2.1577	1.3592
5067	0–10	-0.6896	0.2021	0.1789	0.1660	0.2830	0.1969	-0.6811	0.5147	0.3164	-0.2127	0.4270	0.3747	-0.9698	1.0473	0.8755
	10–30	0.0373	0.0522	0.0492	-0.1798	0.6369	0.5413	0.5682	1.3988	0.8701	2.2532	1.0289	1.0194	-13.8586	3.7778	3.1291
	50–100	-0.0716	0.0217	0.0660	4.1177	2.0645	1.1132	-4.8032	3.0530	1.6681	-3.1805	1.2464	1.9784	-10.7462	5.2078	5.3972
	100+	0.0019	0.0061	0.0033	5.7110	2.8462	1.8915	-6.2886	6.3528	3.3150	-7.7006	4.3032	3.9687	-4.4052	19.8825	16.6514
6891	0–10	-1.0620	0.7286	0.9291	0.2115	0.2892	0.3912	-1.3241	1.2294	1.5454	0.2611	0.2030	0.4168	-8.6671	1.3018	3.2661
	10–30	-0.0924	0.0494	0.0545	0.5512	0.5967	0.5714	-4.3170	2.3513	2.4161	0.9099	0.5955	0.5884	-17.2007	7.7080	6.1620
92115	0–10	0.2969	0.1598	0.1651	0.5306	0.4004	0.2988	-0.2891	1.1053	0.9145	0.8018	0.2686	0.2065	-1.6445	1.8395	1.6840

Table A-2 Green Bay Zones 1 and 2 Outliers

	Database ID	Reach	Fish Type	Sample Type	Total PCBs
Fish Data: Comparison of Green Bay Zones 1 and 2	WDF209006BC1	Green Bay Zone 2	alewife	whole body	19,000

Reason:

Large outlier. Other PCB values range from 990 to 4,500.

Table A-3 Detailed Data for All Fish Results

Reach	Model	Species	Sample Type	Year of Break-point	Number of Samples	Number of Samples Below Detection Limit	Standard Deviation	Chi-squared	Intercept			Final			Early		
									Intercept	Std. Err.	*p*-value	Slope	Std. Err.	*p*-value	Slope Difference	Std. Err.	*p*-value
Little Lake Butte des Morts	No Break-point	carp	skin-on fillet		55		49.63		3.3515	0.1131		-0.0456	0.0095	0.0000			
			whole body		40	1	36.67		3.6775	0.1089		-0.0750	0.0106	0.0000			
		northern pike	skin-on fillet		19	1	12.83		2.6670	0.1303	0.0000	-0.0547	0.0115	0.0003			
		walleye	skin-on fillet		63	8	42.31		2.5700	0.0737		-0.0465	0.0066	0.0000			
			whole body		18	3	26.16		2.6490	0.4089	0.0000	-0.0026	0.0429	0.9532			
		yellow perch	skin-on fillet		34	10	27.99		2.1767	0.0925		-0.0262	0.0097	0.0112			
	Best Fitting	carp	skin-on fillet	1979	55		42.91	6.72	3.3574	0.1064		-0.0276	0.0112	0.0177	-0.2280	0.0853	0.0102
			whole body	1987	40	1	29.39	7.28	3.3104	0.1645		0.0031	0.0295	0.9172	-0.1647	0.0588	0.0084
		northern pike	skin-on fillet		19	1	12.83		2.6670	0.1303	0.0000	-0.0547	0.0115	0.0003			
		walleye	skin-on fillet	1990	63	8	35.98	6.33	2.2105	0.1605		0.0147	0.0249	0.5576	-0.0945	0.0373	0.0140
			whole body	1987	18	3	16.69	9.48	2.1870	0.3811	0.0001	0.0845	0.0454	0.0874	-0.2608	0.0802	0.0069
		yellow perch	skin-on fillet	1981	34	10	17.83	10.16	2.3384	0.0908		0.0031	0.0125	0.8025	-0.2467	0.0771	0.0034
Appleton to Little Rapids	No Break-point	walleye	skin-on fillet		30		-7.15		3.0085	0.1256		-0.0456	0.0138	0.0028			
	Best Fitting	walleye	skin-on fillet		30		-7.15		3.0085	0.1256		-0.0456	0.0138	0.0028			
De Pere to Green Bay	No Break-point	carp	whole body		90		58.07		4.0144	0.0542		-0.0341	0.0055	0.0000			
		gizzard shad	whole body		19		-42.45		3.4553	0.0325		-0.0226	0.0045	0.0002			
		northern pike	skin-on fillet		40	1	-11.40		3.1688	0.0998		-0.0455	0.0073	0.0000			
		walleye	skin-on fillet		120	1	-41.16		3.1963	0.0435		-0.0324	0.0036	0.0000			
			whole body		58		-12.22		3.9812	0.0541		-0.0367	0.0054	0.0000			
		white bass	skin-on fillet		58		-41.00		3.6259	0.0678		-0.0210	0.0065	0.0020			
		white sucker	skin-on fillet		44		-3.92		3.1349	0.0762		-0.0357	0.0056	0.0000			
	Best Fitting	carp	whole body	1995	90		48.59	9.48	2.9712	0.3339	0.0000	0.0855	0.0382	0.0277	-0.1406	0.0445	0.0022
		gizzard shad	whole body		19		-42.45		3.4553	0.0325		-0.0226	0.0045	0.0002			
		northern pike	skin-on fillet		40	1	-11.40		3.1688	0.0998		-0.0455	0.0073	0.0000			
		walleye	skin-on fillet		120	1	-41.16		3.1963	0.0435		-0.0324	0.0036	0.0000			
			whole body		58		-12.22		3.9812	0.0541		-0.0367	0.0054	0.0000			
		white bass	skin-on fillet		58		-41.00		3.6259	0.0678		-0.0210	0.0065	0.0020			
		white sucker	skin-on fillet		44		-3.92		3.1349	0.0762		-0.0357	0.0056	0.0000			
Green Bay Zone 2 (2A and 2B)	No Break-point	alewife	whole body		44		-30.42		3.4844	0.0544		-0.0176	0.0087	0.0497			
		carp	skin-on fillet		28		-4.77		3.8869	0.0803		-0.0226	0.0154	0.1557			
			whole body		57		-11.66		3.7679	0.0530		-0.0414	0.0090	0.0000			
		gizzard shad	whole body		32		-51.90		3.2444	0.0535		0.0249	0.0095	0.0144			
		yellow perch	skin-on fillet		19	3	-8.96		2.6539	0.4357	0.0000	-0.0494	0.0143	0.0038			
	Best Fitting	alewife	whole body		44		-30.42		3.4844	0.0544		-0.0176	0.0087	0.0497			
		carp	skin-on fillet		28		-4.77		3.8869	0.0803		-0.0226	0.0154	0.1557			
			whole body	1983	57		-29.32	17.66	3.8825	0.0519		-0.0733	0.0104	0.0000	0.2664	0.0585	0.0000
		gizzard shad	whole body		32		-51.90		3.2444	0.0535		0.0249	0.0095	0.0144			
		yellow perch	skin-on fillet		19	3	-8.96		2.6539	0.4357	0.0000	-0.0494	0.0143	0.0038			

Note:

In the fitted models, amplitude and month of peak can be ignored if $\log_{10}$ PCB concentration estimates are needed for July 1 of any year. For other times of year, let M be the $\log_{10}$ of the estimated concentration on July 1, A = amplitude, t_{max} = ("*month of peak*" − 1)/12, and t = the specified time of year as a value between zero (1 January) and 1.0 (31 December). Define $Q(t) = -A \cdot \cos[2\pi(0.5 - t_{max})] + A \cdot \cos[2\pi(t - t_{max})]$. Then the estimated mean concentration (ppb) at time-of-year t is $M \cdot 10^{Q(t)}$.

Table A-3 Detailed Data for All Fish Results

Reach	Model	Species	Sample Type	Year of Break-point	Fat			Month Peak	Amplitude		Covariate Intercept Time	Mean Squared Error	Percent Change per Year	T-squared		
					Log_{10}	Std. Err.	*p*-value		Amplitude	*p*-value				T-squared	Std. Err.	*p*-value
Little Lake Butte des Morts	No Break-point	carp	skin-on fillet		0.8927	0.1611	0.0000	1.328	0.5316	0.2260	0.0006	0.1444	-9.9650	0.00231	0.00190	0.2292
			whole body		0.8753	0.3590	0.0200	6.356	0.6174	0.0965	-0.0004	0.1374	-15.8538	0.00360	0.00229	0.1249
		northern pike	skin-on fillet		0.4469	0.2976	0.1554	1.311	0.6671	0.1594	0.0005	0.1034	-11.8315	-0.00334	0.00242	0.1904
		walleye	skin-on fillet		0.3898	0.1444	0.0091	1.558	0.1861	0.6458	0.0001	0.0934	-10.1572	0.00285	0.00123	0.0241
			whole body		0.9062	0.4038	0.0429	12.515	0.9205	0.4523	-0.0156	0.2303	-0.5888	0.00789	0.00327	0.0329
		yellow perch	skin-on fillet		0.3972	0.2323	0.0980	1.338	0.3079	0.1117	0.0001	0.0955	-5.8564	0.00609	0.00210	0.0071
	Best Fitting	carp	skin-on fillet	1979	0.8675	0.1519	0.0000	12.904	0.3939	0.0078	0.0006	0.1277	-6.1477	-0.00137	0.00236	0.5645
			whole body	1987	0.8626	0.3293	0.0131	7.013	0.8307	0.0025	-0.0039	0.1156	0.7139	-0.01442	0.00670	0.0388
		northern pike	skin-on fillet		0.4469	0.2976	0.1554	1.311	0.6671	0.1594	0.0005	0.1034	-11.8315	-0.00334	0.00242	0.1904
		walleye	skin-on fillet	1990	0.5012	0.1455	0.0011	11.638	0.2005	0.0273	-0.0034	0.0857	3.4395	-0.00949	0.00939	0.3167
			whole body	1987	0.9858	0.3619	0.0185	11.562	0.4627	0.0040	-0.0157	0.1410	21.4715	-0.02024	0.01008	0.0698
		yellow perch	skin-on fillet	1981	0.4946	0.2067	0.0236	7.033	0.2185	0.0007	0.0005	0.0719	0.7276	-0.00211	0.00587	0.7217
Appleton to Little Rapids	No Break-point	walleye	skin-on fillet		1.0801	0.1555	0.0000	8.121	0.4280	0.0010	0.0015	0.0461	-9.9680	-0.00472	0.00405	0.2554
	Best Fitting	walleye	skin-on fillet		1.0801	0.1555	0.0000	8.121	0.4280	0.0010	0.0015	0.0461	-9.9680	-0.00472	0.00405	0.2554
De Pere to Green Bay	No Break-point	carp	whole body		0.8225	0.1180	0.0000	6.889	0.1825	0.0471	-0.0001	0.1116	-7.5413	0.00214	0.00103	0.0411
		gizzard shad	whole body		0.5055	0.0897	0.0001	8.558	0.5814	0.0000	-0.0001	0.0063	-5.0657	0.00318	0.00289	0.2902
		northern pike	skin-on fillet		0.7224	0.1664	0.0001	10.122	0.1730	0.3531	-0.0004	0.0407	-9.9517	0.00093	0.00079	0.2489
		walleye	skin-on fillet		0.8509	0.0673		9.454	0.0172	0.7566	-0.0001	0.0406	-7.1920	-0.00051	0.00062	0.4177
			whole body		0.4449	0.1231	0.0007	6.973	0.1190	0.2038	-0.0001	0.0474	-8.1055	-0.00003	0.00082	0.9712
		white bass	skin-on fillet		0.8170	0.1134	0.0000	6.750	0.3258	0.1043	0.0001	0.0289	-4.7229	0.00152	0.00183	0.4104
		white sucker	skin-on fillet		0.4255	0.1496	0.0071	6.923	0.0827	0.5528	0.0000	0.0536	-7.8956	0.00110	0.00104	0.2996
	Best Fitting	carp	whole body	1995	0.7871	0.1125	0.0000	6.657	0.0642	0.0004	-0.0126	0.1005	21.7626	0.01676	0.03616	0.6442
		gizzard shad	whole body		0.5055	0.0897	0.0001	8.558	0.5814	0.0000	-0.0001	0.0063	-5.0657	0.00318	0.00289	0.2902
		northern pike	skin-on fillet		0.7224	0.1664	0.0001	10.122	0.1730	0.3531	-0.0004	0.0407	-9.9517	0.00093	0.00079	0.2489
		walleye	skin-on fillet		0.8509	0.0673		9.454	0.0172	0.7566	-0.0001	0.0406	-7.1920	-0.00051	0.00062	0.4177
			whole body		0.4449	0.1231	0.0007	6.973	0.1190	0.2038	-0.0001	0.0474	-8.1055	-0.00003	0.00082	0.9712
		white bass	skin-on fillet		0.8170	0.1134	0.0000	6.750	0.3258	0.1043	0.0001	0.0289	-4.7229	0.00152	0.00183	0.4104
		white sucker	skin-on fillet		0.4255	0.1496	0.0071	6.923	0.0827	0.5528	0.0000	0.0536	-7.8956	0.00110	0.00104	0.2996
Green Bay Zone 2 (2A and 2B)	No Break-point	alewife	whole body		0.9126	0.1409	0.0000	6.054	0.1664	0.0335	-0.0001	0.0293	-3.9623	0.00191	0.00113	0.0992
		carp	skin-on fillet		0.7643	0.1515	0.0000	3.941	0.2377	0.0288	-0.0001	0.0494	-5.0631	-0.00608	0.00349	0.0956
			whole body		0.9578	0.1099	0.0000	6.794	0.1308	0.2408	0.0000	0.0477	-9.1004	-0.00275	0.00118	0.0238
		gizzard shad	whole body		-0.1295	0.1177	0.2811	2.645	0.3356	0.0300	-0.0002	0.0116	5.9098	-0.00074	0.00319	0.8176
		yellow perch	skin-on fillet		1.0912	0.4683	0.0353	4.726	0.4459	0.5489	-0.0020	0.0316	-10.7477	0.01258	0.00339	0.0026
	Best Fitting	alewife	whole body		0.9126	0.1409	0.0000	6.054	0.1664	0.0335	-0.0001	0.0293	-3.9623	0.00191	0.00113	0.0992
		carp	skin-on fillet		0.7643	0.1515	0.0000	3.941	0.2377	0.0288	-0.0001	0.0494	-5.0631	-0.00608	0.00349	0.0956
			whole body	1983	0.8981	0.0950	0.0000	6.864	0.2382	0.0000	-0.0002	0.0350	-15.5359	0.00335	0.00175	0.0616
		gizzard shad	whole body		-0.1295	0.1177	0.2811	2.645	0.3356	0.0300	-0.0002	0.0116	5.9098	-0.00074	0.00319	0.8176
		yellow perch	skin-on fillet		1.0912	0.4683	0.0353	4.726	0.4459	0.5489	-0.0020	0.0316	-10.7477	0.01258	0.00339	0.0026

Note:

In the fitted models, amplitude and month of peak can be ignored if $\log_{10}$ PCB concentration estimates are needed for July 1 of any year. For other times of year, let M be the $\log_{10}$ of the estima concentration on July 1, A = amplitude, t_{max} = ("*month of peak*" – 1)/12, and t = the specified time of year as a value between zero (1 January) and 1.0 (31 December). Define $Q(t) = -A \cdot \cos[2\pi(0.5 - t_{max})] + A \cdot \cos[2\pi(t - t_{max})]$. Then the estimated mean concentration (ppb) at time-of-year t is $M \cdot 10^{Q(t)}$.

Table A-4 Testing the Null Hypothesis that a Straight Line Fits As Well As a Spline Model with a Breakpoint

Reach	Species	Sample Type	Year of Best-fitting Breakpoint	Sample Size	*p*-value for Breakpoint	$p < 0.05$	Final (post-break) Slope	*p*-value for Final Slope	Pre-break Slope Minus Final Slope	*p*-value for Slope Difference	Pre-break Slope
Little Lake Butte des Morts	Carp	skin-on fillet	1979	55	0.0347	*	-0.028	0.0177	-0.228	0.0102	-0.256
		whole body	1987	40	0.0263	*	0.003	0.9172	-0.165	0.0084	-0.162
	Northern Pike	skin-on fillet	1996	19	0.2723		-0.325	0.0685	0.301	0.1214	-0.024
	Walleye	skin-on fillet	1990	63	0.0423	*	0.015	0.5576	-0.095	0.0140	-0.080
		whole body	1987	18	0.0088	*	0.084	0.0874	-0.261	0.0069	-0.176
	Yellow Perch	skin-on fillet	1981	34	0.0062	*	0.003	0.8025	-0.247	0.0034	-0.244
	Combined++			**229**	**0.0000**	*					
Appleton to Little Rapids	Walleye	skin-on fillet	1983	30	0.4526		-0.056	0.0015	0.103	0.2142	0.047
De Pere to Green Bay	Carp	whole body	1995	90	0.0087	*	0.086	0.0277	-0.141	0.0022	-0.055
	Gizzard Shad	whole body	1990	19	0.4672		-0.020	0.0018	-0.042	0.2303	-0.062
	Northern Pike	skin-on fillet	1996	40	0.1421		0.060	0.2616	-0.117	0.0514	-0.056
	Walleye	skin-on fillet	1993	120	0.5680		-0.046	0.0006	0.019	0.2885	-0.027
		whole body	1996	58	0.5550		0.010	0.8196	-0.052	0.2805	-0.042
	White Bass	skin-on fillet	1996	58	0.6059		0.019	0.6373	-0.045	0.3193	-0.025
	White Sucker	skin-on fillet	1990	44	0.1986		-0.006	0.7235	-0.049	0.0749	-0.055
	Combined++			**429**	**0.0906**						
Green Bay Zone 2 (2A and 2B)	Alewife	whole body	1986	44	0.0863		-0.001	0.9394	-0.076	0.0285	-0.077
	Carp	skin-on fillet	1985	28	0.1811		-0.063	0.0226	0.105	0.0698	0.042
		whole body	1983	57	0.0001	*	-0.073	0.0000	0.266	0.0000	0.193
	Gizzard Shad	whole body	1996	32	0.6655		-0.014	0.7556	0.047	0.3721	0.033
	Yellow Perch	skin-on fillet	1986	19	0.0008	*	0.062	0.0325	-0.573	0.0004	-0.511
	Combined++			**180**	**0.0000**	*					

Note:

++ Indicates *p*-value for the test that all fish categories in a reach do not have a breakpoint.

Table A-5 Breakpoint, Final Slope, and Percent Change per Year of PCB Concentration from Best-fitting Model

Reach	Species	Sample Type	Year of Breakpoint	Number of Samples	Final (post-break) Slope	*p*-value for Final Slope (versus zero)	Percent per Year
Little Lake Butte des Morts	Carp	skin-on fillet	1979	55	-0.028	0.0177	-6.1
		whole body	1987	40	0.003	0.9172	0.7
	Northern Pike	skin-on fillet	0	19	-0.055	0.0003	-11.8
	Walleye	skin-on fillet	1990	63	0.015	0.5576	3.4
		whole body	1987	18	0.084	0.0874	21.5
	Yellow Perch	skin-on fillet	1981	34	0.003	0.8025	0.7
Appleton to Little Rapids	Walleye	skin-on fillet	0	30	-0.046	0.0028	-10.0
De Pere to Green Bay	Carp	whole body	1995	90	0.086	0.0277	21.8
	Gizzard Shad	whole body	0	19	-0.023	0.0002	-5.1
	Northern Pike	skin-on fillet	0	40	-0.046	0.0000	-10.0
	Walleye	skin-on fillet	0	120	-0.032	0.0000	-7.2
		whole body	0	58	-0.037	0.0000	-8.1
	White Bass	skin-on fillet	0	58	-0.021	0.0020	-4.7
	White Sucker	skin-on fillet	0	44	-0.036	0.0000	-7.9
Green Bay Zone 2 (2A and 2B)	Alewife	whole body	0	44	-0.018	0.0497	-4.0
	Carp	skin-on fillet	0	28	-0.023	0.1557	-5.1
		whole body	1983	57	-0.073	0.0000	-15.5
	Gizzard Shad	whole body	0	32	0.025	0.0144	5.9
	Yellow Perch	skin-on fillet	0	19	-0.049	0.0038	-10.7

Table A-6 Model Parameters and Other Statistics for the Best-fitting Model

Reach	Species	Sample Type	Year of Breakpoint	Number of Samples			Final (post-break) Slope	
				n	Intercept	Standard Error	Final	Standard Error
Little Lake Butte des Morts	Carp	skin-on fillet	1979	55	3.36	0.11	-0.028	0.011
		whole body	1987	40	3.31	0.16	0.003	0.030
	Northern Pike	skin-on fillet	0	19	2.67	0.13	-0.055	0.011
	Walleye	skin-on fillet	1990	63	2.21	0.16	0.015	0.025
		whole body	1987	18	2.19	0.38	0.084	0.045
	Yellow Perch	skin-on fillet	1981	34	2.34	0.09	0.003	0.012
Appleton to Little Rapids	Walleye	skin-on fillet	0	30	3.01	0.13	-0.046	0.014
De Pere to Green Bay	Carp	whole body	1995	90	2.97	0.33	0.086	0.038
	Gizzard Shad	whole body	0	19	3.46	0.03	-0.023	0.005
	Northern Pike	skin-on fillet	0	40	3.17	0.10	-0.046	0.007
	Walleye	skin-on fillet	0	120	3.20	0.04	-0.032	0.004
		whole body	0	58	3.98	0.05	-0.037	0.005
	White Bass	skin-on fillet	0	58	3.63	0.07	-0.021	0.006
	White Sucker	skin-on fillet	0	44	3.13	0.08	-0.036	0.006
Green Bay Zone 2 (2A and 2B)	Alewife	whole body	0	44	3.48	0.05	-0.018	0.009
	Carp	skin-on fillet	0	28	3.89	0.08	-0.023	0.015
		whole body	1983	57	3.88	0.05	-0.073	0.010
	Gizzard Shad	whole body	0	32	3.24	0.05	0.025	0.010
	Yellow Perch	skin-on fillet	0	19	2.65	0.44	-0.049	0.014

Notes:

MSE - Mean square error.

* An estimate of the residual variance.

** An estimate of residual standard deviation.

Table A-6 Model Parameters and Other Statistics for the Best-fitting Model

Reach	Species	Sample Type	Year of Breakpoint	*p*-value for Final Slope				*p*-value for Early Slope Difference		
				p-value	Percent per Year	Pre-break Slope Minus Final Slope	Standard Error	*p*-value	Coefficient of Log(% lipid)	Standard Error
Little Lake Butte des Morts	Carp	skin-on fillet	1979	0.0177	-6.1	-0.228	0.085	0.0102	0.87	0.15
		whole body	1987	0.9172	0.7	-0.165	0.059	0.0084	0.86	0.33
	Northern Pike	skin-on fillet	0	0.0003	-11.8				0.45	0.30
	Walleye	skin-on fillet	1990	0.5576	3.4	-0.095	0.037	0.0140	0.50	0.15
		whole body	1987	0.0874	21.5	-0.261	0.080	0.0069	0.99	0.36
	Yellow Perch	skin-on fillet	1981	0.8025	0.7	-0.247	0.077	0.0034	0.49	0.21
Appleton to Little Rapids	Walleye	skin-on fillet	0	0.0028	-10.0				1.08	0.16
De Pere to Green Bay	Carp	whole body	1995	0.0277	21.8	-0.141	0.044	0.0022	0.79	0.11
	Gizzard Shad	whole body	0	0.0002	-5.1				0.51	0.09
	Northern Pike	skin-on fillet	0	0.0000	-10.0				0.72	0.17
	Walleye	skin-on fillet	0	0.0000	-7.2				0.85	0.07
		whole body	0	0.0000	-8.1				0.44	0.12
	White Bass	skin-on fillet	0	0.0020	-4.7				0.82	0.11
	White Sucker	skin-on fillet	0	0.0000	-7.9				0.43	0.15
Green Bay Zone 2 (2A and 2B)	Alewife	whole body	0	0.0497	-4.0				0.91	0.14
	Carp	skin-on fillet	0	0.1557	-5.1				0.76	0.15
		whole body	1983	0.0000	-15.5	0.266	0.059	0.0000	0.90	0.10
	Gizzard Shad	whole body	0	0.0144	5.9				-0.13	0.12
	Yellow Perch	skin-on fillet	0	0.0038	-10.7				1.09	0.47

Notes:

MSE - Mean square error.

* An estimate of the residual variance.

** An estimate of residual standard deviation.

Table A-6 Model Parameters and Other Statistics for the Best-fitting Model

Reach	Species	Sample Type	Year of Breakpoint	*p*-value for Log(% lipid)	Month of Seasonal Peak	Amplitude of Seasonal Peak	*p*-value for Seasonal Effect	Mean Square Error*	Square Root of MSE**
Little Lake Butte des Morts	Carp	skin-on fillet	1979	0.0000	12.9	0.39	0.0078	0.128	0.357
		whole body	1987	0.0131	7.0	0.83	0.0025	0.116	0.340
	Northern Pike	skin-on fillet	0	0.1554	1.3	0.67	0.1594	0.103	0.322
	Walleye	skin-on fillet	1990	0.0011	11.6	0.20	0.0273	0.086	0.293
		whole body	1987	0.0185	11.6	0.46	0.0040	0.141	0.376
	Yellow Perch	skin-on fillet	1981	0.0236	7.0	0.22	0.0007	0.072	0.268
Appleton to Little Rapids	Walleye	skin-on fillet	0	0.0000	8.1	0.43	0.0010	0.046	0.215
De Pere to Green Bay	Carp	whole body	1995	0.0000	6.7	0.06	0.0004	0.100	0.317
	Gizzard Shad	whole body	0	0.0001	8.6	0.58	0.0000	0.006	0.079
	Northern Pike	skin-on fillet	0	0.0001	10.1	0.17	0.3531	0.041	0.202
	Walleye	skin-on fillet	0	0.0000	9.5	0.02	0.7566	0.041	0.201
		whole body	0	0.0007	7.0	0.12	0.2038	0.047	0.218
	White Bass	skin-on fillet	0	0.0000	6.7	0.33	0.1043	0.029	0.170
	White Sucker	skin-on fillet	0	0.0071	6.9	0.08	0.5528	0.054	0.231
Green Bay Zone 2 (2A and 2B)	Alewife	whole body	0	0.0000	6.1	0.17	0.0335	0.029	0.171
	Carp	skin-on fillet	0	0.0000	3.9	0.24	0.0288	0.049	0.222
		whole body	1983	0.0000	6.9	0.24	0.0000	0.035	0.187
	Gizzard Shad	whole body	0	0.2811	2.6	0.34	0.0300	0.012	0.108
	Yellow Perch	skin-on fillet	0	0.0353	4.7	0.45	0.5489	0.032	0.178

Notes:

MSE - Mean square error.

* An estimate of the residual variance.

** An estimate of residual standard deviation.

Table A-7 Final Slope and Percent Change per Year for Best-fitting Model, and Sensitivity Analysis

Reach	Species	Sample Type	Sample Size	Year of Breakpoint—Best Model			Year of Breakpoint—Earliest			Year of Breakpoint—Latest			Year of Breakpoint—1985		
				Year	Percent Change per Year	*p*-value (for % = 0)	Year	Percent Change per Year	*p*-value (for % = 0)	Year	Percent Change per Year	*p*-value (for % = 0)	Year	Percent Change per Year	*p*-value*
Little Lake Butte des Morts	Carp	skin-on fillet	55	1979	-6.15	0.0177	1979	-6.15	0.0177	1985	-1.56	0.7419	1985	-1.56	0.7419
		whole body	40	1987	0.71	0.9172	1985	-4.04	0.5264	1990	-0.25	0.9765	1985	-4.04	0.5264
	Northern Pike	skin-on fillet	19	0	-11.83	0.0003									
	Walleye	skin-on fillet	63	1990	3.44	0.5576	1979	-8.37	0.0000	1994	8.82	0.4482	1985	-5.83	0.0379
		whole body	18	1987	21.47	0.0874	1984	15.10	0.2024	1990	21.11	0.1324	1985	18.49	0.1285
	Yellow Perch	skin-on fillet	34	1981	0.73	0.8025	1979	0.27	0.9252	1996	333.61	0.0122	1985	4.33	0.3297
	Combined				**-4.86**	**0.0055**									
Appleton to Little Rapids	Walleye	skin-on fillet	30	0	-9.97	0.0028									
De Pere to Green Bay	Carp	whole body	90	1995	21.76	0.0277	1990	-0.69	0.8232	1996	29.80	0.0191	1985	-5.63	0.0238
	Gizzard Shad	whole body	19	0	-5.07	0.0002									
	Northern Pike	skin-on fillet	40	0	-9.95	0.0000									
	Walleye	skin-on fillet	120	0	-7.19	0.0000									
		whole body	58	0	-8.11	0.0000									
	White Bass	skin-on fillet	58	0	-4.72	0.0020									
	White Sucker	skin-on fillet	44	0	-7.90	0.0000									
	Combined				**-6.89**	**0.0000**								**-6.92**	**0.0000**
Green Bay Zone 2 (2A and 2B)	Alewife	whole body	44	0	-3.96	0.0497									
	Carp	skin-on fillet	28	0	-5.06	0.1557									
		whole body	57	1983	-15.54	0.0000	1983	-15.54	0.0000	1984	-16.15	0.0000	1985	-15.90	0.0000
	Gizzard Shad	whole body	32	0	5.91	0.0144									
	Yellow Perch	skin-on fillet	19	0	-10.75	0.0038									
	Combined				**-5.11**	**0.0000**								**-5.99**	**0**

Note:

* For testing whether percent change per year is different from zero.

Table A-8 Computing Whole Body PCB Concentrations*

Species	Convert	Modify PCB Target by this Factor
Carp	0.59	1.69
Northern Pike	0.1	10.00
Walleye	0.1	10.00
White Bass	0.43	2.33
White Sucker	0.59	1.69
Yellow Perch	0.04	25.00

Note:

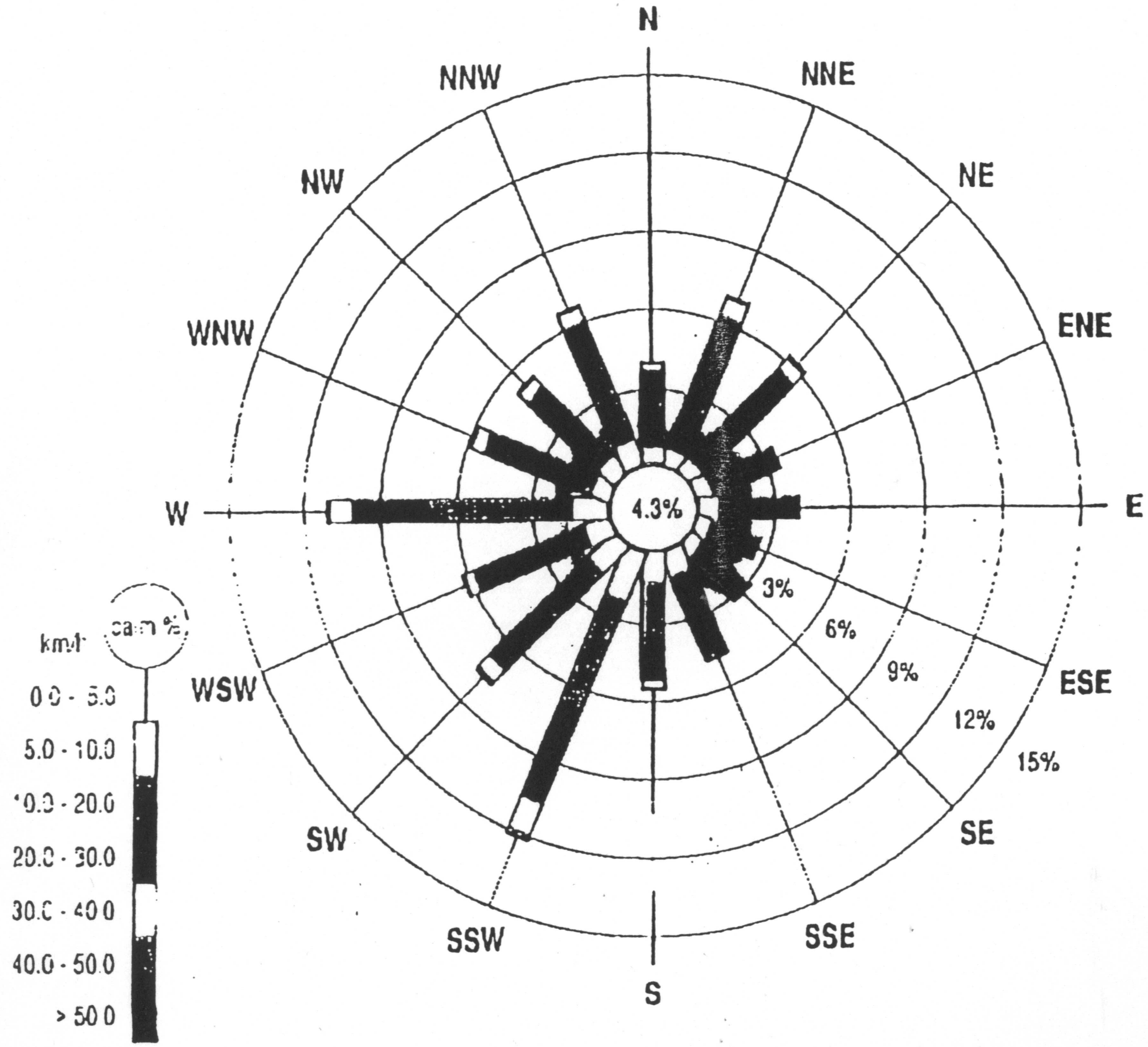
* Based on fillet-to-whole body conversion factors. These conversion factors were used to multiply specified skin-on fillet PCB concentrations to yield the corresponding expected concentration in a whole-body sample—used in analyses of time to reach specified PCB concentrations.

APPENDIX C

A WINDROSE DIAGRAM, DEVELOPED FROM THE NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION

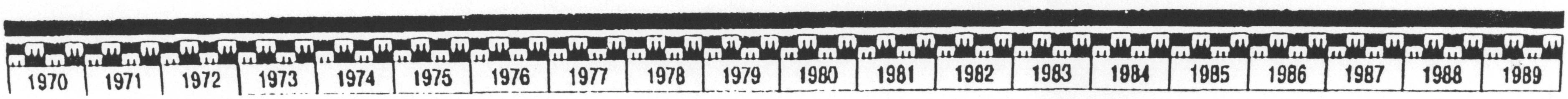
Wind Rose

Wind Station: Green Bay



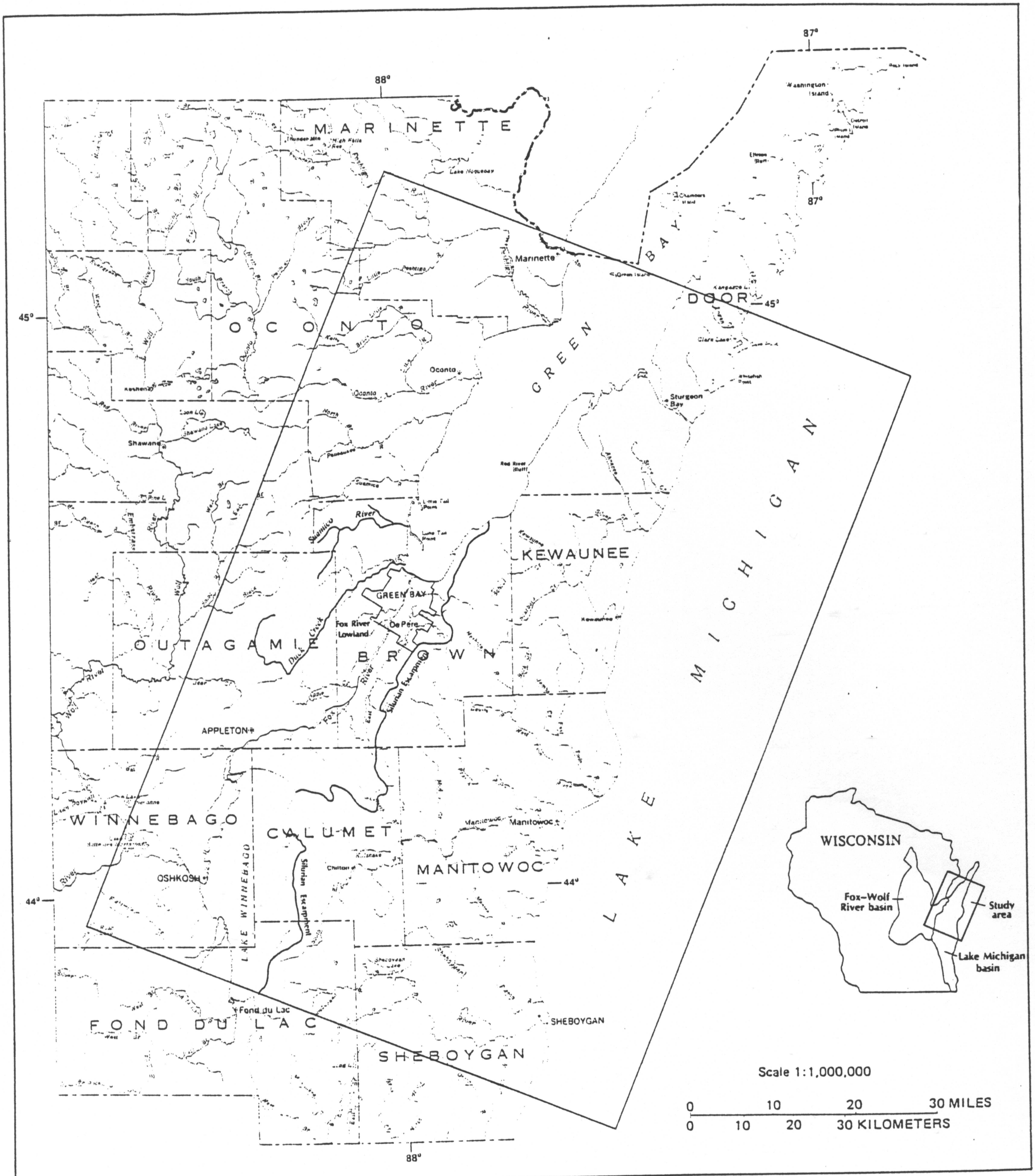
Cumulative Distribution (%)

	0.0	5.0	10.0	20.0	30.0	40.0	50.0 km/h
NNE	0.0	0.8	4.0	6.3	6.9	7.0	
NE	0.0	0.7	3.7	5.6	6.1	6.3	6.3
ENE	0.0	0.7	2.6	3.3	3.4	3.4	
E	0.1	0.9	3.1	3.8	3.9		
ESE	0.0	0.6	2.0	2.5	2.6		
SE	0.0	0.7	2.4	3.0	3.1		
SSE	0.1	1.1	3.6	4.6	4.7	4.8	
S	0.1	1.3	4.1	5.2	5.5	5.5	
SSW	0.1	2.2	7.4	10.6	11.9	12.1	12.1
SW	0.1	1.5	5.0	6.9	7.5	7.7	7.7
WSW	0.0	1.1	4.4	5.7	6.1	6.2	6.2
W	0.1	1.5	7.1	10.1	11.0	11.1	11.1
WNW	0.0	0.8	3.6	5.3	5.8	5.9	5.9
NW	0.1	0.9	3.4	4.7	5.2	5.3	
NNW	0.1	1.2	4.3	6.0	6.6	6.7	
N	0.1	0.8	2.8	3.7	4.0	4.1	



APPENDIX D

STRATIGRAPHIC CROSS-SECTION AND OTHER PERTINENT INFORMATION CONCERNING THE REGIONAL GEOLOGY OF THE AREA (KROHELSKI AND BROWN, 1986)



Base from U.S.G.S.
State base 1:1,000,000, 1968

Figure 1. Location of the study area.

HYDROGEOLOGY

GEOLOGY

The descriptions of rock units presented in this report are based on drill cuttings obtained from Brown County wells. Lithologies of many of the rock formations are not uniform areally and, in fact, can differ over short distances. The formations include aquifers and confining units. The lithology and areal extent of the rocks and sediments in Brown County are summarized in table 1. The stratigraphy and nomenclature used in this report is that of Mudrey, Brown, and Greenberg (1982).

Bedrock Geology

***By B. A. Brown*[1]**

Brown County is underlain by Paleozoic sedimentary rocks that range in age from Cambrian to Silurian. The rocks rest directly on Precambrian basement rocks that consist predominantly of red granite. The Paleozoic rocks and the Precambrian surface slope to the east beneath Lake Michigan toward the Michigan Basin at about 30 to 40 ft/mi (fig. 2). Erosion has removed the Silurian rocks and the Maquoketa Formation in the western part of the county (fig. 3). The total thickness of the Paleozoic rocks ranges from 200 ft in the west to about 1,600 ft in eastern Brown County.

Cambrian System

The basal unit of the Cambrian is the Elk Mound Group, which overlies the Precambrian. The group normally consists of, in ascending order, the Mount Simon, Eau Claire, and Wonewoc Formations. The group name is used because the Eau Claire Formation cannot be identified in Brown County, and the sandstones of the Mount Simon and Wonewoc Formations commonly cannot be distinguished from one another.

In areas where these formations are distinguishable, the Mount Simon Formation consists of poorly cemented, subangular, fine to very fine-grained sandstone, which may locally be silty. The Wonewoc Formation consists of poorly cemented, subrounded medium to coarse-grained sandstone.

