Lower Fox River/Green Bay Remedial Investigation and Feasibility Study

Development and Application of a PCB Transport Model for the Lower Fox River

Prepared by:

Wisconsin Department of Natural Resources

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1.0 SUMMARY

This report is provided in support of U.S. Environmental Protection Agency (USEPA) Cooperative Agreement #V985769-01 with the Wisconsin Department of Natural Resources (WDNR). The water quality model presented in this report is one of several tools to examine contaminant transport in the Lower Fox River. The primary contaminant of concern was polychlorinated biphenyls (PCBs). The goal of this effort was to provide estimates of: 1) PCB export to Green Bay, and 2) biotic PCB exposure in the river.

Efforts to assess PCB transport in the Lower Fox River using water quality models have been extensive. The model developed as part of RI/FS efforts is the result of continued assessments of Lower Fox River water quality model performance and represents the fourth generation of model development. This fourth generation model is identified as the "whole" Lower Fox River model (wLFRM). The wLFRM describes PCB transport in all 39 miles of the Lower Fox River from Lake Winnebago to the river mouth at Green Bay in a single spatial domain. The state variables simulated were suspended solids (three classes) and total PCBs. Short-term and long-term simulations were conducted. The short-term simulation period was 1989-95 and was used for model calibration. The long-term simulation period was 100 years and was used to project future PCB export to Green Bay and exposure trends in the river. Numerical simulations were performed using the USEPA IPX Version 2.7.4 water quality modeling framework.

The wLFRM was developed from the results of the Model Evaluation Workgroup (MEW) that was formed in collaboration with the Fox River Group (FRG) of Companies on the basis of a January 31, 1997 Agreement. The MEW prepared a series of technical reports that define values for the most critical model features such as flows, loads, initial conditions, boundary conditions, and sediment transport. The MEW reports represent the most detailed description possible of pertinent river conditions using existing information and provided the majority of the information necessary for model development. The FRG also initiated a peer review of model performance that was managed by the American Geological Institute (AGI, 2000). To the greatest extent practical, peer review panel recommendations were integrated into wLFRM development efforts.

Model performance was evaluated according to the metrics identified in Technical Memorandum 1 (LTI and WDNR, 1998). When making comparisons, it is important to understand how the observations and model results used to assess model performance were interpreted. Successful application of a metric depends on how closely the interpretation of field data represent the true condition of the river as well as whether the spatial and temporal scale of observations and model results are comparable. For the water column, interpretation of observations was straightforward and permitted direct comparison of observed values and model results. However, interpretation of sediment observations was not straightforward. Representative sediment conditions applicable to broad areas are difficult to accurately determine from observations at individual points or along a line. For the water column, relative differences between observed solids and PCB concentrations and model results were within ±30%. Relative differences for the sediment column were much larger. Nonetheless, the wLFRM was able to capture the trend and magnitude

of inferred PCB concentration changes over time in surface sediments. Given these considerations, the wLFRM calibration was judged to adequately meet the criteria identified in Technical Memorandum 1.

Note that, as demonstrated by the results of field sampling efforts, the only significant source of PCBs to Lower Fox River is the river sediments. Further, PCB concentrations in river water are essentially zero at the upstream boundary with Lake Winnebago and increase to an average of more than 50 ng/L at the river mouth. The wLFRM reproduces these critical site features: 1) the origin of PCB from sediments; and 2) the trend and magnitude of PCB concentrations in the water column. In consideration of model performance strengths and limitations, the wLFRM calibration was considered to provide a reasonable description of PCB concentrations and export in the Lower Fox River on a year-by-year, reach-by-reach basis. The best use of this model may therefore be as an indicator of the relative trend and magnitude of PCBs concentrations and export. In this context, year-by-year, reach-by-reach resolution of this model was considered sufficient to meet overall project goals.

The wLFRM was used to prepare long-term projections of the trend and magnitude of PCB concentrations in the river for a range of different sediment management cases. Over time, water column and sediment PCB concentrations decrease for all cases. This is an expected result since, without significant PCB inputs from point source discharges, the surrounding watershed, or the atmosphere, the PCB inventory of river surface sediments will decrease by dilution and dispersal.

Relative differences in forecast simulation results are clearly present. Compared to all other cases, the no action simulation has the greatest PCB concentrations and cumulative export to Green Bay over time. Note that as action levels decrease, the differences between simulation results for each action level increase relative to the no action simulation. The level of relative reduction is a reflection of decreased sediment PCB initial conditions for each case. Also note that at the lowest action levels, which represent larger sediment management efforts, the relative decrease in PCB concentration and export between cases becomes smaller. For example, the difference between the 250 and 125 µg/kg cases is smaller than the difference between the 500 and 250 µg/kg cases. The relative difference between the 250 and 125 µg/kg cases is comparatively small since the average reduction in initial surface sediment PCB concentrations is small.

2.0 INTRODUCTION

2.1 PROJECT OVERVIEW

This report is provided in support of U.S. Environmental Protection Agency (USEPA) Cooperative Agreement #V985769-01 with the Wisconsin Department of Natural Resources (WDNR). As part of this agreement, WDNR developed remedial investigation (RI), risk assessment (RA), feasibility study (FS) reports to describe the degree and extent of contamination, risks to human health and the environment, and aspects of implementing remedial approaches for the Lower Fox River and Green Bay study area. These reports were prepared for, and in cooperation with, the USEPA Region V Superfund Division as authorized under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

The water quality model presented in this report is one of several tools to examine contaminant transport in the Lower Fox River. The primary contaminant of concern was polychlorinated biphenyls (PCBs). Data collected during the 1989-90 Green Bay Mass Balance Study (GBMBS), the 1994-95 Lake Michigan Mass Balance Study (LMMBS), and other sampling efforts were sufficient to permit development of a water quality model to describe the transport of suspended solids and total PCBs for the Lower Fox River. The goal of this effort was to provide estimates of: 1) PCB export to Green Bay, and 2) biotic PCB exposure in the river.

The state variables simulated were suspended solids (three classes) and total PCBs (the sum of all congeners). Short-term and long-term simulations were conducted. The short-term simulation period was 1989-95 and was used for model calibration. The long-term simulation period was 100 years and was used to project future PCB export to Green Bay and exposure trends in the river. All numerical simulations for the river were performed using the USEPA IPX Version 2.7.4 water quality modeling framework.

2.2 SITE DESCRIPTION AND PROBLEM IDENTIFICATION

Located in northeast Wisconsin, the Lower Fox River is the largest tributary to Green Bay, Lake Michigan (Figure 2-1). The river is 63 km (39 miles) long, flows from Lake Winnebago to Green Bay, and has a total watershed area of over 17,000 km^2 (6,640 mi^2). The drainage basin includes much of the central and eastern regions of the state, including Lake Winnebago. River flow is regulated by a series of dams and water surface elevations decrease 51.3 m (168.3 feet) from the river head to the river mouth (Figure 2-2). The upstream boundary of the study area was the river head at Lake Winnebago. The downstream boundary was the river mouth at Green Bay.

The river is heavily industrialized and includes one of the greatest concentrations of pulp and paper manufacturing facilities in the world. Within the study area boundaries, more than 25 major facilities discharge wastewater to the river (WDNR, 1999a). As a result of wastewater discharges, the river sediments are highly contaminated. PCBs are the contaminant of primary concern for human health and ecological risks.

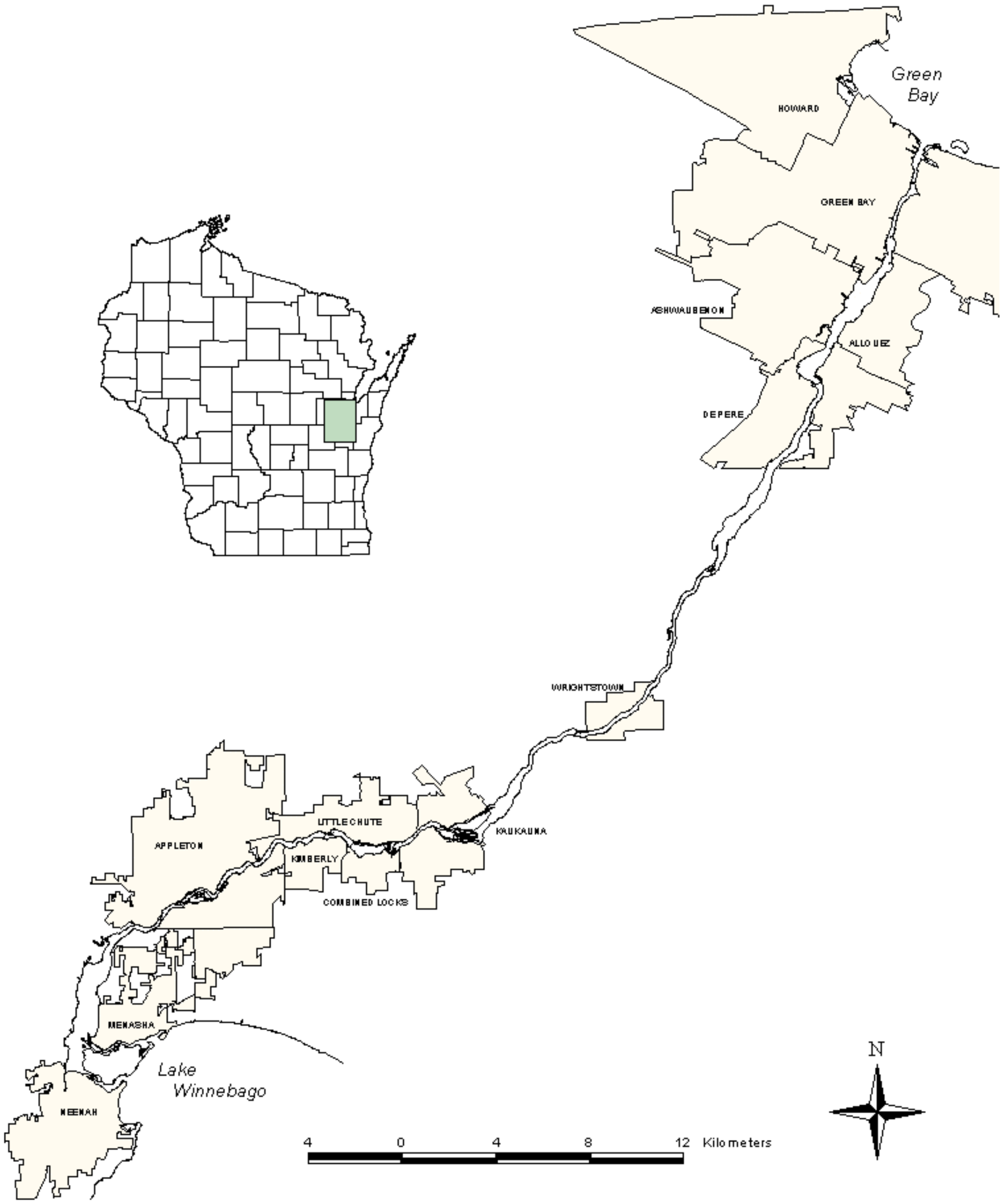

Figure 2—1. Lower Fox River study area.

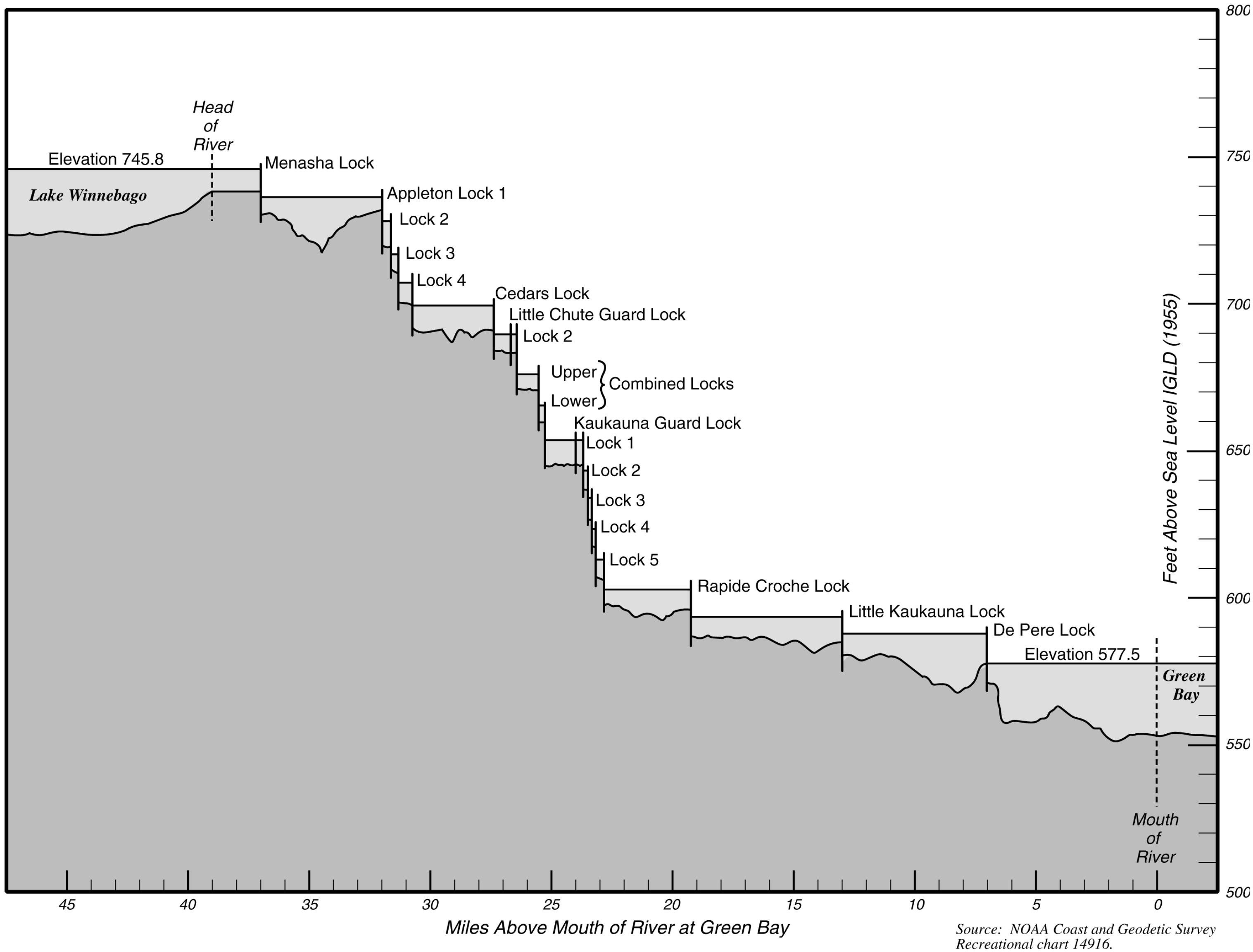

Figure 2—2. Profile of Lower Fox River.

Over the period 1954-1997, more than 300,000 kg of PCBs were discharged to the river (WDNR, 1999a). Of that amount, the vast majority was discharged between 1954 and 1971. The PCB mass inventory of Lower Fox River sediments was estimated to be 40,000 kg (WDNR, 1999b). Based on the GBMBS results, major PCB fate pathways in Green Bay include sediment storage, net transport to Lake Michigan, and net volatilization (Bierman et al. 1992; DePinto et al. 1993). The minimum PCB mass inventory of Green Bay sediments was estimated to be 70,000 kg (WDNR, 2000b). Cumulative PCB losses from Green Bay to the open lake and the atmosphere have not been quantified. The Renard Island and Bayport sediment disposal facilities (as well as several other shoreline sediment placement sites) also contain an additional mass of PCBs that was associated with dredged sediments placed into these facilities as a result of navigation channel maintenance operations (WDNR, 1999c).

As part of the 1989-90 GBMBS water quality monitoring stations were established at the river mouth and several additional locations throughout the river. As part of the 1994-95 LMMBS, the water quality monitoring station at the river mouth was re-established. The U.S. Geological Survey (USGS) collected water quality samples at the river mouth monitoring station during the GBMBS and the LMMBS. In addition, WDNR collected sediment samples at numerous locations throughout the river during the GBMBS and LMMBS. These data provide the basis for model development and application efforts.

2.3 CONCEPTUAL MODEL FRAMEWORK

The conceptual framework of the Lower Fox River water quality model is presented in Figure 2-3. The transport and fate processes included in the model are:

- Advective and dispersive water column transport;
- Sediment transport (settling, resuspension, and burial)
- chemical partitioning between water (truly dissolved), dissolved organic compounds (DOC) (DOC-bound), and solid (particulate) phases;
- Sediment-water exchange of dissolved and DOC-bound chemicals;
- Air-water exchange of dissolved chemicals; and
- External inputs of solids and chemicals.

From these process descriptions, dynamic mass balance equations were developed. In their most general form, the mass balance equations are a system of partial differential equations and are functions of time and space. These equations describe the relationship between material inputs (loads) and concentration (water quality). To solve these equations, three simplifying assumptions were made (Thomann and Mueller, 1987; Chapra, 1997):

1. Water column volumes are constant with respect to time ($\partial V/\partial t=0$);
2. Surficial sediments do not move horizontally in the sediment bed; and
3. Chemical partitioning to solids and DOC is rapid relative to other processes (local equilibrium).

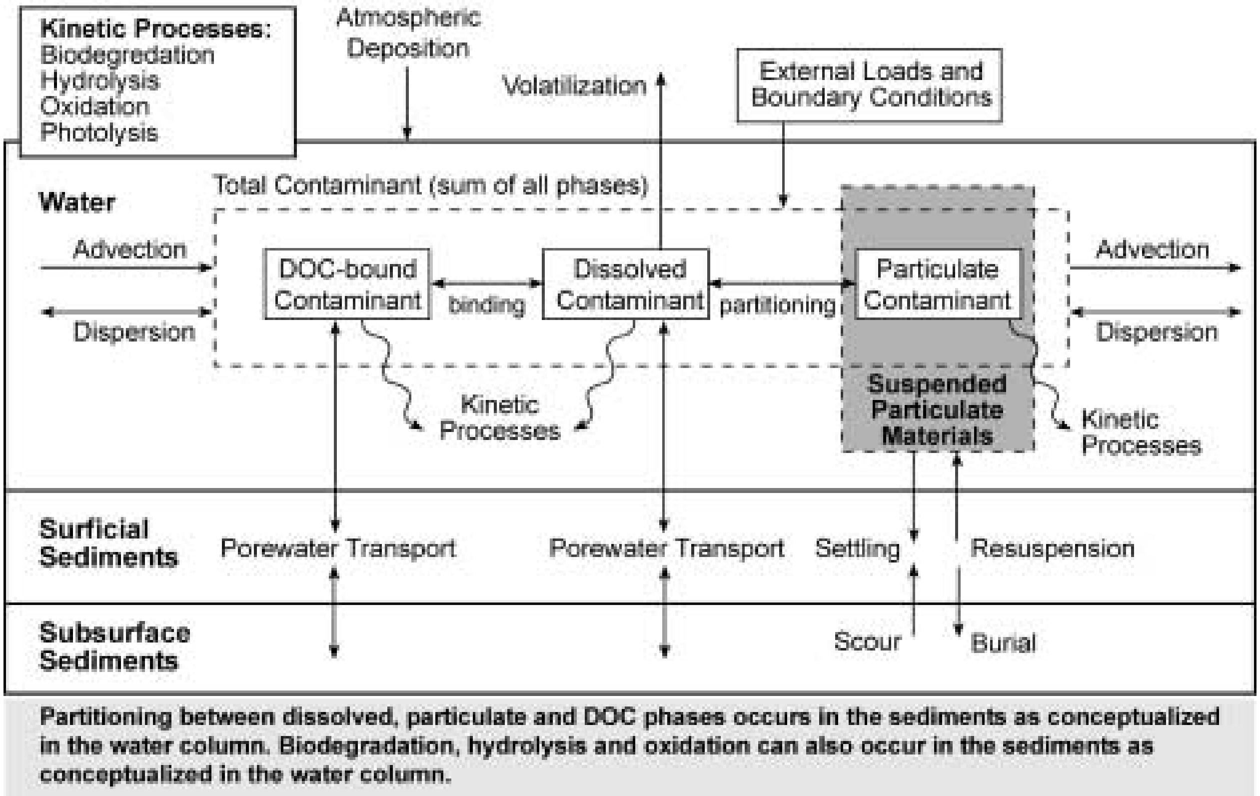

Figure 2—3. Conceptual model framework.

The state variables simulated were suspended solids and total PCBs. The mass balance equations that describe the transport and fate processes for PCBs are:

Solids in the Water Column (for each of three solids state variables)

$$\frac{dm_1}{dt} = \frac{Q_{in}}{V_w} m_{1_i} - \frac{Q_{out}}{V_w} m_1 + \frac{E_b}{V_w}\left(m_{1_i} - m_1\right) - \mathrm{v}_s \frac{A_s}{V_w} m_1 + \mathrm{v}_r \frac{A_s}{V_w} m_2 + W \tag{2.1}$$

Total Hydrophobic Contaminant in the Water Column (PCBs)

$$\begin{aligned} \frac{dC_{T1}}{dt} &= \frac{Q_{in}}{V_w} C_{T1i} - \frac{Q_{out}}{V_w} C_{T1} + \frac{E_b}{V_w}\left(C_{T1i} - C_{T1}\right) - \mathrm{v}_s \frac{A_s}{V_w} f_{p1} C_{T1} + \mathrm{v}_r \frac{A_s}{V_w} f_{p2} C_{T2} \\ &+ k_f \frac{A_s}{V_w} \left[\left(f_{d2} + f_{b2}\right) C_{T2} - \left(f_{d1} + f_{b1}\right) C_{T1}\right] - k_V \frac{A_s}{V_w}\left[f_{d1} C_{T1} - \frac{C_a}{H / RT}\right] + W \end{aligned} \tag{2.2}$$

Solids in the Sediments (for each of three solids state variables)

$$\frac{dm_2}{dt} = \mathrm{v}_s \frac{A_s}{V_s} m_1 - \mathrm{v}_r \frac{A_s}{V_s} m_2 + \mathrm{v}_u \frac{A_s}{V_s} m_{2i} - \mathrm{v}_b \frac{A_s}{V_s} m_2 + \frac{E_m}{V_s}\left(m_{2i} - m_2\right) \tag{2.3}$$

Total Hydrophobic Contaminant in the Sediments (PCBs)

$$\begin{aligned} \frac{dC_{T2}}{dt} &= \mathrm{v}_s \frac{A_s}{V_s} f_{p1} C_{T1} - \mathrm{v}_r \frac{A_s}{V_s} f_{p2} C_{T2} + \mathrm{v}_u \frac{A_s}{V_s} C_{T2i} - \mathrm{v}_b \frac{A_s}{V_s} C_{T2} \\ &\quad - k_f \frac{A_s}{V_s}\left[\left(f_{d2} + f_{b2}\right)C_{T2} - \left(f_{d1} + f_{b1}\right)C_{T1}\right] + \frac{E_m}{V_s}\left(f_{p2_i} C_{T2i} - f_{p2_i} C_{T2i}\right) \end{aligned} \tag{2.4}$$

where:

C_{T1}, C_{T2}	=	total (sum of all phases) contaminant concentration in water and sediments (M/L^3)
m_1, m_2	=	solids concentration in the water column and sediments (M/L^3)
Q_{in}, Q_{out}	=	water inflow and outflow (L^3/T)
V_w, V_s	=	volume of water and sediments (L^3)
v_s, v_r	=	settling and resuspension velocities (L/T)
v_u, v_b	=	scour (unburial) and burial velocities (L/T)
f_d, f_b, f_p	=	dissolved, DOC-bound, and particulate fractions of contaminant (dimensionless)
E_B, E_M	=	bulk dispersion and mixing coefficients (L^3/T)
A_s	=	surface area (L^2)
k_f	=	sediment diffusion coefficient (L/T)
k_V	=	volatilization coefficient (L/T)
C_a	=	gas phase contaminant concentration in air (M/L^3)
H	=	Henry's Law constant [8.206×10^{-5}] (atm/molar)
R	=	gas constant (atm/molar-K)
T	=	absolute temperature (K)
W	=	load (M/T)
i	=	index indicating transfer of material from an adjacent area

Each term in the mass balance equations represents a process described in the conceptual model framework. The variables in each term represent model parameters. More detailed presentations of the mass balance equations are provided by Thomann and Mueller (1987) and Chapra (1997).

2.4 GENERAL DESCRIPTION OF THE COMPUTATIONAL FRAMEWORK

To simulate contaminant transport, values must be assigned to each model parameter and the mass balance equations defined by the conceptual model framework must be solved. Numerical integration techniques are typically used to solve the model equations. Numerical simulations were performed using the IPX Version 2.7.4 (Velleux et al. 2000) water quality modeling framework. IPX uses a finite segment implementation of the generalized contaminant mass balance equation and Euler’s method for numerical integration. To generate solutions, the framework computes dynamic mass balances for each state variable simulated and accounts for all material that enters, accumulates within, or leaves a control volume (segment) through loading, transport, and physicochemical and biological transfers and transformations. IPX Version 2.7.4 also features a “semi-Lagrangian” sediment bed submodel to address potential concerns regarding particle and chemical mass transfer in the sediment column. A detailed description of the computational framework is provided by Velleux et al. (2000).

2.5 COMPUTATIONAL CONSIDERATIONS

The IPX Version 2.7.4 source code is written in FORTRAN77. To generate an executable file, the compiler used should support sequential evaluation of terms in compound Boolean expressions. Numerical simulations were performed on several computing systems to ensure code portability. Short-term simulations were performed on a Compaq AlphaServer DS/20 computer running the Digital UNIX (Version 4.0F) operating system. On that platform, model code was compiled using the Compaq FORTRAN compiler for Alpha-powered UNIX systems. Long-term simulations were performed on an Intel Pentium IV-powered computer running the Mandrake Linux (Version 7.2 with the Version 2.4 Kernel) operating system. On that platform, model code was compiled using the Portland Group FORTRAN compiler.

2.6 DISTRIBUTION OF MODEL CODES AND INPUT AND OUTPUT FILES

A user’s manual and source code for the IPX Version 2.7.4 water quality modeling framework, model input files, and selected model output files are included on a CD-ROM that accompanies this report. An overview of model input and output files is presented in Table 2-1. In that table, the root name of the simulation is presented in Column 1. Specific input and output file names for each simulation are obtained by appending the suffixes listed in Columns 3 and 4 to the root name listed in Column 1.

Note that the full set of input and output files for each simulation are voluminous. Beyond the input and selected output files listed in Table 2-1, each simulation generates a series of additional output files with the suffixes: .out (input echo file); .dmp (main output file); .dma (secondary output file). Output from the .dmp and .dma files can be retrieved using the W4DIS274 post-processing program included as part of the IPX Version 2.7.4 framework. Output retrieved with the W4DIS274 post-processor generates further output files with the suffix .tbl (table file). A full description of IPX Version 2.7.4 output files is provided by Velleux et al. (2000). Output from .tbl files was used to generate the .rr1, .rr2, .rr3, and rr4 exposure files listed in Table 2-1.

Table 2-1. Overview of model input and output files.

<table>
<tr><th>Simulation (Root Name)</th><th>Description</th><th>Input File (suffix)</th><th>Selected Output Files (suffix)</th></tr>
<tr><td>lf8995-rifs</td><td>Calibration</td><td rowspan="9">.inp</td><td rowspan="9">.exp export file
.msb mass balance file
.rr1 PCB exposure for river reach 1
.rr2 PCB exposure for river reach 2
.rr3 PCB exposure for river reach 3
.rr4 PCB exposure for river reach 4</td></tr>
<tr><td>lf-forecast-noaction</td><td>No action (“natural recovery”) forecast</td></tr>
<tr><td>lf-forecast-5000</td><td>5000 µg/kg action level (all reaches)</td></tr>
<tr><td>lf-forecast-1000</td><td>1000 µg/kg action level (all reaches)</td></tr>
<tr><td>lf-forecast-0500</td><td>500 µg/kg action level (all reaches)</td></tr>
<tr><td>lf-forecast-0250</td><td>250 µg/kg action level (all reaches)</td></tr>
<tr><td>lf-forecast-0125</td><td>125 µg/kg action level (all reaches)</td></tr>
<tr><td>lf-forecast-H</td><td>500 µg/kg action level (Reach 1)
No action (“natural recovery”) (Reach 2)
250 µg/kg action level (Reach 3)
250 µg/kg action level (Reach 4)</td></tr>
<tr><td>lf-forecast-I</td><td>1000 µg/kg action level (Reach 1)
No action (“natural recovery”) (Reach 2)
500 µg/kg action level (Reach 3)
500 µg/kg action level (Reach 4)</td></tr>
</table>

3.0 MODEL DEVELOPMENT

3.1 BACKGROUND

The Lower Fox River/Green Bay ecosystem was extensively studied as part of the 1989-90 GBMBS (USEPA 1989; USEPA 1992a,b). As part of that study, a suite of coupled water quality models describing PCB transport in the Lower Fox River and Green Bay were developed. Two of those coupled models described PCB transport in upstream and downstream portions of the Lower Fox River.

Since the end of the GBMBS, efforts to examine and assess the performance of Lower Fox River water quality models have continued. Four generations of water quality model development have been initiated. The models calibrated to GBMBS conditions represent the first generation of model development for the Lower Fox River portion of the project area (Steuer et al. 1995; Velleux and Endicott, 1994). The extension of those models to forecast future water quality trends represents the second generation of development (Velleux et al. 1995, Velleux et al. 1996). The models used to conduct a post-audit analysis of model performance represent the third generation of development (WDNR, 1997). The model developed as part of RI/FS efforts is the result of continued assessments of Lower Fox River water quality model performance and represents the fourth generation of model development. To distinguish it from prior generations of development, this fourth generation model is identified as the "whole" Lower Fox River model (wLFRM). As described in Section 3.2, development of the wLFRM for the RI/FS was based on the results of a 1997 agreement and a peer review of model performance.

3.2 EVALUATIONS OF MODEL PERFORMANCE

On January 31, 1997, the State of Wisconsin entered into a Memorandum of Agreement (Agreement) with seven companies that have primary responsibility for PCB discharges to the Lower Fox River. Those seven companies form the Fox River Group (FRG). One component of the Agreement was to "evaluate water quality models for the Lower Fox River and Green Bay." The intent was to establish goals to evaluate the quality of model results. As specified by the Agreement, the Model Evaluation Workgroup (MEW) was formed. The MEW was comprised of technical representatives for the FRG and WDNR in order to undertake "cooperative and collaborative" evaluations of model performance. Development of a series of technical reports followed. While the model evaluation process was ongoing, the FRG also initiated what was described as a peer review of model performance that was managed by the American Geological Institute (AGI, 2000).

The series of reports developed by the MEW were each prepared as a Technical Memorandum (TM). A listing of selected MEW TMs is presented in Table 3-1. Each TM listed provides detailed analyses of key aspects of model development such as solids and PCB loads, sediment transport dynamics, and initial conditions. These analyses were designed to take maximum advantage of information from a wide array of sources and were not restricted to the exclusive consideration of information generated during GBMBS or LMMBS data collection efforts. The

Table 3-1. List of selected Model Evaluation Workgroup technical reports.

Report[1]	*Title/Topic*	*Source*
Workplan	Workplan to Evaluate the Fate and Transport Models for the Fox River and Green Bay	LTI and WDNR (1997)
TM1	Model Evaluation Metrics	LTI and WDNR (1998)
TM2a	Simulation of Historical and Projected Total Suspended Solids Loads and Flows to the Lower Fox River, N.E. Wisconsin with the Soil and Water Assessment Tool (SWAT)	FWB2000 (1998)
TM2b	Computation of Watershed Solids and PCB Load Estimates for Green Bay	LTI (1999a)
TM2c	Computation of Internal Solids Loads in Green Bay and the Lower Fox River	LTI (1999b)
TM2d	Compilation and Estimation of Historical Discharges of Total Suspended Solids and Polychlorinated Biphenyls from Lower Fox River Point Sources	WDNR (1999a)
TM2e	Estimation of Lower Fox River Sediment Bed Properties	WDNR (1999b)
TM2f	Estimation of Sediment Bed Properties for Green Bay	WDNR (2000)
TM2g	Quantification of Lower Fox River Sediment Bed Elevation Dynamics through Direct Observations	WDNR (1999c)
TM3a	Evaluation of Flows, Loads, Initial Conditions, and Boundary Conditions	WDNR (2001a)
TM5b	ECOM-siz-SEDZL Model Application: Lower Fox River Downstream of the DePere Dam	Baird (2000a)
TM5c	Evaluation of the Hydrodynamics in the Lower Fox River Between Lake Winnebago and DePere, WI	HQI (2000)
TM “5d”[2]	ECOMSED Model Application: Upstream Lower Fox River from Lake Winnebago to DePere Dam	Baird (2000b)

1 TM = Technical Memorandum.

2 The designation of this report as TM “5d” is informal based on its relation to companion documents.

reports examining solids inputs to the river are of particular importance. Successful simulation of PCB (or any hydrophobic chemical) transport is critically dependent and the transport of the particles with which the contaminant is associated. Given that contemporary point and nonpoint sources of PCBs to the Lower Fox River are near zero (WDNR, 1999a; LTI 1999a; WDNR, 2001a), it is important to distinguish between solids originating from the watershed (which are essentially free of PCBs) and those originating from the sediment bed (which are PCB contaminated). Those reports (TMs 2a, 2b, 2c, 2d, and 3a) consider solids inputs in much greater detail than was possible during the GBMBS and LMMBS and present a very different assessment of the global solids budget for the river. As described in TM3a (WDNR, 2001a), the MEW reports listed in Table 2-1 were the source of the majority of the information necessary for model development.

In addition to MEW efforts, additional assessments of model performance were presented by a peer review panel. Among the peer review panel recommendations were (AGI, 2000):

1. use Lake Winnebago as the upstream limit of the model spatial domain to achieve a zero upstream PCB boundary condition (i.e. a point upstream of the PCB contaminated area);
2. use a numerical integration scheme that avoids mixing in deep sediments; and
3. treat solids as (at least) three state variables

To the greatest extent practical, peer review panel recommendations were integrated into wLFRM development efforts. The wLFRM describes PCB transport in all 39 miles of the Lower Fox River from Lake Winnebago to the river mouth at Green Bay in a single spatial domain. All simulations were performed using the IPX 2.7.4 framework (Velleux et al. 2000). Solids were treated as three state variables throughout the model spatial domain.

3.3 MODEL SEGMENTATION AND SPATIAL ORGANIZATION

The full length of the Lower Fox River, from its head at Lake Winnebago to its mouth at Green Bay, was simulated in a single domain. The optimal choice of model segmentation depends on system physical characteristics, gradients in contaminant concentrations, the dominant transport processes, and the desired spatial and temporal resolution of the model. Based on these considerations, the spatial domain of the river was divided into segments for the water column, surficial sediments, subsurface sediment layers.

The river water column was divided into 40 water column segments. The physical characteristics of these water column segments (volume, surface area, water depth, etc.) were estimated from information presented in National Oceanic and Atmospheric Administration (NOAA) navigation chart number 14916. Additional supporting information was obtained from Lower Fox River hydrographic surveys performed by the U.S. Army Corps of Engineers (USACE) and Ocean Surveys, Inc. (OSI, 1998).

Between Lake Winnebago and the DePere dam, most PCB contaminated sediments exist as a series of discrete deposits. Several of these discrete deposits are spread over large surface areas. To better represent these sediments within the model, several of the largest discrete deposits were considered as a series of adjacent sub-deposits. Additional PCB contaminated sediments exist in interdeposit areas between the discrete deposits. Between the DePere dam and the river mouth, PCB contaminated sediments exist as a single, very large deposit. To better represent these sediments within the model, this single deposit was considered as a series of contiguous sediment management units (SMUs). In all, 165 sediment stacks were defined: 46 deposit areas (including all sub-deposit divisions), 24 interdeposit areas, and 95 SMUs.[3]

Based on these delineations, the river sediment column was divided into 165 stacks. The physical characteristics of all sediment stacks (and layers within each stack as described below) were estimated from interpolations of field survey results from sediment sampling data collected from 1989 through 1997 as described in TM2e (WDNR, 1999b). Each stack represents one deposit (or sub-deposit division), interdeposit, or sediment management unit (SMU). These stacks were further divided into 10 vertical layers[4] (to the limit of sediment thickness in any location) as follows, expressed as a distance below the initial position sediment-water interface: 0-5 cm, 5-10 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. The first three layers in each stack (surface layer and two subsurface layers) were represented in the model as active model segments. Any remaining sediments in each stack were represented as deep sediment layers (see Velleux et al. 2000 for further discussion). A summary of sediment stack organization and properties is presented in Appendix A.

In total, there are 40 water column segments, 165 surface sediment segments, 330 subsurface sediment segments (165 segments in each of two subsurface layers), and 652 deep sediment sections in the model. The model segmentation and spatial organization are presented in Figures 3-1 through 3-4. Groups of segments divide the river into four reaches as presented in Table 3-2.

Table 3-2. Lower Fox River reach definitions.

Reach	*Description*	*Water Segments*	*Sediment Stacks*
1	Little Lake Butte des Morts (Appleton dam)	1-7	1-11, 47-53
2	Appleton to Little Rapids (Little Rapids dam)	8-18	12-37, 54-64
3	Little Rapids to DePere (DePere dam)	19-24	38-46, 65-70
4	DePere to Green Bay (the river mouth)	25-40	71-165

[3] As described by WDNR (1997), the sediment area downstream of the DePere dam was divided into 96 SMUs. However, due to its distance from the nearest sampling locations, it was not possible to define sediment thickness (and subsequently volume) for SMU 66. Consequently, SMU 66 was considered to be “null” (undefined) for wLFRM development.

[4] TM2e defines nine vertical layers. For wLFRM development, the first layer defined in TM2e (0-10 cm) was subdivided into two layers (0-5 cm and 5-10 cm).

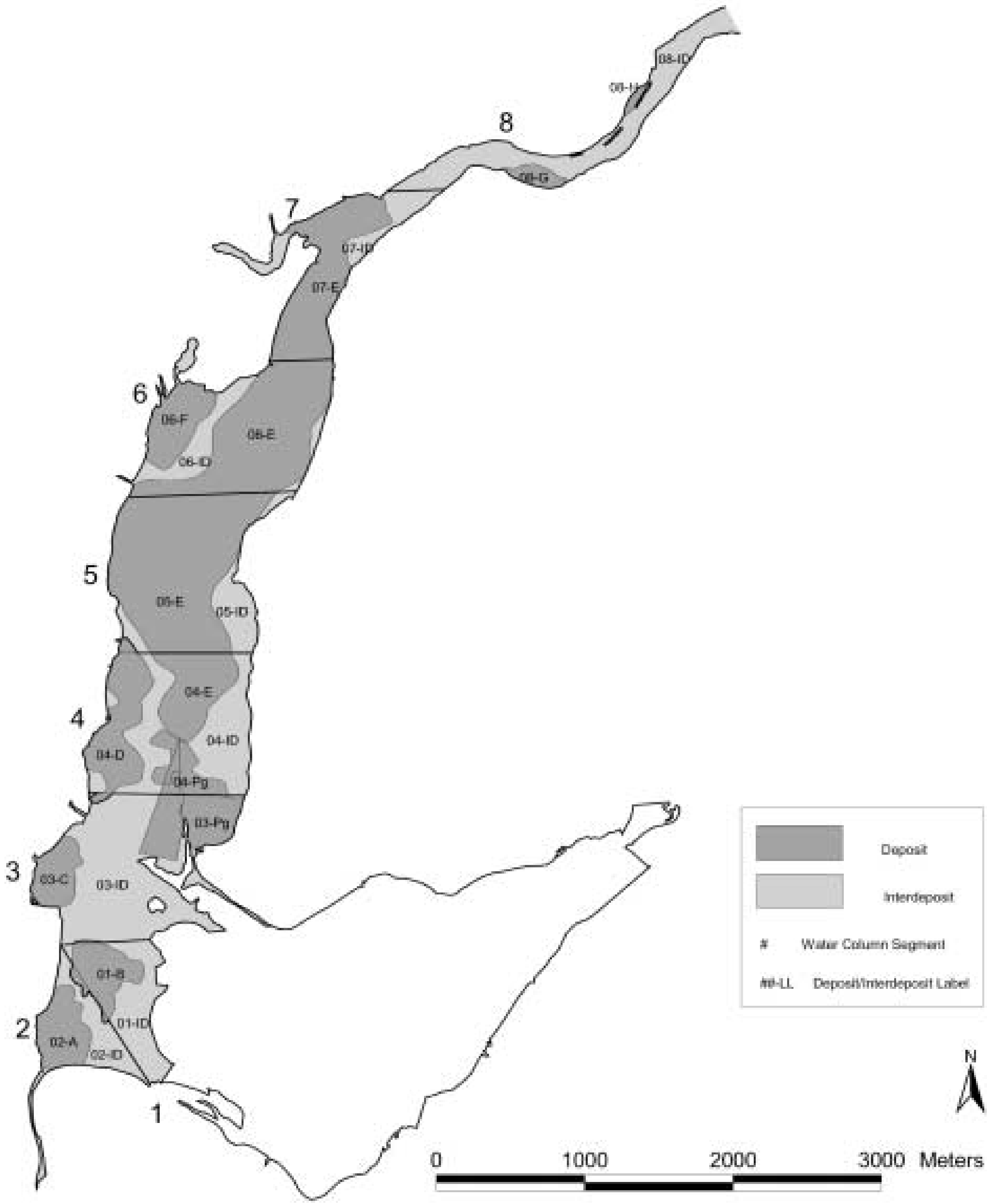

Figure 3—1. Model segmentation and spatial organization: Reach 1.

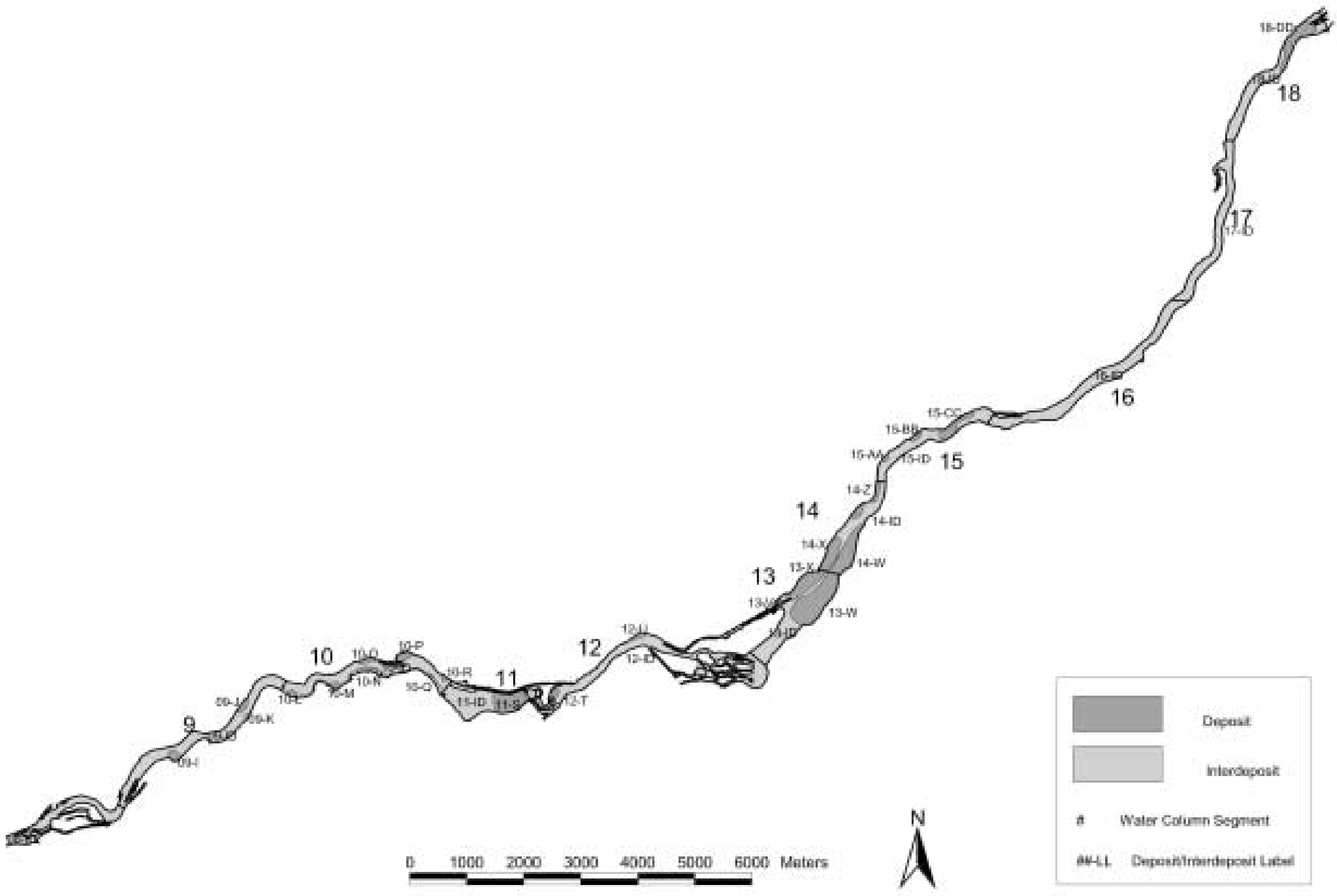

Figure 3—2. Model segmentation and spatial organization: Reach 2.

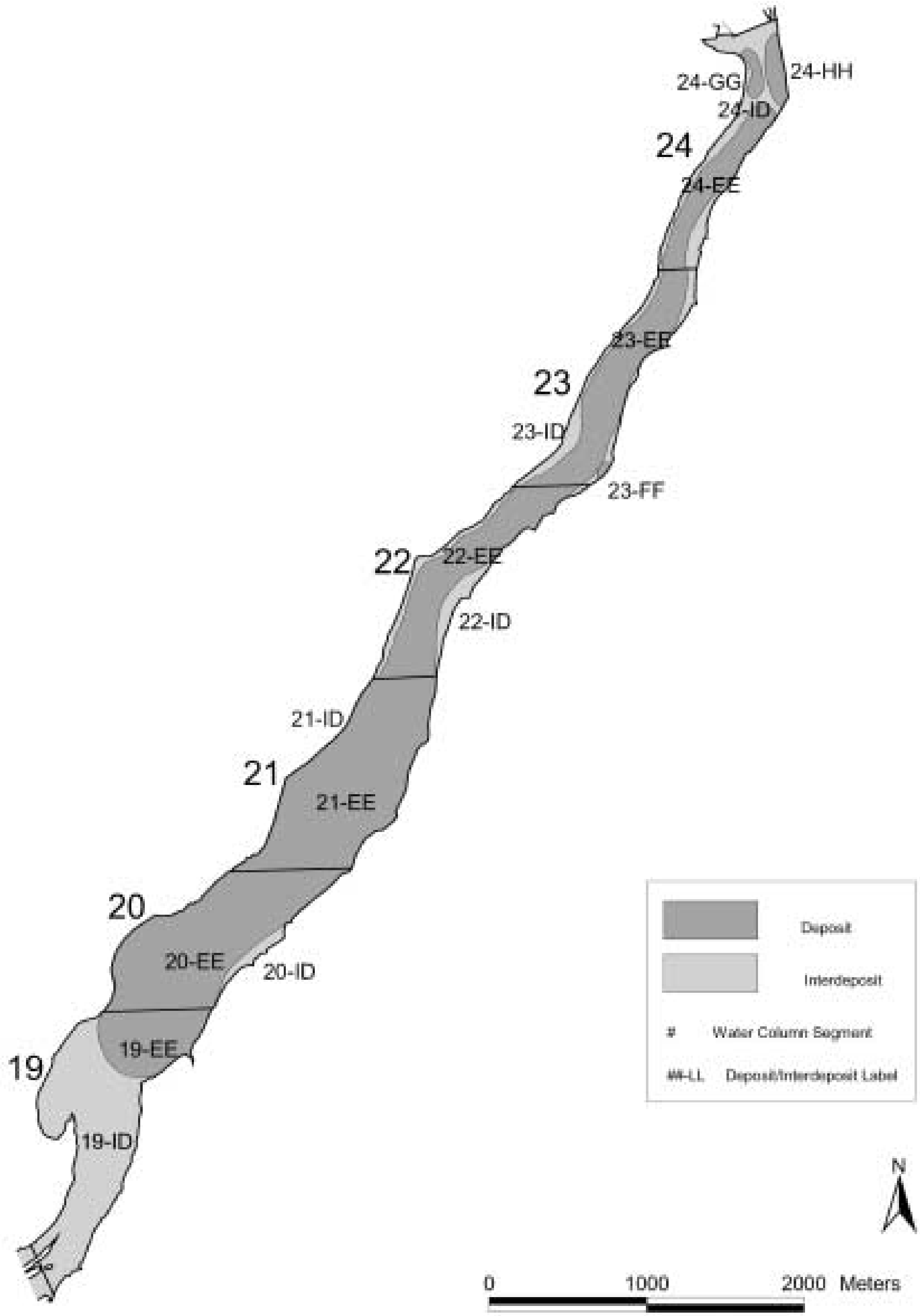

Figure 3—3. Model segmentation and spatial organization: Reach 3.

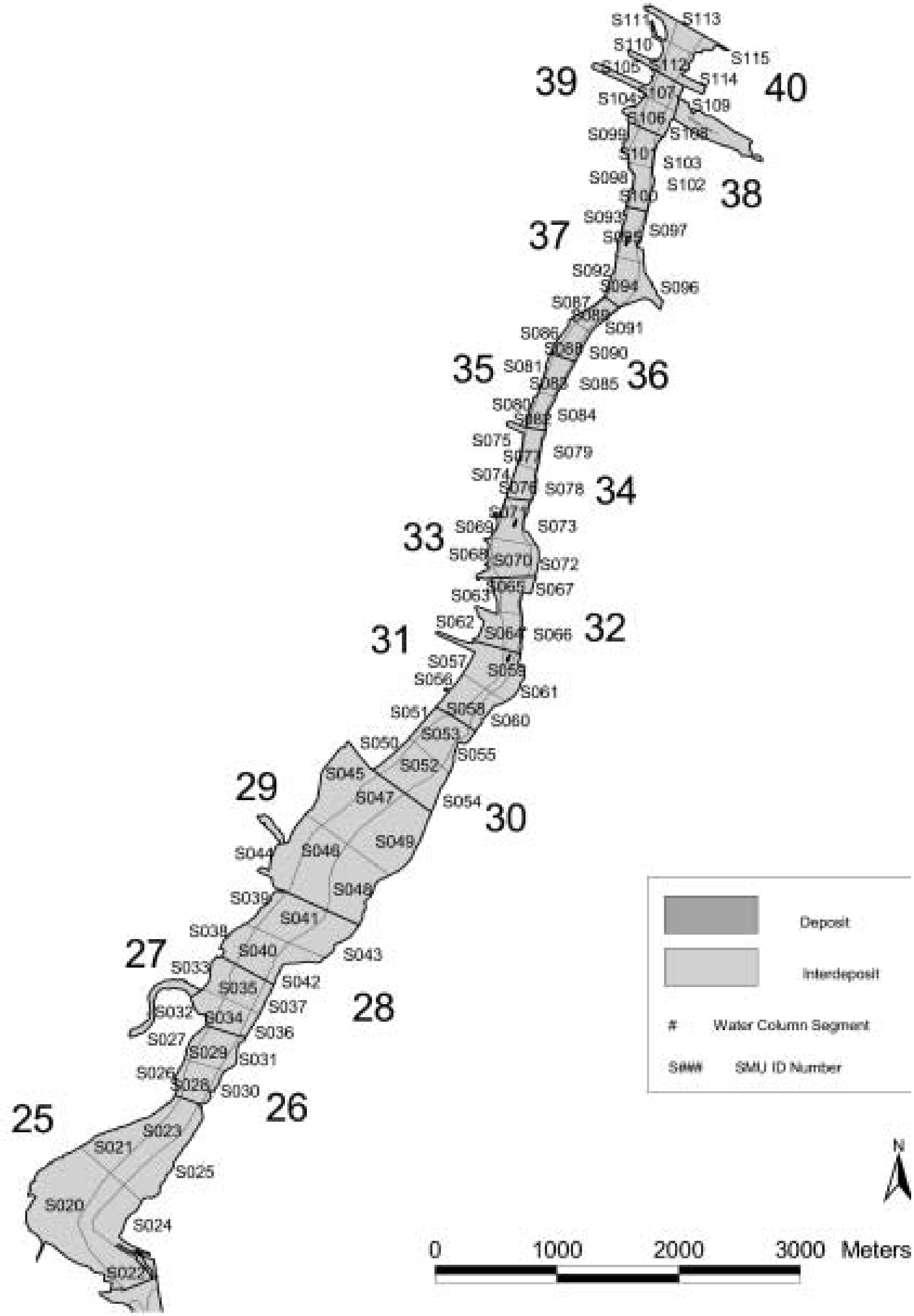

Figure 3—4. Model segmentation and spatial organization: Reach 4.

3.4 FLOW SOURCES, HYDRODYNAMICS, AND FLOW ROUTING

Water flows into the Lower Fox River from several sources: the upstream boundary at Lake Winnebago, tributary streams and direct run-off from the surrounding watershed, and point sources. As described in the model evaluation workplan (LTI and WDNR, 1997), these flow sources were examined as part of TM2a (FWB2000, 1998), TM2d (WDNR, 1999a), and TM3a (WDNR, 2001a). Hydrodynamic models of the Lower Fox River were also developed as part of TM5c (HQI, 2000) and TM5b (Baird, 2000a) to examine the structure of river currents. This information was used to describe the magnitude and temporal dynamics of flows and velocities in the wLFRM.