The Tunnel City Group overlies the Elk Mound Group and includes the Lone Rock and the Mazomanie Formations. The Mazomanie Formation is a fine to medium-grained, feldspathic sandstone. The Lone Rock Formation ranges from a dolomitic, feldspathic, glauconitic siltstone or sandstone to a sandy glauconitic dolomite. The Mazomanie and Lone Rock Formations are laterally equivalent facies and either or both facies may be present in the same well. Where fine-grained dolomite of the Lone Rock facies is present, it is difficult to identify the upper contact of the Tunnel City Group because of the similarity of these rocks to the overlying St. Lawrence Formation.

The Trempealeau Group, which consists of the St. Lawrence Formation and Jordan Formations, overlies the Tunnel City Group. The St. Lawrence Formation is a silty, shaly dolomite that commonly contains glauconite. The Jordan Formation can locally be subdivided into the Van Oser and Coon Valley Members. The Van Oser Member consists of very fine to very coarse sandstone, commonly dolomitic that contains minor glauconite. The Coon Valley Member consists of dolomite that contains variable amounts of sand, shale, and minor glauconite. This member is difficult to identify from drill cuttings. The Trempleau Group can be subdivided only where the Van Oser Member is present.

Ordovician System

The Prairie du Chien Group consists of the Oneota and Shakopee Formations. The Shakopee Formation is further subdivided into the lower New Richmond Member and upper Willow River Member. The Oneota Formation and the Willow River Member are very similar, consisting of massive dolomite with minor limestone and oolitic chert. The New Richmond Member consists of sandstone, shaly sandstone, or dolomitic sandstone. The Prairie du Chien Group can be subdivided only in wells where the New Richmond is present. Erosion that occurred prior to deposition of the overlying Ancell Group has removed the Prairie du Chien Group rocks in some areas of Brown County.

The Ancell Group consists of the St. Peter and Glenwood Formation. The St. Peter Formation is composed of two members—the lower Readstown Member, which consists of sandy shale with chert layers, and the overlying Tonti Member, which consists of poorly cemented fine to medium-grained sandstone. The overlying Glenwood Formation is a silty sandstone.

The St. Peter Formation varies areally in thickness because of erosion of the Prairie du Chien strata in pre-St. Peter time. The St. Peter reaches a maximum thickness of up to 300 ft under the Fox River Valley in the area of De Pere, but thins rapidly to as little as 40 ft several miles to the east and west.

The Ancell Group is overlain by the Sinnipee Group, which includes the Platteville, Decorah, and Galena Formations. The Platteville and Galeña Formations consist of dolomite that contains fossil fragments and shaly layers. The Galena is distinguished from the Platteville by its chert content. The Decorah Formation is predominantly shale. The Sinnipee Group can be subdivided with certainly only in wells where shale of the Decorah Formation is present between the underlying Platteville and overlying Galena Formations.

The Maquoketa Formation overlies the Sinnipee Group in the area to the east of the Fox River. This formation consists of the Scales Member (a dolomitic shale), which is overlain by the Fort Atkinson Member (a fossiliferous dolomite), which is overlain by the Brainerd Member (another dolomitic shale). The Maquoketa Formation can be subdivided only in northeastern Brown County, where the Fort Atkinson Member is present.

Silurian System

The rocks of the Silurian System are not subdivided in the subsurface of Brown County. These rocks underlie the area east of the Fox River lowland, and consist of massive

[1] Wisconsin Geological and Natural History Survey.

dolomite containing variable amounts of fossil fragments, calcite and gypsum crystals, pyrite, and minor limestone.

Pleistocene

Pleistocene deposits overlie the Paleozoic rock in Brown County and are more than 50 ft thick in most places and more than 200 ft thick in the southwestern part of the county (fig. 4). These unconsolidated deposits were mapped by Need (1983) and the following description is based on that work.

Several glacial episodes are recorded in Brown County Pleistocene deposits. Seven tills and their associated fluvial

Table 1. Stratigraphy of Brown County

Age	Rock unit	Lithology	Areal extent
Quaternary Pleistocene	Kewaunee Formation Horicon Formation	Fluvial, lacustrine, wind blown, and peat deposits, and till	Predominantly fine-grained till except for Fox River valley and area adjacent to west side of Green Bay where lacustrine silt and clay are common. Sand and gravel deposits of small areal extent are present throughout the county.
Silurian	Undifferentiated	Dolomite with varying amounts of fossil fragments, gypsum crystals, pyrite, and limestone.	Subcrops east of the Silurian escarpment.
Ordovician	Maquoketa Formation Brainerd Member Fort Atkinson Member Scales Member	Predominantly dolomitic shale. The Fort Atkinson Member is fossiliferous dolomite.	Subcrops in a band generally less than 3 mi wide west of the Silurian escarpment. Present directly beneath the Silurian dolomite.
	Sinnipee Group Galena Formation Decorah Formation Platteville Formation	Galena and Platteville Formations are dolomite. The Decorah Formation is shale.	Subcrops just east of the Fox River and throughout the county west of the river.
	Ancell Group Glenwood Formation St. Peter Formation Tonti Member Readstown Member	The Glenwood Formation is a silty sandstone, the Tonti Member is a fine- to medium-grained sandstone and the Readstown Member is a sandy shale.	Commonly present in the Fox River valley but thins rapidly east and west of the valley.
	Prairie du Chien Group Shakopee Formation Willow River Member New Richmond Member Oneota Formation	The Prairie du Chien Group is generally dolomite with varying amounts of oolitic chert. The group can be subdivided only when the New Richmond Member, a sandstone, shaly sandstone, or dolomitic sandstone, is present.	Thin or absent where the St. Peter Sandstone is thick (Fox River valley).
Cambrian	Trempealeau Group Jordan Formation St. Lawrence Formation	The Jordan Formation is a fine- to medium-grained sandstone. The St. Lawrence Formation is a silty glauconitic dolomite.	Present throughout the county.
	Tunnel City Group Mazomanie Formation Lone Rock Formation	The Mazomanie Formation is a fine- to medium-grained sandstone. The Lone Rock Formation is a silty sandstone to a sandy dolomite.	Present throughout the county.
	Elk Mound Group Wonowoc Formation Eau Claire Formation Mount Simon Formation	The members of the Elk Mound Group are usually not differentiated. Where distinguishable the units generally present are a very fine to fine-grained sandstone and a medium- to coarse-grained sandstone.	Present throughout the county.
Precambrian		Red granite	Basement rock throughout the county.

1/ The stratigraphic nomenclature used in this report is that of the Wisconsin Geological and Natural History Survey and does not necessarily follow usage of the U.S. Geological Survey.

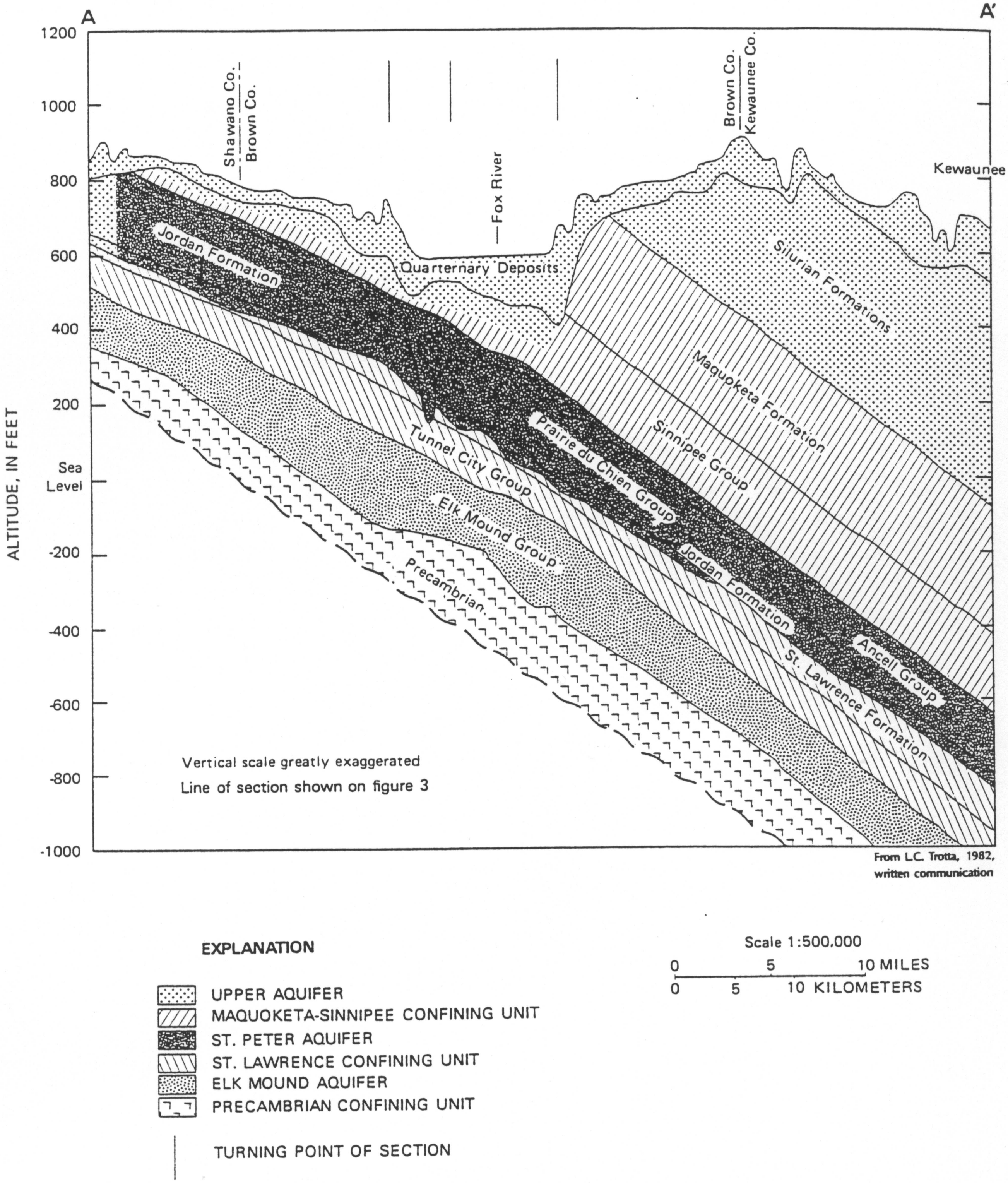


Figure 2. Hydrogeologic section through study area.

and lacustrine deposits are present in the Brown County area. Tills were deposited by the Green Bay and Lake Michigan Lobes of the ice sheet. Fluvial sand and gravel were deposited by glacial meltwater from the lobes. Lacustrine sediment, generally fine grained (silt or clay), was deposited in two ice dammed lakes—Nipissing Lake and Lake Oshkosh. Modern sediments deposited by wind, water, and the accumulation of organic matter are also present in Brown County. Figure 5 shows the areal distribution of groupings of Pleistocene surface deposits in Brown County. The groupings are till, silt and clay, and sand and gravel. Figure 6 is an east-west geologic section through northern Brown

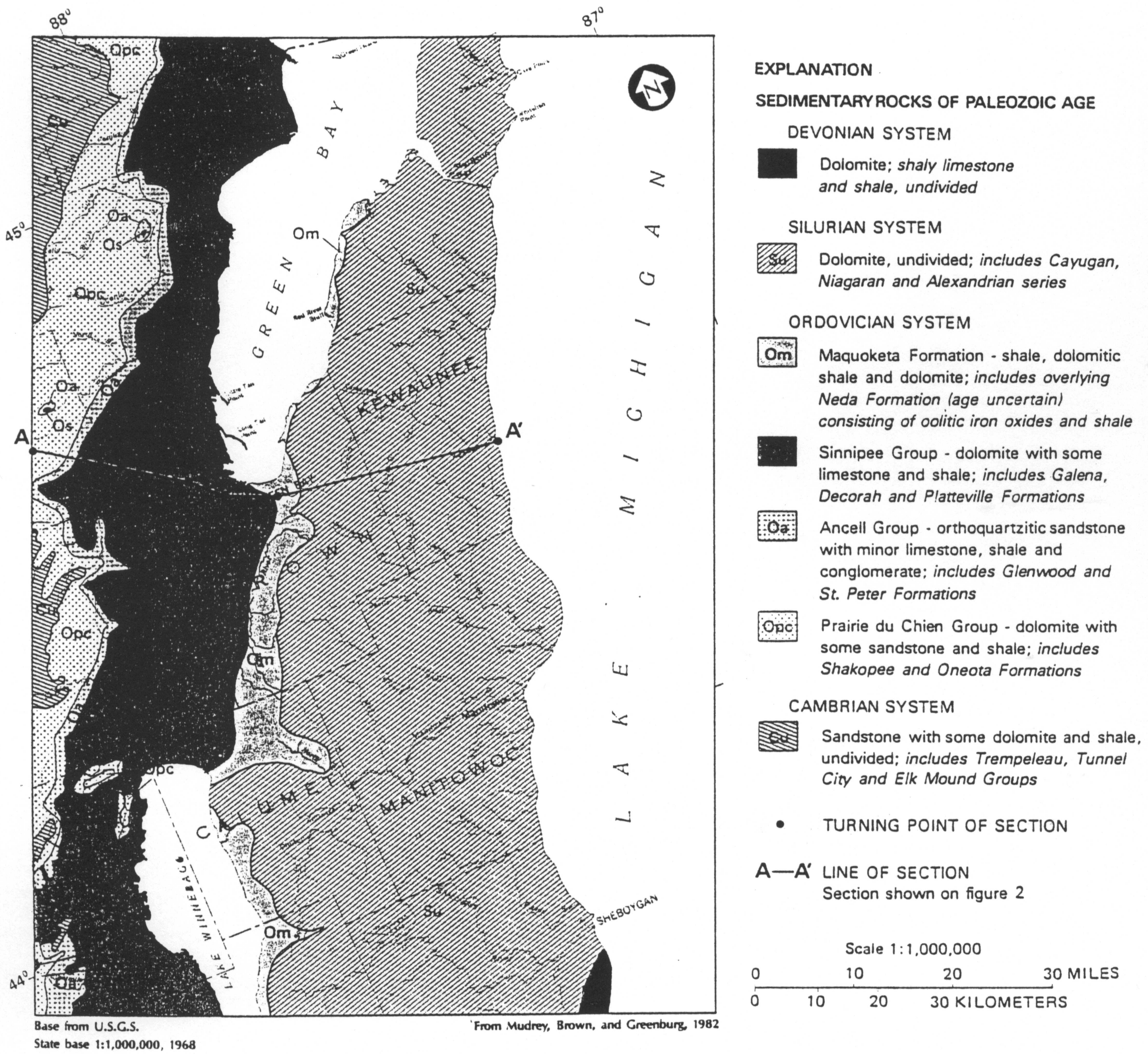


Figure 3. Bedrock geology.

County showing the vertical distribution of Pleistocene deposits.

The following is a brief description of the Pleistocene deposits in order of their relative age from youngest to oldest.

Modern Deposits

1. *Modern stream sediment* is silt loam and silt channel-fill and flood-plain deposits. It is present adjacent to most county streams.
2. *Windblown sand* is well-sorted fine sand in transverse dunes present in northwestern Brown County.
3. *Organic and hillslope sediment in topographic depressions* is loam to silty clay slopewash sediment overlain by peat and muck. It is present in small areas throughout the county.

Kewaunee Formation

1. *Nipissing Lake Plain and Lake Oshkosh Plain sediment* vary from clay to silt loam. This sediment is present at the surface in the Fox River lowland.
2. *Stream sediment in spillways* is gravelly sand, sand, and sandy gravel point-bar and channel-lag deposits in steep-walled channels that drained proglacial Lake Oshkosh. It is present in two locations in eastern Brown County.
3. *Till of the Middle Inlet Member* is reddish brown, calcareous, loam till and is the surface unit in northwestern Brown County. It is present discontinuously in the subsurface in the Fox River lowland near the west side of Green Bay.
4. *Till of the Glenmore Member* is reddish brown, calcareous, silty clay loam till that is the surface unit throughout most of eastern Brown County. It has been identified in the subsurface in the Fox River lowland west of the Fox River.
5. *The Duck Creek Ridge Complex* is sediment of the Middle Inlet and Kirby Lake Members, stream sediment, and clayey lake sediment. It is present in a glacially eroded, elongated ridge near the east side of Duck Creek.
6. *Meltwater-stream sediment exposed by glacial and postglacial erosion* is well-sorted sand exposed along elongated ridges and steep slopes. It is present at the surface and in the subsurface in western and northwestern Brown County.
7. *Till of the Kirby Lake Member* is reddish brown, calcareous, clay loam to silty clay loam till. It is not exposed at the surface but is present in the subsurface throughout northwestern and west-central Brown County.
8. *Till of the Chilton Member* is reddish brown, calcareous, silty clay loam till. It is exposed at the surface in southern Brown County and present in the subsurface in the Fox River lowland south of Green Bay.
9. *Till of the Valders Member* is reddish brown, calcareous, silt loam till and is exposed in southeastern Brown County but is not present to any significant extent in the subsurface.
10. *Clayey offshore sediment exposed by glacial and stream erosion* is silty clay loam, silty clay, and clay that was deposited in proglacial lakes predating the Chilton and Kirby Lake Members. This unit is exposed at the surface in northwestern Brown County and in the subsurface throughout most of the Fox River lowland.
11. *Meltwater stream sediment* is gravelly sand, sand, and sandy gravel with minor amounts of silt loam. It is present at the surface in southern Brown County near the Branch River and is discontinuous in the subsurface in the Fox River lowland.
12. *Till of the Branch River Member* is light reddish brown, calcareous, loam till. It is exposed at the surface in southern Brown County and around the margins of an erosional window of the Wayside till in northeastern Brown County. The Branch River Member is also thought to be present in the subsurface throughout the eastern part of the county.

Horicon Formation

1. *Till of the Wayside Member* is light-grayish brown, calcareous, stony loam till and is exposed at the surface in southern Brown County.
2. *Meltwater-stream sediment* is sand and gravel, discontinuous in the subsurface in eastern Brown County.

AQUIFERS AND CONFINING UNITS

The complex hydrogeologic system in the Brown County area consists of aquifers and confining units. The hydrogeologic system includes an upper aquifer and deep aquifers separated by confining units. Previous studies have defined the ''sandstone aquifer'' in the Brown County area to include Cambrian and Ordovician Formations older than the Maquoketa Formation (Donohue, 1976; Drescher, 1953; Knowles, 1964). Although it was recognized in previous studies that the ''sandstone aquifer'' did not have uniform hydraulic properties and was not a single aquifer, it was considered a single aquifer because hydraulic data on individual formations were not available. Most high-capacity wells in Brown County are drilled through and open to most of the formations of the ''sandstone aquifer''.

The division of aquifers and confining units in this report is based on the composition and hydraulic information of the rock groups or formations present in the Brown County area. Figure 2 shows rock groups and formations present in the Brown County area and the aquifers and confining units defined in this report. The general range in thickness of the aquifers and confining units can be seen in figures 7 and 15a. Table 2 lists hydraulic parameters for the aquifers and confining units. The locations of pump tests and

APPENDIX E

BATHYMETRY INFORMATION AVAILABLE FROM THE NOAA RECREATIONAL CHARTS FOR LAKE WINNEBAGO AND THE LOWER FOX RIVER

LAKE WINNEBAGO AND LOWER FOX RIVER

WISCONSIN

COAST AND GEODETIC SURVEY

Polyconic Projection
North American Datum of 1983
(World Geodetic System 1984)

SOUNDINGS IN FEET

NOTE B

The channel legend reflects the Corps of Engineers project depth. The Corps of Engineers publishes the controlling depth periodically in the U.S. Coast Guard Local Notice to Mariners. For further information on channel depths, direct inquiries to Office of the District Engineer, Corps of Engineers, Detroit, Michigan.

FATHOMS	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
FEET	6	12	18	24	30	36	42	48	54	60	66	72	78	84	90	96	102

METERS 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31

RADAR REFLECTORS

Radar reflectors have been placed on many floating aids to navigation. Individual radar reflector identification on these aids has been omitted from this chart.

RACING BUOYS

Racing buoys within the limits of this chart are not shown hereon. Information may be obtained from the U.S. Coast Guard District Offices as racing and other privately maintained buoys are not all listed in the U.S. Coast Guard Light List.

NOTES

PLANES OF REFERENCE OF THIS CHART (Low Water Datum)
LAKE WINNEBAGO .... 745.8 ft.
FOX RIVER (Between Locks) .... See table below
LAKE MICHIGAN .... 577.5 ft.
Referred to mean water level at Rimouski, Quebec, International Great Lakes Datum (1985).

AIDS TO NAVIGATION. Consult U.S. Coast Guard Light List for supplemental information concerning aids to navigation.

SYMBOLS AND ABBREVIATIONS. For complete list of symbols and abbreviations see Chart No. 1.

BRIDGE AND OVERHEAD CABLE CLEARANCES. When the water surface is above Low Water Datum, bridge and overhead clearances are reduced correspondingly. For clearances see U.S. Coast Pilot 6.

AUTHORITIES. Hydrography and topography by the National Ocean Service, Coast and Geodetic Survey, with additional data from the Corps of Engineers, Geological Survey, and U.S. Coast Guard.

LOGARITHMIC SPEED SCALE

1 2 3 4 5 6 7 8 9 10 15 20 25 30 40 50 60

To find SPEED, place one point of dividers on distance run (in any unit) and the other on minutes run. Without changing divider spread, place right point on 60 and left point will then indicate speed in units per hour. Example: with 4.0 nautical miles run in 15 minutes, the speed is 16.0 knots

SUPPLEMENTAL INFORMATION

Consult U.S. Coast Pilot 6 for important supplemental information.

POLLUTION REPORTS

Report all spills of oil and hazardous substances to the National Response Center via 800-424-8802 (toll free), or to the nearest U.S. Coast Guard facility if telephone communication is impossible (33 CFR 153).

CAUTION

POTABLE WATER INTAKE (PWI)

Vessels operating in fresh water lakes or rivers shall not discharge sewage, or ballast, or bilge water within such areas adjacent to domestic water intakes as are designated by the Surgeon General (21 CFR 1250.93). Consult U.S. Coast Pilot 6 for important supplemental information.

NOTE A

Navigation regulations are published in Chapter 2, U.S. Coast Pilot 6. Additions or revisions to Chapter 2 are published in the Notices to Mariners. Information concerning the regulations may be obtained at the Office of the Commander, 9th Coast Guard District in Cleveland, Ohio, or at the Office of the District Engineer, Corps of Engineers in Detroit, Michigan.

Refer to charted regulation section numbers.

Ⓕ Fumi-out facilities

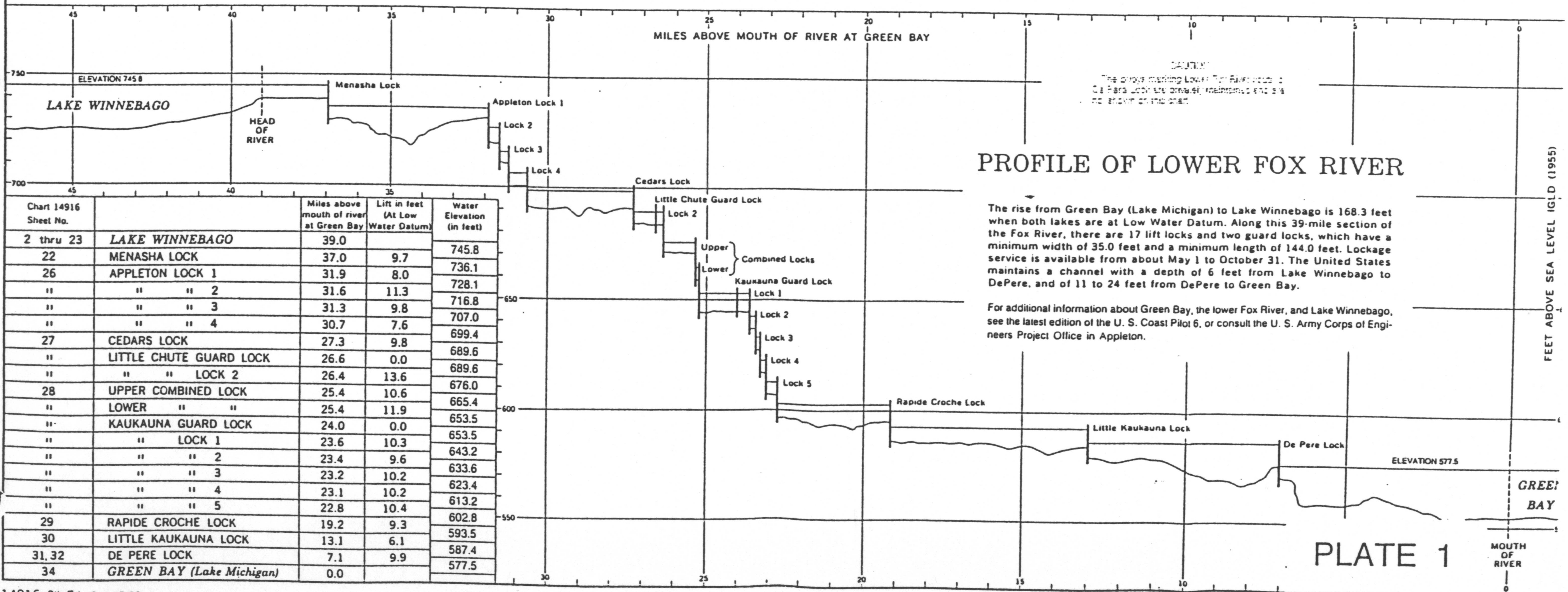


Chart 14916 Sheet No.		Miles above mouth of river at Green Bay	Lift in feet (At Low Water Datum)	Water Elevation (in feet)
2 thru 23	*LAKE WINNEBAGO*	39.0		745.8
22	MENASHA LOCK	37.0	9.7	736.1
26	APPLETON LOCK 1	31.9	8.0	728.1
"	" " 2	31.6	11.3	716.8
"	" " 3	31.3	9.8	707.0
"	" " 4	30.7	7.6	699.4
27	CEDARS LOCK	27.3	9.8	689.6
"	LITTLE CHUTE GUARD LOCK	26.6	0.0	689.6
"	" " LOCK 2	26.4	13.6	676.0
28	UPPER COMBINED LOCK	25.4	10.6	665.4
"	LOWER " "	25.4	11.9	653.5
"	KAUKAUNA GUARD LOCK	24.0	0.0	653.5
"	" LOCK 1	23.6	10.3	643.2
"	" " 2	23.4	9.6	633.6
"	" " 3	23.2	10.2	623.4
"	" " 4	23.1	10.2	613.2
"	" " 5	22.8	10.4	602.8
29	RAPIDE CROCHE LOCK	19.2	9.3	593.5
30	LITTLE KAUKAUNA LOCK	13.1	6.1	587.4
31, 32	DE PERE LOCK	7.1	9.9	577.5
34	*GREEN BAY (Lake Michigan)*	0.0		

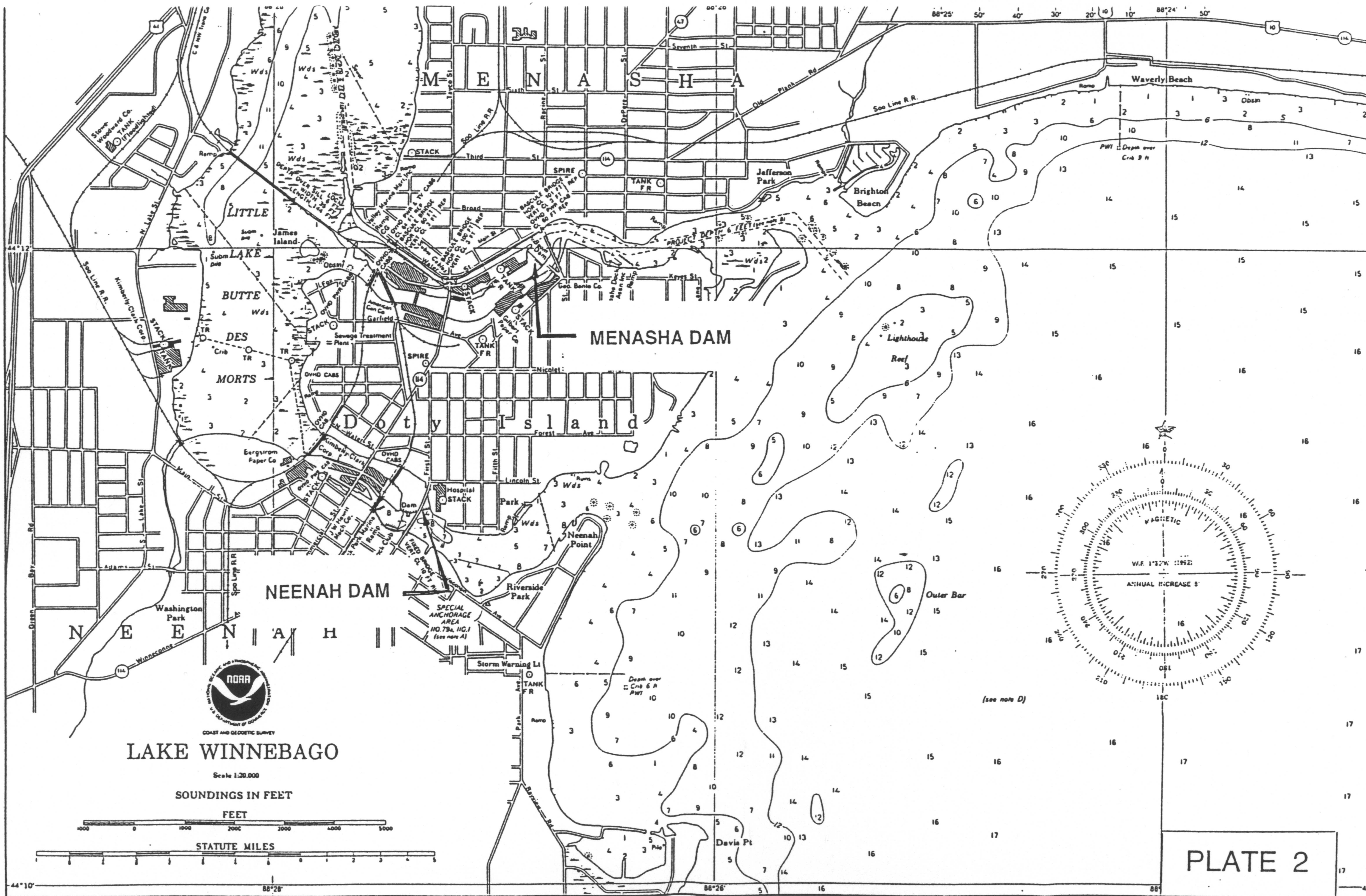
PROFILE OF LOWER FOX RIVER

The rise from Green Bay (Lake Michigan) to Lake Winnebago is 168.3 feet when both lakes are at Low Water Datum. Along this 39-mile section of the Fox River, there are 17 lift locks and two guard locks, which have a minimum width of 35.0 feet and a minimum length of 144.0 feet. Lockage service is available from about May 1 to October 31. The United States maintains a channel with a depth of 6 feet from Lake Winnebago to DePere, and of 11 to 24 feet from DePere to Green Bay.

For additional information about Green Bay, the lower Fox River, and Lake Winnebago, see the latest edition of the U. S. Coast Pilot 6, or consult the U. S. Army Corps of Engineers Project Office in Appleton.