3.4.1 Upstream Flow Boundary Condition

Upstream boundary flows include all flows entering the Lower Fox River from Lake Winnebago across the dams at Neenah and Menasha. These flows were examined in TM3a (WDNR, 2001a). In that effort, observed flows at the Rapide Croche gaging site and the watershed flow estimates presented TM2a (FWB2000, 1998) were used to estimate the upstream boundary flow. As described in TM3a (WDNR, 2001a), a 4-day running average procedure was applied to the raw TM2a flow estimates as part of this computation. Flows were estimated for the period 1954 though 1995. In addition, flows for a 25-year forecast period were also estimated. For the period 1989-1995, the daily flows entering the river from Lake Winnebago (i.e. the sum of flows across the Neenah and Menasha dams) are presented in Figure 3-5.

3.4.2 Watershed Flows

Watershed flows include all flows entering the Lower Fox River from tributary streams as well as direct run-off from the surrounding watershed. Flows to the river between Lake Winnebago and Green Bay were examined in TM2a (FWB2000, 1998). In that effort, the Soil and Water Assessment Tool (SWAT) was applied to estimate flows (and solids loads) to the Lower Fox River. SWAT used watershed characteristics such as land use, crop rotations and soil type along with climatic data (rainfall, temperature, etc.) to estimate flows for the period 1954-1995. In addition, flows for a 25-year forecast period were also estimated. As described in TM3a (WDNR, 2001a), a 4-day running average procedure was applied to the raw TM2a flow estimates. For the period 1989-1995, the daily flows entering the river from the watershed between Lake Winnebago and the river mouth (i.e. the sum of all tributary flows and direct run-off) are presented in Figure 3-6.

3.4.3 Point Source Flows

Point source flows include all flows entering the Lower Fox River from wastewater treatment facilities that discharge to the river. Point source flows to the river were examined as part of TM2d (WDNR, 1999a). Flows were estimated for the period 1954-1995. For the period 1989-1995, daily flow information was available. The relative importance of these flows was further considered as part of TM3a (WDNR, 2001a). Relative to the total flow of the river, net point source flows are negligible. Based on the recommendation presented in TM3a, point source flows to the river were treated as zero for both short-term and long-term simulations.

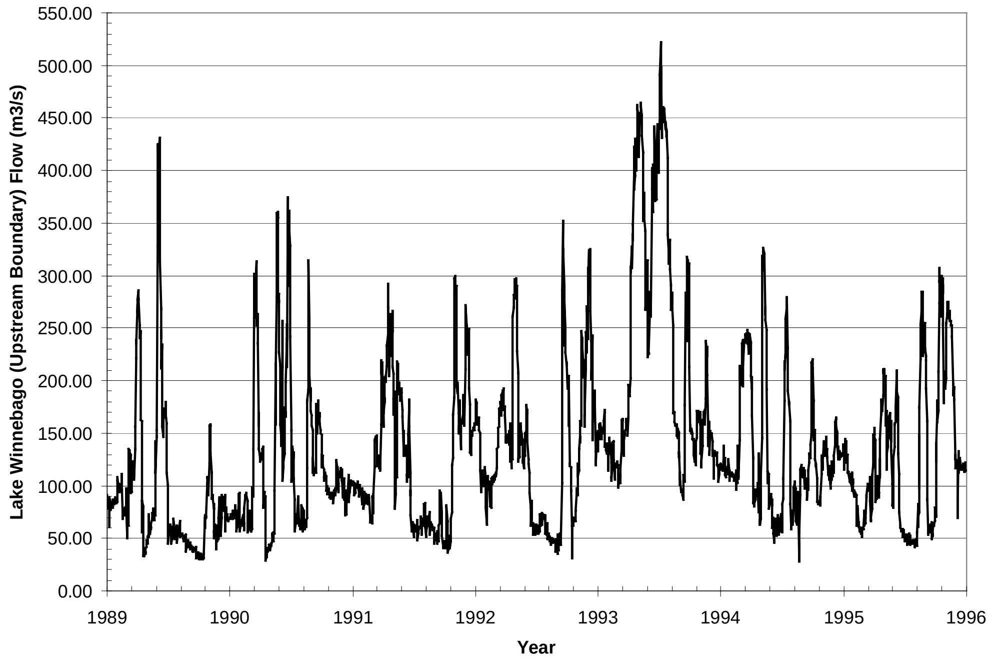

Figure 3—5. Flow to the Lower Fox River from Lake Winnebago: 1989-1995.

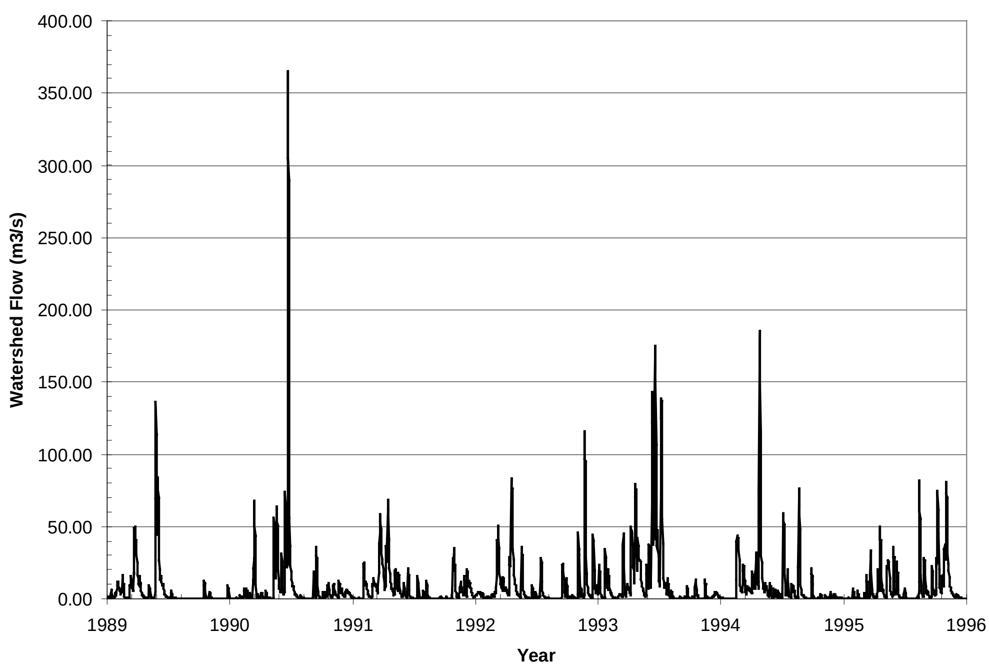

Figure 3—6. Flow to the Lower Fox River from the remaining watershed: 1989-1995.

3.4.4 Flow-Velocity Relationships

The velocity at which water moves over the sediment bed surface is the key determinant of the shear stress that is exerted at the sediment-water interface. The shear stress is a controlling factor in the transport of particle-associated contaminants that originate from the sediment bed. The representation of river hydrodynamics is therefore a significant component of model development.

The hydrodynamics of the Lower Fox River were examined as part of MEW efforts. Technical Memorandum 5c (TM5c) (HQI, 2000) examined hydrodynamics between Lake Winnebago and the DePere dam. Technical Memorandum 5b (TM5b) (Baird, 2000a) examined hydrodynamics (and sediment transport) between the DePere dam and the river mouth. For both efforts, two-dimensional hydrodynamic models were constructed and calibrated to available data (flow, water surface elevation, etc.). As described in TM5c and TM5b, the comparison between simulated and observed water surface elevations and flow was excellent. For example, as presented in TM5c regression analyses of the hydrodynamic model results and observed values yielded correlation coefficients greater than or equal to 0.98. This indicates that the hydrodynamic models are appropriate tools for simulating river currents.

The hydrodynamic models were then used to develop relationships between the currents at various locations throughout the river and the average river flow as reported for the gaging station at Rapide Croche. These relationships were expressed in the form of a power function:

$$U_{ij} = f_{LS,ij}\left(a_j Q^{b_j}\right) \tag{3.1}$$

where:

where:	U_{ij}	=	daily averaged current velocity at cross-section "j" as computed by the hydrodynamic models (m/s)
	Q	=	observed daily average flow rate (m^3/s)
	a_j, b_j	=	parameters specific to cross-section "j" as determined by regression analysis
	$f_{LS,ij}$	=	lateral structure factor used to relate the current velocity at cross-channel location "i" to the average current velocity at cross-section "j"

In general, the correlation between the simulated velocity at each cross-section and observed flow was quite good. With few exceptions, correlation coefficients were generally 0.85 or greater. This indicates that the relationships between flow and velocity are strong. Therefore, especially for long-term simulations, flow can be used as a reasonable estimator of velocity. For wLFRM development, hydrodynamic model simulation results were effectively integrated within the contaminant transport model through use of the relationships described by Equation (3.1). Subsequent estimates of sediment transport (erosion and deposition fluxes) based on these flow-velocity relationships are described in Section 3.5.

It is worth noting that for some locations, the correlation between velocity and the gaged river flow was less strong. One such location was near the upstream-most portion of Little Lake Butte des Morts. However, this area is upstream of the Menasha Channel inflow that delivers a significant portion of the total river flow originating from Lake Winnebago. As a result, the lower correlation for this region was expected. For a few locations near the river mouth the correlation between velocity and flow was also less strong. This was again expected because, near the river mouth, velocities can be affected by water surface elevation fluctuations in Green Bay (e.g. flow reversals due to seiches). These fluctuations can alter the current field such that the velocity at a given location at a particular time may depend more on bay water levels than the flow at an upstream gaging site (which is not influenced by bay water surface elevations). Even in those few cases where the correlation was less strong, flow was nonetheless the best single parameter that could be used to estimate velocity for which a long-term record exists.

3.4.5 Advective Transport

In the river, advective transport represents the downstream movement of water (and associated dissolved and particulate materials). In the wLFRM, 40 flow time series were specified: two upstream boundary flows (one each of the Neenah and Menasha Channels) and 38 watershed flows (one for each tributary and direct run-off). As noted in Section 3.3, the model water column was sectioned into 40 segments. All flows were routed upstream to downstream from their point of entry to the river mouth. As noted in Section 3.4.4, the flow-velocity relationships developed from the hydrodynamic model results were used to describe river current velocities (and subsequent shear stresses).

3.4.6 Dispersive Transport

In the river, dispersive transport represents the lateral and longitudinal physical mixing of dissolved and particulate materials caused by the fine-scale differential motion of water. A discussion of physical mixing in rivers is presented by Fisher et al. (1979).

In the wLFRM, such physical mixing can be explicitly described by specification of a dispersion coefficient. In the absence of other mixing effects, the explicit dispersion in a model would be set equal to physical dispersion. However, in addition to explicit dispersion, mixing in a numerical model also occurs as a consequence of numerical dispersion. Numerical dispersion arises from truncation of higher order Taylor Series terms during the finite difference approximation of the governing differential equations. The scale of this truncation error is influenced by the spatial scale of model segments (Δx) and the time step used for numerical integration (Δt). Ideally, during model development the sum of explicitly specified dispersion and numerical dispersion would equal the physical dispersion of the system. An example of this is presented by Vreugdenhil (1989).

As described in TM5c (HQI, 2000), numerical dispersion in the wLFRM[5] equals or exceeds the physical dispersion of the system as a result of its comparatively coarse spatial scale (relative to the hydrodynamic analysis). Therefore, in the wLFRM explicit dispersion coefficients for the water column were set to zero.

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[5] TM5c examined the dispersion characteristics of the "UFRM" (Steuer et al. 1995). However, the spatial scale of the wLFRM and "UFRM" are sufficiently similar such that the analysis presented in TM5c is applicable.

3.5 SOLIDS SOURCES AND SEDIMENT TRANSPORT

Solids enter the Lower Fox River from several sources: the upstream boundary at Lake Winnebago, tributary streams and direct run-off from the surrounding watershed, internal production, point sources, and the sediment bed. As described in the model evaluation workplan (LTI and WDNR, 1997), these solids sources were examined as part of TM2a (FWB2000, 1998), TM2c (LTI, 1999b), TM2d (WDNR, 1999a), TM2e (WDNR, 1999b), and TM3a (WDNR, 2001a). Sediment transport models of the Lower Fox River were also developed as part of TM5b (Baird, 2000a) and TM5d (Baird, 2000b) to explore interactions between the water column and sediment bed. This information was used to describe the magnitude and temporal dynamics of solids inputs and behavior in the wLFRM.

Suspended solids were simulated as three state variables: coarse; medium, and fine. Total solids is the sum of these three solids classes. Separation of total solids into these three classes was based on expected differences in the sediment transport properties of various particulate materials. Another determinant of solids class was particle grain size, delineated according to the Wentworth scale (Wentworth, 1922): sand (>62 μm), silt (4-62 μm), and clay (<4 μm). Note that while particle grain size was an indicator of solids class, it was not the main determinant. For example, algal particles may have diameters in the silt size range but generally exhibit quiescent settling speeds far less than those of silts.

3.5.1 Upstream Solids Boundary Condition

Upstream boundary solids include all solids entering the Lower Fox River from Lake Winnebago across the dams at Neenah and Menasha. This solids source was examined in TM3a (WDNR, 2001a). Based on samples collected between 1986 and 1991, the annual total solids load to the river was estimated to average 68,000 metric tons (MT)/year (Gustin, 1995). A representation of the total solids concentration boundary condition inferred from the field observations and the annual load estimate is presented in Figure 3-7. Using this approach, when the inferred solids concentration boundary condition is multiplied by the flow boundary condition, the average total solids load for the period 1989-1995 was approximately 68,000 MT/year.

A portion of the total solids input to the river from Lake Winnebago was then assigned to each of the three solids classes. Lake Winnebago is a shallow, highly eutrophic, dimictic waterbody. In addition, depending on operating conditions, the dams at Neenah and Menasha can act to limit the free transport of particles with high settling speeds (see Figure 4.50, Baird, 2000b). As a consequence, it is reasonable to expect that a large portion of the total solids passing the dams consists of algae and other fine particles.

As part of GBMBS efforts, the USGS reported the percentage of particles smaller than 62 μm in diameter in 23 samples collected at the Neenah and Menasha sampling sites (USGS, 1991). The average fine particle percentage was determined from these data and the relationship between particle size and flow investigated. On average, 83% of the particles were smaller than 62 μm. A typical interpretation of this result might be that 17% of the particles were coarse, non-cohesive, inorganic materials with generally high settling speeds. However, it should be noted that samples of this type are filtered (wet sieved) but organic materials are not necessarily removed prior to

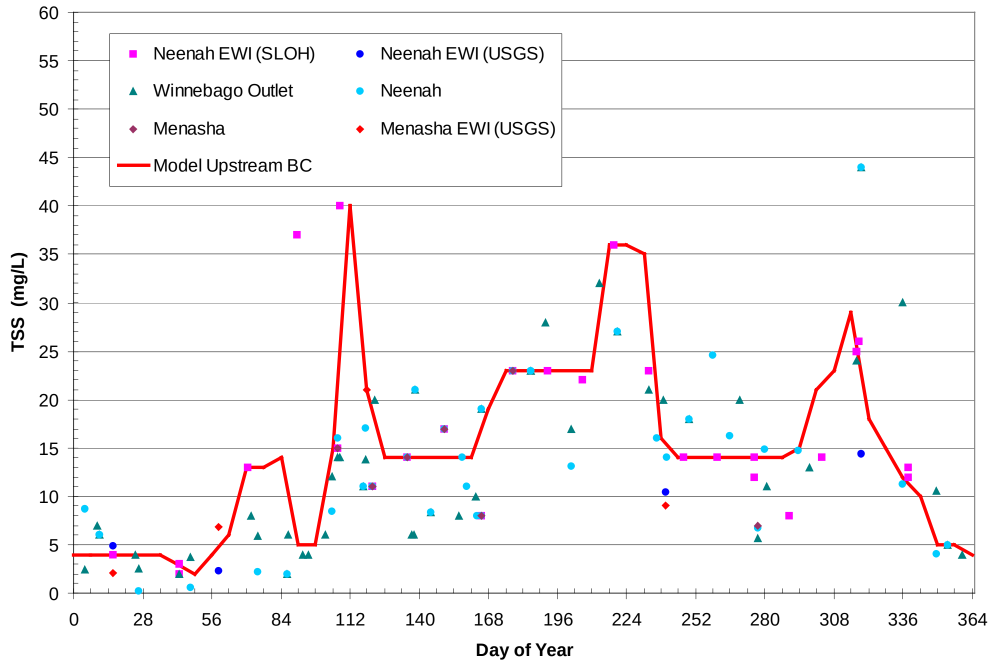

Figure 3—7. Total solids concentration at the Lake Winnebago upstream boundary.

analysis.[6] As a result, it is possible that a portion of the material in the "coarse" fraction may in fact be organic materials such as stands of filamentous algae or aggregated flocs of cohesive sediment with comparatively low settling speeds. This factor complicated further analysis. As a consequence, no clear relationship between flow and particle size could be determined.[7] In the absence of wholly quantitative information, the total solids entering the river from Lake Winnebago were assumed to be comprised of 10% medium (moderate settling speed) and 90% fine (low settling speed) particles. The uncertainty associated with the grain size distribution of the upstream solids boundary condition is significant.

3.5.2 Watershed Solids Loads

Watershed solids inputs are a significant component of the overall mass budget of solids for the Lower Fox River. The following sections describe the magnitude of solids loads from the river watershed between Lake Winnebago and the river mouth and the estimated composition (grain size distribution) of those inputs.

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[6] Removal of organics is at the discretion of the analyst. See Techniques of Water-Resources Investigations of the United States Geological Survey, Book 5, Chapter C1 for a description of the wet sieve (sand/fine split) method.

[7] This relationship was also investigated in TM5d (2000b). However, that analysis included data for sites downstream of Lake Winnebago and also assumed that all materials in the "coarse" fraction were coarse-grained, non-cohesive particles. As a result, the relationship presented in TM5d was not directly applicable.

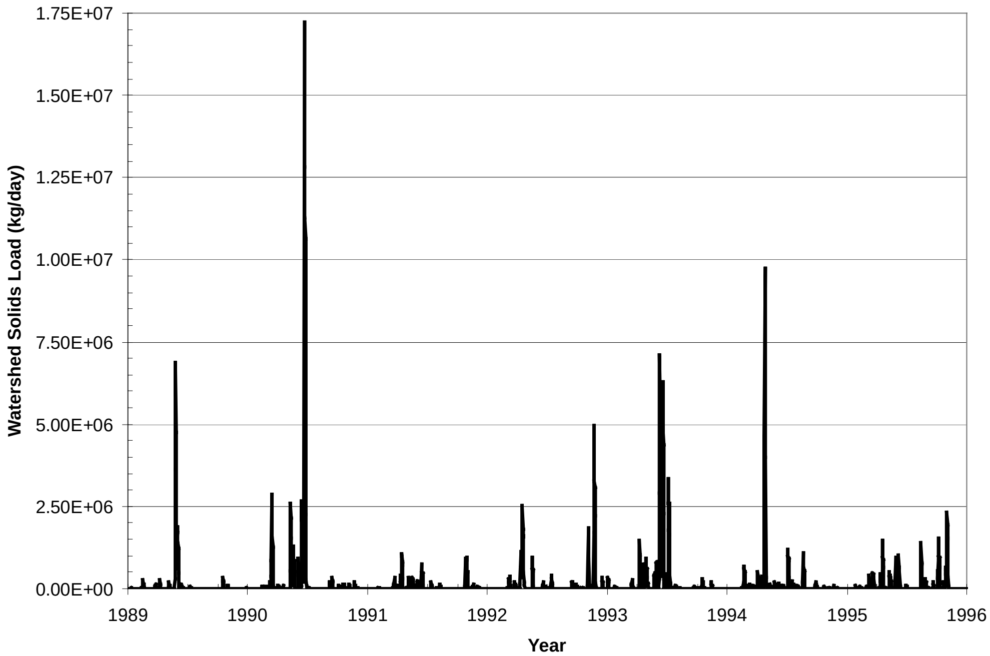

Figure 3—8. Solids load to the Lower Fox River from the watershed: 1989-1995.

3.5.2.1 Solids Load Estimates

Watershed solids loads include all solids loads entering the Lower Fox River from tributary streams as well as direct run-off from the surrounding watershed. Solids loads to the river between Lake Winnebago and Green Bay were examined in TM2a (FWB2000, 1998). In that effort, the Soil and Water Assessment Tool (SWAT) was applied to estimate solids loads (and flows) to the Lower Fox River. SWAT used watershed characteristics such as land use, crop rotations and soil type along with climatic data (rainfall, temperature, etc.) to estimate loads for the period 1954-1995. In addition, loads for a 25-year forecast period were also estimated. As described in TM3a (WDNR, 2001a), a 4-day running average procedure was applied to the raw TM2a solids load estimates. For the period 1989-1995, the daily solids loads entering the river from the watershed between Lake Winnebago and the river mouth (i.e. the sum of all tributary loads and direct run-off) are presented in Figure 3-8. The average overall total solids load from the watershed for 1989-1995 was approximately 54,000 MT/year.

3.5.2.2 Solids Load Fractionation

Watershed solids loads to the Lower Fox River were estimated on a total particle basis (i.e. the sum of all particle types). To permit simulation of multiple solids types, these total loads were fractionated into three particle types based on expected settling speed and size: “sand” (coarse, high settling speed), “silt” (medium, moderate settling speed), and “clay” (fine, low settling speed). It is important to note that while these particle classes are based, in part, on grain size, particle size does not necessarily infer mineral properties or the sediment transport behavior. For example, while the mean diameter of algal particles can be similar to that of fine silt particles, algae have substantially different properties than silts.

The grain size distribution (GSD) of sediments transported (routed) from an upland location to some downstream delivery point may vary from site to site and time to time as a function of soil type, particle size, and transport conditions (Arnold et al. 1990; Barfield et al. 1981). The particle GSD at the point of delivery can be estimated as follows:

$$C_{r_i} = C_{0_i} \boldsymbol{e}^{-\beta\sqrt{d_i}} \tag{3.2}$$

where:

	C_{r_i}	=	"concentration" of particle type "i" in the matrix of particles routed to the downstream delivery point
	d_i	=	typical diameter of particle type "i" (mm)
	β	=	transport condition coefficient
	C_{0_i}	=	"concentration" of particle type "i" in the matrix of detached particles in soils at the upland site

Values for C_{0_i} are available from Natural Resources Conservation Service (NRCS) soil survey reports. These values differ from site to site as a function of the predominant soil types (soil associations). The predominant soil types for each watershed sub-basin were determined from soil survey reports for the watershed areas delineated during development of TM2a (FWB2000, 1998). The grain size distribution (concentrations) of particles comprising the predominant soils types were obtained from the NRCS "National Soil Characterization Database". For each soil association, an average GSD was computed based on the composition of each soil association as listed in the soil surveys. Soil association and GSD information for each watershed sub-basin area are presented in Table 3-3.

Values for d_i were assigned according to the Wentworth scale sand-silt-clay size definitions as presented in Table 3-4. The particle diameter values used are those identified by Arnold et al. (1990) and are considered typical for many midwestern soils. Additional data reported by Greb and Bannerman (1997) suggest that these values are also reasonable for urbanized areas.

The transport condition coefficient β is a general parameter used to account for the many explicit and implicit factors other than particle size that affect particle delivery to a downstream location. For all practical purposes, β is a calibration parameter. In this application, values for β were estimated based on drainage conditions and flow as follows:

$$\beta = \alpha \left[\frac{1}{1 + Q_t / Q_{max}} \right] \tag{3.3}$$

Table 3-3. Lower Fox River watershed soil association grain size distributions.

Basin Name	*Basin Number*	*Soil Associations*	*Sand*[8] *(%)*	*Silt (%)*	*Clay (%)*	*Source*
East River (LF01)	1	Kewaunee-Manawa	32.6	52.9	14.5	USDA, 1974
Apple, Ashwaubenon, Dutchman Creeks (LF02)	2	Oshkosh-Manawa Kewaunee-Manawa Winneconne-Manawa	20.7	57.5	21.8	USDA, 1974 USDA, 1974 USDA, 1978
Plum, Kankapot, Garners Creeks (LF03)	3	Kewaunee-Manawa-Poygan Winneconne-Manawa Oshkosh-Manawa	15.0	59.6	25.4	USDA, 1980a USDA, 1978 USDA, 1974
Lower Fox River Appleton, Mud Creek (LF04)	4	Winneconne-Manawa	8.4	58.0	33.6	USDA, 1978
Little Lake Butte des Morts, Neenah Slough (LF06)	5	Kewaunee-Manawa-Hortonville	32.6	52.9	14.5	USDA, 1980b
Lower Fox River Main Channel (LFM)	6	Oshkosh-Manawa	13.7	64.0	22.3	USDA, 1974

Table 3-4. Particle grain size classifications.

Particle Type	*Size Range (Wentworth scale)*	*Typical Diameter (upland)*[9]
Sand-sized	> 0.062 mm	0.200 mm
Silt-sized	0.062 - 0.004 mm	0.010 mm
Clay-sized	< 0.004 mm	0.002 mm

---

[8] The sand fraction for the East River (LF01) and Little Lake Butte des Morts (LF06) sub-basin areas may be lower than presented. For example, some grain size distribution data were from a Hortonville sandy loam soil sample collected in Waupaca County (located outside the river basin) which has a much higher sand content than the silt loam soils generally found within the Lower Fox River basin.

[9] During routing downstream from the erosion site, the average grain size distribution of the eroding particles will generally shift (decrease) as a result of the greater loss of coarser particles during transport

where: α = watershed "weighting factor" for sub-basin area

Q_t = river flow at time "t" (m^3/s)

Q_{max} = maximum river flow (m^3/s) (assumed equal to the 1-in-100 year event flow of approximately 610 m^3/s)

The watershed weighting factor expresses the travel conditions of transported particles. Watershed sub-basins with areas further away from the river are assigned larger weighting factors. As the weighting factor increases, the proportion of large particles reaching a downstream location decreases. Conversely, as weighting factor decreases, a greater proportion of the sand-sized particles that erode from the land surface may be routed downstream. Weighting factors differ from site to site but are constant over time and constant for any one sub-basin area. Assigned values of the weighting factor ranged from 1 to 10. River flow expresses the "intensity" of transport and is analogous to rainfall intensity/duration. Under high flow conditions (which typically occur in response to high rainfall/runoff amounts), a greater proportion of larger particles may reach a downstream location.

The grain size distribution at the downstream delivery point (the location where a given sub-watershed area connects to the receiving water body) is then computed as:

$$f_{r_i} = \frac{C_{r_i}}{\sum_{i=1}^{3} C_{r_i}} \tag{3.4}$$

where: f_{r_i} = fraction of particle type "i" routed to the downstream delivery location

Once the routed fraction of each particle type f_{r_i} is computed, the fraction of the total solids load comprised of a given particle type is computed as follows:

$$W_i = f_{r_i} W_{tss} \tag{3.5}$$

where: W_i = load of solids type "i" (kg/day)

W_{tss} = total solids load delivered as computed in TM2a (kg/day)

Using this approach, for the period 1989-1995, the average grain size distribution of routed sediments entering the river was approximately 9% coarse, 63% medium, and 28% fine.

3.5.3 Internal Solids Loads

Internal solids loads include all solids generated within the Lower Fox River resulting from the growth of biotic solids (such as plankton and zooplankton) in the water column. Internal solids loads within the river between Lake Winnebago and Green Bay were examined in TM2c (LTI, 1999b). In that effort, a simplified primary production (SPP) approach was applied to estimate internal production in the Lower Fox River. The SPP approach used Secchi disk depth (which described the depth to which light penetrates the water column), water temperature, nutrients (phosphorus), and chlorophyll-a data to estimate biotic solids inputs to the Lower Fox River for the period 1954-1995. For the period 1989-1995, the overall internal solids loads to the river are presented in Figure 3-9. For long-term (future) simulations, internal solids loads for the 1989-1995 period were repeated. The average overall internal solids load for 1989-1995 was approximately 20,000 MT/year. These loads were assumed to be comprised of 100% fine particles.

3.5.4 Point Source Solids Loads

Point source solids loads include all solids loads entering the Lower Fox River from wastewater treatment facilities that discharge to the river. Point source solids loads to the river were examined as part of TM2d (WDNR, 1999a). Loads were estimated for the period 1954-1995. For the period 1989-1995, daily and monthly load information was available. The relative importance of these loads was further considered as part of TM3a (WDNR, 2001a). During 1989-1995, point source solids loads represented about 5% or less of the overall total solids loads to the river. However, during earlier time periods, point source solids loads represented approximately 30% of the overall total solids input to the river. Therefore, for long-term retrospective simulations (e.g. a hindcast), it would be necessary to include point source solids loads. Based on the recommendation presented in TM3a, point source solids loads to the river were included in the model for the short-term at their measured (monthly average) values. For the period 1989-1995, the overall point source solids loads to the river are presented in Figure 3-10. For long-term (future) simulations, point source solids loads to the river for the 1989-1995 period were repeated. A summary of point source solids loads to the river is presented in Table 3-5. The average overall point source solids load for 1989-1995 was approximately 4,000 MT/year. These loads were assumed to be comprised of 50% medium and 50% fine particles based on the recommendation of TM2d (WDNR, 1999a).

3.5.5 Sediment Bed (Initial Conditions)

In response to flow conditions and other factors, a portion of the solids that originate from Lake Winnebago, the watershed, internal production, and point sources may fall out of the water column and contribute to the development of the sediment bed. Materials in the sediment bed can also be returned to the water column. As described in TM2g (WDNR, 1999c) the sediment bed is dynamic. Solids and other materials may continually exchange between the water column and the sediment bed. These exchanges depend, in part, on the physical properties of the bed. Sediment bed properties for the Lower Fox River were examined as part of TM2e (WDNR, 1999b). In that effort, sediment thickness, surface area, and volume, bulk density, grain size distribution, organic carbon, and other observations were used to estimate sediment bed properties. As described in TM3a (WDNR, 2001a), these sediment bed property estimates were based on a large database of observations and define model initial conditions for the short-term simulation period. For long-term (future) simulations, the physical properties of the sediment bed (volume, area, thickness, bulk density, grain size distribution, and organic carbon) were assumed to equal those defined in TM2e for the short-term simulation period. A summary of the physical properties of the sediment bed is presented in Appendix A. The average grain size distribution of solids in the sediment bed was 38% coarse, 44% medium, and 18% fine particles.

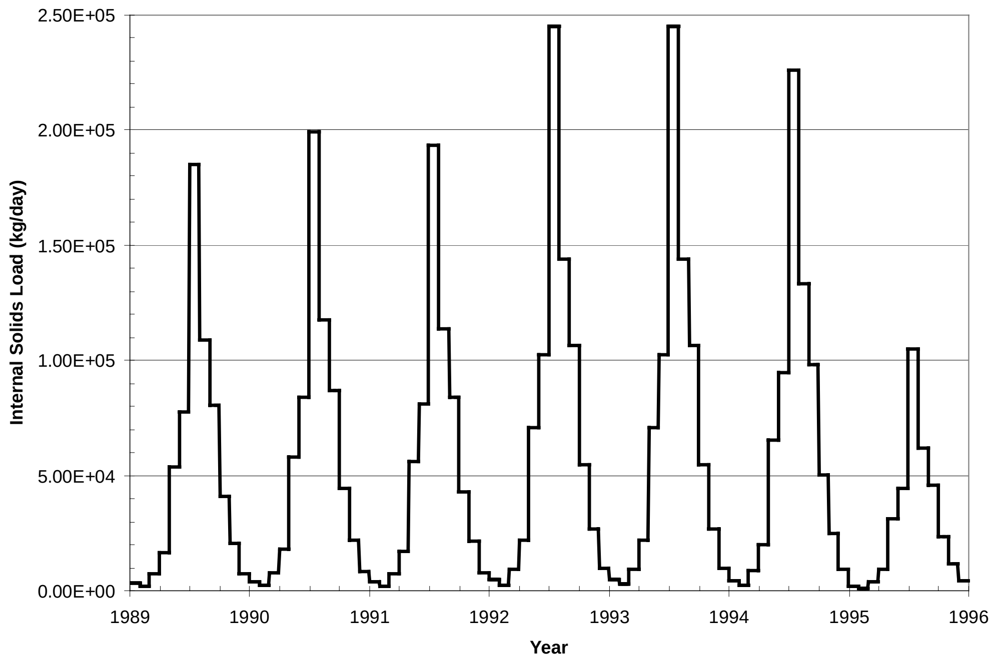

Figure 3—9. Solids loads to the Lower Fox River from internal production: 1989-1995.

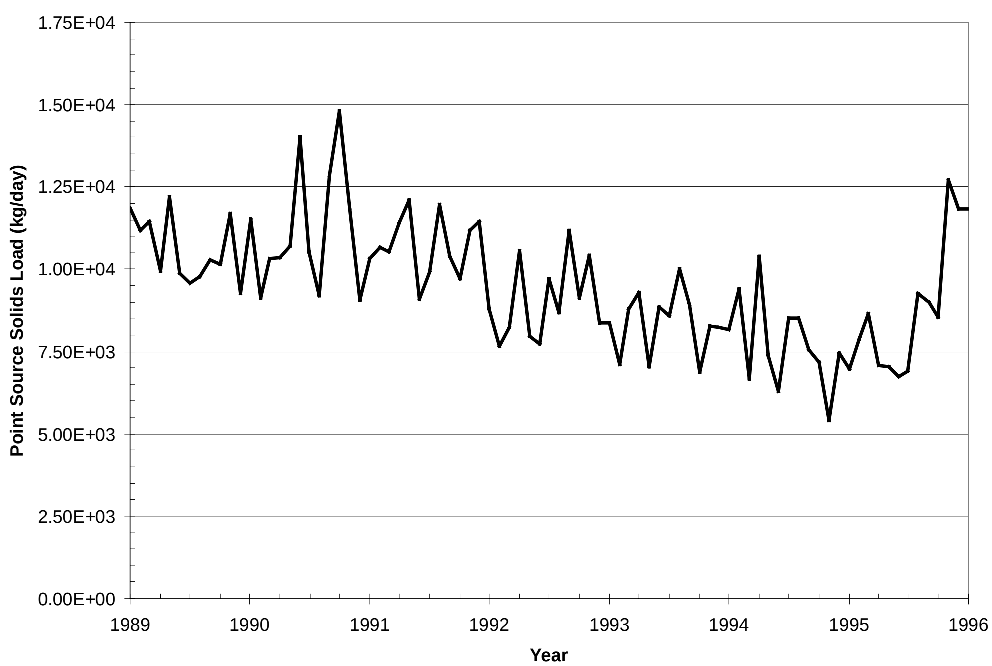

Figure 3—10. Solids loads to the Lower Fox River from point sources: 1989-1995.

Table 3-5. TM2d point source flows and solids loads to the Lower Fox River: 1989-1995.

Model Segment	Point Source	1989		1990		1991		1992		1993		1994		1995	
		Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)
Lower Fox River Upstream of the DePere Dam		**1.0E+8**	**1.9E+6**	**1.1E+8**	**2.3E+6**	**1.1E+8**	**2.3E+6**	**1.2E+8**	**1.8E+6**	**1.3E+8**	**1.8E+6**	**1.2E+8**	**1.6E+6**	**1.3E+8**	**1.9E+6**
1	American Tissue Mills	3.3E+6	1.0E+4	2.9E+6	7.1E+3	2.9E+6	7.5E+3	2.9E+6	8.0E+3	1.8E+6	4.2E+3	1.6E+6	4.8E+3	1.4E+6	4.7E+3
1	Kimberly Clark Corp.-Neenah/Badger Globe	4.8E+6	3.4E+4	4.7E+6	3.1E+4	4.6E+6	3.9E+4	5.0E+6	4.4E+4	4.9E+6	6.3E+4	5.1E+6	7.8E+4	5.1E+6	7.6E+4
1	P H Glatfelter Company	5.7E+6	1.2E+5	6.0E+6	2.7E+5	6.1E+6	2.5E+5	6.1E+6	2.8E+5	5.7E+6	2.2E+5	5.8E+6	2.3E+5	5.8E+6	3.5E+5
3	Neenah Menasha Sewerage Commission POTW	9.3E+6	3.1E+4	1.1E+7	5.7E+4	1.1E+7	5.7E+4	1.4E+7	8.3E+4	1.7E+7	1.1E+5	1.2E+7	5.2E+4	1.2E+7	6.1E+4
3	Menasha East POTW	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0
3	American Can Canal Plant, Menasha	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0
3	George Whiting Paper Corp.	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0
3	Mead Corp., Gilbert Paper Division	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0
3	U.S. Paper Mills Corp., Menasha Division	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0
4	Wisconsin Tissue Mills	4.0E+6	1.5E+5	6.3E+6	3.4E+5	7.9E+6	2.7E+5	8.0E+6	1.9E+5	8.2E+6	1.4E+5	7.9E+6	1.8E+5	7.9E+6	1.0E+5
6	Grand Chute Menasha West POTW	4.3E+6	6.9E+4	5.2E+6	7.9E+4	5.5E+6	6.8E+4	6.4E+6	7.9E+4	7.3E+6	8.4E+4	6.2E+6	8.3E+4	6.9E+6	7.7E+4

Table 3-5 (continued). TM2d point source flows and solids loads to the Lower Fox River: 1989-1995.

Model Segment	Point Source	1989		1990		1991		1992		1993		1994		1995	
		Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)
8	Riverside Paper Corp., Kerwin Division	1.8E+6	1.2E+5	8.4E+5	1.2E+5	8.4E+5	1.3E+5	1.1E+6	1.6E+5	9.2E+5	1.1E+5	7.1E+5	9.4E+4	6.2E+5	9.7E+4
9	Appleton POTW	1.6E+7	3.5E+5	1.8E+7	3.4E+5	1.8E+7	3.9E+5	2.0E+7	2.7E+5	2.2E+7	2.5E+5	2.0E+7	1.3E+5	2.2E+7	1.4E+5
9	Consolidated Paper, Appleton	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0
10	Kimberly POTW	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0
10	Consolidated Paper, Interlake Paper Inc.	1.7E+7	2.5E+5	1.6E+7	2.5E+5	1.6E+7	2.8E+5	1.6E+7	1.3E+5	1.7E+7	1.8E+5	1.7E+7	1.6E+5	1.8E+7	1.4E+5
12	Little Chute STP	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0
12	Appleton Papers Inc., Locks Mill	7.6E+6	1.4E+5	7.7E+6	2.3E+5	7.3E+6	2.2E+5	7.5E+6	1.3E+5	7.7E+6	1.8E+5	1.0E+7	1.7E+5	1.2E+7	3.2E+5
13	HOV Metro Sewerage Dist/Kaukauna	5.1E+6	6.7E+4	6.5E+6	4.7E+4	6.9E+6	6.7E+4	7.4E+6	1.1E+5	8.5E+6	6.2E+4	7.0E+6	5.0E+4	7.3E+6	8.4E+4
13	International Paper Corp., Thilmany Division	2.3E+7	5.3E+5	2.6E+7	5.8E+5	2.5E+7	5.1E+5	2.4E+7	3.6E+5	2.6E+7	3.7E+5	2.9E+7	4.0E+5	2.6E+7	4.4E+5
15	Wrightstown Sewer & Water Utility	1.6E+5	1.1E+3	2.0E+5	7.5E+2	2.1E+5	7.1E+2	2.3E+5	8.6E+2	2.7E+5	1.3E+3	2.0E+5	1.1E+3	2.1E+5	1.1E+3
19	Charmin, Little Rapids Mill	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0

Table 3-5 (continued). TM2d point source flows and solids loads to the Lower Fox River: 1989-1995.

Model Segment	Point Source	1989		1990		1991		1992		1993		1994		1995	
		Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)	Flow (m3/yr)	TSS (kg/yr)
Lower Fox River Downstream of the DePere Dam		**8.7E+7**	**2.0E+6**	**9.6E+7**	**1.8E+6**	**9.4E+7**	**1.6E+6**	**9.4E+7**	**1.5E+6**	**9.2E+7**	**1.3E+6**	**8.5E+7**	**1.2E+6**	**8.3E+7**	**1.3E+6**
25	DePere POTW	5.2E+6	1.5E+4	5.8E+6	1.1E+4	6.2E+6	9.3E+3	7.9E+6	1.4E+4	9.0E+6	4.2E+4	8.3E+6	4.7E+4	8.7E+6	2.0E+4
25	International Paper Corp., Nicolet Paper Division	3.2E+6	7.7E+4	3.9E+6	9.4E+4	3.7E+6	1.1E+5	3.5E+6	9.8E+4	3.7E+6	7.4E+4	3.6E+6	7.0E+4	3.4E+6	6.7E+4
25	U.S. Paper Mills Corp., DePere Division	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0	0.0E+0
31	Fort James Corp., Green Bay West Mill	1.9E+7	7.5E+5	2.2E+7	4.3E+5	2.3E+7	5.2E+5	2.1E+7	4.6E+5	1.7E+7	5.8E+5	1.4E+7	6.2E+5	1.4E+7	8.3E+5
37	Procter And Gamble Paper Products Company	6.0E+6	1.7E+5	5.1E+6	9.7E+4	4.4E+6	8.9E+4	4.2E+6	6.6E+4	6.8E+6	1.0E+5	7.0E+6	1.0E+5	6.8E+6	1.1E+5
38	Green Bay Packaging Inc.	2.6E+6	6.4E+4	2.8E+6	1.1E+5	2.4E+6	6.6E+4	2.3E+6	6.9E+4	2.4E+6	4.7E+4	2.3E+6	8.2E+4	1.9E+6	4.4E+4
39	Fort James Corp., Green Bay East Mill	1.2E+7	2.6E+5	1.0E+7	2.2E+5	1.1E+7	2.3E+5	1.1E+7	1.7E+5	1.1E+7	1.1E+5	1.1E+7	8.2E+4	1.1E+7	6.7E+4
40	Green Bay Metropolitan Sewerage District	3.9E+7	6.8E+5	4.7E+7	8.0E+5	4.3E+7	6.2E+5	4.4E+7	6.0E+5	4.2E+7	3.2E+5	3.9E+7	1.9E+5	3.7E+7	1.2E+5

3.5.6 Sediment Transport

Solids and particulate phase chemicals exchange between the water column and the sediment bed as a result of sediment transport processes. Materials denser than water can enter the bed by gravity settling. Materials at the sediment water-interface can be returned to the water column by resuspension. The shear stress at the sediment-water interface (generated by water flowing over the river bed) is a key determinant of the extent to which materials are incorporated into the bed or are resuspended. Interactions between the water column and the sediment bed also depend, in part, on the properties of particles in suspension and in the bed.

As described in the model evaluation workplan (LTI and WDNR, 1997), the hydrodynamics and sediment transport of the river were examined as part of the Task 5 series of technical reports. Hydrodynamic models of the Lower Fox River were developed as part of TM5c (HQI, 2000) and TM5b (Baird, 2000a) to examine the structure of river currents. This information was used to estimate shear stresses in the wLFRM. Sediment transport models of the Lower Fox River were also developed as part of TM5d (Baird, 2000b) and TM5b (Baird, 2000a) to examine aspects of sediment transport. This information was used to help estimate the magnitude and temporal dynamics of settling and resuspension velocities in the wLFRM.

In the sections that follow, a brief overview of each sediment transport process is presented. Following the overview, a description of process parameterization for the wLFRM application is presented.

3.5.6.1 Shear Stresses at the Sediment-Water Interface

As water flows over the sediment bed, shear stresses are generated. The magnitude of these shear stresses is a key determinant in the transport of material between the water column and sediment bed. As described in TM5c (HQI, 2000) and TM5b (Baird, 2000a), shear stresses at the sediment-water interface were computed from water velocities according to:

$$\tau = C_f \rho (U)^2 \tag{3.6}$$

where:

where:	τ	=	shear stress exerted at the sediment-water interface, dynes/cm^2 [M/L/T^2]
	C_f	=	coefficient of friction [dimensionless] ≈ 0.003 (from TM5b and TM5c)
	ρ	=	density of water, g/cm^3 [M/L^3] = 1.0
	U	=	advective water velocity, cm/sec [L/T]

In the wLFRM, water velocities were estimated from the flow-velocity relationships computed using the results of the hydrodynamic models as described in Section 3.4.4. Shear stresses were estimated from velocity using Equation (3.6). Water velocity and shear stress functions were computed for the area over each sediment deposit (including sub-deposit divisions), interdeposit, and SMU. The coefficient of friction used for shear stress computations was approximately 0.003 as determined by calibration of the hydrodynamic models presented in TM5c (HQI, 2000), and TM5b (Baird, 2000a).

3.5.6.2 Settling and the Probability of Deposition (Deposition)

Coarse particles (>62 µm) are often non-cohesive and, compared to finer particles, have high settling velocities under quiescent conditions. A number of empirical relationships to describe the settling velocities of non-cohesive particles such as sands are available. A summary of representative relationships is presented by Yang (1996). For non-cohesive (fine sand) particles with diameters from 62 to 500 µm, settling velocity can be computed as (Cheng, 1997):

$$\mathrm{v_s} = \frac{\nu}{d_p}\left[\left(25 + 1.2d_*^2\right)^{0.5} - 5\right]^{1.5} \tag{3.7}$$

$$d_* = d_p\left[\frac{(S-1)g}{\nu^2}\right]^{1/3} \tag{3.8}$$

where: $\mathrm{v_s}$ = quiescent settling velocity, m/s [L/T]

ν = kinematic viscosity of water, m^2/s [L^2/T] = 1.007×10^{-6} at 20 °C

d_p = average particle diameter, m [L]

d_* = non-dimensional particle diameter [dimensionless]

S = specific gravity of particle [dimensionless] = 2.65 for pure sands

g = gravitational acceleration, m/s^2 [L/T^2] = 9.81

Medium particles (<62 µm) are often cohesive and may flocculate. Floc size and settling velocity depend on the conditions under which the floc was formed (Burban et al. 1990). Settling velocities of cohesive particles can be approximated by:

$$\mathrm{v_s} = B_1\left(m_1 G\right)^{-0.85} d_m^{-[0.8+0.5\,\mathbf{log}(m_1 G - B_2)]} \tag{3.9}$$

where: $\mathrm{v_s}$ = floc settling velocity cm/s [L/T]

B_1 = experimentally determined constant = 9.6×10^{-4}

G = internal fluid shear stress, dynes/cm2 [$M/L/T^2$]

d_m = median floc diameter, cm [L]

B_2 = experimentally determined constant = 7.5×10^{-4}

Under conditions found in freshwater tributaries, settling speeds range can vary widely. Settling velocities for particles of this type range from 2-10 m/day or more.

Fine particles (<10 µm) generally may not extensively flocculate and typically have relatively small settling velocities as a result of their size, shape, density, and other physicochemical properties. For example, clay particles often have negative electrical charges which can inhibit direct particle aggregation in dilute suspensions. Also, biotic materials such as algae often fall into this size class of particles. Algae in particular generally possess mechanisms (such as gas vacuoles) to minimize their settling velocities (Wetzel, 1983). As a result of these attributes and other conditions, fine particles may have near-zero settling velocities.

Not all particles settling through the water column will necessarily reach the sediment-water interface or be incorporated into the sediment bed. As a result, effective settling velocities of particles in flowing water are usually less than quiescent settling velocities. The effective settling velocity can be described as a reduction in the quiescent settling velocity by the probability of deposition:

$$\mathrm{v}_{se} = P_{dep}\mathrm{v}_s \tag{3.10}$$

where: v_{se} = effective settling velocity [L/T]

P_{dep} = Probability of deposition [dimensionless]

The probability of deposition varies with shear stress near the sediment bed and particle size. As particle size decreases or shear stress increases, the probability of deposition decreases.

For non-cohesive particles, the probability of deposition has been described as a function of bottom shear stress (Gessler, 1967):

$$P_{dep} = P = \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{Y} e^{-0.5x^2}\,dx \tag{3.11}$$

$$Y = \frac{1}{\sigma}\left(\frac{\tau_{cd,n}}{\tau} - 1\right) \tag{3.12}$$

where: P = probability integral for the Gaussian distribution

σ = experimentally determined constant = 0.57

$\tau_{cd,n}$ = critical shear stress for deposition of non-cohesive particles, defined as the shear stress at which 50% of the particles in the size class settle, dynes/cm^2

The coarse particle critical shear stress for deposition can be computed from a force balance following the method of van Rijn (1984a,b) as summarized by QEA (1999) with the particle diameter equal to the mean diameter of the size class (i.e. $d_p = d_{50}$).

For cohesive particles, the probability of deposition has been described as a function of bottom shear stress (Patheniades, 1992):

$$P_{dep} = 1 - P = 1 - \frac{1}{\sqrt{2\pi}}\int_{-\infty}^{Y} e^{-0.5x^2}\,dx \tag{3.13}$$

$$Y = \frac{1}{\sigma} \boldsymbol{ln} \left[0.25 \left(\frac{\tau_{cd,c}}{\tau} - 1 \right) e^{1.27\tau_{cd}} \right] \tag{3.14}$$

where: σ = experimentally determined constant = 0.49

$\tau_{cd,c}$ = critical shear stress for deposition of cohesive particles, defined as the shear stress at which 100% of the particles in the size class settle

The probability integral in Equations 3.11 and 3.13 can be approximated as (Abramowitz and Stegun, 1972):

$$\begin{aligned} P &= 1 - F(Y)\left(0.4362X - 0.1202X^2 + 0.9373X^3\right) && \text{for } Y > 0 \\ P &= 1 - P(|Y|) && \text{for } Y < 0 \end{aligned} \tag{3.15}$$

$$F(Y) = \frac{1}{\sqrt{2\pi}} e^{-0.5Y^2} \tag{3.16}$$

$$X = (1 + 0.3327Y)^{-1} \tag{3.17}$$

In the wLFRM, the mean diameter (d_{50}) of coarse particles was assumed to be 100 μm. Using the Cheng (1997) relationship, a settling velocity (v_s) of approximately 470 m/day was estimated. The critical shear stress for non-cohesive deposition (τ_{cd}) was estimated by the force balance method. Given a d_{50} of 100 μm, the critical shear stress for deposition was approximately 0.8 dynes/cm^2. For medium particles, settling velocities varied by season and ranged from 2.15 m/day to 3.9 m/day and the critical shear stress for deposition was assumed to be 0.15 dynes/cm^2. For fine particles, the settling velocity was represented by a small constant value of approximately 0.1 m/day and the critical shear stress for deposition was assumed to be 0.10 dynes/cm^2. Probability of deposition functions for the wLFRM application are presented in Figure 3-11.

3.5.6.3 Resuspension (Erosion)

For any given resuspension event, the particle resuspension flux can be described as a function of the shear stress at the sediment-water interface, which can in turn be approximated as a function of flow (Ziegler et al. 1988; Gailani et al. 1991):

$$\begin{aligned} \varepsilon_{\tau>\tau_c} &= \frac{a_0}{Z}\left(\frac{\tau - \tau_c}{\tau_c}\right)^m && \text{for } \tau > \tau_c \\ \varepsilon_{\tau\le\tau_c} &<< \varepsilon_{\tau>\tau_c} && \text{for } \tau \le \tau_c \end{aligned} \tag{3.18}$$

where: $\varepsilon_{\tau>\tau_c}$ = amount of sediment resuspended when the shear stress exerted at the sediment-water interface (τ) exceeds the critical shear for entrainment (τ_c), g/cm^2 [M/L^2]

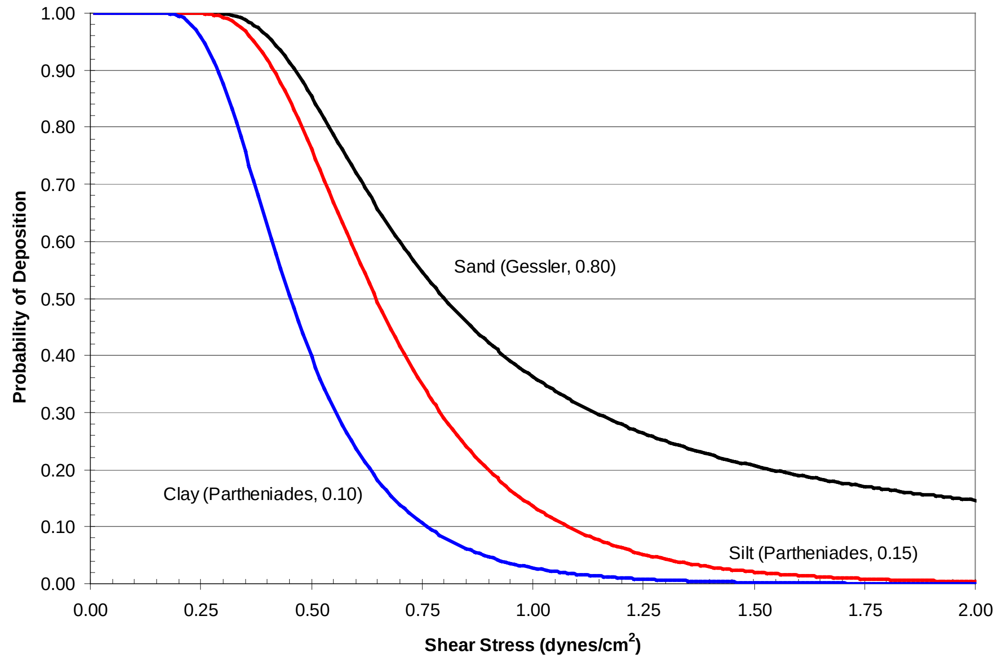

Figure 3—11. Probability of deposition functions for the wLFRM application.

a_0	=	empirical sediment yield constant
Z	=	empirical sediment age constant
τ	=	average shear stress at the sediment-water interface, dynes/cm^2 [M/L/T^2]
τ_c	=	average critical shear stress for entrainment, dynes/cm^2 [M/L/T^2]
m	=	empirical sediment entrainment exponent
$\varepsilon_{\tau \le \tau_c}$	=	amount of sediment resuspended when τ is less than or equal to the average critical shear for entrainment, g/cm^2 [M/L^2]

The parameters τ_c, m, a_0, and Z depend on the physical characteristics (age, water content, cohesiveness, etc.) of a particular sediment. Once τ_c is exceeded, sediments are quickly entrained. From the amount resuspended (ε), a resuspension velocity can be computed:

$$\mathrm{v}_r = \frac{\varepsilon}{\rho_b t_e} \tag{3.19}$$

where:	v_r	=	resuspension velocity, cm/s [L/T]
	ρ_b	=	bulk density of sediments, g/cm^3 [M/L^3]
	t_e	=	time to entrain sediments, s [T]

The most significant factors controlling resuspension are the critical shear stress for entrainment (τ_c) and the shear stress exerted at the sediment-water interface by water flowing over the sediments (τ). When the shear stress exceeds the critical shear, significant resuspension (mass erosion) occurs. Shear stress was computed as presented in Section 3.5.6.1.