PLATE 1

14916 8th Ed., Oct. 17/92



14916 8th Ed., Oct. 17/92

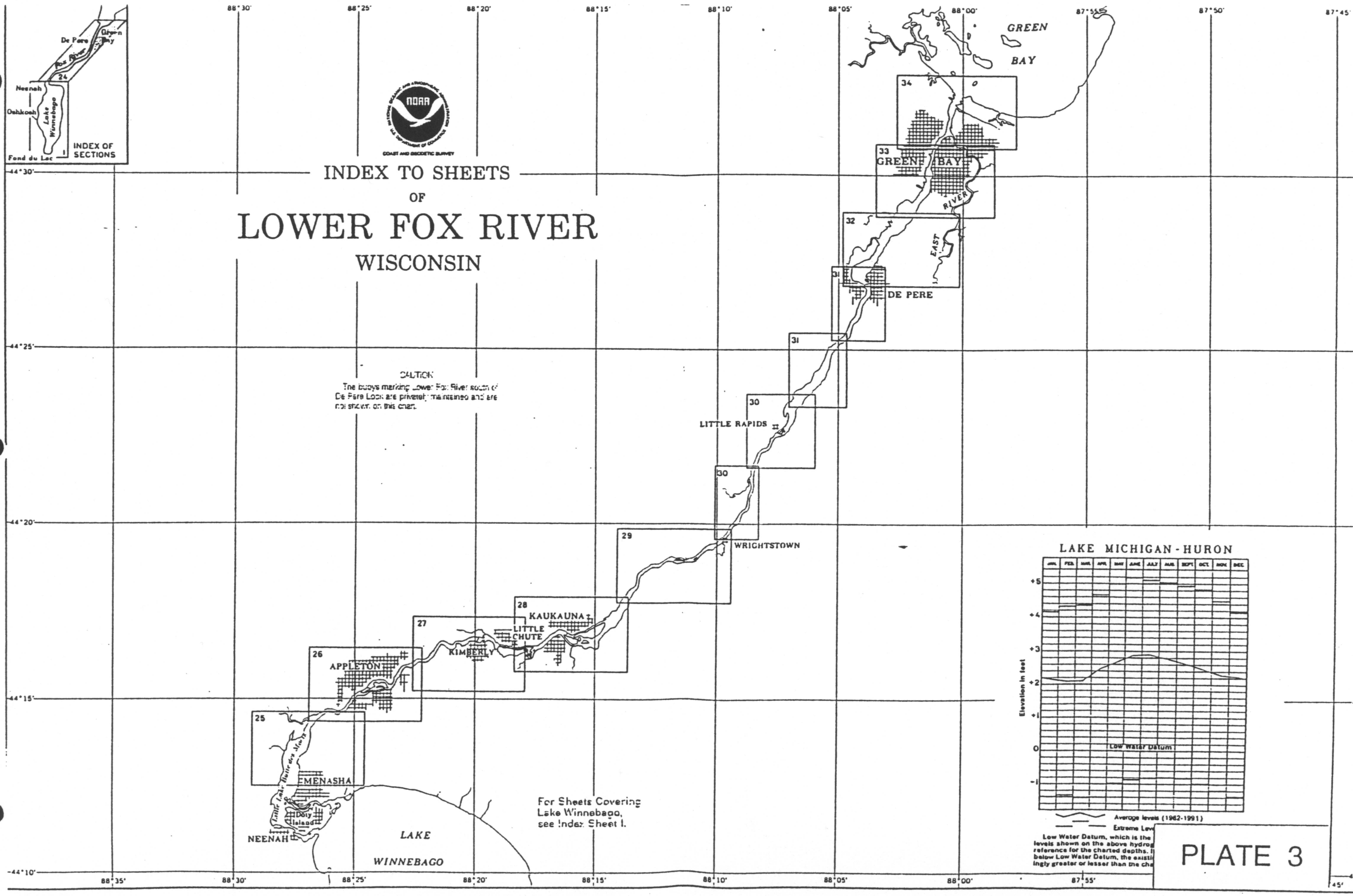


PLATE 3

14916 8th Ed., Oct. 17/92

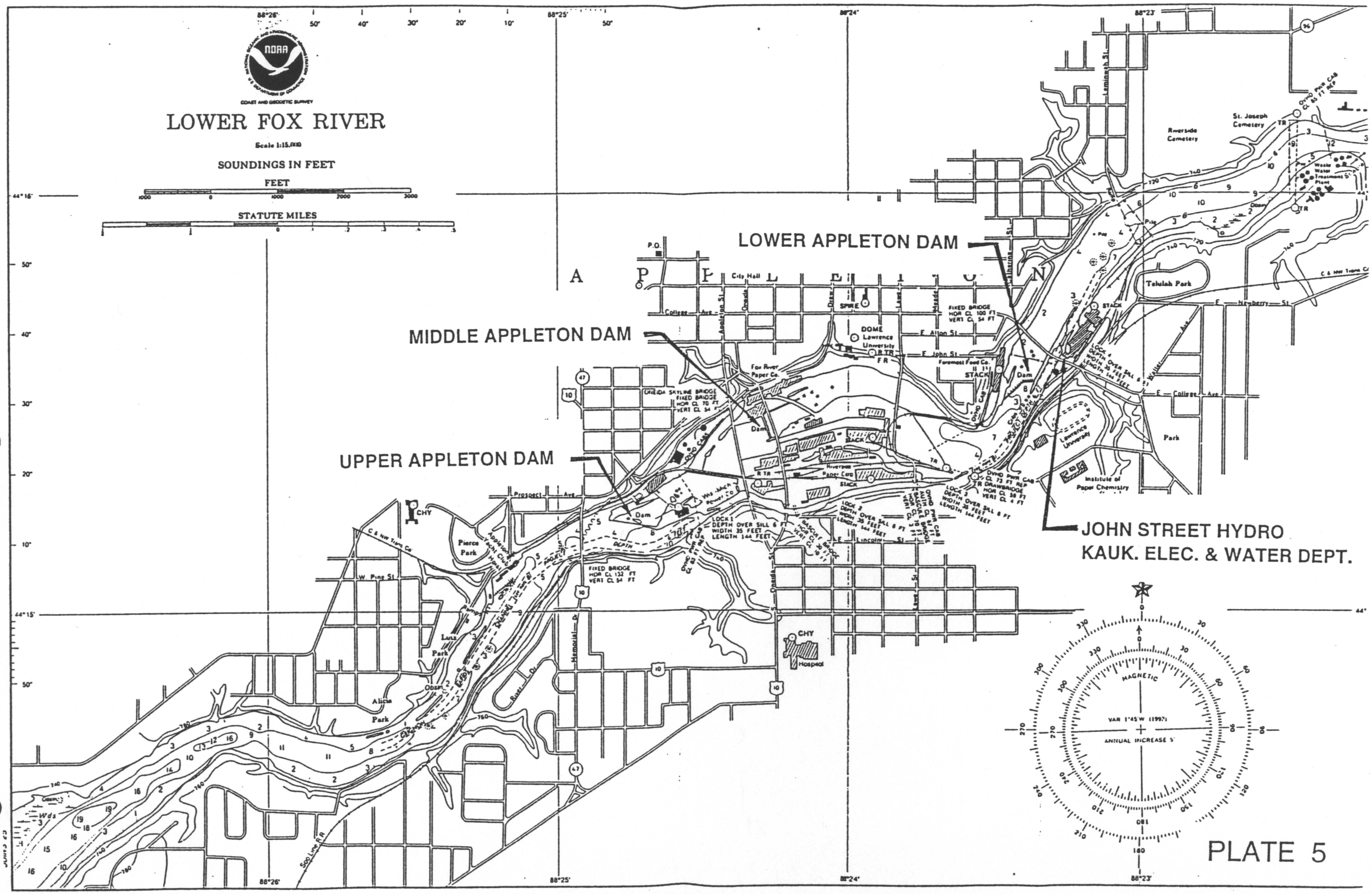
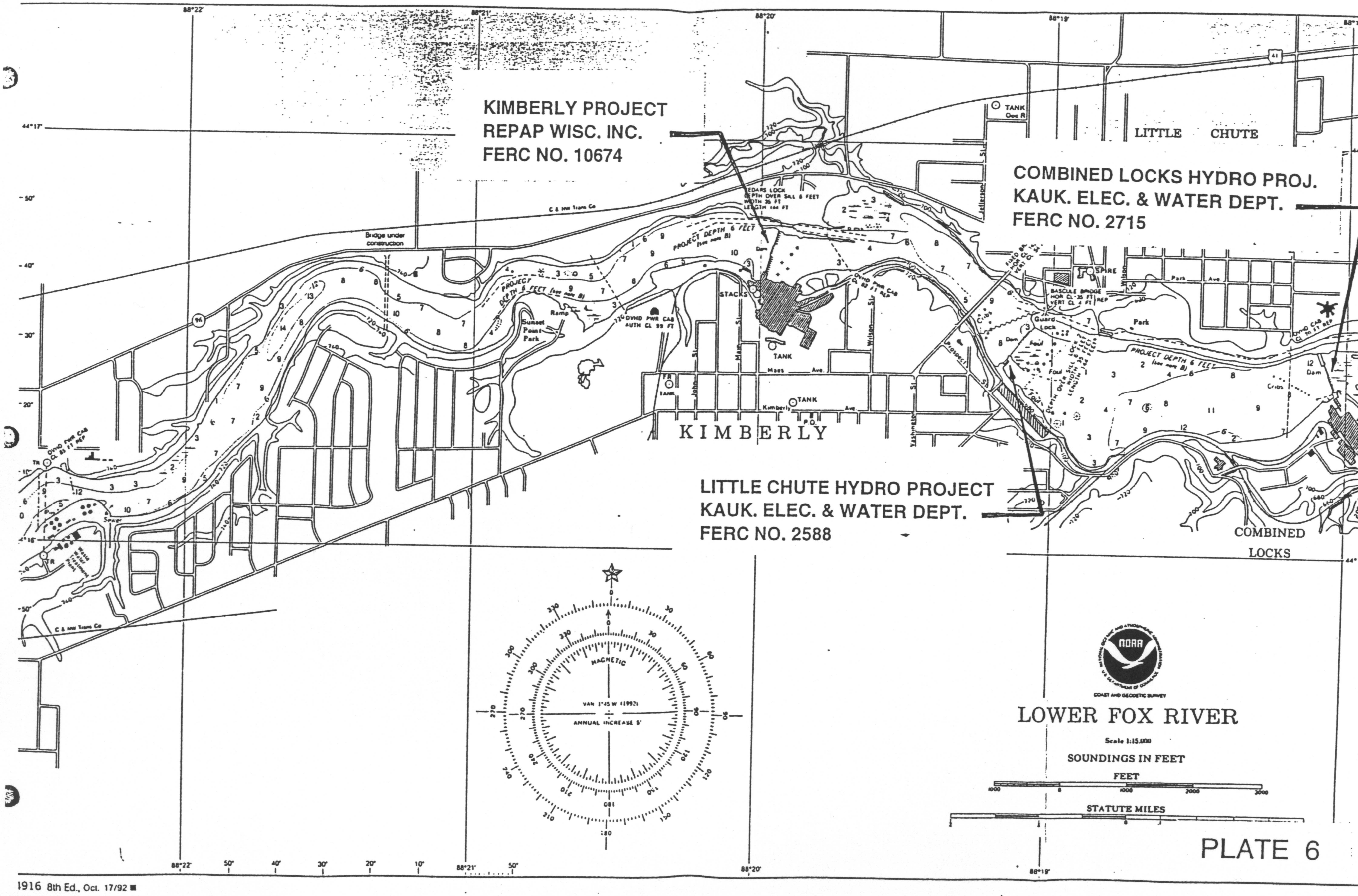
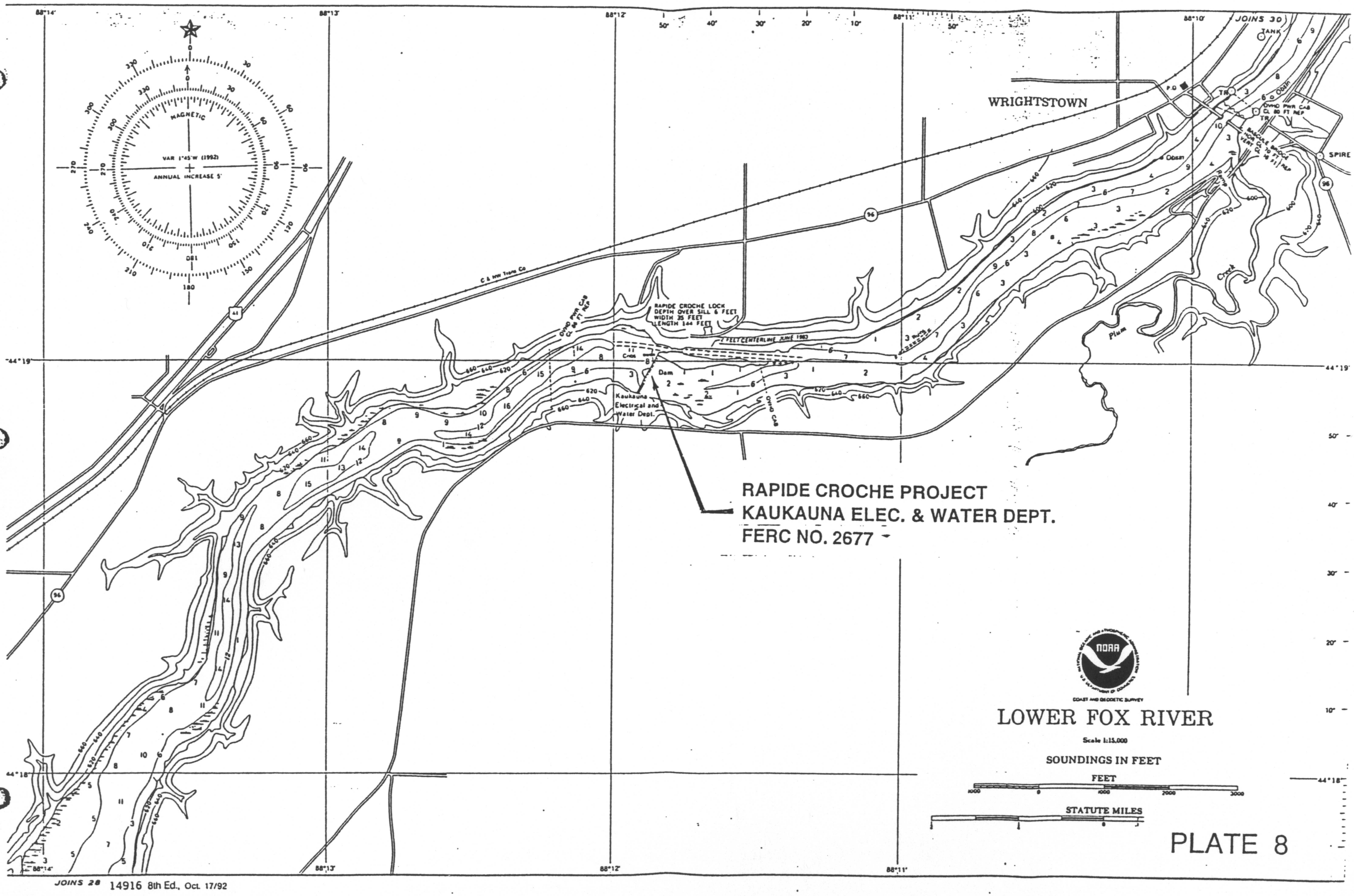
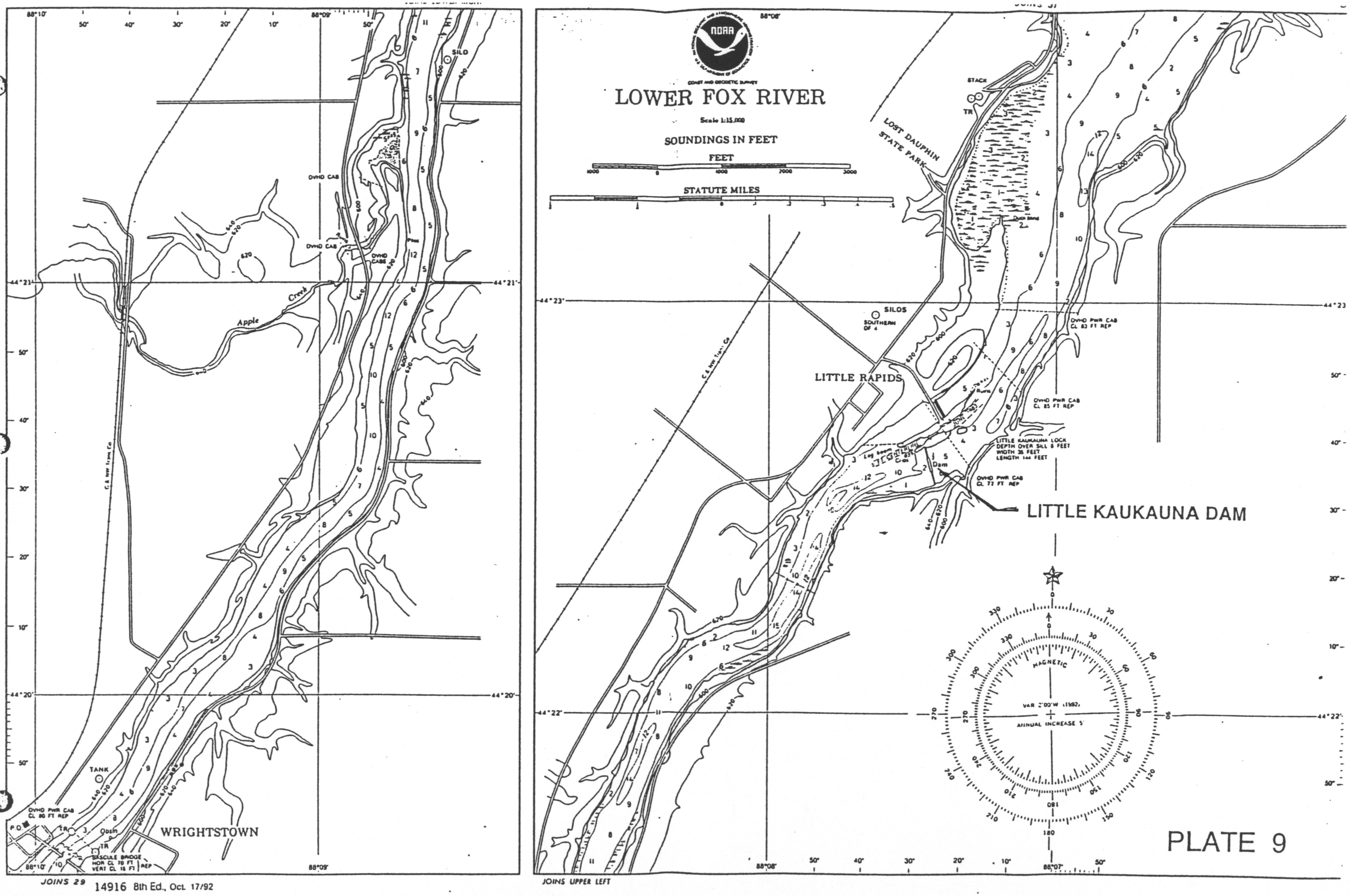


PLATE 5

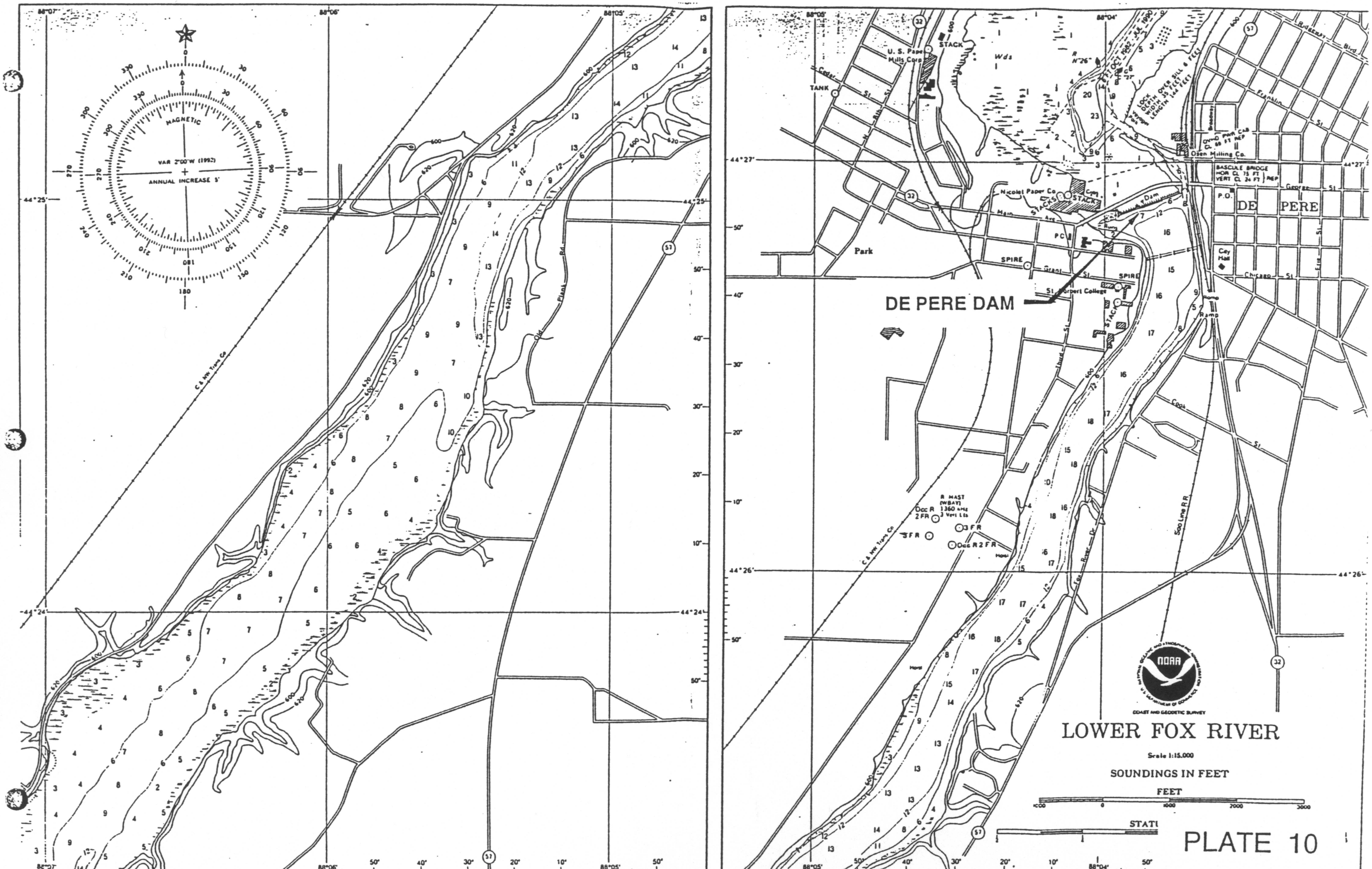
14916 8th Ed., Oct. 17/92


KIMBERLY PROJECT
REPAP WISC. INC.
FERC NO. 10674
COMBINED LOCKS HYDRO PROJ.
KAUK. ELEC. & WATER DEPT.
FERC NO. 2715
LITTLE CHUTE HYDRO PROJECT
KAUK. ELEC. & WATER DEPT.
FERC NO. 2588
LITTLE CHUTE
KIMBERLY
COMBINED LOCKS
LOWER FOX RIVER
Scale 1:15,000
SOUNDINGS IN FEET
FEET
STATUTE MILES
PLATE 6
1916 8th Ed., Oct. 17/92


RAPIDE CROCHE PROJECT
KAUKAUNA ELEC. & WATER DEPT.
FERC NO. 2677
WRIGHTSTOWN
RAPIDE CROCHE LOCK
DEPTH OVER SILL 6 FEET
WIDTH 35 FEET
LENGTH 144 FEET
Dam
Kaukauna Electrical and Water Dept.
OVHD CAB
SPIRE
TANK
JOINS 30
JOINS 28
MAGNETIC
VAR 1°45'W (1992)
ANNUAL INCREASE 5'
Plum
Creek
LOWER FOX RIVER
Scale 1:15,000
SOUNDINGS IN FEET
FEET
STATUTE MILES
PLATE 8
14916 8th Ed., Oct. 17/92



LOWER FOX RIVER
Scale 1:15,000
SOUNDINGS IN FEET
FEET
STATUTE MILES
LOST DAUPHIN STATE PARK
STACK
SILOS
SOUTHERN OF 4
LITTLE RAPIDS
OVHD PWR CAB CL 83 FT REP
OVHD PWR CAB CL 85 FT REP
LITTLE KAUKAUNA LOCK DEPTH OVER SILL 6 FEET WIDTH 35 FEET LENGTH 144 FEET
OVHD PWR CAB CL 73 FT REP
Dam
LITTLE KAUKAUNA DAM
MAGNETIC
ANNUAL INCREASE 5'
Apple Creek
SILO
OVHD CAB
TANK
OVHD PWR CAB CL 80 FT REP
BASCULE BRIDGE HOR CL 70 FT VERT CL 18 FT REP
WRIGHTSTOWN
JOINS 29
14916 8th Ed., Oct. 17/92
JOINS UPPER LEFT
PLATE 9



JOINS 30 14916 8th Ed., Oct. 17/92

JOINS UPPER LEFT

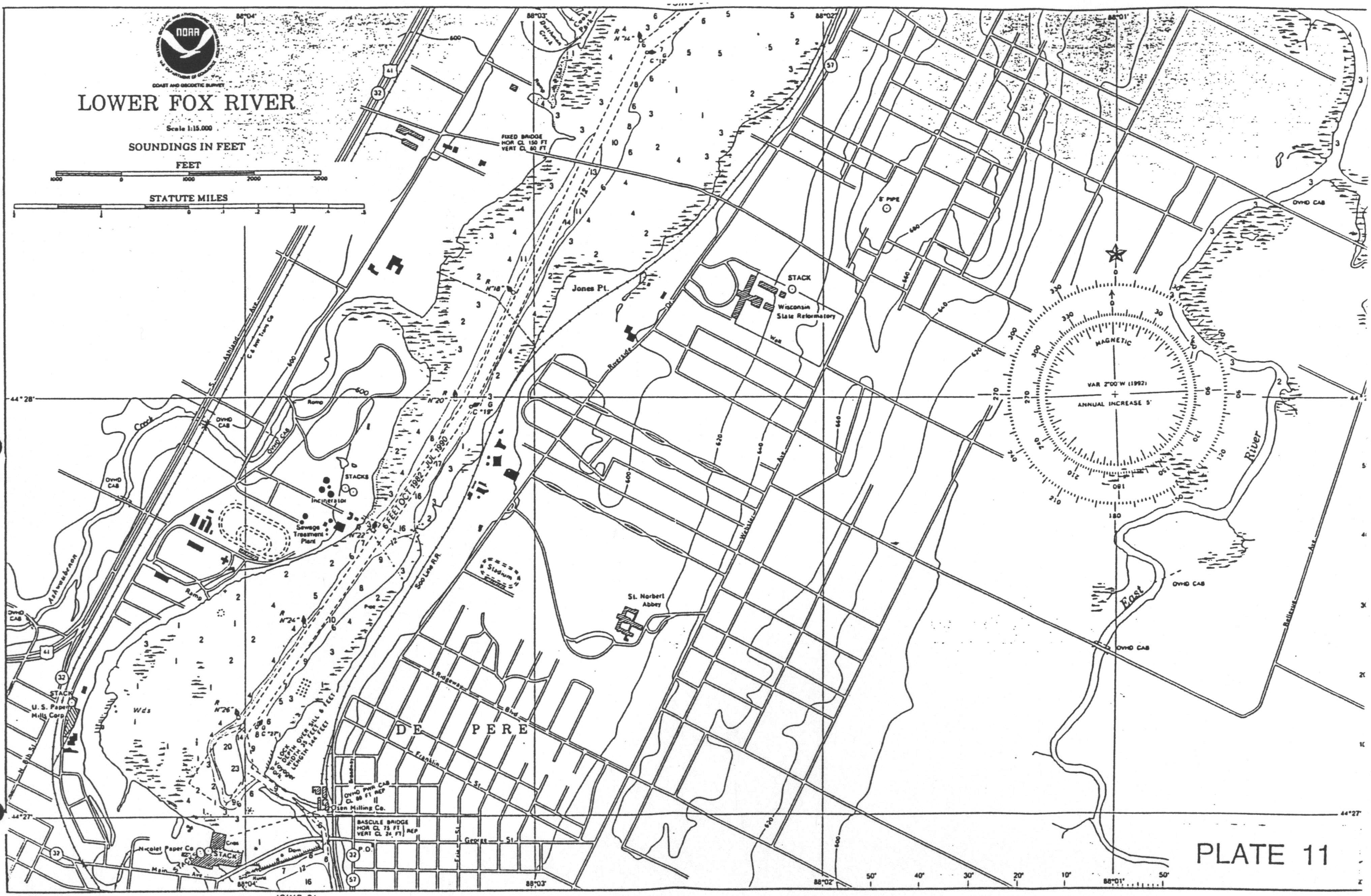
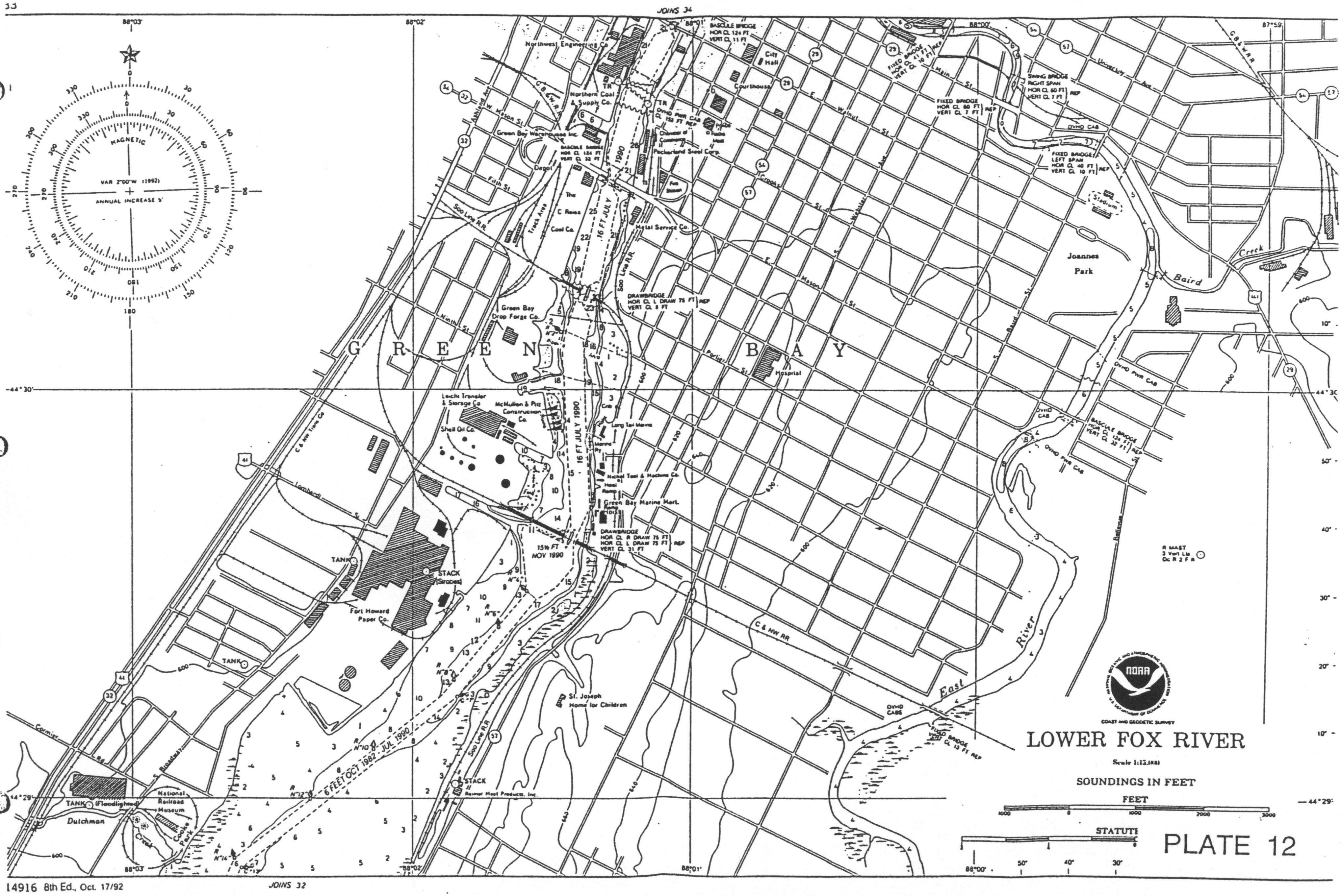
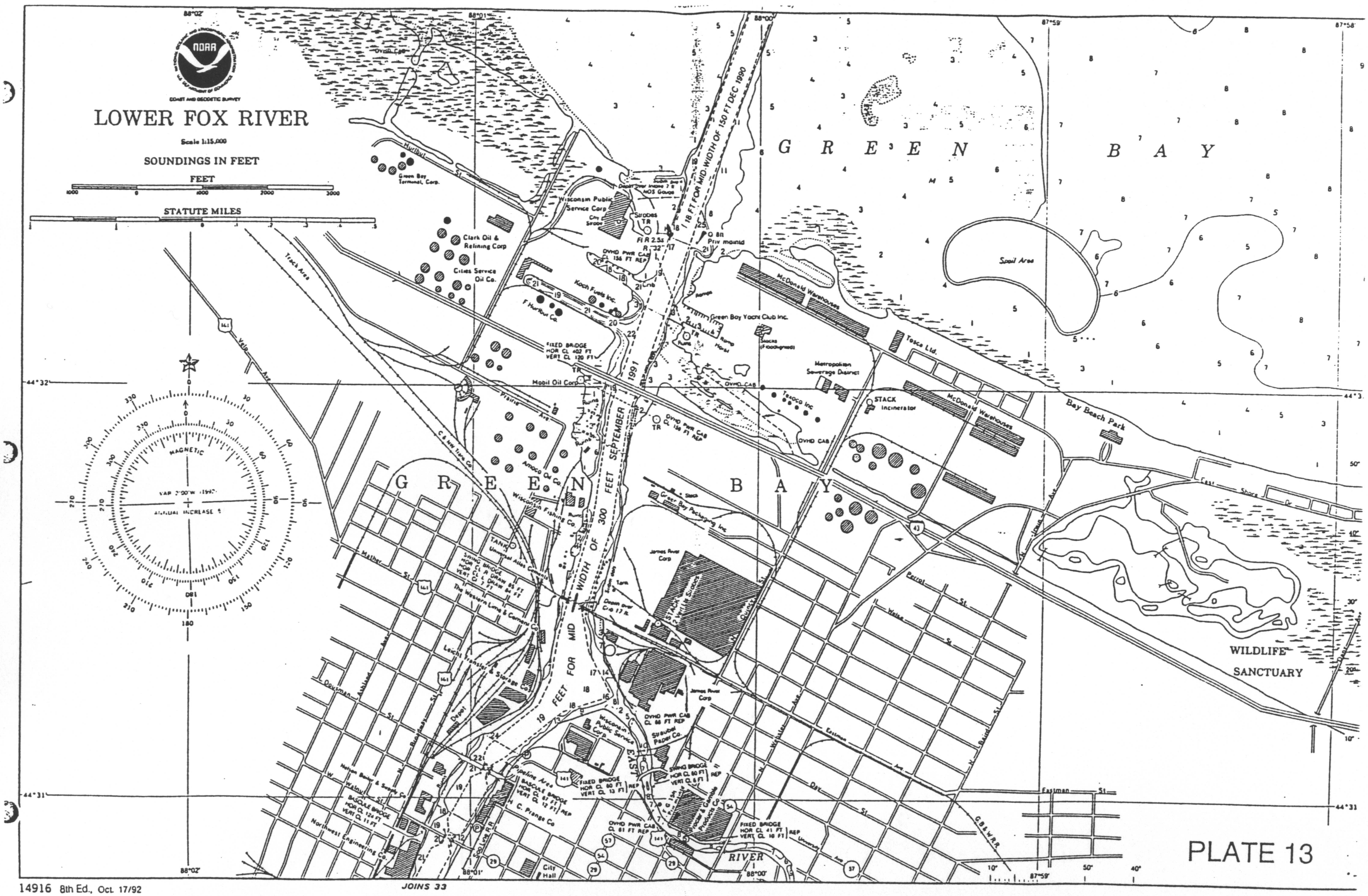


PLATE 11

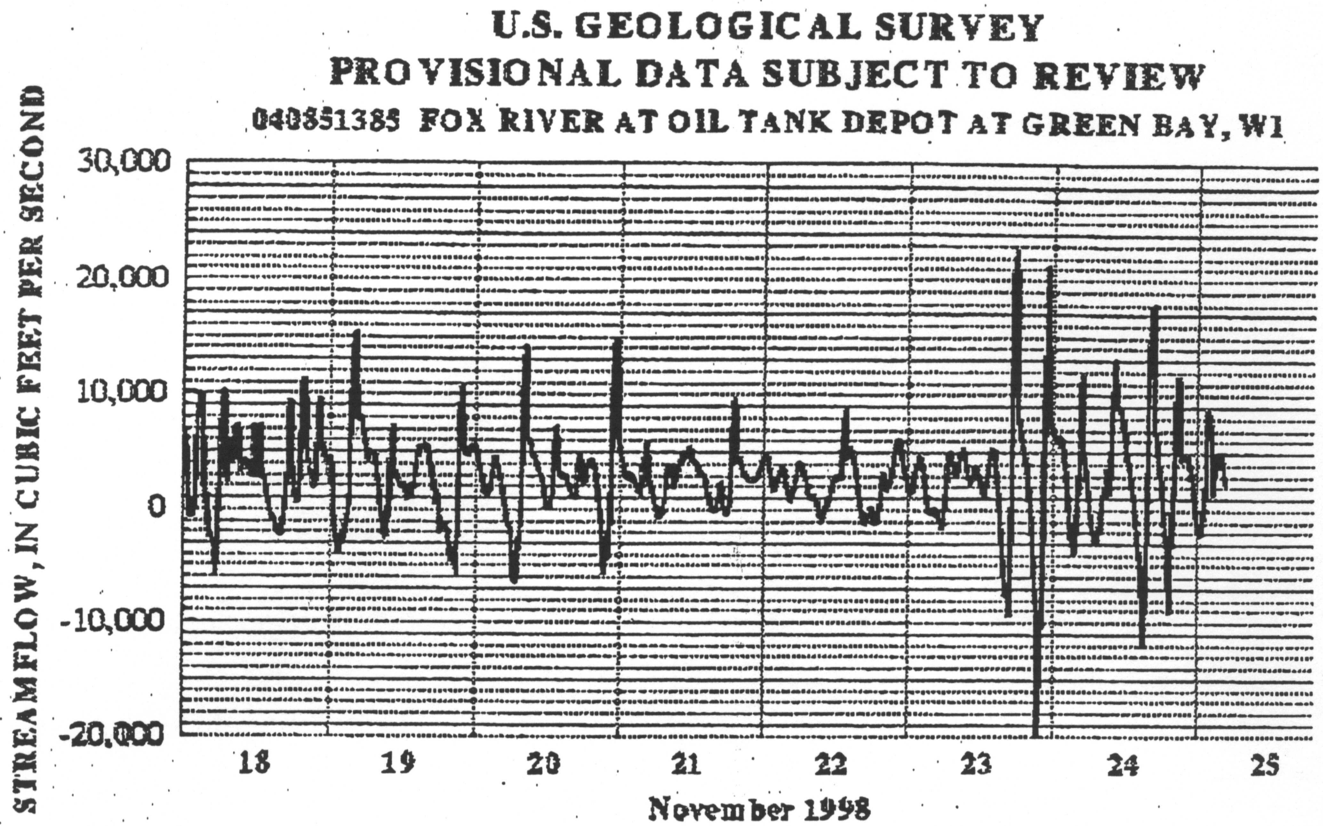
14916 8th Ed., Oct. 17/92


JOINS 34
LOWER FOX RIVER
Scale 1:15,000
SOUNDINGS IN FEET
FEET
STATUTE
PLATE 12
COAST AND GEODETIC SURVEY
GREEN BAY
East River
Baird Creek
Dutchman Creek
Joannes Park
Stadium
Hospital
City Hall
Courthouse
St. Joseph Home for Children
National Railroad Museum
Fort Howard Paper Co.
Green Bay Drop Forge Co.
Northwest Engineering Co.
Northern Coal & Supply Co.
Green Bay Warehouses Inc.
Packerland Steel Corp.
Metal Service Co.
C. Reiss Coal Co.
Leicht Transfer & Storage Co.
McMullen & Pitz Construction Co.
Shell Oil Co.
Nichol Tool & Machine Co.
Green Bay Marine Mart.
Reimer Meat Products, Inc.
BASCULE BRIDGE HOR CL 124 FT VERT CL 11 FT
BASCULE BRIDGE HOR CL 124 FT VERT CL 32 FT
DRAWBRIDGE HOR CL L DRAW 75 FT VERT CL 8 FT REP
DRAWBRIDGE HOR CL R DRAW 75 FT HOR CL L DRAW 75 FT VERT CL 21 FT REP
FIXED BRIDGE HOR CL 60 FT VERT CL 7 FT REP
SWING BRIDGE RIGHT SPAN HOR CL 60 FT VERT CL 7 FT REP
FIXED BRIDGE LEFT SPAN HOR CL 40 FT VERT CL 10 FT REP
BASCULE BRIDGE HOR CL 124 FT VERT CL 32 FT REP
FIXED BRIDGE VERT CL 13 FT REP
16 FT JULY 1990
15½ FT NOV 1990
6 FEET OCT 1982 JUL 1990
R MAST 3 Vert Lts Oc R 2 F R
VAR 2°00'W (1992) ANNUAL INCREASE 5'
MAGNETIC
88°03'
88°02'
88°01'
88°00'
87°59'
44°30'
44°29'
JOINS 32


LOWER FOX RIVER
Scale 1:15,000
SOUNDINGS IN FEET
FEET
STATUTE MILES
GREEN BAY
GREEN BAY
18 FT FOR MID WIDTH OF 150 FT DEC 1990
WIDTH OF 300 FEET SEPTEMBER 1991
19 FEET FOR MID
Spoil Area
McDonald Warehouses
Tosca Ltd.
Green Bay Yacht Club Inc.
Metropolitan Sewerage District
Texaco Inc
STACK Incinerator
Bay Beach Park
East Shore Dr
WILDLIFE SANCTUARY
Wisconsin Public Service Corp
Clark Oil & Refining Corp
Cities Service Oil Co.
Koch Fuels Inc.
Green Bay Terminal Corp.
Hurlbut St
FIXED BRIDGE HOR CL 402 FT VERT CL 120 FT
Mobil Oil Corp
Amoco Oil Co.
Wisconsin Fishing Co.
Green Bay Packaging Inc
James River Corp
Universal Atlas Cement
The Western Lime & Cement Co
Leicht Transfer & Storage Co
Pipeline Area
H. C. Prange Co
Northwest Engineering Co.
City Hall
Straubel Paper Co.
Procter & Gamble Products Co.
Mather St
Dousman St
Walnut St
Eastman Ave
Day St
Perrot St
Willow St
Webster Ave
University Ave
G B & W RR
RIVER
EAST
PLATE 13
14916 8th Ed., Oct. 17/92
JOINS 33

APPENDIX F

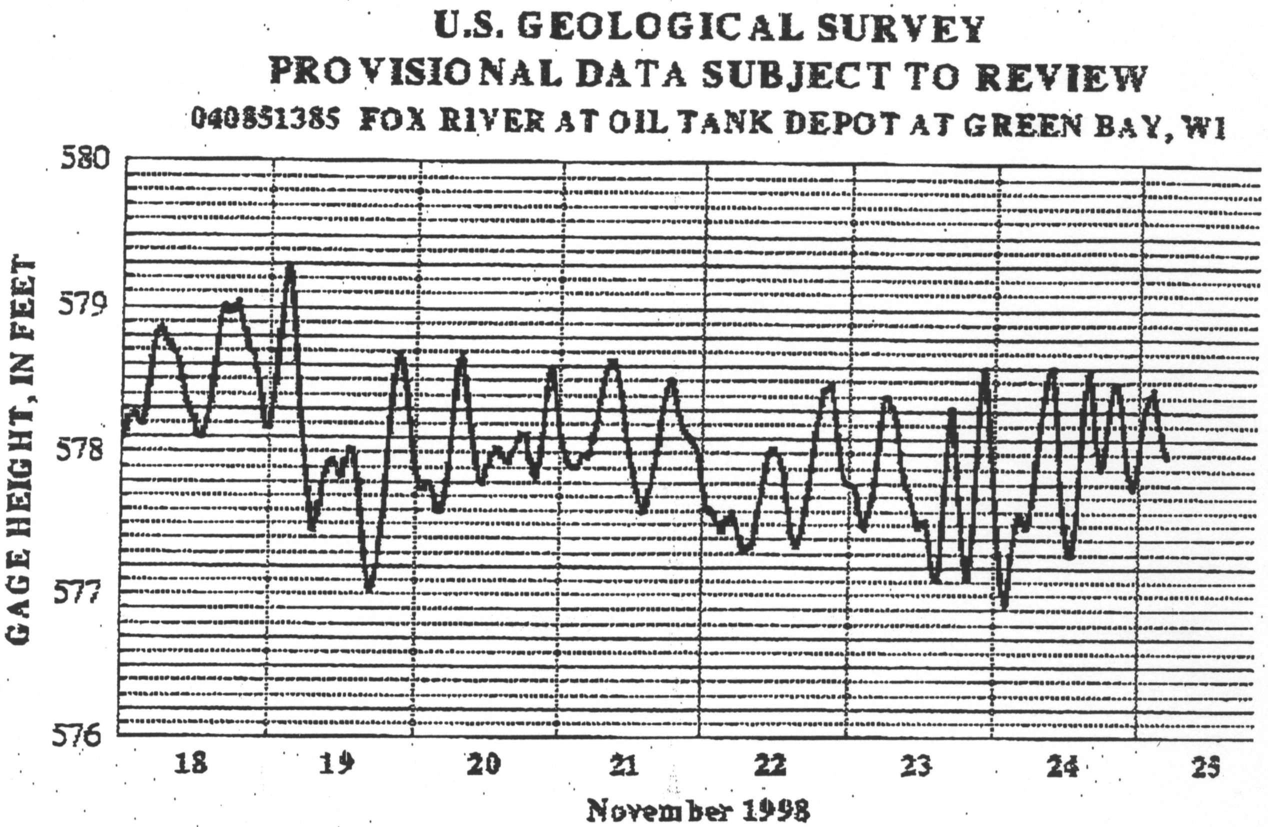
THE USGS HYDROGRAPHS FOR TWO STORM EVENTS IN NOVEMBER 1998



Updated: 11-25-98 08:02

↑ High flow associated with rapid seiche activity

218871

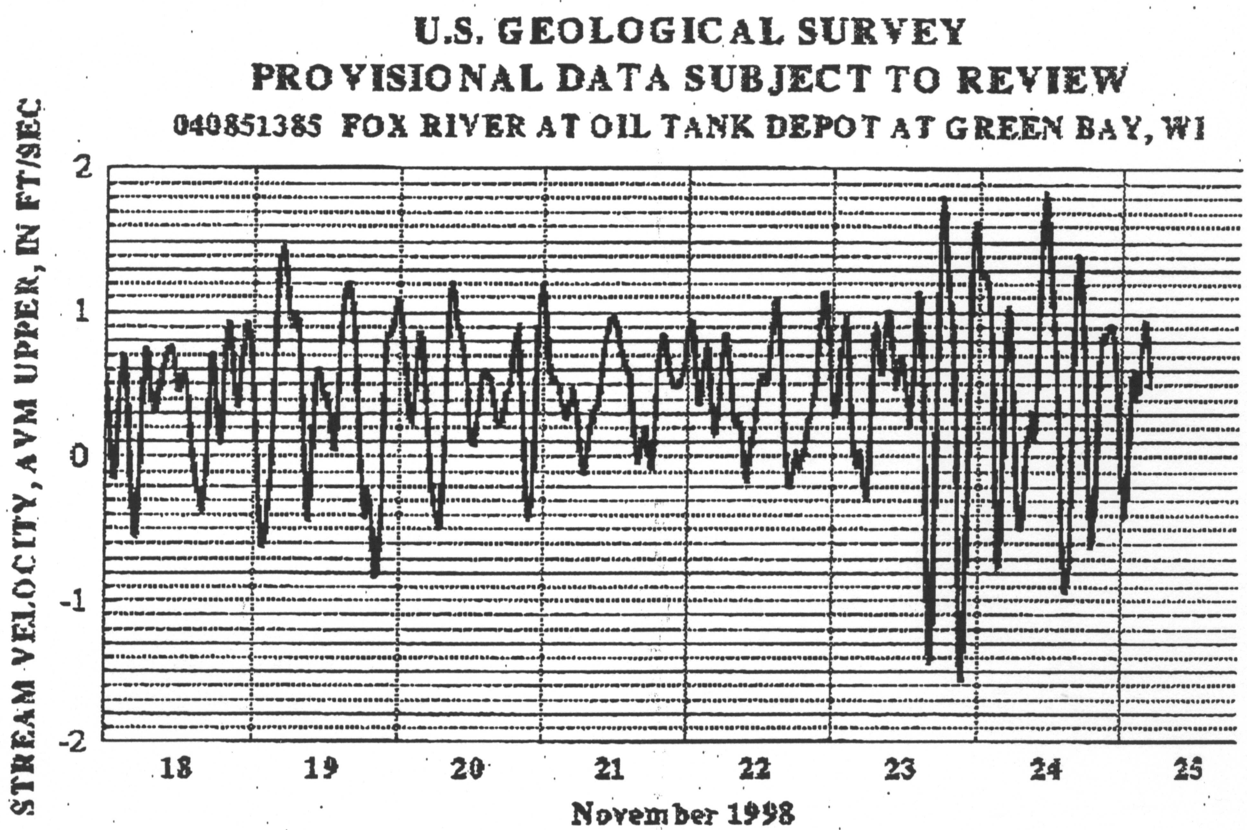


Updated: 11-25-98 07:17

↑

Rapid Seiche activity

218870



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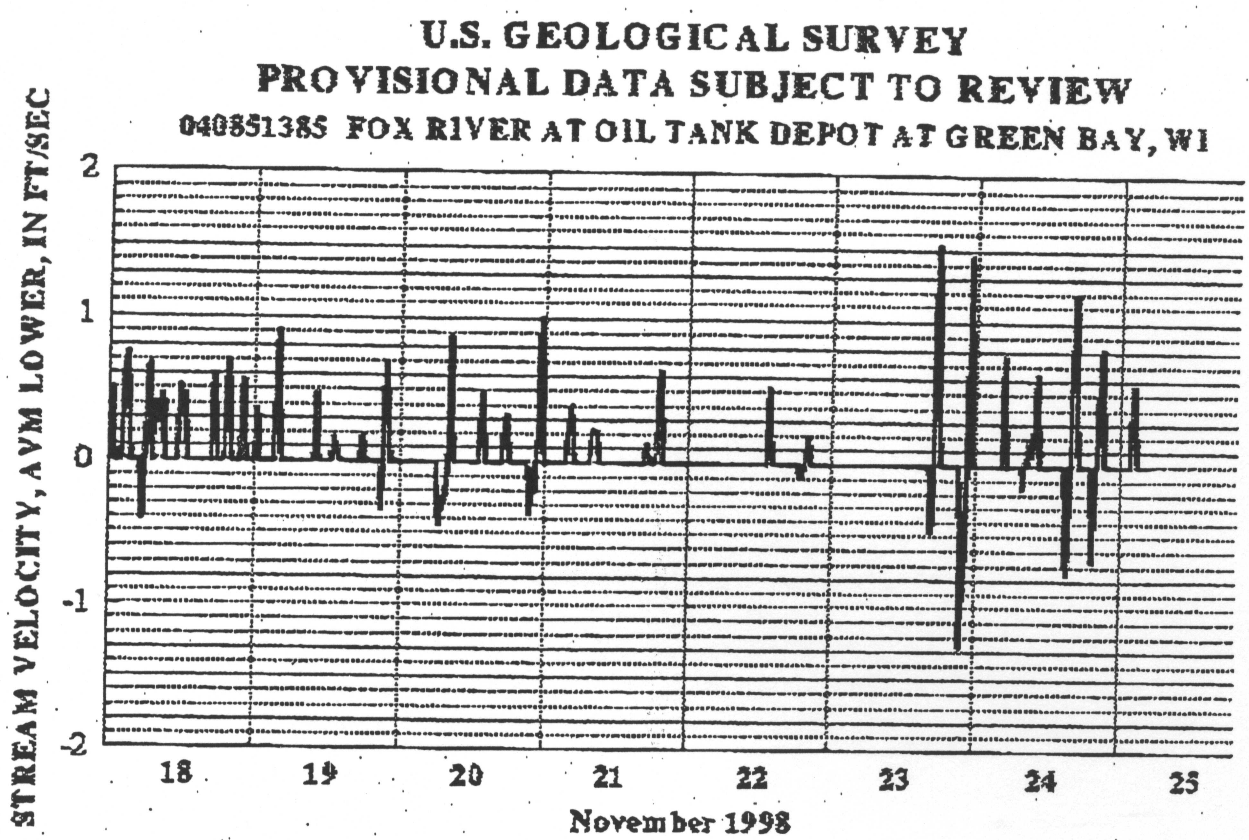
218869



Updated: 11-25-98 08:04

Map of region surrounding station

STATION.-- 040851385 FOX RIVER AT OIL TANK DEPOT AT GREEN BAY, WI

LOCATION.--Lat 44°31'43", long 88°01'12" in section 25, T.24 N., R.20 E., Brown County, Hydrologic Unit 04030204, about 0.5 mi upstream of Interstate Highway 43 bridge in Green Bay, and 0.8 mi upstream from mouth.