The critical shear stress represents the average threshold beyond which mass erosion of sediment occurs. When average shear stresses are below this average threshold for mass erosion, limited resuspension may occur at a "background" level that is significantly less than when the average critical threshold is exceeded. This is defined as background resuspension. Background resuspension is a lumped parameter used to represent any particle movement that may occur when average shear stresses are less than the average critical shear stress for mass erosion. Very fresh sediments can form "fluff" layers that have significantly different erosion properties (greater yield coefficients and much lower critical shear stresses) than older sediments. For example, as described by Gailani et al. (1991), the yield coefficient assigned to fresh sediments was more than ten times greater than the normal value and the critical shear stress was ten times lower (0.1 dynes/cm^2). In addition, bed sediments are comprised of a mixture of particle types and sizes. Even within a single size class, particles smaller than the average particle size (d_{50}) may begin to resuspend before larger particles within the class. Further, some particles at the sediment-water interface, such as freshly deposited particulate detrital material (dead algae), can have very low specific gravities and, therefore, submerged weights. Lift forces generated as a result of water column turbulent may be sufficient to entrain such particles.

Background resuspension is typically so small that it does not significantly impact sediment bed morphometry or resultant water column suspended solids concentrations. From the perspective of overall particle transport, the mass of solids entering the water column from the sediment bed as a result of any background resuspension is negligible. However, in tributaries with significant in-place pollutant reservoirs, hydrophobic contaminants are typically present in the sediments at levels much higher than found in the water column relative to particulate materials. As a consequence, even minute resuspension (a little as several mm/year) can result in significant increases in water column contaminant concentrations. Therefore, although background resuspension is typically unimportant for accurate sediment transport simulation, it may be necessary to accurately simulate contaminant transport. For simplicity, background resuspension is assumed to be a function of flow following the form of Equation 3.18.

Other significant factors that influence resuspension are sediment armoring and the extent of sediment aging. These factors are described through the parameters τ_c, m, a_0, and Z. The parameters a_0 and m express how readily erodible a given sediment is. Sediment resuspension is a highly nonlinear function of flow. Laboratory experiments have determined that for many sediments m is in the range of 2 to 3 (Xu, 1991; Lick et al. 1995). For a limited number of sediments, a_0 has been determined to be in the range of 0.27×10^{-3} to 8×10^{-3} (Xu, 1991, Lick et al. 1995). The parameter Z is used to express the effects armoring and sediment age on resuspension. To represent armoring, the shear stress exposure history of the sediments is tracked and Z values increase (erosion potentials decrease) with increasing shear stress. The effects of armoring (bed "memory") are assumed to last for up to 30 days. To represent sediment aging, Z is an exponential function of the time after deposition and can vary from 0.1 to 50 (Tsai and Lick, 1987; Xu, 1991).

In the wLFRM, resuspension parameters were selected based on the results of the Shaker studies of Lower Fox River sediments as reported by Xu (1991) and Lick et al. (1995). The Shaker is a device that can be used in the field estimate the erosion potential of sediments as a function of the speed of an moving grid that generates turbulence which causes sediment to resuspend. The turbulence generated, and therefore the amount of sediment resuspended, is proportional to the speed at which the grid in the Shaker moves. The reported erosion potential of sediments from twelve locations between the DePere dam and the river mouth (Reach 4) as determined using the Shaker device are presented in Figure 3-12. Based on visual inspection, seven of the twelve samples tested were classified as "soft mud", one of the samples was classified as "silt", and the remaining four sample were classified as "sandy." As noted by Lick et al. (1995), in the Lower Fox River from the DePere dam to the East River, the sediments were primarily soft mud. Also as noted, from the East River junction to the mouth of the Lower Fox River, nearshore areas were generally muddy while deeper areas were sandy with pockets of muds.

Given the overall predominance of sediments classified as soft mud (and the expected preference of PCBs for such materials due to their greater organic carbon content and particle surface areas), the sediments were assumed to behave as soft mud. The average critical shear stress (τ_c) was assumed to be 1 dyne/cm^2. The sediment resuspension exponent (m) was assumed to equal 2.3. The sediment yield coefficient varied by reach as follows: 1.5 x 10^{-3} (Reaches 1, 3); 7.5 x 10^{-4} (Reach 2); and 1.0 x 10^{-3} (Reach 4). The sediment age constant (Z) was assumed to equal 1.74. Resuspension amounts as a function of shear stress for this parameterization are presented in Figure 3-13. Background resuspension was parameterized as a function of shear stress. Also as presented in Figure 3-13, the very small resuspension amounts that occur when the average shear stress is less than 1 dyne/cm^2 represent background resuspension. As shear stress goes to zero, background resuspension also goes to zero. This specification of background resuspension is analogous to the specification of sediment "fluff" layers as described by Gailani et al. (1991). When resuspension occurs, all particles resuspend in proportion to their abundance.

3.5.6.4 Displacement of the Sediment-Water Interface (Burial and Scour)

When particles are added to or removed from the sediment bed, the vertical position (elevation) of the sediment water interface is displaced relative to a fixed reference location (datum). The addition of particles to the bed causes the elevation of the sediment-water interface to increase (burial). The removal of particles from the sediment bed causes the elevation of the interface to decrease (scour). Addition of particles to the bed occurs through deposition. Removal of particles occurs through erosion. The difference between the fluxes of material entering and leaving the bed at a location defines the direction and magnitude of sediment-water interface displacement.

In the wLFRM, displacement of the sediment-water interface was determined from differences in the deposition and erosion fluxes for each sediment stack (deposit/sub-deposit, interdeposit, and SMU). No parameters to explicitly define the direction or magnitude of sediment-water interface displacements were specified. For each sediment stack, the reference location for displacements was the hard bottom of the sediment column determined from sediment thickness observations as described in TM2e (WDNR, 1999b). It is important to note that no material can ever move into or out of the model network across the hard bottom of the sediment column. Further discussion of this representation of burial and scour is presented in Velleux et al. (2000).

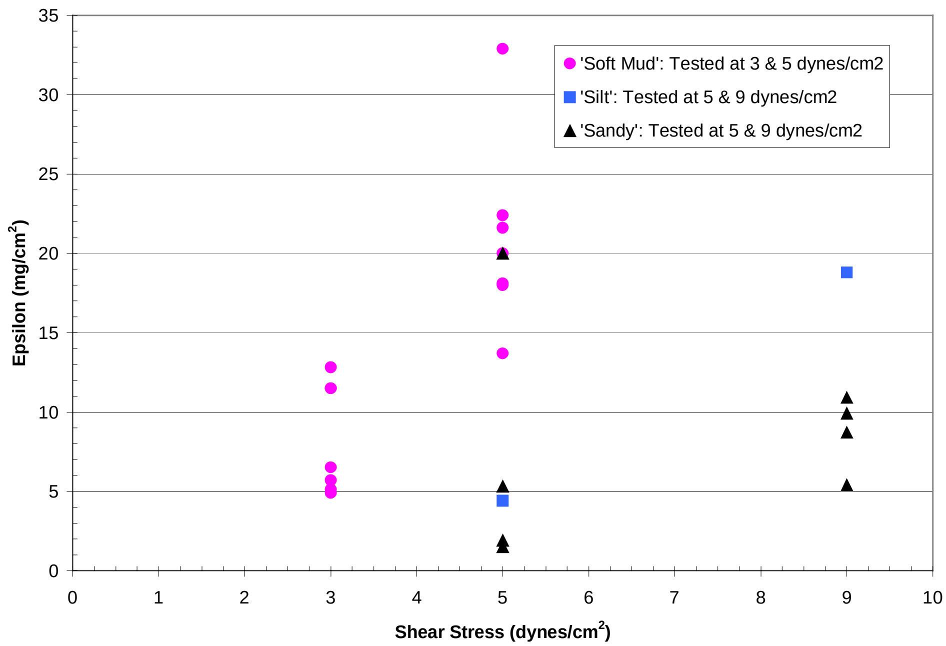

Figure 3—12. Erosion potential of Lower Fox River sediments (Lick et al. 1995).

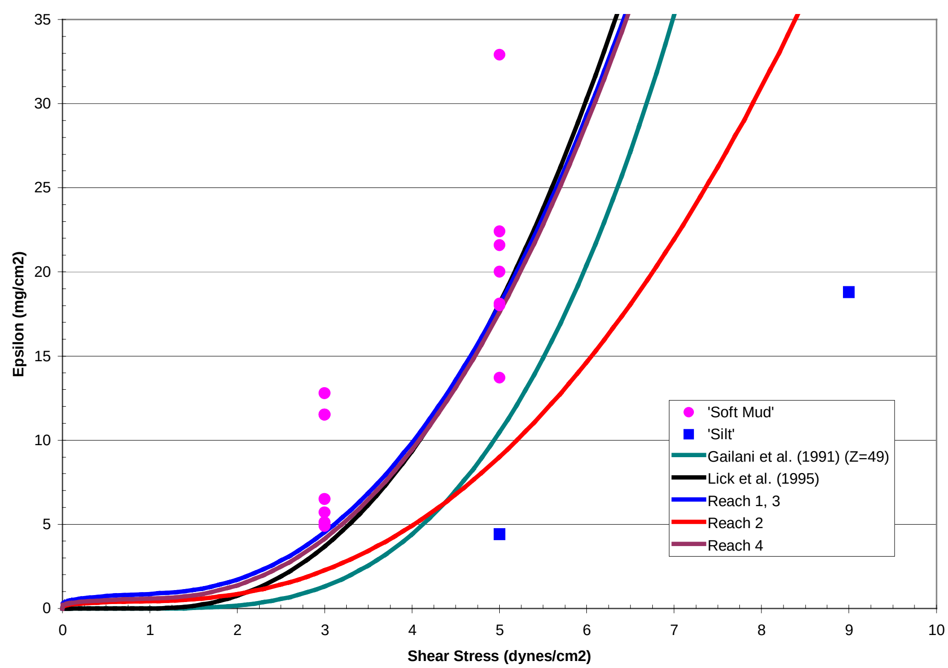

Figure 3—13. Representation of erosion potentials as parameterized in the wLFRM.

3.5.6.5 Sediment Mixing Processes

Near the sediment-water interface, disturbances of sediments by bioturbation and flow events can cause the exchange of particles (and associated contaminants) between layers within the sediment column. Bioturbation can extensively mix sediments (Lee and Schwartz, 1980; McCall and Tevesz, 1982). The depth through which mixing may occur depends on a variety of conditions (pH, dissolved oxygen, temperature, etc.) and the types and densities of organisms involved. Flow events can also mix sediments. As described in TM2g (WDNR, 1999c), sediment bed elevations in the Lower Fox River are very dynamic. Over monthly to annual times scales, sediment bed elevations have been observed to regularly fluctuate between 10 to 30 cm. Larger fluctuations of approximately 200 cm have also been recorded. Radioisotope tracer studies of Lower Fox River sediments also confirm extensive mixing in the upper sediments (Fitzgerald et al. 2001).

In the wLFRM, sediment mixing coefficients were specified to account for biological and flow induced particle exchange. Based on differences in the physical and chemical properties with depth, the sediment column was divided into a series of vertical layers as described in Section 3.3. Mixing coefficients were specified between the top three layers: 1) 0-5 cm, 2) 5-10 cm, and 3) 10-30 cm. The mixing coefficient was set to a value of 1.0×10^{-10} m^2/s for the spring, summer and fall months and set to zero for the winter months. Because of differences in volumes and mixing lengths, mixing between layers 1 and 2 is more rapid than mixing between layers 2 and 3. Given the specified mixing coefficient, the volumes of the sediment layers, and mixing lengths, this equates to a complete mixing time of 2-4 years for layers 1 and 2 and 25-40 years for layers 2 and 3.

It is should again be noted that sediment mixing can effect both particles as well as particle-associated contaminants. Nonetheless, in the wLFRM the concentration of each solids class does not vary with depth in a sediment stack as described in TM2e (WDNR, 1999b). Consequently, regardless of the magnitude of gross mixing, the net flux of solids between sediment layers would be zero. However, even if the net particle flux is zero, the flux of particle-associated contaminants will be greater than zero as long as particle phase chemical concentration gradients in the sediment column exist.

3.6 SOURCES OF PCBS AND PCB TRANSPORT

PCBs can enter the Lower Fox River from several sources (if present in those sources): the upstream boundary at Lake Winnebago, tributary streams and direct run-off from the surrounding watershed, point sources, and the sediment bed. As described in the model evaluation workplan (LTI and WDNR, 1997), these possible PCB sources were examined as part of TM2a (FWB2000, 1998) (see TM3a), TM2d (WDNR, 1999a), TM2e (WDNR, 1999b), and TM3a (WDNR, 2001a). This information was used to describe the magnitude and temporal dynamics of PCB inputs in the wLFRM.

PCBs were simulated as one state variable: total PCBs. Total PCBs represents a family of 209 possible related compounds. Each of these different PCB compounds is known as a congener. Total PCBs is the sum of all congeners present.

3.6.1 Upstream PCB Boundary Condition

Upstream boundary PCBs include all PCBs that may enter the Lower Fox River from Lake Winnebago across the dams at Neenah and Menasha. This potential PCB source was examined in TM3a (WDNR, 2001a). Upstream boundary conditions for PCB concentrations were estimated from 26 samples collected at the Neenah and Menasha dams during the GBMBS (see Tables 5-9 and 5-10 in Steuer et al. 1995). In addition to these samples, 10 field blanks were obtained by processing purified water through the sampling equipment. The average PCB concentration of these 26 samples was very similar to the average concentration of the 10 field blanks (Steuer et al 1995). As a result, and as recommended in TM3a, the PCB concentration at the Lake Winnebago boundary was treated as zero. Therefore, for the period 1989-1995, upstream PCB boundary loads were zero. For long-term (future) simulations, upstream PCB boundary loads were also zero.

3.6.2 Watershed PCB Loads

Watershed PCB loads include all PCB loads that may enter the Lower Fox River from tributary streams as well as direct run-off from the surrounding watershed. PCB loads to the river between Lake Winnebago and Green Bay were examined in TM3a (WDNR, 2001a) based on watershed flows estimates presented in TM2a (FWB2000, 1998) and measured PCB concentrations in tributaries and stormwater. PCBs were detected in 10% to 20% of samples collected during a study of four urban Wisconsin streams and 10 urban storm-sewer locations (Bannerman, 1996). In this study, the mean PCB concentration during events at the storm sewer sites was 110 ng/L.[10] This concentration, along with the estimate of watershed flow from urban areas in TM2a, was used to estimate nonpoint source PCB loads to the Lower Fox River. For the period 1989-1995, the daily PCB loads entering the river from the watershed between Lake Winnebago and the river mouth (i.e. the sum of all tributary loads and direct run-off) are presented in Figure 3-14. For long-term (future) simulations, watershed PCB inputs were assumed to decrease by 16% per year for 25 years and were set to zero for all subsequent years. The average overall PCB load from the watershed for 1989-1995 was approximately 7.5 kg/year.

3.6.3 Point Source PCB Loads

Point source PCB loads include all PCB loads entering the Lower Fox River from wastewater treatment facilities that discharge to the river. Point source PCB loads to the river were examined as part of TM2d (WDNR, 1999a). Loads were estimated for the period 1954-1995 based on production records and a limited number of effluent PCB concentration measurements. Based on the recommendation presented in TM3a, point source PCB loads to the river were included in the model at the value estimated in TM2d (WDNR, 1999a). For the period 1989-1995, the overall point source PCB loads to the river are presented in Figure 3-15. For long-term (future)

[10] It should be noted that the urban storm sewer PCB concentration data were collected from much larger and more heavily industrialized urban areas than the City of Green Bay or other urbanized regions of the Lower Fox River watershed. Therefore watershed PCB loads estimated from those data may represent an upper bound. It should be further noted that while the mean PCB concentration in the storm sewer samples was 110 ng/L, the median PCB concentration was less than detectable; PCBs were detectable in 20% or fewer of stream and storm sewer samples.

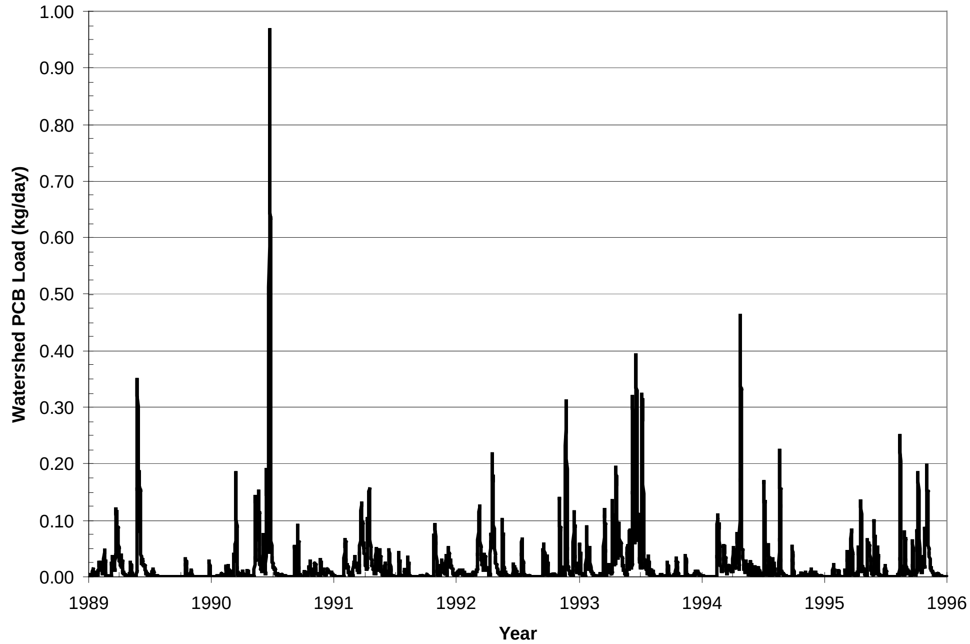

Figure 3—14. PCB loads to the Lower Fox River from the watershed: 1989-1995.

Figure 3—15. PCB loads to the Lower Fox River from point sources: 1989-1995.

Table 3-6. TM2d point source PCB loads to the Lower Fox River: 1989-95.

Model Segment	***Point Source***	***PCB Load (kg/yr)***						
		1989	***1990***	***1991***	***1992***	***1993***	***1994***	***1995***
Lower Fox River Upstream of the DePere Dam		*1.91*	*3.08*	*2.49*	*1.86*	*1.63*	*1.36*	*1.95*
1	PH Glatfelter	0.86	1.63	1.27	1.27	0.86	0.77	1.00
3	Neenah/Menasha POTW	0.00	0.00	0.00	0.00	0.00	0.00	0.00
9	Appleton POTW	0.00	0.00	0.00	0.00	0.00	0.00	0.00
12	Appleton Paper-Locks Mill	1.04	1.45	1.22	0.59	0.77	0.59	0.95
Lower Fox River Downstream of the DePere Dam		*19.50*	*9.62*	*10.16*	*7.57*	*8.26*	*7.62*	*8.75*
31	Fort James West	19.50	9.62	10.16	7.57	8.26	7.62	8.75
Sum of All Other Lower Fox River Dischargers		*2.04*	*2.27*	*1.77*	*1.41*	*1.09*	*0.95*	*0.73*

simulations, point source PCB loads to the river decreased by 15% per year for 25 years and were set to zero for all subsequent years. A summary of point source PCB loads to the river is presented in Table 3-6. The average overall point source PCB load for 1989-1995 was approximately 12 kg/year.

3.6.4 Sediment Bed PCBs

As noted in Section 3.5.5, particles may enter or leave the sediment bed in response to flow conditions and other factors. PCBs associated with those particles will also move between the bed and water column. Dissolved and DOC-bound PCBs can move between the bed and water column as well. As documented by the GBMBS results (USEPA 1992a,b), the sediment bed is presently the predominant source of PCBs to river. In addition to the physical properties of the bed, PCB interactions between sediments and water also depend on the concentration of PCBs in the sediment bed. Lower Fox River sediment bed PCB concentrations were examined as part of TM2e (WDNR, 1999b). As described in TM3a (WDNR, 2001a), these PCB concentration estimates were based on a large database of observations and define model sediment PCB initial conditions for the short-term simulation period. A summary of sediment PCB concentration initial conditions for the short-term is presented in Appendix A. Sediment PCB initial conditions for long-term (future) simulations are described in Section 5.2.

3.6.5 Partitioning, Sediment Transport, and Other Mass Transfer Mechanisms

In the aquatic environment, PCBs typically exist in three phases: 1) dissolved in water, 2) bound with dissolved organic compounds (DOC); and 3) particle-associated. The processes that affect PCB movements and interactions in the environment depend on the phase with which the PCBs are associated. Partitioning controls the distribution of PCBs between phases. All PCB phases move in the water column by advective transport and dispersive exchange as described in Sections 3.4.5 and 3.4.6. Dissolved PCBs can exchange between the water column and the atmosphere by volatilization. Dissolved and DOC-bound PCBs can move between the water column and sediments as well as within the sediment column by diffusive exchange. Particle-associated PCBs can move between the water column and sediments by settling and resuspension. Within the sediment column, particle-associated PCBs can move by sediment mixing processes. In concept, PCBs may also be subject to biodegradation.

3.6.5.1 Partitioning to Particles and Binding to Dissolved Organic Compounds

PCBs are hydrophobic and readily partition between dissolved, DOC-bound, and particle-associated (particulate) phases. Partitioning to bound and particulate phases is a function of PCB affinity for organic carbon. The equilibrium distribution of PCBs between phases is described by the organic carbon partition coefficient, the concentration of particles and dissolved organic compounds, the organic carbon content of particles, and DOC-binding effectiveness.

For particulate phases in the sediments, equilibrium partition coefficients are defined as:

$$\P_{p\,n} = f_{oc\,n} K_{oc} \tag{3.20}$$

where: $\P_{p_n}$ = equilibrium partition coefficient to particle type "*n*", L/kg [L^3/M]

f_{oc_n} = fraction organic carbon of particle type "*n*" [dimensionless]

K_{oc} = organic carbon partition coefficient, L/kg [L^3/M]

For particulate phases in the water column, equilibrium partition coefficients vary with the concentration of suspended solids as a result of particle interactions. The particle-dependent partition coefficients are described as (DiToro, 1985):

$$\P_{px\,n} = \frac{\P_{p\,n}}{1 + \sum_{n=1}^{3} m_n \P_{p\,n} / \nu_x} = \frac{f_{oc} K_{oc}}{1 + \sum_{n=1}^{3} f_{oc\,n} m_n K_{oc} / \nu_x} \tag{3.21}$$

where: $\P_{px_n}$ = particle-dependent partition coefficient, L/kg [L^3/M]

n = particle type index = 1, 2, or 3

m_n = concentration of solids type "*n*", kg/L [M/L^3]

ν_x = particle interaction parameter [dimensionless]

For the DOC-bound phase, the equilibrium binding coefficient is defined as:

$$\P_b = D_e \, f_{oc\,D} K_{oc} \tag{3.22}$$

where: $\P_b$ = equilibrium binding coefficient, L/kg [L^3/M]

f_{ocD} = fraction organic carbon of DOC [dimensionless]

D_e = DOC-binding effectiveness coefficient [dimensionless] = 0.01 (water), 0.1 (sediment)

Conceptually, dissolved organic compounds are composed entirely of organic carbon (f_{ocD} = 1). Under those conditions, the equilibrium binding coefficient would equal the organic carbon partition coefficient. However, in Great Lakes waters observed binding coefficients are up to100 times smaller than K_{oc} (Eadie et al. 1990; Eadie et al. 1992). In sediments, observed binding coefficients are up to 10 times smaller than K_{oc} (Landrum et al. 1985; Landrum et al. 1987; Capel and Eisenreich, 1990).

The partition coefficient can be used to describe the fraction of the total chemical (sum of all phases) that is associated with each phase as follows:

$$f_d = \frac{1}{1 + D_{oc}\P_b + \sum_{n=1}^{3} m_n \P_{px\,n}} \tag{3.23}$$

$$f_b = \frac{D_{oc}\P_b}{1 + D_{oc}\P_b + \sum_{n=1}^{3} m_n \P_{px\,n}} \tag{3.24}$$

$$f_{p\,n} = \frac{m_n \P_{px\,n}}{1 + D_{oc}\P_b + \sum_{n=1}^{3} m_n \P_{px\,n}} \tag{3.25}$$

$$f_d + f_b + \sum_{n=1}^{3} f_{p\,n} = 1 \tag{3.26}$$

where: f_d = fraction of the total chemical in the dissolved phase [dimensionless]

f_b = fraction of the total chemical in the DOC-bound phase [dimensionless]

n = particle type index = 1, 2, or 3

f_b = fraction of the total chemical in the particulate phase associated with particle type "*n*" [dimensionless]

Equations 3.23-3.25 are presented for the water column. For sediments, $\P_{pn}$ is used in place of $\P_{px_n}$.

In the wLFRM, a PCB K_{oc} value of $10^{6.30}$ was selected. This is consistent with site-specific partitioning analyses of GBMBS data (Velleux and Endicott, 1994; Steuer et al. 1995). This value is also consistent with typical K_{oc} values for PCB congeners that range from $10^{5.50}$ to $10^{7.10}$ (Burkhard et al. 1985; Swackhammer and Armstrong, 1987). The particle interaction parameter (ν_x) value of 9.0 was selected based on site-specific analyses of GBMBS data (Velleux and Endicott, 1994). Particle organic carbon content (f_{oc}) values for the water column were determined from GBMBS data. Particle f_{oc} values for the sediment were determined from TM2e (WDNR, 1999b). It is reasonable to expect that different particle types will have different organic carbon contents. However, f_{oc} data were only available on a total solids basis. Given this data limitation, the same f_{oc} values were specified for all particle types. With this assumption, the total carbon particle organic concentration associated with the total solids concentration equals observed values. The water column DOC concentration was determined from GBMBS data and set to the data average value of 8 mg/L (Velleux and Endicott, 1994). No DOC concentration data were available for sediment interstitial porewater. Given this data limitation, the water column DOC concentration value of 8 mg/L was also assigned to the sediments. The water column and sediment DOC-binding effective coefficients were set to 0.01 and 0.1, respectively.

3.6.5.2 Settling and Resuspension of Particulate Phases PCBs

PCBs associated with particles in the water column will enter the sediment bed if those particles settle. Similarly, PCBs associated with particles in the sediment bed will return to the water column if those particles resuspend. The factors that control particle transport between the water column and sediment bed were described in Section 3.5.6. Since particle phase PCBs move with the particles transported, the settling and resuspension fluxes of PCBs are described as:

$$J_s = A_s \sum_{n=1}^{3} \mathrm{v}_{s\,n} f_{p1_n} C_{T1} \tag{3.27}$$

$$J_r = \mathrm{v}_r A_s \sum_{n=1}^{3} f_{p2_n} C_{T2} \tag{3.28}$$

where:

J_s	=	settling flux, g/day [M/T]
J_r	=	resuspension flux, g/day [M/T]
A_s	=	sediment surface area across which transport occurs, m^2 [L^2]
n	=	particle type index = 1, 2, or 3
v_{s_n}	=	settling velocity of particle type "*n*", m/day [L/T]
v_r	=	resuspension velocity of particles, m/day [L/T]
f_{p1_n}	=	fraction of the total chemical in particulate phase associated with particle type "*n*" in the water column [dimensionless]
f_{p2_n}	=	fraction of the total chemical in particulate phase associated with particle type "*n*" in the sediment column [dimensionless]
C_{T1}	=	total chemical concentration in the water column, mg/L = g/m^3 [M/L^3]

3.6.5.3 Air-Water Exchange of Dissolved Phase PCBs (Volatilization)

PCBs are semi-volatile compounds. PCBs associated with the dissolved phase can move between the water column and atmosphere by volatilization. The volatilization flux of a chemical can be described the two-layer resistance approach (Whitman, 1923):

$$J_v = k_v A_s \left(f_{d1} C_{T1} - \frac{C_a}{H/RT} \right) \tag{3.29}$$

$$k_v = \left(R_L + R_G \right)^{-1} = \left(K_L^{-1} + K_G^{-1} \right)^{-1} \tag{3.30}$$

where:

- J_v = volatilization flux, g/day [M/T]
- k_v = volatilization rate, m/day [L/T]
- A_s = water surface area across which volatilization occurs, m^2 [L^2]
- f_{d1} = fraction of the total chemical in the water column associated with the dissolved phase [dimensionless]
- C_{T1} = total chemical concentration in the water column, mg/L = g/m^3 [M/L^3]
- C_a = atmospheric (gas phase) concentration of chemical, mg/L = g/m^3 [M/L^3]
- H = Henry's Law constant, atm/molar
- R = universal gas constant, atm/molar-K = 8.206×10^{-5}
- T = absolute temperature, K
- R_L = liquid phase resistance, day/m [T/L]
- R_G = gas phase resistance, day/m [T/L]
- K_L = liquid phase transfer coefficient (conductivity), m/day [L/T]
- K_G = gas phase transfer coefficient (conductivity), m/day [L/T]

The liquid and gas phase transfer coefficients determine the overall volatilization rate. Numerous relationships exist to describe these coefficients. For the liquid phase, the modified O'Connor-Dobbins relationship was used. For the gas phase, the O'Connor/Rathbun relationship was used.

$$K_L = \left(\frac{D_{wO_2} U}{D} \right)^{0.5} \left(\frac{MW_{O_2}}{MW_C} \right)^{0.5} 8.64\text{x}10^4 \tag{3.31}$$

$$K_G = \left[0.001 \left(\frac{1}{Sc_a} \right)^{0.667} W_{10} \right] 8.64\text{x}10^4 \tag{3.32}$$

where:

- $D_{w_{O_2}}$ = diffusivity of oxygen in water, cm^2/s [L^2/T]
- U = water velocity, cm/s [L/T]

D	=	water depth, cm [L]
MW_{O_2}	=	molecular weight of oxygen (diatomic), g/mol = 32
MW_C	=	molecular weight of chemical, g/mol ≈ 295 for PCBs
S_{c_a}	=	Schmidt Number for air = ν_a / D_a [dimensionless]
ν_w	=	viscosity of air, cm^2/sec [L^2/T]
D_a	=	diffusivity of air, cm^2/s [L^2/T]
W_{10}	=	wind speed 10 m above water surface, m/s [L/T]

In the wLFRM, PCB volatilization parameters were based on values reported in the literature. For simplicity, the atmospheric concentration of PCBs was assumed to be zero. The potential for increased volatile losses as a consequence of increased aeration at dams was also assumed to be negligible.[11] The Henry's Law constant was computed as a function of temperature according to the method described by Tateya et al. (1988):

$$\ln H = 18.53 - \frac{7868}{T + 273.15} \tag{3.33}$$

The molecular weight of PCBs was assumed to be 295 based on a broad average of the molecular weight of individual PCB congeners. Wind speeds reported at the Green Bay airport were used to represent 10-meter wind speeds. Wind speed data for the year 1989 were repeated for all years of short-term and long-term simulations. Temperature observations collected during the GBMBS for the year 1989 were also used and repeated for all years of each simulation.

3.6.5.4 Sediment-Water Exchange of Dissolved and DOC-bound Phase PCBs

PCBs associated with dissolved and DOC-bound phases in the water and sediment are mobile and can exchange between the water column and sediment bed as well as within the sediment bed. Fine scale flows such as pore water exfiltration, molecular diffusion, biologically enhanced diffusion, and other factors may contribute to this exchange. For simplicity, this type of exchange can be represented as a gradient-driven diffusion process:

$$J_f = k_f A_s \left[(f_{d2} + f_{b2}) C_{T2} - (f_{d1} + f_{b1}) C_{T1} \right] \tag{3.34}$$

where:	J_f	=	sediment diffusive flux, g/day [M/T]
	k_f	=	sediment diffusion rate, m/day [L/T]
	A_s	=	water surface area across which diffusion occurs, m^2 [L^2]

[11] These assumptions were also made in the development of the Upper Hudson River PCB model (QEA, 1999). For further detail regarding the appropriateness of these assumptions, see the discussion by QEA (1999).

f_{d1}	=	fraction of the total chemical in the water column associated with the dissolved phase [dimensionless]
f_{b1}	=	fraction of the total chemical in the water column associated with the DOC-bound phase [dimensionless]
C_{T1}	=	total chemical concentration in the water column, mg/L = g/m^3 [M/L^3]
f_{d2}	=	fraction of the total chemical in the sediment associated with the dissolved phase [dimensionless]
f_{b2}	=	fraction of the total chemical in the sediment associated with the DOC-bound phase [dimensionless]
C_{T2}	=	total chemical concentration in the sediment, mg/L = g/m^3 [M/L^3]

In the wLFRM, sediment diffusion coefficient value of approximately 3.5 cm/day was selected. It should be noted that field data to directly estimate a sediment diffusion coefficient for the Lower Fox River, such as sediment pore water dissolved and bound PCB concentrations, do not exist. In the absence of site-specific data, the coefficient value was based on consideration of the site-specific sediment diffusion information for the Hudson River presented by QEA (1999). The assumed sediment diffusion coefficient value for the Lower Fox River is similar to the estimated value for the Hudson River.

3.6.5.5 *Sediment Mixing of Particulate Phase PCBs*

As noted in Section 3.5.6.5, near the sediment-water interface bioturbation and flow events can disturb the sediments and cause the exchange of particles and associated contaminants between layers within the sediment column. Radioisotope tracer studies of Lower Fox River sediments revealed that rapid sediment mixing occurs through depths of 10 cm as determined by the presence of Beryllium-7 (Fitzgerald et al. 2001). Periodic mixing through deeper sediment strata resulting from flow disturbances may also occur as described in TM2g (WDNR, 1999c). The mixing flux of PCBs between sediment layers can be described as:

$$J_E = E_M A_s \left[\left(\sum_{n=1}^{3} f_{p2_n} \right) C_{T2} - \left(\sum_{n=1}^{3} f_{p2_{i\,n}} \right) C_{T2i} \right] \tag{3.35}$$

where:			
	J_E	=	sediment diffusive flux, g/day [M/T]
	E_M	=	sediment diffusion rate, m/day [L/T]
	A_s	=	water surface area across which diffusion occurs, m^2 [L^2]
	n	=	particle type index = 1, 2, or 3
	i	=	index indicating an adjacent sediment layer
	f_{p2_n}	=	fraction of the total chemical in particulate phase associated with particle type "*n*" in the sediment [dimensionless]

f_{p2n_i}	=	fraction of the total chemical in particulate phase associated with particle type "*n*" in an adjacent layer of the sediment column [dimensionless]
C_{T2}	=	total chemical concentration in the sediment, mg/L = g/m^3 [M/L^3]
C_{T2_i}	=	total chemical concentration in an adjacent layer of the sediment column, mg/L = g/m^3 [M/L^3]

In the wLFRM, sediment mixing coefficients were specified to account for biological and flow induced particle exchange. As noted in Section 3.5.6.5, the mixing coefficient was set to a value of 1.0 x 10^{-10} m^2/s for the spring, summer and fall months and set to zero for the winter months. Mixing was specified between the top three layers. Mixing between layers 1 and 2 is more rapid than mixing between layers 2 and 3. Given the specified mixing coefficient, the volumes of the sediment layers, and mixing lengths, this equates to a complete mixing time of 2-4 years for layers 1 and 2 and 25-40 years for layers 2 and 3.

3.6.5.6 Biodegradation of PCBs

Under field conditions typical of the Lower Fox River, biodegradation of PCBs is not expected to be significant. In an extensive field and laboratory study of Lower Fox River sediment, no evidence of microbially mediated degradation of PCBs was found where PCB concentrations were less than 30 mg/kg (McLaughlin, 1994). Based on these findings, the biodegradation rate of PCBs was zero in the wLFRM.

3.7 MODEL FEATURE AND PARAMETERIZATION SUMMARY

The development history, general structure, and parameterization of the wLFRM were described in Sections 3.1 through 3.6. For convenience, a wLFRM feature and parameterization summary is presented in Table 3-7. More detailed descriptions of the mathematical formulations for all mass transport and transfer processes as implemented in the IPX 2.7.4 framework are presented in Velleux et al. (2000).

Table 3-7. Model feature and parameterization summary.

Feature	***Value***	***Basis***
Spatial Domain	39 Miles (Whole River)	Upstream PCB boundary condition is zero; Steuer et al (1995), Velleux and Endicott (1994); WDNR (1997); AGI recommendation
Temporal Domain	1989-1995 (calibration) 100 years (long-term forecast)	TM1 (LTI and WDNR, 1998); period of greatest data availability for calibration
State Variables	3 solids types Total PCBs	Multiple particle types needed to represent transport of different particles; TM2d (WDNR, 1999a); AGI recommendation
Total Segments	535	Steuer et al (1995), Velleux and Endicott (1994); WDNR (1997)
Water Segments	40	Steuer et al (1995), Velleux and Endicott (1994); WDNR (1997)
Surface Sediment Segments	165 (deposits, interdeposits, SMUs)	GBMBS and other field data; WDNR (1997); TM2e (WDNR, 1999b)
Subsurface Sediment Segments	330 (remaining sediment in "deep layers")	Two layers under each surface segment to permit description of sediment mixing; radioisotope tracer study (Fitzgerald et al. 2001); TM2g (WDNR, 1999c)
Framework	Semi-Lagrangian bed submodel	Avoid mixing in deep sediments; AGI recommendation
Sediment Layers (nominal thickness)	0-5 cm, 5-10 cm, 10-30 cm, 30-50 cm, 50-100 cm, 100-150 cm, 150-200 cm, 200-250 cm, 250-300 cm, 300+ cm	TM2e (WDNR, 1999b); radioisotope tracer study (Fitzgerald et al. 2001) results help define 5 cm surface layer thickness
Flow	Average: 146 m^3/s Range: 29.5 to 667 m^3/s	Observed flow at Rapide Croche extrapolated to include downstream inputs; TM2a (FWB2000, 1998); TM3a (WDNR, 2001a)
Upstream Boundary Loads	Solids: 68,000 MT/year PCBs: 0	Measurements at Lake Winnebago (1986-90); Gustin (1995); Steuer et al (1995); TM3a (WDNR, 2001a)
Watershed Loads	Solids: 54,000 MT/year PCBs: 7.5 kg/year	TM2a (FWB2000, 1998); TM2b (LTI, 1999a), TM3a (WDNR, 2001a)
Internal Loads	Solids: 20,000 MT/year PCBs: not applicable	TM2c (LTI, 1999b)
Point Source Loads	Solids: 4,000 MT/year PCBs: 12.25 kg/year	TM2d (WDNR, 1999a)
Initial Conditions	sand, silt, clay, bulk density, organic carbon, PCBs	TM2e (WDNR, 1999b)
Water Velocity	$U_{ij} = F_{LSij}(a\ Q^b)$	TM5c (HQI, 2000), TM5b (Baird, 2000a)

Table 3-7 (continued). Model feature and parameterization summary.

Feature	***Value***	***Basis***
Shear Stress	$\tau = C_f \rho U^2$ $C_f \approx 0.003$	TM5c (HQI, 2000), TM5b (Baird, 2000a)
Coarse Settling	$V_s = 470$ m/day $\tau_{cd} = 0.80$ dynes/cm^2	Gessler (1967); Cheng (1997); force balance
Medium Settling	$V_s = 2.9\text{-}4.3$ m/day $\tau_{cd} = 0.15$ dynes/cm^2	Partheniades (1992); Burban (1990); Chapra (1997)
Fine Settling	$V_s = 0.1$ m/day $\tau_{cd} = 0.10$ dynes/cm^2	Partheniades (1992); Wetzel (1983); Chapra (1997)
Event Resuspension	Epsilon Equation V_r varies as a function of τ $\tau_c = 1$ dyne/cm^2 $a_0 = 0.75 - 1.5 \times 10^{-3}$ $m = 2.3$ $Z = 1.74$	Lick et al. (1995); TM5b (Baird, 2000a); TM5d (Baird, 2000b); Gailani et al. (1991)
"Background" Resuspension	In form of Epsilon Equation V_{rb} varies as a function of τ Average: $V_{rb} \approx 0.7$ cm/year	interpretation of "fluff" layer resuspension as described by Gailani et al. (1991)
Partitioning	$K_{oc} = 10^{6.3}$ $\nu_x = 9$	GBMBS field data; Velleux and Endicott (1994)
Volatilization	$\ln K_H = 18.53 - 7868/T$ K_L = modified O'Connor-Dobbins K_G = O'Connor/Rathbun	Tateya et al. (1988); Velleux and Endicott (1994)
Sediment Diffusion	$K_f = 2 \times 10^{-8}$ m^2/s (≈ 3.5 cm/day)	After QEA (1999)
Sediment Mixing	$E_M = 1 \times 10^{-10}$ m^2/s	Interpretation of field data; TM2g (WDNR, 1999c)
PCB Biodegradation	$k_B = 0$	McLaughlin (1994)

4.0 MODEL CALIBRATION RESULTS AND EVALUATION

4.1 MODEL EVALUATION METRICS AND QUALITY CRITERIA

Model evaluation metrics are comparative standards used to assess model performance. Model quality criteria express the idealized level of correspondence between model results and observations. The metrics and quality criteria for this assessment are described in TM1 (LTI and WDNR, 1998). These metrics and criteria were developed jointly by the FRG and WDNR as part of MEW efforts to facilitate comparison of model results (output) and specific types of observations. The relative difference between model results and observations quantifies model performance and provides an indication of overall model quality.

The metrics identified in TM1 fall into four general categories as shown in Table 4-1. These types of metrics can be used to assess the quality of model results for the water column and sediments and can be applied to solids or chemicals. Time series metrics are useful for comparing the trends and magnitudes of results and observations over time at one location. Frequency distribution metrics are useful for comparing statistical properties. Point-in-time and cumulative performance metrics are useful for comparisons over many locations at one point in time or for a specified time period. Specific condition metrics are useful for comparisons as functions of specific conditions such as high flow periods or a particular time of year. Detailed descriptions of these metrics are presented in TM1 (LTI and WDNR, 1998). The model quality criteria identified in TM1 was that the mean value of model results for solids and PCBs should be within ±30% of observed values in the water column and sediments. Discussion of these model quality criteria is also presented in TM1 (LTI and WDNR, 1998).

Table 4-1. TM1 general categories of model evaluation metrics.

Metric Category	***Media***	***Application***	***Use***
Time Series	water	solids, PCBs	Trend and magnitude over time at one location
Frequency Distributions	water, sediment	solids, PCBs	Statistical properties
Point-in-Time/Cumulative Performance: *End of period mass balance* *Sediment bed elevation change* *Net burial rate (sediment trap efficiency)*	 water, sediment sediment sediment	 PCBs solids solids	Trend and magnitude over many locations at one time or specified time periods
Specific Condition Performance[12]	water	solids, PCBs	Trend and magnitude as functions of river conditions such as flow, time of year, etc.

[12] In TM1, this metric category was described as event and non-event concentration and flux comparisons.

4.2 DATA TO DEFINE MODEL EVALUATION METRICS

The general categories of metrics and criteria were intended to provide an ordered, yet flexible, set of tools to evaluate model performance. The basis for these evaluations is the difference between model results and observations. Successful application of these metrics therefore depends on the extent of data to make comparisons as well as the degree to which the data accurately depict river conditions. A description of data to define model evaluation metrics for the water column and sediments are presented in the sections that follow.

4.2.1 Data for Water Column Metrics

Extensive data for time series and frequency distribution comparisons of water column solids and PCB concentrations were collected during the GBMBS and LMMBS. These data are available for several monitoring locations: Appleton, Kaukauna, Little Rapids, DePere, and the river mouth. Data for the Appleton, Kaukauna, Little Rapids, and DePere monitoring stations collected during the 1989-1990 GBMBS period were presented by Steuer et al. (1995). Data for the river mouth monitoring station for the 1989-1990 GBMBS and 1994-1995 LMMBS periods as presented by Velleux and Endicott (1994) and WDNR (1997). Frequency distributions were also computed for these data as presented by WDNR (1997).

Data to develop specific condition metrics were more limited. One intent of this type of metric was to provide model performance evaluations for high flow conditions. However, relatively few water column solids or PCB concentration observations were collected during high flow periods. So, rather than limiting evaluations to specific conditions where few data exist, data for the full range of river conditions were aggregated. For example, rather than limiting comparisons to conditions with flows greater than some threshold value (such as 300 m^3/s), all water column particulate PCB concentrations were examined as a function of the flows for which all data were collected. This approach makes the greatest use of the available data and permits at least some exploration of model performance for high flow conditions.

4.2.2 Data for Sediment Metrics

Large numbers of individual observations of various sediment bed conditions of the Lower Fox River exist. By direct observation or inference, these data permit assessments of sediment bed elevation changes, net burial rates, as well as possible spatial and temporal trends in sediment PCB concentrations. Sediment trap efficiency estimates can be developed from using empirical approaches and can be used to infer net burial rates.

4.2.2.1 Sediment Bed Elevation Changes and Net Burial Rates

Sediment bed elevation dynamics were examined as part of TM2g (WDNR, 1999c). In that effort, hydrographic surveys of the Lower Fox River conducted by the USACE, USEPA, and USGS were reviewed to describe sediment bed elevations at selected locations along the river for the period 1977 to 1998. Most of these data were collected downstream of the DePere dam in the last 15 kilometers (seven miles) of the river. Sediment bed elevation changes are observed in both cross-channel and downstream profiles. Short-term (annual and sub-annual) average net sediment bed elevation changes at individual locations range from a decrease of 28 cm to an increase of 36 cm. Long-term (several years) average net elevation changes at individual locations range from a decrease of more than 100 cm to an increase of nearly 45 cm. These average changes are well-supported by sediment volume calculations performed by the USACE as part of pre- and post-dredge hydrographic surveys as well as results of the USGS surveys performed at intermediate time scales (8 months to 45 months). Average bed elevation changes over time for the selected long-term (USACE) cross-channel range lines presented in TM2g (WDNR, 1999c) range from -5.5 to + 5.4 cm/year (see TM2g, Table 7). These results document that dramatic changes in sediment bed elevations can occur as the bed of the Lower Fox River is continuously reshaped by the wide range of flows and loads the river experiences.

As a follow-up to TM2g, data for three recent hydrographic surveys completed by the USACE were further examined to determine the extent of bed elevation changes. Data for the 1997, 1998, and 1999 surveys were available in a form that permitted calculation of bed elevation changes for all locations surveyed (rather than only at selected locations as shown in TM2g). These results were examined for the portion of the navigation channel from the DePere to Fort James (Georgia Pacific) turning basins as presented in Figure 4-1. This portion of the channel has not been dredged since the 1960s. Therefore changes in bed elevations reflect the natural channel-forming dynamics of the river. Survey results detailing sediment bed elevation changes between the 1997 and 1998, the 1998 and 1999, and the 1997 and 1999 surveys are presented in Figures 4-2, 4-3, and 4-4, respectively. These data were collected at transect lines positioned every 30 meters (100 feet) along the channel. As reported by the USACE, these surveys provide more than 25,000 individual bed elevation observations for this portion of the channel. Note that a net sediment gain or loss ("burial") rate for a given time period may be estimated from sediment bed elevation change data as the net elevation change over the time between surveys. A summary of results is presented in Table 4-2. These results again document that dramatic changes in sediment bed elevations can occur as the bed of the Lower Fox River is continuously reshaped by the wide range of flows and loads the river experiences. These results also document that (at least for the 1997-1999 surveys): 1) the net burial rate over this time period for this portion of the river is very low, approximately 0.35 cm/year (i.e., 0.7 cm over two years); and 2) gross changes in bed elevation at any individual point can differ widely from the net change in elevation in terms of both magnitude and direction.

Table 4-2. Lower Fox River sediment bed elevation changes, DePere to Fort James (Georgia Pacific) turning basins: 1997-1999.

Survey Years	*Minimum (Maximum decrease at a single point) (cm)*	*Maximum (Maximum increase at a single point) (cm)*	*Mean (Average change over all points) (cm)*	*Volume Change (Cumulative over all points) (m^3)*
97-98	- 174	+ 131	+ 6.3	+ 43,717
98-99	- 115	+ 270	- 5.6	- 38,986
97-99	- 209	+ 226	+ 0.7	+ 4,981

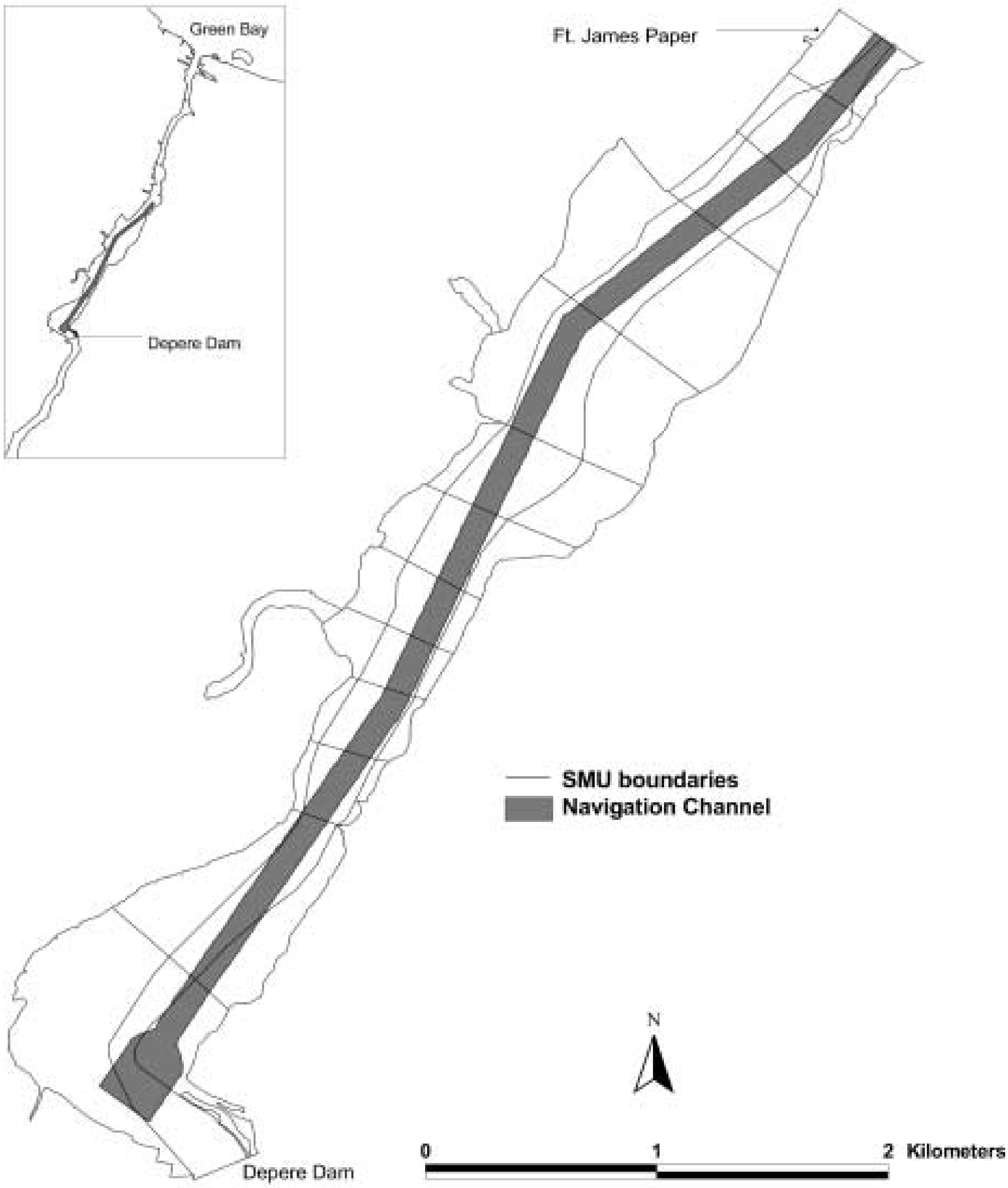

Figure 4—1. Location of USACE hydrographic survey study area: 1997-1999.