DRAINAGE AREA.--6,330 square miles.

PERIOD OF RECORD.--October 1988 to current year.

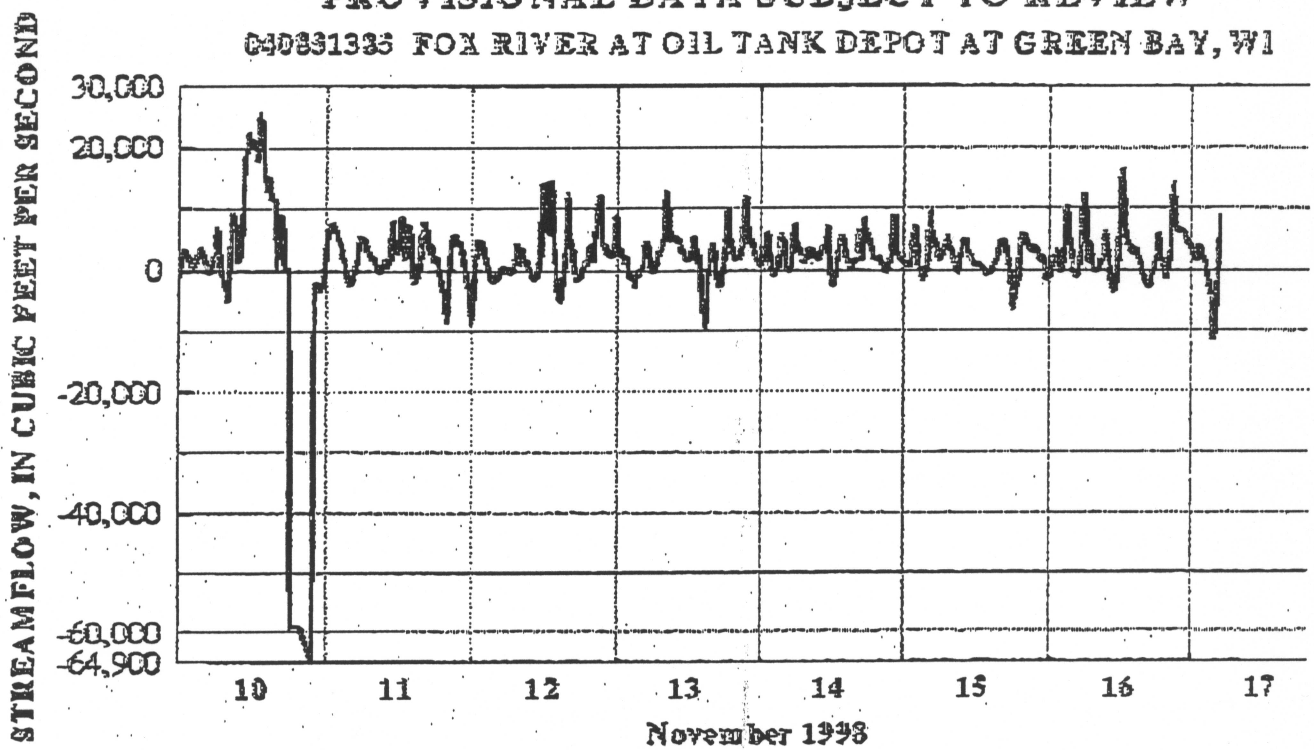
GAGE.--Acoustical Velocity Meter (AVM) system. Two-path transducer installation.

REMARKS.--Gage-height telemeter at station.

Retrieve postscript of discharge hydrograph or retrieve postscript of gage height hydrograph or retrieve postscript of velocity (upper avm) hydrograph or retrieve postscript of velocity (lower avm) hydrograph or complete station data from the 1997 Water Resources Data Report

218868

U.S. GEOLOGICAL SURVEY
PROVISIONAL DATA SUBJECT TO REVIEW
040851385 FOX RIVER AT OIL TANK DEPOT AT GREEN BAY, WI

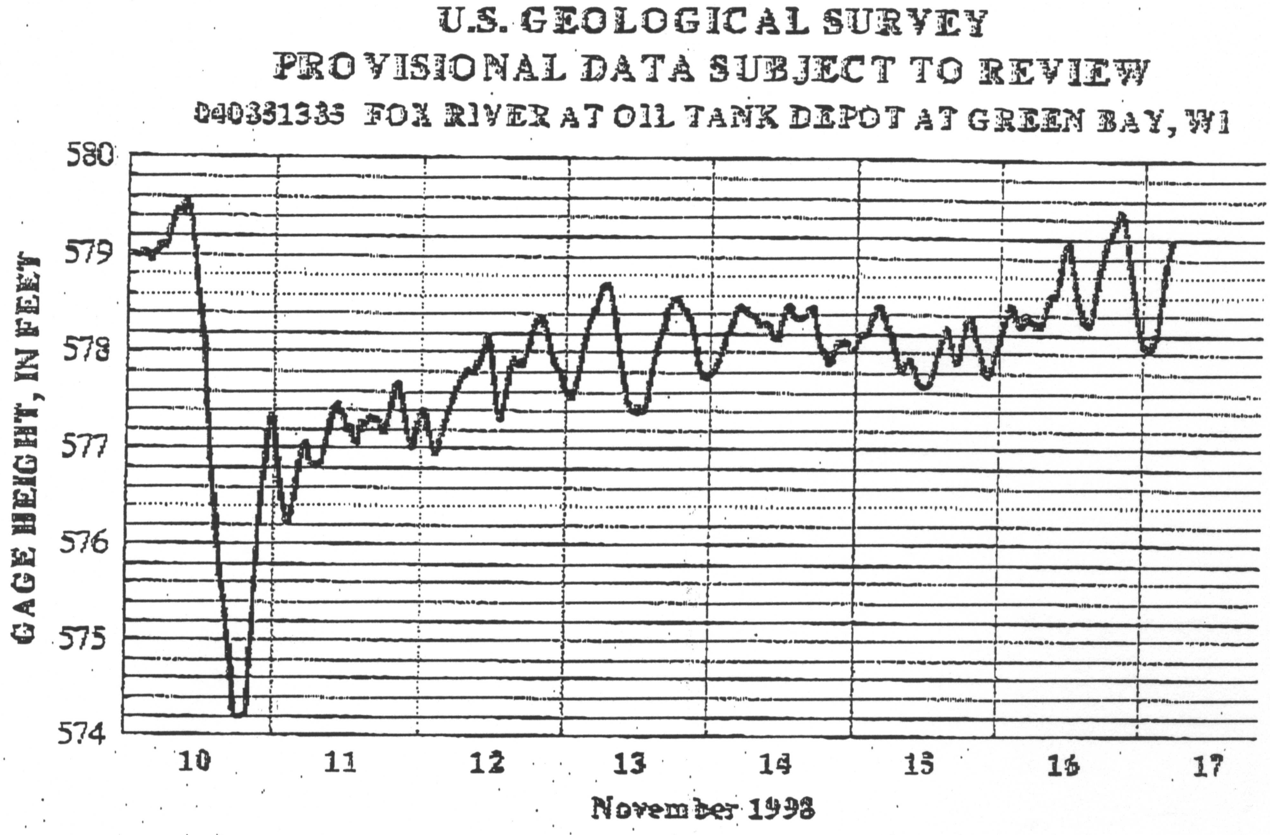


Updated: 11-17-98 07:52

↑

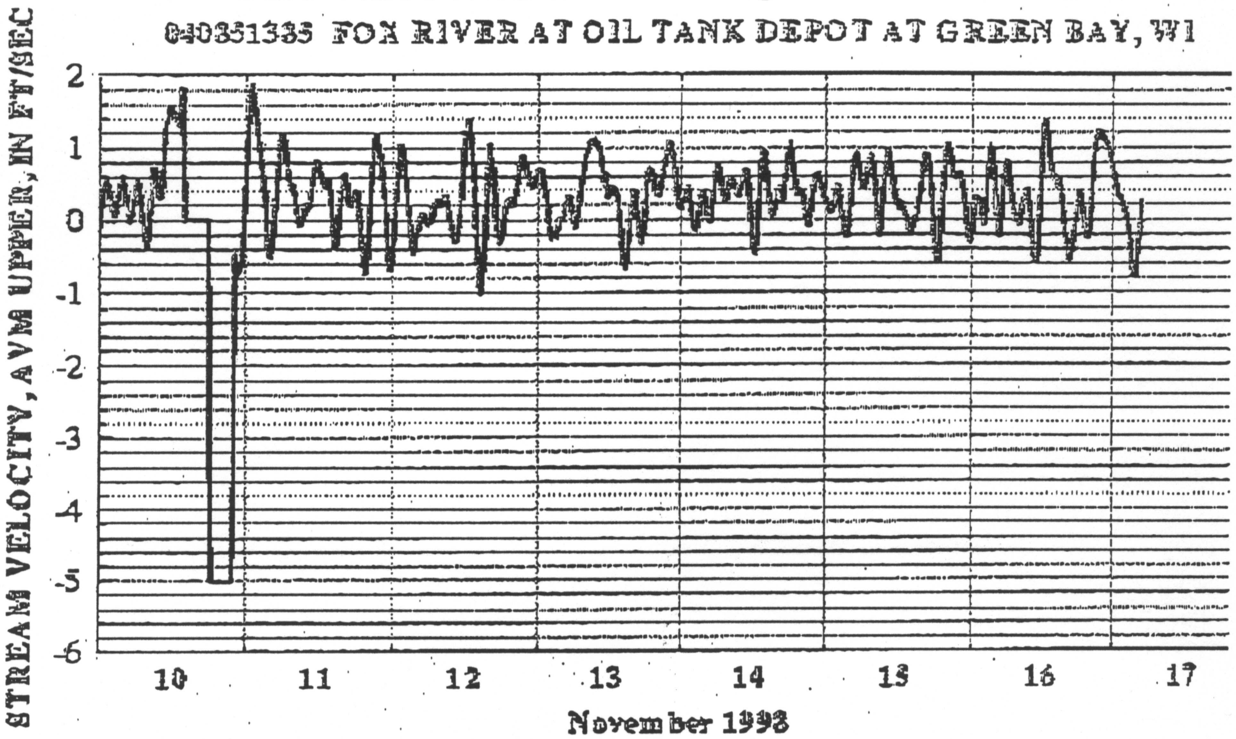
* 11/10/98
Storm force winds, southerly;
with strong Low barometric pressure.

218712



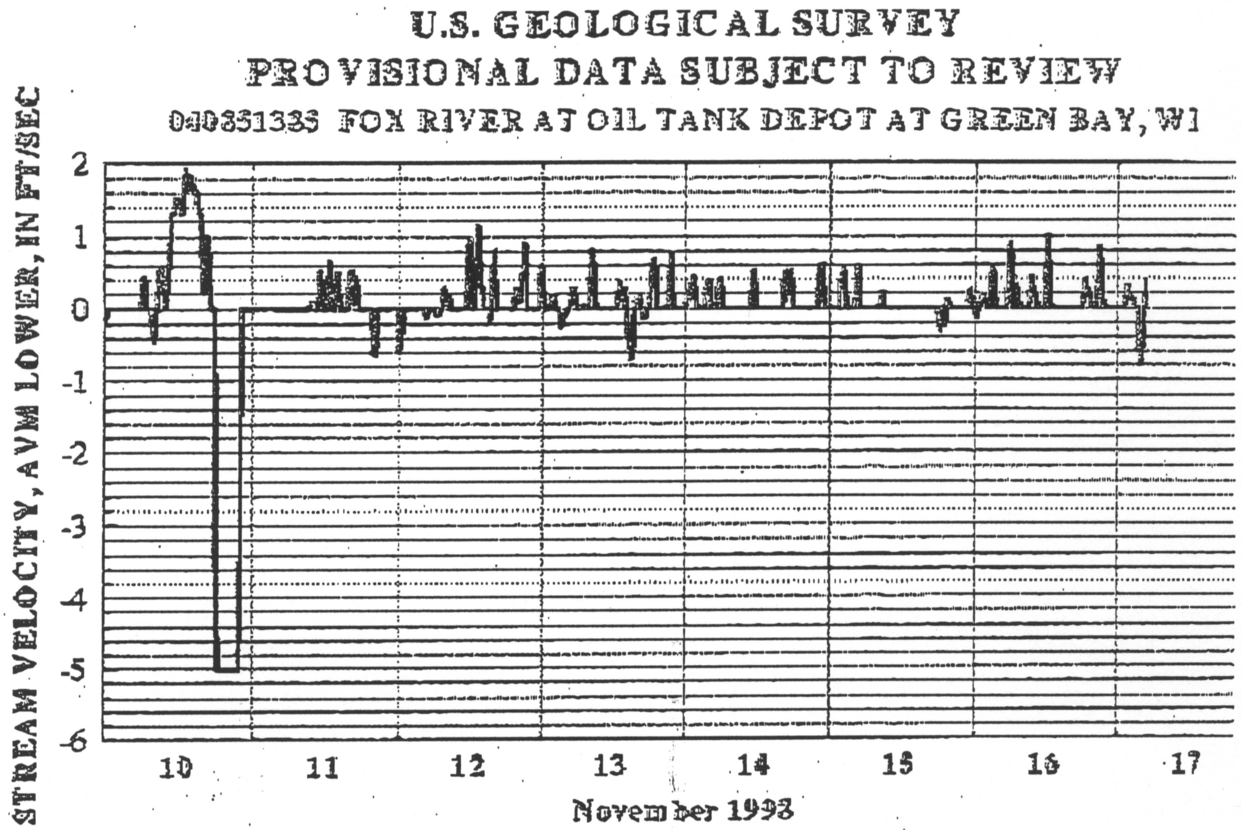
Updated: 11-17-98 07:11

U.S. GEOLOGICAL SURVEY
PROVISIONAL DATA SUBJECT TO REVIEW
040851335 FOX RIVER AT OIL TANK DEPOT AT GREEN BAY, WI



Updated: 11-17-98 07:53

218710



Updated: 11-17-98 07:53

Map of region surrounding station

STATION.-- 040851385 FOX RIVER AT OIL TANK DEPOT AT GREEN BAY, WI

LOCATION.--Lat 44°31'43", long 88°01'12" in section 25, T.24 N., R.20 Brown County, Hydrologic Unit 04030204, about 0.5 mi upstream of I Highway 43 bridge in Green Bay, and 0.8 mi upstream from mouth.

DRAINAGE AREA.--6,330 square miles.

PERIOD OF RECORD.--October 1988 to current year.

218709

APPENDIX G

PHYSICAL PARAMETERS TABLES

Appendix G - Table 1
Lower Fox River Grain Size Results

Deposit or SMU Group	Grain Size Averages			
	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
Lake Winnebago	0.0	14.0	48.7	37.3
Little Lake Butte Des Morts Reach				
Deposit A	0.0	37.5	45.2	17.3
Deposit B	0.0	64.7	25.1	10.1
Deposit C	0.0	26.1	53.8	20.1
Deposit POG	2.2	57.4	34.4	6.0
Deposit D	0.3	43.8	44.1	11.9
Deposit E	0.1	27.7	50.5	21.8
Deposit F	0.0	27.1	50.8	22.1
Deposit G	0.0	55.7	31.0	13.3
Deposit H	0.0	67.7	20.3	12.0
Interdeposit Areas	3.2	49.3	35.6	12.0
Reach Average	**0.6**	**45.7**	**39.1**	**14.7**
Appleton to Little Rapids Reach				
Deposit I	0.0	35.0	45.3	19.8
Deposit J	0.0	15.0	65.7	19.3
Deposit K	0.0	62.7	22.3	15.0
Deposit L	0.0	45.3	34.0	20.8
Deposit M	0.0	7.3	63.3	29.3
Deposit N	0.5	41.1	46.9	11.6
Deposit O	0.0	39.4	43.6	17.0
Deposit P	0.0	36.0	49.6	14.4
Deposit Q	0.0	49.0	39.7	11.3
Deposit R	0.0	12.0	56.0	32.0
Deposit S	0.0	46.5	36.0	17.5
Deposit T	0.0	87.7	7.3	5.0
Deposit U	0.0	51.8	35.8	12.5
Deposit V	0.0	32.2	52.0	15.8
Deposit W	0.0	50.1	32.5	17.4
Deposit X	0.0	33.2	52.8	14.0
Deposit Y	0.0	45.0	39.7	15.3
Deposit Z	0.0	34.7	42.7	22.7
Deposit AA	0.0	54.7	20.7	24.7
Deposit BB	0.0	47.7	33.0	19.3
Deposit CC	0.0	31.3	26.0	42.7
Deposit DD	0.0	32.6	42.1	25.3
Interdeposit Areas	NA	NA	NA	NA
Reach Average	**0.0**	**40.5**	**40.3**	**19.2**

Appendix G - Table 1
Lower Fox River Grain Size Results

Deposit or SMU Group	Grain Size Averages			
	Gravel (%)	Sand (%)	Silt (%)	Clay (%)
Little Rapids to DePere Reach				
Deposit EE	0.5	26.8	49.7	23.0
Deposit FF	0.0	27.2	51.6	21.1
Deposit GG	1.3	18.0	57.6	23.1
Deposit HH	2.9	21.7	57.1	18.4
Interdeposit Areas	3.7	31.9	24.3	40.1
Reach Average	**1.2**	**23.4**	**54.0**	**21.4**
DePere to Green Bay Reach				
SMU 20 to 25	0.0	42.3	42.5	15.2
SMU 26 to 31	0.0	50.8	34.5	14.7
SMU 32 to 37	0.0	31.8	49.9	18.3
SMU 38 to 43	0.0	34.5	47.4	18.1
SMU 44 to 49	0.0	37.8	44.6	17.6
SMU 50 to 55	0.0	40.5	44.2	15.3
SMU 56 to 61	0.0	32.1	51.9	16.0
SMU 62 to 67	0.0	29.8	51.7	18.6
SMU 68 to 73	0.5	34.8	41.6	23.1
SMU 74 to 79	0.0	34.8	42.2	23.0
SMU 80 to 85	0.0	45.4	36.8	17.8
SMU 86 to 91	0.0	45.5	37.6	17.0
SMU 92 to 97	0.0	60.3	27.9	11.8
SMU 98 to 103	0.0	73.2	17.8	9.0
SMU 104 to 109	0.0	41.7	40.5	17.8
SMU 110 to 115	0.0	44.2	38.9	16.9
Reach Average	**0.0**	**42.5**	**40.6**	**16.9**
Lower Fox River Average Values	**0.5**	**38.0**	**43.5**	**18.0**

Appendix G - Table 2
Green Bay Grain Size Results

Green Bay Zone	Sample Label	Gravel	Sand	Silt	Clay
Zone 2 (2A & 2B)	S00030	0.0%	64.8%	30.7%	4.5%
Zone 2 (2A & 2B)	S00031	0.1%	93.1%	2.3%	4.5%
Zone 2 (2A & 2B)	S00032	0.0%	98.6%	0.0%	1.4%
Zone 2 (2A & 2B)	S00037	0.0%	70.4%	17.6%	12.0%
Zone 2 (2A & 2B)	S00038	0.7%	69.1%	23.7%	6.5%
Zone 2 (2A & 2B)	S00039	0.0%	65.8%	20.2%	14.0%
Zone 2 (2A & 2B)	S00040	0.0%	51.6%	29.4%	19.0%
Zone 2 (2A & 2B)	S00056	0.1%	90.9%	4.5%	4.5%
Zone 2 (2A & 2B)	S00057	0.0%	61.8%	32.2%	6.0%
Zone 2 (2A & 2B)	S00058	0.1%	67.8%	18.1%	14.0%
Zone 2 (2A & 2B)	S00063	0.2%	72.5%	19.3%	8.0%
Zone 2 Averages		**0.1%**	**73.3%**	**18.0%**	**8.6%**
Zone 3A	S00042	0.0%	99.2%	0.8%	0.0%
Zone 3A	S00043	0.0%	97.6%	0.7%	1.7%
Zone 3A Averages		**0.0%**	**98.4%**	**0.8%**	**0.9%**
Zone 3B	S00041	0.0%	83.3%	10.2%	6.5%
Zone 3B	S00047	0.0%	73.1%	20.9%	6.0%
Zone 3B	S00048	0.0%	66.3%	21.7%	12.0%
Zone 3B	S00054	0.2%	27.9%	46.9%	25.0%
Zone 3B Averages		**0.1%**	**62.7%**	**24.9%**	**12.4%**
Zone 4	S00044	3.0%	96.1%	0.9%	0.0%
Zone 4	S00045	0.0%	92.9%	5.3%	1.8%
Zone 4	S00046	0.8%	97.7%	1.5%	0.0%
Zone 4	S00055	1.6%	98.4%	0.0%	0.0%
Zone 4 Averages		**1.4%**	**96.3%**	**1.9%**	**0.5%**
Green Bay Average		**0.3%**	**78.0%**	**14.6%**	**7.0%**

Notes: 1) All samples collected from 0 to 10 cm.

Appendix G - Table 3
Lower Fox River - Atterberg Limits

Deposit or SMU	Sample Label	Sample Depth (cm)	Liquid Limit	Plastic Limit	Plasticity Index	Plasticity Index
Little Lake Butte des Morts Reach						
Deposit A	BA-SD01e	61 - 79	74	N/A	49	na
Deposit A	BA-SD02d	48 - 58	50	N/A	26	na
Deposit A	BA-SD03comp	0 - 30	148	N/A	84	na
Deposit A	BA-SD04c	30 - 43	178	N/A	65	na
Deposit A	BA-SD04d	43 - 53	46	N/A	26	na
Deposit A	BA-SD08d	45 - 61	35	N/A	18	na
Deposit C	SDC-C-1-G	5 - 35	113.4	51.4	62	MH
Deposit C	SDC-C-4-G	5 - 35	186.3	61.3	125	MH
Deposit E	SDC-E-2-G	5 - 35	104.7	56.8	47.9	MH
Deposit E	SDC-E-5b-G	5 - 35	N/A	Non-Plastic	N/A	na
Deposit F	GT0110	0 - 182.9	114	64.3	49.7	na
Appleton to Little Rapids Reach						
Deposit W	SDC-W-2-G	5 - 35	71.1	37.2	33.9	MH
Deposit W	SDC-W-5-G	5 - 35	106.9	58.9	48	MH
Deposit X	GT0143	0 - 195.1	92.6	52.9	39.7	na
Deposit X	GT0144	0 - 195.1	83.3	44.9	38.4	na
Deposit X	SDC-X-1-G	5 - 35	N/A	Non-Plastic	N/A	MH
Deposit X	SDC-X-2-G	5 - 35	73.4	52.6	20.8	CH
Little Rapids to De Pere Reach						
Deposit EE	GT0125	0 - 182.9	73.2	36.6	36.6	na
Deposit EE	SDC-EE22-3-G	5 - 35	61.3	30.3	31	CH
Deposit EE	SDC-EE22-4-G	5 - 35	85	45.1	39.9	MH
Deposit EE	SDC-EE23-1-G	5 - 35	N/A	Non-Plastic	N/A	na
Deposit EE	SDC-EE23-4-G	5 - 35	144	45.9	98.1	MH
Deposit EE	SDC-EE24-1-G	5 - 35	92.5	45.2	47.3	MH
Deposit EE	SDC-EE24-3-G	5 - 32	76.6	39.7	36.9	MH
Deposit EE	SDC-EE25-2-G	5 - 35	93.4	50	43.4	MH
Deposit EE	SDC-EE25-3-G	5 - 35	176.7	113.4	63.3	MH
Deposit EE	SDC-EE26-2-G	5 - 35	88.8	48.5	40.3	MH
Deposit EE	SDC-EE26-5-G	5 - 35	89.5	44	45.5	MH
Deposit GG	GT0068	0 - 182.9	89.4	45.1	44.3	na
Deposit HH	GT0079	0 - 182.9	85.4	44.5	40.9	na
De Pere to Green Bay Reach						
SMU 20	GT0005	0 - 173.7	94.3	47	47.3	na
SMU 20	SDC-DPD-2-G	5 - 35	95	49.5	45.5	MH
SMU 24	GT0013	0 - 185.9	97.3	53	44.3	na
SMU 41	GT0036	0 - 182.9	37.7	21.5	16.2	na
SMU 45	GT0048	0 - 195.1	68.9	33.5	35.4	na
SMU 45	SDC-DPD-3-G	5 - 35	156.9	109.6	47.3	MH
SMU 48	GT0040	0 - 182.9	44.6	23.6	21	na
SMU 62	GT0052	0 - 213.4	89	47.6	41.4	na

Notes:

1. Atterberg Limits testing performed according to ASTM D-4318.
2. Samples listed as non-plastic could not be cut with the grooving tool without tearing or slipping in the cup. Every effort was made to test these samples, but a liquid limit could not be determined.
3. Classifications are based on ASTM D-2487. The samples were visually determined to be organic. Samples classified as "na" were not determined by the laboratory.

Appendix G - Table 4
Lower Fox River & Green Bay Maximum PCB Sampling Depth and Deposit/SMU Area

Deposit/SMU Group	Maximum PCB Sampling Depth		Sediment Area	
	(m)	(ft)	(hectares)	(acres)
LLBdM				
Deposit A	1.80	5.90	15.26	37.71
Deposit B	0.43	1.41	14.74	36.42
Deposit C	0.91	2.98	12.36	30.54
Deposit POG	1.89	6.20	21.32	52.68
Deposit D	1.22	4.00	25.24	62.37
Deposit E	1.74	5.71	202.51	500.41
Deposit F	1.83	6.00	16.91	41.79
Deposit G	0.30	0.98	4.11	10.16
Deposit H	0.38	1.25	1.08	2.67
Reach Totals	**na**	**na**	**313.53**	**774.75**
Appleton-Little Rapids				
Deposit I	0.54	1.77	2.98	7.36
Deposit J	0.42	1.38	2.51	6.20
Deposit K	0.21	0.69	0.53	1.31
Deposit L	0.30	0.98	1.06	2.62
Deposit M	0.36	1.18	1.33	3.29
Deposit N	0.89	2.92	2.25	5.56
Deposit O	0.35	1.15	1.85	4.57
Deposit P	0.94	3.08	3.14	7.76
Deposit Q	0.55	1.80	0.42	1.04
Deposit R	0.13	0.43	0.77	1.90
Deposit S	0.34	1.12	16.64	41.12
Deposit T	0.52	1.71	2.08	5.14
Deposit U	0.26	0.85	1.74	4.30
Deposit V	0.63	2.07	2.41	5.96
Deposit W	1.52	4.99	56.41	139.39
Deposit X	1.83	6.00	25.60	63.26
Deposit Y	0.34	1.12	3.19	7.88
Deposit Z	0.83	2.72	2.44	6.03
Deposit AA	0.35	1.15	0.81	2.00
Deposit BB	0.39	1.28	1.58	3.90
Deposit CC	0.43	1.41	8.47	20.93
Deposit DD	0.53	1.74	14.92	36.87
Reach Totals	**NA**	**NA**	**153.13**	**378.39**

Appendix G - Table 4
Lower Fox River & Green Bay Maximum PCB Sampling Depth and Deposit/SMU Area

Deposit/SMU Group	Maximum PCB Sampling Depth		Sediment Area	
	(m)	(ft)	(hectares)	(acres)
Little Rapids to De Pere				
Deposit EE	2.30	7.54	258.81	639.53
Deposit FF	0.46	1.51	0.49	1.21
Deposit GG	2.30	7.54	2.40	5.93
Deposit HH	2.30	7.54	4.46	11.02
Reach Totals	**NA**	**NA**	**266.16**	**657.69**
De Pere to Green Bay				
SMU 20-25	2.13	6.99	113.39	280.19
SMU 26-31	2.13	6.99	22.04	54.46
SMU 32-37	2.74	8.99	26.78	66.17
SMU 38-43	2.74	8.99	46.46	114.80
SMU 44-49	3.35	10.99	107.15	264.77
SMU 50-55	1.52	4.99	32.91	81.32
SMU 56-61	3.96	12.99	29.66	73.29
SMU 62-67	2.13	6.99	18.22	45.02
SMU 68-73	2.74	8.99	21.58	53.33
SMU 74-79	1.52	4.99	11.81	29.18
SMU 80-85	2.13	6.99	10.62	26.24
SMU 86-91	2.13	6.99	11.27	27.85
SMU 92-97	0.91	2.98	19.76	48.83
SMU 98-103	0.91	2.98	14.00	34.59
SMU 104-109	0.30	0.98	17.02	42.06
SMU 110-115	1.52	4.99	20.82	51.45
Reach Totals	**NA**	**NA**	**523.49**	**1293.57**
Green Bay Zones				
Zone 2 (2A&2B)	0.91	2.98	11,081	27,382
Zone 3A	0.30	0.98	85,891	212,240
Zone 3B	0.62	2.03	69,339	171,340
Zone 4	0.30	0.98	254,977	630,059
Bay Totals	**NA**	**NA**	**421,288**	**1,041,021**

na - Total value result not applicable.

Appendix G - Table 5
Lower Fox River and Green Bay TOC and Bulk Density Results

Sampling Location	Average TOC Values	
	(mg/kg)	Percent
Lake Winnebago	78,000	7.80%
Little Lake Butte des Morts Reach		
Creek Trib.	31,000	3.10%
Deposit A	90,359	9.04%
Deposit B	26,064	2.61%
Deposit C	70,577	7.06%
Deposit POG	79,129	7.91%
Deposit D	54,863	5.49%
Deposit E	61,210	6.12%
Deposit F	122,917	12.29%
Deposit G	39,633	3.96%
Deposit H	37,100	3.71%
Reach Average	**64,650**	**6.47%**
Appleton to Little Rapids Reach		
Creek Trib.	12,600	1.26%
Deposit I	43,555	4.36%
Deposit J	35,300	3.53%
Deposit K	31,567	3.16%
Deposit L	24,920	2.49%
Deposit M	54,900	5.49%
Deposit N*	---	---
Deposit O	54,917	5.49%
Deposit P	43,109	4.31%
Deposit Q	73,360	7.34%
Deposit R	3,300	0.33%
Deposit S	80,300	8.03%
Deposit T	86,000	8.60%
Deposit U	45,033	4.50%
Deposit V	52,767	5.28%
Deposit W	38,005	3.80%
Deposit X	51,962	5.20%
Deposit Y	0	0.00%
Deposit Z	0	0.00%
Deposit AA	0	0.00%
Deposit BB	16,100	1.61%
Deposit CC	21,486	2.15%
Deposit DD	38,924	3.89%
Interdeposit	25,000	2.50%
Reach Average	**37,881**	**3.79%**

Sampling Location	Average TOC Values	
	(mg/kg)	Percent
Little Rapids to DePere Reach		
Creek Trib.	20,300	2.03%
Deposit EE	55,957	5.60%
Deposit FF	49,183	4.92%
Deposit GG	59,318	5.93%
Deposit HH	64,196	6.42%
Interdeposit	29,333	2.93%
Reach Average	**49,791**	**4.98%**
DePere to Green Bay Reach		
Past Mouth	45,826	4.58%
SMU 20-25	50,855	5.09%
SMU 26-31	36,761	3.68%
SMU 32-37	56,387	5.64%
SMU 38-43	45,921	4.59%
SMU 44-49	47,306	4.73%
SMU 50-55	37,107	3.71%
SMU 56-61	56,616	5.66%
SMU 62-67	66,420	6.64%
SMU 68-73	50,735	5.07%
SMU 74-79	50,979	5.10%
SMU 80-85	53,088	5.31%
SMU 86-91	47,022	4.70%
SMU 92-97	27,769	2.78%
SMU 98-103	20,543	2.05%
SMU 104-109	29,033	2.90%
SMU 110-115	46,474	4.65%
Reach Average	**45,188**	**4.52%**
Entire River Average	**49,378**	**4.94%**
Green Bay		
Zone 2 (2A & 2B)	14,845	1.48%
Zone 3A	1,900	0.19%
Zone 3B	23,325	2.33%
Zone 4	1,400	0.14%
Lake Michigan	3,461	0.35%
Other	83,600	8.36%
USGS Reference	56,800	5.68%

1) Reach and entire river averages do not include tributary results.
na - Parameter result not available.
* Data for Depsoit N is not included due to completion of the remediation demonstration project.

Appendix G - Table 6
Lower Fox River - Total Solids

Deposit/Interval	Average	Minimum	Maximum
Lake Winnebago	**14.07%**	**12.80%**	**15.70%**
Little Lake Butte Des Morts Reach			
Deposit A	36.80%	36.80%	82.50%
Deposit B	57.21%	26.80%	82.40%
Deposit C	31.60%	15.80%	76.30%
Deposit POG	32.09%	18.10%	67.00%
Deposit D	41.95%	21.50%	73.80%
Deposit E	37.78%	12.60%	71.30%
Deposit F	26.11%	17.10%	38.50%
Deposit G	47.40%	40.40%	56.80%
Deposit H	57.93%	54.70%	61.00%
Interdeposit	42.60%	19.20%	66.00%
Entire Reach	41.15%	12.60%	82.50%
Appleton to Little Rapids Reach			
Deposit I	50.18%	35.60%	81.40%
Deposit J	46.13%	43.20%	51.20%
Deposit K	51.00%	39.00%	61.70%
Deposit L	59.18%	47.70%	87.20%
Deposit M	35.73%	33.70%	37.60%
Deposit O	41.34%	33.30%	56.80%
Deposit P	42.21%	20.80%	72.70%
Deposit Q	37.49%	31.40%	42.10%
Deposit R	61.10%	61.10%	61.10%
Deposit S	47.60%	31.80%	63.40%
Deposit T	34.93%	22.90%	49.60%
Deposit U	47.78%	35.50%	79.80%
Deposit V	32.53%	26.50%	43.10%
Deposit W	44.05%	19.70%	75.10%
Deposit X	37.49%	21.00%	70.30%
Deposit Y	46.63%	36.80%	52.50%
Deposit Z	51.50%	46.30%	54.80%
Deposit AA	67.70%	62.60%	72.20%
Deposit BB	57.80%	43.50%	67.20%
Deposit CC	57.08%	35.70%	69.60%
Deposit DD	44.61%	19.90%	75.50%
Interdeposit	26.00%	26.00%	26.00%
Entire Reach	46.37%	19.70%	87.20%

Appendix G - Table 6

Lower Fox River - Total Solids, continued

Deposit/Interval	Average	Minimum	Maximum
Little Rapids to DePere Reach			
Deposit EE	37.07%	16.70%	88.20%
Deposit EG	42.60%	26.00%	69.70%
Deposit FF	45.14%	21.90%	86.10%
Deposit GG	36.36%	25.70%	85.90%
Deposit HH	36.70%	21.10%	85.80%
Interdeposit	36.03%	19.80%	76.30%
Entire Reach	38.98%	16.70%	88.20%
DePere to Green Bay Reach			
Less than 61 cm deep	35.70%	12.70%	80.20%
62 cm - 240 cm	45.60%	22.10%	81.70%
Entire Reach (all depths)	41.20%	12.70%	83.90%
Entire River			
Entire River	**44.40%**	**12.70%**	**88.20%**
Green Bay			
Zones 2A/2B	49.52%	30.10%	73.80%
Zone 3A	28.45%	2.60%	72.00%
Zone 3B	28.37%	15.10%	59.20%
Zone 4	72.58%	68.60%	77.60%
Entire Bay	44.73%	2.60%	77.60%

Notes: 1) All samples collected above 61 cm (2 ft) except in the De Pere to Green Bay Reach. These sample results were delineated to evaluate the solids content in the upper 61 cm of sediment.