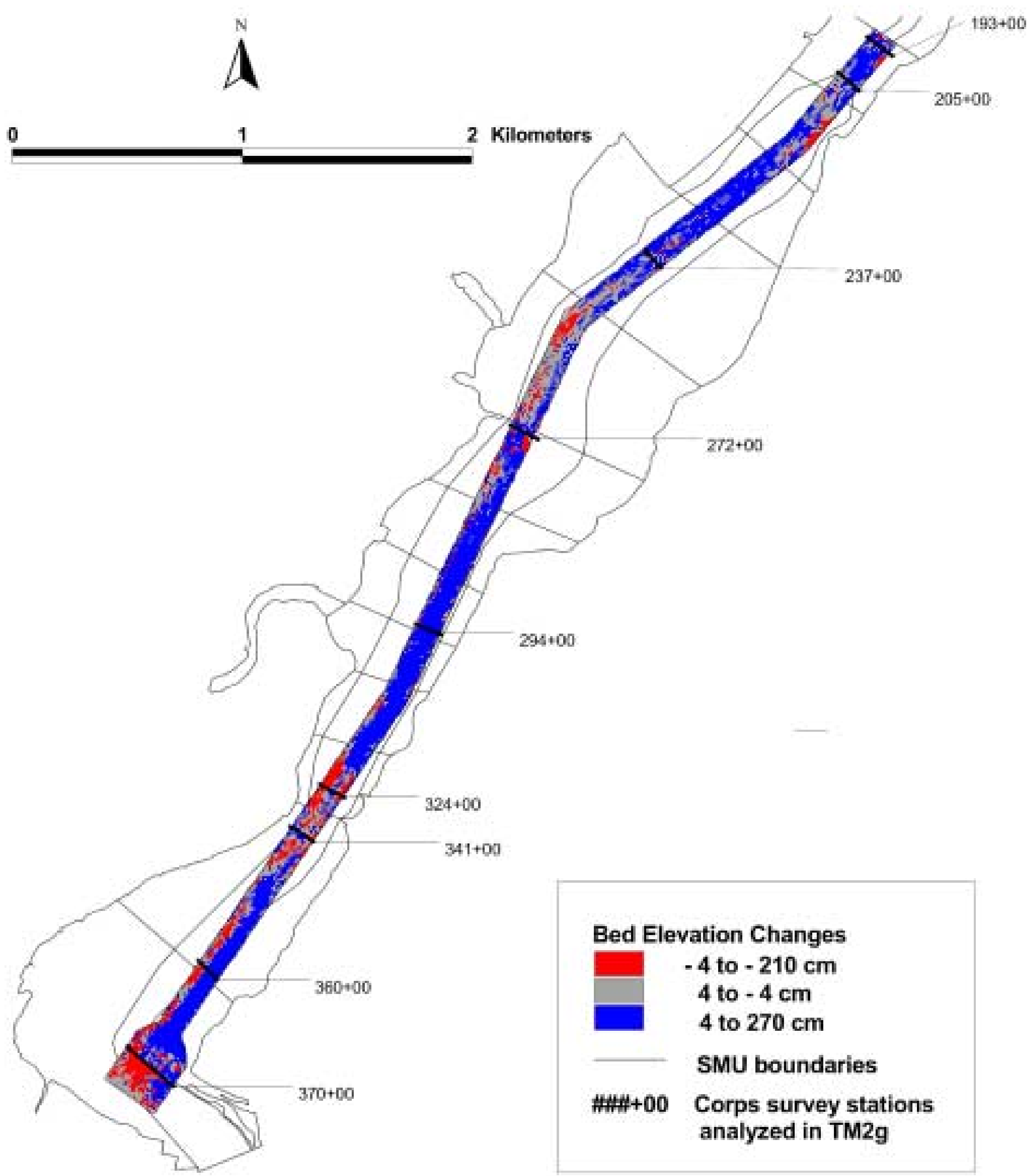

Figure 4—2. Lower Fox River sediment bed elevation changes: difference between 1997 and 1998 USACE hydrographic survey results.

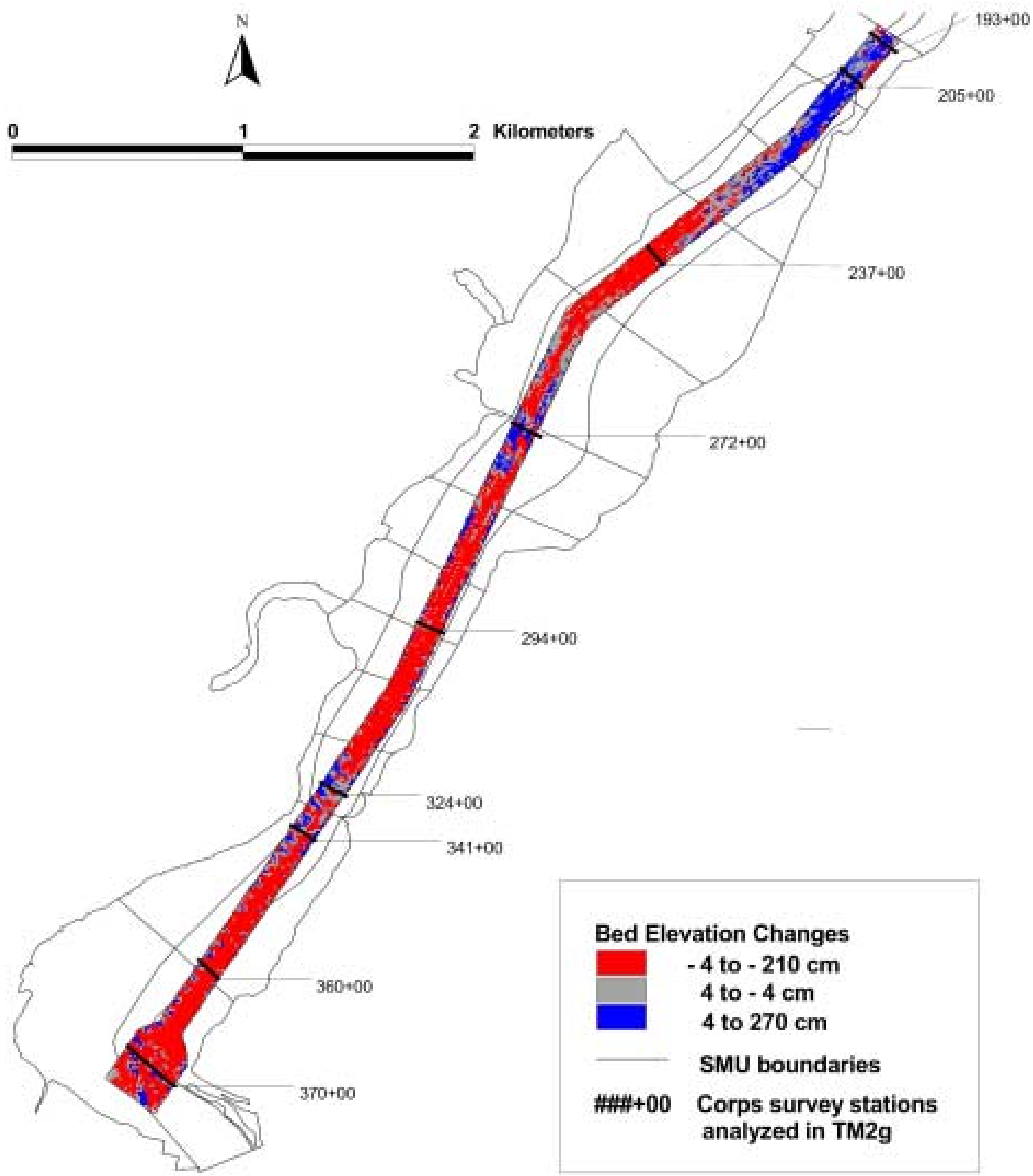

Figure 4—3. Lower Fox River sediment bed elevation changes: difference between 1998 and 1999 USACE hydrographic survey results.

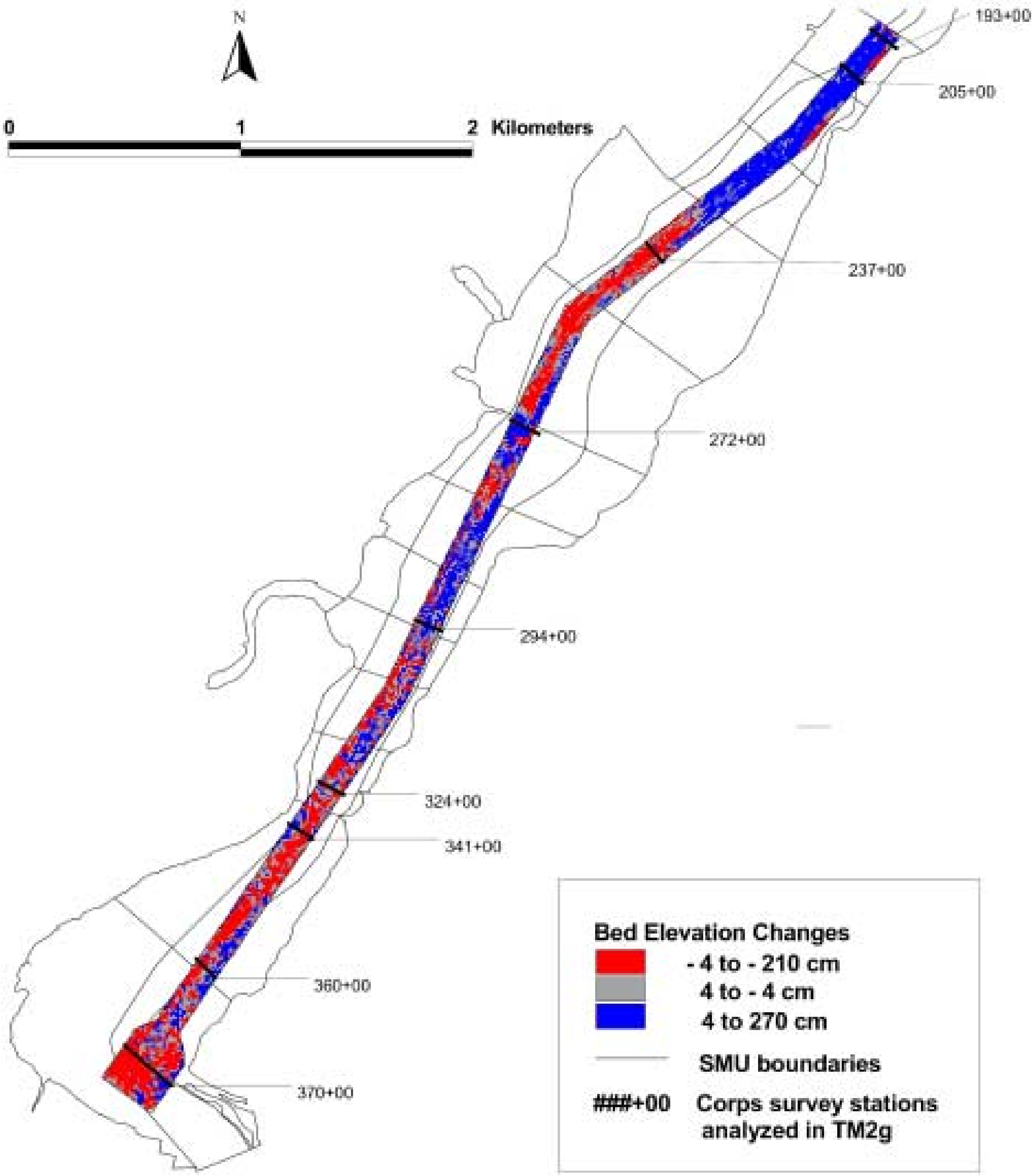

Figure 4—4. Lower Fox River sediment bed elevation changes: difference between 1997 and 1999 USACE hydrographic survey results.

Net burial rates may also be inferred by extrapolating net elevation changes between transects. Using this approach, separate estimates of net burial rates may be developed from the USACE, USEPA, and USGS sediment bed elevation data described in TM2g (WDNR, 1999c). However, such inferences may not accurately represent bed conditions. As documented by the results of TM2g and follow-up efforts, sediment bed elevations show tremendous station-to-station variability. Extrapolation between distant stations neglects this variability. Consequently, net burial rates inferred by this approach are highly uncertain and may be inaccurate. For example, between 1997 and 1998, the net burial rate for Station 324+00 was -1 cm/year as presented in TM2g (WDNR, 1999c). When all observations within ±61 meters (±200 feet) of this station are also considered, the net burial rate is -2.1 cm/year. Similarly, as extrapolated from the results for the nine stations presented in TM2g (Stations 370+00 through 193+00) the average net burial rate between 1997 and 1998 for the navigation channel between the DePere and Fort James (Georgia Pacific) turning basins is +3 cm/year. When all observations for the channel during this period are considered, the net burial rate is approximately +6 cm/year. Therefore, the accuracy of a net burial rate inference will directly depend on the spatial variability of bed elevations between the transects from which the inference was made.

As with any estimate or inference, it is important to note the limitations of the approach used. Note that net burial rate inferences may be either positive (elevation gain) or negative (elevation loss). In either case, a net change in elevation for a given area during some time interval does not necessarily indicate that sediments move by erosion or deposition. Other processes such as bed load and slumping may cause large quantities of sediments to move over time. Also note that net burial rates are highly variable over time. Further, a rate inferred for one time period may not be representative of conditions at that location for a different time.

It is also worth noting that, in concept, dredging records and the depths of occurrence of PCBs, Cesium-137 (Cs-137), and Beryllium-7 (Be-7) in the sediment column may also be used to infer net burial rates. However, such inferences can be inaccurate. For example, dredging is limited to those areas where bed elevation increases impede ship traffic; the volume of sediment lost from areas where bed elevation decreases occur is not included in dredged sediment volume estimates. As a consequence, net burial rates inferred from dredging records can significantly overestimate natural rates. The difficulties with inferring net burial rates from radioisotope and contaminant profiles are also significant. For example, changes in the magnitude and characteristics of point source loads over time strongly affect interpretation of PCB profiles. Further, repeated sediment disturbances (gross bed elevation losses and gains) can mix radioisotope and contaminant profiles to considerable depths in the sediment column. Such disturbances, documented in TM2g (WDNR, 1999c), can render radioisotope profiles uninterpretable.

Considering the possible limitations of these different data types and the difficulties associated with comparing observations and model results on similar spatial and temporal scales, the USACE sediment bed elevation data were considered the most appropriate and reliable basis for assessing model performance. The USEPA bed elevation data were considered to be the next most reliable data type. Dredging records, radioisotope activity profiles, and contaminant concentration profiles were considered to be less appropriate for model evaluation and potentially unreliable. Data limitations and the difficulties with comparing observations and model results are further discussed in Section 4.4.

4.2.2.2 Spatial and Temporal PCB Concentration Trends in Surface Sediments

Accurate quantification of spatial and temporal PCB concentration trends in Lower Fox River sediments is complex. The PCB concentration data for river sediments presented in TM2e (WDNR, 1999b) were collected as part of many different efforts between 1989-1997. It is important to recognize that none of these sampling efforts were specifically designed to estimate PCB trends over time. Sediment cores from each sampling effort were collected at different horizontal and vertical locations, different times, and often using different analytical techniques and quantitation standards. Differences attributable to spatial heterogeneity, temporal variability, and analytical bias confound direct analysis and makes clear identification of possible trends challenging. The nature and influence of these confounding factors must be considered when estimating the scale of possible PCB concentration trends. A description of efforts to infer PCB concentration trends in Lower Fox River surface sediments (0-10 cm) is presented in Appendix B.

Regression analyses suggest that sediment PCB concentrations may vary with time and distance. Considering the river as a whole, the results suggest that concentrations increase with time and decrease with distance downstream of Lake Winnebago. On an individual reach basis, the results suggest that concentrations may increase or decrease with time. However, apparent concentration changes with time may be a reflection of shifting sampling locations over time. Differences in sample location may explain much of any apparent difference in PCB concentrations that may occur in a reach. The overall trend of decreasing concentration with distance is generally consistent with the discharge history of PCBs to the river presented in TM2d (WDNR, 1999a).

Analytical bias may significantly contribute to apparent PCB concentration differences. Based on inter-laboratory comparison studies, the estimate of analytical bias is ±30% (Grace Analytical, 1996; Kuehl, 1999). This means that on average approximately 30% of any difference in PCB concentrations between different data sets may be solely attributable to analytical bias. Additional biases attributable to different sample extraction methods can also occur.

Recognizing that there are numerous caveats, regression results may be used to infer PCB concentration trends. A summary of inferred surface sediment (0-10 cm) PCB concentration trends over time for different levels of analytical bias is presented in Table 4-3. The upper and lower 95% confidence limits (CL) express regression uncertainty and help bound apparent concentration trend estimates. It is important to note the limitations of these trend estimates. First, apparent trends over time may be the result of sediment PCB spatial heterogeneity due to shifting sample locations. This caveat is particularly important to note for the inferred trends of Reaches 1 and 2. Second, regression results describe little of the variability of the sediment PCB concentrations (as evidenced by very low correlation coefficients) and may not necessarily provide an accurate description of observed conditions. While applicable to the trends for all four reaches, this caveat is particularly important to note for the inferred trends of Reaches 3 and 4 since the slopes of the lines associated with those regression results were not significantly different than zero. Third, regression results do not establish causality or elucidate the processes that gave rise to observed conditions. Fourth, extrapolation of inferred trend estimates beyond the range of the observations (either spatially or temporally) may yield unreliable or spurious results.

Table 4-3. Inferred surface sediment (0-10 cm) PCB concentration trends over time.

Reach	*Inferred Rate of Change (%/year)*	*Rate at Lower 95% CL (%/year)*	*Rate at Upper 95% CL (%/year)*	*Notes*
1	-22.8 (-16.0 to -29.7)	-29.2 (-20.4 to -37.9)	-15.9 (-11.1 to -20.7)	Apparent trends may be attributable to shifts in sampling sites over time.
2	+41.8 (+29.3 to +54.4)	+22.2 (+15.4 to +28.9)	+64.4 (+45.2 to +84.0)	
3	-8.1 (-5.7 to -10.6)	-19.6 (-13.7 to -25.4)	+4.9 (+3.4 to+6.4)	Apparent trends may not be significantly different from zero.
4	0	-6.6 (-4.6 to -8.5)	+7.0 (+4.9 to +9.1)	
All	+5.6 (+3.9 to +7.3)	+0.8 (+0.6 to +1.1)	+10.6 (+7.4 to +13.8)	Significance of apparent trend unclear. Sampling efforts varied spatially and over time.

4.3 CALIBRATION SIMULATION RESULTS AND EVALUATION

The model calibration period was 1989-1995. Simulation results for this period were evaluated according to the metrics and criteria identified in TM1 (LTI and WDNR, 1998). The overall appropriateness of the model is judged by the level of agreement between the model metrics and simulation results. Evaluations for the water column and sediment are presented in the sections that follow.

4.3.1 Water Column

For the water column, observations exist to permit evaluation for time series, frequency distribution, point-in-time/cumulative performance, and specific condition metrics. Model performance assessments relative to these metrics for the five water column monitoring stations are presented in the sections that follow.

4.3.1.1 Time Series and Frequency Distribution Comparisons

Time series and frequency distribution comparisons of observations and model results were developed for each of the five river monitoring stations: Appleton, Kaukauna, Little Rapids, DePere, and the river mouth at Green Bay. At all five monitoring stations, water column solids and PCB observations exist for the 1989-90 GBMBS period. For the Appleton, Kaukauna, Little Rapids, and DePere stations, solids and PCB observations are also exist for four dates in 1992. For the Little Rapids, DePere, and river mouth stations, solids and PCB observations were collected on one date (several days after the peak of a high flow event) in 1993. Note that the 1993 samples used to represent the river mouth station were actually collected at Dutchman Creek and the Dousman Street Bridge. Although downstream of the DePere dam, these sites are located well upstream of the river mouth. Especially for PCBs, true concentrations at the river mouth could be much greater. For the river mouth station, observations also exist for the 1994-1995 LMMBS period. Comparisons for suspended solids are presented in Figures 4-5 through 4-

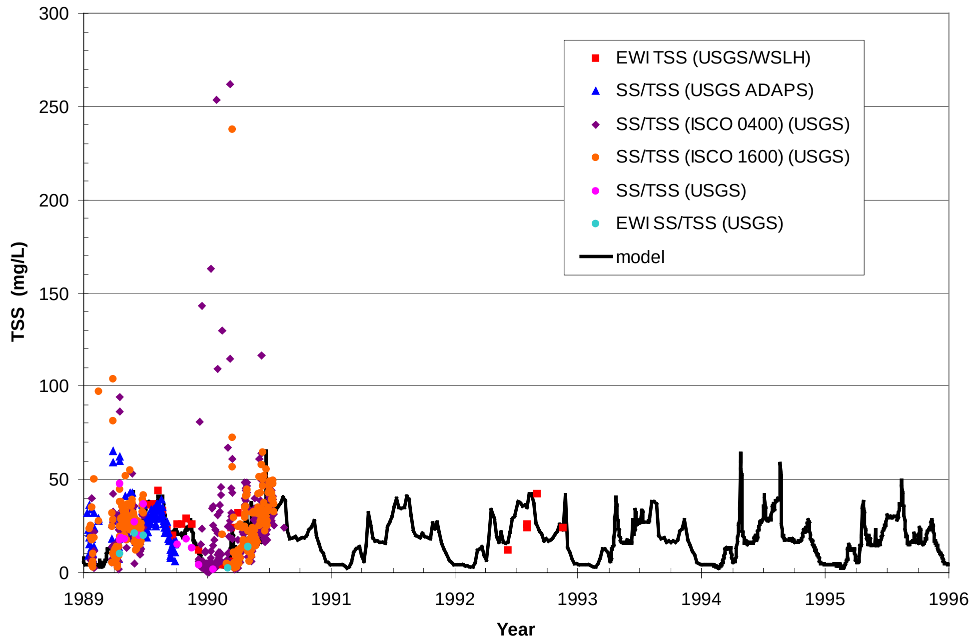

Figure 4—5. Time series of water column solids concentrations at Appleton: 1989-1995.

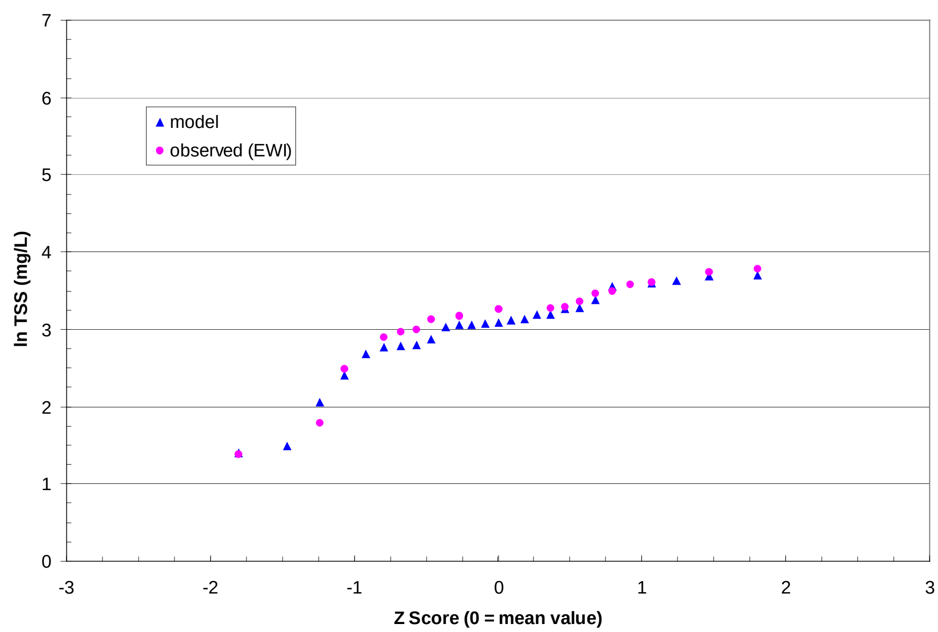

Figure 4—6. Frequency distributions of water column solids concentrations at Appleton: 1989-1995.

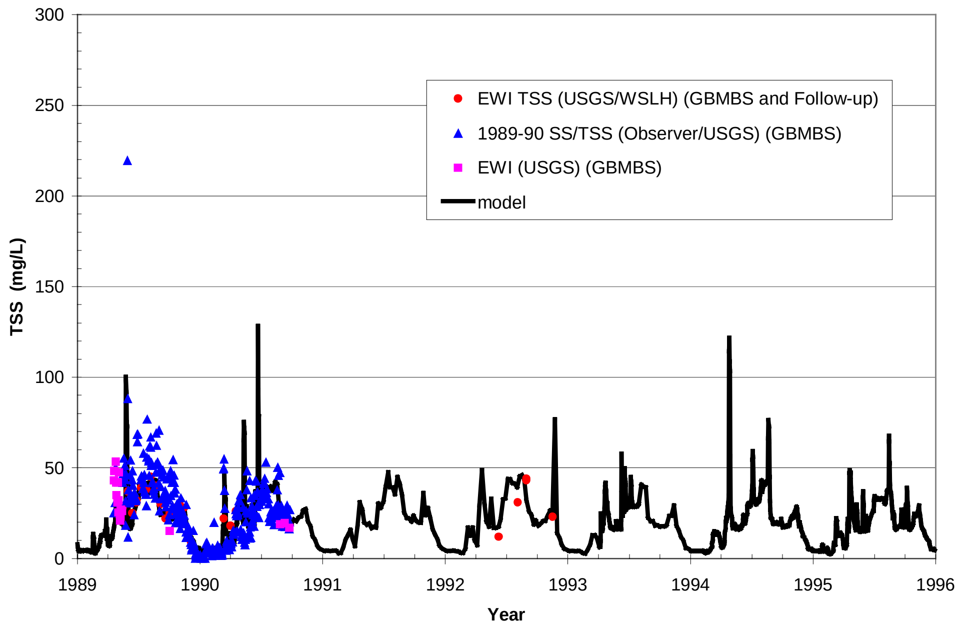

Figure 4—7. Time series of water column solids concentrations at Kaukauna: 1989-1995.

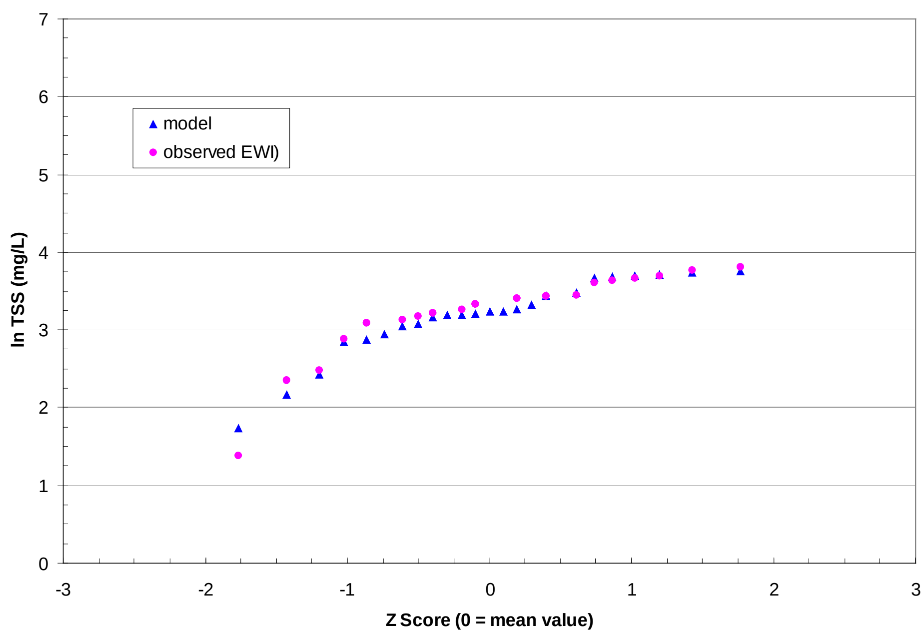

Figure 4—8. Frequency distributions of water column solids concentrations at Kaukauna: 1989-1995.

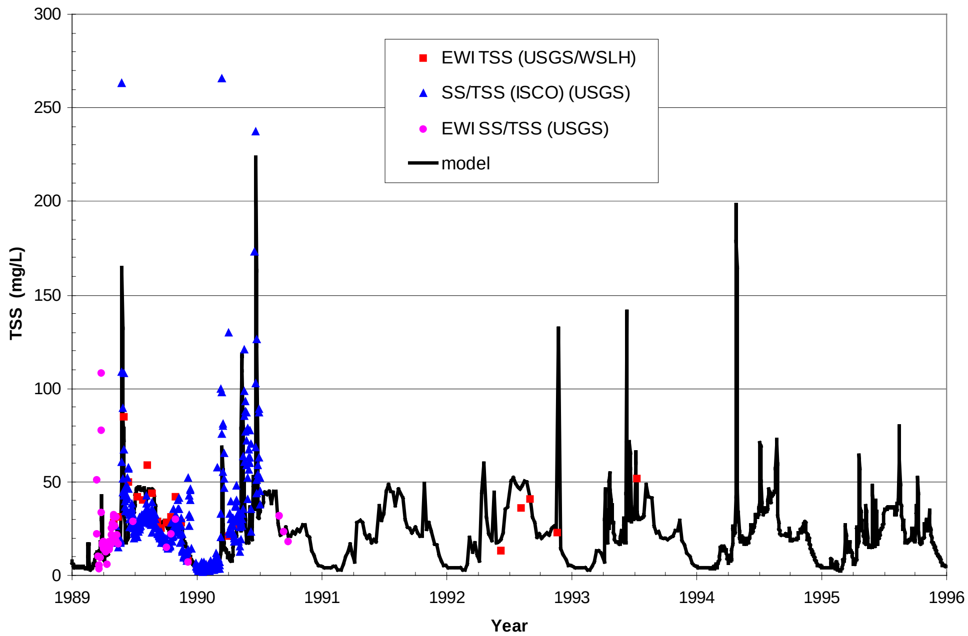

Figure 4—9. Time series of water column solids concentrations at Little Rapids: 1989-1995.

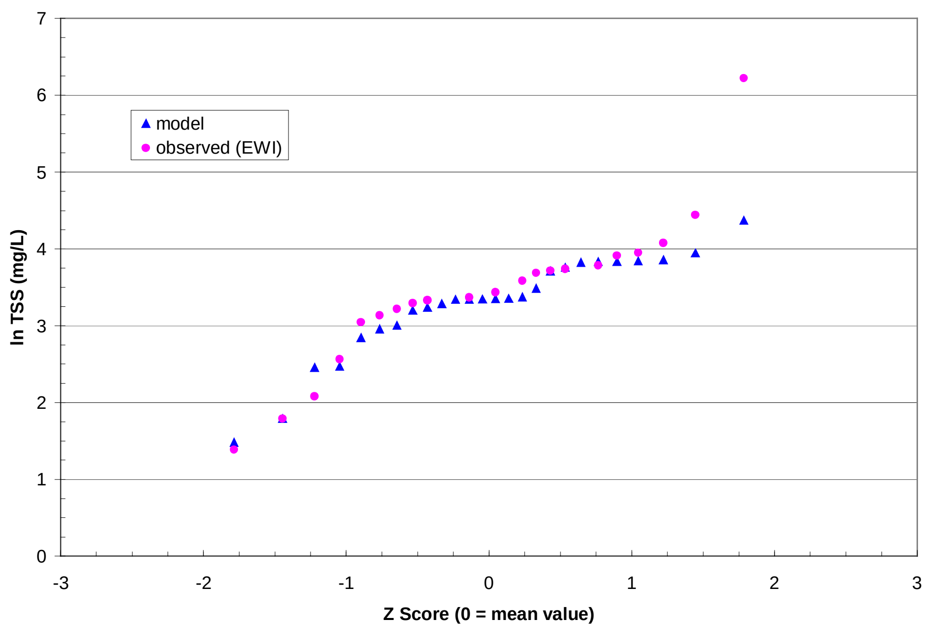

Figure 4—10. Frequency distributions of water column solids concentrations at Little Rapids: 1989-1995.

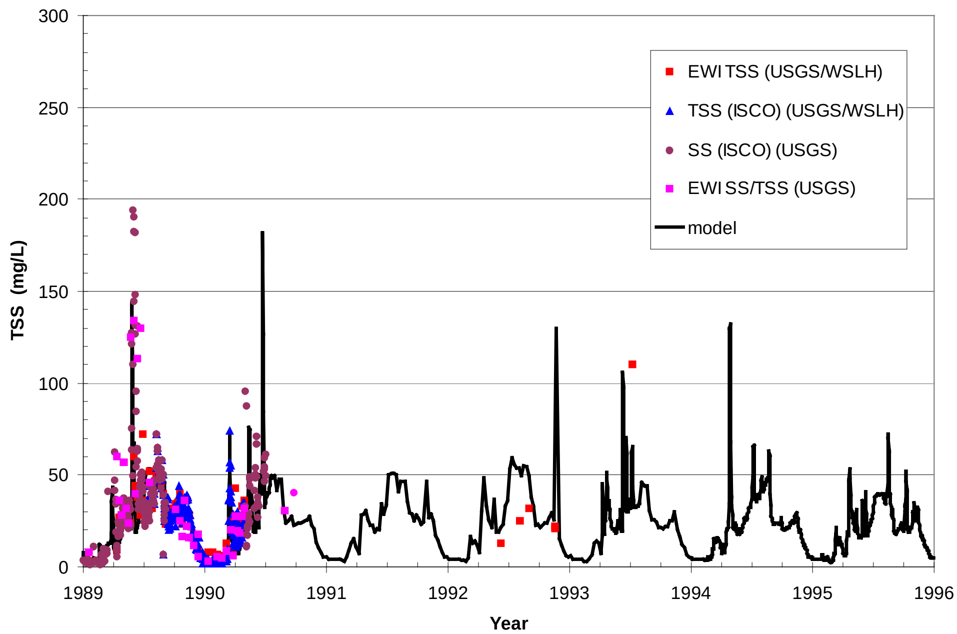

Figure 4—11. Time series of water column solids concentrations at Little Rapids: 1989-1995.

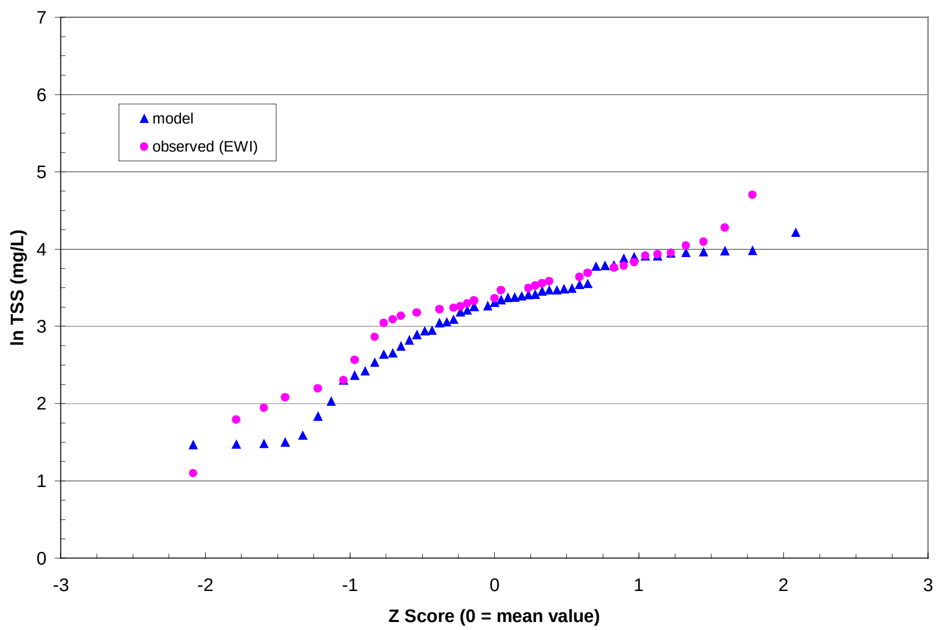

Figure 4—12. Frequency distributions of water column solids concentrations at DePere: 1989-1995.

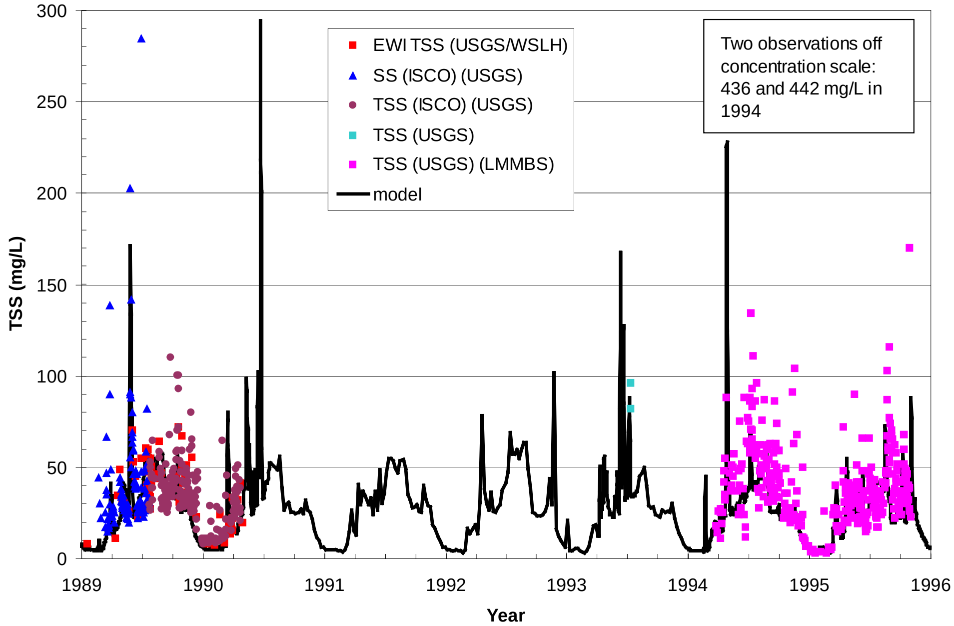

Figure 4—13. Time series of water column solids concentrations at the river mouth: 1989-1995.

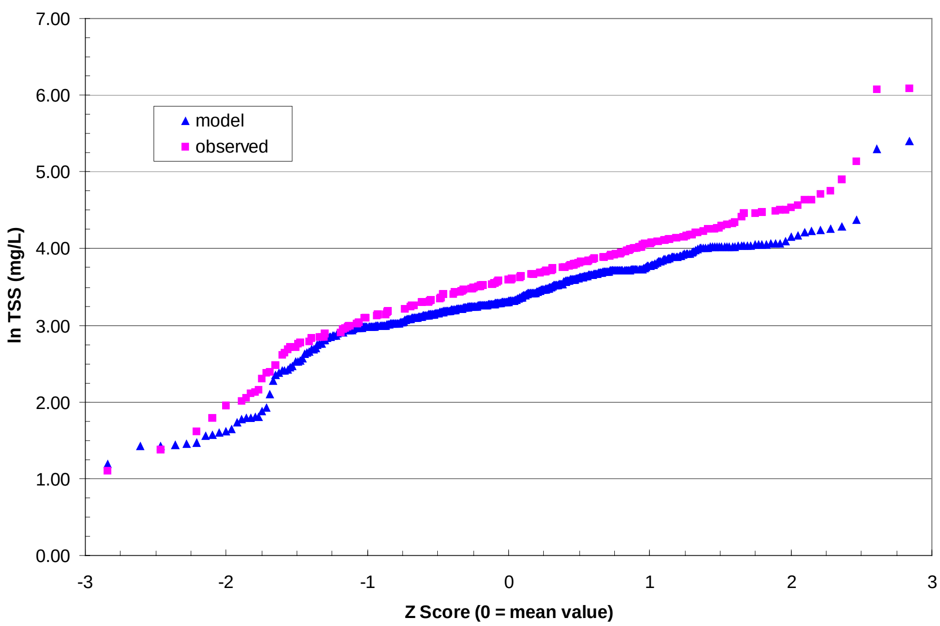

Figure 4—14. Frequency distributions of water column solids concentrations at the river mouth: 1989-1995.

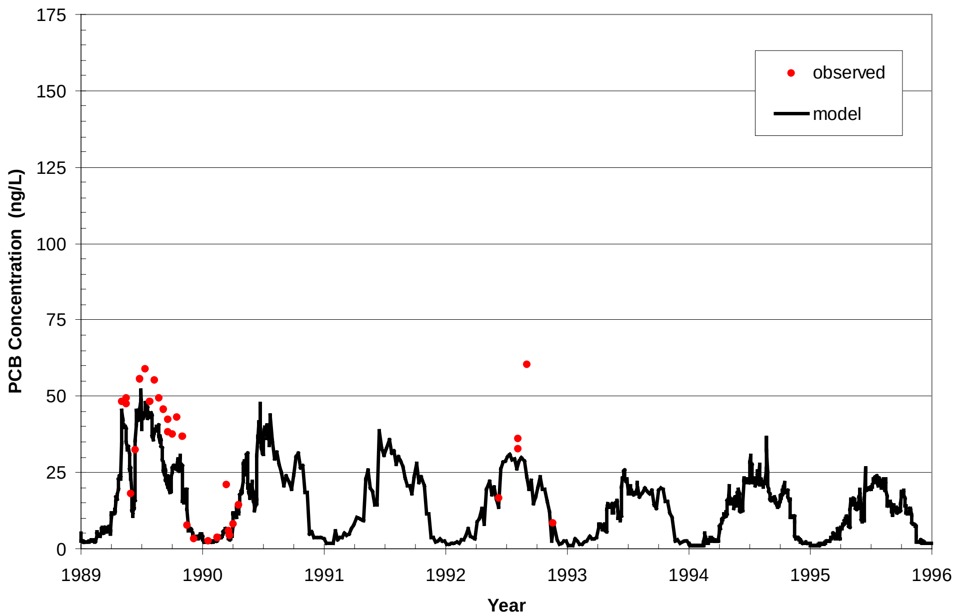

Figure 4—15. Time series of water column total PCB concentrations at Appleton: 1989-1995.

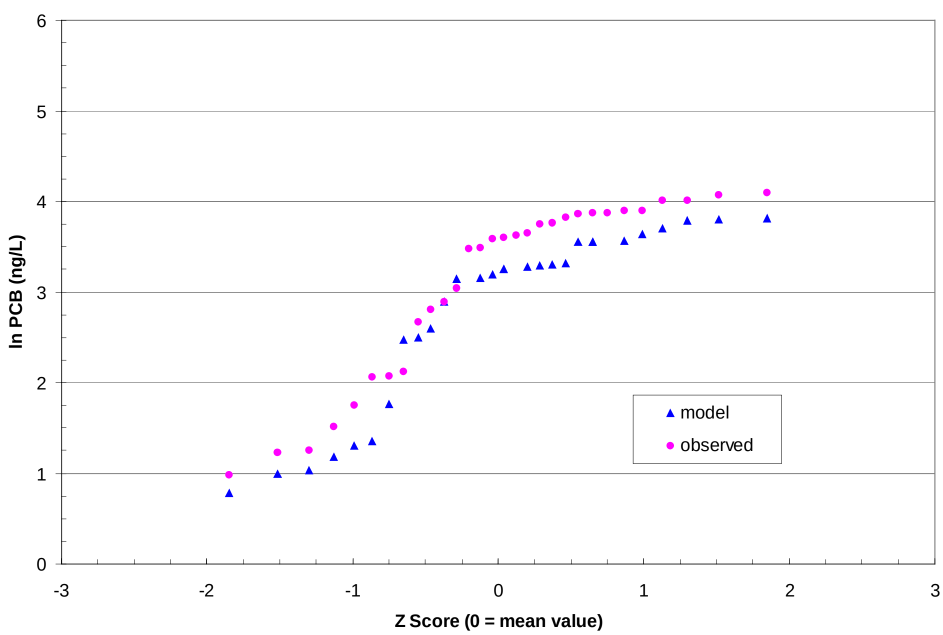

Figure 4—16. Frequency distributions of water column total PCB concentrations at Appleton: 1989-1995.

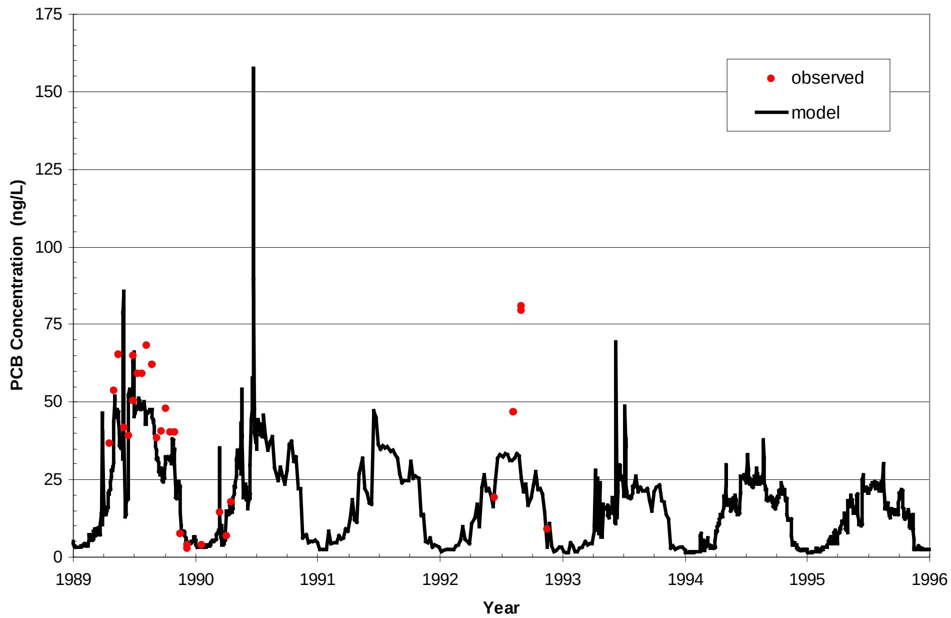

Figure 4—17. Time series of water column total PCB concentrations at Kaukauna: 1989-1995.

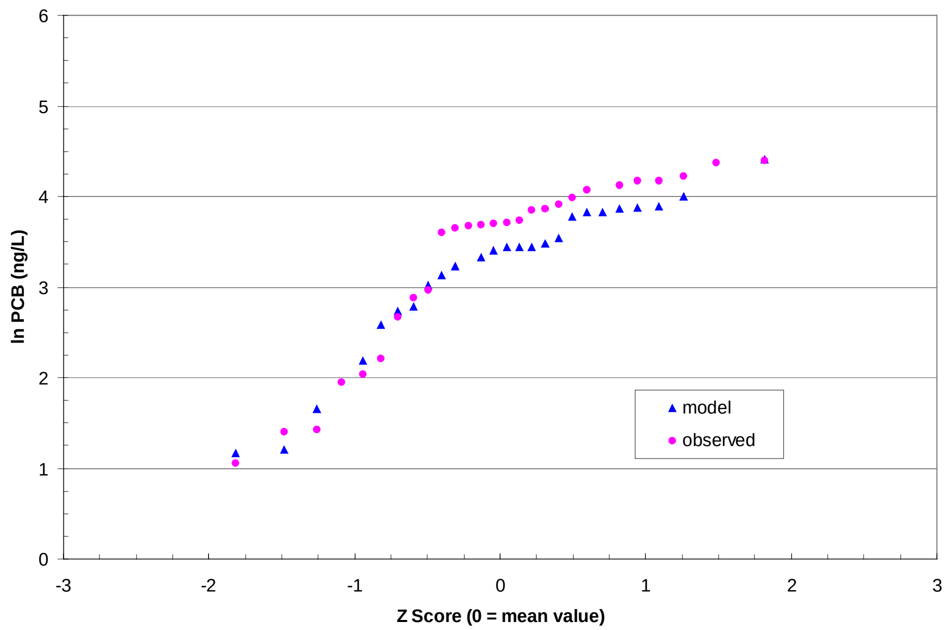

Figure 4—18. Frequency distributions of water column total PCB concentrations at Kaukauna: 1989-1995.

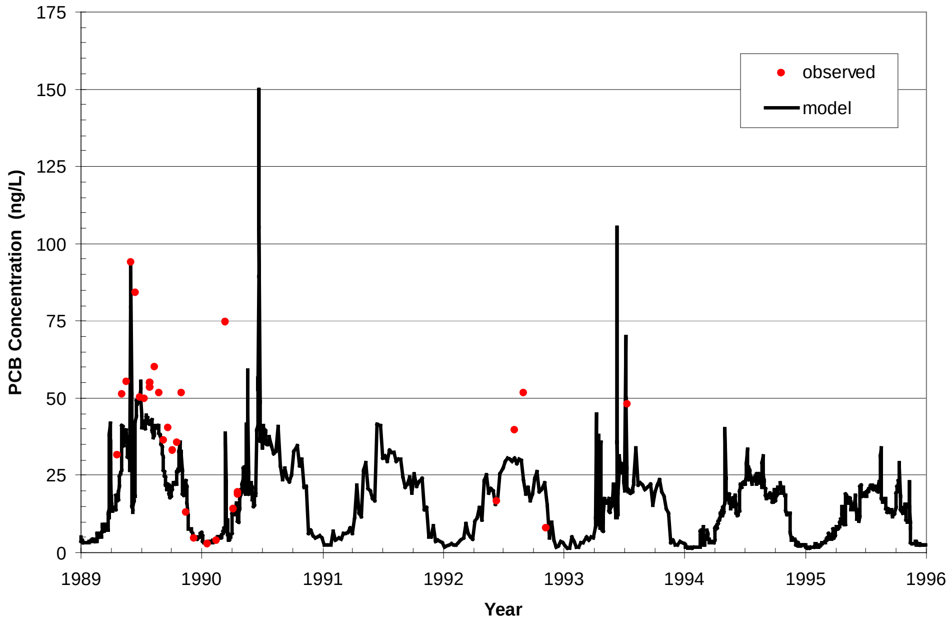

Figure 4—19. Time series of water column total PCB concentrations at Little Rapids: 1989-1995.

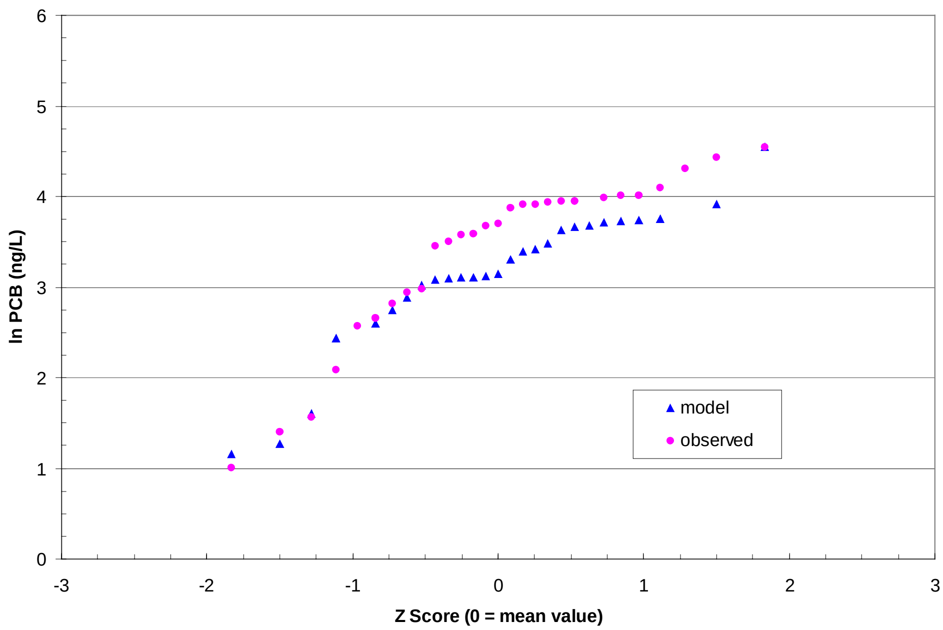

Figure 4—20. Frequency distributions of water column total PCB concentrations at Little Rapids: 1989-1995.

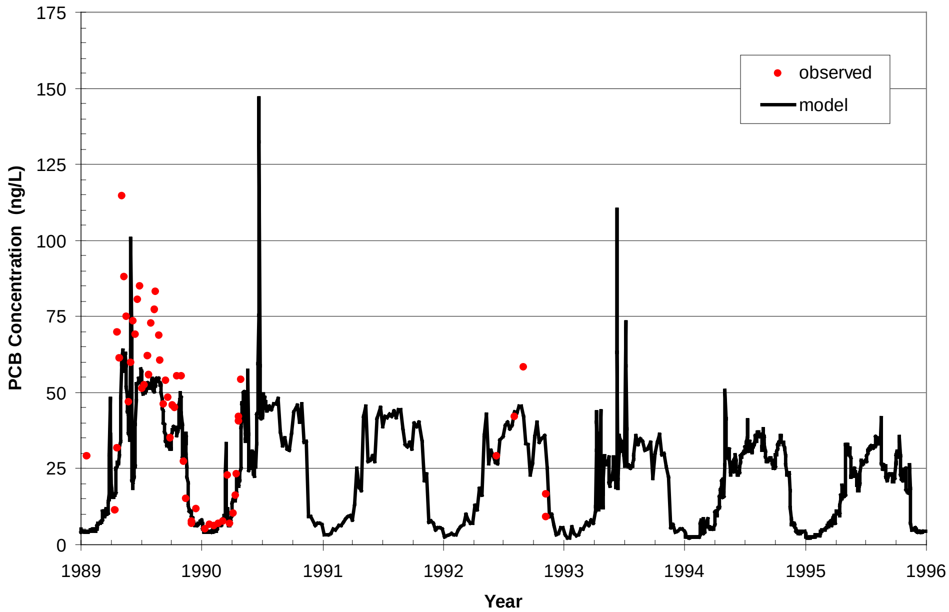

Figure 4—21. Time series of water column total PCB concentrations at DePere: 1989-1995.

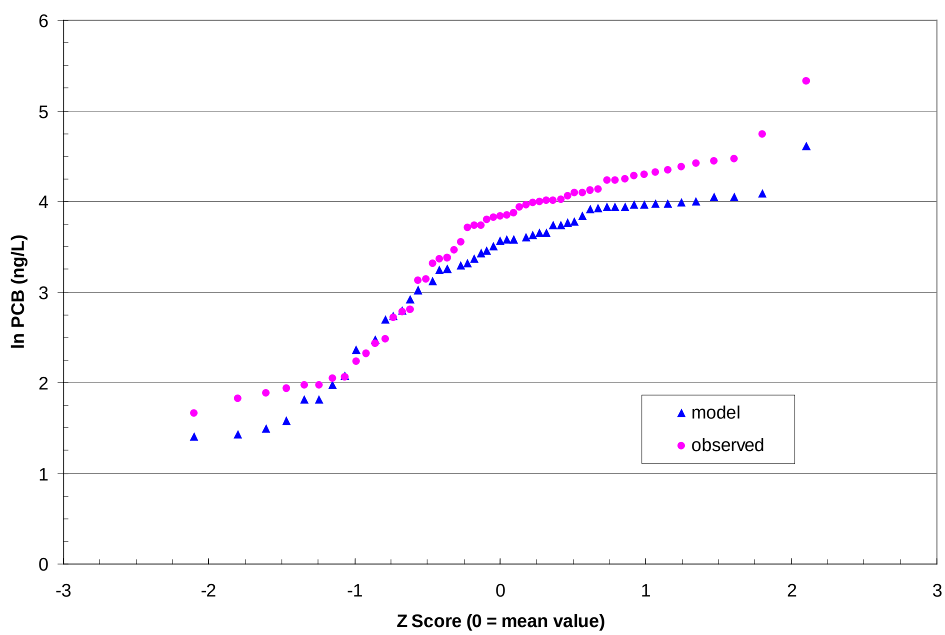

Figure 4—22. Frequency distributions of water column total PCB concentrations at DePere: 1989-1995.

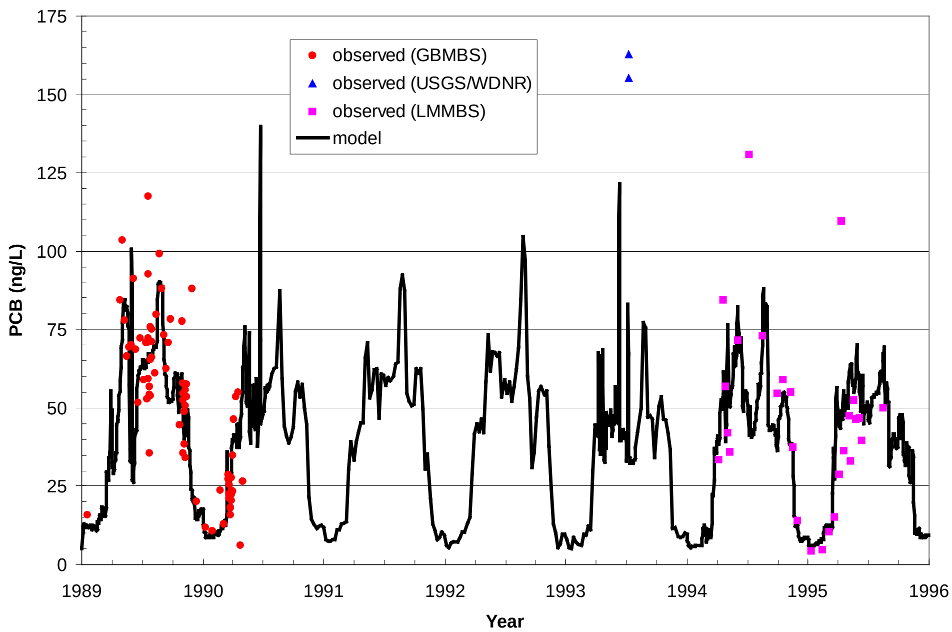

Figure 4—23. Time series of water column total PCB concentrations at the river mouth: 1989-1995.

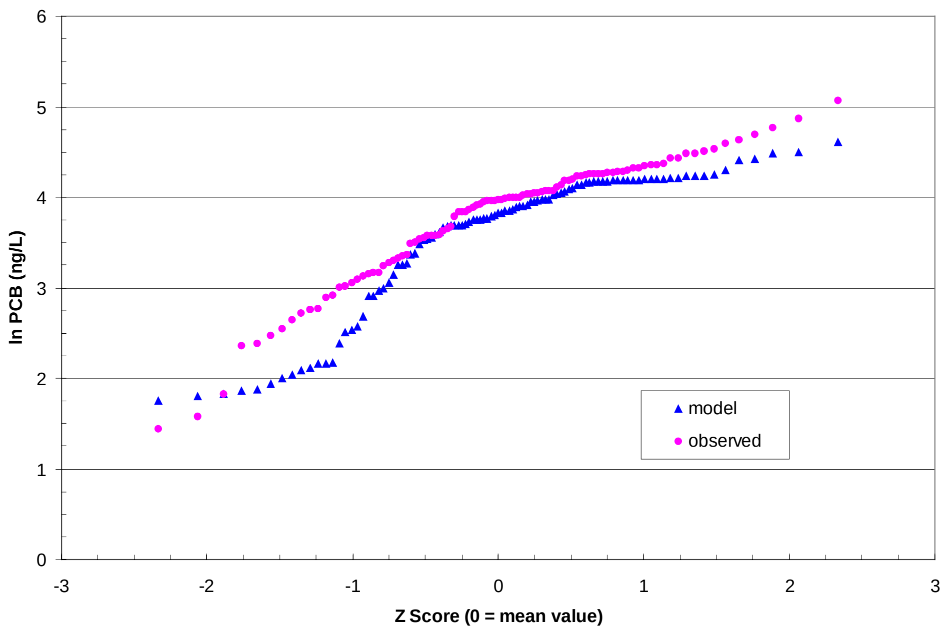

Figure 4—24. Frequency distributions of water column total PCB concentrations at the river mouth: 1989-1995.

Table 4-4. Frequency distribution comparisons for the water column.

Constituent	*Relative Difference Between Mean Observed and Modeled Concentrations by Monitoring Site*						
	Appleton	*Kaukauna*	*Little Rapids*	*DePere*	*River Mouth*	*Average (All Sites)*	*Average (4 sites)*[13]
TSS	-19.5%	-13.5%	-8.6%	-5.8%	-32.4%	-16.0%	-17.8%
PCBs	-40.5%	-31.0%	-73.3%	-31.0%	-16.8%	-38.5%	-29.8%

14. Note that for solids there are many different kinds of measurements from which comparisons may be developed. For simplicity, frequency distribution comparisons for solids are based on the solids measurements associated with PCB observations (generally noted as EWI TSS). Comparisons for total PCBs are presented in Figures 4-15 through 4-24.

In general, the time series comparisons indicate that the model results agree with the trend and magnitude of the observations. However, the results are generally less than observed values indicating that the model has a low bias. With the exception of PCBs at the Little Rapids monitoring site, the frequency distribution comparisons also indicate that agreement between results and observations is generally good. However, the results are generally less than observed values and again indicate that the model has a low bias. Note that model results are also less than the maximum observed values. Model results are nonetheless in satisfactory agreement with observed values and meet the ±30% quality criteria established in TM1 based on frequency distribution comparisons. A summary of calibration simulation performance for solids and PCBs in the water column based on frequency distribution comparisons is presented in Table 4-4.

4.3.1.2 Point-in-Time/Cumulative Performance Comparisons

A series of different point-in-time and cumulative performance comparisons of observations and model results can be developed. As an example, for each date where solids or PCB observations exist it is possible to develop point-in-time comparisons of observations and results along the longitudinal axis of the river on that date (e.g. concentration versus distance from Lake Winnebago). However, at least for PCBs, observations on the same date often do not exist for all monitoring stations. Given the considerable distances (miles) between river monitoring stations, the nature and extent of concentration differences over any distance may also be difficult to assess. Therefore, given the extent of observations, cumulative performance comparisons were considered to provide a better basis for evaluating model performance.

For simplicity, cumulative performance comparisons were developed for the river mouth monitoring station at Green Bay. Based on flow and PCB concentration observations at the river mouth, the USGS estimated PCB export to Green Bay to be 241 kg in 1994 and 190 kg in 1995 (USGS, 1999). The total PCB export for the 1994-1995 period was 431 kg. Model results for

[13] Average of four sites: Appleton, Kaukauna, DePere, and the river mouth.

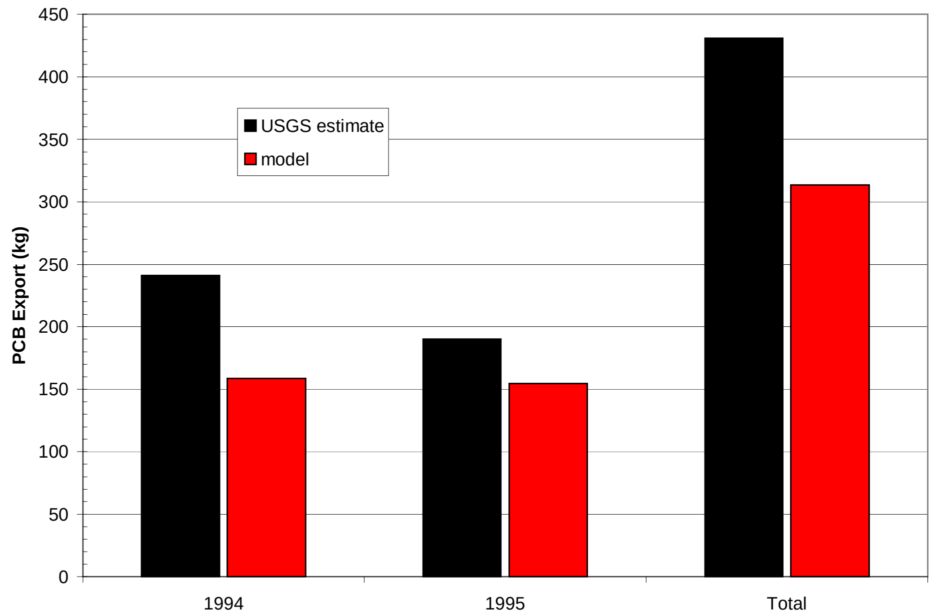

Figure 4—25. Comparison of cumulative PCB export to Green Bay: 1994-1995.

1994 and 1995 were 159 kg and 155 kg, respectively. The model result total for this two year period was 314 kg. Comparisons of USGS PCB export estimates and model results are presented in Figure 4-25. Overall, model results are 27% less than the USGS estimates. This again indicates that the model has a low bias. Model results are nonetheless in satisfactory agreement with USGS estimates and meet the ±30% quality criteria established in TM1 based on these cumulative performance comparisons. Similar comparisons for solids could be developed for the Appleton, Kaukauna, Little Rapids, and DePere monitoring stations during the GBMBS period based on solids load estimates presented by USGS (1990) and USGS (1991).

4.3.1.3 Specific Condition Comparisons

Specific condition (concentration-flow) comparisons of observations and model results were developed for each of the five river monitoring stations: Appleton, Kaukauna, Little Rapids, DePere, and the river mouth at Green Bay. At all five monitoring stations, water column solids and PCB observations exist for a wide range of flows. Again note there are many different kinds of solids measurements from which comparisons may be developed. For simplicity, comparisons for solids are based on the solids measurements associated with PCB observations (generally EWI TSS measurements). Specific condition comparisons for solids and total PCBs are presented in Figures 4-26 through 4-35.

In general, the comparisons indicate that model results agree with the trend and magnitude of the observations. However, it is important to note that most PCB observations (and associated solids

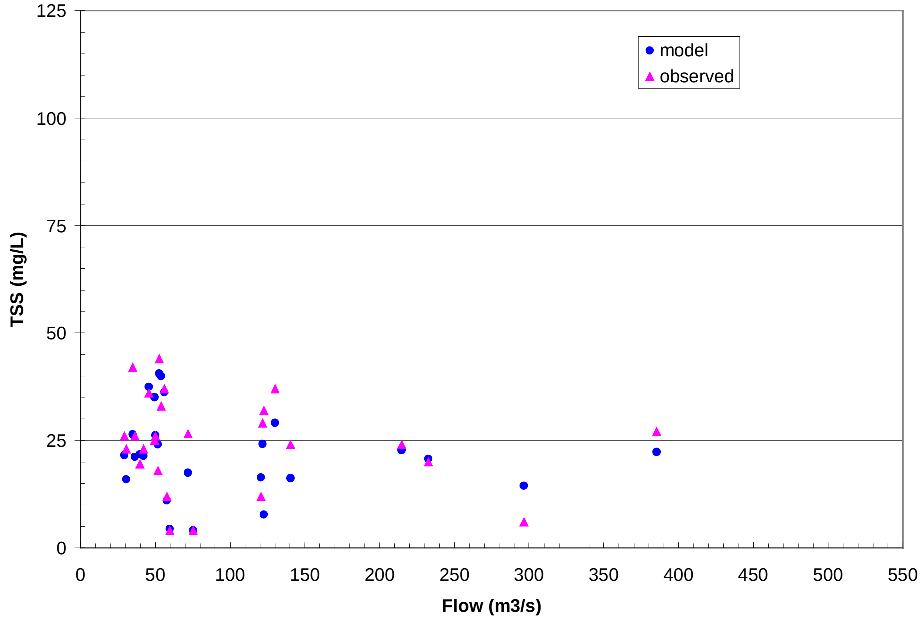

Figure 4—26. Water column TSS concentration versus river flow at Appleton: 1989-1995.

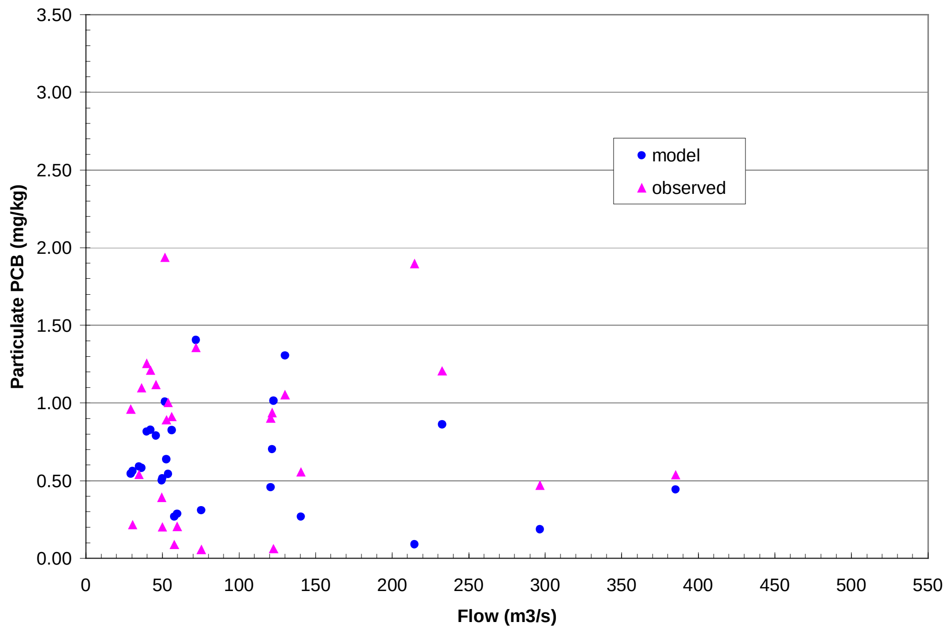

Figure 4—27. Water column particle-associated PCB concentration versus river flow at Appleton: 1989-1995.

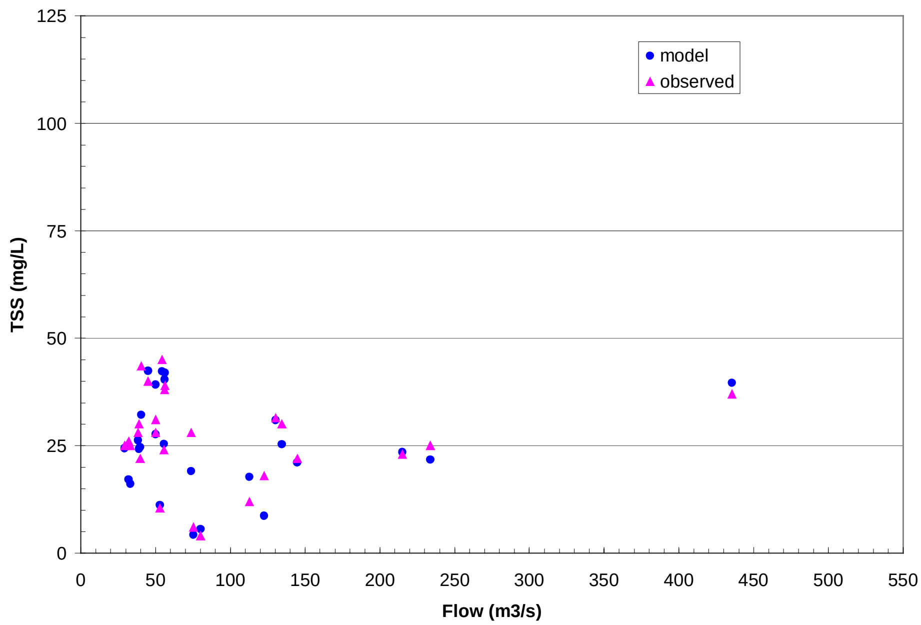

Figure 4—28. Water column TSS concentration versus river flow at Kaukauna: 1989-1995.

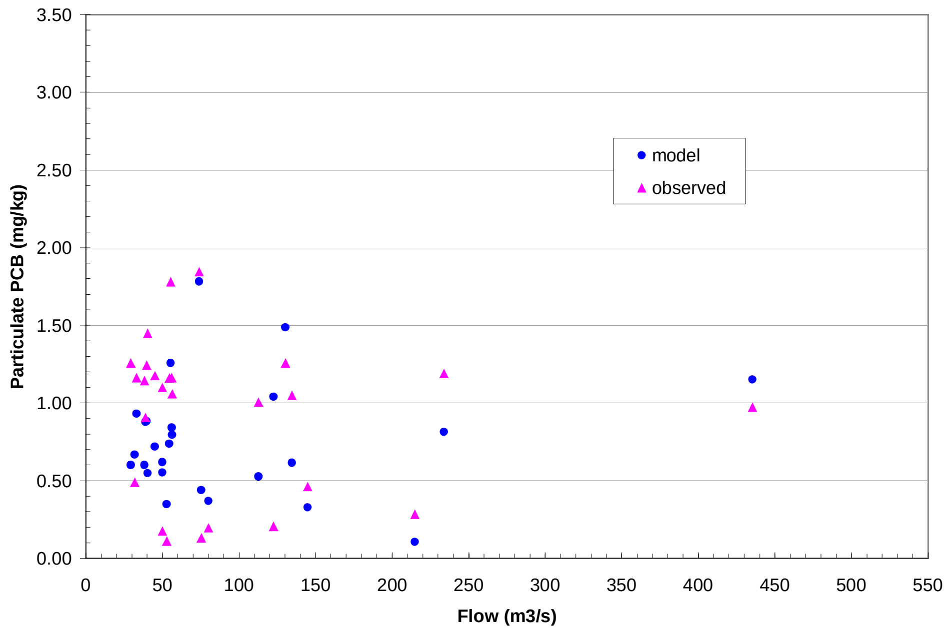

Figure 4—29. Water column particle-associated PCB concentration versus river flow at Kaukauna: 1989-1995.

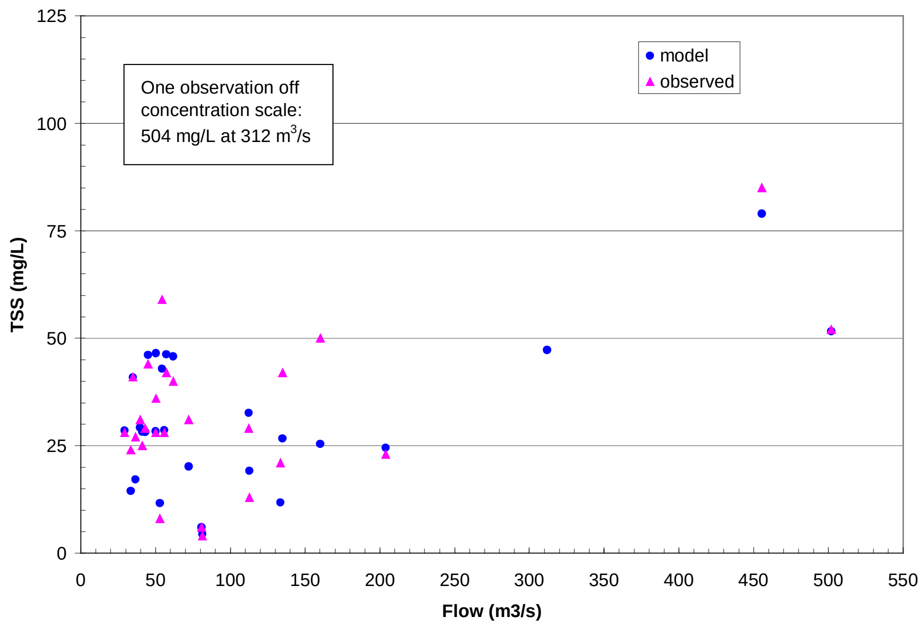

Figure 4—30. Water column TSS concentration versus river flow at Little Rapids: 1989-1995.

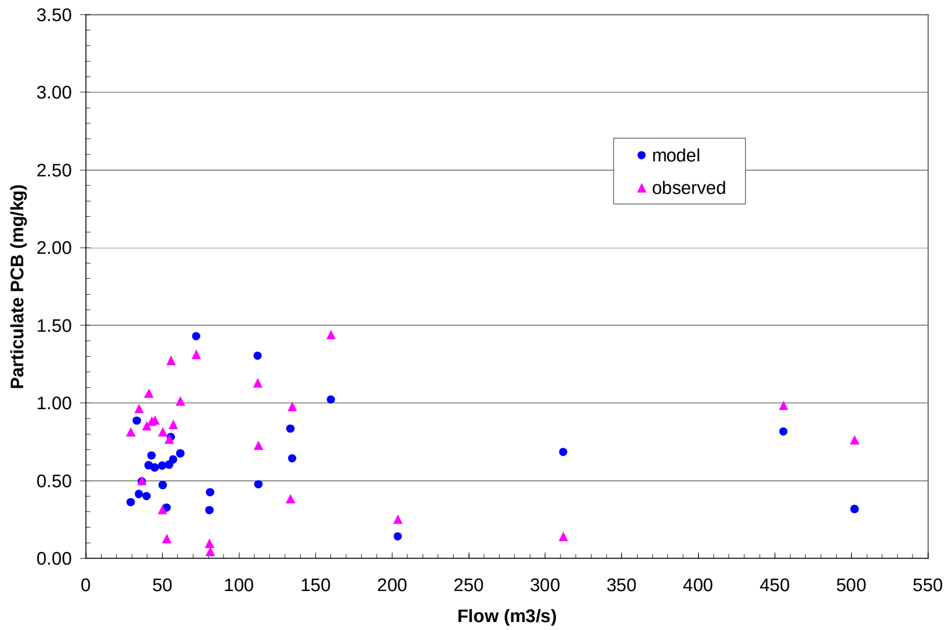

Figure 4—31. Water column particle-associated PCB concentration versus river flow at Little Rapids: 1989-1995.

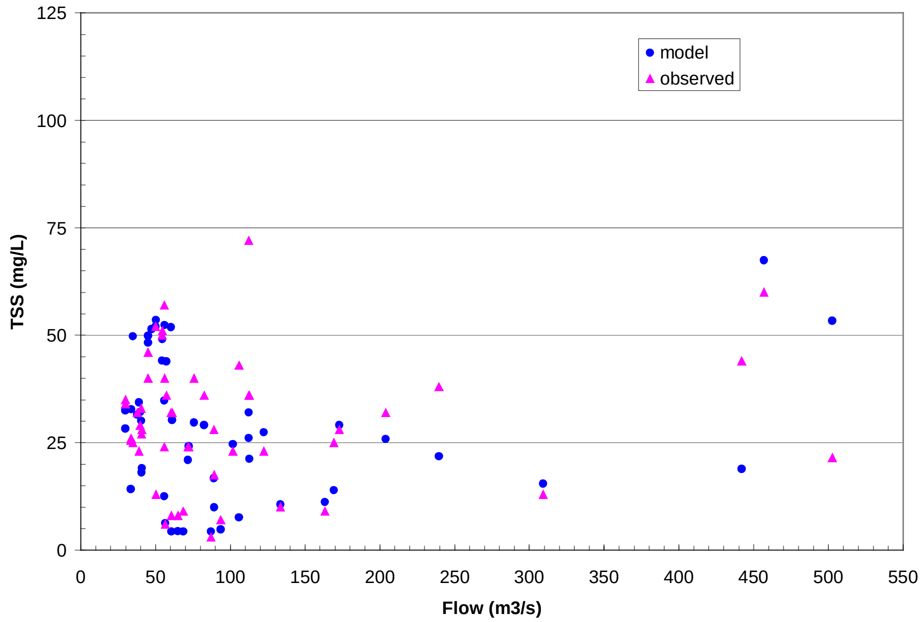

Figure 4—32. Water column TSS concentration versus river flow at DePere: 1989-1995.

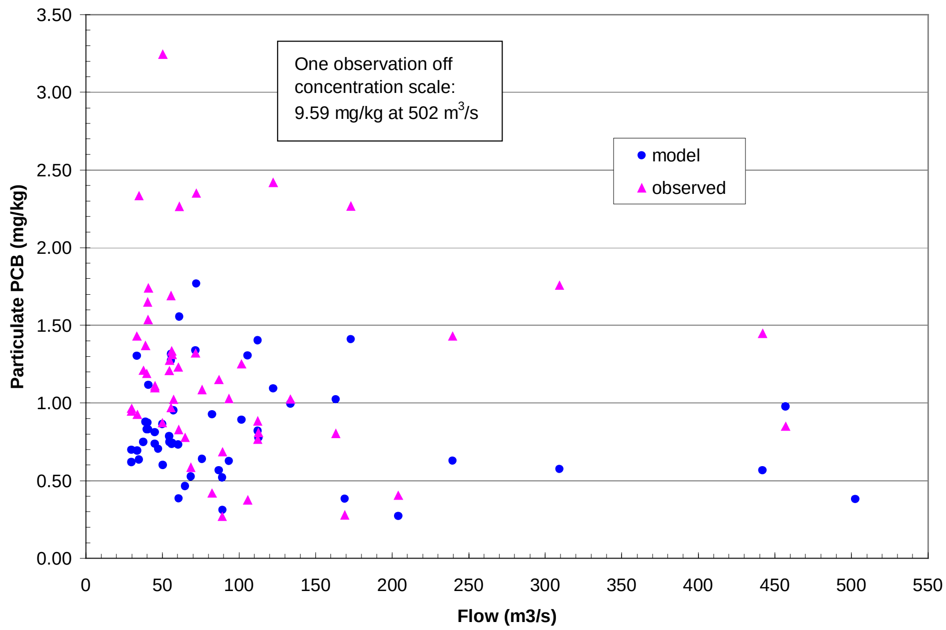

Figure 4—33. Water column particle-associated PCB concentration versus river flow at DePere: 1989-1995.

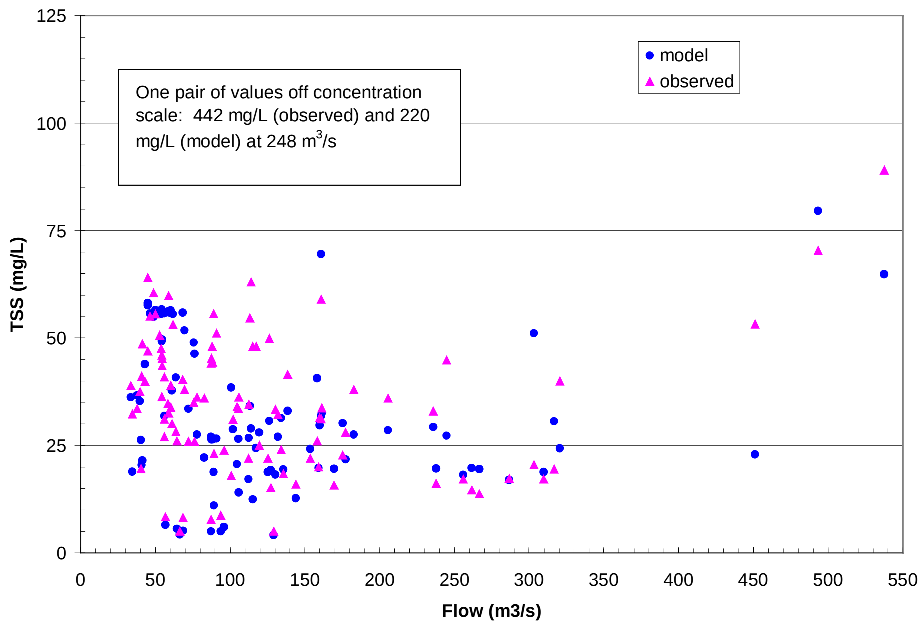

Figure 4—34. Water column TSS concentration versus river flow at the river mouth: 1989-1995.

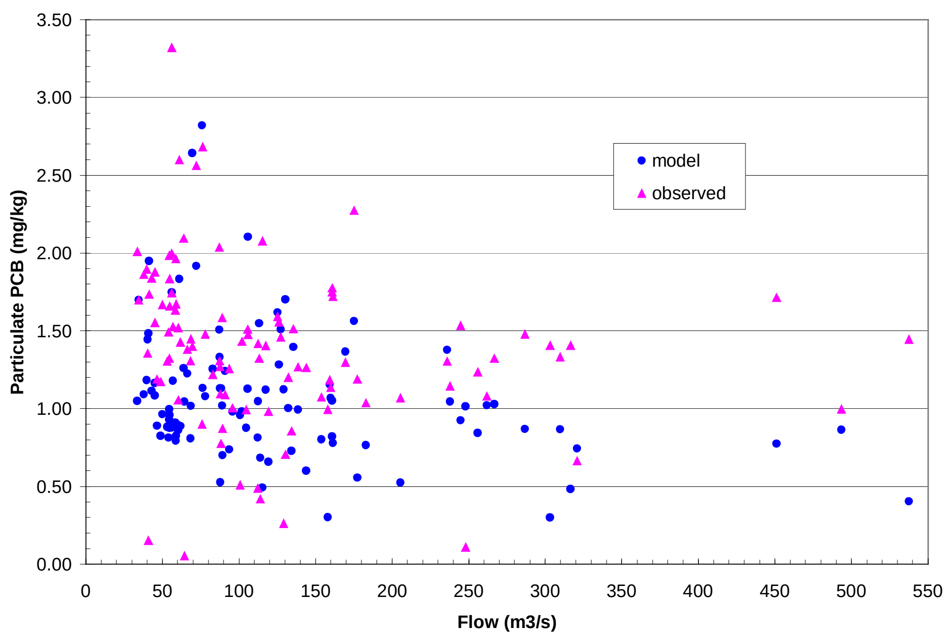

Figure 4—35. Water column particle-associated PCB concentration versus river flow at the river mouth: 1989-1995.

Table 4-5. Specific condition comparisons for the water column.

Constituent	*Mean Relative Difference Between Observed and Model Concentrations by Monitoring Site*[14]						
	Appleton	*Kaukauna*	*Little Rapids*	*DePere*	*River Mouth*	*Average (All Sites)*	*Average (4 sites)*
TSS	-2.0%	-2.2%	-6.5%	1.0%	-1.8%	-1.5%	-0.1%
PCBs	18.0%	2.4%	46.7%	-18.0%	20.7%	14.0%	5.8%

measurements) were collected at flow rates less than 200 m^3/s. For the Lower Fox River, a 200 m^3/s or greater daily average flow occurs approximately 44 times per year. At the Appleton, Kaukauna, and Little Rapids stations, only four observations were collected at flows greater than 200 m^3/s. At the DePere station, only six observations were at flows above this threshold. At the river mouth station, 16 of 100 observations were at flows greater than 200 m^3/s. Model results are often less than observed values at flows greater than 200 m^3/s. This again indicates that the model has a low bias. Model results are nonetheless in satisfactory agreement with observed values and meet the ±30% quality criteria established in TM1 based on these specific condition comparisons. A summary of calibration simulation performance for solids and PCBs in the water column based on specific condition performance comparisons is presented in Table 4-5.

4.3.2 Sediments

For sediments, observations or inferences exist to permit evaluation for point-in-time/cumulative performance metrics. Evaluations can be constructed to examine sediment bed elevation changes, net sediment burial rates and trap efficiencies, and sediment PCB concentration trends. Model performance assessments relative to these metrics are presented in the sections that follow.

4.3.2.1 Sediment Bed Elevation Change Comparisons

Cumulative performance comparisons of observed sediment bed elevation changes and model results were developed for a series of hydrographic survey stations and station groups presented in TM2g (WDNR, 1999c): T10; 370+00, 360+00, and T9; 205+00 and T5; 91+00; and 61+00 and T3. As most bed elevation data are restricted to the river navigation channel, most of the stations selected for comparisons are located between the DePere dam and the river mouth. Station T10 is located just upstream of the DePere dam in the area of Deposits GG and HH. Stations 370+00, 360+00, and T9 are located just downstream of the DePere dam in the area of SMUs 20-25. Stations 205+00 and T5 are located approximately 3.9 miles (6.2 km) upstream of the river mouth near the Fort James (Georgia Pacific) West mill in the area of SMUs 50-55. Station 91+00 is located just upstream of the East River turning basin, approximately 1.7 miles

[14] Differences computed from signed errors. Across the range of flows, errors offset each other. Average root mean square (RMS) errors (relative to the mean) were much larger: 42.6% for solids and 65.8% for PCBs. However, note that RMS errors can be sensitive to a few large differences between simulated and observed values.

(2.8 km) upstream of the river mouth, in the area of SMUs 86-91. Stations 61+00 and T3 are located just downstream of the East River turning basin, approximately 1.2 miles (1.8 km) upstream of the river mouth, in the area of SMUs 92-97. Observed bed elevation changes at these locations were described in TM2g (WDNR, 1999c) and follow-up efforts presented in Section 4.2.2.1. To facilitate comparisons, model results in the area of these stations were averaged. Note that observations for Stations 370+00 and 360+00 were also averaged. Comparisons of sediment bed elevation changes are presented in Table 4-6.

In general, model results can differ considerably from observed values. For the comparisons presented in Table 4-6, the model results are 83% less than the observations on average. For many of the locations and time periods examined, the results may match the direction of the observations (increase or decrease) but usually differ in scale. For some locations and times, results differ from observations in terms of both direction and scale. However, it is important to consider the nature of the observations and results. Observed values represent conditions along a line. USACE hydrographic surveys demonstrate that observed bed elevations along a line can differ widely from station to station. In contrast, model results represent average conditions for large areas (the average surface area of a sediment segment is 100,000 m^2). Given the wide station-to-station variations, the average elevation across a large area can be distinctly different

Table 4-6. Comparison of sediment bed elevation changes.

Station (Agency)	*Time Period*	*Observed (cm)*	*Model (cm)*[15]
T10 (USEPA)	May 1994 to November 1994 November 1994 to August 1995	-9 -5	-0.09 +0.01
370+00 - 360+00 (USACE)	1990 to 1993 1993 to 1997	-3.5 -15	-1.26 -0.11
T9 (USEPA)	May 1994 to November 1994 November 1994 to August 1995	+10 -6	+0.31 -0.27
205+00 (USACE)	1990 to 1993 1993 to 1997	-7 -26	-0.74 ~0 (-0.002)
T5 (USEPA)	May 1994 to July 1994 July 1994 to November 1994 November 1994 to August 1995	+1 -7 +19	-0.02 +0.04 -0.06
91+00 (USACE)	1990 to 1993 1993 to 1997	+5 +2	+1.3 +0.62
61+00 (USACE)	1990 to 1993 1993 to 1997	+5 +7	+7.0 +2.8
T3 (USEPA)	May 1994 to September 1994 September 1994 to November 1994 November 1994 to August 1995	+72 -94 +14	+0.26 +0.03 +1.04

[15] Model results are computed through 1995. Comparisons to observed values through 1997 are qualitative.

Table 4-7. Comparison of net burial rates.

Reach	*1*	*2*	*3*	*4*	*Average*
Range of Estimates/Inferences	+0.35 cm/year (estimated from observed bed elevations changes USACE 1997-1999) +0.2 to +1.4 cm/year (inferred from PCB depth in sediment, indexed to 1989-1995)				
Model	+0.43 cm/year	-0.03 cm/year	+0.25 cm/year	+0.12 cm/year	+0.22 cm/year

than the average elevation along an individual transect line. Consequently, comparisons between these observations and model results may not indicate the quality of model performance.

More importantly, significant differences between the scale of observed sediment bed elevation changes and model results are expected. As described in TM5b (Baird, 2000a) and TM5d (Baird, 2000b), the underlying sediment transport models on which the wLFRM is based do not capture the scale of observed bed elevation changes. Moreover, no sediment transport model developed for this site to date has been able to express the range of observed sediment bed elevation changes over time. As a consequence of the limitations of the underlying sediment transport models, the wLFRM cannot represent the full range of observed sediment bed elevation changes over time. Further discussion of these issues is presented in Section 4.4.

4.3.2.2 Net Burial Rate Comparisons

Cumulative performance comparisons of estimated and inferred net burial rates and model results were developed. One net burial rate value was estimated from results of the 1997-1999 USACE hydrographic surveys of the river navigation channel between the DePere and Fort James (Georgia Pacific) turning basins. As noted in Section 4.2.2.1, in this section of the river, a 0.7 cm increase in average sediment bed elevations occurred over a two year period. This corresponds to an estimated net burial rate of +0.35 cm/year. A second net burial rate value was inferred from the depth of maximum PCB concentrations in river sediment samples collected in 1995 between DePere and Green Bay. Based on TM2d (WDNR, 1999a) the year of peak PCB loads to the river was 1969. Based on the 1995 samples, the average depth to maximum PCB concentrations was 24 to 56 cm below the sediment-water interface. This corresponds to an inferred average net burial rate of approximately 1-2 cm/year for the period 1969-1995. However, also as described in TM2d, it is important to note that most of the PCB discharge to the river occurred prior to the implementation of present-day wastewater treatment practices. During the period of peak PCB discharges, loads of point source solids that delivered PCBs to the river were much larger than contemporary loads. Further, the settling characteristics of the particles comprising those loads were substantially different (i.e. untreated versus treated wastes). Consequently the net burial rate of PCBs was likely very high in the past and much smaller in recent years. When adjusted for the changing magnitude and characteristics of point source solids and indexed to the 1989-1995 period, the inferred average net burial rate is approximately 0.2 to 1.4 cm/year (WDNR, 2001b). Comparisons of net burial rates are presented in Table 4-7.

Table 4-8. Comparison of annual surface sediment (0-10 cm) PCB concentration trends.

Reach	**1**	**2**	**3**	**4**	***All***
Inferred	-11.1% to -37.9%	+15.4% to +84.0%	-25.4% to +6.4%	-8.5% to +9.1%	+0.6% to +13.8%
Model	-6.8%	-5.8%	-1.2%	+9.6%	-1.0%

In general, model results are within the range of estimated and inferred net burial rates. Note that results for Reach 2 differ the most from the estimated and inferred net burial rates. Reach 2 is narrow and fast moving compared to other sections of the river. Therefore, the near zero net burial rate (in fact a small net scour rate) for this reach is an expected result. However, further performance assessments using this metric are difficult to develop for numerous reasons. The estimated and inferred burial rates are based on observations collected between DePere and Green Bay. As presented in TM2g (WDNR, 1999c), bed elevation changes (and therefore net burial rates) vary widely in space and over time. The estimate rate of +0.35 cm/year was computed for 1997-1999. The rate applicable to 1989-1995 in each reach may be different. Further, even after accounting for differences in point source loads and particle deposition characteristics, the net burial rate inferred from the depths of maximum PCB concentrations in the sediment is based on values for individual locations. At each location, the inferred rate can vary widely. Extrapolations from single locations to broad areas may be inaccurate. Further discussion of these issues is presented in Section 4.4.

4.3.2.3 Surface Sediment PCB Concentration Trend Comparisons

Cumulative performance comparisons of inferred annual surface sediment PCB concentration trends and model results were developed for each river reach as well as the whole river. Inferred trends were developed from field observations aggregated to represent the 0-10 cm sediment layer as described in Appendix B and summarized in Section 4.2.2.2. Model results were also aggregated to represent the 0-10 cm layer for each sediment stack (volume-weighted average in the vertical) and then averaged for each reach or the whole river (area-weighted average in the horizontal). Comparisons of annual surface sediment PCB concentration trends are presented in Table 4-8.

Results for Reach 1 agree with the direction of the inferred trend but are smaller in scale. Results for Reach 2 differ in both direction and scale. However, inferred trends over time for these two reaches may actually reflect PCB concentration trends in space due to changes in sampling locations over time. The Result for Reach 3 agrees with both the direction and scale of the inferred trend and is near zero. This is consistent with the inference that no significant PCB concentration trends over time exist in Reach 3. The result for Reach 4 also agrees with the direction of the inferred trend but is slightly larger in scale. Overall model results fall just outside of the lower range of inferred trends.

When considering these comparisons, it is important to recall the numerous caveats associated with inferred surface sediment PCB concentration trends. Apparent trends over time may be strongly influenced by, or reflect, spatial heterogeneity and analytical bias. As a consequence, it is difficult to determine direction or scale of any potential trend from these data. Because apparent trends may really reflect shifts in sampling locations over time or differences in analytical procedures, the uncertainty associate with these trend inferences is very high. As a result, comparisons to these sediment PCB concentrations trend inferences may not indicate the quality of model performance. Further discussion is presented in Section 4.4.

4.4 DISCUSSION OF CALIBRATION SIMULATION RESULTS

4.4.1 Assessment of Overall Model Performance

Overall model performance was considered to meet the quality objectives set forth in TM1 to the extent practical given the resources and constraints of this model development effort. Evaluation metrics for the water column suggest that the model results have a low bias. Average model results tend to be less than observed values. Evaluation metrics for the sediments are more difficult to interpret. Average model results tend to miss the scale and sometimes directions of observed sediment bed elevation changes. Average model results tend to fall near or within the range of estimated or inferred net burial values. However, the difficulty associated with accurate extrapolation of observations for individual points or transects prevents development of meaningful quantitative comparisons. Nonetheless, the model calibration appears to appropriately reflect the trend and magnitude of observations for a wide range of conditions. For example, as demonstrated by the results of field sampling efforts, the only significant source of PCBs to Lower Fox River is the river sediments. PCB concentrations in the river are essentially zero at the upstream boundary with Lake Winnebago and increase to an average of more than 50 ng/L at the river mouth. The wLFRM reproduces these critical site features.

There is a wide range of possible values or uncertainty associated with each model parameter, forcing function, initial condition, and boundary condition. In some cases, the range of values and uncertainties is large. It is important to recognize that the wide range of values and overlapping uncertainty bounds of the information from which the model was developed may sometimes be interpreted (or misinterpreted) to indicate mutually exclusive outcomes. As a consequence, it will nearly always be possible to formulate alternative models that, to one degree or another, may also meet the model performance standards established in TM1 and yet yield different conclusions. This means that no single model formulation will necessarily be (or should claim to be) the best or only possible tool to describe site conditions. In this light, it is therefore appropriate to consider how the basic information used to formulate the model was interpreted in addition to the ability of a model to describe the trend and magnitude of a specified set of conditions. Subsequent examinations of the model focus on those factors that may most significantly influence the overall ability of the model to describe the PCB transport and exposure conditions in the river: 1) the magnitude and characteristics of solids loads from the watershed; 2) sediment transport processes; 3) and sediment bed dynamics.

In consideration of model performance strengths and limitations, the wLFRM was considered to provide a reasonable description of PCB concentrations and export in the Lower Fox River on a year-by-year, reach-by-reach basis. The best use of this model may therefore be as an indicator of the relative trend and magnitude of PCBs concentrations and export. In the context of this model development effort, year-by-year, reach-by-reach resolution of this model was considered sufficient to meet overall project goals.

4.4.2 Magnitude and Characteristics of Solids Loads from the Watershed

Perhaps the single most important aspect of model formulation is successful description of the overall solids balance for the system. Most of the particles entering the river are delivered from the watershed (including Lake Winnebago). Lake Winnebago is the upstream boundary and represents the single largest source of solids to the river. This load was estimated to be approximately 68,000 MT/year. However, this estimate is highly uncertain. Only a limited number of observations to estimate the magnitude of this load exist during the 1989-1995 model calibration period. While the 68,000 MT/year loading estimate may be representative of long-term average conditions, it is not known whether this estimate is descriptive of annual conditions during 1989-1995. Further, the limited range of observations precluded development of meaningful concentration-flow relationships to describe load variations with river flow. As noted in Section 3.5.1, the grain size distribution of particles entering the river from Lake Winnebago was difficult to determine. The limited grain size data are difficult to interpret. In general, it is reasonable to expect that a large portion of the total solids exiting Lake Winnebago consist of algae and other fine particles. However, it is also possible that a sizable fraction of coarse particles enter the river from Lake Winnebago depending on operating conditions at the Neenah and Menasha dams. Consequently, the uncertainty associated with the grain size distribution of the upstream solids boundary condition is significant.

The next largest source of solids is the surrounding watershed downstream of Lake Winnebago. These loads were estimated to total approximately 54,000 MT/year as described in TM2a (FWB2000, 1998) and TM3a (WDNR, 2001a). In a general, these load estimates offer an improved description of watershed solids inputs relative to the estimates on which prior generations of model development were based. However, it is likely that the TM2a loads underestimate the total load delivered from the watershed and/or do not capture the temporal dynamics of solids delivery. As an example of this, consider the solids load estimate for the East River. TM2a 4-day average solids loads for the East River were estimated to be zero 45% of the time during the model calibration period. Such a condition could only occur if either the flow and/or solids concentration of the East River were zero. Since corresponding flow estimates for the East River were zero only once during the calibration period, it therefore seems likely that the TM2a solids load estimates may have a low bias and considerable uncertainty. This was noted during the development of TM5b (Baird, 2000a). In that effort, TM2a solids load estimates were augmented to reflect a minimum solids concentration (and therefore minimum load). Note that the TM2a load estimates were not augmented during development of the wLFRM.

Further, the grain size distribution of these watershed solids load estimates was difficult to determine. No data exist to confirm the computed grain size distributions of particles comprising the total solids load at their point of delivery to the Lower Fox River. Nonetheless, the approach used to fractionate total watershed solids loads is reasonable since it is based on the best estimates of the physical characteristic of the particles in the watershed and transport conditions as described by Arnold et al. (1990) and Barfield et al. (1981). Note that particle grain size and the flow conditions under which particles are delivered to the river are linked to sediment transport processes. Uncertainties in grain size distribution and time of delivery can effect model performance particularly in the areas of sediment bed elevation changes and net burial rates.

4.4.3 Sediment Transport Processes

Sediment transport processes are also key aspects of model formulation. Particle erosion and deposition are both controlled by the shear stress at the sediment-water interface. As described in Sections 3.4.4 and 3.5.6.1, shear stresses in the model were computed from average velocities derived from flow-velocity relationships that summarize the results of hydrodynamic models developed for the river. The spatial scale of the wLFRM is coarser than the underlying hydrodynamic models. As a result, some of the spatial detail in the hydrodynamic models is lost on translation to the wLFRM. Differences in spatial resolution may therefore contribute to overall model uncertainty.

Erosion potentials assigned to river sediments were derived from erosion amounts as functions of shear stress as described in Section 3.5.6.3. Note that the assigned erosion potentials as shown in Figure 3-13 have a low bias for shear stresses in the region of 3 dynes/cm^2. It is possible that this low bias may also occur across a broader range of conditions (e.g. 1-4 dynes/cm^2). As river shear stresses are often in this range, the low bias to the assigned erosion potentials may contribute to the overall low bias of model results. Further, erosion potentials are observed to vary widely with location. As a result, there is no means to determine whether the present erosion potential measurements collected at a limited number of locations in one reach of the river are applicable to the whole system. In addition, it is also possible that sediment erosion potential may be variable over time in response to changing physicochemical conditions such as temperature, dissolved oxygen, and reduction-oxidation (redox) potential. Biological activity can also affect sediment properties such as shear strength and increase bed roughness (Rhoads and Boyer, 1982). Also note that the annualized average background resuspension velocity in the wLFRM (parameterized as a function of flow) was approximately 7 mm/year.

Settling velocities and probabilities of deposition in the model were based on consideration of the size and nature of particles transported in the river as described in Section 3.5.6.2. However, the uncertainty associated with these parameters is significant, especially for cohesive particle types. For example, the critical shear stress for deposition for a non-cohesive particle can be estimated from a force balance. In contrast, there is no comparable means to determine appropriate values for cohesive particles. Similarly, settling velocities for cohesive particles are more difficult to estimate due to a numerous site-, particle-, and condition-specific factors. For this reason the possible settling velocities for these particles can range widely. As sediment transport parameters cannot be precisely defined the uncertainty associated with the model is correspondingly large.

4.4.4 Sediment Bed Dynamics

Sediment bed dynamics encompass an array of model features and performance attributes including sediment mixing rates, bed elevation changes, and net burial rates. The sediment mixing rate is an explicit parameter specified in the model. Sediment bed elevation changes and net burial in the model occur as a consequence of the net difference between gross erosion and deposition fluxes. Gross erosion and deposition fluxes in the model are influenced by the solids loads to the river and the sediment transport parameterization.

Sediment mixing is a key aspect of model formulation. The radioisotope study of the Lower Fox River described by Fitzgerald et al. (2001) indicates that Be-7 is found at depths of 5-10 cm below the sediment-water interface. Given the rapid decay of Be-7, this suggests that sediment mixing is relatively fast through the top 5-10 cm of the sediment column. Rapid mixing is also consistent with the pattern of sediment bed elevation gains and losses described in TM2g and Section 4.2.2.1; such extensive bed elevation changes can mix sediments. The sediment mixing rate used in the model was selected to reflect this rapid mixing. However, the rapid mixing rate contributes to the rate of surface sediment PCB increase over time in Reach 4. Reducing the mixing rate eliminates the simulated increase in sediment PCB concentrations over time but also has the adverse impact of decreasing simulated water column PCB concentrations to levels considerable below observed values. Overall model performance is sensitive to the uncertainty in the sediment mixing rate.

Sediment bed elevations and net burial rates provide insight into the sediment transport parameterization of the model. In the case of the Lower Fox River, it is critical to note that essentially all PCBs exported to Green Bay during 1989-1995 originate from the sediment bed. Therefore the ability to match the trend and magnitude of bed elevation changes and net burial rates is a key aspect of model performance. As was noted in Section 4.3, the present model cannot describe the full range of observed sediment bed elevation changes. Again note that this result was expected given that the underlying sediment transport models on which the wLFRM is based do not capture the scale of observed bed elevation changes.

However, it is also important to note that the sediment transport processes in the model are limited to erosion and deposition, where particles leave the sediment bed, become fully suspended in the water column, and eventually return to the bed. In contrast, observed changes in sediment bed elevations can be caused by additional factors not represented in the model. In particular bed load, fluid mud flow, and slumping can move material over time and affect sediment bed elevations. Sediments moved by these mechanisms are not measured as suspended solids in the water column and are unmonitored components of total sediment transport. For example, the standard method used to sample the water column (at 20% and 80% of the water depth) is specifically designed to avoid sampling sediments moving near the sediment-water interface. Thus, it is important to recognize that bed elevation increases at a location do not necessarily indicate that particles were fully entrained in the river flow then returned to the sediment bed. Similarly, in the absence of consolidation, bed elevation decreases only indicate that sediments have moved to some other location and do not necessarily indicate that those sediments were fully suspended in the water column. It is therefore essential to recognize that substantial sediment movement can occur without necessarily causing corresponding increases in water column suspended solids measurements.

Net burial rates in the model are within the range of estimated and inferred values. However, at least in the case of Reach 4, the simulated net burial is somewhat low. This may be attributable to the temporal dynamics of watershed solids loads in the model. A large portion of the total watershed solids load was estimated to be fine particles based on upland soil classifications and delivery distance. Further much of the total load is delivered to the river during relatively high flow periods. Under those conditions, the probability of deposition and corresponding deposition flux of fine particles is typically very small (near zero). One possibility to explore is whether the grain size distribution of the particles comprising watershed solids loads includes a large fraction of coarse particles. However, it is unclear if such coarse particle delivery through the watershed occurs given the distances particles must travel through the watershed and that the settling velocities of those particles may be several hundred meters per day. Unfortunately, grain size data for watershed loads at the point of delivery to the Lower Fox River do not exist.

Consideration was also given to assessing whether dredging records might also be used to infer net burial rates. Unfortunately, such inferences from dredging records can be inaccurate and misleading. These inaccuracies may be attributable to a number of factors. One factor is that dredging alters channel geometry and can increase the tendency for sediments to accumulate in those areas. A second factor is that dredging in any year is limited only to those areas where sediment bed elevation increases impede ship passage; the volume of sediment lost from areas where bed elevation decreases occur is not included into the volume of material dredged. A third factor is that the volume of sediment dredged may include additional sediments removed as planned or incidental overbite or sediment removed as part of channel expansion projects. As a consequence of these and other factors, net burial rates inferred from dredging records may significantly overestimate natural rates. It is also important to note that sediment accumulation (gain or loss) rates vary with location and over time. Therefore, net burial rates inferred from long-term dredging records may not meaningfully represent conditions during the model calibration period. In light of these factors, net burial rate inferences derived from dredging records were considered too uncertain to evaluate model performance.

Some indication of sediment net burial (and mixing) rates may also be inferred from the depths of occurrence of Cesium-137 (Cs-137), Beryllium-7 (Be-7), and PCBs in the sediment column. Cs-137 is a long-lived radioisotope (30-year half-life) that originated from atmospheric tests of nuclear weapons. Unfortunately, as a result of its long half-life, the large watershed area of the river, and frequency of sediment disturbances, Cs-137 is not a reliable means to infer net burial rates. For example, as presented by Steuer et al. (1995), Cs-137 profiles in most sediment cores collected during the GBMBS were not interpretable as a result of sediment disturbance. Widespread sediment disturbance is consistent with the results of TM2g (e.g. bed elevations change and can decrease over time). The limited utility of Cs-137 as a mean to infer net burial rates in the Lower Fox River was also described by WDNR (1999d) during development of TM2g.