Appendix G - Table 7
Lower Fox River - Bulk Density Results

Deposit/SMU	Sample Identification	Depth (cm)	Wet Density (g/cm^3)	Dry Density (g/cm^3)	Specific Gravity
Lake Winnebago					
	SDC-LW-1-P-S	0 - 5	NA	0.17	NA
	SDC-LW-2-P-S	0 - 5	NA	0.14	NA
	SDC-LW-3-P-S	0 - 5	NA	0.15	NA
Reach Average			---	0.15	---
LLBdM Reach					
A	2A1.1	0 - 5	NA	0.49	NA
A	2A1.2	5 - 15	NA	0.47	NA
A	2A1.3	15 - 25	NA	0.40	NA
A	2A1.4	25 - 37	NA	0.52	NA
A	2A10.1	0 - 5	NA	0.35	NA
A	2A10.2	5 - 15	NA	0.37	NA
A	2A10.3	15 - 25	NA	0.80	NA
A	2A2.2	5 - 15	NA	0.55	NA
A	2A2.3	15 - 25	NA	0.54	NA
A	2A3.3	15 - 25	NA	0.42	NA
A	2A3.4	25 - 35	NA	0.54	NA
A	2A4.1	0 - 5	NA	0.26	NA
A	2A4.2	5 - 15	NA	0.42	NA
A	2A5.1	0 - 5	NA	0.49	NA
A	2A5.2	5 - 15	NA	0.45	NA
A	2A5.3	15 - 25	NA	0.39	NA
A	2A5.4	25 - 35	NA	0.33	NA
A	2A6.1	0 - 5	NA	0.31	NA
A	2A6.2	5 - 15	NA	0.44	NA
A	2A6.3	15 - 25	NA	0.42	NA
A	2A6.4	25 - 35	NA	0.44	NA
A	2A6.5	35 - 45	NA	0.34	NA
A	2A6.6	45 - 55	NA	0.35	NA
A	2A6.7	55 - 65	NA	0.37	NA
A	2A7.1	0 - 5	NA	0.51	NA
A	2A7.2	5 - 15	NA	0.54	NA
A	2A7.4	25 - 35	NA	0.57	NA
A	2A7.5	35 - 45	NA	1.50	NA
A	2A7.6	45 - 51	NA	1.71	NA
A	2A8.1	0 - 5	NA	0.54	NA
A	2A8.2	5 - 15	NA	0.57	NA
A	2A8.3	15 - 25	NA	0.60	NA
A	2A8.4	25 - 35	NA	0.99	NA
A	2A9.1	0 - 5	NA	0.40	NA
A	2A9.2	5 - 15	NA	0.38	NA

Appendix G - Table 7
Lower Fox River - Bulk Density Results

Deposit/SMU	Sample Identification	Depth (cm)	Wet Density (g/cm^3)	Dry Density (g/cm^3)	Specific Gravity
A	2A9.3	15 - 25	NA	0.44	NA
A	2A9.5	35 - 45	NA	0.42	NA
A	2A9.6	45 - 61	NA	0.41	NA
A	2NS1.2 OF 2	-	NA	0.98	NA
A	2NS3.1 OF 2	-	NA	0.82	NA
A	3A1.1	0 - 5	NA	0.35	NA
A	3A1.2	0 - 10	NA	0.39	NA
A	3A1.3	10 - 20	NA	0.44	NA
A	3A1.4	20 - 30	NA	0.40	NA
A	3A1.5	30 - 42	NA	0.33	NA
A	3A2.1	0 - 5	NA	0.40	NA
A	3A2.2	5 - 15	NA	0.55	NA
A	3A2.3	15 - 25	NA	0.42	NA
A	3A2.4	25 - 38	NA	0.41	NA
A	3A21.1	0 - 5	NA	0.41	NA
A	3A21.2	5 - 15	NA	0.48	NA
A	3A21.3	15 - 25	NA	1.18	NA
A	3NS1.1	0 - 5	NA	0.52	NA
A	3NS2.1	0 - 5	NA	1.20	NA
A	3NS2.2	5 - 15	NA	1.09	NA
A	3NS2.3	15 - 25	NA	0.51	NA
A	3NS2.4	25 - 35	NA	0.36	NA
A	3NS4.1	0 - 5	NA	0.61	NA
A	3NS4.2	5 - 15	NA	0.85	NA
A	3NS4.3	15 - 22	NA	0.69	NA
A	4A1.1	0 - 2	NA	0.40	NA
A	4A1.10	18 - 20	NA	0.25	NA
A	4A1.11	20 - 22	NA	0.29	NA
A	4A1.12	22 - 24	NA	0.25	NA
A	4A1.13	24 - 26	NA	0.24	NA
A	4A1.14	26 - 28	NA	0.27	NA
A	4A1.15	28 - 30	NA	0.21	NA
A	4A1.2	2 - 4	NA	0.44	NA
A	4A1.3	4 - 6	NA	0.43	NA
A	4A1.4	6 - 8	NA	0.38	NA
A	4A1.5	8 - 10	NA	0.35	NA
A	4A1.6	10 - 12	NA	0.37	NA
A	4A1.7	12 - 14	NA	0.32	NA
A	4A1.8	14 - 16	NA	0.31	NA
A	4A1.9	16 - 18	NA	0.27	NA
A	A1.1	0 - 6	NA	0.44	NA
A	A1.2	6 - 30	NA	0.38	NA
A	A1.3	30 - 55	NA	0.74	NA
A	A2.1	0 - 20	NA	0.46	NA
A	A2.2	20 - 40	NA	0.80	NA
A	A2.3	40 - 60	NA	0.35	NA
A	A3.1	0 - 25	NA	0.48	NA
A	A3.2	25 - 55	NA	0.49	NA
A	A4.1	0 - 24	NA	0.55	NA
A	A4.2	24 - 48	NA	0.94	NA
A	A5.1	0 - 30	NA	0.42	NA
A	A5.2	30 - 52	NA	0.38	NA
A	A5.3	52 - 74	NA	0.49	NA
A	AC1c1	0 - 10	NA	0.39	NA
A	AC1c2	10 - 25	NA	0.36	NA
A	AC1c3	25 - 36	NA	1.36	NA
A	AC2c1	0 - 27	NA	0.45	NA
A	AC2c2	27 - 54	NA	0.47	NA
A	AC2c3	54 - 60	NA	0.32	NA
A	BA-SD01e	61 - 79	NA	1.82	NA
A	BA-SD02d	48 - 58	NA	1.61	NA
A	BA-SD03comp	0 - 30	NA	1.08	NA
A	BA-SD04c	30 - 43	NA	1.16	NA
A	BA-SD04d	43 - 53	NA	1.80	NA
A	BA-SD07b	15 - 30	NA	1.62	NA
A	BA-SD08d	45 - 61	NA	1.57	NA
A	POG2	0 - 5	NA	1.46	NA
B	2B2.1	0 - 5	NA	0.90	NA
B	2B2.2	5 - 13	NA	1.61	NA
B	B1.1	0 - 6	NA	0.32	NA
B	B1.2	6 - 17	NA	0.40	NA
B	B1.3	17 - 20	NA	0.71	NA
B	B2.1	0 - 19	NA	1.34	NA
B	POG1	0 - 5	NA	1.70	NA
C	2C1.1	0 - 5	NA	0.26	NA
C	2C1.2	5 - 15	NA	0.23	NA

Appendix G - Table 7
Lower Fox River - Bulk Density Results

Deposit/SMU	Sample Identification	Depth (cm)	Wet Density (g/cm^3)	Dry Density (g/cm^3)	Specific Gravity
C	2C1.4	25 - 41	NA	0.36	NA
C	2C2.1	0 - 5	NA	0.26	NA
C	2C2.2	5 - 15	NA	0.26	NA
C	2C2.4	25 - 36	NA	0.41	NA
C	2C3.1	0 - 5	NA	0.42	NA
C	2C3.2	5 - 15	NA	0.32	NA
C	2C3.3	15 - 26	NA	1.46	NA
C	3C1.1	0 - 5	NA	0.50	NA
C	3C1.2	5 - 15	NA	0.52	NA
C	3C1.3	15 - 25	NA	0.65	NA
C	3C1.4	25 - 35	NA	0.39	NA
C	3C1.5	35 - 45	NA	0.42	NA
C	3C2.1	0 - 5	NA	0.34	NA
C	3C2.2	5 - 15	NA	0.31	NA
C	3C2.3	15 - 25	NA	0.26	NA
C	3C2.4	25 - 35	NA	0.37	NA
C	3C2.5	35 - 45	NA	0.32	NA
C	3C3.1	0 - 5	NA	0.51	NA
C	3C3.2	5 - 15	NA	0.44	NA
C	3C3.3	15 - 25	NA	0.35	NA
C	3C3.5	35 - 45	NA	0.63	NA
C	3C3.6	45 - 53	NA	0.52	NA
C	3C4.1	0 - 5	NA	0.43	NA
C	3C4.2	5 - 15	NA	0.38	NA
C	3C4.3	15 - 25	NA	0.37	NA
C	3C4.4	25 - 35	NA	0.44	NA
C	C1.1	0 - 10	NA	0.42	NA
C	C1.2	10 - 22	NA	0.55	NA
C	C1.3	22 - 38	NA	0.94	NA
C	SDC-C-1-P-S	0 - 5	NA	0.21	NA
C	SDC-C-2-P-S	0 - 5	NA	0.25	NA
C	SDC-C-3-P-S	0 - 5	NA	0.33	NA
C	SDC-C-4-P-S	0 - 5	NA	0.22	NA
C	SDC-C-5-P-S	0 - 5	NA	0.24	NA
C	SDC-C-1-G	5-35	1.17	0.34	2.69
C	SDC-C-4-G	5-35	1.13	0.34	2.48
POG	2POG1	0 - 10	NA	0.63	NA
POG	POG3	0 - 5	NA	0.65	NA
POG	P-RI-1(0-2)	0 - 61	NA	0.67	NA
POG	P-RI-10(0-0.5)	0 - 15	NA	0.52	NA
POG	P-RI-11(0-2)	0 - 61	NA	0.28	NA
POG	P-RI-11(2-4)	61 - 122	NA	0.32	NA
POG	P-RI-11(4-6.2)	122 - 189	NA	0.36	NA
POG	P-RI-12(0-1.4)	0 - 43	NA	0.33	NA
POG	P-RI-13(0-1.1)	0 - 34	NA	0.43	NA
POG	P-RI-14(0-1.2)	0 - 37	NA	0.40	NA
POG	P-RI-15(0-2)	0 - 61	NA	0.28	NA
POG	P-RI-15(2-4)	61 - 122	NA	0.32	NA
POG	P-RI-15(2-4)-FD	61 - 122	NA	0.33	NA
POG	P-RI-15(4-6)	122 - 183	NA	0.42	NA
POG	P-RI-16(0-1.3)	0 - 40	NA	0.28	NA
POG	P-RI-17(0-1.2)	0 - 37	NA	0.38	NA
POG	P-RI-18(0-1.4)	0 - 43	NA	0.27	NA
POG	P-RI-19(0-0.5)	0 - 15	NA	0.98	NA
POG	P-RI-2(0-1)	0 - 30	NA	0.72	NA
POG	P-RI-20(0-2)	0 - 61	NA	0.22	NA
POG	P-RI-20(2-4.3)	61 - 131	NA	0.37	NA
POG	P-RI-21(0-1.8)	0 - 55	NA	0.30	NA
POG	P-RI-22(0-0.4)	0 - 12	NA	0.62	NA
POG	P-RI-3(0-1.0)	0 - 30	NA	0.29	NA
POG	P-RI-4(0-2)	0 - 61	NA	0.24	NA
POG	P-RI-4(2-3.4)	61 - 104	NA	0.32	NA
POG	P-RI-5(0-0.9)	0 - 27	NA	0.44	NA
POG	P-RI-6(0-2.2)	0 - 67	NA	0.66	NA
POG	P-RI-7(0-2)	0 - 61	NA	0.20	NA
POG	P-RI-7(2-2.7)	61 - 82	NA	0.26	NA
POG	P-RI-8(0-1.7)	0 - 52	NA	0.24	NA
POG	P-RI-Comp1(0-2)	0 - 61	NA	0.31	NA
POG	P-RI-Comp1(2-4)	61 - 122	NA	0.34	NA
POG	P-RI-Comp1(4-6)	122 - 183	NA	0.40	NA
D	2D1.1	0 - 5	NA	0.71	NA
D	2D1.2	5 - 20	NA	0.90	NA
D	2D2.1	0 - 5	NA	0.42	NA
D	2D2.2	5 - 15	NA	0.59	NA
D	2D2.3	15 - 25	NA	0.62	NA
D	2D2.4	25 - 44	NA	1.16	NA

Appendix G - Table 7
Lower Fox River - Bulk Density Results

Deposit/SMU	Sample Identification	Depth (cm)	Wet Density (g/cm^3)	Dry Density (g/cm^3)	Specific Gravity
D	2D3.1	0 - 5	NA	0.50	NA
D	2D3.2	5 - 15	NA	0.51	NA
D	2D3.3	15 - 25	NA	0.52	NA
D	2D3.5	35 - 45	NA	0.36	NA
D	2D4.1	0 - 5	NA	0.42	NA
D	2D4.2	5 - 15	NA	0.54	NA
D	2D4.3	15 - 25	NA	0.34	NA
D	2D4.4	25 - 35	NA	0.70	NA
D	3D1.2	5 - 15	NA	0.42	NA
D	3D1.4	25 - 35	NA	0.35	NA
D	3D1.5	35 - 48	NA	0.41	NA
D	3D2.1	0 - 5	NA	0.37	NA
D	3D2.3	15 - 25	NA	0.29	NA
D	3D3.1	0 - 5	NA	0.37	NA
D	3D3.2	5 - 15	NA	0.70	NA
D	D2.2	15 - 39	NA	0.40	NA
D	D-RI-1(0-0.5)	0 - 15	NA	0.53	NA
D	D-RI-10(0-2.2)	0 - 67	NA	0.31	NA
D	D-RI-11(0-1.3)	0 - 40	NA	1.07	NA
D	D-RI-12(0-2)	0 - 61	NA	0.42	NA
D	D-RI-12(2-3.5)	61 - 107	NA	0.98	NA
D	D-RI-13(0-2)	0 - 61	NA	0.40	NA
D	D-RI-13(2-3.6)	61 - 110	NA	1.20	NA
D	D-RI-14(0-0.75)	0 - 23	NA	0.54	NA
D	D-RI-15(0-2)	0 - 61	NA	0.77	NA
D	D-RI-15(2-3.7)	61 - 113	NA	0.99	NA
D	D-RI-16(0-1.6)	0 - 49	NA	0.66	NA
D	D-RI-17(0-1.1)	0 - 34	NA	0.29	NA
D	D-RI-18(0-1.5)	0 - 46	NA	0.39	NA
D	D-RI-19(0-0.5)	0 - 15	NA	0.52	NA
D	D-RI-2(0-0.5)	0 - 15	NA	0.83	NA
D	D-RI-20(0-2)	0 - 61	NA	0.87	NA
D	D-RI-20(2-3)	61 - 91	NA	1.37	NA
D	D-RI-21(0-2)	0 - 61	NA	0.88	NA
D	D-RI-21(2-4)	61 - 122	NA	1.33	NA
D	D-RI-3(0-0.5)	0 - 15	NA	0.52	NA
D	D-RI-4(0-0.5)	0 - 15	NA	0.47	NA
D	D-RI-5(0-0.5)	0 - 15	NA	0.40	NA
D	D-RI-6(0-0.5)	0 - 15	NA	0.51	NA
D	D-RI-7(0-1.3)	0 - 40	NA	0.56	NA
D	D-RI-8(0-1.7)	0 - 52	NA	0.59	NA
D	D-RI-9(0-2)	0 - 61	NA	0.49	NA
D	D-RI-9(2-2.8)	61 - 85	NA	0.98	NA
D	D-RI-Comp1(0-2)	0 - 61	NA	0.37	NA
D	D-RI-Comp1(2-4)	61 - 122	NA	1.27	NA
D	D-RI-Comp2(0-2)	0 - 61	NA	0.34	NA
E	2E1.1	0 - 5	NA	0.52	NA
E	2E1.2	5 - 23	NA	0.96	NA
E	2E10.1	0 - 5	NA	0.33	NA
E	2E10.2	5 - 15	NA	0.36	NA
E	2E11.1	0 - 5	NA	0.37	NA
E	2E11.2	5 - 15	NA	0.27	NA
E	2E11.3	15 - 25	NA	0.37	NA
E	2E12.1	0 - 5	NA	0.53	NA
E	2E12.2	5 - 15	NA	0.69	NA
E	2E12.3	15 - 30	NA	0.76	NA
E	2E13.2	5 - 19	NA	1.21	NA
E	2E14.1	0 - 5	NA	0.40	NA
E	2E14.2	5 - 15	NA	0.43	NA
E	2E14.3	15 - 25	NA	0.38	NA
E	2E15.1	0 - 5	NA	0.18	NA
E	2E15.2	5 - 15	NA	0.26	NA
E	2E15.3	15 - 30	NA	0.32	NA
E	2E16.1	0 - 5	NA	0.45	NA
E	2E16.2	5 - 15	NA	0.38	NA
E	2E16.4	25 - 32	NA	1.05	NA
E	2E17.1	0 - 5	NA	0.37	NA
E	2E17.3	15 - 29	NA	0.34	NA
E	2E18.1	0 - 5	NA	0.28	NA
E	2E18.3	15 - 29	NA	0.27	NA
E	2E19.3	15 - 25	NA	0.48	NA
E	2E19.4	25 - 37	NA	1.08	NA
E	2E2.1	0 - 5	NA	0.32	NA
E	2E2.2	5 - 15	NA	0.30	NA
E	2E2.3	15 - 25	NA	0.37	NA
E	2E20.2	5 - 15	NA	0.63	NA

Appendix G - Table 7
Lower Fox River - Bulk Density Results

Deposit/SMU	Sample Identification	Depth (cm)	Wet Density (g/cm^3)	Dry Density (g/cm^3)	Specific Gravity
E	2E20.3	15 - 25	NA	0.50	NA
E	2E20.4	25 - 35	NA	0.39	NA
E	2E21.3	15 - 25	NA	0.46	NA
E	2E24.1	0 - 5	NA	0.22	NA
E	2E24.2	5 - 15	NA	0.30	NA
E	2E24.4	25 - 35	NA	0.32	NA
E	2E3.1	0 - 5	NA	0.33	NA
E	2E3.2	5 - 15	NA	0.35	NA
E	2E3.3	15 - 25	NA	0.37	NA
E	2E4.2	5 - 15	NA	0.43	NA
E	2E4.3	15 - 25	NA	0.26	NA
E	2E5.1	0 - 5	NA	0.38	NA
E	2E5.2	5 - 15	NA	0.34	NA
E	2E6.1	0 - 5	NA	0.34	NA
E	2E6.2	5 - 15	NA	0.31	NA
E	2E6.3	15 - 24	NA	0.32	NA
E	2E7.1	0 - 5	NA	0.33	NA
E	2E7.2	5 - 15	NA	0.27	NA
E	2E7.3	15 - 25	NA	0.30	NA
E	2E8.1	0 - 5	NA	0.26	NA
E	2E8.2	5 - 15	NA	0.37	NA
E	2E8.3	15 - 25	NA	0.38	NA
E	2E8.4	25 - 35	NA	0.49	NA
E	2E9.2	5 - 15	NA	0.39	NA
E	2E9.3	15 - 25	NA	0.28	NA
E	2POG3	0 - 10	NA	0.54	NA
E	E1-1.1	0 - 18	NA	0.41	NA
E	E1-1.2	18 - 43	NA	0.44	NA
E	E1-1.3	43 - 18	NA	0.43	NA
E	E1C1C1	0 - 7	NA	0.19	NA
E	E1C1C2	7 - 18	NA	0.28	NA
E	E1C1C3	18 - 30	NA	0.47	NA
E	E2-1.1	0 - 13	NA	0.29	NA
E	E2-1.2	13 - 27	NA	0.49	NA
E	E2-1.3	27 - 33	NA	0.43	NA
E	E2-2.1	0 - 6	NA	0.69	NA
E	E2-2.2	6 - 13	NA	0.67	NA
E	E2-2.3	13 - 21	NA	0.73	NA
E	E2-3.1	0 - 17	NA	0.46	NA
E	E2-3.2	17 - 36	NA	0.44	NA
E	E2-3.3	36 - 39	NA	0.44	NA
E	E2-4.1	0 - 7	NA	0.91	NA
E	E2-4.2	7 - 18	NA	0.71	NA
E	E2-4.3	18 - 30	NA	0.60	NA
E	E2C1C1	-	NA	0.41	NA
E	E2C1C2	-	NA	0.62	NA
E	E2C1C3	-	NA	0.53	NA
E	E-RI-1(0-0.5)	0 - 15	NA	0.94	NA
E	E-RI-10(0-1.5)	0 - 46	NA	1.28	NA
E	E-RI-11(0-2)	0 - 61	NA	0.94	NA
E	E-RI-11(2-3.6)	61 - 110	NA	1.14	NA
E	E-RI-12(0-2)	0 - 61	NA	0.26	NA
E	E-RI-12(2-4.2)	61 - 128	NA	0.81	NA
E	E-RI-13(0-2)	0 - 61	NA	0.24	NA
E	E-RI-13(2-3.75)	61 - 114	NA	0.94	NA
E	E-RI-14(0-2)	0 - 61	NA	0.55	NA
E	E-RI-15(0-2)	0 - 61	NA	0.53	NA
E	E-RI-16(0-2)	0 - 61	NA	0.25	NA
E	E-RI-16(2-3)	61 - 91	NA	0.33	NA
E	E-RI-17(0-2)	0 - 61	NA	0.27	NA
E	E-RI-17(2-4)	61 - 122	NA	0.31	NA
E	E-RI-2(0-2)	0 - 61	NA	0.48	NA
E	E-RI-2(2-4)	61 - 122	NA	1.26	NA
E	E-RI-2(4-4.7)	122 - 143	NA	1.29	NA
E	E-RI-3(0-2)	0 - 61	NA	0.75	NA
E	E-RI-3(2-2.8)	61 - 85	NA	0.93	NA
E	E-RI-4(0-2)	0 - 61	NA	0.75	NA
E	E-RI-4(2-3)	61 - 91	NA	0.82	NA
E	E-RI-5(0-2)	0 - 61	NA	0.66	NA
E	E-RI-6(0-2)	0 - 61	NA	0.91	NA
E	E-RI-6(2-4)	61 - 122	NA	0.82	NA
E	E-RI-7(0-2)	0 - 61	NA	0.89	NA
E	E-RI-7(2-2.8)	61 - 85	NA	1.15	NA
E	E-RI-8(0-2)	0 - 61	NA	0.93	NA
E	E-RI-8(2-3.25)	61 - 99	NA	1.01	NA
E	E-RI-9(0-2)	0 - 61	NA	0.98	NA

Appendix G - Table 7
Lower Fox River - Bulk Density Results

Deposit/SMU	Sample Identification	Depth (cm)	Wet Density (g/cm^3)	Dry Density (g/cm^3)	Specific Gravity
E	E-RI-9(2-4)	61 - 122	NA	1.17	NA
E	E-RI-9(4-5.7)	122 - 174	NA	1.17	NA
E	E-RI-Comp1(0-2)	0 - 61	NA	0.42	NA
E	E-RI-Comp1(2-4)	61 - 122	NA	0.75	NA
E	E-RI-Comp2(0-2)	0 - 61	NA	0.29	NA
E	SDC-E-1-P-S	0 - 5	NA	0.25	NA
E	SDC-E-2-P-S	0 - 5	NA	0.20	NA
E	SDC-E-3-P-S	0 - 5	NA	0.34	NA
E	SDC-E-4-P-S	0 - 5	NA	0.14	NA
E	SDC-E-5-P-S	0 - 5	NA	0.63	NA
E	SDC-E-6-P-S	0 - 5	NA	0.44	NA
E	SDC-E-2-G	5-35	1.18	0.43	2.62
E	SDC-E-5b-G	5-35	1.12	0.32	2.24
F	2F1.1	0 - 5	NA	0.51	NA
F	2F1.2	5 - 27	NA	0.50	NA
F	2F2.1	0 - 5	NA	0.36	NA
F	2F2.2	5 - 15	NA	0.29	NA
F	2F2.3	15 - 25	NA	0.20	NA
F	2F3.2	5 - 15	NA	0.36	NA
F	F1.1	0 - 4	NA	0.28	NA
F	F1.2	4 - 15	NA	0.22	NA
F	F1.3	15 - 26	NA	0.25	NA
F	F2.1	0 - 6	NA	0.33	NA
F	F2.2	6 - 17	NA	0.23	NA
F	F2.3	17 - 29	NA	0.20	NA
G	G1.1	0 - 17	NA	0.63	NA
G	G1.2	17 - 30	NA	0.54	NA
G	G1.3	30 - 37	NA	0.88	NA
H	H1.1	0 - 8	NA	0.83	NA
H	H1.2	8 - 17	NA	0.99	NA
H	H1.3	17 - 38	NA	0.91	NA
Reach Average			**1.15**	**0.55**	**2.51**
Appleton to Little Rapids Reach					
I	I1.1	0 - 14	NA	0.46	NA
I	I1.2	14 - 34	NA	0.56	NA
I	I1.3	34 - 54	NA	0.58	NA
I	POG9	0 - 2	NA	1.66	NA
J	J1.1	0 - 20	NA	0.59	NA
J	J1.2	20 - 42	NA	0.61	NA
J	J1.3	42 - 50	NA	0.75	NA
K	K1.1	0 - 11	NA	1.01	NA
K	K1.2	11 - 16	NA	0.78	NA
K	K1.3	16 - 21	NA	0.52	NA
L	L1.1	0 - 15	NA	0.77	NA
L	L1.2	15 - 30	NA	0.68	NA
L	L1.3	30 - 41	NA	0.73	NA
L	POG8	0 - 5	NA	1.92	NA
M	M1.1	0 - 19	NA	0.49	NA
M	M1.2	19 - 36	NA	0.43	NA
M	M1.3	36 - 41	NA	0.46	NA
O	3O1.2	5 - 15	NA	0.61	NA
O	3O1.3	15 - 25	NA	0.49	NA
O	3O1.4	25 - 35	NA	0.42	NA
O	3O2.1	0 - 5	NA	0.88	NA
O	O1.1	0 - 10	NA	0.61	NA
O	O1.2	10 - 23	NA	0.47	NA
O	O1.3	23 - 35	NA	0.48	NA
P	2P1.1	0 - 5	NA	0.96	NA
P	2P1.2	5 - 15	NA	1.33	NA
P	2P1.4	25 - 35	NA	1.07	NA
P	2P1.6	45 - 55	NA	1.02	NA
P	2P2.1	0 - 5	NA	0.24	NA
P	2P2.2	5 - 15	NA	0.33	NA
P	2P2.4	25 - 35	NA	0.54	NA
P	2P2.6	45 - 56	NA	0.57	NA
P	2P3.1	0 - 5	NA	0.43	NA
P	2P3.2	5 - 15	NA	0.67	NA
P	2P3.3	15 - 25	NA	0.42	NA
P	2P3.6	45 - 58	NA	0.43	NA
Q	2Q1.1	0 - 5	NA	0.45	NA
Q	2Q1.2	5 - 15	NA	0.48	NA
Q	2Q1.3	15 - 25	NA	0.56	NA
Q	2Q1.4	25 - 35	NA	0.50	NA
Q	2Q1.5	35 - 45	NA	0.57	NA
Q	3Q1.3	15 - 25	NA	0.44	NA
Q	3Q2.2	5 - 15	NA	0.56	NA

Appendix G - Table 7
Lower Fox River - Bulk Density Results

Deposit/SMU	Sample Identification	Depth (cm)	Wet Density (g/cm^3)	Dry Density (g/cm^3)	Specific Gravity
Q	3Q2.3	15 - 25	NA	0.39	NA
Q	3Q2.5	35 - 45	NA	0.48	NA
R	2R1.1	0 - 5	NA	0.99	NA
S	2S1.1	0 - 5	NA	1.05	NA
S	2S1.2	5 - 15	NA	0.40	NA
T	2T1.1	0 - 5	NA	0.27	NA
T	2T1.2	5 - 15	NA	0.41	NA
T	T1.1	0 - 28	NA	0.72	NA
U	POG10	0 - 5	NA	1.59	NA
U	U1.1	0 - 12	NA	0.53	NA
U	U1.2	12 - 26	NA	0.46	NA
U	U1.3	26 - 40	NA	0.46	NA
V	2V1.2	5 - 15	NA	0.59	NA
V	2V2.1	0 - 5	NA	0.40	NA
V	2V2.2	5 - 15	NA	0.54	NA
V	2V2.3	15 - 25	NA	0.32	NA
V	2V2.4	25 - 35	NA	0.32	NA
V	2V2.5	35 - 45	NA	0.32	NA
W	2W2.1	0 - 5	NA	1.40	NA
W	2W2.2	5 - 15	NA	0.89	NA
W	2W4.1	0 - 5	NA	0.39	NA
W	2W4.2	5 - 15	NA	0.90	NA
W	2W5.2	5 - 15	NA	0.22	NA
W	2W6.1	0 - 5	NA	1.08	NA
W	2W6.2	5 - 22	NA	1.17	NA
W	2W7.1	0 - 5	NA	0.34	NA
W	2W7.4	25 - 35	NA	0.52	NA
W	2W8.1	0 - 5	NA	0.43	NA
W	2W8.3	15 - 25	NA	0.48	NA
W	2W9.1	0 - 5	NA	0.85	NA
W	2W9.2	5 - 15	NA	0.43	NA
W	POG4	0 - 5	NA	1.42	NA
W	SDC-W-1-P-S	0 - 5	NA	0.67	NA
W	SDC-W-2-P-S	0 - 5	NA	0.54	NA
W	SDC-W-3-P-S	0 - 5	NA	1.12	NA
W	SDC-W-4-P-S	0 - 5	NA	0.57	NA
W	SDC-W-5-P-S	0 - 5	NA	0.34	NA
W	W1	0 - 19	NA	0.64	NA
W	W2.1	0 - 23	NA	0.47	NA
W	W2.2	23 - 48	NA	0.51	NA
W	W2.3	48 - 74	NA	0.50	NA
W	W3.1	0 - 15	NA	0.59	NA
W	W3.2	15 - 26	NA	0.48	NA
W	WC1C1	0 - 17	NA	0.53	NA
W	WC1C2	17 - 27	NA	0.66	NA
W	WC1C3	27 - 41	NA	0.68	NA
W	WC2C1	0 - 7	NA	0.97	NA
W	SDC-W-2-G	5-35	1.15	0.46	2.38
W	SDC-W-5-G	5-35	1.17	0.29	2.30
X	2X1.1	0 - 5	NA	0.33	NA
X	2X1.2	5 - 19	NA	0.39	NA
X	2X2.1	0 - 5	NA	0.47	NA
X	2X2.2	5 - 15	NA	0.58	NA
X	2X2.3	15 - 28	NA	0.42	NA
X	2X3.1	0 - 5	NA	0.48	NA
X	2X3.3	15 - 25	NA	0.39	NA
X	2X3.4	25 - 35	NA	0.44	NA
X	2X3.6	45 - 61	NA	0.52	NA
X	2X4.1	0 - 5	NA	0.88	NA
X	2X4.3	15 - 25	NA	0.83	NA
X	2X4.4	25 - 34	NA	0.62	NA
X	2X5.1	0 - 5	NA	0.59	NA
X	2X5.2	5 - 15	NA	0.60	NA
X	2X6.1	0 - 5	NA	0.24	NA
X	2X6.2	5 - 15	NA	0.49	NA
X	2X6.4	25 - 35	NA	0.53	NA
X	2X7.1	0 - 5	NA	1.12	NA
X	2X7.3	15 - 25	NA	0.48	NA
X	SDC-X-1-P-S	0 - 5	NA	0.37	NA
X	SDC-X-2-P-S	0 - 5	NA	1.26	NA
X	SDC-X-3-P-S	0 - 5	NA	0.52	NA
X	SDC-X-4-P-S	0 - 5	NA	0.41	NA
X	SDC-X-5-P-S	0 - 5	NA	0.34	NA
X	X1.1	0 - 16	NA	0.39	NA
X	X1.2	16 - 49	NA	0.35	NA
X	X1.3	49 - 92	NA	0.41	NA

Appendix G - Table 7
Lower Fox River - Bulk Density Results

Deposit/SMU	Sample Identification	Depth (cm)	Wet Density (g/cm^3)	Dry Density (g/cm^3)	Specific Gravity
X	XC1C1	0 - 8	NA	0.42	NA
X	XC1C2	8 - 12.5	NA	0.44	NA
X	XC1C3	12.5 - 17	NA	0.46	NA
X	SDC-X-1-G	5-35	1.26	0.55	2.49
X	SDC-X-2-G	5-35	1.19	0.40	2.58
Y	Y1.1	0 - 14	NA	0.74	NA
Y	Y1.2	14 - 24	NA	0.48	NA
Y	Y1.3	24 - 34	NA	0.78	NA
Z	Z1.1	0 - 11	NA	0.80	NA
Z	Z1.2	11 - 39	NA	0.65	NA
Z	Z1.3	39 - 44	NA	0.83	NA
AA	AA1.1	0 - 6	NA	1.32	NA
AA	AA1.2	6 - 12	NA	1.19	NA
AA	AA1.3	12 - 17	NA	1.03	NA
BB	BB1.1	0 - 14	NA	1.16	NA
BB	BB1.2	14 - 31	NA	0.60	NA
BB	BB1.3	31 - 39	NA	1.03	NA
CC	2CC1.1	0 - 5	NA	0.93	NA
CC	2CC1.2	5 - 15	NA	0.76	NA
CC	2CC1.3	15 - 25	NA	0.47	NA
CC	2CC2.1	0 - 5	NA	0.46	NA
CC	CC1.1	0 - 6	NA	0.85	NA
CC	CC1.2	6 - 12	NA	1.12	NA
CC	CC1.3	12 - 17	NA	1.15	NA
CC	CC2.1	0 - 5	NA	1.22	NA
CC	CC2.2	5 - 9	NA	1.00	NA
CC	CC2.3	9 - 13	NA	1.23	NA
DD	2DD1.1	0 - 5	NA	0.66	NA
DD	2DD1.3	15 - 25	NA	0.63	NA
DD	2DD2.1	0 - 5	NA	0.23	NA
DD	2DD2.3	15 - 26	NA	0.44	NA
DD	2DD3.1	0 - 5	NA	0.82	NA
DD	2DD3.2	5 - 15	NA	1.43	NA
DD	2DD4.2	5 - 15	NA	0.68	NA
DD	2DD4.3	15 - 25	NA	0.51	NA
DD	2DD6.1	0 - 5	NA	0.80	NA
DD	3DD1.2	5 - 15	NA	0.69	NA
DD	3DD1.3	15 - 27	NA	0.69	NA
DD	3DD2.1	0 - 5	NA	1.12	NA
DD	3DD2.2	5 - 15	NA	0.45	NA
DD	DD1.1	0 - 9	NA	0.43	NA
DD	DD1.2	9 - 18	NA	0.52	NA
DD	DD1.3	18 - 26	NA	0.64	NA
DD	DD2.1	0 - 15	NA	0.56	NA
DD	DD2.2	15 - 36	NA	0.39	NA
DD	DD2.3	36 - 49	NA	0.59	NA
Reach Average			**1.19**	**0.66**	**2.44**
Little Rapids to De Pere Reach					
EE	2EE1.1	0 - 5	NA	1.43	NA
EE	2EE1.2	5 - 18	NA	0.81	NA
EE	2EE10.1	0 - 5	NA	0.27	NA
EE	2EE10.2	5 - 15	NA	0.34	NA
EE	2EE10.3	15 - 25	NA	0.38	NA
EE	2EE10.4	25 - 32	NA	0.35	NA
EE	2EE11.1	0 - 5	NA	0.25	NA
EE	2EE11.2	5 - 15	NA	0.31	NA
EE	2EE11.3	15 - 25	NA	0.44	NA
EE	2EE11.4	25 - 35	NA	0.45	NA
EE	2EE12.1	0 - 5	NA	0.68	NA
EE	2EE12.2	5 - 15	NA	0.54	NA
EE	2EE12.3	15 - 28	NA	0.57	NA
EE	2EE13.1	0 - 5	NA	0.46	NA
EE	2EE13.2	5 - 15	NA	0.45	NA
EE	2EE13.3	15 - 25	NA	0.66	NA
EE	2EE13.4	25 - 35	NA	0.62	NA
EE	2EE14.1	0 - 5	NA	0.45	NA
EE	2EE14.2	5 - 15	NA	0.28	NA
EE	2EE14.3	15 - 25	NA	0.24	NA
EE	2EE14.4	25 - 35	NA	0.36	NA
EE	2EE14.5	35 - 46	NA	0.33	NA
EE	2EE15.1	0 - 5	NA	0.38	NA
EE	2EE15.2	5 - 15	NA	0.45	NA
EE	2EE15.3	15 - 29	NA	0.48	NA
EE	2EE16.1	0 - 5	NA	0.82	NA
EE	2EE16.2	5 - 15	NA	0.50	NA
EE	2EE17.1	0 - 5	NA	0.37	NA

Appendix G - Table 7
Lower Fox River - Bulk Density Results

Deposit/SMU	Sample Identification	Depth (cm)	Wet Density (g/cm^3)	Dry Density (g/cm^3)	Specific Gravity
EE	2EE17.2	5 - 15	NA	0.37	NA
EE	2EE17.3	15 - 25	NA	0.39	NA
EE	2EE18.1	0 - 5	NA	1.11	NA
EE	2EE19.2	5 - 15	NA	0.41	NA
EE	2EE19.4	25 - 34	NA	0.51	NA
EE	2EE2.1	0 - 5	NA	0.41	NA
EE	2EE2.2	5 - 15	NA	0.47	NA
EE	2EE2.3	15 - 25	NA	0.39	NA
EE	2EE2.4	25 - 35	NA	0.26	NA
EE	2EE2.5	35 - 45	NA	0.24	NA
EE	2EE2.6	45 - 55	NA	0.30	NA
EE	2EE2.7	55 - 66	NA	0.29	NA
EE	2EE20.1	0 - 5	NA	0.53	NA
EE	2EE21.2	5 - 15	NA	0.32	NA
EE	2EE21.3	15 - 25	NA	0.84	NA
EE	2EE22.1	0 - 5	NA	0.30	NA
EE	2EE22.2	5 - 15	NA	0.47	NA
EE	2EE22.3	15 - 25	NA	0.37	NA
EE	2EE22.4	25 - 35	NA	0.34	NA
EE	2EE22.5	35 - 45	NA	0.40	NA
EE	2EE23.1	0 - 5	NA	0.23	NA
EE	2EE23.2	5 - 15	NA	0.33	NA
EE	2EE23.3	15 - 23	NA	0.65	NA
EE	2EE24.1	0 - 5	NA	0.40	NA
EE	2EE24.2	5 - 15	NA	0.55	NA
EE	2EE24.3	15 - 29	NA	0.38	NA
EE	2EE25.1	0 - 5	NA	0.35	NA
EE	2EE25.2	5 - 15	NA	0.33	NA
EE	2EE25.3	15 - 25	NA	0.34	NA
EE	2EE26.1	0 - 5	NA	1.10	NA
EE	2EE27.1	0 - 5	NA	0.38	NA
EE	2EE27.2	5 - 15	NA	0.35	NA
EE	2EE28.1	0 - 5	NA	0.22	NA
EE	2EE28.2	5 - 15	NA	0.47	NA
EE	2EE28.3	15 - 25	NA	0.45	NA
EE	2EE29.1	0 - 5	NA	0.37	NA
EE	2EE29.2	5 - 15	NA	0.43	NA
EE	2EE3.1	0 - 5	NA	0.95	NA
EE	2EE3.2	5 - 15	NA	1.16	NA
EE	2EE3.3	15 - 28	NA	0.78	NA
EE	2EE30.1	0 - 5	NA	1.33	NA
EE	2EE30.2	5 - 18	NA	0.82	NA
EE	2EE31.1	0 - 5	NA	0.41	NA
EE	2EE31.2	5 - 15	NA	0.40	NA
EE	2EE31.3	15 - 25	NA	0.51	NA
EE	2EE32.1	0 - 5	NA	0.31	NA
EE	2EE32.2	5 - 15	NA	0.31	NA
EE	2EE32.3	15 - 29	NA	0.41	NA
EE	2EE33.1	0 - 5	NA	0.24	NA
EE	2EE33.2	5 - 15	NA	0.47	NA
EE	2EE33.3	15 - 25	NA	0.40	NA
EE	2EE34.1	0 - 5	NA	0.62	NA
EE	2EE34.2	5 - 15	NA	0.40	NA
EE	2EE34.3	15 - 25	NA	0.49	NA
EE	2EE34.4	25 - 35	NA	0.49	NA
EE	2EE34.5	35 - 45	NA	0.63	NA
EE	2EE35.1	0 - 5	NA	0.33	NA
EE	2EE35.2	5 - 15	NA	0.36	NA
EE	2EE35.3	15 - 25	NA	0.45	NA
EE	2EE35.4	25 - 38	NA	0.53	NA
EE	2EE36.1	0 - 5	NA	0.32	NA
EE	2EE36.2	5 - 15	NA	0.43	NA
EE	2EE36.3	15 - 30	NA	0.53	NA
EE	2EE37.1	0 - 5	NA	0.95	NA
EE	2EE37.2	5 - 15	NA	1.10	NA
EE	2EE38.1	0 - 5	NA	0.59	NA
EE	2EE38.2	5 - 15	NA	0.34	NA
EE	2EE39.1	0 - 5	NA	0.51	NA
EE	2EE39.2	5 - 15	NA	0.51	NA
EE	2EE39.3	15 - 25	NA	0.48	NA
EE	2EE4.1	0 - 5	NA	0.47	NA
EE	2EE4.2	5 - 15	NA	0.88	NA
EE	2EE4.3	15 - 25	NA	0.49	NA
EE	2EE4.4	25 - 35	NA	0.38	NA
EE	2EE4.5	35 - 48	NA	0.43	NA
EE	2EE40.1	0 - 5	NA	0.46	NA

Appendix G - Table 7
Lower Fox River - Bulk Density Results

Deposit/SMU	Sample Identification	Depth (cm)	Wet Density (g/cm^3)	Dry Density (g/cm^3)	Specific Gravity
EE	2EE40.2	5 - 15	NA	0.51	NA
EE	2EE40.3	15 - 29	NA	0.59	NA
EE	2EE41.1	0 - 5	NA	0.49	NA
EE	2EE41.2	5 - 15	NA	0.22	NA
EE	2EE41.3	15 - 25	NA	0.38	NA
EE	2EE42.1	0 - 5	NA	0.45	NA
EE	2EE42.2	5 - 15	NA	0.33	NA
EE	2EE42.3	15 - 23	NA	0.42	NA
EE	2EE43.1	0 - 5	NA	0.25	NA
EE	2EE43.2	5 - 15	NA	0.29	NA
EE	2EE43.3	15 - 25	NA	0.34	NA
EE	2EE43.4	25 - 34	NA	0.52	NA
EE	2EE44.1	0 - 5	NA	0.32	NA
EE	2EE44.3	15 - 25	NA	0.33	NA
EE	2EE44.4	25 - 33	NA	0.30	NA
EE	2EE45.1	0 - 5	NA	0.31	NA
EE	2EE45.3	15 - 25	NA	0.33	NA
EE	2EE45.4	25 - 35	NA	0.40	NA
EE	2EE46.1	0 - 5	NA	0.49	NA
EE	2EE46.3	15 - 25	NA	0.46	NA
EE	2EE46.4	25 - 35	NA	0.45	NA
EE	2EE47.1	0 - 5	NA	1.17	NA
EE	2EE48.1	0 - 5	NA	0.75	NA
EE	2EE48.2	5 - 15	NA	0.52	NA
EE	2EE48.3	15 - 25	NA	0.65	NA
EE	2EE49.3	15 - 25	NA	0.51	NA
EE	2EE49.4	25 - 38	NA	0.44	NA
EE	2EE50.1	0 - 5	NA	0.45	NA
EE	2EE50.3	15 - 25	NA	0.39	NA
EE	2EE50.4	25 - 41	NA	0.38	NA
EE	2EE51.3	15 - 25	NA	0.37	NA
EE	2EE51.4	25 - 35	NA	0.70	NA
EE	2EE52.2	5 - 15	NA	0.53	NA
EE	2EE52.3	15 - 30	NA	0.62	NA
EE	2EE53.1	0 - 5	NA	0.37	NA
EE	2EE53.2	5 - 15	NA	0.41	NA
EE	2EE53.3	15 - 25	NA	0.56	NA
EE	2EE53.4	25 - 35	NA	0.48	NA
EE	2EE54.1	0 - 5	NA	0.54	NA
EE	2EE54.2	5 - 15	NA	0.54	NA
EE	2EE54.3	15 - 25	NA	0.45	NA
EE	2EE55.1	0 - 5	NA	0.61	NA
EE	2EE55.3	15 - 25	NA	0.50	NA
EE	2EE55.4	25 - 38	NA	0.43	NA
EE	2EE6.1	0 - 5	NA	0.87	NA
EE	2EE6.2	5 - 15	NA	1.40	NA
EE	2EE6.3	15 - 25	NA	1.29	NA
EE	2EE7.1	0 - 5	NA	0.56	NA
EE	2EE7.2	5 - 15	NA	0.37	NA
EE	2EE7.3	15 - 25	NA	0.49	NA
EE	2EE7.4	25 - 35	NA	0.48	NA
EE	2EE7.5	35 - 51	NA	0.43	NA
EE	2EE8.1	0 - 5	NA	0.24	NA
EE	2EE8.2	5 - 15	NA	0.33	NA
EE	2EE8.3	15 - 25	NA	0.23	NA
EE	2EE8.4	25 - 35	NA	0.22	NA
EE	2EE8.5	35 - 45	NA	0.28	NA
EE	2EE8.6	45 - 55	NA	0.29	NA
EE	2EE8.7	55 - 67	NA	0.49	NA
EE	2EE9.1	0 - 5	NA	0.19	NA
EE	2EE9.2	5 - 15	NA	0.35	NA
EE	2EE9.3	15 - 25	NA	0.25	NA
EE	2EE9.4	25 - 38	NA	0.28	NA
EE	3EE1.1	0 - 5	NA	1.22	NA
EE	3EE1.2	5 - 15	NA	0.71	NA
EE	3EE1.3	15 - 25	NA	0.37	NA
EE	3EE2.1	0 - 5	NA	0.51	NA
EE	3EE2.2	5 - 15	NA	0.41	NA
EE	3EE2.3	15 - 25	NA	0.49	NA
EE	4EE1.1	0 - 2	NA	0.35	NA
EE	4EE1.10	18 - 20	NA	0.33	NA
EE	4EE1.11	20 - 22	NA	0.41	NA
EE	4EE1.12	22 - 24	NA	0.41	NA
EE	4EE1.13	24 - 26	NA	0.42	NA
EE	4EE1.14	26 - 28	NA	0.43	NA
EE	4EE1.15	28 - 30	NA	0.39	NA