Be-7 is a short-lived (53-day half-life) radioactive isotope that originates from the cosmogenic spallation of atmospheric oxygen and nitrogen. A study of sediment resuspension and deposition in the Lower Fox River concluded that rates of particle exchange computed from Be-7 activities were up to ~130 times greater than rates inferred from Cs-137, suggesting an extremely dynamic sediment transport environment (Fitzgerald et al. 2001). This finding further indicates the limited utility of Cs-137 as a means to infer sediment net burial rates. In addition, the presence of Be-7 at depth in the sediment column indicates the rapid rate and depth to which particles mix in the sediments. As reported by Fitzgerald et al. (2001) Be-7 was found in the top 5-10 cm of the sediments. However, BBL (1999) reported Be-7 activities to be less than detectable in all but one depth interval out of more than 100 samples collected at eight sites including all samples collected at the sediment-water interface. Such a result would indicate either unreliable laboratory results or that all sediments sampled (including those at the sediment-water interface) had been isolated from the water column for more than one year. If the results reported by BBL (1999) are valid, then the absence of Be-7 would suggest that buried sediments at those sites had recently been returned to the sediment surface. Such a finding, again assuming that the results reported by BBL (1999) are valid, would be consistent with the sediment bed elevation information presented in TM2g (WDNR, 1999c).

Empirical methods can be used to estimate sediment trap efficiencies. Sediment trap efficiency estimates may permit at least some confirmation of the net burial rate estimates. The small net change in bed elevation in the USACE 1997-1999 hydrographic surveys suggests low sediment trap efficiencies. As described by Brune (1953) and Dendy (1974), the capacity-inflow (CI) ratio can be used to estimate the sediment trap efficiency of a reservoir (an impoundment on a river). Capacity represents the volume of water stored by the impoundment. Inflow represents the total flow of water through the impoundment. Capacities for each pool of the four river reaches were determined from the water column volumes reported in TM5c (HQI, 2000) and Velleux and Endicott (1994). A pool represents a portion of the river impounded between two dams as described in TM5c (HQI, 2000). Inflows for each pool were computed from the results of TM2a (FWB2000, 1998). CI ratios and trap efficiencies were then estimated for each river reach as summarized in Table 4-9.

Table 4-9. Estimated Lower Fox River sediment trap efficiencies by river reach.

Reach	*Pool*	*Description*	*Capacity (acre-feet)*	*Inflow (acre-feet/year)*	*CI Ratio*	*Trap Efficiency (%)*	
						Brune (1953)	*Dendy (1974)*
1	1	Little Lake Butte des Mort	9.89E+03	3.55E+06	0.003	10 (0-22)	12.0
2	2	Appleton to Little Rapids: Upper Appleton to Cedars	2.70E+03	3.55E+06	0.001	~0 (0-2)	0.4
2	3	Appleton to Little Rapids: Cedars to Kaukauna	1.99E+03	3.58E+06	0.001	~0 (0-2)	0.1
2	4	Appleton to Little Rapids: Kaukauna to Rapide Croche	5.70E+03	3.58E+06	0.002	~0 (0-10)	4.2
2	5	Appleton to Little Rapids: Rapide Croche to Little Rapids	4.14E+03	3.63E+06	0.001	~0 (0-3)	1.8
3	6	Little Rapids to DePere	7.30E+03	3.63E+06	0.002	1.5 (0-18)	6.8
4	“7”	DePere to Green Bay[16]	1.54E+04	3.73E+06	0.004	20 (6-36)	20.2

[16] Sediment trap efficiency estimates for Reach 4 may represent a maximum upper bound.

Note that the sediment trap efficiency estimate for the area between the DePere dam and the river mouth may be quite high. The CI ratio methods used to estimate this value are most applicable to systems where a dam regulates flow at the downstream end of the impoundment. In general, dams cause water to pool and hinder the free transport of particles, thereby increasing sediment trap efficiencies. Since there are no dams on the river between DePere and Green Bay, the effective sediment trap efficiency for this reach may be much lower than estimated.

Given the total external load of solids to the river, these sediment trap efficiency estimates were used to infer a net burial rate. As estimated from the results of TM2a (FWB2000, 1998), TM2c (LTI, 1999b), TM2d (WDNR, 1999a), and TM3a (WDNR, 2001a), the average total solids load to the Lower Fox River for the period 1989-1995 was approximately 146,000 MT/year. With this total load and an overall sediment trap efficiency estimate of roughly 10-20%, approximately 14,600-29,200 MT of sediment would be added to the sediment bed annually. Given the total surface area of all deposits and SMUs (1.19×10^7 m^2) and the average bulk density of sediments in those areas (5.96×10^6 g/m^3), this corresponds to a net burial rate of approximately 0.21-0.42 cm/year. This is in rough agreement with the estimated net burial rate of 0.35 cm/year for the river navigation channel between the DePere and Fort James (Georgia Pacific) turning basins. This is also within the bounds of the net burial rate inference of 0.2 to 1.4 cm/year derived from the depth of maximum PCB concentrations in the sediment column and indexed to 1989-1995 conditions.

Beyond these aspects of model development, it is important to understand how the observations and model results used to assess model performance were interpreted. Successful application of a metric depends on how closely the interpretation of field data represent the true condition of the river as well as whether the spatial and temporal scale of observations and model results are comparable.

Interpretation of water column observations is usually straightforward. For PCBs and associated solids measurements, samples were often collected using an equal width increment (EWI) approach. EWI observations were generally collected from six locations for each sampled cross section (one sub-sample from each of two depths at each of three locations across the river width) and combined to form a single composite sample. Given this sample collection approach, it is reasonable to expect that water column observations provide a good indication of average river conditions at the monitoring stations. This usually permits direct comparisons between observations and model results. However, at the river mouth interpretation of observations can be more difficult. In response to varying seiche conditions, samples collected at the river mouth station can reflect conditions in Green Bay rather than the river. For data collected at the river mouth as part of the GBMBS, it was possible to develop an adjustment to account for this (see Velleux, 1994; Velleux and Endicott, 1994). Unfortunately, for data collected at the river mouth as part of the LMMBS, it was not possible to develop such an adjustment.

Interpretation of sediment observations is generally not straightforward. Representative sediment conditions are often difficult to accurately determine from observations. Sediment observations generally describe conditions only at individual points or along a line. However, sediment bed conditions are highly heterogeneous. As described in TM2e (WDNR, 1999b) and TM2g (WDNR, 1999c) and noted in Section 4.2.2.1, sediment bed conditions show tremendous point-to-point and station-to-station variability. Extrapolation between distant locations neglects this variability. Sediment condition estimates for large areas may be highly uncertain and may be inaccurate when derived from conditions at distant individual points or lines. Therefore, the accuracy of sediment bed condition estimates will directly depend on the spatial variability of bed elevations between individual points or lines from which an estimate was developed. In contrast, model results represent average conditions over broad areas. As a consequence, it is difficult to make meaningful quantitative comparisons between estimated sediment conditions and model results in a direct manner.

5.0 MODEL APPLICATION: FORECAST SIMULATIONS

5.1 FORECAST OVERVIEW

To explore the possible response of the river to different sediment conditions, the calibrated wLFRM was applied to generate a series of eight long-term forecast (future projection) simulations. The forecast simulation period was 100 years in length. For this 100-year period, model conditions for flows and loads were each comprised of a 25-year cycle that was repeated four times. Flows, solids loads and boundary conditions, PCB loads and boundary conditions, sediment transport, and PCB mass transfer processes for each forecast were parameterized as described in Chapter 3. Also as described in Chapter 3, watershed and point source PCB loads to the river were assumed to be zero after the first 25-year cycle of all forecasts. Different sediment PCB initial conditions were used for each forecast. Each set of PCB initial conditions represents a different action level for managing PCBs in the river sediments. Action levels and development of forecast sediment PCB initial conditions are described in Section 5.2.

5.2 ACTION LEVELS AND SEDIMENT BED PROPERTY INITIAL CONDITIONS

Eight forecast simulations were developed. Each simulation uses a different set of sediment bed PCB initial conditions. Each set of initial conditions represents a different action level for managing PCBs in the river sediments. For simplicity, each action level represents a specific management goal and was expressed as a categorical maximum sediment PCB concentration limit for each reach of the river. Larger action level values indicate that greater PCB mass inventories and contaminated sediment volumes are within the river. Smaller action level values indicate that lesser PCB inventories and contaminated sediment volumes exist. Six action levels were explored: no action (no change to initial conditions; no action level applied), 5000 µg/kg, 1000 µg/kg, 500 µg/kg, 250 µg/kg, and 125 µg/kg (1 mg/kg = 1000 µg/kg). A summary of model forecast simulation action levels and initial sediment conditions is presented in Table 5-1.

The basic set of sediment bed PCB initial conditions was developed from PCB concentration data as described in TM2e (WDNR, 1999b). Beyond those data, PCB concentration observations collected on behalf of the FRG (BBL, 1999) and additional samples collected by WDNR and contractors in 1998 were also considered. Sediment bed PCB initial conditions were then established using the interpolation method summarized by WDNR (2000a). This method is similar to the procedure presented in TM2e (WDNR, 1999b) with additional steps to aggregate data by the year of sample collection. These additional steps were used to account for any potential temporal trends in sediment PCB concentrations. In sediment areas where samples from more than one time group were located, those samples from the most recent time group were used to establish initial conditions. A summary of this sediment PCB initial condition interpolation method is presented by WDNR (2000a). Note that the basic set of conditions was developed for the case of minimum extent of PCB contamination (see TM2e for a description).

The basic set of sediment bed PCB initial conditions for forecasts represents a no action state. No action means that no active management efforts (such as removal or isolation) are implemented

Table 5-1. Summary of forecast simulation action levels and sediment conditions.

Forecast	*Action Level(s)*	*Reach*	*Surface Area of Sediment Affected by Action Level (m^2)*[17]	*Volume of Sediment Affected by Action Level (m^3)*	*Average Initial Sediment PCB Concentration (0-10 cm) (μg/kg)*
No action	None (no action level) (all reaches)	1 2 3 4	0.00E+00 0.00E+00 0.00E+00 0.00E+00	0.00E+00 0.00E+00 0.00E+00 0.00E+00	3628 1190 2186 3087
5000	5000 μg/kg (all reaches)	1 2 3 4	1.51E+06 7.64E+05 6.18E+05 4.25E+06	2.19E+05 1.77E+04 1.48E+05 4.15E+06	2502 669 1211 1546
1000	1000 μg/kg (all reaches)	1 2 3 4	3.86E+06 1.65E+06 1.39E+06 4.45E+06	6.81E+05 1.04E+05 4.86E+05 4.30E+06	464 388 555 508
500	500 μg/kg (all reaches)	1 2 3 4	4.41E+06 2.92E+06 2.97E+06 4.49E+06	7.26E+05 1.32E+05 6.23E+05 4.31E+06	278 232 208 281
250	250 μg/kg (all reaches)	1 2 3 4	4.41E+06 3.90E+06 3.35E+06 4.49E+06	1.19E+06 2.09E+05 8.98E+05 4.36E+06	123 131 156 165
125	125 μg/kg (all reaches)	1 2 3 4	4.41E+06 4.74E+06 3.35E+06 4.49E+06	1.38E+06 4.91E+05 1.03E+06 4.40E+06	91 96 93 84
H	500 μg/kg No action 250 μg/kg 250 μg/kg	1 2 3 4	4.41E+06 0.00E+00 3.35E+06 4.49E+06	7.26E+05 0.00E+00 8.98E+05 4.36E+06	278 1190 156 165
I	1000 μg/kg No action 500 μg/kg 500 μg/kg	1 2 3 4	3.86E+06 0.00E+00 2.97E+06 4.49E+06	6.81E+05 0.00E+00 6.23E+05 4.31E+06	464 1190 208 281

[17] Values presented indicate the total surface area at the initial sediment-water interface of sediment stacks affected by the listed action level. Note that sediment surface areas generally decrease with depth below the sediment-water interface.

to alter sediment PCB levels. No action is sometimes described as natural recovery. Application of an action level represents a modification to the basic set of sediment PCB initial conditions such that the maximum PCB concentration within a sediment stack does not exceed the action level for that river reach. This results in a reorganization of the vertical structure of each affected sediment stack. A summary of the basic set of sediment bed PCB initial conditions for long-term (future) forecast simulations is presented in Appendix C.

In addition to sediment PCB initial conditions, the physical properties of the sediment bed must also be defined. As described in Section 3.5.5, for all forecast simulations the physical properties of the sediment bed (bulk density, grain size distribution, etc.) were assumed to equal those defined in TM2e for the short-term simulation period. Again note that application of an action level modifies the basic sediment initial conditions and results in a reorganization of the vertical structure of affected sediment stacks. A summary of the physical properties of the sediment bed, organized for the no action forecast, is presented in Appendix A.

5.3 FORECAST SIMULATION RESULTS

The model forecast period was 100 years. Results for this period are presented for each of the eight forecast simulations for each river reach. The results presented are PCB export (transport) at the downstream limit of the reach, reach average dissolved and particulate water column PCB concentrations, and reach average surface sediment (0-10 cm) PCB concentrations. Results, grouped by reach, are presented in Figures 5-1 through 5-4 (Reach 1), 5-5 through 5-8 (Reach 2), Figures 5-9 through 5-12 (Reach 3), and 5-13 through 5-16 (Reach 4).[18]

Over time, water column and sediment PCB concentrations decrease for all cases. This is an expected result since, in the absence PCB inputs from point source discharges, the surrounding watershed or the atmosphere, the PCB inventory of river surface sediments decreases by dilution and dispersal. Relative differences in forecast simulation results are nonetheless clearly present. Compared to all other cases, the no action simulation has the greatest PCB concentrations and cumulative export to Green Bay over time. Note that as action levels decrease, the differences between simulation results for each action level increase relative to the no action simulation. The level of relative reduction is a reflection of decreased sediment PCB initial conditions for each case. Also note that at the lowest action levels, which represent larger sediment management efforts, the relative decrease in PCB concentration and export between cases becomes smaller. For example, the difference between the 250 and 125 µg/kg cases is smaller than the difference between the 500 and 250 µg/kg cases. The relative difference between the 250 and 125 µg/kg cases is comparatively small since the average reduction in initial surface sediment PCB concentrations is small (93% versus 95% reduction). A summary of the relative reductions in forecast simulation results is presented in Table 5-2.

[18] Several of the results presented appear anomalous. For example, the apparent increase in surface sediment PCB concentration for the “H” action level is unexpected. This may be attributable to an error in sediment PCB initial conditions specified for this simulation. Inquiries into this situation are underway. If any errors are identified, forecast simulation results may be revised if any differences would affect management decisions for the site.

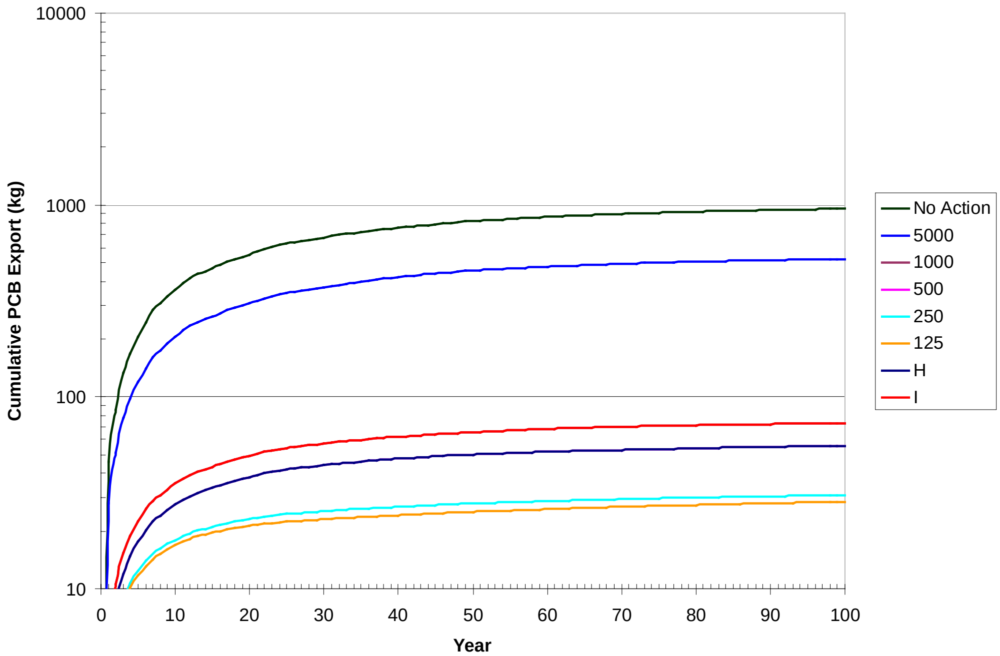

Figure 5—1. Projected long-term cumulative PCB export: Reach 1.

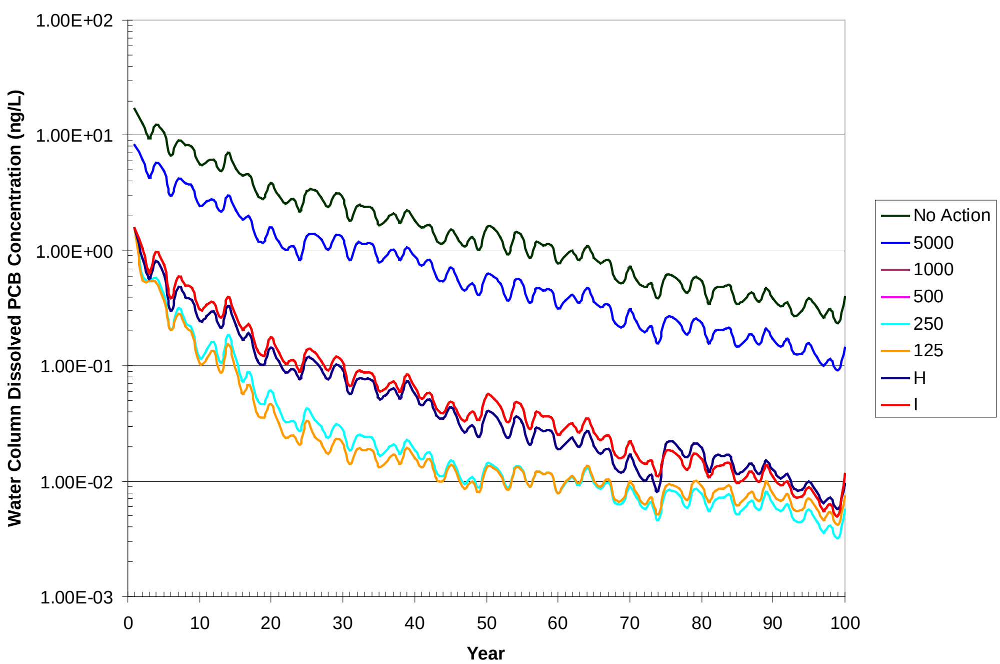

Figure 5—2. Projected long-term water column dissolved PCB concentrations: Reach 1.

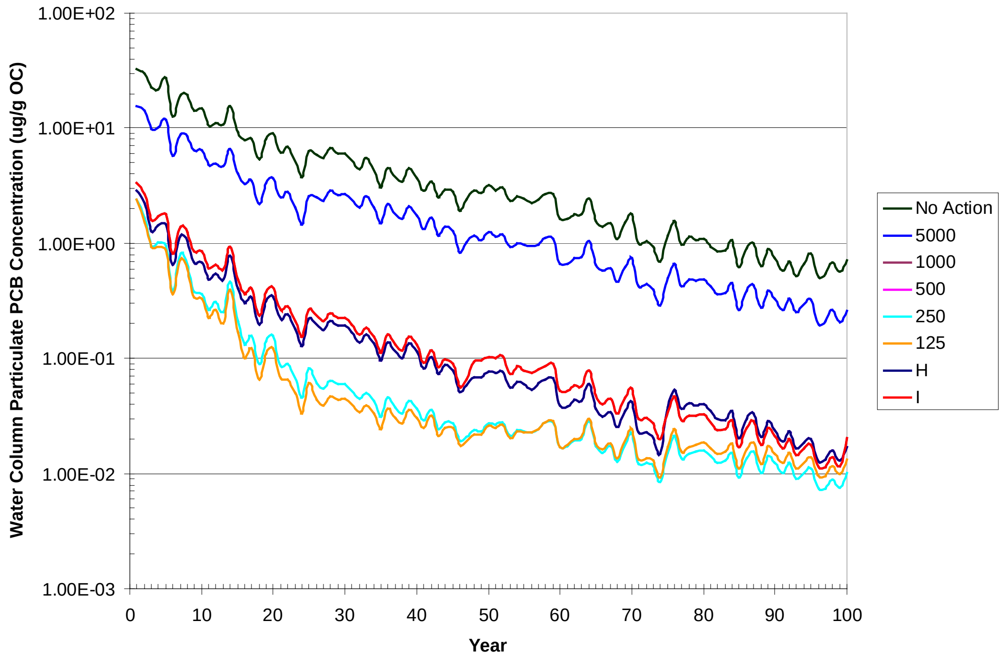

Figure 5—3. Projected long-term water column particulate PCB concentrations: Reach 1.

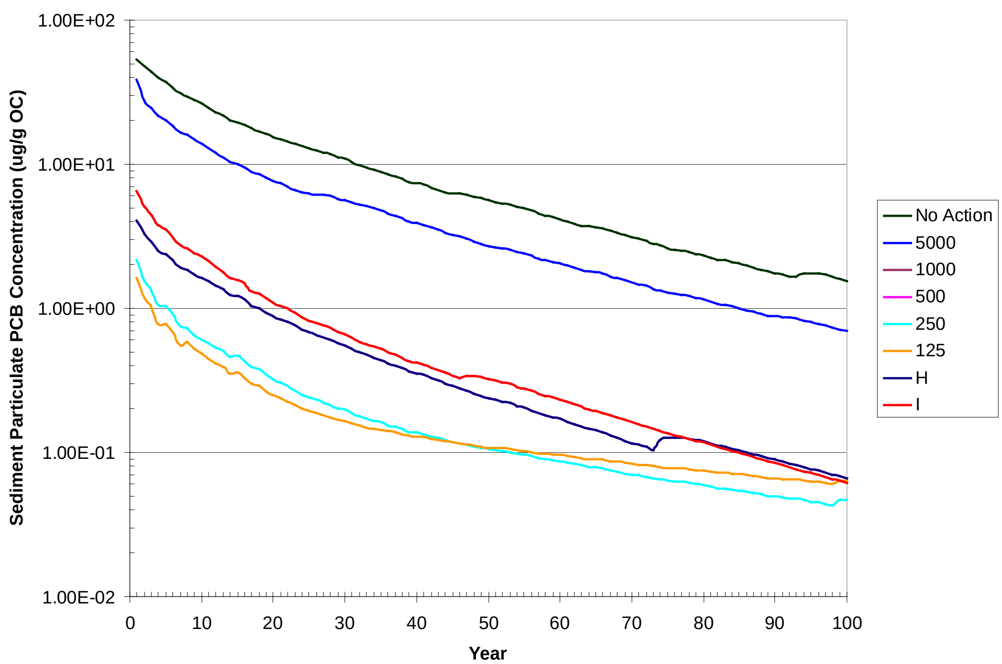

Figure 5—4. Projected long-term sediment particulate PCB concentrations: Reach 1.

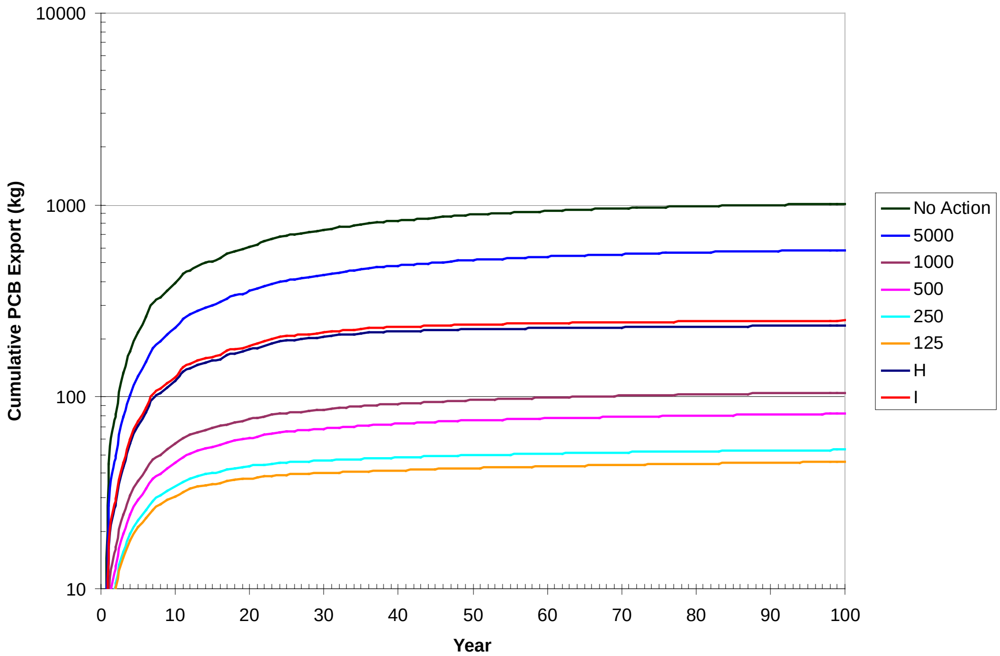

Figure 5—5. Projected long-term cumulative PCB export: Reach 2.

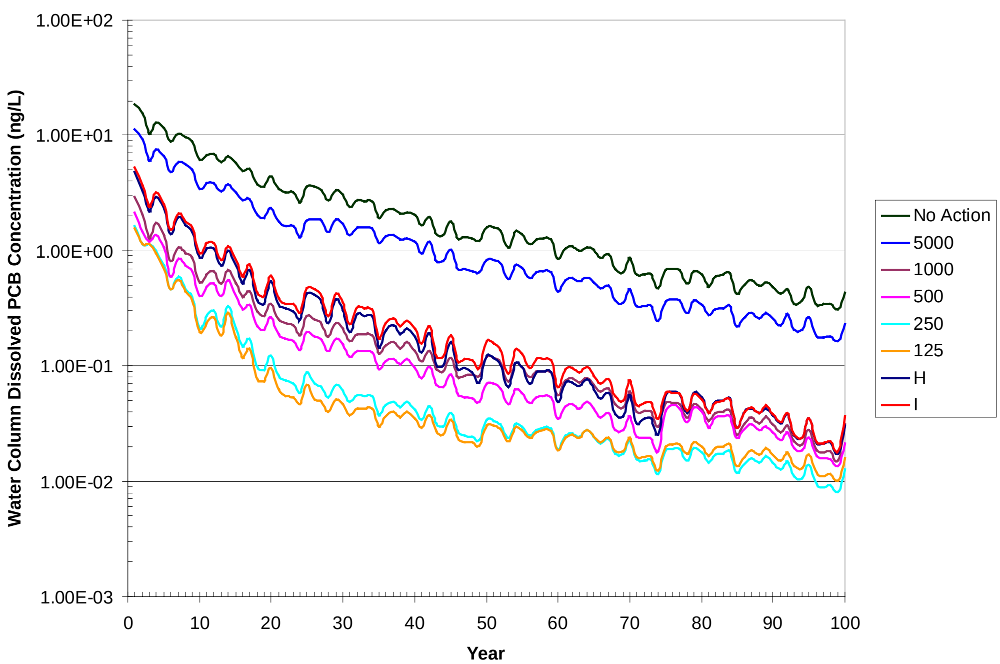

Figure 5—6. Projected long-term water column dissolved PCB concentrations: Reach 2.

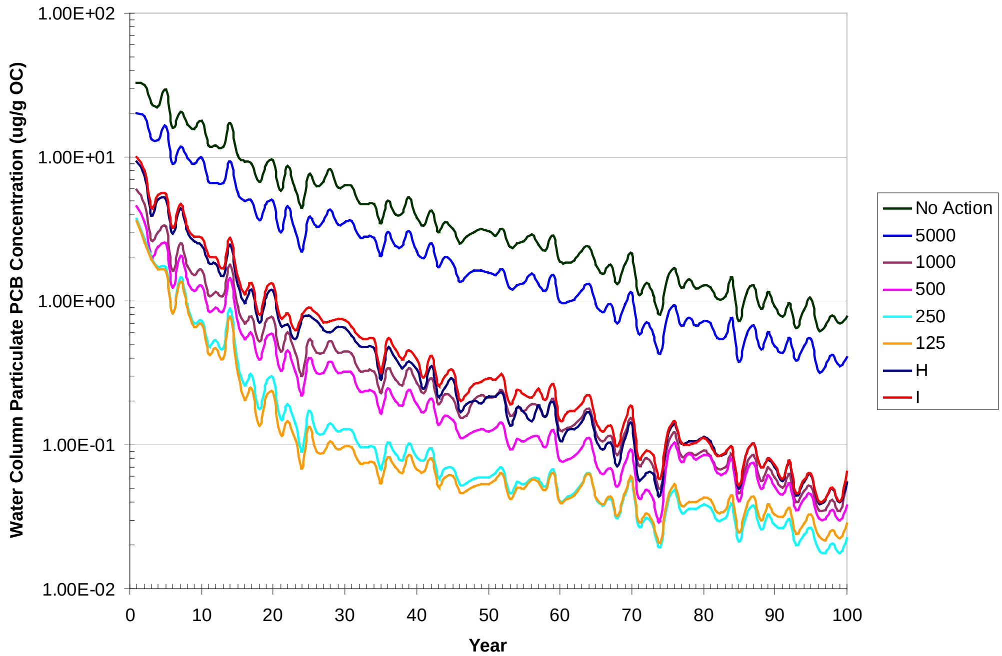

Figure 5—7. Projected long-term water column particulate PCB concentrations: Reach 2.

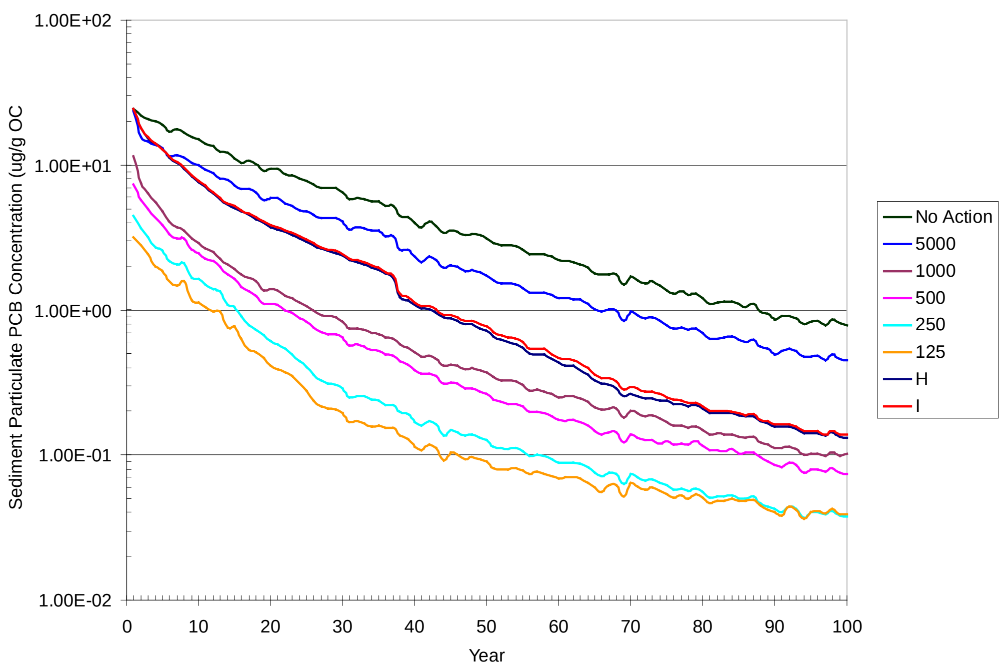

Figure 5—8. Projected long-term sediment particulate PCB concentrations: Reach 2.

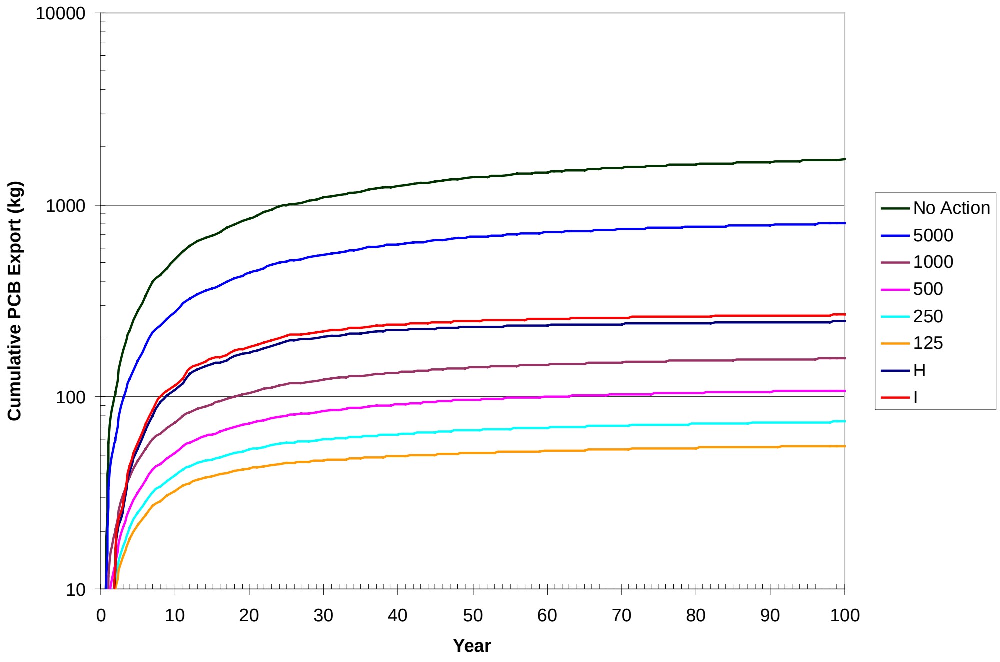

Figure 5—9. Projected long-term cumulative PCB export: Reach 3.

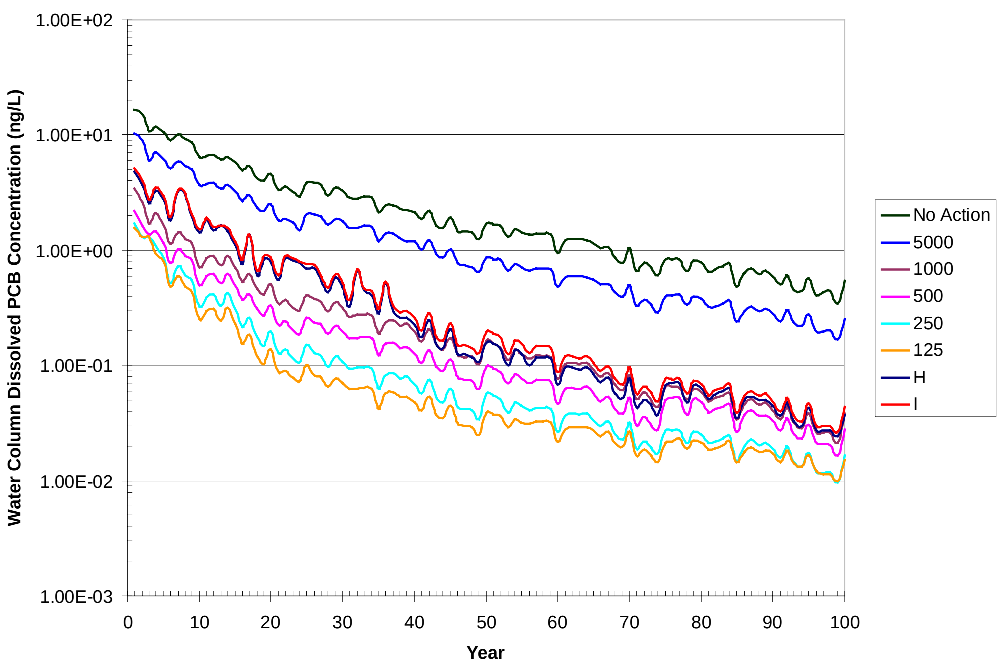

Figure 5—10. Projected long-term water column dissolved PCB concentrations: Reach 3.

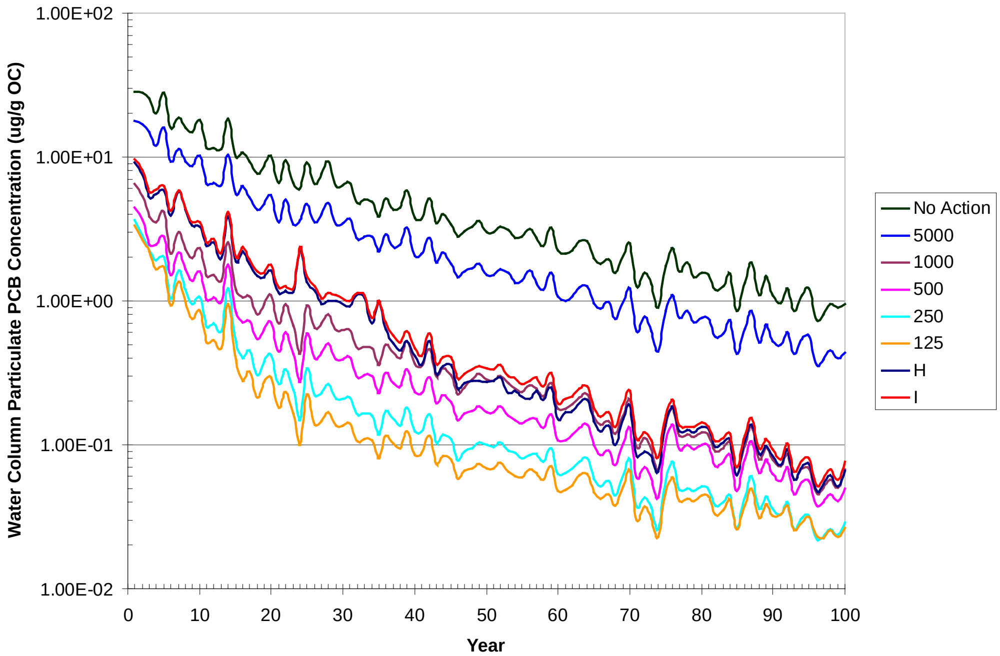

Figure 5—11. Projected long-term water column particulate PCB concentrations: Reach 3.

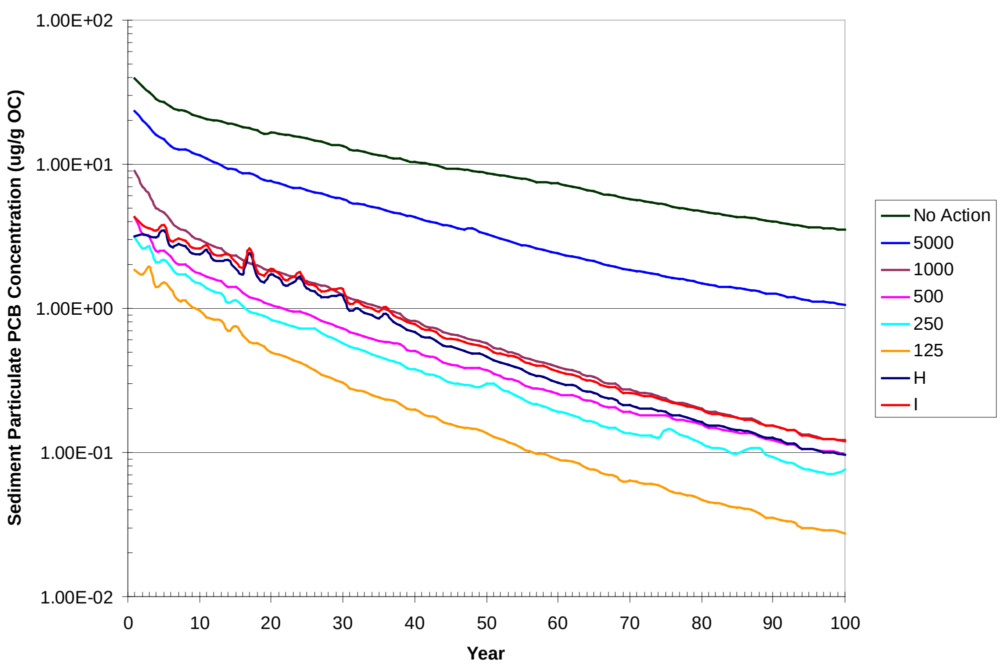

Figure 5—12. Projected long-term sediment particulate PCB concentrations: Reach 3.

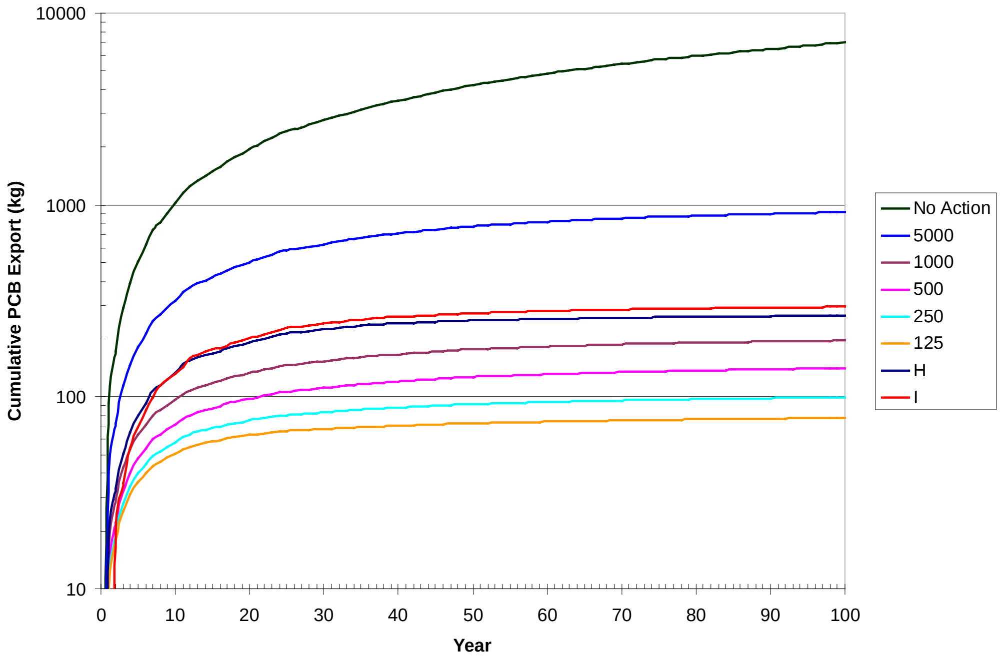

Figure 5—13. Projected long-term cumulative PCB export (to Green Bay): Reach 4.

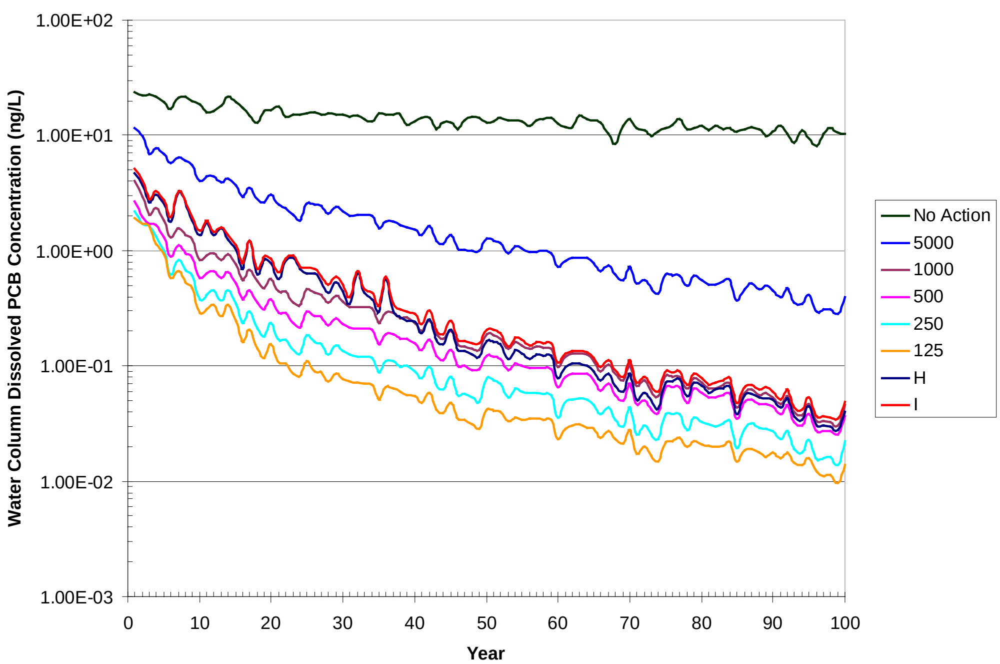

Figure 5—14. Projected long-term water column dissolved PCB concentrations: Reach 4.

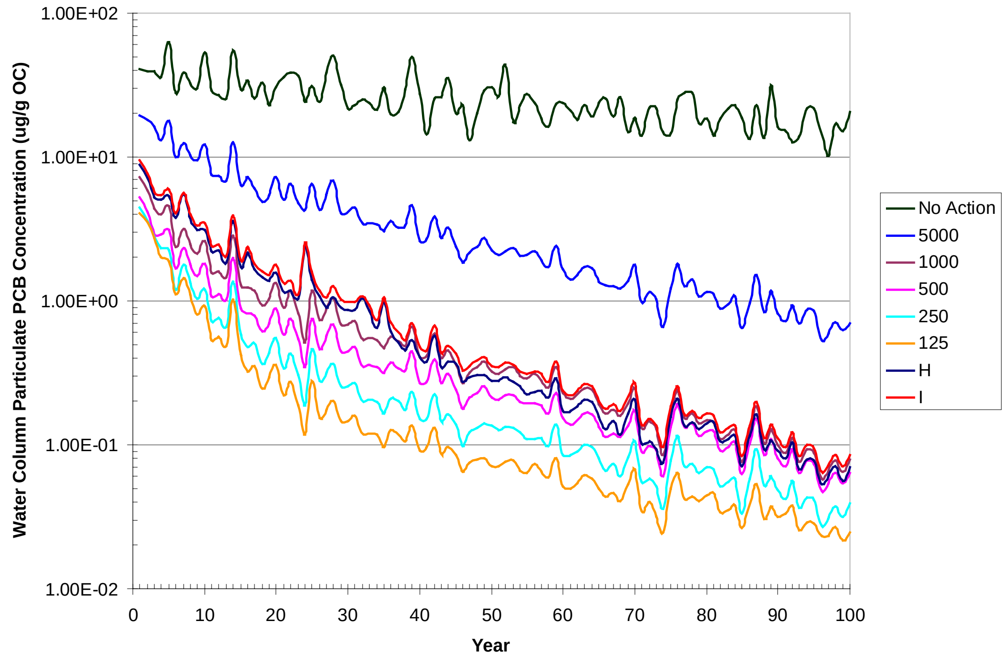

Figure 5—15. Projected long-term water column particulate PCB concentrations: Reach 4.

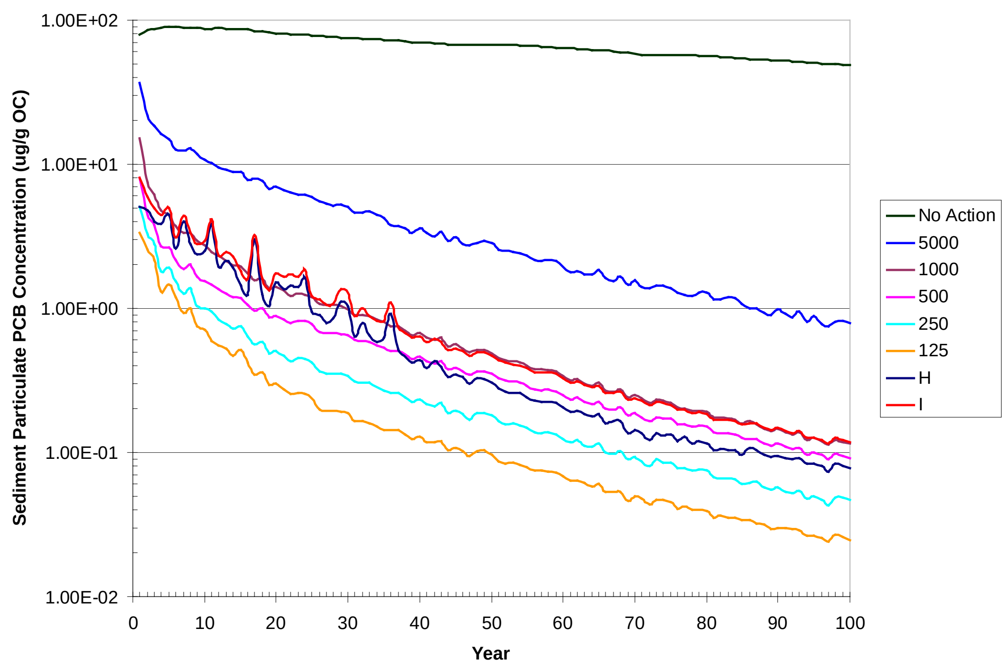

Figure 5—16. Projected long-term sediment particulate PCB concentrations: Reach 4.

Table 5-2. Relative reductions of forecast simulation conditions compared to no action case.

Forecast	*Reach*	*Reduction in Average Surface Sediment PCB Concentration Initial Conditions (0-10 cm) (%)*	*Reduction in Average Water Total PCB Concentration During Last 10-Years Of Simulation (%)*	*Reduction in Average Surface Sediment PCB Concentration During Last 10-Years Of Simulation (0-10 cm) (%)*	*Reduction in Cumulative PCB Transport/Export at Simulation End (%)*
No action	1 2 3 4	0 0 0 0	0 0 0 0	0 0 0 0	0 0 0 0
5000	1 2 3 4	31.0 43.8 44.6 49.9	46.5 46.0 65.0 96.4	52.8 41.6 69.3 98.6	45.2 45.5 53.4 86.8
1000	1 2 3 4	87.2 67.4 74.6 83.5	95.2 93.3 96.0 99.6	95.7 85.7 96.5 99.8	92.4 89.6 90.8 97.2
500	1 2 3 4	92.3 80.5 90.5 90.9	95.4 94.5 96.8 99.6	95.4 89.2 97.2 99.8	94.2 91.9 93.7 98.0
250	1 2 3 4	96.6 89.0 92.9 94.6	97.3 96.9 98.0 99.8	97.2 94.7 97.9 99.9	96.8 94.8 95.7 98.6
125	1 2 3 4	97.5 91.9 95.8 97.3	96.6 96.4 98.6 99.9	96.2 94.9 99.2 > 99.9	97.0 95.5 96.8 98.9
H	1 2 3 4	92.3 0 92.9 94.6	95.4 91.7 96.2 99.6	95.4 80.0 97.2 99.9	94.2 76.8 85.7 96.2
I	1 2 3 4	87.2 0 90.5 90.9	95.2 91.4 95.6 99.5	95.7 79.2 96.5 99.8	92.4 75.4 84.4 95.8

6.0 CONCLUSIONS

The following conclusions regarding wLFRM development and application are offered:

1. The wLFRM was developed from the results of the Model Evaluation Workgroup (MEW) that was formed in collaboration with the Fox River Group (FRG) of Companies on the basis of a January 31, 1997 Agreement. The MEW prepared a series of technical reports that define values for the most critical model features such as flows, loads, initial conditions, boundary conditions, and sediment transport. The MEW reports listed in Table 2-1 represent the most detailed description possible of pertinent river conditions using existing data and provided the majority of the information necessary for model development.

2. The FRG initiated a peer review of model performance that was managed by the American Geological Institute. To the greatest extent practical, peer review panel recommendations were integrated into wLFRM development efforts.

3. The wLFRM describes PCB transport in all 39 miles of the Lower Fox River from Lake Winnebago to the river mouth at Green Bay in a single spatial domain. All simulations were performed using the IPX 2.7.4 framework (Velleux et al. 2000). Solids were treated as three state variables throughout the model spatial domain. This approach is consistent with peer review recommendations.

4. Model performance was evaluated according to the metrics identified in Technical Memorandum 1 (LTI and WDNR, 1998), a MEW work product. When making comparisons, it is important to understand how the observations and model results used to assess model performance were interpreted. Successful application of a metric depends on how closely the interpretation of field data represent the true condition of the river as well as whether the spatial and temporal scale of observations and model results are comparable. For the water column, interpretation of observations was straightforward and permitted direct comparison of observed values and model results. However, interpretation of sediment observations was not straightforward. Representative sediment conditions applicable to broad areas were difficult to accurately determine from observations at individual points or along a line. For the water column, the relative difference between observed solids and PCB concentrations and model results was within ±30%. Relative differences for the sediment column were much larger. Nonetheless, the wLFRM was able to capture the trend and magnitude of inferred PCB concentration changes over time in surface sediments. Given these considerations, the wLFRM calibration was judged to adequately meet the criteria identified in Technical Memorandum 1.

5. The most critical features of the site are the origin of PCBs from river sediments and the general trend and magnitude of PCB concentrations in river water. As demonstrated by the results of field sampling efforts, the only significant present-day source of PCBs to Lower Fox River is the river sediments. PCB concentrations in river water are essentially zero at the upstream boundary with Lake Winnebago and increase to an average of more than 50 ng/L at

the river mouth. The wLFRM reproduces the sediment origin of PCBs as well as the trend and magnitude of PCB concentrations in the water column.

6. In consideration of model performance strengths and limitations, the wLFRM calibration was considered to provide a reasonable description of PCB concentrations and export in the Lower Fox River on a year-by-year, reach-by-reach basis. The best use of this model may therefore be as an indicator of the relative trend and magnitude of PCBs concentrations and export. In this context, year-by-year, reach-by-reach resolution of this model was considered sufficient to meet overall project goals.

7. The wLFRM was used to prepare long-term projections of the trend and magnitude of PCB concentrations in the river for a range of different sediment management cases. Over time, water column and sediment PCB concentrations decrease for all cases. This is an expected result since, without significant PCB inputs from point source discharges, the surrounding watershed, or the atmosphere, the PCB inventory of river surface sediments will decrease by dilution and dispersal.