Appendix G - Table 7
Lower Fox River - Bulk Density Results

Deposit/SMU	Sample Identification	Depth (cm)	Wet Density (g/cm^3)	Dry Density (g/cm^3)	Specific Gravity
EE	4EE1.16	30 - 32	NA	0.37	NA
EE	4EE1.17	32 - 34	NA	0.66	NA
EE	4EE1.18	34 - 36	NA	0.44	NA
EE	4EE1.19	36 - 38	NA	0.49	NA
EE	4EE1.2	2 - 4	NA	0.35	NA
EE	4EE1.20	38 - 40	NA	0.49	NA
EE	4EE1.21	40 - 42	NA	0.53	NA
EE	4EE1.3	4 - 6	NA	0.22	NA
EE	4EE1.4	6 - 8	NA	0.35	NA
EE	4EE1.5	8 - 10	NA	0.52	NA
EE	4EE1.6	10 - 12	NA	0.47	NA
EE	4EE1.8	14 - 16	NA	0.29	NA
EE	4EE1.9	16 - 18	NA	0.38	NA
EE	4EE2.1	0 - 2	NA	0.38	NA
EE	4EE2.10	16 - 18	NA	0.41	NA
EE	4EE2.11	18 - 20	NA	0.38	NA
EE	4EE2.12	20 - 22	NA	0.40	NA
EE	4EE2.13	22 - 24	NA	0.45	NA
EE	4EE2.14	24 - 26	NA	0.52	NA
EE	4EE2.2	2 - 4	NA	0.40	NA
EE	4EE2.3	4 - 6	NA	0.29	NA
EE	4EE2.4	6 - 8	NA	0.30	NA
EE	4EE2.5	8 - 10	NA	0.28	NA
EE	4EE2.6	10 - 12	NA	0.30	NA
EE	4EE2.7	12 - 14	NA	0.30	NA
EE	4EE2.8	14 - 16	NA	0.32	NA
EE	4EE2.9	16 - 18	NA	0.35	NA
EE	EE1.1	0 - 9	NA	0.78	NA
EE	EE1.2	9 - 20	NA	0.64	NA
EE	EE1.3	20 - 28	NA	0.75	NA
EE	EE10.1	0 - 11	NA	0.31	NA
EE	EE10.2	11 - 27	NA	0.45	NA
EE	EE10.3	27 - 33	NA	0.47	NA
EE	EE11.1	0 - 8	NA	0.25	NA
EE	EE11.2	8 - 26	NA	0.34	NA
EE	EE11.3	26 - 32	NA	0.44	NA
EE	EE12.1	0 - 19	NA	0.87	NA
EE	EE12.2	19 - 38	NA	0.67	NA
EE	EE13.1	0 - 15	NA	0.48	NA
EE	EE13.3	22 - 30	NA	0.90	NA
EE	EE14.1	0 - 20	NA	0.89	NA
EE	EE14.2	20 - 40	NA	0.62	NA
EE	EE14.3	40 - 60	NA	0.80	NA
EE	EE16.1	0 - 5	NA	0.42	NA
EE	EE16.2	5 - 23	NA	0.39	NA
EE	EE16.3	23 - 41	NA	0.58	NA
EE	EE17.1	0 - 5	NA	0.33	NA
EE	EE17.2	5 - 15	NA	0.41	NA
EE	EE17.3	15 - 27	NA	0.50	NA
EE	EE18.1	0 - 6	NA	0.23	NA
EE	EE18.2	6 - 17	NA	0.28	NA
EE	EE18.3	17 - 25	NA	0.47	NA
EE	EE19.1	0 - 3	NA	0.33	NA
EE	EE19.2	3 - 14	NA	0.37	NA
EE	EE19.3	14 - 33	NA	0.42	NA
EE	EE2.1	0 - 7	NA	0.48	NA
EE	EE2.2	7 - 15	NA	0.58	NA
EE	EE2.3	15 - 22	NA	0.67	NA
EE	EE20.1	0 - 6	NA	0.37	NA
EE	EE20.2	6 - 18	NA	0.56	NA
EE	EE20.3	18 - 27	NA	1.01	NA
EE	EE21.1	0 - 4	NA	0.40	NA
EE	EE21.2	4 - 14	NA	0.56	NA
EE	EE21.3	14 - 29	NA	0.46	NA
EE	EE22.1	0 - 4	NA	0.28	NA
EE	EE22.2	4 - 17	NA	0.33	NA
EE	EE22.3	17 - 34	NA	0.50	NA
EE	EE23.1	0 - 17	NA	0.28	NA
EE	EE23.2	17 - 23	NA	0.32	NA
EE	EE23.3	23 - 38	NA	0.39	NA
EE	EE24.1	0 - 10	NA	0.38	NA
EE	EE24.2	10 - 16	NA	0.65	NA
EE	EE24.3	16 - 21	NA	0.58	NA
EE	EE25.1	0 - 10	NA	0.29	NA
EE	EE25.2	10 - 29	NA	0.42	NA
EE	EE25.3	29 - 38	NA	0.48	NA

Appendix G - Table 7
Lower Fox River - Bulk Density Results

Deposit/SMU	Sample Identification	Depth (cm)	Wet Density (g/cm^3)	Dry Density (g/cm^3)	Specific Gravity
EE	EE26.1	0 - 4	NA	0.55	NA
EE	EE26.2	4 - 8	NA	0.73	NA
EE	EE26.3	8 - 42	NA	0.42	NA
EE	EE27.1	0 - 6	NA	0.25	NA
EE	EE27.2	6 - 19.5	NA	0.34	NA
EE	EE27.3	19.5 - 33	NA	0.40	NA
EE	EE28.1	0 - 22	NA	0.40	NA
EE	EE28.2	22 - 40	NA	0.40	NA
EE	EE28.3	40 - 65	NA	0.48	NA
EE	EE29.1	0 - 26	NA	1.30	NA
EE	EE3.1	0 - 5	NA	0.38	NA
EE	EE3.2	5 - 17	NA	0.46	NA
EE	EE3.3	17 - 31	NA	0.55	NA
EE	EE4.1	0 - 10	NA	0.42	NA
EE	EE4.2	10 - 21	NA	0.48	NA
EE	EE4.3	21 - 28	NA	0.52	NA
EE	EE5.1	0 - 10	NA	0.36	NA
EE	EE5.2	10 - 23	NA	0.49	NA
EE	EE5.3	23 - 28	NA	0.44	NA
EE	EE6.1	0 - 7	NA	0.51	NA
EE	EE6.2	7 - 19.5	NA	0.39	NA
EE	EE6.3	19.5 - 31	NA	0.48	NA
EE	EE7.1	0 - 10	NA	0.43	NA
EE	EE7.2	10 - 20.5	NA	0.59	NA
EE	EE7.3	20.5 - 30	NA	0.47	NA
EE	EE8.1	0 - 5	NA	0.31	NA
EE	EE8.2	5 - 19	NA	0.36	NA
EE	EE8.3	19 - 34	NA	0.48	NA
EE	EE9.1	0 - 30	NA	0.47	NA
EE	EE9.2	30 - 59	NA	0.53	NA
EE	EE9.3	59 - 88	NA	0.47	NA
EE	EEC1C1	0 - 8	NA	0.76	NA
EE	EEC1C2	8 - 14	NA	1.13	NA
EE	EEC1C3	14 - 20	NA	0.99	NA
EE	EEC2C1	0 - 15	NA	0.30	NA
EE	EEC2C2	15 - 28	NA	0.47	NA
EE	EEC2C3	28 - 41	NA	0.35	NA
EE	EEC3C1	0 - 13	NA	0.35	NA
EE	EEC3C2	13 - 30	NA	0.44	NA
EE	EEC3C3	30 - 41	NA	0.45	NA
EE	EE-RI-1(0-2)	0 - 61	NA	0.34	NA
EE	EE-RI-1(2-4)	61 - 122	NA	0.50	NA
EE	EE-RI-1(6-7.8)	183 - 238	NA	1.26	NA
EE	EE-RI-10(0-2)	0 - 61	NA	0.29	NA
EE	EE-RI-10(2-4)	61 - 122	NA	0.58	NA
EE	EE-RI-10(6-7.1)	183 - 216	NA	0.57	NA
EE	EE-RI-11(0-2)	0 - 61	NA	0.35	NA
EE	EE-RI-11(2-4)	61 - 122	NA	0.57	NA
EE	EE-RI-11(4-4.5)	122 - 137	NA	1.53	NA
EE	EE-RI-12(0-2)	0 - 61	NA	0.38	NA
EE	EE-RI-12(2-4)	61 - 122	NA	0.51	NA
EE	EE-RI-12(4-4.7)	122 - 143	NA	1.47	NA
EE	EE-RI-13(0-2)	0 - 61	NA	0.33	NA
EE	EE-RI-13(4-6)	122 - 183	NA	0.72	NA
EE	EE-RI-13(6-6.9)	183 - 210	NA	1.73	NA
EE	EE-RI-14(0-0.7)	0 - 21	NA	0.33	NA
EE	EE-RI-15(0-2)	0 - 61	NA	0.27	NA
EE	EE-RI-15(2-4)	61 - 122	NA	0.43	NA
EE	EE-RI-15(6-7.3)	183 - 223	NA	1.25	NA
EE	EE-RI-16(0-1.8)	0 - 55	NA	0.28	NA
EE	EE-RI-17(0-2)	0 - 61	NA	0.29	NA
EE	EE-RI-17(2-3.1)	61 - 94	NA	0.46	NA
EE	EE-RI-18(0-2)	0 - 61	NA	0.35	NA
EE	EE-RI-18(2-3.3)	61 - 101	NA	1.13	NA
EE	EE-RI-19(0-2)	0 - 61	NA	0.38	NA
EE	EE-RI-19(2-4.1)	61 - 125	NA	0.53	NA
EE	EE-RI-2(0-2)	0 - 61	NA	0.30	NA
EE	EE-RI-2(2-4)	61 - 122	NA	0.42	NA
EE	EE-RI-2(4-5)	122 - 152	NA	1.04	NA
EE	EE-RI-20(0-2)	0 - 61	NA	0.30	NA
EE	EE-RI-20(2-4.2)	61 - 128	NA	0.51	NA
EE	EE-RI-21(0-2)	0 - 61	NA	0.27	NA
EE	EE-RI-21(2-4)	61 - 122	NA	0.50	NA
EE	EE-RI-21(4-5.7)	122 - 174	NA	1.33	NA
EE	EE-RI-22(0-2)	0 - 61	NA	0.40	NA
EE	EE-RI-22(2-3.2)	61 - 98	NA	0.68	NA

Appendix G - Table 7
Lower Fox River - Bulk Density Results

Deposit/SMU	Sample Identification	Depth (cm)	Wet Density (g/cm^3)	Dry Density (g/cm^3)	Specific Gravity
EE	EE-RI-23(0-2)	0 - 61	NA	0.31	NA
EE	EE-RI-23(2-4.1)	61 - 125	NA	0.66	NA
EE	EE-RI-24(0-2)	0 - 61	NA	0.27	NA
EE	EE-RI-24(2-4)	61 - 122	NA	0.43	NA
EE	EE-RI-24(6-7.3)	183 - 223	NA	1.77	NA
EE	EE-RI-25(0-1.6)	0 - 49	NA	0.74	NA
EE	EE-RI-26(0-2)	0 - 61	NA	0.30	NA
EE	EE-RI-26(2-4)	61 - 122	NA	0.46	NA
EE	EE-RI-26(6-6.9)	183 - 210	NA	1.97	NA
EE	EE-RI-27(0-2)	0 - 61	NA	0.32	NA
EE	EE-RI-27(2-4)	61 - 122	NA	0.43	NA
EE	EE-RI-27(4-6.2)	122 - 189	NA	0.78	NA
EE	EE-RI-28(0-2)	0 - 61	NA	0.26	NA
EE	EE-RI-28(2-3.4)	61 - 104	NA	0.44	NA
EE	EE-RI-29(0-2)	0 - 61	NA	0.37	NA
EE	EE-RI-29(2-2.75)	61 - 84	NA	0.60	NA
EE	EE-RI-3(0-2)	0 - 61	NA	0.30	NA
EE	EE-RI-3(2-4)	61 - 122	NA	0.42	NA
EE	EE-RI-3(6-7)	183 - 213	NA	0.58	NA
EE	EE-RI-4(0-2)	0 - 61	NA	0.29	NA
EE	EE-RI-4(2-4)	61 - 122	NA	0.78	NA
EE	EE-RI-4(4-6.1)	122 - 186	NA	1.27	NA
EE	EE-RI-5(0-2)	0 - 61	NA	0.31	NA
EE	EE-RI-5(4-6)	122 - 183	NA	0.54	NA
EE	EE-RI-5(6-8)	183 - 244	NA	0.56	NA
EE	EE-RI-6(0-2)	0 - 61	NA	0.31	NA
EE	EE-RI-6(2-4)	61 - 122	NA	0.44	NA
EE	EE-RI-6(4-5.7)	122 - 174	NA	0.97	NA
EE	EE-RI-7(0-2)	0 - 61	NA	0.34	NA
EE	EE-RI-7(2-4)	61 - 122	NA	0.42	NA
EE	EE-RI-7(6-6.7)	183 - 204	NA	0.70	NA
EE	EE-RI-8(0-2)	0 - 61	NA	0.31	NA
EE	EE-RI-8(4-6)	122 - 183	NA	0.51	NA
EE	EE-RI-8(6-7.7)	183 - 235	NA	0.56	NA
EE	EE-RI-9(0-2)	0 - 61	NA	0.29	NA
EE	EE-RI-9(2-4)	61 - 122	NA	0.41	NA
EE	EE-RI-9(4-5.6)	122 - 171	NA	0.81	NA
EE	POG7	0 - 5	NA	1.49	NA
EE	SDC-EE22-1-P-S	0 - 5	NA	0.83	NA
EE	SDC-EE22-2-P-S	0 - 5	NA	0.43	NA
EE	SDC-EE22-3-P-S	0 - 5	NA	0.38	NA
EE	SDC-EE22-4-P-S	0 - 5	NA	1.31	NA
EE	SDC-EE23-1-P-S	0 - 5	NA	0.90	NA
EE	SDC-EE23-2-P-S	0 - 5	NA	0.62	NA
EE	SDC-EE23-3-P-S	0 - 5	NA	0.45	NA
EE	SDC-EE23-4-P-S	0 - 5	NA	0.48	NA
EE	SDC-EE23-5-P-S	0 - 5	NA	0.29	NA
EE	SDC-EE24-1-P-S	0 - 5	NA	0.75	NA
EE	SDC-EE24-2-P-S	0 - 5	NA	0.54	NA
EE	SDC-EE24-3-P-S	0 - 5	NA	0.49	NA
EE	SDC-EE24-4-P-S	0 - 5	NA	0.30	NA
EE	SDC-EE24-5-P-S	0 - 5	NA	0.40	NA
EE	SDC-EE25-1-P-S	0 - 5	NA	0.26	NA
EE	SDC-EE25-2-P-S	0 - 5	NA	0.34	NA
EE	SDC-EE25-3-P-S	0 - 5	NA	0.33	NA
EE	SDC-EE25-4-P-S	0 - 5	NA	0.39	NA
EE	SDC-EE25-5-P-S	0 - 5	NA	0.30	NA
EE	SDC-EE26-1-P-S	0 - 5	NA	0.39	NA
EE	SDC-EE26-2-P-S	0 - 5	NA	0.37	NA
EE	SDC-EE26-3-P-S	0 - 5	NA	0.34	NA
EE	SDC-EE26-4-P-S	0 - 5	NA	0.44	NA
EE	SDC-EE26-5-P-S	0 - 5	NA	0.22	NA
EE	SDC-EE27-1-P-S	0 - 5	NA	0.36	NA
EE	SDC-EE27-2-P-S	0 - 5	NA	0.37	NA
EE	SDC-EE22-3-G	5-35	1.17	0.42	2.61
EE	SDC-EE22-4-G	5-35	1.21	0.56	2.56
EE	SDC-EE23-1-G	5-32	1.48	0.93	2.36
EE	SDC-EE23-4-G	5-35	1.21	0.44	2.33
EE	SDC-EE24-1-G	5-35	0.93	0.29	2.44
EE	SDC-EE24-3-G	5-35	1.15	0.45	2.55
EE	SDC-EE25-2-G	5-35	1.14	0.38	2.43
EE	SDC-EE25-3-G	5-35	1.11	0.37	2.42
EE	SDC-EE26-2-G	5-35	1.13	0.36	2.52
EE	SDC-EE26-5-G	5-35	1.11	0.37	2.52
EG	EGH-RI-Comp1(0-2)	0 - 61	NA	0.31	NA
EG	EGH-RI-Comp1(2-4)	61 - 122	NA	0.43	NA

Appendix G - Table 7
Lower Fox River - Bulk Density Results

Deposit/SMU	Sample Identification	Depth (cm)	Wet Density (g/cm^3)	Dry Density (g/cm^3)	Specific Gravity
EG	EGH-RI-Comp1(4-6)	122 - 183	NA	0.55	NA
EG	EGH-RI-Comp1(6-8)	183 - 244	NA	1.24	NA
FF	3FF1.1	0 - 5	NA	1.87	NA
FF	3FF1.2	5 - 15	NA	1.12	NA
FF	3FF1.3	15 - 25	NA	1.18	NA
FF	3FF2.1	0 - 5	NA	0.40	NA
FF	3FF2.3	15 - 25	NA	0.39	NA
FF	3FF2.4	25 - 35	NA	0.55	NA
FF	FF1.1	0 - 10	NA	0.25	NA
FF	FF1.2	10 - 22	NA	0.35	NA
FF	FF1.3	22 - 46	NA	0.41	NA
GG	2GG1.1	0 - 5	NA	0.37	NA
GG	2GG1.2	5 - 15	NA	0.48	NA
GG	2GG1.3	15 - 25	NA	0.88	NA
GG	2GG1.5	25 - 35	NA	0.58	NA
GG	2GG2.1	0 - 5	NA	0.40	NA
GG	2GG2.2	5 - 15	NA	0.41	NA
GG	2GG2.3	15 - 25	NA	0.36	NA
GG	2GG2.4	25 - 35	NA	0.46	NA
GG	2GG2.5	35 - 45	NA	0.68	NA
GG	2GG3.3	15 - 25	NA	0.35	NA
GG	2GG3.4	25 - 39	NA	0.45	NA
GG	3GG20.1	0 - 5	NA	0.46	NA
GG	3GG20.2	5 - 15	NA	0.37	NA
GG	3GG20.3	15 - 25	NA	0.38	NA
GG	3GG20.4	25 - 35	NA	0.36	NA
GG	3GG20.5	35 - 45	NA	0.40	NA
GG	3GG20.6	45 - 55	NA	0.48	NA
GG	GG1.1	0 - 12	NA	0.31	NA
GG	GG1.2	12 - 22	NA	0.31	NA
GG	GG1.3	22 - 62	NA	0.41	NA
GG	GG1.4	62 - 85	NA	0.47	NA
GG	GG2.1	0 - 7	NA	0.40	NA
GG	GG2.2	7 - 19	NA	0.35	NA
GG	GG2.3	19 - 36	NA	0.43	NA
GG	GG-RI-1(0-2)	0 - 61	NA	0.33	NA
GG	GG-RI-1(2-4.2)	61 - 128	NA	0.49	NA
GG	GG-RI-10(0-0.9)	0 - 27	NA	0.44	NA
GG	GG-RI-11(0-2)	0 - 61	NA	0.37	NA
GG	GG-RI-11(2-3.7)	61 - 113	NA	0.51	NA
GG	GG-RI-12(0-2)	0 - 61	NA	0.58	NA
GG	GG-RI-12(2-2.5)	61 - 76	NA	1.86	NA
GG	GG-RI-13(0-2)	0 - 61	NA	0.37	NA
GG	GG-RI-13(2-4.1)	61 - 125	NA	0.90	NA
GG	GG-RI-14(0-1.1)	0 - 34	NA	0.37	NA
GG	GG-RI-15(0-2)	0 - 61	NA	0.37	NA
GG	GG-RI-15(2-4.2)	61 - 128	NA	0.61	NA
GG	GG-RI-2(0-2)	0 - 61	NA	0.37	NA
GG	GG-RI-2(2-2.9)	61 - 88	NA	0.73	NA
GG	GG-RI-3(0-2)	0 - 61	NA	0.33	NA
GG	GG-RI-3(2-3.7)	61 - 113	NA	0.44	NA
GG	GG-RI-4(0-2)	0 - 61	NA	0.31	NA
GG	GG-RI-4(2-4)	61 - 122	NA	0.38	NA
GG	GG-RI-4(4-5.2)	122 - 158	NA	0.55	NA
GG	GG-RI-5(0-2.2)	0 - 67	NA	0.39	NA
GG	GG-RI-6(0-2)	0 - 61	NA	0.33	NA
GG	GG-RI-6(2-4)	61 - 122	NA	0.45	NA
GG	GG-RI-6(4-5.2)	122 - 158	NA	0.58	NA
GG	GG-RI-7(0-2)	0 - 61	NA	0.39	NA
GG	GG-RI-8(0-2)	0 - 61	NA	0.32	NA
GG	GG-RI-8(2-4)	61 - 122	NA	0.42	NA
GG	GG-RI-8(4-5.1)	122 - 155	NA	0.50	NA
GG	GG-RI-9(0-2)	0 - 61	NA	0.34	NA
GG	GG-RI-9(2-4.2)	61 - 128	NA	0.77	NA
HH	2HH1.1	0 - 5	NA	0.30	NA
HH	2HH1.2	5 - 15	NA	0.32	NA
HH	2HH1.3	15 - 26	NA	0.33	NA
HH	2HH10.1	0 - 5	NA	0.25	NA
HH	2HH10.2	5 - 15	NA	0.43	NA
HH	2HH10.3	15 - 25	NA	0.46	NA
HH	2HH10.4	25 - 35	NA	0.38	NA
HH	2HH10.5	35 - 50	NA	0.34	NA
HH	2HH11.1	0 - 5	NA	0.35	NA
HH	2HH2.3	15 - 30	NA	0.32	NA
HH	HH1.1	0 - 11	NA	0.24	NA
HH	HH1.2	11 - 34	NA	0.32	NA

Appendix G - Table 7
Lower Fox River - Bulk Density Results

Deposit/SMU	Sample Identification	Depth (cm)	Wet Density (g/cm^3)	Dry Density (g/cm^3)	Specific Gravity
HH	HH1.3	34 - 46	NA	0.34	NA
HH	HH-RI-1(0-2)	0 - 61	NA	0.39	NA
HH	HH-RI-1(2-3)	61 - 91	NA	1.85	NA
HH	HH-RI-10(0-0.7)	0 - 21	NA	0.55	NA
HH	HH-RI-2(0-2)	0 - 61	NA	0.35	NA
HH	HH-RI-2(2-3.25)	61 - 99	NA	1.71	NA
HH	HH-RI-3(0-2)	0 - 61	NA	0.31	NA
HH	HH-RI-3(2-4)	61 - 122	NA	0.38	NA
HH	HH-RI-3(4-6)	122 - 183	NA	0.48	NA
HH	HH-RI-3(6-6.7)	183 - 204	NA	0.96	NA
HH	HH-RI-4(0-1.2)	0 - 37	NA	0.28	NA
HH	HH-RI-5(0-2)	0 - 61	NA	0.51	NA
HH	HH-RI-5(2-4)	61 - 122	NA	1.31	NA
HH	HH-RI-5(4-5.1)	122 - 155	NA	1.38	NA
HH	HH-RI-6(0-2)	0 - 61	NA	0.30	NA
HH	HH-RI-6(2-4)	61 - 122	NA	0.35	NA
HH	HH-RI-6(4-5.2)	122 - 158	NA	0.46	NA
HH	HH-RI-7(0-0.5)	0 - 15	NA	0.41	NA
HH	HH-RI-8(0-2)	0 - 61	NA	0.28	NA
HH	HH-RI-8(2-2.9)	61 - 88	NA	0.53	NA
HH	HH-RI-9(0-2)	0 - 61	NA	0.30	NA
HH	HH-RI-9(2-3.7)	61 - 113	NA	0.40	NA
	2FRA1.2	69 - 129	NA	0.98	NA
	2FRA2.2	34 - 64	NA	0.31	NA
	2FRA4.2	34 - 60	NA	0.31	NA
	2FRA4.3	69 - 96	NA	0.37	NA
	2FRA4.4	103 - 136	NA	0.44	NA
	2FRA4.5	137 - 162	NA	0.37	NA
	2FRA5.2	34 - 55	NA	0.29	NA
	2FRA5.3	69 - 98	NA	0.40	NA
	2FRA5.4	103 - 132	NA	0.41	NA
	2FRA5.5	137 - 167	NA	0.52	NA
	POG6	0 - 5	NA	1.46	NA
Reach Average			**1.16**	**0.51**	**2.47**
De Pere to Green Bay Reach					
20	2FRBg27.1	0 - 5	NA	0.65	NA
20	2FRBg27.2	5 - 15	NA	0.62	NA
20	2FRBg27.3	15 - 25	NA	1.39	NA
20	SDC-DPD-1-P-S	0 - 5	NA	0.30	NA
20	SDC-DPD-2-P-S	0 - 5	NA	0.27	NA
20	SDC-DPD-2-G	5-35	1.15	0.39	2.32
21	2FRBg24.1	0 - 5	NA	0.35	NA
21	2FRBg24.2	5 - 15	NA	0.34	NA
21	2FRBg24.3	15 - 25	NA	0.31	NA
21	2FRBg24.4	25 - 44	NA	0.42	NA
21	2FRBg26.2	5 - 15	NA	0.82	NA
21	2FRBg26.3	15 - 25	NA	0.40	NA
23	2FRBg22.1	0 - 5	NA	0.52	NA
23	2FRBg22.2	5 - 15	NA	0.41	NA
25	2FRBg23.1	0 - 5	NA	0.95	NA
25	2FRBg23.3	15 - 25	NA	1.32	NA
25	2FRBg23.4	25 - 35	NA	0.74	NA
34	2FRBg20.1	0 - 5	NA	0.40	NA
34	2FRBg6.1	0 - 5	NA	0.31	NA
34	2FRBg6.2	5 - 15	NA	0.28	NA
34	2FRBg6.3	15 - 25	NA	0.35	NA
34	2FRBg6.5	35 - 45	NA	0.36	NA
41	2FRBg17.1	0 - 5	NA	0.31	NA
41	2FRBg17.2	5 - 15	NA	0.40	NA
41	2FRBg17.3	15 - 25	NA	0.41	NA
41	2FRBg17.4	25 - 31	NA	0.35	NA
43	2FRBg18.1	0 - 5	NA	0.56	NA
43	2FRBg18.2	5 - 15	NA	0.63	NA
43	2FRBg18.3	15 - 25	NA	0.83	NA
45	2FRBg13.1	0 - 5	NA	0.37	NA
45	2FRBg13.3	15 - 25	NA	0.42	NA
45	2FRBg13.4	25 - 35	NA	0.48	NA
45	2FRBg14.1	0 - 5	NA	0.43	NA
45	2FRBg14.3	15 - 25	NA	0.46	NA
45	2FRBg14.4	25 - 35	NA	0.59	NA
45	SDC-DPD-3-P-S	0 - 5	NA	0.28	NA
45	SDC-DPD-3-G	5-35	1.21	0.45	2.40
46	2FRBg16.1	0 - 5	NA	0.67	NA
46	2FRBg16.2	5 - 15	NA	0.49	NA
48	2FRBg15.1	0 - 5	NA	0.55	NA
48	2FRBg15.2	5 - 15	NA	1.55	NA

Appendix G - Table 7
Lower Fox River - Bulk Density Results

Deposit/SMU	Sample Identification	Depth (cm)	Wet Density (g/cm^3)	Dry Density (g/cm^3)	Specific Gravity
49	2FRBg12.1	0 - 5	NA	0.63	NA
49	2FRBg12.2	5 - 15	NA	0.94	NA
51	2FRBg3.1	0 - 5	NA	1.02	NA
51	2FRBg3.2	5 - 15	NA	1.27	NA
51	2FRBg3.3	15 - 26	NA	0.62	NA
52	2FRBg1.1	0 - 5	NA	0.37	NA
52	2FRBg1.2	5 - 15	NA	0.38	NA
52	2FRBg1.3	15 - 25	NA	0.37	NA
52	2FRBg1.4	25 - 33	NA	0.37	NA
53	2FRBg2.1	0 - 5	NA	0.32	NA
53	2FRBg2.2	5 - 15	NA	0.37	NA
53	2FRBg2.4	25 - 35	NA	0.44	NA
57	2FRBg5.1	0 - 5	NA	0.40	NA
57	2FRBg5.2	5 - 15	NA	0.46	NA
57	2FRBg5.3	15 - 25	NA	0.42	NA
61	2FRBg4.1	0 - 5	NA	0.98	NA
61	2FRBg4.2	5 - 15	NA	0.99	NA
70	2FRBg7.1	0 - 5	NA	0.30	NA
70	2FRBg7.2	5 - 15	NA	0.36	NA
70	2FRBg7.4	25 - 35	NA	0.41	NA
71	2FRBg11.1	0 - 5	NA	0.52	NA
71	2FRBg11.2	5 - 15	NA	0.42	NA
71	2FRBg11.3	15 - 25	NA	0.36	NA
77	2FRBg8.1	0 - 5	NA	0.67	NA
77	2FRBg8.2	5 - 15	NA	0.68	NA
77	2FRBg8.3	15 - 21	NA	0.78	NA
86	2FRBg9.1	0 - 5	NA	1.49	NA
86	2FRBg9.2	5 - 15	NA	0.52	NA
86	2FRBg9.3	15 - 27	NA	0.34	NA
94	2FRBg30.1	0 - 5	NA	0.43	NA
94	2FRBg30.2	5 - 15	NA	0.41	NA
94	2FRBg31.2	5 - 15	NA	0.30	NA
96	SDC-DPD-4-P-S	0 - 5	NA	1.32	NA
106	2FRBg28.1	0 - 5	NA	0.57	NA
106	2FRBg28.2	5 - 15	NA	0.68	NA
112	2FRBg10.1	0 - 5	NA	0.74	NA
112	2FRBg10.2	5 - 15	NA	0.46	NA
112	2FRBg10.4	25 - 35	na	0.51	NA
115	SDC-DPD-5-P-S	0 - 5	NA	0.28	NA
	2FRBg19.1	0 - 5	NA	0.63	NA
	2FRBg21.1	0 - 5	NA	0.58	NA
	2FRBg25.1	0 - 5	NA	1.61	NA
	2FRBg25.2	5 - 15	NA	1.32	NA
Reach Average			**1.18**	**0.59**	**2.36**
Entire River Average			**1.17**	**0.55**	**2.46**

APPENDIX H

PCB CONGENERS AND HOMOLOG GROUP LIST
(ATSDR, 1997a)

Table 3-2. Chemical Identity of Polychlorinated Biphenyl Congeners

IUPAC No.[a]	Compound/substituents	CAS No. [b]
Monochlorobiphenyl		27323-18-8
1	2	2051-60-7
2	3	2051-60-8
3	4	2051-60-9
Dichlorobiphenyl		25512-42-9
4	2,2′	13029-08-8
5	2,3	16605-91-7
6	2,3′	25569-80-6
7	2,4	33284-50-3
8	2,4′	34883-43-7
9	2,5	34883-39-1
10	2,6	33146-45-1
11	3,3′	2050-67-1
12	3,4	2974-92-7
13	3,4′	2974-90-5
14	3,5	34883-41-5
15	4,4′	2050-68-2
Trichlorobipheyl		25323-68-6
16	2,2′,3	38444-78-9
17	2,2′,4	37680-66-3
18	2,2′,5	37680-65-2
19	2,2′,6	38444-73-4
20	2,3,3′	38444-84-7
21	2,3,4	55702-46-0
22	2,3,4′	38444-85-8
23	2,3,5	55720-44-0
24	2,3,6	58702-45-9
25	2,3′,4	55712-37-3
26	2,3′,5	38444-81-4
27	2,3,6	38444-76-7
28	2,4,4′	7012-37-5
29	2,4,5	15862-07-4
30	2,4,6	35693-92-6
31	2,4′,5	16606-02-3
32	2,4′,6	38444-77-8
33	2′,3,4	38444-86-9
34	2′,3,5	37680-68-5
35	3,3′,4	37680-69-6

Table 3-2. Chemical Identity of Polychlorinated Biphenyl Congeners (continued)

IUPAC No.[a]	Compound/substituents	CAS No. [b]
36	3,3′,5	38444-87-0
37	3,4,4′	38444-90-5
38	3,4,5	53555-66-1
39	3,4′,5	38444-88-1
Tetrachlorobiphenyl		26914-33-0
40	2,2′,3,3′	38444-93-8
41	2,2′,3,4	52663-59-9
42	2,2′,3,4′	36559-22-5
43	2,2′,3,5	70362-46-8
44	2,2′,3,5′	41464-39-5
45	2,2′,3,6	70362-45-7
46	2,2′,3,6′	41464-47-5
47	2,2′,4,4′	2437-79-8
48	2,2′,4,5	70362-47-9
49	2,2′,4,5′	41464-40-8
50	2,2′,4,6	62796-65-8
51	2,2′,4,6′	64194-04-7
52	2,2′,5,5′	35693-99-3
53	2,2′,5,6′	41464-41-9
54	2,2′,6,6′	15968-05-5
55	2,3,3′,4	74338-24-2
56	2,3,3′,4′	41464-43-1
57	2,3,3′,5	70424-67-8
58	2,3,3′,5′	41464-49-7
59	2,3,3′,6	74472-33-6
60	2,3,4,4′	33025-41-1
61	2,3,4,5	33284-53-6
62	2,3,4,6	54230-23-7
63	2,3,4′,5	74472-35-8
64	2,3,4′,6	52663-58-8
65	2,3,5,6	33284-54-7
66	2,3′,4,4′	32698-10-0
67	2,3′,4,5	73575-53-8
68	2,3′,4,5′	73575-52-7
69	2,3′,4,6	60233-24-1
70	2,3′,4′,5	32598-11-1
71	2,3′,4′,6	41464-46-4
72	2,3′,5,5′	41464-42-0

Table 3-2. Chemical Identity of Polychlorinated Biphenyl Congeners (continued)

IUPAC No.[a]	Compound/substituents	CAS No.[b]
73	2,3',5',6	743338-23-1
74	2,4,4',5	32690-93-0
75	2,4,4',6	32598-12-2
76	2',3,4,5	70362-48-0
77	3,3',4,4'	32598-13-3
78	3,3',4,5	70362-49-1
79	3,3',4,5'	41464-48-6
80	3,3',5,5'	33284-52-5
81	3,4,4',5	70362-50-4
Pentachlorobiphenyl		25429-29-2
82	2,2',3,3',4	52663-62-4
83	2,2',3,3',5	60145-20-2
84	2,2',3,3',6	52663-60-2
85	2,2',3,4,4'	65510-45-4
86	2,2',3,4,5	55312-69-1
87	2,2',3,4,5'	38380-02-8
88	2,2',3,4,6	55215-17-3
89	2,2',3,4,6'	73575-57-2
90	2,2',3,4',5	68194-07-0
91	2,2',3,4',6	58194-05-8
92	2,2',3,5,5'	52663-61-3
93	2,2',3,5,6	73575-56-1
94	2,2',3,5,6'	73575-55-0
95	2,2',3,5',6	38379-99-6
96	2,2',3,6,6'	73575-54-9
97	2,2',3',4,5	41464-51-1
98	2,2',3',4,6	60233-25-2
99	2,2',3',4',5	38380-01-7
100	2,2',4',4',6	39485-83-1
101	2,2',4,5,5'	37680-73-2
102	2,2',4,5,6'	68194-06-9
103	2,2',4,5',6	61045-21-3
104	2,2',4,6,6'	56558-16-8
105	2,3,3',4,4'	32598-14-4
106	2,3,3',4,5	70424-69-0
107	2,3,3',4',5	70424-68-9
108	2,3,3',4,5'	70362-41-3
109	2,3,3',4,6	74472-35-8

Table 3-2. Chemical Identity of Polychlorinated Biphenyl Congeners (continued)

IUPAC No.[a]	Compound/substituents	CAS No. [b]
110	2,3,3′,4′,6	38380-03-9
111	2,3,3′,5,5′	39635-32-0
112	2,3,3′,5,6	74472-36-9
113	2,3,3′,5′,6	68194-10-5
114	2,3,4,4′,5	74472-37-0
115	2,3,4,4′,6	74472-38-1
116	2,3,4,5,6	18259-05-7
117	2,3,4′,5,6	68194-11-6
118	2,3′,4,4′,5	31508-00-6
119	2,3′,4,4′,6	56558-17-9
120	2,3′,4,5,5′	68194-12-7
121	2,3′,4,5′,6	56558-18-0
122	2′,3,3′,4,5	76842-07-4
123	2′,3,4,4′,5	65510-44-3
124	2′,3,4,5,5′	70424-70-3
125	2′,3,4,5,6′	74472-39-2
126	3,3′,4,4′,5	57465-28-8
127	3,3′,4,5,5′	39635-33-1
Hexachlorobiphenyl		26601-64-9
128	2,2′,3,3′,4,4′	38380-07-3
129	2,2′,3,3′,4,5	55215-18-4
130	2,2′,3,3′,4,5′	52663-3-66-8
131	2,2′,3,3′,4,6	61798-70-7
132	2,2′,3,3′,4,6′	38380-05-1
133	2,2′,3,3′,5,5′	35694-04-3
134	2,2′,3,3′,5,6	52704-70-8
135	2,2′,3,3′,5,6′	52744-13-5
136	2,2′,3,3′,6,6′	38411-22-2
137	2,2′,3,4,4′,5	35694-06-5
138	2,2′,3,4,4′,5′	35065-28-2
139	2,2′,3,4,4′,6	56030-56-9
140	2,2′,3,4,4′,6′	59291-64-4
141	2,2′,3,4,5,5′	52712-04-6
142	2,2′,3,4,5,6	41411-61-4
143	2,2′,3,4,5,6′	68194-15-0
144	2,2′,3,4,5′,6	68194-14-9
145	2,2′,3,4′,6,6′	74472-40-5
146	2,2′,3,4′,5,5′	51908-16-8

Table 3-2. Chemical Identity of Polychlorinated Biphenyl Congeners (continued)

IUPAC No.[a]	Compound/substituents	CAS No.[b]
147	2,2',3,4',5,6	68194-13-8
148	2,2',3,4',5,6'	74472-42-7
149	2,2',3,4',5',6	38380-04-0
150	2,2',3,4',5,6'	68194-08-1
151	2,2',3,5,5',6	52663-63-5
152	2,2',3,5,6,6'	68194-09-2
153	2,2',4,4',5,5'	35065-27-1
154	2,2',4,4',5,6'	60145-22-4
155	2,2',4,4',6,6'	33979-03-2
156	2,3,3',4,4',5	38380-08-4
157	2,3,3',4,4',5'	69782-90-7
158	2,3,3',4,4',6	74472-42-7
159	2,3,3',4,5,5'	39635-35-3
160	2,3,3',4,5,6	41411-62-5
161	2,3,3',4,5',6	74472-43-8
162	2,3,3',4',5,5'	39635-34-2
163	2,3,3',4',5,6	74472-44-9
164	2,3,3',4',5',6	74472-45-0
165	2,3,3',5,5',6	74472-46-1
166	2,3,4,4',5,6	41411-63-6
167	2,3',4,4',5,5'	52663-72-6
168	2,3',4,4',5',6	59291-65-5
169	3,3',4,4',5,5'	32774-16-6
Heptachlorobiphenyl		28655-71-2
170	2,2',3,3',4,4',5	35065-30-6
171	2,2',3,3',4,4',6	52663-71-5
172	2,2',3,3',4,5,5'	52663-74-8
173	2,2',3,3',4,5,6	68194-16-1
174	2,2',3,3',4,5,6'	38411-25-5
175	2,2',3,3',4,5',6	40186-70-7
176	2,2',3,3',4,6,6'	52663-65-7
177	2,2',3,3',4',5,6	52663-70-4
178	2,2',3,3',5,5',6,	52663-67-9
179	2,2',3,3',5,6,6'	52663-64-6
180	2,2',3,4,4',5,5'	35065-29-3
181	2,2',3,4,4',5,6	74472-47-2
182	2,2',3,4,4',5,6'	60145-23-5
183	2,2',3,4,4',5',6	52663-69-1

Table 3-2. Chemical Identity of Polychlorinated Biphenyl Congeners (continued)

IUPAC No.[a]	Compound/substituents	CAS No.[b]
184	2,2',3,4,4',6,6'	74472-48-3
185	2,2',3,4,5,5',6	52712-05-7
186	2,2',3,4,5,6,6'	74472-49-4
187	2,2',3,4',5,5',6	52663-68-0
188	2,2',3,4',5,6,6'	74487-85-7
189	2,3,3',4,4',5,5'	39635-31-9
190	2,3,3',4,4',5,6	41411-64-7
191	2,3,3',4,4',5',6	74472-50-7
192	2,3,3',4,5,5',6	74472-51-8
193	2,3,3',4',5,5',6	69782-91-8
Octachlorobiphenyl		31472-83-0
194	2,2',3,3',4,4',5,5'	35694-08-7
195	2,2',3,3',4,4',5,6	52663-78-2
196	2,2',3,3',4,4',5,6'	42740-50-1
197	2,2',3,3',4,4',6,6'	33091-17-7
198	2,2',3,3',4,5,5',6	68194-17-2
199	2,2',3,3',4,5,5',6'	52663-75-9
200	2,2',3,3',4,5,6,6'	52663-73-7
201	2,2',3,3',4,5',6,6'	40186-71-8
202	2,2',3,3',5,5',6,6'	2136-99-4
203	2,2',3,4,4',5,5',6	52663-76-0
204	2,2',3,4,4',5,6,6'	74472-52-9
205	2,3,3',4,4',5,5',6	74472-53-0
Nonachlorobiphenyl		53742-07-7
206	2,2',3,3',4,4',5,5',6	40186-72-9
207	2,2',3,3',4,4',5,6,6'	52663-79-3
208	2,2',3,3',4,5,5',6,6'	52663-77-1
Decachlorobiphenyl		2051-24-3
209	2,2',3,3',4,4',5,5',6,6'	2051-24-3

[a] Ballschmiter and Zell 1980
[b] Erickson 1985

Table 3-4. Approximate Weight Percent of Chlorobiphenyl in Some Aroclors

Empirical Formula	Aroclor 1016	Aroclor 1221	Aroclor 1232[a]	Aroclor 1242	Aroclor 1248[a]
$C_{12}H_{10}$	Not detected	10	Not detected	Not detected	Not detected
$C_{12}H_9Cl$	2	50	26	1	Not detected
$C_{12}H_8Cl_2$	19	35	29	13	1
$C_{12}H_7Cl_3$	57	4	24	45	2
$C_{12}H_6Cl_4$	22	1	15	31	49
$C_{12}H_5Cl_5$	Not detected	Not detected	Not detected	10	27
$C_{12}H_4Cl_6$	Not detected	Not detected	Not detected	Not detected	2
$C_{12}H_3Cl_7$	Not detected	Not detected	Not detected	Not detected	Not detected
$C_{12}H_2Cl_8$	Not detected	Not detected	Not detected	Not detected	Not detected
$C_{12}H_1Cl_9$	Not detected	Not detected	Not detected	Not detected	Not detected
Average molecular mass	257.9	200.7	232.2	266.5	299.5

Empirical formula	Aroclor 1254[a]	Aroclor 1260	Aroclor 1262	Aroclor 1268
$C_{12}H_{10}$	Not detected	Not detected	No data	No data
$C_{12}H_9Cl$	Not detected	Not detected	No data	No data
$C_{12}H_8Cl_2$	Not detected	Not detected	No data	No data
$C_{12}H_7Cl_3$	1	Not detected	No data	No data
$C_{12}H_6Cl_4$	15	Not detected	No data	No data
$C_{12}H_5Cl_5$	53	12	No data	No data
$C_{12}H_4Cl_6$	26	42	No data	No data
$C_{12}H_3Cl_7$	4	38	No data	No data
$C_{12}H_2Cl_8$	Not detected	7	No data	No data
$C_{12}H_1Cl_9$	Not detected	1	No data	No data
Average molecular mass	328.4	375.7	389	453

[a] Compounds that contributed the remaining composition were not given.

Source: derived from Ballschmiter et al. 1989

Table 3-5. PCB Congener Compositions (in mol%) in Aroclors[a]

IUPAC No.	Chlorine substitution pattern	Aroclor				
		1242	1016	1248	1254	1260
	BP	0.01	0.50	—[b]	—	—
1	2	0.68	0.80	—	—	—
2	3	0.04	0.10	—	—	—
3	4	0.22	1.00	—	—	—
4	2,2′	3.99	4.36	0.25	—	—
6	2,3′	1.24	1.37	0.69	0.07	—
7	2,4	1.04	1.16	—	—	—
8	2,4′	8.97	10.30	0.18	—	—
9	2,5	0.31	0.34	trace	—	—
10	2,6	0.13	0.20	—	—	—
12	3,4	0.09	0.11	—	—	—
13	3,4′	0.12	0.12	—	—	—
14	3,5	0.35	0.37	—	—	—
15	4,4′	0.99	1.07	—	—	—
16	2,3,2′	3.25	3.50	0.84	—	—
17	2,4,2′	2.92	3.14	0.19	—	—
18	2,5,2′	9.36	10.87	9.95	0.07	—
19	2,6,2′	0.97	1.08	—	—	—
20	2,3,3′	3.64	3.99	—	—	—
22	2,3,4′	2.64	2.80	1.24	trace	trace
25	2,4,3′	1.68	1.79	—	—	—
26	2,5,3′	0.55	0.62	0.75	—	—
27	2,6,3′	0.54	0.58	—	—	—
28	2,4,4′	13.30	14.48	trace	—	—
31	2,5,4′	4.53	4.72	9.31	0.72	—
32	2,6,4′	2.15	2.31	1.46	—	—
33	3,4,2′	2.83	3.08	—	—	—
35	3,4,3′	0.66	0.38	—	—	—
37	3,4,4′	1.62	1.89	1.28	0.20	0.09
39	3,5,4′	1.03	1.08	—	—	—
40	2,3,2′,3′	0.15	0.18	1.12	0.26	0.04
41	2,3,4,2′	1.67	2.00	—	—	—
42	2,3,2′,4′	—	—	7.05	2.18	0.66
43	2,3,5,2′	0.44	0.47	—	—	—
44	2,3,2′,5′	1.06	1.14	—	—	—

Table 3-5. PCB Congener Compositions (in mol%) in Aroclors[a] (continued)

IUPAC No.	Chlorine substitution pattern	Aroclor 1242	1016	1248	1254	1260
45	2,3,6,2′	0.90	1.00	5.73	0.15	—
46	2,3,2′,6′	0.31	0.33	—	—	—
47	2,4,2′,4′	1.65	1.8	3.18	0.52	0.88
48	2,4,5,2′	1.33	1.41	—	—	—
49	2,4,2′,5′	3.28	3.48	3.81	1.63	0.44
52	2,5,2′,5′	4.08	4.35	8.36	4.36	1.91
53	2,5,2′,6′	0.97	1.07	6.30	0.13	—
54	2,6,2′,6′	0.17	0.19	—	—	—
55	2,3,4,3′	—	—	0.11	0.43	0.12
56	2,3,3′,4′	0.60	trace	0.18	0.03	—
60	2,3,4,4′	0.21	—	—	—	—
66	2,4,3′,4′	0.81	0.14	4.95	2.24	0.22
70	2,5,3′,4′	1.11	—	6.38	4.75	0.85
71	2,6,3′,4′	—	—	0.65	—	—
72	2,5,3′,5′	0.33	—	2.10	1.01	0.28
74	2,4,5,4′	2.02	1.35	0.25	0.30	0.09
75	2,4,6,4′	2.18	2.40	—	—	—
76	3,4,5,2′	trace	—	trace	0.18	0.01
77	3,4,3′,4′	0.34	—	0.47	0.12	0.04
78	3,4,5,3′	0.52	—	—	—	—
79	3,4,3′,5′	0.24	—	trace	0.23	0.04
80	3,5,3′,5	—	—	trace	trace	trace
81	3,4,5,4′	0.28	—	—	—	—
83	2,3,5,2′,3′	—	—	trace	0.32	0.09
84	2,3,6,2′,3′	0.38	0.01	0.71	1.72	0.69
85	2,3,4,2′,4′	0.40	—	0.55	2.15	0.31
87	2,3,4,2′,5′	0.09	—	1.05	3.81	1.10
91	2,3,6,2′,4′	trace	—	1.78	5.00	3.22
92	2,3,5,2′,5′	0.12	0.20	0.63	0.21	—
95	2,3,6,2′,5′	0.53	0.18	—	—	—
97	2,4,5,2′,3′	—	—	0.78	2.59	0.63
98	2,4,6,2′,3′	0.13	0.04	—	—	—
99	2,4,5,2′,4′	0.55	—	2.52	6.10	0.82
101	2,4,5,2′,5′	0.27	—	1.50	6.98	5.04
102	2,4,5,2′,6′	—	—	trace	trace	trace
105	2,3,4,3′,4′	0.25	—	—	—	—

Table 3-5. PCB Congener Compositions (in mol%) in Aroclors[a] (continued)

IUPAC No.	Chlorine substitution pattern	Aroclor 1242	1016	1248	1254	1260
106	2,3,4,5,3′	—	—	—	0.40	0.06
108	2,3,4,3′,5′	0.46	0.16	0.02	0.55	0.14
110	2,3,6,3′,4′	—[c]	—	1.69	8.51	3.57
113	2,3,6,3′,5′	0.39	0.01	3.10	trace	0.01
114	2,3,4,5,4′	—	—	—	0.25	0.03
118	2,4,5,3′,4′	—[c]	—	—[c]	8.09	2.00
120	2,4,5,3′,5′	0.31	—	trace	0.15	3.01
121	2,4,6,3′,5′	0.92	—	4.32	3.51	0.57
122	3,4,5,2′,3′	—	—	trace	0.76	1.88
123	3,4,5,2′,4′	0.36	—	—	—	—
126	3,4,5,3′,4′	0.03	—	—	0.16	1.59
127	3,4,5,3′,5′	0.05	—	—	—	—
128	2,3,4,2′,3′,4′	—	—	—	1.31	0.47
131	2,3,4,6,2′,3′	—	—	—	0.14	0.01
132	2,3,4,2′,3′,6′	—	—	trace	2.00	2.77
133	2,3,5,2′,3′,5′	—	—	1.13	0.03	0.06
134	2,3,5,6,2′,3′	—	—	0.11	0.38	1.01
135	2,3,5,2′,3′,6′	—	trace	0.20	0.29	—
136	2,3,6,2′,3′,6′	—	—	0.20	0.34	1.12
138	2,3,4,2′,4′,5′	0.08	—	0.19	4.17	5.01
143	2,3,4,5,2′,6′	0.07	—	—	—	—
148	2,3,5,2′,4′,6′	—	—	0.12	0.07	0.06R
149	2,4,5,2′,3′,6′	—	—	0.77	3.59	9.52
151	2,3,5,6,2′,5′	—	—	trace	0.33	0.06
153	2,4,5,2′,4′,5′	0.02	—	0.13	3.32	8.22
154	2,4,5,4′,6′	—	—	—	0.14	—
156	2,3,4,5,3′,4′	—	—	—	—	0.41
157	2,3,4,3′,4′,5′	—	—	—	0.18	0.03
158	2,3,4,6,3′,4′	—	—	—	0.46	0.18
159	2,4,5,2′,3′,5′	—	—	—	0.75	1.48
163	2,3,5,6,3′,4′	—	—	—	—	trace
167	2,4,5,3′,4′,5′	—	—	—	0.21	0.17
168	2,4,6,3′,4′,5′	—	—	0.56	4.23	0.59
170	2,3,4,5,2′,3′,4′	—	—	—	0.43	0.62
171	2,3,4,6,2′,3′,4′	—	—	—	0.30	4.31
174	2,3,4,5,2′,3′,6′	—	—	—	trace	0.09

Table 3-5. PCB Congener Compositions (in mol%) in Aroclors[a] (continued)

IUPAC No.	Chlorine substitution pattern	Aroclor 1242	1016	1248	1254	1260
176	2,3,4,6,2',3',6'	—	—	0.09	trace	0.57
177	2,3,5,6,2',3',4'	—	—	—	—	trace
179	2,3,5,6,2',3',6'	—	—	—	0.56	0.83
180	2,3,4,5,2',4',5'	—	—	—	0.76	7.20
181	2,3,4,5,6,2',4'	—	—	—	0.28	2.72
182	2,3,4,5,2',4',6'	—	—	—	trace	0.47
183	2,3,4,6,2',4',5'	—	—	—	1.16	2.58
185	2,3,4,5,6,2',5'	—	—	—	1.11	5.65
186	2,3,4,5,6,2',6'	—	—	trace	trace	0.37
187	2,3,5,6,2',4',5'	—	—	—	0.48	1.12
189	2,3,4,5,3',4',5'	—	—	—	—	0.13
190	2,3,4,5,6,3',4'	—	—	—	—	0.02
192	2,3,4,5,6,3',5'	—	—	—	0.20	0.97
193	2,3,5,6,3',4',5'	—	—	—	2.30	—
194	2,3,4,5,2',3',4',5'	—	—	—	—	2.21
195	2,3,4,5,6,2',3',4'	—	—	—	—	trace
196	2,3,4,5,2',3',4',6'	—	—	—	—	0.79
197	2,3,4,6,2',3',4',6'	—	—	—	—	0.30
198	2,3,4,5,6,2',3',5'	—	—	—	1.00	0.15
199	2,3,4,5,6,2',3',6'	—	—	—	—	0.38
200	2,3,4,6,2',3',5',6'	—	—	—	trace	0.15
201	2,3,4,5,2',3',5',6'	—	—	—	—	1.54
202	2,3,5,6,2',3',5',6'	—	—	—	—	0.31
203	2,3,4,5,6,2',4',5'	—	—	—	—	0.08
204	2,3,4,5,6,2',4',6'	—	—	—	trace	0.13
205	2,3,4,5,6,3',4',5'	—	—	—	—	0.01
206	2,3,4,5,6,2',3',4',5'	—	—	—	—	0.51
207	2,3,4,5,6,2',3',4',6'	—	—	—	—	1.15
208	2,3,4,5,6,2',3',5',6'	—	—	—	—	0.18

[a] WHO 1993; the congener 169 (3,4,5,3',4',5') was not found in Aroclors; Albro and Parker 1979; Albro et al. 1981

[b] — Not detected

[c] Presence of these congeners has been reported by other investigators (see Section 3.2)

APPENDIX I

PCB CONGENER RESULTS FOR EACH REACH AND ZONE

Appendix I. PCB Congener Data and Homolog Results in Sediment

Location (Reach/Zone)	PCB Homolog Group #	PCB Congener	Total Number of Samples	Total Number Detected	RI Mean Result (ug/kg)	Cumulative Homolog Result	Reach Zone Total PCB	Percent of Reach/Zone Total PCB
Lake Winnebago	3	PCB Congener 20/33	3	2	2.9815	2.9815	10.35	28.81%
Lake Winnebago	4	PCB Congener 53	3	2	1.4685	1.4685		14.19%
Lake Winnebago	7	PCB Congener 170	3	1	2.8000	2.8		27.05%
Lake Winnebago	8	PCB Congener 194	3	1	3.1000	3.1		29.95%
LLBdM	2	PCB Congener 4/10	4	2	30.5000	1,462.1401	15,218.45	9.61%
LLBdM	2	PCB Congener 5	6	1	4.3000			
LLBdM	2	PCB Congener 6	33	30	192.6767			
LLBdM	2	PCB Congener 7	26	24	16.4775			
LLBdM	2	PCB Congener 7/9	4	2	11.1000			
LLBdM	2	PCB Congener 8	6	6	98.0167			
LLBdM	2	PCB Congener 8/5	29	29	1,014.6276			
LLBdM	2	PCB Congener 12	6	3	12.8667			
LLBdM	2	PCB Congener 15	2	2	6.4500			
LLBdM	2	PCB Congener 15	4	4	75.1250			
LLBdM	3	PCB Congener 16	6	6	61.1333	5,119.7345		33.64%
LLBdM	3	PCB Congener 16/32	29	29	472.6828			
LLBdM	3	PCB Congener 17	31	31	382.4806			
LLBdM	3	PCB Congener 17	4	4	75.1250			
LLBdM	3	PCB Congener 18	35	35	282.4314			
LLBdM	3	PCB Congener 19	27	25	37.8344			
LLBdM	3	PCB Congener 20	2	2	1.5000			
LLBdM	3	PCB Congener 20/33	4	4	60.1325			
LLBdM	3	PCB Congener 22	35	34	414.8941			
LLBdM	3	PCB Congener 24/27	27	26	70.7658			
LLBdM	3	PCB Congener 25	6	6	35.0333			
LLBdM	3	PCB Congener 26	35	35	330.3137			
LLBdM	3	PCB Congener 27	6	6	9.5500			
LLBdM	3	PCB Congener 28	6	6	157.1667			
LLBdM	3	PCB Congener 28/31	29	29	2,030.8690			
LLBdM	3	PCB Congener 31	6	6	146.3333			
LLBdM	3	PCB Congener 33	31	29	355.4586			
LLBdM	3	PCB Congener 37	6	6	29.9833			
LLBdM	3	PCB Congener 37	32	32	166.0466			
LLBdM	4	PCB Congener 40	35	33	72.4085	3,927.6891		25.81%
LLBdM	4	PCB Congener 41	6	6	31.9500			
LLBdM	4	PCB Congener 41/64/71	29	28	371.6679			
LLBdM	4	PCB Congener 42	2	2	7.0000			
LLBdM	4	PCB Congener 42	32	32	166.0466			
LLBdM	4	PCB Congener 44	35	35	336.6543			
LLBdM	4	PCB Congener 45	34	27	61.9519			
LLBdM	4	PCB Congener 46	28	27	32.5119			
LLBdM	4	PCB Congener 47	2	2	14.5000			
LLBdM	4	PCB Congener 47/48	29	29	337.4307			
LLBdM	4	PCB Congener 47/75	4	4	42.1750			
LLBdM	4	PCB Congener 49	35	31	341.9971			
LLBdM	4	PCB Congener 52	35	35	357.1523			
LLBdM	4	PCB Congener 53	2	2	5.8000			
LLBdM	4	PCB Congener 53	4	4	29.6175			
LLBdM	4	PCB Congener 56	2	2	6.5500			
LLBdM	4	PCB Congener 56/60	28	28	218.5429			
LLBdM	4	PCB Congener 56/60	4	4	30.8200			
LLBdM	4	PCB Congener 59	6	5	4.8600			
LLBdM	4	PCB Congener 66	2	2	23.5000			
LLBdM	4	PCB Congener 66	33	33	433.3045			

Appendix I. PCB Congener Data and Homolog Results in Sediment

Location (Reach/Zone)	PCB Homolog Group #	PCB Congener	Total Number of Samples	Total Number Detected	RI Mean Result (ug/kg)	Cumulative Homolog Result	Reach Zone Total PCB	Percent of Reach/Zone Total PCB
LLBdM	4	PCB Congener 70	6	6	46.8333			
LLBdM	4	PCB Congener 70/76	29	29	466.2069			
LLBdM	4	PCB Congener 74	35	35	150.9143			
LLBdM	4	PCB Congener 77	18	14	14.0071			
LLBdM	4	PCB Congener 77	33	33	318.7452			
LLBdM	4	PCB Congener 81	16	10	0.1359			
LLBdM	4	PCB Congener 81	4	4	4.4055			
LLBdM	5	PCB Congener 82	32	27	50.5307	2,428.7749		15.96%
LLBdM	5	PCB Congener 83	6	1	4.9000			
LLBdM	5	PCB Congener 84	6	6	12.1333			
LLBdM	5	PCB Congener 84/92	28	28	331.4357			
LLBdM	5	PCB Congener 85	33	27	89.3789			
LLBdM	5	PCB Congener 87	29	29	200.2893			
LLBdM	5	PCB Congener 87/115	4	4	8.9445			
LLBdM	5	PCB Congener 91	33	32	87.6006			
LLBdM	5	PCB Congener 92	2	2	5.0500			
LLBdM	5	PCB Congener 92	4	4	15.1800			
LLBdM	5	PCB Congener 95	2	2	25.5000			
LLBdM	5	PCB Congener 95	33	33	433.3045			
LLBdM	5	PCB Congener 97	34	33	110.7209			
LLBdM	5	PCB Congener 99	34	34	153.8388			
LLBdM	5	PCB Congener 101	34	34	271.5029			
LLBdM	5	PCB Congener 105	18	16	6.7875			
LLBdM	5	PCB Congener 107	6	2	3.4500			
LLBdM	5	PCB Congener 110	2	2	31.0000			
LLBdM	5	PCB Congener 110	33	33	318.7452			
LLBdM	5	PCB Congener 114	16	13	1.5623			
LLBdM	5	PCB Congener 118	46	46	257.0804			
LLBdM	5	PCB Congener 123	14	2	0.7400			
LLBdM	5	PCB Congener 123	4	4	7.5500			
LLBdM	5	PCB Congener 126	18	8	0.0971			
LLBdM	5	PCB Congener 126	4	1	1.4520			
LLBdM	6	PCB Congener 128	6	6	5.3333	1,501.9168		9.87%
LLBdM	6	PCB Congener 129	4	1	1.4520			
LLBdM	6	PCB Congener 132/153	29	29	426.6759			
LLBdM	6	PCB Congener 135	6	3	3.0333			
LLBdM	6	PCB Congener 135/144	28	28	52.3596			
LLBdM	6	PCB Congener 136	32	27	33.1633			
LLBdM	6	PCB Congener 137/176	19	3	7.3833			
LLBdM	6	PCB Congener 138	6	6	22.3167			
LLBdM	6	PCB Congener 141	31	20	59.2355			
LLBdM	6	PCB Congener 146	24	22	107.8409			
LLBdM	6	PCB Congener 149	30	30	198.9993			
LLBdM	6	PCB Congener 149	4	4	7.5500			
LLBdM	6	PCB Congener 151	33	29	52.8990			
LLBdM	6	PCB Congener 153	6	6	18.9667			
LLBdM	6	PCB Congener 156	18	15	2.0360			
LLBdM	6	PCB Congener 157	14	10	0.4483			
LLBdM	6	PCB Congener 163/138	28	28	490.5786			
LLBdM	6	PCB Congener 167	18	12	2.0450			
LLBdM	6	PCB Congener 168	6	3	9.6000			
LLBdM	7	PCB Congener 170	18	14	4.6121	448.7165		2.95%
LLBdM	7	PCB Congener 170/190	26	26	116.9692			
LLBdM	7	PCB Congener 202/171	23	22	13.6455			

Appendix I. PCB Congener Data and Homolog Results in Sediment

Location (Reach/Zone)	PCB Homolog Group #	PCB Congener	Total Number of Samples	Total Number Detected	RI Mean Result (ug/kg)	Cumulative Homolog Result	Reach Zone Total PCB	Percent of Reach/Zone Total PCB
LLBdM	7	PCB Congener 172/197	13	13	11.4177			
LLBdM	7	PCB Congener 174	32	26	44.9985			
LLBdM	7	PCB Congener 137/176	19	3	7.3833			
LLBdM	7	PCB Congener 177	31	26	34.6904			
LLBdM	7	PCB Congener 178	21	19	22.3979			
LLBdM	7	PCB Congener 178	4	1	1.4520			
LLBdM	7	PCB Congener 180	46	45	67.6460			
LLBdM	7	PCB Congener 182/187	27	26	58.0008			
LLBdM	7	PCB Congener 183	31	24	38.6992			
LLBdM	7	PCB Congener 185	16	9	13.0444			
LLBdM	7	PCB Congener 187	6	3	13.6000			
LLBdM	7	PCB Congener 189	18	8	0.1595			
LLBdM	8	PCB Congener 194	31	27	25.6481	226.5845		1.49%
LLBdM	8	PCB Congener 195	6	1	4.9000			
LLBdM	8	PCB Congener 195	24	24	18.8104			
LLBdM	8	PCB Congener 196	6	2	32.0000			
LLBdM	8	PCB Congener 196/203	23	23	61.7609			
LLBdM	8	PCB Congener 172/197	13	13	11.4177			
LLBdM	8	PCB Congener 199	16	8	2.6913			
LLBdM	8	PCB Congener 201	32	29	45.7107			
LLBdM	8	PCB Congener 202	6	1	10.0000			
LLBdM	8	PCB Congener 202/171	23	22	13.6455			
LLBdM	9	PCB Congener 206	31	27	37.5815	89.8919		0.59%
LLBdM	9	PCB Congener 208	6	2	33.5000			
LLBdM	9	PCB Congener 208	24	24	18.8104			
LLBdM	10	PCB Congener 209	6	1	13.0000	13.0000		0.09%
App. - LR	1	PCB Congener 1	8	2	4.5000	4.5000	16,599.37	0.03%
App. - LR	2	PCB Congener 4/10	7	4	176.0750	1,975.7597		11.90%
App. - LR	2	PCB Congener 6	15	15	195.2133			
App. - LR	2	PCB Congener 7	8	8	2.1613			
App. - LR	2	PCB Congener 7/9	7	6	54.4167			
App. - LR	2	PCB Congener 8	7	7	837.4143			
App. - LR	2	PCB Congener 8/5	8	8	137.3000			
App. - LR	2	PCB Congener 12	8	6	23.8167			
App. - LR	2	PCB Congener 15	8	8	549.3625			
App. - LR	3	PCB Congener 16	8	8	938.6000	8,591.7803		51.76%
App. - LR	3	PCB Congener 16/32	8	8	55.9125			
App. - LR	3	PCB Congener 17	8	8	40.1750			
App. - LR	3	PCB Congener 17	8	8	549.3625			
App. - LR	3	PCB Congener 18	16	16	843.1875			
App. - LR	3	PCB Congener 19	14	12	79.9925			
App. - LR	3	PCB Congener 20/33	7	7	810.3841			
App. - LR	3	PCB Congener 22	15	15	355.5600			
App. - LR	3	PCB Congener 24/27	8	8	6.7125			
App. - LR	3	PCB Congener 25	7	7	287.1857			
App. - LR	3	PCB Congener 26	15	15	236.9333			
App. - LR	3	PCB Congener 27	7	6	150.5333			
App. - LR	3	PCB Congener 28	7	7	1,975.5714			
App. - LR	3	PCB Congener 28/31	8	8	328.7500			
App. - LR	3	PCB Congener 31	7	7	1,642.2857			
App. - LR	3	PCB Congener 33	8	8	103.0875			
App. - LR	3	PCB Congener 37	4	4	7.5000			
App. - LR	3	PCB Congener 37	15	15	180.0467			
App. - LR	4	PCB Congener 40	15	15	124.9600	4,755.9229		28.65%

Appendix I. PCB Congener Data and Homolog Results in Sediment

Location (Reach/Zone)	PCB Homolog Group #	PCB Congener	Total Number of Samples	Total Number Detected	RI Mean Result (ug/kg)	Cumulative Homolog Result	Reach Zone Total PCB	Percent of Reach/Zone Total PCB
App. - LR	4	PCB Congener 41	7	7	447.6571			
App. - LR	4	PCB Congener 41/64/71	8	8	63.4375			
App. - LR	4	PCB Congener 42	15	15	180.0467			
App. - LR	4	PCB Congener 44	15	15	380.5333			
App. - LR	4	PCB Congener 45	15	11	130.9382			
App. - LR	4	PCB Congener 46	7	7	5.6000			
App. - LR	4	PCB Congener 47/48	8	8	41.7250			
App. - LR	4	PCB Congener 47/75	7	7	252.3714			
App. - LR	4	PCB Congener 49	15	11	468.1818			
App. - LR	4	PCB Congener 52	15	15	447.1200			
App. - LR	4	PCB Congener 53	7	7	399.1444			
App. - LR	4	PCB Congener 56/60	8	8	85.1375			
App. - LR	4	PCB Congener 56/60	7	7	282.4624			
App. - LR	4	PCB Congener 59	7	5	118.5200			
App. - LR	4	PCB Congener 66	15	15	254.1600			
App. - LR	4	PCB Congener 70	7	7	658.0000			
App. - LR	4	PCB Congener 70/76	8	8	103.3125			
App. - LR	4	PCB Congener 74	15	15	209.3333			
App. - LR	4	PCB Congener 77	9	5	11.1740			
App. - LR	4	PCB Congener 77	15	15	79.2200			
App. - LR	4	PCB Congener 81	9	5	0.1694			
App. - LR	4	PCB Congener 81	7	5	12.7182			
App. - LR	5	PCB Congener 82	15	13	39.0723	976.3604		5.88%
App. - LR	5	PCB Congener 84	7	6	85.0500			
App. - LR	5	PCB Congener 84/92	8	8	20.4875			
App. - LR	5	PCB Congener 85	14	10	18.1600			
App. - LR	5	PCB Congener 87	8	8	12.5250			
App. - LR	5	PCB Congener 87/115	7	5	25.8218			
App. - LR	5	PCB Congener 91	15	9	22.8333			
App. - LR	5	PCB Congener 92	7	7	139.1233			
App. - LR	5	PCB Congener 95	15	15	254.1600			
App. - LR	5	PCB Congener 97	15	14	35.3214			
App. - LR	5	PCB Congener 99	15	11	60.4364			
App. - LR	5	PCB Congener 101	16	16	92.0000			
App. - LR	5	PCB Congener 105	13	9	18.4489			
App. - LR	5	PCB Congener 110	15	15	79.2200			
App. - LR	5	PCB Congener 114	13	5	0.2012			
App. - LR	5	PCB Congener 118	21	21	54.2305			
App. - LR	5	PCB Congener 123	8	7	19.2179			
App. - LR	5	PCB Congener 126	9	2	0.0510			
App. - LR	6	PCB Congener 128	8	3	1.4733	221.7616		1.34%
App. - LR	6	PCB Congener 132/153	8	8	23.1375			
App. - LR	6	PCB Congener 135	8	3	1.2433			
App. - LR	6	PCB Congener 135/144	8	8	2.3788			
App. - LR	6	PCB Congener 136	14	5	1.3240			
App. - LR	6	PCB Congener 137/176	1	1	0.3450			
App. - LR	6	PCB Congener 138	8	8	69.3125			
App. - LR	6	PCB Congener 141	14	5	2.2600			
App. - LR	6	PCB Congener 146	6	3	7.1333			
App. - LR	6	PCB Congener 149	8	8	10.3000			
App. - LR	6	PCB Congener 149	8	7	19.2179			
App. - LR	6	PCB Congener 151	16	8	3.1338			
App. - LR	6	PCB Congener 153	8	8	58.1900			
App. - LR	6	PCB Congener 156	13	7	0.6941			

Appendix I. PCB Congener Data and Homolog Results in Sediment

Location (Reach/Zone)	PCB Homolog Group #	PCB Congener	Total Number of Samples	Total Number Detected	RI Mean Result (ug/kg)	Cumulative Homolog Result	Reach Zone Total PCB	Percent of Reach/Zone Total PCB
App. - LR	6	PCB Congener 157	5	5	0.1190			
App. - LR	6	PCB Congener 163/138	8	8	18.9625			
App. - LR	6	PCB Congener 167	13	5	0.7366			
App. - LR	6	PCB Congener 168	8	1	1.8000			
App. - LR	7	PCB Congener 170	13	6	2.0150	50.0656		0.30%
App. - LR	7	PCB Congener 170/190	8	6	5.7333			
App. - LR	7	PCB Congener 202/171	6	6	0.9792			
App. - LR	7	PCB Congener 174	16	8	3.6463			
App. - LR	7	PCB Congener 137/176	1	1	0.3450			
App. - LR	7	PCB Congener 177	16	9	2.5989			
App. - LR	7	PCB Congener 178	3	3	1.8667			
App. - LR	7	PCB Congener 180	21	18	18.0544			
App. - LR	7	PCB Congener 182/187	8	8	5.2125			
App. - LR	7	PCB Congener 183	14	6	2.9467			
App. - LR	7	PCB Congener 185	9	1	2.2000			
App. - LR	7	PCB Congener 187	8	1	1.1000			
App. - LR	7	PCB Congener 189	13	3	0.0677			
App. - LR	7	PCB Congener 192	4	1	3.3000			
App. - LR	8	PCB Congener 194	15	11	2.1282	18.1534		0.11%
App. - LR	8	PCB Congener 195	4	4	2.0000			
App. - LR	8	PCB Congener 196	7	1	2.7000			
App. - LR	8	PCB Congener 196/203	7	7	5.9571			
App. - LR	8	PCB Congener 201	15	9	4.3889			
App. - LR	8	PCB Congener 202/171	6	6	0.9792			
App. - LR	9	PCB Congener 206	15	9	3.0667	5.0667		0.03%
App. - LR	9	PCB Congener 208	4	4	2.0000			
LR - DP	1	PCB Congener 3	14	5	96.2000	96.2000	9,156.20	1.05%
LR - DP	2	PCB Congener 4	2	2	109.0000	1,051.9877		11.49%
LR - DP	2	PCB Congener 4/10	12	3	36.0667			
LR - DP	2	PCB Congener 6	31	28	41.0571			
LR - DP	2	PCB Congener 7	19	17	4.3076			
LR - DP	2	PCB Congener 7/9	12	5	9.2600			
LR - DP	2	PCB Congener 8	14	14	169.3786			
LR - DP	2	PCB Congener 8/5	17	17	351.1176			
LR - DP	2	PCB Congener 9	2	2	14.7000			
LR - DP	2	PCB Congener 12	14	6	6.8500			
LR - DP	2	PCB Congener 15	2	2	239.5000			
LR - DP	2	PCB Congener 15	12	11	70.7500			
LR - DP	3	PCB Congener 16	14	13	165.1538	3,539.6776		38.66%
LR - DP	3	PCB Congener 16/32	17	17	178.6941			
LR - DP	3	PCB Congener 17	19	19	156.5579			
LR - DP	3	PCB Congener 17	12	11	70.7500			
LR - DP	3	PCB Congener 18	31	31	228.3323			
LR - DP	3	PCB Congener 19	27	16	22.9813			
LR - DP	3	PCB Congener 20	2	2	204.5000			
LR - DP	3	PCB Congener 20/33	12	11	98.0636			
LR - DP	3	PCB Congener 22	31	31	182.5968			
LR - DP	3	PCB Congener 24/27	17	17	18.1376			
LR - DP	3	PCB Congener 25	14	12	46.6667			
LR - DP	3	PCB Congener 26	31	29	84.3138			
LR - DP	3	PCB Congener 27	14	12	25.8167			
LR - DP	3	PCB Congener 28	14	14	380.1714			
LR - DP	3	PCB Congener 28/31	17	17	881.2941			
LR - DP	3	PCB Congener 29	14	1	8.3000			

Appendix I. PCB Congener Data and Homolog Results in Sediment

Location (Reach/Zone)	PCB Homolog Group #	PCB Congener	Total Number of Samples	Total Number Detected	RI Mean Result (ug/kg)	Cumulative Homolog Result	Reach Zone Total PCB	Percent of Reach/Zone Total PCB
LR - DP	3	PCB Congener 31	14	14	314.2429			
LR - DP	3	PCB Congener 33	19	19	321.2105			
LR - DP	3	PCB Congener 37	14	13	87.3923			
LR - DP	3	PCB Congener 37	29	28	64.5018			
LR - DP	4	PCB Congener 40	31	27	42.8852	3,289.5029		35.93%
LR - DP	4	PCB Congener 41	14	13	87.1846			
LR - DP	4	PCB Congener 41/64/71	16	16	170.9375			
LR - DP	4	PCB Congener 42	2	2	188.5000			
LR - DP	4	PCB Congener 42	29	28	64.5018			
LR - DP	4	PCB Congener 44	31	30	159.7767			
LR - DP	4	PCB Congener 45	31	30	30.7780			
LR - DP	4	PCB Congener 46	17	17	15.4618			
LR - DP	4	PCB Congener 47	2	2	228.5000			
LR - DP	4	PCB Congener 47/48	17	17	109.0529			
LR - DP	4	PCB Congener 47/75	12	11	45.7545			
LR - DP	4	PCB Congener 49	31	27	136.5370			
LR - DP	4	PCB Congener 52	31	30	148.2433			
LR - DP	4	PCB Congener 53	2	2	99.0000			
LR - DP	4	PCB Congener 53	12	11	48.3000			
LR - DP	4	PCB Congener 56	2	2	257.0000			
LR - DP	4	PCB Congener 56/60	17	17	184.1176			
LR - DP	4	PCB Congener 56/60	12	11	38.2935			
LR - DP	4	PCB Congener 59	14	4	18.3000			
LR - DP	4	PCB Congener 66	2	2	525.0000			
LR - DP	4	PCB Congener 66	29	28	128.6250			
LR - DP	4	PCB Congener 70	14	14	150.0286			
LR - DP	4	PCB Congener 70/76	17	17	259.0000			
LR - DP	4	PCB Congener 74	31	30	88.2467			
LR - DP	4	PCB Congener 75	2	2	8.6500			
LR - DP	4	PCB Congener 77	23	15	22.1000			
LR - DP	4	PCB Congener 77	29	28	30.1857			
LR - DP	4	PCB Congener 81	22	10	0.5194			
LR - DP	4	PCB Congener 81	12	11	4.0230			
LR - DP	5	PCB Congener 82	31	25	10.7272	761.3397		8.32%
LR - DP	5	PCB Congener 83	14	2	13.5500			
LR - DP	5	PCB Congener 84	14	9	19.5889			
LR - DP	5	PCB Congener 84/92	17	17	41.3118			
LR - DP	5	PCB Congener 85	31	23	14.2078			
LR - DP	5	PCB Congener 87	19	19	22.8632			
LR - DP	5	PCB Congener 87/115	12	11	8.1679			
LR - DP	5	PCB Congener 91	31	22	13.9455			
LR - DP	5	PCB Congener 92	2	2	14.7000			
LR - DP	5	PCB Congener 92	12	11	18.8610			
LR - DP	5	PCB Congener 95	2	2	136.5000			
LR - DP	5	PCB Congener 95	29	28	128.6250			
LR - DP	5	PCB Congener 97	31	25	19.7960			
LR - DP	5	PCB Congener 99	31	28	22.8321			
LR - DP	5	PCB Congener 101	31	29	39.8069			
LR - DP	5	PCB Congener 105	23	20	12.1820			
LR - DP	5	PCB Congener 107	14	3	6.7667			
LR - DP	5	PCB Congener 110	2	2	127.5000			
LR - DP	5	PCB Congener 110	29	28	30.1857			
LR - DP	5	PCB Congener 114	21	9	4.5382			
LR - DP	5	PCB Congener 118	40	39	34.2692			

Appendix I. PCB Congener Data and Homolog Results in Sediment

Location (Reach/Zone)	PCB Homolog Group #	PCB Congener	Total Number of Samples	Total Number Detected	RI Mean Result (ug/kg)	Cumulative Homolog Result	Reach Zone Total PCB	Percent of Reach/Zone Total PCB
LR - DP	5	PCB Congener 119	14	1	6.8000			
LR - DP	5	PCB Congener 123	11	1	5.9000			
LR - DP	5	PCB Congener 123	12	8	6.4000			
LR - DP	5	PCB Congener 126	23	5	0.2256			
LR - DP	5	PCB Congener 126	12	2	1.0890			
LR - DP	6	PCB Congener 128	14	5	9.0600	221.8007		2.42%
LR - DP	6	PCB Congener 129	12	2	1.0890			
LR - DP	6	PCB Congener 132/153	17	17	37.8706			
LR - DP	6	PCB Congener 135	14	5	10.7200			
LR - DP	6	PCB Congener 135/144	15	15	3.6440			
LR - DP	6	PCB Congener 136	27	7	6.7571			
LR - DP	6	PCB Congener 137/176	4	3	0.7000			
LR - DP	6	PCB Congener 138	14	13	23.9154			
LR - DP	6	PCB Congener 141	29	16	5.5131			
LR - DP	6	PCB Congener 146	13	7	26.0429			
LR - DP	6	PCB Congener 149	19	19	21.5158			
LR - DP	6	PCB Congener 149	12	8	6.4000			
LR - DP	6	PCB Congener 151	31	21	6.5586			
LR - DP	6	PCB Congener 153	14	13	21.0308			
LR - DP	6	PCB Congener 156	23	14	2.5757			
LR - DP	6	PCB Congener 157	11	9	0.2768			
LR - DP	6	PCB Congener 157	12	1	1.0000			
LR - DP	6	PCB Congener 163/138	17	17	26.8471			
LR - DP	6	PCB Congener 167	23	9	1.1089			
LR - DP	6	PCB Congener 168	14	4	9.1750			
LR - DP	7	PCB Congener 170	23	14	8.2129	99.0852		1.08%
LR - DP	7	PCB Congener 170/190	16	13	9.6000			
LR - DP	7	PCB Congener 171	14	2	8.8500			
LR - DP	7	PCB Congener 202/171	14	14	1.8036			
LR - DP	7	PCB Congener 172/197	1	1	0.9000			
LR - DP	7	PCB Congener 174	31	21	8.0348			
LR - DP	7	PCB Congener 176	14	3	4.6667			
LR - DP	7	PCB Congener 137/176	4	3	0.7000			
LR - DP	7	PCB Congener 177	29	19	5.9474			
LR - DP	7	PCB Congener 178	6	4	1.9250			
LR - DP	7	PCB Congener 178	12	2	1.0890			
LR - DP	7	PCB Congener 179	14	1	6.6000			
LR - DP	7	PCB Congener 180	40	36	14.1722			
LR - DP	7	PCB Congener 182/187	17	17	9.2088			
LR - DP	7	PCB Congener 183	29	17	5.9482			
LR - DP	7	PCB Congener 187	14	9	11.2778			
LR - DP	7	PCB Congener 189	23	8	0.1489			
LR - DP	8	PCB Congener 194	30	27	5.0407	50.9273		0.56%
LR - DP	8	PCB Congener 195	14	2	4.8500			
LR - DP	8	PCB Congener 195	16	16	3.4728			
LR - DP	8	PCB Congener 196	14	3	11.7000			
LR - DP	8	PCB Congener 196/203	16	16	9.7638			
LR - DP	8	PCB Congener 172/197	1	1	0.9000			
LR - DP	8	PCB Congener 200	12	1	1.0000			
LR - DP	8	PCB Congener 201	31	26	8.2631			
LR - DP	8	PCB Congener 202	14	3	4.1333			
LR - DP	8	PCB Congener 202/171	14	14	1.8036			
LR - DP	9	PCB Congener 206	30	21	7.5300	31.2600		0.34%
LR - DP	9	PCB Congener 207	14	1	2.1000			