8. Relative differences in forecast simulation results are clearly present. Compared to all other cases, the no action simulation has the greatest PCB concentrations and cumulative export to Green Bay over time. Note that as action levels decrease, the differences between simulation results for each action level increase relative to the no action simulation. The level of relative reduction is a reflection of decreased sediment PCB initial conditions for each case. Also note that at the lowest action levels, which represent larger sediment management efforts, the relative decrease in PCB concentration and export between cases becomes smaller. For example, the difference between the 250 and 125 μg/kg cases is smaller than the difference between the 500 and 250 μg/kg cases. The relative difference between the 250 and 125 μg/kg cases is comparatively small since the average reduction in initial surface sediment PCB concentrations is small (93% versus 95% reduction). A summary of the relative reductions in forecast simulation results was presented in Table 5-2.

7.0 REFERENCES

AGI. 2000. Peer Review of Models Predicting the Fate and Export of PCBs in the Lower Fox River below the DePere Dam: A Report of the Lower Fox River Fate and Transport Peer Review Panel. J.C. Tracy and C.M. Keane, editors. American Geological Institute, Alexandria, Virginia. 88 pp.

Arnold, J. G., Williams, J. R., Nicks, A. D., and Sammons, N. B. 1990. SWRRB: A Basin Scale Simulation Model for Soil and Water Resources Management. Texas A&M University Press, College Station, Texas. First edition.

Baird. 2000a. Technical Memorandum 5b: ECOM-siz-SEDZL Model Application: Lower Fox River Downstream of the DePere Dam. W.F. Baird and Associates, Ltd., Madison, Wisconsin. 41 pp. plus figures and appendices.

Baird. 2000b. ECOMSED Model Application: Upstream Lower Fox River from Lake Winnebago to DePere Dam. W.F. Baird and Associates, Ltd., Madison, Wisconsin.

Bannerman, R.T, A.D. Legg, and S.R. Greb. 1996. Quality of Wisconsin Stormwater, 1989-94. U.S. Geological Survey Open-File Report 96-458. U.S. Geological Survey, Madison, Wisconsin.

Barfield, B. J, Warner, R. C., and Haan, C. T. 1981. Applied Hydrology and Sedimentology for Disturbed Areas. Oklahoma Technical Press, Stillwater, Oklahoma. Fourth Printing, 1987.

BBL. 1999. Analytical Data Summary Tables: 1998 NRDA Fox River Sampling Program. Blasland, Bouck, and Lee, Inc. Syracuse, New York. January 28.

Bierman, V.J., Jr., J.V. DePinto, T.C. Young, P.W. Rodgers, S.C. Martin and R. Raghunathan. 1992. Development and Validation of an Integrated Exposure Model for Toxic Chemicals in Green Bay, Lake Michigan. U.S. Environmental Protection Agency, Large Lakes and Rivers Research Branch, Grosse Ile, Michigan. 265 pp. plus appendices.

Brune, G.M. 1953. Trap efficiency of reservoirs. Transactions of the American Geophysical Union, 34(3):407-418.

Burban, P.Y., Y. Xu, and W. Lick. 1990. Settling speeds of flocs in fresh and sea waters. Journal of Geophysical Research, 95(C10):18213-18220.

Burkhard, L., D. Armstrong, and A. Andren. Henry's Law constants for the polychlorinated biphenyls. Environmental Science and Technology, 19(7):590-596. Supplemental material.

Capel, P. and S. Eisenriech, S. 1990.Relationship between chlorinated hydrocarbons and organic carbon in sediment and porewater. Journal of Great Lakes Research, 16(2):245-257.

Chapra, S.C. 1997. Surface Water-Quality Modeling. McGraw-Hill Companies, Inc. New York, New York.

Connolly, J.P.; Parkerton, T.F.; Quadrini, J.D., Taylor, S.T., Thumann, A.J. 1992. Development and Application of a Model of PCBs in the Green Bay, Lake Michigan Walleye and Brown Trout and Their Food Webs. Environmental Engineering and Science Program, Manhattan College, Riverdale, New York. October 2, 1992.

Dendy, F.E. 1974. Sediment trap efficiency of small reservoirs. Transactions of the American Society of Agricultural Engineers, 17(5):898-908.

DePinto, J.V., R. Raghunathan, P. Sierzenga, X. Zhang, V. J. Bierman, Jr., P.W. Rodgers, and T.C. Young. 1993. Recalibration of GBTOX: An Integrated Exposure Model For Toxic Chemicals in Green Bay, Lake Michigan. U.S. Environmental Protection Agency, Large Lakes and Rivers Research Branch, Grosse Ile, Michigan. December 31. Cooperative Agreement No. CR-818560. 136 pp.

DiToro, D. 1985. A particle interaction model of reversible organic chemical sorption. Chemosphere, 14(9-10):1503-1538.

Dolan, D., D. Endicott, A. H. El-Shaarawi, and K. Freeman. 1993. "Estimation of Replacement Values for Censored Data in Green Bay Point Sources," 36th Conference of the International Association for Great Lakes Research, St. Norbert College, DePere, Wisconsin. June 4-10, 1993.

Eadie, B., N. Morehead, and P. Landrum. 1990. Three-phase partitioning of hydrophobic organic compounds in Great Lakes waters. Chemosphere, 20(1-2):161-178.

Eadie, B., N. Morehead, V. Klump, and P. Landrum. 1992. Distribution of hydrophobic organic compounds between dissolved and particulate organic matter in Green Bay waters. Journal of Great Lakes Research, 18(1):91-97.

Edington, D.W. and A.W. Andren. 1992. Data obtained as part of the Green Bay Mass Balance Study sampling program.

Fisher, H., E. List, R. Koh, J. Imberger, and N. Brooks. 1979. Mixing in inland and coastal waters. Academic Press, New York, New York. 483 pp.

Fitzgerald, S.A., J.V. Klump, P.W. Swarzenski, R.A. Mackenzie, and K.D. Richards. 2001. Beryllium-7 as a tracer of short-term sediment deposition and resuspension in the Fox River, Wisconsin. Environmental Science and Technology, 35(2):300-305.

FWB2000. 1998. Technical memorandum 2a: Simulation of Historical and Projected Total Suspended Solids Loads and Flows to the Lower Fox River, N.E. Wisconsin, with the Soil and Water Assessment Tool (SWAT). Fox-Wolf Basin 2000, Appleton, Wisconsin. August 18.

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(4):479-494.

Greb, S. R., and Bannerman, R. T. 1997. Influence of particle on wet pond effectiveness. Water Environment Research, 69(6)1134-1138.

Gustin, M-P. 1995. Source, Transport and Fate of Sediments and Nutrients in the Winnebago Pool System. Ph.D. dissertation. University of Wisconsin-Milwaukee, Milwaukee, Wisconsin. August.

Grace Analytical. 1996. Transmittal Memorandum: Final Evaluation of Ultra PE Ampule Results, Organic PE Study #1. Memorandum from Marcia A. Kuehl, LMMB Organic QC Coordinator. Grace Analytical. December 5.

HQI. 1995. Addendum to Green Bay Final Report: Food Chain Model Projections. Prepared for U.S. Environmental Protection Agency, Grosse Ille, MI, by HydroQual, Inc., Mahwah, NJ.

HQI. 1999. Hydrodynamics, Sediment Transport, and Sorbent Dynamics in Green Bay. Prepared for Remediation Technologies, Inc. and the Wisconsin Department of Natural Resources. HydroQual, Inc., Mahwah, NJ. Project Number: RTCH0010.

HQI. 2000. Technical Memorandum 5c: Evaluation of the Hydrodynamics in the Lower Fox River Between Lake Winnebago and DePere, WI. Hydroqual, Inc., Mahwah, New Jersey.

Killian, J. 1999. Analysis of COE Sounding Data at 56/57. Memorandum to Greg Hill, Mark Velleux, and Bob Paulson. Wisconsin Department of Natural Resources, Madison, Wisconsin. September 27.

Kuehl, M. 1999. Technical Memorandum: Congener Standards Comparison for Deposit N Project. Memorandum from Marcia A. Kuehl. MAKuehl Company. August 30.

Landrum, P., M. Rheinhold, S. Nihart, and B. Eadie. 1985. Predicting bioavailability of xenobiotics to Pontoporeia Hoya in the presence of humic and fulvic materials and natural dissolved organic matter. Environmental Toxicology and Chemistry, 4(4):459-467.

Landrum, P., S. Nihart, B. Eadie, and Herche L. 1987. Reduction in bioavailability of organic contaminants to the amphipod Pontoporeia Hoya by dissolved organic matter of sediment interstitial waters. Environmental Toxicology and Chemistry, 6(1):11-20.

Lick, W., J. McNeil, Y.J. Xu, and C. Taylor. 1995. Measurement of the Resuspension and Erosion of Sediments in Rivers. Department of Mechanical Engineering, University of California - Santa Barbara, Santa Barbara, California. June 2.

LTI and WDNR. 1998. Technical Memorandum 1: Model Evaluation Metrics. Limno-Tech Inc., Ann Arbor, Michigan and Wisconsin Department of Natural Resources, Madison, Wisconsin. March 13.

LTI. 1999a. Technical Memorandum 2b: Computation of Watershed Solids and PCB Load Estimates for Green Bay. Limno-Tech Inc., Ann Arbor, Michigan. January 6.

LTI. 1999b. Technical Memorandum 2c: Computation of Internal Solids Loads in Green Bay and the Lower Fox River. Limno-Tech, Inc., Ann Arbor, Michigan. February 12.

Martin, S.C., Hinz, S.C., Rodgers, P.W., Bierman, V.J., Jr., DePinto, J.V., and Young, T.C. 1995. Calibration of a hydraulic transport model for Green Bay, Lake Michigan. Journal of Great Lakes Research, 21(4):599-609.

McCall, P.L. and M.J.S. Tevesz. 1982. The effects of benthos on physical properties of freshwater sediments. In: Animal-Sediment Relations: The Biogenic Alteration of Sediments. Eds. P.L. McCall and M.J.S. Tevesz. Plenum Press, New York.

OSI. 1998. Remote sensing survey, Lower Fox River, Neenah-Green Bay, Wisconsin. Ocean Surveys, Inc., Old Saybrook, CT. September.

QEA. 1999. PCBs in the Upper Hudson River, Volume 2: A model of PCB Fate, Transport, and Bioaccumulation. Prepared for General Electric, Albany, New York. Prepared by Quantitative Environmental Analysis, LLC, Montvale, New Jersey. Job Number GENhud:131. May.

Raghunathan, R.K. 1990. Development of a Dynamic Mass Balance Model for PCBs in Green Bay. M.S. Thesis. Department of Civil and Environmental Engineering, Clarkson University, Potsdam, New York.

Raghunathan, R.K. 1994. The Development and Calibration of a Coupled Sorbent-Toxics Model for PCBs in Green Bay, Lake Michigan. Ph.D. dissertation. Department of Civil and Environmental Engineering, State University of New York at Buffalo, Buffalo, New York.

Rhoads, D.C. and Boyer, L.F. 1982. The effects of marine benthos on physical properties of sediments: a seasonal perspective. In: Animal-Sediment Relations: The Biogenic Alteration of Sediments. Eds. P.L. McCall and M.J.S. Tevesz. Plenum Press, New York.

Steuer, J., S. Jaeger, and D. Patterson. 1995. A Deterministic PCB Transport Model for the Lower Fox River between Lake Winnebago and DePere, Wisconsin. Wisconsin Department of Natural Resources, PUBL WR 389-95.

Swackhammer, D. and D. Armstrong. 1987. Distribution and characterization of PCBs in Lake Michigan water. Journal of Great Lakes Research, 13(1):24-37.

Tateya, S., S. Tanabe, and R. Tatsukawa. 1988. PCBs on the globe: possible trend of future levels in the open ocean environment. In: Toxic Contamination in Large Lakes, Volume III. Ed, Schmidtke, N. pp. 237-282. Lewis Publishers, Inc., Chelsea, Michigan.

Tsai, C.H. and W. Lick. 1987. Resuspension of sediments from Long Island Sound. Water Science Technology, 21(6/7):155-184.

Thomann, R.V. and J.A. Meuller. 1987. Principles of Surface Water Quality Modeling and Control. Harper and Row Publishers, Inc., New York, New York.

USDA. 1974. Soil Survey of Brown County, Wisconsin. U.S. Department of Agriculture, Soil Conservation Service, Washington, D. C. Issued: June, 1974.

USDA. 1978. Soil Survey of Outagamie County, Wisconsin. U.S. Department of Agriculture, Soil Conservation Service, Washington, D. C. Issued: November, 1978.

USDA. 1980a. Soil Survey of Calumet and Manitowoc Counties, Wisconsin. United States Department of Agriculture, Soil Conservation Service, Washington, D. C. Issued: February, 1980.

USDA. 1980b. Soil Survey of Winnebago County, Wisconsin. United States Department of Agriculture, Soil Conservation Service, Washington, D. C. Issued: May, 1980.

USEPA. 1989. Green Bay/Fox River Mass Balance Study. EPA-905/8-89/002. GLNPO Report No. 07-89. Prepared for the U.S. Environmental Protection Agency, Great Lakes National Program Office. Prepared by Science Applications International Corporation, McLean, Virginia.

USEPA. 1992a. Green Bay/Fox River Mass Balance Study: Preliminary Management Summary. Report prepared by Robert F. Beltran, U.S. Environmental Protection Agency, Great Lakes National Program Office, Chicago, Illinois. December 1992. 24 pp.

USEPA. 1992b. Addendum to Green Bay/Fox River Mass Balance Study: Preliminary Management Summary. Report prepared by William Richardson, Doug Endicott, and Dale Patterson for USEPA Great Lakes National Program Office, Chicago, IL. December, 1992. 31 pp.

USGS. 1990. Water Resources Data - Wisconsin, Water Year 1989. Report prepared by B. Holmstrom and R. Erickson. U.S. Geological Survey, Water Resources Division, Madison, Wisconsin. USGS/WRD/HD-90/298.

USGS. 1991. Water Resources Data - Wisconsin, Water Year 1990. Report prepared by B. Holmstrom, P. Kammerer, Jr., and R. Erickson. U.S. Geological Survey, Water Resources Division, Madison, Wisconsin. USGS/WRD/HD-91/292.

USGS. 1999. PCB loads from Lake Michigan tributaries: 1994-1995. Spreadsheet file prepared by D. Hall. U.S. Geological Survey, Water Resources Division, Madison, Wisconsin.

van Rijn, L.C. 1984a. Sediment transport, part I: bed load transport. ASCE Journal of Hydraulic Engineering, 110(10):1431-1456.

van Rijn, L.C. 1984b. Sediment transport, part I: suspended load transport. ASCE Journal of Hydraulic Engineering, 110(11):1612-1638.

Velleux, M. 1992. An Application of the Mass Balance Approach for Estimating the Export of In-Place Pollutants from Tributary Sources to Receiving Waterbodies. M.S. Thesis. Department of Civil and Environmental Engineering. Clarkson University, Potsdam, New York.

Velleux, M. and D. Endicott. 1994. Development of a Mass Balance Model for Estimating PCB Export from the Lower Fox River to Green Bay. J. Great Lakes Res. 20(2):416-434.

Velleux, M., D. Endicott, J. Steuer, S. Jaeger, and D. Patterson. 1995. Long-Term Simulation of PCB Export from the Fox River to Green Bay. J. Great Lakes Res. 21(3):359-372.

Velleux, M., J. Gailani and D. Endicott. 1996. Screening-level approach for estimating contaminant export from tributaries. ASCE Journal of Environmental Engineering, 122(6):503-514.

Velleux, M., S. Westenbroek, J. Ruppel, M. Settles, and D. Endicott. 2000. A User's Guide to IPX, the In-Place Pollutant Export Water Quality Modeling Framework, Version 2.7.4. U.S. Environmental Protection Agency, Office of Research and Development, National Health and Environmental Effects Research Laboratory, Mid-Continent Ecology Division, Large Lakes Research Station, Grosse Ile, Michigan. October 31. 179 pp.

Vreugdenhil, C.B. 1989. Computational Hydraulics: An Introduction. Springer-Verlag, New York. 182 pp.

WDNR. 1997. Polychlorinated Biphenyl (PCB) Contaminated Sediment in the Lower Fox River: Modeling Analysis of Selective Sediment Remediation. Wisconsin Department of Natural Resources, Bureau of Watershed Management, Madison, Wisconsin. PUBL-WT-482-97 (February, 1997).

WDNR. 1999a. Technical Memorandum 2d: Compilation and Estimation of Historical Discharges of Total Suspended Solids and PCB from Lower Fox River Point Sources. Wisconsin Department of Natural Resources, Madison, Wisconsin. February 23.

WDNR. 1999b. Technical Memorandum 2e: Estimation of Lower Fox River Sediment Bed Properties. Wisconsin Department of Natural Resources, Madison, Wisconsin. March 31.

WDNR, 1999c. Technical Memorandum 2g: Quantification of Lower Fox River Sediment Bed Elevation Dynamics through Direct Observations. Wisconsin Department of Natural Resources, Madison, Wisconsin. July 23.

WDNR, 1999d. Technical response to Fox River Group comments regarding Technical Memorandum 2g. Memorandum prepared by Mark Velleux. Wisconsin Department of Natural Resources, Madison, Wisconsin. June 18.

WDNR. 2000a. Addendum to Technical Memorandum 2e: Estimation of Sediment Bed Properties for the Lower Fox River (4 reach effort). Memorandum prepared by G. Fritz Statz. Wisconsin Department of Natural Resources, Madison, Wisconsin. October 26.

WDNR. 2000b. Technical Memorandum 2f: Estimation of Sediment Bed Properties for Green Bay. Wisconsin Department of Natural Resources, Madison, Wisconsin. December 15.

WDNR. 2001a. Technical Memorandum 3a: Evaluation of Flows, Loads, Initial Conditions, and Boundary Conditions. Wisconsin Department of Natural Resources, Madison, Wisconsin. February 20.

WDNR. 2001b. Estimation of contemporary net burial rates from the depth of PCB occurrence in the Lower Fox River sediments. Memorandum prepared by Mark Velleux. Wisconsin Department of Natural Resources, Madison, Wisconsin. March 23.

Wentworth, C. 1922. A scale of grade class terms for clastic sediments. Journal of Geology, 30, 377-392.

Whitman, R.G. 1923. A preliminary experimental confirmation of the two-film theory of gas absorption. Chem. Metallurg. Eng., 29:146-148.

Xu, Y.J. 1991. Transport properties of fine-grained sediments. Ph.D. dissertation. University of California-Santa Barbara, Santa Barbara, California.

Yang, C. T. 1996. Sediment Transport: Practice and Theory. McGraw-Hill, Inc. New York, New York. 480 pp.

Ziegler, C.K., W. Lick, and J. Lick. 1988. The transport of fine-grained sediments in the Trenton Channel of the Detroit River. University of California-Santa Barbara, Santa Barbara, California. Report to the U.S. Environmental Protection Agency, Office of Research and Development, ERL-Duluth, Large Lakes Research Station, Grosse Ile, Michigan.

APPENDIX A. SEDIMENT STACK ORGANIZATION AND PROPERTIES OF THE SEDIMENT BED

Table A-1. Sediment stack organization and properties: model initial conditions, short-term simulation.