Appendix I. PCB Congener Data and Homolog Results in Sediment

Location (Reach/Zone)	PCB Homolog Group #	PCB Congener	Total Number of Samples	Total Number Detected	RI Mean Result (ug/kg)	Cumulative Homolog Result	Reach Zone Total PCB	Percent of Reach/Zone Total PCB
LR - DP	9	PCB Congener 208	14	7	18.1571			
LR - DP	9	PCB Congener 208	16	16	3.4728			
LR - DP	10	PCB Congener 209	14	5	14.4200	14.4200		0.16%
DP - GB	1	PCB Congener 3	5	1	10.0000	10.0000	4,066.09	0.25%
DP - GB	2	PCB Congener 6	8	8	45.9250	546.9683		13.45%
DP - GB	2	PCB Congener 7	3	3	3.8333			
DP - GB	2	PCB Congener 7/9	5	3	9.1000			
DP - GB	2	PCB Congener 8	5	5	128.5000			
DP - GB	2	PCB Congener 8/5	3	3	296.6667			
DP - GB	2	PCB Congener 12	5	3	8.2333			
DP - GB	2	PCB Congener 15	5	5	54.7100			
DP - GB	3	PCB Congener 16	5	5	84.7000	1,993.0505		49.02%
DP - GB	3	PCB Congener 16/32	3	3	110.0000			
DP - GB	3	PCB Congener 17	3	3	77.0000			
DP - GB	3	PCB Congener 17	5	5	54.7100			
DP - GB	3	PCB Congener 18	8	8	129.2125			
DP - GB	3	PCB Congener 19	8	7	10.0000			
DP - GB	3	PCB Congener 20/33	5	5	70.5376			
DP - GB	3	PCB Congener 22	8	8	86.7875			
DP - GB	3	PCB Congener 24/27	3	3	9.0333			
DP - GB	3	PCB Congener 25	5	5	39.0400			
DP - GB	3	PCB Congener 26	8	5	54.4000			
DP - GB	3	PCB Congener 27	5	4	15.8000			
DP - GB	3	PCB Congener 28	5	5	242.4000			
DP - GB	3	PCB Congener 28/31	3	3	586.6667			
DP - GB	3	PCB Congener 31	5	5	183.9400			
DP - GB	3	PCB Congener 33	3	3	136.6667			
DP - GB	3	PCB Congener 37	5	5	71.6000			
DP - GB	3	PCB Congener 37	8	8	30.5563			
DP - GB	4	PCB Congener 40	8	8	22.2225	1,091.3948		26.84%
DP - GB	4	PCB Congener 41	5	5	43.6800			
DP - GB	4	PCB Congener 41/64/71	3	3	96.0000			
DP - GB	4	PCB Congener 42	8	8	30.5563			
DP - GB	4	PCB Congener 44	8	8	79.2875			
DP - GB	4	PCB Congener 45	8	6	17.8333			
DP - GB	4	PCB Congener 46	3	3	9.2000			
DP - GB	4	PCB Congener 47/48	3	3	65.0000			
DP - GB	4	PCB Congener 47/75	5	5	40.0200			
DP - GB	4	PCB Congener 49	8	7	72.7714			
DP - GB	4	PCB Congener 52	8	8	90.3875			
DP - GB	4	PCB Congener 53	5	5	34.7424			
DP - GB	4	PCB Congener 56/60	3	3	98.6667			
DP - GB	4	PCB Congener 56/60	5	5	32.9238			
DP - GB	4	PCB Congener 59	5	4	7.7750			
DP - GB	4	PCB Congener 66	8	8	53.8188			
DP - GB	4	PCB Congener 70	5	5	69.1800			
DP - GB	4	PCB Congener 70/76	3	3	143.3333			
DP - GB	4	PCB Congener 74	8	8	44.9125			
DP - GB	4	PCB Congener 77	26	24	13.9667			
DP - GB	4	PCB Congener 77	8	8	20.4875			
DP - GB	4	PCB Congener 81	21	16	0.0823			
DP - GB	4	PCB Congener 81	5	5	4.5474			
DP - GB	5	PCB Congener 82	8	8	6.8150	242.9705		5.98%
DP - GB	5	PCB Congener 84	5	4	11.6250			

Appendix I. PCB Congener Data and Homolog Results in Sediment

Location (Reach/Zone)	PCB Homolog Group #	PCB Congener	Total Number of Samples	Total Number Detected	RI Mean Result (ug/kg)	Cumulative Homolog Result	Reach Zone Total PCB	Percent of Reach/Zone Total PCB
DP - GB	5	PCB Congener 84/92	3	3	24.6667			
DP - GB	5	PCB Congener 85	8	3	8.8333			
DP - GB	5	PCB Congener 87	3	3	13.3333			
DP - GB	5	PCB Congener 87/115	5	5	9.2326			
DP - GB	5	PCB Congener 91	8	3	5.4333			
DP - GB	5	PCB Congener 92	5	5	16.2162			
DP - GB	5	PCB Congener 95	8	8	53.8188			
DP - GB	5	PCB Congener 97	8	7	9.2429			
DP - GB	5	PCB Congener 99	8	7	13.2143			
DP - GB	5	PCB Congener 101	8	8	24.3250			
DP - GB	5	PCB Congener 105	26	25	5.8464			
DP - GB	5	PCB Congener 110	8	8	20.4875			
DP - GB	5	PCB Congener 114	23	17	1.0948			
DP - GB	5	PCB Congener 118	26	26	12.7077			
DP - GB	5	PCB Congener 123	21	3	1.1867			
DP - GB	5	PCB Congener 123	5	4	4.8125			
DP - GB	5	PCB Congener 126	26	5	0.0786			
DP - GB	6	PCB Congener 128	7	4	5.8250	123.2046		3.03%
DP - GB	6	PCB Congener 132/153	3	3	28.3333			
DP - GB	6	PCB Congener 135/144	3	3	2.9333			
DP - GB	6	PCB Congener 136	8	2	2.7500			
DP - GB	6	PCB Congener 138	5	5	14.4600			
DP - GB	6	PCB Congener 141	8	3	2.5000			
DP - GB	6	PCB Congener 146	3	3	15.0000			
DP - GB	6	PCB Congener 149	3	3	11.8667			
DP - GB	6	PCB Congener 149	5	4	4.8125			
DP - GB	6	PCB Congener 151	8	3	3.6000			
DP - GB	6	PCB Congener 153	5	5	12.4000			
DP - GB	6	PCB Congener 156	26	21	0.6490			
DP - GB	6	PCB Congener 157	21	16	0.0491			
DP - GB	6	PCB Congener 163/138	3	3	17.6667			
DP - GB	6	PCB Congener 167	23	18	0.3589			
DP - GB	7	PCB Congener 170	23	18	1.3228	31.1289		0.77%
DP - GB	7	PCB Congener 174	8	1	4.5000			
DP - GB	7	PCB Congener 177	8	1	12.0000			
DP - GB	7	PCB Congener 180	26	24	4.1154			
DP - GB	7	PCB Congener 182/187	3	3	6.4667			
DP - GB	7	PCB Congener 183	7	2	2.6500			
DP - GB	7	PCB Congener 189	23	6	0.0740			
DP - GB	8	PCB Congener 194	8	5	4.5200	21.9200		0.54%
DP - GB	8	PCB Congener 195	2	1	1.7000			
DP - GB	8	PCB Congener 196	5	1	4.8000			
DP - GB	8	PCB Congener 196/203	3	3	5.8667			
DP - GB	8	PCB Congener 201	8	3	5.0333			
DP - GB	9	PCB Congener 206	8	2	3.7500	5.4500		0.13%
DP - GB	9	PCB Congener 208	2	1	1.7000			
GB Zone 2	1	PCB Congener 1	4	1	18.7590	23.9435	550.68	4.35%
GB Zone 2	1	PCB Congener 3	4	2	5.1845			
GB Zone 2	2	PCB Congener 4/10	4	3	0.4050	38.3098		6.96%
GB Zone 2	2	PCB Congener 7	4	3	1.0197			
GB Zone 2	2	PCB Congener 8/5	4	3	35.3137			
GB Zone 2	2	PCB Congener 12/13	4	2	1.5715			
GB Zone 2	3	PCB Congener 16/32	4	3	11.1297	153.4626		27.87%
GB Zone 2	3	PCB Congener 17	4	3	7.5823			

Appendix I. PCB Congener Data and Homolog Results in Sediment

Location (Reach/Zone)	PCB Homolog Group #	PCB Congener	Total Number of Samples	Total Number Detected	RI Mean Result (ug/kg)	Cumulative Homolog Result	Reach Zone Total PCB	Percent of Reach/Zone Total PCB
GB Zone 2	3	PCB Congener 18	4	4	10.2173			
GB Zone 2	3	PCB Congener 19	4	1	1.0520			
GB Zone 2	3	PCB Congener 21	4	2	0.1480			
GB Zone 2	3	PCB Congener 22	4	3	31.5537			
GB Zone 2	3	PCB Congener 24/27	4	1	0.8410			
GB Zone 2	3	PCB Congener 25	4	3	4.4237			
GB Zone 2	3	PCB Congener 26	4	4	6.8410			
GB Zone 2	3	PCB Congener 28/31	4	4	50.9130			
GB Zone 2	3	PCB Congener 29	4	4	0.1865			
GB Zone 2	3	PCB Congener 33	4	4	21.6815			
GB Zone 2	3	PCB Congener 37	4	1	6.8930			
GB Zone 2	4	PCB Congener 40	4	3	5.8867	218.3708		39.65%
GB Zone 2	4	PCB Congener 41/64/71	4	4	16.7390			
GB Zone 2	4	PCB Congener 42	4	1	6.8930			
GB Zone 2	4	PCB Congener 43	4	1	3.5020			
GB Zone 2	4	PCB Congener 45	4	4	2.3463			
GB Zone 2	4	PCB Congener 46	4	1	4.5510			
GB Zone 2	4	PCB Congener 47/48	4	2	12.8135			
GB Zone 2	4	PCB Congener 49	4	3	18.4027			
GB Zone 2	4	PCB Congener 52	4	3	18.9647			
GB Zone 2	4	PCB Congener 53	4	3	1.5893			
GB Zone 2	4	PCB Congener 56/60	4	4	37.3703			
GB Zone 2	4	PCB Congener 63	4	3	2.2890			
GB Zone 2	4	PCB Congener 66	4	4	18.3600			
GB Zone 2	4	PCB Congener 70/76	4	4	45.1458			
GB Zone 2	4	PCB Congener 74	4	4	13.7695			
GB Zone 2	4	PCB Congener 77	11	11	3.2344			
GB Zone 2	4	PCB Congener 77	4	4	6.3291			
GB Zone 2	4	PCB Congener 81	15	12	0.1848			
GB Zone 2	5	PCB Congener 82	4	3	2.4943	72.0384		13.08%
GB Zone 2	5	PCB Congener 83	4	3	0.7897			
GB Zone 2	5	PCB Congener 84/92	4	3	7.9770			
GB Zone 2	5	PCB Congener 85	4	4	4.0218			
GB Zone 2	5	PCB Congener 87	4	4	4.2118			
GB Zone 2	5	PCB Congener 89	4	3	0.1213			
GB Zone 2	5	PCB Congener 91	4	3	1.5403			
GB Zone 2	5	PCB Congener 95	4	4	18.3600			
GB Zone 2	5	PCB Congener 97	4	4	1.9723			
GB Zone 2	5	PCB Congener 99	4	4	3.5993			
GB Zone 2	5	PCB Congener 100	4	3	1.3547			
GB Zone 2	5	PCB Congener 101	4	4	5.3833			
GB Zone 2	5	PCB Congener 105	11	10	2.0212			
GB Zone 2	5	PCB Congener 105	4	4	5.6258			
GB Zone 2	5	PCB Congener 107	4	2	1.6135			
GB Zone 2	5	PCB Congener 110	4	4	6.3291			
GB Zone 2	5	PCB Congener 114	11	8	0.1876			
GB Zone 2	5	PCB Congener 118	15	14	4.0893			
GB Zone 2	5	PCB Congener 119	4	2	0.1755			
GB Zone 2	5	PCB Congener 124	4	4	0.1222			
GB Zone 2	5	PCB Congener 126	11	5	0.0486			
GB Zone 2	6	PCB Congener 128	4	3	0.7257	19.2484		3.50%
GB Zone 2	6	PCB Congener 129	4	4	0.2425			
GB Zone 2	6	PCB Congener 130	4	4	0.3435			
GB Zone 2	6	PCB Congener 131	4	3	0.1850			

Appendix I. PCB Congener Data and Homolog Results in Sediment

Location (Reach/Zone)	PCB Homolog Group #	PCB Congener	Total Number of Samples	Total Number Detected	RI Mean Result (ug/kg)	Cumulative Homolog Result	Reach Zone Total PCB	Percent of Reach/Zone Total PCB
GB Zone 2	6	PCB Congener 132/153	4	4	5.6258			
GB Zone 2	6	PCB Congener 135/144/1	4	4	0.3666			
GB Zone 2	6	PCB Congener 137/176	4	2	0.0663			
GB Zone 2	6	PCB Congener 138/158/1	4	4	4.7700			
GB Zone 2	6	PCB Congener 141	4	4	0.6868			
GB Zone 2	6	PCB Congener 146	4	3	1.6010			
GB Zone 2	6	PCB Congener 149	4	3	3.1307			
GB Zone 2	6	PCB Congener 151	4	4	0.7355			
GB Zone 2	6	PCB Congener 156	11	8	0.1841			
GB Zone 2	6	PCB Congener 156	4	3	0.2705			
GB Zone 2	6	PCB Congener 157	11	7	0.0560			
GB Zone 2	6	PCB Congener 167	15	11	0.2586			
GB Zone 2	7	PCB Congener 170	11	11	0.4102	11.8947		2.16%
GB Zone 2	7	PCB Congener 170/190	4	4	2.2940			
GB Zone 2	7	PCB Congener 171	4	3	0.2705			
GB Zone 2	7	PCB Congener 172/197	4	1	0.0990			
GB Zone 2	7	PCB Congener 173	4	1	0.1060			
GB Zone 2	7	PCB Congener 174	4	3	1.6693			
GB Zone 2	7	PCB Congener 175	4	1	0.4480			
GB Zone 2	7	PCB Congener 137/176	4	2	0.0663			
GB Zone 2	7	PCB Congener 177	4	3	1.3483			
GB Zone 2	7	PCB Congener 178	4	4	0.2425			
GB Zone 2	7	PCB Congener 180	15	13	1.2165			
GB Zone 2	7	PCB Congener 182/187	4	4	1.5838			
GB Zone 2	7	PCB Congener 183	4	3	1.0497			
GB Zone 2	7	PCB Congener 185	4	3	0.3050			
GB Zone 2	7	PCB Congener 189	15	3	0.1027			
GB Zone 2	7	PCB Congener 191	4	1	0.3950			
GB Zone 2	7	PCB Congener 193	4	3	0.2880			
GB Zone 2	8	PCB Congener 194	4	2	0.9255	10.2542		1.86%
GB Zone 2	8	PCB Congener 195	4	1	0.8890			
GB Zone 2	8	PCB Congener 196/203	4	2	2.7965			
GB Zone 2	8	PCB Congener 172/197	4	1	0.0990			
GB Zone 2	8	PCB Congener 198	4	1	0.2140			
GB Zone 2	8	PCB Congener 199	4	2	0.0970			
GB Zone 2	8	PCB Congener 201	4	3	3.3247			
GB Zone 2	8	PCB Congener 202	4	3	0.2705			
GB Zone 2	8	PCB Congener 205	4	1	1.6380			
GB Zone 2	9	PCB Congener 206	4	1	1.9400	2.8290		0.51%
GB Zone 2	9	PCB Congener 208	4	1	0.8890			
GB Zone 2	10	PCB Congener 209	4	1	0.3270	0.3270		0.06%
GB Zone 3A	1	PCB Congener 1	13	7	4.3679	11.1525	472.59	2.36%
GB Zone 3A	1	PCB Congener 3	13	3	6.7847			
GB Zone 3A	2	PCB Congener 4/10	13	10	0.5980	25.5100		5.40%
GB Zone 3A	2	PCB Congener 6	13	3	1.1973			
GB Zone 3A	2	PCB Congener 7	13	13	0.8700			
GB Zone 3A	2	PCB Congener 8/5	13	12	22.0933			
GB Zone 3A	2	PCB Congener 12/13	13	11	0.7515			
GB Zone 3A	3	PCB Congener 16/32	13	13	5.4380	119.4549		25.28%
GB Zone 3A	3	PCB Congener 17	13	12	5.5622			
GB Zone 3A	3	PCB Congener 18	13	13	8.3340			
GB Zone 3A	3	PCB Congener 19	13	8	0.3958			
GB Zone 3A	3	PCB Congener 21	13	8	0.4376			
GB Zone 3A	3	PCB Congener 22	13	12	19.4934			

Appendix I. PCB Congener Data and Homolog Results in Sediment

Location (Reach/Zone)	PCB Homolog Group #	PCB Congener	Total Number of Samples	Total Number Detected	RI Mean Result (ug/kg)	Cumulative Homolog Result	Reach Zone Total PCB	Percent of Reach/Zone Total PCB
GB Zone 3A	3	PCB Congener 24/27	13	8	0.6333			
GB Zone 3A	3	PCB Congener 25	13	12	3.3117			
GB Zone 3A	3	PCB Congener 26	13	12	5.9483			
GB Zone 3A	3	PCB Congener 28/31	13	12	44.8115			
GB Zone 3A	3	PCB Congener 29	13	8	0.3323			
GB Zone 3A	3	PCB Congener 33	13	13	17.4222			
GB Zone 3A	3	PCB Congener 37	13	2	7.3348			
GB Zone 3A	4	PCB Congener 40	13	11	3.6555	180.7664		38.25%
GB Zone 3A	4	PCB Congener 41/64/71	13	12	16.9991			
GB Zone 3A	4	PCB Congener 42	13	2	7.3348			
GB Zone 3A	4	PCB Congener 43	13	7	0.6460			
GB Zone 3A	4	PCB Congener 45	13	11	1.5173			
GB Zone 3A	4	PCB Congener 46	13	8	1.3573			
GB Zone 3A	4	PCB Congener 47/48	13	7	5.9351			
GB Zone 3A	4	PCB Congener 49	13	13	11.1544			
GB Zone 3A	4	PCB Congener 52	13	12	12.8433			
GB Zone 3A	4	PCB Congener 53	13	10	0.9681			
GB Zone 3A	4	PCB Congener 56/60	13	13	34.8905			
GB Zone 3A	4	PCB Congener 63	13	9	1.9296			
GB Zone 3A	4	PCB Congener 66	13	13	20.5125			
GB Zone 3A	4	PCB Congener 70/76	13	13	39.3267			
GB Zone 3A	4	PCB Congener 74	13	13	14.2927			
GB Zone 3A	4	PCB Congener 77	2	2	0.0420			
GB Zone 3A	4	PCB Congener 77	13	13	6.9159			
GB Zone 3A	4	PCB Congener 81	15	14	0.4457			
GB Zone 3A	5	PCB Congener 82	13	13	1.8583	80.5422		17.04%
GB Zone 3A	5	PCB Congener 83	13	12	0.6175			
GB Zone 3A	5	PCB Congener 84/92	13	13	6.6253			
GB Zone 3A	5	PCB Congener 85	13	13	3.4478			
GB Zone 3A	5	PCB Congener 87	13	12	4.7658			
GB Zone 3A	5	PCB Congener 89	13	8	0.3065			
GB Zone 3A	5	PCB Congener 91	13	11	1.4870			
GB Zone 3A	5	PCB Congener 95	13	13	20.5125			
GB Zone 3A	5	PCB Congener 97	13	13	2.6139			
GB Zone 3A	5	PCB Congener 99	13	13	4.5394			
GB Zone 3A	5	PCB Congener 100	13	10	1.2399			
GB Zone 3A	5	PCB Congener 101	13	13	6.6102			
GB Zone 3A	5	PCB Congener 105	2	1	1.6000			
GB Zone 3A	5	PCB Congener 105	13	13	6.9265			
GB Zone 3A	5	PCB Congener 107	13	9	1.4812			
GB Zone 3A	5	PCB Congener 110	13	13	6.9159			
GB Zone 3A	5	PCB Congener 114	2	1	0.0930			
GB Zone 3A	5	PCB Congener 114	13	4	0.4580			
GB Zone 3A	5	PCB Congener 118	15	11	7.6610			
GB Zone 3A	5	PCB Congener 119	13	11	0.5803			
GB Zone 3A	5	PCB Congener 124	13	11	0.2020			
GB Zone 3A	6	PCB Congener 128	13	12	1.0562	26.4454		5.60%
GB Zone 3A	6	PCB Congener 129	13	12	0.5795			
GB Zone 3A	6	PCB Congener 130	13	11	0.7565			
GB Zone 3A	6	PCB Congener 131	13	9	0.3253			
GB Zone 3A	6	PCB Congener 132/153	13	13	6.9265			
GB Zone 3A	6	PCB Congener 134	13	4	0.4580			
GB Zone 3A	6	PCB Congener 135/144/1	13	11	0.6061			
GB Zone 3A	6	PCB Congener 137/176	13	7	0.0931			

Appendix I. PCB Congener Data and Homolog Results in Sediment

Location (Reach/Zone)	PCB Homolog Group #	PCB Congener	Total Number of Samples	Total Number Detected	RI Mean Result (ug/kg)	Cumulative Homolog Result	Reach Zone Total PCB	Percent of Reach/Zone Total PCB
GB Zone 3A	6	PCB Congener 138/158/1	13	13	7.4459			
GB Zone 3A	6	PCB Congener 141	13	11	1.0925			
GB Zone 3A	6	PCB Congener 146	13	12	1.6548			
GB Zone 3A	6	PCB Congener 149	13	13	3.0812			
GB Zone 3A	6	PCB Congener 151	13	13	0.9704			
GB Zone 3A	6	PCB Congener 156	2	1	0.4800			
GB Zone 3A	6	PCB Congener 156	13	10	0.2503			
GB Zone 3A	6	PCB Congener 157	2	1	0.0830			
GB Zone 3A	6	PCB Congener 167	15	8	0.5859			
GB Zone 3A	7	PCB Congener 170	2	1	0.7800	14.1858		3.00%
GB Zone 3A	7	PCB Congener 170/190	13	10	2.1566			
GB Zone 3A	7	PCB Congener 171	13	10	0.2503			
GB Zone 3A	7	PCB Congener 172/197	13	7	0.2560			
GB Zone 3A	7	PCB Congener 173	13	1	0.0160			
GB Zone 3A	7	PCB Congener 174	13	12	1.6533			
GB Zone 3A	7	PCB Congener 175	13	8	0.4044			
GB Zone 3A	7	PCB Congener 137/176	13	7	0.0931			
GB Zone 3A	7	PCB Congener 177	13	12	1.1793			
GB Zone 3A	7	PCB Congener 178	13	12	0.5795			
GB Zone 3A	7	PCB Congener 180	15	13	2.0082			
GB Zone 3A	7	PCB Congener 182/187	13	12	2.4848			
GB Zone 3A	7	PCB Congener 183	13	12	1.2763			
GB Zone 3A	7	PCB Congener 185	13	6	0.2582			
GB Zone 3A	7	PCB Congener 189	15	6	0.1915			
GB Zone 3A	7	PCB Congener 191	13	1	0.2640			
GB Zone 3A	7	PCB Congener 193	13	9	0.3344			
GB Zone 3A	8	PCB Congener 194	13	10	0.8751	10.9323		2.31%
GB Zone 3A	8	PCB Congener 195	13	11	1.0118			
GB Zone 3A	8	PCB Congener 196/203	13	7	2.2071			
GB Zone 3A	8	PCB Congener 172/197	13	7	0.2560			
GB Zone 3A	8	PCB Congener 198	13	5	4.0386			
GB Zone 3A	8	PCB Congener 199	13	5	0.1062			
GB Zone 3A	8	PCB Congener 201	13	9	2.1871			
GB Zone 3A	8	PCB Congener 202	13	10	0.2503			
GB Zone 3A	9	PCB Congener 206	13	11	1.5355	2.7247		0.58%
GB Zone 3A	9	PCB Congener 207	13	9	0.1773			
GB Zone 3A	9	PCB Congener 208	13	11	1.0118			
GB Zone 3A	10	PCB Congener 209	13	11	0.8754	0.8754		0.19%
GB Zone 3B	1	PCB Congener 1	33	20	8.4662	19.3947	663.37	2.92%
GB Zone 3B	1	PCB Congener 3	33	6	10.9285			
GB Zone 3B	2	PCB Congener 4/10	33	30	0.7071	40.3738		6.09%
GB Zone 3B	2	PCB Congener 6	33	4	1.0568			
GB Zone 3B	2	PCB Congener 7	33	26	1.3457			
GB Zone 3B	2	PCB Congener 8/5	33	33	35.4009			
GB Zone 3B	2	PCB Congener 12/13	33	29	1.8634			
GB Zone 3B	3	PCB Congener 16/32	33	32	9.3606	161.1755		24.30%
GB Zone 3B	3	PCB Congener 17	33	31	7.5766			
GB Zone 3B	3	PCB Congener 18	33	33	12.9205			
GB Zone 3B	3	PCB Congener 19	33	24	0.4962			
GB Zone 3B	3	PCB Congener 21	33	15	0.4486			
GB Zone 3B	3	PCB Congener 22	33	33	32.7182			
GB Zone 3B	3	PCB Congener 24/27	33	17	1.2219			
GB Zone 3B	3	PCB Congener 25	33	33	4.6565			
GB Zone 3B	3	PCB Congener 26	33	33	8.8535			

Appendix I. PCB Congener Data and Homolog Results in Sediment

Location (Reach/Zone)	PCB Homolog Group #	PCB Congener	Total Number of Samples	Total Number Detected	RI Mean Result (ug/kg)	Cumulative Homolog Result	Reach Zone Total PCB	Percent of Reach/Zone Total PCB
GB Zone 3B	3	PCB Congener 28/31	33	33	48.1308			
GB Zone 3B	3	PCB Congener 29	33	23	0.3081			
GB Zone 3B	3	PCB Congener 33	33	33	29.0042			
GB Zone 3B	3	PCB Congener 37	33	3	5.4797			
GB Zone 3B	4	PCB Congener 40	33	29	6.1076	249.9880		37.68%
GB Zone 3B	4	PCB Congener 41/64/71	33	33	22.3618			
GB Zone 3B	4	PCB Congener 42	33	3	5.4797			
GB Zone 3B	4	PCB Congener 43	33	15	0.8621			
GB Zone 3B	4	PCB Congener 45	33	24	2.9187			
GB Zone 3B	4	PCB Congener 46	33	17	1.6671			
GB Zone 3B	4	PCB Congener 47/48	33	12	23.4554			
GB Zone 3B	4	PCB Congener 49	33	28	15.8384			
GB Zone 3B	4	PCB Congener 52	33	28	17.0753			
GB Zone 3B	4	PCB Congener 53	33	22	1.6578			
GB Zone 3B	4	PCB Congener 56/60	33	33	43.9080			
GB Zone 3B	4	PCB Congener 63	33	21	2.5280			
GB Zone 3B	4	PCB Congener 66	33	33	24.4177			
GB Zone 3B	4	PCB Congener 70/76	33	33	48.3495			
GB Zone 3B	4	PCB Congener 74	33	33	22.2603			
GB Zone 3B	4	PCB Congener 77	4	4	0.6100			
GB Zone 3B	4	PCB Congener 77	33	33	9.9160			
GB Zone 3B	4	PCB Congener 81	37	32	0.5747			
GB Zone 3B	5	PCB Congener 82	33	32	2.5683	112.7651		17.00%
GB Zone 3B	5	PCB Congener 83	33	33	0.9134			
GB Zone 3B	5	PCB Congener 84/92	33	29	11.0144			
GB Zone 3B	5	PCB Congener 85	33	33	5.1421			
GB Zone 3B	5	PCB Congener 87	33	33	6.1528			
GB Zone 3B	5	PCB Congener 89	33	26	0.2863			
GB Zone 3B	5	PCB Congener 91	33	31	1.8598			
GB Zone 3B	5	PCB Congener 95	33	33	24.4177			
GB Zone 3B	5	PCB Congener 97	33	33	3.2681			
GB Zone 3B	5	PCB Congener 99	33	33	6.5144			
GB Zone 3B	5	PCB Congener 100	33	30	2.0197			
GB Zone 3B	5	PCB Congener 101	33	33	9.6962			
GB Zone 3B	5	PCB Congener 105	4	4	0.5675			
GB Zone 3B	5	PCB Congener 105	33	33	10.3893			
GB Zone 3B	5	PCB Congener 107	33	26	2.7028			
GB Zone 3B	5	PCB Congener 110	33	33	9.9160			
GB Zone 3B	5	PCB Congener 114	4	2	0.0655			
GB Zone 3B	5	PCB Congener 114	33	7	0.2910			
GB Zone 3B	5	PCB Congener 118	37	33	13.7993			
GB Zone 3B	5	PCB Congener 119	33	27	0.8160			
GB Zone 3B	5	PCB Congener 124	33	29	0.3644			
GB Zone 3B	6	PCB Congener 128	33	33	1.1920	36.6579		5.53%
GB Zone 3B	6	PCB Congener 129	33	32	0.5620			
GB Zone 3B	6	PCB Congener 130	33	32	1.1079			
GB Zone 3B	6	PCB Congener 131	33	23	0.4337			
GB Zone 3B	6	PCB Congener 132/153	33	33	10.3893			
GB Zone 3B	6	PCB Congener 134	33	7	0.2910			
GB Zone 3B	6	PCB Congener 135/144/1	33	29	1.0931			
GB Zone 3B	6	PCB Congener 137/176	33	11	0.1496			
GB Zone 3B	6	PCB Congener 138/158/1	33	32	11.2302			
GB Zone 3B	6	PCB Congener 141	33	33	1.4413			
GB Zone 3B	6	PCB Congener 146	33	30	2.2344			

Appendix I. PCB Congener Data and Homolog Results in Sediment

Location (Reach/Zone)	PCB Homolog Group #	PCB Congener	Total Number of Samples	Total Number Detected	RI Mean Result (ug/kg)	Cumulative Homolog Result	Reach Zone Total PCB	Percent of Reach/Zone Total PCB
GB Zone 3B	6	PCB Congener 149	33	33	4.3656			
GB Zone 3B	6	PCB Congener 151	33	33	1.3791			
GB Zone 3B	6	PCB Congener 156	4	1	0.0680			
GB Zone 3B	6	PCB Congener 156	33	22	0.3380			
GB Zone 3B	6	PCB Congener 157	4	1	0.0420			
GB Zone 3B	6	PCB Congener 167	37	22	0.3405			
GB Zone 3B	7	PCB Congener 170	4	3	0.1500	19.4548		2.93%
GB Zone 3B	7	PCB Congener 170/190	33	30	3.8601			
GB Zone 3B	7	PCB Congener 171	33	22	0.3380			
GB Zone 3B	7	PCB Congener 172/197	33	17	0.3779			
GB Zone 3B	7	PCB Congener 173	33	2	0.1060			
GB Zone 3B	7	PCB Congener 174	33	31	2.1793			
GB Zone 3B	7	PCB Congener 175	33	18	0.3732			
GB Zone 3B	7	PCB Congener 137/176	33	11	0.1496			
GB Zone 3B	7	PCB Congener 177	33	31	2.2413			
GB Zone 3B	7	PCB Congener 178	33	32	0.5620			
GB Zone 3B	7	PCB Congener 180	37	34	3.1355			
GB Zone 3B	7	PCB Congener 182/187	33	33	2.9870			
GB Zone 3B	7	PCB Congener 183	33	33	1.8023			
GB Zone 3B	7	PCB Congener 185	33	13	0.2805			
GB Zone 3B	7	PCB Congener 189	37	13	0.2145			
GB Zone 3B	7	PCB Congener 191	33	16	0.3550			
GB Zone 3B	7	PCB Congener 193	33	14	0.3427			
GB Zone 3B	8	PCB Congener 194	33	26	1.4137	17.0732		2.57%
GB Zone 3B	8	PCB Congener 195	33	27	1.6040			
GB Zone 3B	8	PCB Congener 196/203	33	21	6.0761			
GB Zone 3B	8	PCB Congener 172/197	33	17	0.3779			
GB Zone 3B	8	PCB Congener 198	33	4	0.5108			
GB Zone 3B	8	PCB Congener 199	33	21	0.2794			
GB Zone 3B	8	PCB Congener 201	33	25	6.2843			
GB Zone 3B	8	PCB Congener 202	33	22	0.3380			
GB Zone 3B	8	PCB Congener 205	33	1	0.1890			
GB Zone 3B	9	PCB Congener 206	33	26	2.9855	4.8507		0.73%
GB Zone 3B	9	PCB Congener 207	33	17	0.2612			
GB Zone 3B	9	PCB Congener 208	33	27	1.6040			
GB Zone 3B	10	PCB Congener 209	33	26	1.6382	1.6382		0.25%
GB Zone 4	1	PCB Congener 1	27	13	2.0243	4.9621	102.58	4.84%
GB Zone 4	1	PCB Congener 3	27	6	2.9378			
GB Zone 4	2	PCB Congener 4/10	27	26	0.3325	3.7919		3.70%
GB Zone 4	2	PCB Congener 6	27	4	0.4548			
GB Zone 4	2	PCB Congener 7	27	17	0.1330			
GB Zone 4	2	PCB Congener 8/5	27	20	2.6141			
GB Zone 4	2	PCB Congener 12/13	27	15	0.2575			
GB Zone 4	3	PCB Congener 16/32	27	26	0.7281	18.6330		18.16%
GB Zone 4	3	PCB Congener 17	27	8	0.6011			
GB Zone 4	3	PCB Congener 18	27	26	1.2855			
GB Zone 4	3	PCB Congener 19	27	14	0.0851			
GB Zone 4	3	PCB Congener 21	27	16	0.1250			
GB Zone 4	3	PCB Congener 22	27	25	1.9688			
GB Zone 4	3	PCB Congener 24/27	27	13	0.2820			
GB Zone 4	3	PCB Congener 25	27	26	0.4237			
GB Zone 4	3	PCB Congener 26	27	26	0.5198			
GB Zone 4	3	PCB Congener 28/31	27	27	10.1617			
GB Zone 4	3	PCB Congener 29	27	8	0.2581			

Appendix I. PCB Congener Data and Homolog Results in Sediment

Location (Reach/Zone)	PCB Homolog Group #	PCB Congener	Total Number of Samples	Total Number Detected	RI Mean Result (ug/kg)	Cumulative Homolog Result	Reach Zone Total PCB	Percent of Reach/Zone Total PCB
GB Zone 4	3	PCB Congener 33	27	27	1.8574			
GB Zone 4	3	PCB Congener 37	27	3	0.3367			
GB Zone 4	4	PCB Congener 40	27	15	0.3694	30.7348		29.96%
GB Zone 4	4	PCB Congener 41/64/71	27	27	1.8457			
GB Zone 4	4	PCB Congener 42	27	3	0.3367			
GB Zone 4	4	PCB Congener 43	27	5	0.0940			
GB Zone 4	4	PCB Congener 45	27	19	0.4082			
GB Zone 4	4	PCB Congener 46	27	16	0.2266			
GB Zone 4	4	PCB Congener 47/48	27	13	1.1982			
GB Zone 4	4	PCB Congener 49	27	23	1.4382			
GB Zone 4	4	PCB Congener 52	27	27	1.7965			
GB Zone 4	4	PCB Congener 53	27	7	0.2114			
GB Zone 4	4	PCB Congener 56/60	27	25	5.9397			
GB Zone 4	4	PCB Congener 63	27	22	0.4315			
GB Zone 4	4	PCB Congener 66	27	27	5.6385			
GB Zone 4	4	PCB Congener 70/76	27	27	5.8307			
GB Zone 4	4	PCB Congener 74	27	27	3.0719			
GB Zone 4	4	PCB Congener 77	4	2	0.0250			
GB Zone 4	4	PCB Congener 77	27	27	1.6262			
GB Zone 4	4	PCB Congener 81	31	27	0.2466			
GB Zone 4	5	PCB Congener 82	27	26	0.3182	24.2265		23.62%
GB Zone 4	5	PCB Congener 83	27	22	0.2520			
GB Zone 4	5	PCB Congener 84/92	27	18	2.1434			
GB Zone 4	5	PCB Congener 85	27	27	1.1971			
GB Zone 4	5	PCB Congener 87	27	26	0.8422			
GB Zone 4	5	PCB Congener 89	27	7	0.1423			
GB Zone 4	5	PCB Congener 91	27	11	0.2488			
GB Zone 4	5	PCB Congener 95	27	27	5.6385			
GB Zone 4	5	PCB Congener 97	27	27	1.0555			
GB Zone 4	5	PCB Congener 99	27	24	1.6614			
GB Zone 4	5	PCB Congener 100	27	4	0.6223			
GB Zone 4	5	PCB Congener 101	27	25	2.0490			
GB Zone 4	5	PCB Congener 105	4	2	0.0480			
GB Zone 4	5	PCB Congener 105	27	27	2.2273			
GB Zone 4	5	PCB Congener 107	27	24	0.4522			
GB Zone 4	5	PCB Congener 110	27	27	1.6262			
GB Zone 4	5	PCB Congener 114	27	6	0.1770			
GB Zone 4	5	PCB Congener 118	31	28	3.0913			
GB Zone 4	5	PCB Congener 119	27	27	0.3317			
GB Zone 4	5	PCB Congener 124	27	24	0.1022			
GB Zone 4	6	PCB Congener 128	27	27	0.5943	9.9753		9.72%
GB Zone 4	6	PCB Congener 129	27	23	0.2113			
GB Zone 4	6	PCB Congener 130	27	24	0.3299			
GB Zone 4	6	PCB Congener 131	27	12	0.1402			
GB Zone 4	6	PCB Congener 132/153	27	27	2.2273			
GB Zone 4	6	PCB Congener 134	27	6	0.1770			
GB Zone 4	6	PCB Congener 135/144/1	27	24	0.3067			
GB Zone 4	6	PCB Congener 137/176	27	2	0.0458			
GB Zone 4	6	PCB Congener 138/158/1	27	24	3.3320			
GB Zone 4	6	PCB Congener 141	27	26	0.3175			
GB Zone 4	6	PCB Congener 146	27	24	0.6942			
GB Zone 4	6	PCB Congener 149	27	27	0.9519			
GB Zone 4	6	PCB Congener 151	27	27	0.3213			
GB Zone 4	6	PCB Congener 156	4	1	0.0089			

Appendix I. PCB Congener Data and Homolog Results in Sediment

Location (Reach/Zone)	PCB Homolog Group #	PCB Congener	Total Number of Samples	Total Number Detected	RI Mean Result (ug/kg)	Cumulative Homolog Result	Reach Zone Total PCB	Percent of Reach/Zone Total PCB
GB Zone 4	6	PCB Congener 156	27	14	0.0860			
GB Zone 4	6	PCB Congener 167	31	20	0.2310			
GB Zone 4	7	PCB Congener 170/190	27	25	0.6776	4.5844		4.47%
GB Zone 4	7	PCB Congener 171	27	14	0.0860			
GB Zone 4	7	PCB Congener 172/197	27	15	0.0682			
GB Zone 4	7	PCB Congener 173	27	3	0.0700			
GB Zone 4	7	PCB Congener 174	27	24	0.4304			
GB Zone 4	7	PCB Congener 175	27	20	0.1761			
GB Zone 4	7	PCB Congener 137/176	27	2	0.0458			
GB Zone 4	7	PCB Congener 177	27	20	0.4112			
GB Zone 4	7	PCB Congener 178	27	23	0.2113			
GB Zone 4	7	PCB Congener 180	31	23	0.8312			
GB Zone 4	7	PCB Congener 182/187	27	27	0.7720			
GB Zone 4	7	PCB Congener 183	27	22	0.5081			
GB Zone 4	7	PCB Congener 189	31	3	0.1043			
GB Zone 4	7	PCB Congener 191	27	7	0.0991			
GB Zone 4	7	PCB Congener 193	27	16	0.0932			
GB Zone 4	8	PCB Congener 194	27	25	0.5615	4.1716		4.07%
GB Zone 4	8	PCB Congener 195	27	22	0.3888			
GB Zone 4	8	PCB Congener 196/203	27	18	0.5237			
GB Zone 4	8	PCB Congener 172/197	27	15	0.0682			
GB Zone 4	8	PCB Congener 198	27	12	1.7107			
GB Zone 4	8	PCB Congener 199	27	2	0.0415			
GB Zone 4	8	PCB Congener 201	27	22	0.7913			
GB Zone 4	8	PCB Congener 202	27	14	0.0860			
GB Zone 4	9	PCB Congener 206	27	22	0.6337	1.1377		1.11%
GB Zone 4	9	PCB Congener 207	27	16	0.1152			
GB Zone 4	9	PCB Congener 208	27	22	0.3888			
GB Zone 4	10	PCB Congener 209	27	24	0.3598	0.3598		0.35%