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
1	02-A	1	41	2	6.04E+03	1.51E+05	4.01E-02	0.528	41.0	42.6	16.4	6.50	3.16E+01	1.67E+01
2	01-B	1	42	1	4.83E+03	1.46E+05	3.30E-02	1.240	57.5	29.8	12.7	2.50	2.81E+00	3.50E+00
3	03-C	1	43	3	4.78E+03	1.16E+05	4.12E-02	0.506	29.9	47.9	22.2	6.70	1.46E+01	7.39E+00
4	04-D	1	44	4	9.69E+03	2.49E+05	3.89E-02	0.681	58.1	34.8	7.1	6.60	2.34E+00	1.59E+00
5	03-Pg	1	45	3	8.11E+03	1.72E+05	4.72E-02	0.382	46.1	46.3	7.6	8.80	7.88E+00	3.00E+00
6	04-Pg	1	46	4	6.43E+03	1.41E+05	4.58E-02	0.417	60.1	33.2	6.7	9.90	1.27E+01	5.30E+00
7	04-E	1	47	4	6.74E+03	2.16E+05	3.13E-02	0.673	30.9	52.5	16.6	7.00	1.28E+00	8.63E-01
8	05-E	1	48	5	3.48E+04	8.21E+05	4.24E-02	0.458	25.5	54.4	20.1	6.00	2.82E+00	1.29E+00
9	06-E	1	49	6	2.20E+04	5.99E+05	3.67E-02	0.436	19.9	54.0	26.1	7.30	2.87E+00	1.25E+00
10	07-E	1	50	7	1.44E+04	3.86E+05	3.72E-02	0.485	27.0	50.9	22.1	7.40	1.15E+00	5.60E-01
11	06-F	1	51	6	6.37E+03	1.68E+05	3.79E-02	0.343	25.3	52.0	22.7	14.00	1.26E+00	4.32E-01
12	08-G	1	52	8	1.40E+03	4.11E+04	3.41E-02	0.630	54.4	32.1	13.6	3.80	1.85E-01	1.17E-01
13	08-H	1	53	8	1.15E+02	1.06E+04	1.09E-02	0.886	62.8	24.2	13.0	3.00	2.10E+00	1.86E+00
14	09-I	1	54	9	5.75E+02	2.98E+04	1.93E-02	0.529	14.2	61.2	24.7	5.70	7.60E-01	4.02E-01
15	09-J	1	55	9	5.30E+02	2.49E+04	2.13E-02	0.634	22.6	57.8	19.7	3.70	1.18E-01	7.49E-02
16	09-K	1	56	9	8.03E+01	5.20E+03	1.55E-02	0.810	67.3	19.1	13.6	2.90	2.60E-01	2.11E-01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
17	10-L	1	57	10	1.20E+02	1.06E+04	1.13E-02	0.711	29.8	43.8	26.5	3.40	2.90E-01	2.06E-01
18	10-M	1	58	10	2.70E+02	1.33E+04	2.03E-02	0.454	8.5	62.1	29.4	5.60	7.00E-01	3.18E-01
19	10-N	1	59	10	8.15E+02	2.22E+04	3.67E-02	0.601	51.5	37.0	11.5	8.30	3.82E+01	2.29E+01
20	10-O	1	60	10	6.09E+02	1.85E+04	3.29E-02	0.668	64.4	25.9	9.8	6.70	1.36E+01	9.10E+00
21	10-P	1	61	10	1.29E+03	3.13E+04	4.11E-02	0.968	46.2	39.7	14.1	2.40	1.50E+00	1.45E+00
22	10-Q	1	62	10	3.51E+01	4.20E+03	8.40E-03	0.474	45.4	41.9	12.6	8.60	1.80E+00	8.53E-01
23	10-R	1	63	10	2.11E+02	7.70E+03	2.75E-02	0.954	35.4	43.3	21.3	8.50	1.85E+00	1.77E+00
24	11-S	1	64	11	6.44E+03	1.66E+05	3.87E-02	0.599	63.3	23.6	13.1	8.10	7.15E-01	4.29E-01
25	12-T	1	65	12	8.08E+02	2.08E+04	3.89E-02	0.532	91.1	4.0	4.9	8.20	5.99E+00	3.19E+00
26	12-U	1	66	12	4.60E+02	1.74E+04	2.65E-02	0.474	35.4	48.5	16.2	6.60	1.00E+00	4.74E-01
27	13-V	1	67	13	8.56E+02	2.37E+04	3.61E-02	0.520	52.8	36.3	10.9	4.40	1.67E+00	8.70E-01
28	13-W	1	68	13	1.61E+04	3.78E+05	4.25E-02	0.573	53.2	32.7	14.1	4.20	1.17E+00	6.72E-01
29	14-W	1	69	14	7.97E+03	1.84E+05	4.35E-02	0.682	48.6	35.0	16.4	3.50	7.10E-01	4.84E-01
30	13-X	1	70	13	5.35E+03	1.44E+05	3.71E-02	0.537	40.2	48.2	11.6	4.70	9.09E-01	4.88E-01
31	14-X	1	71	14	4.32E+03	1.11E+05	3.91E-02	0.424	25.1	57.2	17.7	5.30	1.98E+00	8.39E-01
32	14-Y	1	72	14	5.41E+02	3.19E+04	1.70E-02	0.660	47.6	37.6	14.7	2.50	3.70E-01	2.44E-01
33	14-Z	1	73	14	8.20E+02	2.43E+04	3.38E-02	0.695	28.6	48.5	22.9	2.20	3.10E-01	2.16E-01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
34	15-AA	1	74	15	6.48E+01	8.10E+03	8.00E-03	1.140	55.7	20.1	24.2	1.90	2.46E-01	2.81E-01
35	15-BB	1	75	15	2.50E+02	1.58E+04	1.58E-02	0.861	46.4	34.1	19.5	1.90	1.30E-01	1.12E-01
36	15-CC	1	76	15	3.70E+03	8.36E+04	4.42E-02	0.781	30.2	21.3	48.5	1.90	1.46E+00	1.14E+00
37	18-DD	1	77	18	6.38E+03	1.47E+05	4.34E-02	0.641	31.9	42.7	25.3	4.60	9.18E-01	5.88E-01
38	19-EE	1	78	19	9.48E+03	2.30E+05	4.13E-02	0.706	54.1	32.0	13.9	4.00	8.65E-01	6.11E-01
39	20-EE	1	79	20	2.95E+04	6.86E+05	4.31E-02	0.537	32.1	49.0	18.9	5.70	1.84E+00	9.87E-01
40	21-EE	1	80	21	3.46E+04	7.70E+05	4.49E-02	0.508	35.6	44.2	20.2	5.70	2.02E+00	1.02E+00
41	22-EE	1	81	22	1.72E+04	3.76E+05	4.58E-02	0.474	24.2	52.6	23.3	6.10	2.72E+00	1.29E+00
42	23-EE	1	82	23	1.51E+04	3.47E+05	4.36E-02	0.504	23.5	51.1	25.5	6.30	3.35E+00	1.69E+00
43	24-EE	1	83	24	8.54E+03	1.72E+05	4.96E-02	0.659	29.5	49.9	20.7	7.30	8.44E+00	5.57E+00
44	23-FF	1	84	23	1.73E+02	4.80E+03	3.60E-02	0.360	3.4	62.4	34.2	5.90	1.52E+01	5.47E+00
45	24-GG	1	85	24	1.10E+03	2.40E+04	4.60E-02	0.392	24.3	56.1	19.6	6.50	1.15E+01	4.51E+00
46	24-HH	1	86	24	1.81E+03	4.46E+04	4.06E-02	0.593	23.2	55.1	21.7	6.00	3.63E+00	2.15E+00
47	01-ID	1	87	1	1.57E+03	9.76E+04	1.61E-02	1.140	68.5	8.6	22.9	3.20	7.02E+00	7.97E+00
48	02-ID	1	88	2	2.19E+03	9.08E+04	2.41E-02	0.789	44.4	27.7	27.9	5.20	1.32E+01	1.04E+01
49	03-ID	1	89	3	7.23E+03	2.82E+05	2.57E-02	0.751	65.0	24.9	10.1	6.60	6.03E+00	4.53E+00
50	04-ID	1	90	4	1.42E+04	4.10E+05	3.47E-02	0.557	59.0	31.6	9.4	7.10	3.93E+00	2.19E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
51	05-ID	1	91	5	1.87E+03	1.34E+05	1.40E-02	0.531	32.1	48.3	19.6	6.90	2.47E+00	1.31E+00
52	06-ID	1	92	6	2.82E+03	1.61E+05	1.76E-02	0.522	17.3	49.7	33.0	9.10	1.96E+00	1.02E+00
53	07-ID	1	93	7	2.54E+03	7.28E+04	3.49E-02	0.459	27.3	48.5	24.3	7.00	1.09E+00	5.03E-01
54	08-ID	1	94	8	1.70E+03	2.20E+05	7.80E-03	0.646	49.6	32.4	18.0	4.40	7.55E-01	4.87E-01
55	09-ID	1	95	9	8.18E+02	4.54E+05	1.80E-03	1.020	57.8	28.3	14.0	2.90	6.58E-01	6.69E-01
56	10-ID	1	96	10	5.46E+03	4.69E+05	1.16E-02	0.658	43.6	39.4	17.0	7.60	9.06E+00	5.96E+00
57	11-ID	1	97	11	4.66E+02	2.52E+05	1.90E-03	0.609	39.1	42.6	18.4	7.90	5.92E-01	3.60E-01
58	12-ID	1	98	12	2.85E+03	3.68E+05	7.80E-03	0.910	76.6	15.7	7.7	5.50	2.14E+00	1.95E+00
59	13-ID	1	99	13	2.65E+03	3.03E+05	8.80E-03	1.020	76.5	15.9	7.7	4.10	5.98E-01	6.09E-01
60	14-ID	1	100	14	2.89E+03	1.95E+05	1.48E-02	0.629	37.5	45.1	17.4	3.20	7.42E-01	4.67E-01
61	15-ID	1	101	15	3.76E+03	2.61E+05	1.44E-02	0.878	47.6	26.4	26.1	1.60	6.09E-01	5.34E-01
62	16-ID	1	102	16	3.98E+03	3.14E+05	1.27E-02	1.380	86.3	4.4	9.3	0.80	1.83E-01	2.53E-01
63	17-ID	1	103	17	5.20E+02	2.17E+05	2.40E-03	1.400	87.0	4.0	9.0	2.60	1.80E-01	2.51E-01
64	18-ID	1	104	18	3.06E+03	1.51E+05	2.03E-02	0.738	51.9	29.8	18.4	4.40	9.02E-01	6.66E-01
65	19-ID	1	105	19	1.86E+03	2.79E+05	6.70E-03	0.960	64.7	23.9	11.4	3.20	6.69E-01	6.42E-01
66	20-ID	1	106	20	1.03E+03	3.85E+04	2.67E-02	0.659	45.7	37.9	16.4	4.40	1.26E+00	8.29E-01
67	21-ID	1	107	21	3.72E+01	6.70E+03	5.60E-03	0.526	36.8	43.6	19.7	5.60	2.66E+00	1.40E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
68	22-ID	1	108	22	4.31E+03	1.11E+05	3.87E-02	0.630	40.3	39.6	20.2	5.00	1.77E+00	1.12E+00
69	23-ID	1	109	23	3.81E+03	1.11E+05	3.42E-02	0.490	20.4	52.3	27.3	6.10	4.84E+00	2.37E+00
70	24-ID	1	110	24	5.55E+03	1.47E+05	3.78E-02	0.579	26.5	53.2	20.3	6.80	6.99E+00	4.05E+00
71	S020	1	111	25	1.88E+04	3.89E+05	4.84E-02	0.539	37.3	44.3	18.4	5.50	3.64E+00	1.96E+00
72	S021	1	112	25	7.09E+03	1.49E+05	4.75E-02	0.779	28.9	54.2	16.9	4.00	3.22E+00	2.50E+00
73	S022	1	113	25	4.91E+03	9.89E+04	4.97E-02	0.680	27.5	48.5	24.1	5.80	3.25E+00	2.21E+00
74	S023	1	114	25	6.81E+03	1.40E+05	4.86E-02	0.947	22.3	56.6	21.1	2.80	9.80E-01	9.28E-01
75	S024	1	115	25	5.23E+03	1.07E+05	4.91E-02	0.625	32.9	46.6	20.6	5.60	2.09E+00	1.30E+00
76	S025	1	116	25	6.20E+03	1.35E+05	4.60E-02	1.020	27.9	51.5	20.6	2.70	1.20E+00	1.23E+00
77	S026	1	117	26	7.36E+02	1.60E+04	4.60E-02	0.798	18.9	61.5	19.6	2.80	1.68E+00	1.34E+00
78	S027	1	118	26	9.11E+02	1.92E+04	4.75E-02	0.759	25.3	52.6	22.1	3.50	3.16E+00	2.40E+00
79	S028	1	119	26	3.12E+03	7.04E+04	4.43E-02	0.729	21.8	60.9	17.3	3.30	1.04E+00	7.59E-01
80	S029	1	120	26	4.00E+03	8.03E+04	4.98E-02	0.772	32.1	47.0	20.9	3.50	3.22E+00	2.48E+00
81	S030	1	121	26	5.37E+02	1.32E+04	4.07E-02	0.703	25.0	57.8	17.2	3.70	9.96E-01	7.00E-01
82	S031	1	122	26	7.79E+02	1.85E+04	4.21E-02	1.050	29.2	45.5	25.3	1.30	1.30E+00	1.37E+00
83	S032	1	123	27	2.27E+03	4.60E+04	4.94E-02	0.863	32.4	50.5	17.1	4.30	4.02E+00	3.47E+00
84	S033	1	124	27	2.44E+03	5.21E+04	4.68E-02	0.641	40.3	41.5	18.2	5.10	2.86E+00	1.83E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
85	S034	1	125	27	3.06E+03	6.14E+04	4.99E-02	0.849	37.5	45.6	17.0	4.00	3.99E+00	3.39E+00
86	S035	1	126	27	3.69E+03	7.38E+04	5.00E-02	0.631	38.1	41.4	20.5	5.00	2.32E+00	1.46E+00
87	S036	1	127	27	5.87E+02	1.46E+04	4.02E-02	0.938	38.1	38.9	23.0	2.50	3.03E+00	2.84E+00
88	S037	1	128	27	9.89E+02	1.99E+04	4.97E-02	0.776	25.5	48.3	26.2	3.40	4.10E-01	3.18E-01
89	S038	1	129	28	2.40E+03	4.96E+04	4.84E-02	0.729	50.7	37.8	11.5	3.40	2.78E+00	2.03E+00
90	S039	1	130	28	1.32E+03	2.70E+04	4.87E-02	0.801	14.3	63.0	22.7	3.20	1.12E+00	8.95E-01
91	S040	1	131	28	4.79E+03	9.63E+04	4.97E-02	0.643	45.4	38.0	16.6	5.10	2.93E+00	1.88E+00
92	S041	1	132	28	6.58E+03	1.32E+05	4.99E-02	0.744	30.3	52.1	17.6	3.90	2.51E+00	1.87E+00
93	S042	1	133	28	2.19E+03	5.46E+04	4.01E-02	0.808	46.1	38.4	15.5	3.70	1.98E+00	1.60E+00
94	S043	1	134	28	4.31E+03	1.04E+05	4.14E-02	0.941	36.3	47.5	16.3	2.10	1.05E+00	9.90E-01
95	S044	1	135	29	5.58E+03	1.15E+05	4.84E-02	0.592	34.4	48.3	17.4	4.20	2.16E+00	1.28E+00
96	S045	1	136	29	9.09E+03	1.85E+05	4.91E-02	0.509	22.8	58.0	19.2	5.20	2.20E+00	1.12E+00
97	S046	1	137	29	8.71E+03	1.75E+05	4.98E-02	0.635	29.3	53.9	16.8	4.40	2.35E+00	1.49E+00
98	S047	1	138	29	7.56E+03	1.51E+05	5.00E-02	0.476	31.5	49.9	18.6	6.80	2.22E+00	1.06E+00
99	S048	1	139	29	9.05E+03	1.87E+05	4.84E-02	0.721	48.2	38.0	13.8	3.80	3.96E+00	2.86E+00
100	S049	1	140	29	1.23E+04	2.51E+05	4.89E-02	0.516	43.7	41.3	15.0	4.60	1.39E+00	7.14E-01
101	S050	1	141	30	1.23E+03	2.53E+04	4.84E-02	0.922	21.2	58.9	19.9	2.90	1.62E+00	1.49E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
102	S051	1	142	30	1.21E+03	2.43E+04	4.97E-02	0.877	48.8	39.4	11.8	2.90	4.89E+00	4.29E+00
103	S052	1	143	30	5.02E+03	1.03E+05	4.87E-02	0.612	24.1	59.4	16.5	5.60	2.90E+00	1.77E+00
104	S053	1	144	30	4.79E+03	9.70E+04	4.94E-02	0.582	20.9	61.5	17.6	4.60	3.74E+00	2.18E+00
105	S054	1	145	30	2.64E+03	5.89E+04	4.48E-02	0.559	37.4	49.1	13.6	4.80	1.64E+00	9.14E-01
106	S055	1	146	30	5.81E+02	2.04E+04	2.85E-02	0.493	17.3	65.1	17.6	5.10	2.80E+00	1.38E+00
107	S056	1	147	31	3.29E+03	6.60E+04	4.98E-02	0.484	29.3	53.4	17.4	6.50	5.27E+00	2.55E+00
108	S057	1	148	31	4.22E+03	8.43E+04	5.00E-02	0.520	27.9	51.1	21.1	6.70	2.39E+00	1.24E+00
109	S058	1	149	31	1.55E+03	3.09E+04	5.00E-02	0.477	33.0	49.9	17.1	6.00	3.35E+00	1.60E+00
110	S059	1	150	31	1.34E+03	2.71E+04	4.93E-02	0.702	31.6	42.3	26.1	4.30	2.28E+00	1.60E+00
111	S060	1	151	31	1.42E+03	3.14E+04	4.52E-02	0.532	29.7	52.7	17.6	5.60	2.39E+00	1.27E+00
112	S061	1	152	31	2.14E+03	4.28E+04	4.99E-02	0.750	37.1	42.6	20.3	3.10	2.12E+00	1.59E+00
113	S062	1	153	32	2.49E+03	4.98E+04	5.00E-02	0.494	23.0	58.2	18.9	7.10	1.88E+00	9.31E-01
114	S063	1	154	32	2.30E+02	4.60E+03	5.00E-02	0.804	37.5	47.8	14.8	4.10	2.21E+00	1.77E+00
115	S064	1	155	32	9.25E+02	1.85E+04	5.00E-02	0.569	28.5	52.8	18.7	6.10	2.21E+00	1.26E+00
116	S065	1	156	32	1.78E+03	3.56E+04	5.00E-02	0.768	34.8	50.2	15.0	4.50	2.35E+00	1.81E+00
118	S067	1	157	32	4.25E+02	8.50E+03	5.00E-02	0.590	24.1	59.3	16.6	5.90	2.87E+00	1.69E+00
119	S068	1	158	33	2.50E+02	5.00E+03	5.00E-02	0.520	22.8	58.5	18.7	5.90	2.61E+00	1.36E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
120	S069	1	159	33	1.50E+01	3.00E+02	5.00E-02	0.543	30.9	51.5	17.6	5.90	2.86E+00	1.55E+00
121	S070	1	160	33	4.11E+03	8.22E+04	5.00E-02	0.492	26.8	54.9	18.3	6.30	3.74E+00	1.84E+00
122	S071	1	161	33	1.96E+03	3.91E+04	5.00E-02	0.569	35.0	48.8	16.3	5.60	2.84E+00	1.61E+00
123	S072	1	162	33	1.15E+02	2.30E+03	5.00E-02	0.585	31.9	51.5	16.6	5.90	4.61E+00	2.70E+00
124	S073	1	163	33	2.10E+02	4.20E+03	5.00E-02	0.718	39.9	45.0	15.1	5.10	2.98E+00	2.14E+00
125	S074	1	164	34	2.50E+01	5.00E+02	5.00E-02	0.630	49.1	38.2	12.8	4.90	3.14E+00	1.98E+00
126	S075	1	165	34	1.00E+01	2.00E+02	5.00E-02	1.050	22.9	51.7	25.4	2.60	5.60E+00	5.85E+00
127	S076	1	166	34	1.82E+03	3.64E+04	5.00E-02	0.611	50.3	38.0	11.7	5.00	2.84E+00	1.74E+00
128	S077	1	167	34	1.40E+03	2.80E+04	5.00E-02	0.873	40.2	46.6	13.3	3.50	5.25E+00	4.59E+00
129	S078	1	168	34	1.35E+02	2.70E+03	5.00E-02	0.599	50.9	38.5	10.6	5.10	2.56E+00	1.54E+00
130	S079	1	169	34	1.10E+02	2.20E+03	5.00E-02	0.801	37.9	51.0	11.1	3.40	6.25E+00	5.01E+00
131	S080	1	170	35	2.60E+02	5.20E+03	5.00E-02	0.785	50.8	35.1	14.2	4.10	3.26E+00	2.56E+00
132	S081	1	171	35	6.00E+01	1.20E+03	5.00E-02	0.703	40.9	45.0	14.2	5.30	3.42E+00	2.41E+00
133	S082	1	172	35	1.81E+03	3.61E+04	5.00E-02	0.755	43.9	42.4	13.7	4.00	4.77E+00	3.60E+00
134	S083	1	173	35	1.47E+03	2.93E+04	5.00E-02	0.765	40.9	43.7	15.4	5.10	2.96E+00	2.26E+00
135	S084	1	174	35	2.55E+02	5.10E+03	5.00E-02	0.739	35.8	49.7	14.5	3.90	6.34E+00	4.68E+00
136	S085	1	175	35	1.80E+02	3.60E+03	5.00E-02	0.806	39.8	44.3	16.0	5.10	2.57E+00	2.07E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
137	S086	1	176	36	4.25E+02	8.50E+03	5.00E-02	0.745	32.8	52.9	14.3	5.10	2.63E+00	1.96E+00
138	S087	1	177	36	2.00E+02	4.00E+03	5.00E-02	0.936	22.0	54.4	23.6	4.20	9.82E-01	9.19E-01
139	S088	1	178	36	1.60E+03	3.19E+04	5.00E-02	0.849	36.4	50.2	13.4	3.90	2.10E+00	1.78E+00
140	S089	1	179	36	5.50E+02	1.10E+04	5.00E-02	0.899	13.7	56.9	29.4	5.00	1.19E+00	1.07E+00
141	S090	1	180	36	2.50E+02	5.00E+03	5.00E-02	1.020	36.1	50.2	13.7	2.60	8.75E-01	8.95E-01
142	S091	1	181	36	6.50E+01	1.30E+03	5.00E-02	0.814	27.3	49.9	22.8	5.00	1.42E+00	1.15E+00
143	S092	1	182	37	1.50E+01	3.00E+02	5.00E-02	0.477	25.6	54.8	19.5	4.50	1.69E+00	8.09E-01
144	S093	1	183	37	1.70E+02	3.40E+03	5.00E-02	0.920	52.4	30.6	17.0	3.20	7.09E-01	6.52E-01
145	S094	1	184	37	2.52E+03	5.04E+04	5.00E-02	0.498	27.4	52.0	20.6	5.30	1.75E+00	8.69E-01
146	S095	1	185	37	1.47E+03	2.93E+04	5.00E-02	1.130	58.7	26.8	14.5	2.30	5.49E-01	6.19E-01
147	S096	1	186	37	5.75E+02	1.15E+04	5.00E-02	0.400	29.3	55.6	15.2	5.70	1.86E+00	7.43E-01
148	S097	1	187	37	2.35E+02	4.70E+03	5.00E-02	1.020	53.0	31.4	15.7	2.60	7.49E-01	7.65E-01
149	S098	1	188	38	1.40E+02	2.80E+03	5.00E-02	0.938	40.9	37.7	21.4	2.60	5.92E-01	5.55E-01
150	S099	1	189	38	4.55E+02	9.10E+03	5.00E-02	1.190	64.5	24.7	10.8	1.50	1.40E-01	1.67E-01
151	S100	1	190	38	1.44E+03	2.88E+04	5.00E-02	1.100	49.3	32.4	18.3	2.20	7.95E-01	8.71E-01
152	S101	1	191	38	1.40E+03	2.79E+04	5.00E-02	1.140	56.2	30.7	13.1	1.70	2.23E-01	2.54E-01
153	S102	1	192	38	1.80E+02	3.60E+03	5.00E-02	1.380	62.4	24.6	13.1	1.50	1.03E+00	1.42E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
154	S103	1	193	38	1.90E+02	3.80E+03	5.00E-02	0.965	41.0	44.6	14.4	2.00	2.20E-01	2.13E-01
155	S104	1	194	39	5.25E+02	1.05E+04	5.00E-02	0.774	53.8	28.7	17.6	1.40	9.98E-01	7.72E-01
156	S105	1	195	39	1.65E+02	3.30E+03	5.00E-02	0.863	43.3	34.4	22.3	2.70	1.50E+00	1.30E+00
157	S106	1	196	39	1.42E+03	2.84E+04	5.00E-02	0.818	48.0	34.9	17.1	1.60	7.76E-01	6.35E-01
158	S107	1	197	39	1.78E+03	3.56E+04	5.00E-02	0.766	45.3	32.9	21.8	3.20	1.76E+00	1.35E+00
159	S108	1	198	39	5.80E+02	1.16E+04	5.00E-02	0.810	41.8	46.8	11.4	1.90	3.03E-01	2.45E-01
160	S109	1	199	39	4.20E+02	8.40E+03	5.00E-02	0.773	41.6	44.1	14.4	2.90	1.11E+00	8.56E-01
161	S110	1	200	40	3.60E+02	7.20E+03	5.00E-02	0.807	33.0	49.1	18.0	3.90	1.50E+00	1.21E+00
162	S111	1	201	40	2.30E+02	4.60E+03	5.00E-02	0.537	36.7	50.1	13.2	6.00	1.70E+00	9.10E-01
163	S112	1	202	40	2.00E+03	3.99E+04	5.00E-02	0.625	22.1	60.5	17.5	4.60	1.67E+00	1.05E+00
164	S113	1	203	40	2.02E+03	4.04E+04	5.00E-02	0.555	32.4	54.2	13.5	5.90	1.65E+00	9.14E-01
165	S114	1	204	40	2.35E+02	4.70E+03	5.00E-02	0.752	28.0	51.6	20.4	3.80	1.61E+00	1.21E+00
166	S115	1	205	40	6.05E+02	1.64E+04	3.69E-02	0.687	31.4	52.7	15.9	5.80	8.14E-01	5.59E-01
1	02-A	2	206	2	6.04E+03	1.51E+05	4.01E-02	0.528	41.0	42.6	16.4	6.50	3.16E+01	1.67E+01
2	01-B	2	207	1	4.83E+03	1.46E+05	3.30E-02	1.240	57.5	29.8	12.7	2.50	2.81E+00	3.50E+00
3	03-C	2	208	3	4.78E+03	1.16E+05	4.12E-02	0.506	29.9	47.9	22.2	6.70	1.46E+01	7.39E+00
4	04-D	2	209	4	9.69E+03	2.49E+05	3.89E-02	0.681	58.1	34.8	7.1	6.60	2.34E+00	1.59E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
5	03-Pg	2	210	3	8.11E+03	1.72E+05	4.72E-02	0.382	46.1	46.3	7.6	8.80	7.88E+00	3.00E+00
6	04-Pg	2	211	4	6.43E+03	1.41E+05	4.58E-02	0.417	60.1	33.2	6.7	9.90	1.27E+01	5.30E+00
7	04-E	2	212	4	6.74E+03	2.16E+05	3.13E-02	0.673	30.9	52.5	16.6	7.00	1.28E+00	8.63E-01
8	05-E	2	213	5	3.48E+04	8.21E+05	4.24E-02	0.458	25.5	54.4	20.1	6.00	2.82E+00	1.29E+00
9	06-E	2	214	6	2.20E+04	5.99E+05	3.67E-02	0.436	19.9	54.0	26.1	7.30	2.87E+00	1.25E+00
10	07-E	2	215	7	1.44E+04	3.86E+05	3.72E-02	0.485	27.0	50.9	22.1	7.40	1.15E+00	5.60E-01
11	06-F	2	216	6	6.37E+03	1.68E+05	3.79E-02	0.343	25.3	52.0	22.7	14.00	1.26E+00	4.32E-01
12	08-G	2	217	8	1.40E+03	4.11E+04	3.41E-02	0.630	54.4	32.1	13.6	3.80	1.85E-01	1.17E-01
13	08-H	2	218	8	1.15E+02	1.06E+04	1.09E-02	0.886	62.8	24.2	13.0	3.00	2.10E+00	1.86E+00
14	09-I	2	219	9	5.75E+02	2.98E+04	1.93E-02	0.529	14.2	61.2	24.7	5.70	7.60E-01	4.02E-01
15	09-J	2	220	9	5.30E+02	2.49E+04	2.13E-02	0.634	22.6	57.8	19.7	3.70	1.18E-01	7.49E-02
16	09-K	2	221	9	8.03E+01	5.20E+03	1.55E-02	0.810	67.3	19.1	13.6	2.90	2.60E-01	2.11E-01
17	10-L	2	222	10	1.20E+02	1.06E+04	1.13E-02	0.711	29.8	43.8	26.5	3.40	2.90E-01	2.06E-01
18	10-M	2	223	10	2.70E+02	1.33E+04	2.03E-02	0.454	8.5	62.1	29.4	5.60	7.00E-01	3.18E-01
19	10-N	2	224	10	8.15E+02	2.22E+04	3.67E-02	0.601	51.5	37.0	11.5	8.30	3.82E+01	2.29E+01
20	10-O	2	225	10	6.09E+02	1.85E+04	3.29E-02	0.668	64.4	25.9	9.8	6.70	1.36E+01	9.10E+00
21	10-P	2	226	10	1.29E+03	3.13E+04	4.11E-02	0.968	46.2	39.7	14.1	2.40	1.50E+00	1.45E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
22	10-Q	2	227	10	3.51E+01	4.20E+03	8.40E-03	0.474	45.4	41.9	12.6	8.60	1.80E+00	8.53E-01
23	10-R	2	228	10	2.11E+02	7.70E+03	2.75E-02	0.954	35.4	43.3	21.3	8.50	1.85E+00	1.77E+00
24	11-S	2	229	11	6.44E+03	1.66E+05	3.87E-02	0.599	63.3	23.6	13.1	8.10	7.15E-01	4.29E-01
25	12-T	2	230	12	8.08E+02	2.08E+04	3.89E-02	0.532	91.1	4.0	4.9	8.20	5.99E+00	3.19E+00
26	12-U	2	231	12	4.60E+02	1.74E+04	2.65E-02	0.474	35.4	48.5	16.2	6.60	1.00E+00	4.74E-01
27	13-V	2	232	13	8.56E+02	2.37E+04	3.61E-02	0.520	52.8	36.3	10.9	4.40	1.67E+00	8.70E-01
28	13-W	2	233	13	1.61E+04	3.78E+05	4.25E-02	0.573	53.2	32.7	14.1	4.20	1.17E+00	6.72E-01
29	14-W	2	234	14	7.97E+03	1.84E+05	4.35E-02	0.682	48.6	35.0	16.4	3.50	7.10E-01	4.84E-01
30	13-X	2	235	13	5.35E+03	1.44E+05	3.71E-02	0.537	40.2	48.2	11.6	4.70	9.09E-01	4.88E-01
31	14-X	2	236	14	4.32E+03	1.11E+05	3.91E-02	0.424	25.1	57.2	17.7	5.30	1.98E+00	8.39E-01
32	14-Y	2	237	14	5.41E+02	3.19E+04	1.70E-02	0.660	47.6	37.6	14.7	2.50	3.70E-01	2.44E-01
33	14-Z	2	238	14	8.20E+02	2.43E+04	3.38E-02	0.695	28.6	48.5	22.9	2.20	3.10E-01	2.16E-01
34	15-AA	2	239	15	6.48E+01	8.10E+03	8.00E-03	1.140	55.7	20.1	24.2	1.90	2.46E-01	2.81E-01
35	15-BB	2	240	15	2.50E+02	1.58E+04	1.58E-02	0.861	46.4	34.1	19.5	1.90	1.30E-01	1.12E-01
36	15-CC	2	241	15	3.70E+03	8.36E+04	4.42E-02	0.781	30.2	21.3	48.5	1.90	1.46E+00	1.14E+00
37	18-DD	2	242	18	6.38E+03	1.47E+05	4.34E-02	0.641	31.9	42.7	25.3	4.60	9.18E-01	5.88E-01
38	19-EE	2	243	19	9.48E+03	2.30E+05	4.13E-02	0.706	54.1	32.0	13.9	4.00	8.65E-01	6.11E-01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
39	20-EE	2	244	20	2.95E+04	6.86E+05	4.31E-02	0.537	32.1	49.0	18.9	5.70	1.84E+00	9.87E-01
40	21-EE	2	245	21	3.46E+04	7.70E+05	4.49E-02	0.508	35.6	44.2	20.2	5.70	2.02E+00	1.02E+00
41	22-EE	2	246	22	1.72E+04	3.76E+05	4.58E-02	0.474	24.2	52.6	23.3	6.10	2.72E+00	1.29E+00
42	23-EE	2	247	23	1.51E+04	3.47E+05	4.36E-02	0.504	23.5	51.1	25.5	6.30	3.35E+00	1.69E+00
43	24-EE	2	248	24	8.54E+03	1.72E+05	4.96E-02	0.659	29.5	49.9	20.7	7.30	8.44E+00	5.57E+00
44	23-FF	2	249	23	1.73E+02	4.80E+03	3.60E-02	0.360	3.4	62.4	34.2	5.90	1.52E+01	5.47E+00
45	24-GG	2	250	24	1.10E+03	2.40E+04	4.60E-02	0.392	24.3	56.1	19.6	6.50	1.15E+01	4.51E+00
46	24-HH	2	251	24	1.81E+03	4.46E+04	4.06E-02	0.593	23.2	55.1	21.7	6.00	3.63E+00	2.15E+00
47	01-ID	2	252	1	1.57E+03	9.76E+04	1.61E-02	1.140	68.5	8.6	22.9	3.20	7.02E+00	7.97E+00
48	02-ID	2	253	2	2.19E+03	9.08E+04	2.41E-02	0.789	44.4	27.7	27.9	5.20	1.32E+01	1.04E+01
49	03-ID	2	254	3	7.23E+03	2.82E+05	2.57E-02	0.751	65.0	24.9	10.1	6.60	6.03E+00	4.53E+00
50	04-ID	2	255	4	1.42E+04	4.10E+05	3.47E-02	0.557	59.0	31.6	9.4	7.10	3.93E+00	2.19E+00
51	05-ID	2	256	5	1.87E+03	1.34E+05	1.40E-02	0.531	32.1	48.3	19.6	6.90	2.47E+00	1.31E+00
52	06-ID	2	257	6	2.82E+03	1.61E+05	1.76E-02	0.522	17.3	49.7	33.0	9.10	1.96E+00	1.02E+00
53	07-ID	2	258	7	2.54E+03	7.28E+04	3.49E-02	0.459	27.3	48.5	24.3	7.00	1.09E+00	5.03E-01
54	08-ID	2	259	8	1.70E+03	2.20E+05	7.80E-03	0.646	49.6	32.4	18.0	4.40	7.55E-01	4.87E-01
55	09-ID	2	260	9	8.18E+02	4.54E+05	1.80E-03	1.020	57.8	28.3	14.0	2.90	6.58E-01	6.69E-01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
56	10-ID	2	261	10	5.46E+03	4.69E+05	1.16E-02	0.658	43.6	39.4	17.0	7.60	9.06E+00	5.96E+00
57	11-ID	2	262	11	4.66E+02	2.52E+05	1.90E-03	0.609	39.1	42.6	18.4	7.90	5.92E-01	3.60E-01
58	12-ID	2	263	12	2.85E+03	3.68E+05	7.80E-03	0.910	76.6	15.7	7.7	5.50	2.14E+00	1.95E+00
59	13-ID	2	264	13	2.65E+03	3.03E+05	8.80E-03	1.020	76.5	15.9	7.7	4.10	5.98E-01	6.09E-01
60	14-ID	2	265	14	2.89E+03	1.95E+05	1.48E-02	0.629	37.5	45.1	17.4	3.20	7.42E-01	4.67E-01
61	15-ID	2	266	15	3.76E+03	2.61E+05	1.44E-02	0.878	47.6	26.4	26.1	1.60	6.09E-01	5.34E-01
62	16-ID	2	267	16	3.98E+03	3.14E+05	1.27E-02	1.380	86.3	4.4	9.3	0.80	1.83E-01	2.53E-01
63	17-ID	2	268	17	5.20E+02	2.17E+05	2.40E-03	1.400	87.0	4.0	9.0	2.60	1.80E-01	2.51E-01
64	18-ID	2	269	18	3.06E+03	1.51E+05	2.03E-02	0.738	51.9	29.8	18.4	4.40	9.02E-01	6.66E-01
65	19-ID	2	270	19	1.86E+03	2.79E+05	6.70E-03	0.960	64.7	23.9	11.4	3.20	6.69E-01	6.42E-01
66	20-ID	2	271	20	1.03E+03	3.85E+04	2.67E-02	0.659	45.7	37.9	16.4	4.40	1.26E+00	8.29E-01
67	21-ID	2	272	21	3.72E+01	6.70E+03	5.60E-03	0.526	36.8	43.6	19.7	5.60	2.66E+00	1.40E+00
68	22-ID	2	273	22	4.31E+03	1.11E+05	3.87E-02	0.630	40.3	39.6	20.2	5.00	1.77E+00	1.12E+00
69	23-ID	2	274	23	3.81E+03	1.11E+05	3.42E-02	0.490	20.4	52.3	27.3	6.10	4.84E+00	2.37E+00
70	24-ID	2	275	24	5.55E+03	1.47E+05	3.78E-02	0.579	26.5	53.2	20.3	6.80	6.99E+00	4.05E+00
71	S020	2	276	25	1.88E+04	3.89E+05	4.84E-02	0.539	37.3	44.3	18.4	5.50	3.64E+00	1.96E+00
72	S021	2	277	25	7.09E+03	1.49E+05	4.75E-02	0.779	28.9	54.2	16.9	4.00	3.22E+00	2.50E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
73	S022	2	278	25	4.91E+03	9.89E+04	4.97E-02	0.680	27.5	48.5	24.1	5.80	3.25E+00	2.21E+00
74	S023	2	279	25	6.81E+03	1.40E+05	4.86E-02	0.947	22.3	56.6	21.1	2.80	9.80E-01	9.28E-01
75	S024	2	280	25	5.23E+03	1.07E+05	4.91E-02	0.625	32.9	46.6	20.6	5.60	2.09E+00	1.30E+00
76	S025	2	281	25	6.20E+03	1.35E+05	4.60E-02	1.020	27.9	51.5	20.6	2.70	1.20E+00	1.23E+00
77	S026	2	282	26	7.36E+02	1.60E+04	4.60E-02	0.798	18.9	61.5	19.6	2.80	1.68E+00	1.34E+00
78	S027	2	283	26	9.11E+02	1.92E+04	4.75E-02	0.759	25.3	52.6	22.1	3.50	3.16E+00	2.40E+00
79	S028	2	284	26	3.12E+03	7.04E+04	4.43E-02	0.729	21.8	60.9	17.3	3.30	1.04E+00	7.59E-01
80	S029	2	285	26	4.00E+03	8.03E+04	4.98E-02	0.772	32.1	47.0	20.9	3.50	3.22E+00	2.48E+00
81	S030	2	286	26	5.37E+02	1.32E+04	4.07E-02	0.703	25.0	57.8	17.2	3.70	9.96E-01	7.00E-01
82	S031	2	287	26	7.79E+02	1.85E+04	4.21E-02	1.050	29.2	45.5	25.3	1.30	1.30E+00	1.37E+00
83	S032	2	288	27	2.27E+03	4.60E+04	4.94E-02	0.863	32.4	50.5	17.1	4.30	4.02E+00	3.47E+00
84	S033	2	289	27	2.44E+03	5.21E+04	4.68E-02	0.641	40.3	41.5	18.2	5.10	2.86E+00	1.83E+00
85	S034	2	290	27	3.06E+03	6.14E+04	4.99E-02	0.849	37.5	45.6	17.0	4.00	3.99E+00	3.39E+00
86	S035	2	291	27	3.69E+03	7.38E+04	5.00E-02	0.631	38.1	41.4	20.5	5.00	2.32E+00	1.46E+00
87	S036	2	292	27	5.87E+02	1.46E+04	4.02E-02	0.938	38.1	38.9	23.0	2.50	3.03E+00	2.84E+00
88	S037	2	293	27	9.89E+02	1.99E+04	4.97E-02	0.776	25.5	48.3	26.2	3.40	4.10E-01	3.18E-01
89	S038	2	294	28	2.40E+03	4.96E+04	4.84E-02	0.729	50.7	37.8	11.5	3.40	2.78E+00	2.03E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
90	S039	2	295	28	1.32E+03	2.70E+04	4.87E-02	0.801	14.3	63.0	22.7	3.20	1.12E+00	8.95E-01
91	S040	2	296	28	4.79E+03	9.63E+04	4.97E-02	0.643	45.4	38.0	16.6	5.10	2.93E+00	1.88E+00
92	S041	2	297	28	6.58E+03	1.32E+05	4.99E-02	0.744	30.3	52.1	17.6	3.90	2.51E+00	1.87E+00
93	S042	2	298	28	2.19E+03	5.46E+04	4.01E-02	0.808	46.1	38.4	15.5	3.70	1.98E+00	1.60E+00
94	S043	2	299	28	4.31E+03	1.04E+05	4.14E-02	0.941	36.3	47.5	16.3	2.10	1.05E+00	9.90E-01
95	S044	2	300	29	5.58E+03	1.15E+05	4.84E-02	0.592	34.4	48.3	17.4	4.20	2.16E+00	1.28E+00
96	S045	2	301	29	9.09E+03	1.85E+05	4.91E-02	0.509	22.8	58.0	19.2	5.20	2.20E+00	1.12E+00
97	S046	2	302	29	8.71E+03	1.75E+05	4.98E-02	0.635	29.3	53.9	16.8	4.40	2.35E+00	1.49E+00
98	S047	2	303	29	7.56E+03	1.51E+05	5.00E-02	0.476	31.5	49.9	18.6	6.80	2.22E+00	1.06E+00
99	S048	2	304	29	9.05E+03	1.87E+05	4.84E-02	0.721	48.2	38.0	13.8	3.80	3.96E+00	2.86E+00
100	S049	2	305	29	1.23E+04	2.51E+05	4.89E-02	0.516	43.7	41.3	15.0	4.60	1.39E+00	7.14E-01
101	S050	2	306	30	1.23E+03	2.53E+04	4.84E-02	0.922	21.2	58.9	19.9	2.90	1.62E+00	1.49E+00
102	S051	2	307	30	1.21E+03	2.43E+04	4.97E-02	0.877	48.8	39.4	11.8	2.90	4.89E+00	4.29E+00
103	S052	2	308	30	5.02E+03	1.03E+05	4.87E-02	0.612	24.1	59.4	16.5	5.60	2.90E+00	1.77E+00
104	S053	2	309	30	4.79E+03	9.70E+04	4.94E-02	0.582	20.9	61.5	17.6	4.60	3.74E+00	2.18E+00
105	S054	2	310	30	2.64E+03	5.89E+04	4.48E-02	0.559	37.4	49.1	13.6	4.80	1.64E+00	9.14E-01
106	S055	2	311	30	5.81E+02	2.04E+04	2.85E-02	0.493	17.3	65.1	17.6	5.10	2.80E+00	1.38E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
107	S056	2	312	31	3.29E+03	6.60E+04	4.98E-02	0.484	29.3	53.4	17.4	6.50	5.27E+00	2.55E+00
108	S057	2	313	31	4.22E+03	8.43E+04	5.00E-02	0.520	27.9	51.1	21.1	6.70	2.39E+00	1.24E+00
109	S058	2	314	31	1.55E+03	3.09E+04	5.00E-02	0.477	33.0	49.9	17.1	6.00	3.35E+00	1.60E+00
110	S059	2	315	31	1.34E+03	2.71E+04	4.93E-02	0.702	31.6	42.3	26.1	4.30	2.28E+00	1.60E+00
111	S060	2	316	31	1.42E+03	3.14E+04	4.52E-02	0.532	29.7	52.7	17.6	5.60	2.39E+00	1.27E+00
112	S061	2	317	31	2.14E+03	4.28E+04	4.99E-02	0.750	37.1	42.6	20.3	3.10	2.12E+00	1.59E+00
113	S062	2	318	32	2.49E+03	4.98E+04	5.00E-02	0.494	23.0	58.2	18.9	7.10	1.88E+00	9.31E-01
114	S063	2	319	32	2.30E+02	4.60E+03	5.00E-02	0.804	37.5	47.8	14.8	4.10	2.21E+00	1.77E+00
115	S064	2	320	32	9.25E+02	1.85E+04	5.00E-02	0.569	28.5	52.8	18.7	6.10	2.21E+00	1.26E+00
116	S065	2	321	32	1.78E+03	3.56E+04	5.00E-02	0.768	34.8	50.2	15.0	4.50	2.35E+00	1.81E+00
118	S067	2	322	32	4.25E+02	8.50E+03	5.00E-02	0.590	24.1	59.3	16.6	5.90	2.87E+00	1.69E+00
119	S068	2	323	33	2.50E+02	5.00E+03	5.00E-02	0.520	22.8	58.5	18.7	5.90	2.61E+00	1.36E+00
120	S069	2	324	33	1.50E+01	3.00E+02	5.00E-02	0.543	30.9	51.5	17.6	5.90	2.86E+00	1.55E+00
121	S070	2	325	33	4.11E+03	8.22E+04	5.00E-02	0.492	26.8	54.9	18.3	6.30	3.74E+00	1.84E+00
122	S071	2	326	33	1.96E+03	3.91E+04	5.00E-02	0.569	35.0	48.8	16.3	5.60	2.84E+00	1.61E+00
123	S072	2	327	33	1.15E+02	2.30E+03	5.00E-02	0.585	31.9	51.5	16.6	5.90	4.61E+00	2.70E+00
124	S073	2	328	33	2.10E+02	4.20E+03	5.00E-02	0.718	39.9	45.0	15.1	5.10	2.98E+00	2.14E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
125	S074	2	329	34	2.50E+01	5.00E+02	5.00E-02	0.630	49.1	38.2	12.8	4.90	3.14E+00	1.98E+00
126	S075	2	330	34	1.00E+01	2.00E+02	5.00E-02	1.050	22.9	51.7	25.4	2.60	5.60E+00	5.85E+00
127	S076	2	331	34	1.82E+03	3.64E+04	5.00E-02	0.611	50.3	38.0	11.7	5.00	2.84E+00	1.74E+00
128	S077	2	332	34	1.40E+03	2.80E+04	5.00E-02	0.873	40.2	46.6	13.3	3.50	5.25E+00	4.59E+00
129	S078	2	333	34	1.35E+02	2.70E+03	5.00E-02	0.599	50.9	38.5	10.6	5.10	2.56E+00	1.54E+00
130	S079	2	334	34	1.10E+02	2.20E+03	5.00E-02	0.801	37.9	51.0	11.1	3.40	6.25E+00	5.01E+00
131	S080	2	335	35	2.60E+02	5.20E+03	5.00E-02	0.785	50.8	35.1	14.2	4.10	3.26E+00	2.56E+00
132	S081	2	336	35	6.00E+01	1.20E+03	5.00E-02	0.703	40.9	45.0	14.2	5.30	3.42E+00	2.41E+00
133	S082	2	337	35	1.81E+03	3.61E+04	5.00E-02	0.755	43.9	42.4	13.7	4.00	4.77E+00	3.60E+00
134	S083	2	338	35	1.47E+03	2.93E+04	5.00E-02	0.765	40.9	43.7	15.4	5.10	2.96E+00	2.26E+00
135	S084	2	339	35	2.55E+02	5.10E+03	5.00E-02	0.739	35.8	49.7	14.5	3.90	6.34E+00	4.68E+00
136	S085	2	340	35	1.80E+02	3.60E+03	5.00E-02	0.806	39.8	44.3	16.0	5.10	2.57E+00	2.07E+00
137	S086	2	341	36	4.25E+02	8.50E+03	5.00E-02	0.745	32.8	52.9	14.3	5.10	2.63E+00	1.96E+00
138	S087	2	342	36	2.00E+02	4.00E+03	5.00E-02	0.936	22.0	54.4	23.6	4.20	9.82E-01	9.19E-01
139	S088	2	343	36	1.60E+03	3.19E+04	5.00E-02	0.849	36.4	50.2	13.4	3.90	2.10E+00	1.78E+00
140	S089	2	344	36	5.50E+02	1.10E+04	5.00E-02	0.899	13.7	56.9	29.4	5.00	1.19E+00	1.07E+00
141	S090	2	345	36	2.50E+02	5.00E+03	5.00E-02	1.020	36.1	50.2	13.7	2.60	8.75E-01	8.95E-01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
142	S091	2	346	36	6.50E+01	1.30E+03	5.00E-02	0.814	27.3	49.9	22.8	5.00	1.42E+00	1.15E+00
143	S092	2	347	37	1.50E+01	3.00E+02	5.00E-02	0.477	25.6	54.8	19.5	4.50	1.69E+00	8.09E-01
144	S093	2	348	37	1.70E+02	3.40E+03	5.00E-02	0.920	52.4	30.6	17.0	3.20	7.09E-01	6.52E-01
145	S094	2	349	37	2.52E+03	5.04E+04	5.00E-02	0.498	27.4	52.0	20.6	5.30	1.75E+00	8.69E-01
146	S095	2	350	37	1.47E+03	2.93E+04	5.00E-02	1.130	58.7	26.8	14.5	2.30	5.49E-01	6.19E-01
147	S096	2	351	37	5.75E+02	1.15E+04	5.00E-02	0.400	29.3	55.6	15.2	5.70	1.86E+00	7.43E-01
148	S097	2	352	37	2.35E+02	4.70E+03	5.00E-02	1.020	53.0	31.4	15.7	2.60	7.49E-01	7.65E-01
149	S098	2	353	38	1.40E+02	2.80E+03	5.00E-02	0.938	40.9	37.7	21.4	2.60	5.92E-01	5.55E-01
150	S099	2	354	38	4.55E+02	9.10E+03	5.00E-02	1.190	64.5	24.7	10.8	1.50	1.40E-01	1.67E-01
151	S100	2	355	38	1.44E+03	2.88E+04	5.00E-02	1.100	49.3	32.4	18.3	2.20	7.95E-01	8.71E-01
152	S101	2	356	38	1.40E+03	2.79E+04	5.00E-02	1.140	56.2	30.7	13.1	1.70	2.23E-01	2.54E-01
153	S102	2	357	38	1.80E+02	3.60E+03	5.00E-02	1.380	62.4	24.6	13.1	1.50	1.03E+00	1.42E+00
154	S103	2	358	38	1.90E+02	3.80E+03	5.00E-02	0.965	41.0	44.6	14.4	2.00	2.20E-01	2.13E-01
155	S104	2	359	39	5.25E+02	1.05E+04	5.00E-02	0.774	53.8	28.7	17.6	1.40	9.98E-01	7.72E-01
156	S105	2	360	39	1.65E+02	3.30E+03	5.00E-02	0.863	43.3	34.4	22.3	2.70	1.50E+00	1.30E+00
157	S106	2	361	39	1.42E+03	2.84E+04	5.00E-02	0.818	48.0	34.9	17.1	1.60	7.76E-01	6.35E-01
158	S107	2	362	39	1.78E+03	3.56E+04	5.00E-02	0.766	45.3	32.9	21.8	3.20	1.76E+00	1.35E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
159	S108	2	363	39	5.80E+02	1.16E+04	5.00E-02	0.810	41.8	46.8	11.4	1.90	3.03E-01	2.45E-01
160	S109	2	364	39	4.20E+02	8.40E+03	5.00E-02	0.773	41.6	44.1	14.4	2.90	1.11E+00	8.56E-01
161	S110	2	365	40	3.60E+02	7.20E+03	5.00E-02	0.807	33.0	49.1	18.0	3.90	1.50E+00	1.21E+00
162	S111	2	366	40	2.30E+02	4.60E+03	5.00E-02	0.537	36.7	50.1	13.2	6.00	1.70E+00	9.10E-01
163	S112	2	367	40	2.00E+03	3.99E+04	5.00E-02	0.625	22.1	60.5	17.5	4.60	1.67E+00	1.05E+00
164	S113	2	368	40	2.02E+03	4.04E+04	5.00E-02	0.555	32.4	54.2	13.5	5.90	1.65E+00	9.14E-01
165	S114	2	369	40	2.35E+02	4.70E+03	5.00E-02	0.752	28.0	51.6	20.4	3.80	1.61E+00	1.21E+00
166	S115	2	370	40	6.05E+02	1.64E+04	3.69E-02	0.687	31.4	52.7	15.9	5.80	8.14E-01	5.59E-01
1	02-A	3	371	2	1.93E+04	1.21E+05	1.60E-01	0.528	41.0	42.6	16.4	6.50	6.30E+01	3.32E+01
2	01-B	3	372	1	1.34E+04	9.69E+04	1.38E-01	1.240	57.5	29.8	12.7	2.50	3.73E+00	4.63E+00
3	03-C	3	373	3	1.54E+04	9.51E+04	1.62E-01	0.506	29.9	47.9	22.2	6.70	2.15E+01	1.09E+01
4	04-D	3	374	4	1.71E+04	1.65E+05	1.03E-01	0.681	58.1	34.8	7.1	6.60	2.32E+00	1.58E+00
5	03-Pg	3	375	3	1.97E+04	1.39E+05	1.41E-01	0.382	46.1	46.3	7.6	8.80	6.67E+00	2.54E+00
6	04-Pg	3	376	4	1.22E+04	9.92E+04	1.23E-01	0.417	60.1	33.2	6.7	9.90	1.24E+01	5.17E+00
7	04-E	3	377	4	1.12E+04	1.15E+05	9.76E-02	0.673	30.9	52.5	16.6	7.00	1.28E+00	8.63E-01
8	05-E	3	378	5	1.16E+05	6.92E+05	1.68E-01	0.458	25.5	54.4	20.1	6.00	5.63E+00	2.58E+00
9	06-E	3	379	6	6.41E+04	4.36E+05	1.47E-01	0.436	19.9	54.0	26.1	7.30	5.89E+00	2.57E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
10	07-E	3	380	7	4.29E+04	2.89E+05	1.49E-01	0.485	27.0	50.9	22.1	7.40	1.15E+00	5.57E-01
11	06-F	3	381	6	1.93E+04	1.27E+05	1.52E-01	0.343	25.3	52.0	22.7	14.00	1.06E+00	3.63E-01
12	08-G	3	382	8	3.81E+03	2.80E+04	1.36E-01	0.630	54.4	32.1	13.6	3.80	1.85E-01	1.17E-01
13	08-H	3	383	8	9.98E+01	2.30E+03	4.34E-02	0.886	62.8	24.2	13.0	3.00	1.94E+00	1.72E+00
14	09-I	3	384	9	8.88E+02	1.15E+04	7.72E-02	0.529	14.2	61.2	24.7	5.70	7.60E-01	4.02E-01
15	09-J	3	385	9	9.02E+02	1.06E+04	8.51E-02	0.634	22.6	57.8	19.7	3.70	1.15E-01	7.27E-02
16	09-K	3	386	9	9.84E+01	1.60E+03	6.15E-02	0.810	67.3	19.1	13.6	2.90	2.30E-01	1.86E-01
17	10-L	3	387	10	1.09E+02	2.40E+03	4.53E-02	0.711	29.8	43.8	26.5	3.40	2.90E-01	2.06E-01
18	10-M	3	388	10	4.39E+02	5.40E+03	8.12E-02	0.454	8.5	62.1	29.4	5.60	7.00E-01	3.18E-01
19	10-N	3	389	10	1.07E+03	1.26E+04	8.52E-02	0.601	51.5	37.0	11.5	8.30	3.82E+01	2.29E+01
20	10-O	3	390	10	1.58E+03	1.21E+04	1.31E-01	0.668	64.4	25.9	9.8	6.70	1.31E+01	8.74E+00
21	10-P	3	391	10	4.22E+03	2.57E+04	1.64E-01	0.968	46.2	39.7	14.1	2.40	1.79E+00	1.73E+00
22	10-Q	3	392	10	2.33E+01	7.00E+02	3.33E-02	0.474	45.4	41.9	12.6	8.60	1.62E+00	7.68E-01
23	10-R	3	393	10	4.58E+02	4.20E+03	1.09E-01	0.954	35.4	43.3	21.3	8.50	1.68E+00	1.60E+00
24	11-S	3	394	11	1.99E+04	1.29E+05	1.55E-01	0.599	63.3	23.6	13.1	8.10	2.02E-01	1.21E-01
25	12-T	3	395	12	2.49E+03	1.61E+04	1.55E-01	0.532	91.1	4.0	4.9	8.20	5.65E+00	3.01E+00
26	12-U	3	396	12	9.72E+02	9.20E+03	1.06E-01	0.474	35.4	48.5	16.2	6.60	1.00E+00	4.74E-01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
27	13-V	3	397	13	2.47E+03	1.71E+04	1.44E-01	0.520	52.8	36.3	10.9	4.40	1.70E+00	8.86E-01
28	13-W	3	398	13	5.46E+04	3.22E+05	1.70E-01	0.573	53.2	32.7	14.1	4.20	1.03E+00	5.91E-01
29	14-W	3	399	14	2.77E+04	1.59E+05	1.74E-01	0.682	48.6	35.0	16.4	3.50	1.25E+00	8.54E-01
30	13-X	3	400	13	1.59E+04	1.08E+05	1.48E-01	0.537	40.2	48.2	11.6	4.70	3.61E+00	1.94E+00
31	14-X	3	401	14	1.37E+04	8.75E+04	1.56E-01	0.424	25.1	57.2	17.7	5.30	2.07E+00	8.76E-01
32	14-Y	3	402	14	7.31E+02	1.08E+04	6.77E-02	0.660	47.6	37.6	14.7	2.50	3.71E-01	2.45E-01
33	14-Z	3	403	14	2.21E+03	1.64E+04	1.35E-01	0.695	28.6	48.5	22.9	2.20	3.10E-01	2.16E-01
34	15-AA	3	404	15	4.17E+01	1.30E+03	3.21E-02	1.140	55.7	20.1	24.2	1.90	2.46E-01	2.81E-01
35	15-BB	3	405	15	3.17E+02	5.00E+03	6.33E-02	0.861	46.4	34.1	19.5	1.90	1.30E-01	1.12E-01
36	15-CC	3	406	15	1.30E+04	7.38E+04	1.76E-01	0.781	30.2	21.3	48.5	1.90	3.92E-01	3.06E-01
37	18-DD	3	407	18	2.20E+04	1.28E+05	1.73E-01	0.641	31.9	42.7	25.3	4.60	8.78E-01	5.62E-01
38	19-EE	3	408	19	3.17E+04	1.92E+05	1.65E-01	0.706	54.1	32.0	13.9	4.00	1.38E+00	9.75E-01
39	20-EE	3	409	20	1.02E+05	5.89E+05	1.72E-01	0.537	32.1	49.0	18.9	5.70	4.72E+00	2.54E+00
40	21-EE	3	410	21	1.24E+05	6.93E+05	1.80E-01	0.508	35.6	44.2	20.2	5.70	4.81E+00	2.44E+00
41	22-EE	3	411	22	6.29E+04	3.44E+05	1.83E-01	0.474	24.2	52.6	23.3	6.10	4.18E+00	1.98E+00
42	23-EE	3	412	23	5.26E+04	3.02E+05	1.74E-01	0.504	23.5	51.1	25.5	6.30	6.45E+00	3.25E+00
43	24-EE	3	413	24	3.23E+04	1.70E+05	1.91E-01	0.659	29.5	49.9	20.7	7.30	9.27E+00	6.11E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
44	23-FF	3	414	23	4.79E+02	3.40E+03	1.41E-01	0.360	3.4	62.4	34.2	5.90	1.80E+01	6.47E+00
45	24-GG	3	415	24	3.28E+03	2.10E+04	1.56E-01	0.392	24.3	56.1	19.6	6.50	1.13E+01	4.43E+00
46	24-HH	3	416	24	3.94E+03	3.22E+04	1.22E-01	0.593	23.2	55.1	21.7	6.00	3.64E+00	2.16E+00
47	01-ID	3	417	1	1.91E+02	1.53E+04	1.25E-02	1.140	68.5	8.6	22.9	3.20	1.24E+01	1.41E+01
48	02-ID	3	418	2	7.78E+02	2.85E+04	2.73E-02	0.789	44.4	27.7	27.9	5.20	1.95E+01	1.54E+01
49	03-ID	3	419	3	4.04E+03	1.05E+05	3.85E-02	0.751	65.0	24.9	10.1	6.60	6.38E+00	4.79E+00
50	04-ID	3	420	4	1.12E+04	2.00E+05	5.59E-02	0.557	59.0	31.6	9.4	7.10	3.93E+00	2.19E+00
51	05-ID	3	421	5	3.26E+02	2.00E+04	1.63E-02	0.531	32.1	48.3	19.6	6.90	1.60E+00	8.48E-01
52	06-ID	3	422	6	8.88E+02	3.73E+04	2.38E-02	0.522	17.3	49.7	33.0	9.10	5.54E+00	2.89E+00
53	07-ID	3	423	7	2.81E+03	4.01E+04	7.00E-02	0.459	27.3	48.5	24.3	7.00	1.24E+00	5.69E-01
54	08-ID	3	424	8	2.52E+02	2.33E+04	1.08E-02	0.646	49.6	32.4	18.0	4.40	7.46E-01	4.82E-01
55	09-ID	3	425	9	7.20E-01	3.60E+03	2.00E-04	1.020	57.8	28.3	14.0	2.90	6.51E-01	6.62E-01
56	10-ID	3	426	10	1.15E+03	6.92E+04	1.67E-02	0.658	43.6	39.4	17.0	7.60	9.11E+00	5.99E+00
57	11-ID	3	427	11	3.51E+00	2.70E+03	1.30E-03	0.609	39.1	42.6	18.4	7.90	2.33E-01	1.42E-01
58	12-ID	3	428	12	1.54E+02	3.35E+04	4.60E-03	0.910	76.6	15.7	7.7	5.50	1.99E+00	1.81E+00
59	13-ID	3	429	13	3.26E+02	2.47E+04	1.32E-02	1.020	76.5	15.9	7.7	4.10	8.53E-01	8.70E-01
60	14-ID	3	430	14	4.03E+02	2.55E+04	1.58E-02	0.629	37.5	45.1	17.4	3.20	1.05E+00	6.61E-01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
61	15-ID	3	431	15	1.95E+03	5.94E+04	3.29E-02	0.878	47.6	26.4	26.1	1.60	2.51E-01	2.20E-01
62	16-ID	3	432	16	1.31E+03	7.15E+04	1.83E-02	1.380	86.3	4.4	9.3	0.80	1.81E-01	2.49E-01
63	17-ID	3	433	17	7.81E+00	7.10E+03	1.10E-03	1.400	87.0	4.0	9.0	2.60	1.80E-01	2.51E-01
64	18-ID	3	434	18	1.97E+03	4.85E+04	4.07E-02	0.738	51.9	29.8	18.4	4.40	7.94E-01	5.86E-01
65	19-ID	3	435	19	1.88E+02	2.68E+04	7.00E-03	0.960	64.7	23.9	11.4	3.20	6.87E-01	6.60E-01
66	20-ID	3	436	20	5.58E+01	9.30E+03	6.00E-03	0.659	45.7	37.9	16.4	4.40	3.92E+00	2.58E+00
67	21-ID	3	437	21	6.80E-01	2.00E+02	3.40E-03	0.526	36.8	43.6	19.7	5.60	4.69E+00	2.47E+00
68	22-ID	3	438	22	4.83E+03	6.61E+04	7.30E-02	0.630	40.3	39.6	20.2	5.00	2.83E+00	1.78E+00
69	23-ID	3	439	23	3.24E+03	5.44E+04	5.96E-02	0.490	20.4	52.3	27.3	6.10	6.90E+00	3.38E+00
70	24-ID	3	440	24	1.01E+04	9.34E+04	1.08E-01	0.579	26.5	53.2	20.3	6.80	8.00E+00	4.64E+00
71	S020	3	441	25	6.54E+04	3.70E+05	1.77E-01	0.539	37.3	44.3	18.4	5.50	1.22E+01	6.56E+00
72	S021	3	442	25	2.39E+04	1.37E+05	1.74E-01	0.779	28.9	54.2	16.9	4.00	1.50E+01	1.17E+01
73	S022	3	443	25	1.84E+04	9.81E+04	1.87E-01	0.680	27.5	48.5	24.1	5.80	1.32E+01	8.98E+00
74	S023	3	444	25	2.27E+04	1.32E+05	1.72E-01	0.947	22.3	56.6	21.1	2.80	1.24E+00	1.17E+00
75	S024	3	445	25	1.78E+04	1.03E+05	1.72E-01	0.625	32.9	46.6	20.6	5.60	1.07E+01	6.66E+00
76	S025	3	446	25	1.70E+04	1.16E+05	1.47E-01	1.020	27.9	51.5	20.6	2.70	7.00E+00	7.14E+00
77	S026	3	447	26	2.13E+03	1.44E+04	1.48E-01	0.798	18.9	61.5	19.6	2.80	3.63E+00	2.90E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
78	S027	3	448	26	2.44E+03	1.77E+04	1.38E-01	0.759	25.3	52.6	22.1	3.50	1.18E+01	8.98E+00
79	S028	3	449	26	8.87E+03	5.85E+04	1.52E-01	0.729	21.8	60.9	17.3	3.30	7.86E+00	5.73E+00
80	S029	3	450	26	1.56E+04	7.98E+04	1.96E-01	0.772	32.1	47.0	20.9	3.50	1.54E+01	1.19E+01
81	S030	3	451	26	8.20E+02	9.40E+03	8.72E-02	0.703	25.0	57.8	17.2	3.70	1.09E+01	7.64E+00
82	S031	3	452	26	9.21E+02	1.34E+04	6.87E-02	1.050	29.2	45.5	25.3	1.30	5.32E+00	5.59E+00
83	S032	3	453	27	7.43E+03	4.52E+04	1.64E-01	0.863	32.4	50.5	17.1	4.30	1.27E+01	1.09E+01
84	S033	3	454	27	6.12E+03	4.68E+04	1.31E-01	0.641	40.3	41.5	18.2	5.10	5.82E+00	3.73E+00
85	S034	3	455	27	1.21E+04	6.11E+04	1.97E-01	0.849	37.5	45.6	17.0	4.00	1.34E+01	1.14E+01
86	S035	3	456	27	1.47E+04	7.38E+04	1.99E-01	0.631	38.1	41.4	20.5	5.00	4.91E+00	3.09E+00
87	S036	3	457	27	7.40E+02	1.07E+04	6.92E-02	0.938	38.1	38.9	23.0	2.50	9.99E+00	9.37E+00
88	S037	3	458	27	2.61E+03	1.95E+04	1.34E-01	0.776	25.5	48.3	26.2	3.40	9.94E-01	7.71E-01
89	S038	3	459	28	6.97E+03	4.60E+04	1.52E-01	0.729	50.7	37.8	11.5	3.40	1.08E+01	7.84E+00
90	S039	3	460	28	3.33E+03	2.42E+04	1.38E-01	0.801	14.3	63.0	22.7	3.20	9.79E+00	7.84E+00
91	S040	3	461	28	1.77E+04	9.42E+04	1.88E-01	0.643	45.4	38.0	16.6	5.10	1.05E+01	6.75E+00
92	S041	3	462	28	2.51E+04	1.31E+05	1.92E-01	0.744	30.3	52.1	17.6	3.90	1.09E+01	8.13E+00
93	S042	3	463	28	2.43E+03	3.32E+04	7.33E-02	0.808	46.1	38.4	15.5	3.70	8.99E+00	7.27E+00
94	S043	3	464	28	1.03E+04	7.80E+04	1.32E-01	0.941	36.3	47.5	16.3	2.10	9.77E-01	9.19E-01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
95	S044	3	465	29	1.82E+04	1.09E+05	1.68E-01	0.592	34.4	48.3	17.4	4.20	2.92E+00	1.73E+00
96	S045	3	466	29	3.19E+04	1.76E+05	1.81E-01	0.509	22.8	58.0	19.2	5.20	4.40E+00	2.24E+00
97	S046	3	467	29	3.30E+04	1.73E+05	1.91E-01	0.635	29.3	53.9	16.8	4.40	4.02E+00	2.55E+00
98	S047	3	468	29	3.02E+04	1.51E+05	2.00E-01	0.476	31.5	49.9	18.6	6.80	7.63E+00	3.63E+00
99	S048	3	469	29	3.28E+04	1.78E+05	1.84E-01	0.721	48.2	38.0	13.8	3.80	1.05E+01	7.57E+00
100	S049	3	470	29	4.54E+04	2.41E+05	1.88E-01	0.516	43.7	41.3	15.0	4.60	8.30E+00	4.28E+00
101	S050	3	471	30	4.55E+03	2.41E+04	1.89E-01	0.922	21.2	58.9	19.9	2.90	5.06E-01	4.66E-01
102	S051	3	472	30	4.71E+03	2.41E+04	1.95E-01	0.877	48.8	39.4	11.8	2.90	9.81E+00	8.61E+00
103	S052	3	473	30	1.89E+04	9.93E+04	1.90E-01	0.612	24.1	59.4	16.5	5.60	2.50E+00	1.53E+00
104	S053	3	474	30	1.77E+04	9.54E+04	1.86E-01	0.582	20.9	61.5	17.6	4.60	5.08E+00	2.96E+00
105	S054	3	475	30	5.69E+03	4.90E+04	1.16E-01	0.559	37.4	49.1	13.6	4.80	1.89E+00	1.06E+00
106	S055	3	476	30	6.64E+02	9.40E+03	7.06E-02	0.493	17.3	65.1	17.6	5.10	4.33E+00	2.13E+00
107	S056	3	477	31	1.31E+04	6.57E+04	1.99E-01	0.484	29.3	53.4	17.4	6.50	2.02E+01	9.79E+00
108	S057	3	478	31	1.67E+04	8.42E+04	1.99E-01	0.520	27.9	51.1	21.1	6.70	5.26E+00	2.73E+00
109	S058	3	479	31	6.15E+03	3.09E+04	1.99E-01	0.477	33.0	49.9	17.1	6.00	9.63E+00	4.59E+00
110	S059	3	480	31	5.14E+03	2.66E+04	1.93E-01	0.702	31.6	42.3	26.1	4.30	3.44E+00	2.42E+00
111	S060	3	481	31	2.55E+03	2.58E+04	9.88E-02	0.532	29.7	52.7	17.6	5.60	7.65E+00	4.07E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
112	S061	3	482	31	8.03E+03	4.27E+04	1.88E-01	0.750	37.1	42.6	20.3	3.10	3.16E+00	2.37E+00
113	S062	3	483	32	7.13E+03	4.98E+04	1.43E-01	0.494	23.0	58.2	18.9	7.10	2.88E+00	1.42E+00
114	S063	3	484	32	9.20E+02	4.60E+03	2.00E-01	0.804	37.5	47.8	14.8	4.10	3.72E+00	2.99E+00
115	S064	3	485	32	1.01E+03	1.85E+04	5.48E-02	0.569	28.5	52.8	18.7	6.10	2.93E+00	1.67E+00
116	S065	3	486	32	7.12E+03	3.56E+04	2.00E-01	0.768	34.8	50.2	15.0	4.50	8.70E+00	6.68E+00
118	S067	3	487	32	1.70E+03	8.50E+03	2.00E-01	0.590	24.1	59.3	16.6	5.90	1.91E+01	1.13E+01
119	S068	3	488	33	1.00E+03	5.00E+03	2.00E-01	0.520	22.8	58.5	18.7	5.90	3.94E+00	2.05E+00
120	S069	3	489	33	6.00E+01	3.00E+02	2.00E-01	0.543	30.9	51.5	17.6	5.90	8.56E+00	4.65E+00
121	S070	3	490	33	1.64E+04	8.22E+04	2.00E-01	0.492	26.8	54.9	18.3	6.30	9.23E+00	4.54E+00
122	S071	3	491	33	7.82E+03	3.91E+04	2.00E-01	0.569	35.0	48.8	16.3	5.60	1.29E+01	7.35E+00
123	S072	3	492	33	4.60E+02	2.30E+03	2.00E-01	0.585	31.9	51.5	16.6	5.90	1.70E+01	9.93E+00
124	S073	3	493	33	8.40E+02	4.20E+03	2.00E-01	0.718	39.9	45.0	15.1	5.10	1.82E+01	1.30E+01
125	S074	3	494	34	1.00E+02	5.00E+02	2.00E-01	0.630	49.1	38.2	12.8	4.90	7.48E+00	4.71E+00
126	S075	3	495	34	4.00E+01	2.00E+02	2.00E-01	1.050	22.9	51.7	25.4	2.60	9.24E+00	9.66E+00
127	S076	3	496	34	7.28E+03	3.64E+04	2.00E-01	0.611	50.3	38.0	11.7	5.00	5.89E+00	3.60E+00
128	S077	3	497	34	5.60E+03	2.80E+04	2.00E-01	0.873	40.2	46.6	13.3	3.50	9.67E+00	8.44E+00
129	S078	3	498	34	5.40E+02	2.70E+03	2.00E-01	0.599	50.9	38.5	10.6	5.10	4.11E+00	2.47E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
130	S079	3	499	34	4.40E+02	2.20E+03	2.00E-01	0.801	37.9	51.0	11.1	3.40	9.91E+00	7.94E+00
131	S080	3	500	35	1.04E+03	5.20E+03	2.00E-01	0.785	50.8	35.1	14.2	4.10	2.32E+00	1.82E+00
132	S081	3	501	35	2.40E+02	1.20E+03	2.00E-01	0.703	40.9	45.0	14.2	5.30	7.80E+00	5.48E+00
133	S082	3	502	35	7.22E+03	3.61E+04	2.00E-01	0.755	43.9	42.4	13.7	4.00	3.56E+00	2.69E+00
134	S083	3	503	35	5.86E+03	2.93E+04	2.00E-01	0.765	40.9	43.7	15.4	5.10	4.85E+00	3.71E+00
135	S084	3	504	35	1.02E+03	5.10E+03	2.00E-01	0.739	35.8	49.7	14.5	3.90	4.40E+00	3.25E+00
136	S085	3	505	35	7.20E+02	3.60E+03	2.00E-01	0.806	39.8	44.3	16.0	5.10	3.34E+00	2.69E+00
137	S086	3	506	36	1.70E+03	8.50E+03	2.00E-01	0.745	32.8	52.9	14.3	5.10	8.41E+00	6.26E+00
138	S087	3	507	36	8.00E+02	4.00E+03	2.00E-01	0.936	22.0	54.4	23.6	4.20	2.86E+00	2.68E+00
139	S088	3	508	36	6.38E+03	3.19E+04	2.00E-01	0.849	36.4	50.2	13.4	3.90	6.59E+00	5.59E+00
140	S089	3	509	36	2.20E+03	1.10E+04	2.00E-01	0.899	13.7	56.9	29.4	5.00	4.02E+00	3.61E+00
141	S090	3	510	36	1.00E+03	5.00E+03	2.00E-01	1.020	36.1	50.2	13.7	2.60	2.27E+00	2.32E+00
142	S091	3	511	36	2.60E+02	1.30E+03	2.00E-01	0.814	27.3	49.9	22.8	5.00	3.37E+00	2.74E+00
143	S092	3	512	37	6.00E+01	3.00E+02	2.00E-01	0.477	25.6	54.8	19.5	4.50	3.18E+00	1.52E+00
144	S093	3	513	37	6.80E+02	3.40E+03	2.00E-01	0.920	52.4	30.6	17.0	3.20	6.91E-01	6.35E-01
145	S094	3	514	37	1.01E+04	5.04E+04	2.00E-01	0.498	27.4	52.0	20.6	5.30	2.82E+00	1.40E+00
146	S095	3	515	37	5.86E+03	2.93E+04	2.00E-01	1.130	58.7	26.8	14.5	2.30	5.61E-01	6.32E-01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
147	S096	3	516	37	2.30E+03	1.15E+04	2.00E-01	0.400	29.3	55.6	15.2	5.70	2.29E+00	9.17E-01
148	S097	3	517	37	9.40E+02	4.70E+03	2.00E-01	1.020	53.0	31.4	15.7	2.60	8.37E-01	8.55E-01
149	S098	3	518	38	5.60E+02	2.80E+03	2.00E-01	0.938	40.9	37.7	21.4	2.60	4.98E-01	4.67E-01
150	S099	3	519	38	1.82E+03	9.10E+03	2.00E-01	1.190	64.5	24.7	10.8	1.50	1.90E-01	2.27E-01
151	S100	3	520	38	5.76E+03	2.88E+04	2.00E-01	1.100	49.3	32.4	18.3	2.20	7.24E-01	7.94E-01
152	S101	3	521	38	5.58E+03	2.79E+04	2.00E-01	1.140	56.2	30.7	13.1	1.70	2.92E-01	3.33E-01
153	S102	3	522	38	7.20E+02	3.60E+03	2.00E-01	1.380	62.4	24.6	13.1	1.50	1.01E+00	1.39E+00
154	S103	3	523	38	7.60E+02	3.80E+03	2.00E-01	0.965	41.0	44.6	14.4	2.00	3.44E-01	3.32E-01
155	S104	3	524	39	2.10E+03	1.05E+04	2.00E-01	0.774	53.8	28.7	17.6	1.40	1.00E+00	7.75E-01
156	S105	3	525	39	6.60E+02	3.30E+03	2.00E-01	0.863	43.3	34.4	22.3	2.70	1.31E+00	1.13E+00
157	S106	3	526	39	5.68E+03	2.84E+04	2.00E-01	0.818	48.0	34.9	17.1	1.60	7.87E-01	6.44E-01
158	S107	3	527	39	7.12E+03	3.56E+04	2.00E-01	0.766	45.3	32.9	21.8	3.20	1.57E+00	1.20E+00
159	S108	3	528	39	2.32E+03	1.16E+04	2.00E-01	0.810	41.8	46.8	11.4	1.90	3.13E-01	2.53E-01
160	S109	3	529	39	1.68E+03	8.40E+03	2.00E-01	0.773	41.6	44.1	14.4	2.90	9.17E-01	7.08E-01
161	S110	3	530	40	1.44E+03	7.20E+03	2.00E-01	0.807	33.0	49.1	18.0	3.90	2.02E+00	1.63E+00
162	S111	3	531	40	9.20E+02	4.60E+03	2.00E-01	0.537	36.7	50.1	13.2	6.00	1.59E+00	8.54E-01
163	S112	3	532	40	7.98E+03	3.99E+04	2.00E-01	0.625	22.1	60.5	17.5	4.60	1.90E+00	1.18E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
164	S113	3	533	40	8.08E+03	4.04E+04	2.00E-01	0.555	32.4	54.2	13.5	5.90	1.61E+00	8.95E-01
165	S114	3	534	40	9.40E+02	4.70E+03	2.00E-01	0.752	28.0	51.6	20.4	3.80	1.92E+00	1.45E+00
166	S115	3	535	40	1.03E+03	1.00E+04	1.03E-01	0.687	31.4	52.7	15.9	5.80	1.08E+00	7.40E-01
1	02-A	4	Deep	2	1.71E+04	1.18E+05	1.45E-01	0.528	41.0	42.6	16.4	6.50	5.39E+01	2.85E+01
2	01-B	4	Deep	1	7.25E+03	8.52E+04	8.51E-02	1.240	57.5	29.8	12.7	2.50	8.38E+00	1.04E+01
3	03-C	4	Deep	3	1.02E+04	8.73E+04	1.17E-01	0.506	29.9	47.9	22.2	6.70	1.29E+01	6.55E+00
4	04-D	4	Deep	4	5.01E+03	9.14E+04	5.48E-02	0.681	58.1	34.8	7.1	6.60	2.31E+00	1.57E+00
5	03-Pg	4	Deep	3	5.95E+03	7.13E+04	8.35E-02	0.382	46.1	46.3	7.6	8.80	5.59E+00	2.13E+00
6	04-Pg	4	Deep	4	3.74E+03	4.76E+04	7.86E-02	0.417	60.1	33.2	6.7	9.90	1.20E+01	5.01E+00
7	04-E	4	Deep	4	7.94E+03	9.71E+04	8.18E-02	0.673	30.9	52.5	16.6	7.00	1.26E+00	8.50E-01
8	05-E	4	Deep	5	1.06E+05	6.75E+05	1.57E-01	0.458	25.5	54.4	20.1	6.00	3.76E+00	1.72E+00
9	06-E	4	Deep	6	5.60E+04	4.23E+05	1.32E-01	0.436	19.9	54.0	26.1	7.30	3.28E+00	1.43E+00
10	07-E	4	Deep	7	3.38E+04	2.75E+05	1.23E-01	0.485	27.0	50.9	22.1	7.40	1.36E+00	6.60E-01
11	06-F	4	Deep	6	1.47E+04	1.20E+05	1.22E-01	0.343	25.3	52.0	22.7	14.00	4.80E-01	1.65E-01
12	08-G	4	Deep	8	2.30E+03	2.45E+04	9.39E-02	0.630	54.4	32.1	13.6	3.80	2.30E-01	1.45E-01
14	09-I	4	Deep	9	4.26E+02	9.20E+03	4.63E-02	0.529	14.2	61.2	24.7	5.70	7.60E-01	4.02E-01
15	09-J	4	Deep	9	7.35E+01	5.70E+03	1.29E-02	0.634	22.6	57.8	19.7	3.70	9.77E-02	6.19E-02

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
18	10-M	4	Deep	10	5.04E+01	2.80E+03	1.80E-02	0.454	8.5	62.1	29.4	5.60	7.00E-01	3.18E-01
19	10-N	4	Deep	10	3.34E+02	7.20E+03	4.64E-02	0.601	51.5	37.0	11.5	8.30	3.95E+01	2.37E+01
20	10-O	4	Deep	10	1.17E+03	1.14E+04	1.03E-01	0.668	64.4	25.9	9.8	6.70	1.40E+01	9.32E+00
21	10-P	4	Deep	10	3.42E+03	2.49E+04	1.37E-01	0.968	46.2	39.7	14.1	2.40	9.87E-01	9.55E-01
23	10-R	4	Deep	10	1.26E+02	2.70E+03	4.68E-02	0.954	35.4	43.3	21.3	8.50	2.57E+00	2.45E+00
24	11-S	4	Deep	11	1.52E+04	1.21E+05	1.26E-01	0.599	63.3	23.6	13.1	8.10	1.53E-01	9.17E-02
25	12-T	4	Deep	12	1.62E+03	1.43E+04	1.14E-01	0.532	91.1	4.0	4.9	8.20	5.00E+00	2.66E+00
26	12-U	4	Deep	12	2.88E+02	6.60E+03	4.37E-02	0.474	35.4	48.5	16.2	6.60	0.00E+00	0.00E+00
27	13-V	4	Deep	13	1.04E+03	1.26E+04	8.28E-02	0.520	52.8	36.3	10.9	4.40	1.70E+00	8.84E-01
28	13-W	4	Deep	13	3.85E+04	3.07E+05	1.26E-01	0.573	53.2	32.7	14.1	4.20	9.28E-01	5.32E-01
29	14-W	4	Deep	14	2.16E+04	1.51E+05	1.44E-01	0.682	48.6	35.0	16.4	3.50	3.49E+00	2.38E+00
30	13-X	4	Deep	13	1.11E+04	9.70E+04	1.14E-01	0.537	40.2	48.2	11.6	4.70	3.14E+00	1.69E+00
31	14-X	4	Deep	14	8.98E+03	7.97E+04	1.13E-01	0.424	25.1	57.2	17.7	5.30	2.20E+00	9.30E-01
32	14-Y	4	Deep	14	5.33E+01	6.50E+03	8.20E-03	0.660	47.6	37.6	14.7	2.50	3.71E-01	2.45E-01
33	14-Z	4	Deep	14	9.74E+02	1.36E+04	7.16E-02	0.695	28.6	48.5	22.9	2.20	3.70E-01	2.57E-01
36	15-CC	4	Deep	15	8.84E+03	7.11E+04	1.24E-01	0.781	30.2	21.3	48.5	1.90	2.76E-01	2.15E-01
37	18-DD	4	Deep	18	1.60E+04	1.18E+05	1.36E-01	0.641	31.9	42.7	25.3	4.60	2.65E+00	1.70E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
38	19-EE	4	Deep	19	2.49E+04	1.82E+05	1.37E-01	0.706	54.1	32.0	13.9	4.00	7.52E-01	5.31E-01
39	20-EE	4	Deep	20	8.86E+04	5.70E+05	1.56E-01	0.537	32.1	49.0	18.9	5.70	4.11E+00	2.21E+00
40	21-EE	4	Deep	21	1.13E+05	6.74E+05	1.68E-01	0.508	35.6	44.2	20.2	5.70	5.92E+00	3.00E+00
41	22-EE	4	Deep	22	5.58E+04	3.34E+05	1.67E-01	0.474	24.2	52.6	23.3	6.10	2.58E+00	1.22E+00
42	23-EE	4	Deep	23	4.51E+04	2.91E+05	1.55E-01	0.504	23.5	51.1	25.5	6.30	5.94E+00	2.99E+00
43	24-EE	4	Deep	24	2.75E+04	1.56E+05	1.76E-01	0.659	29.5	49.9	20.7	7.30	9.17E+00	6.04E+00
44	23-FF	4	Deep	23	1.91E+02	2.70E+03	7.08E-02	0.360	3.4	62.4	34.2	5.90	2.44E+01	8.77E+00
45	24-GG	4	Deep	24	2.20E+03	1.70E+04	1.30E-01	0.392	24.3	56.1	19.6	6.50	1.45E+01	5.67E+00
46	24-HH	4	Deep	24	2.64E+03	2.49E+04	1.06E-01	0.593	23.2	55.1	21.7	6.00	3.68E+00	2.18E+00
48	02-ID	4	Deep	2	2.45E+01	4.30E+03	5.70E-03	0.789	44.4	27.7	27.9	5.20	2.40E+01	1.89E+01
49	03-ID	4	Deep	3	1.70E+02	2.15E+04	7.90E-03	0.751	65.0	24.9	10.1	6.60	7.68E+00	5.76E+00
50	04-ID	4	Deep	4	1.62E+03	7.12E+04	2.28E-02	0.557	59.0	31.6	9.4	7.10	3.86E+00	2.15E+00
51	05-ID	4	Deep	5	2.54E+01	4.10E+03	6.20E-03	0.531	32.1	48.3	19.6	6.90	1.16E+00	6.16E-01
52	06-ID	4	Deep	6	2.67E+01	5.80E+03	4.60E-03	0.522	17.3	49.7	33.0	9.10	3.53E+00	1.85E+00
53	07-ID	4	Deep	7	5.22E+02	1.63E+04	3.20E-02	0.459	27.3	48.5	24.3	7.00	1.68E+00	7.72E-01
54	08-ID	4	Deep	8	1.28E+00	3.20E+03	4.00E-04	0.646	49.6	32.4	18.0	4.40	9.96E-01	6.43E-01
56	10-ID	4	Deep	10	7.31E+01	2.01E+04	3.60E-03	0.658	43.6	39.4	17.0	7.60	1.20E+01	7.88E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
57	11-ID	4	Deep	11	1.60E-01	8.00E+02	2.00E-04	0.609	39.1	42.6	18.4	7.90	3.20E-01	1.95E-01
58	12-ID	4	Deep	12	7.00E-02	7.00E+02	1.00E-04	0.910	76.6	15.7	7.7	5.50	4.69E+00	4.27E+00
59	13-ID	4	Deep	13	1.07E+02	1.50E+04	7.10E-03	1.020	76.5	15.9	7.7	4.10	7.47E-01	7.61E-01
60	14-ID	4	Deep	14	4.99E+01	9.60E+03	5.20E-03	0.629	37.5	45.1	17.4	3.20	1.32E+00	8.29E-01
61	15-ID	4	Deep	15	3.15E+02	2.81E+04	1.12E-02	0.878	47.6	26.4	26.1	1.60	1.83E-01	1.61E-01
62	16-ID	4	Deep	16	1.64E+02	1.61E+04	1.02E-02	1.380	86.3	4.4	9.3	0.80	2.80E-01	3.87E-01
64	18-ID	4	Deep	18	2.11E+02	1.70E+04	1.24E-02	0.738	51.9	29.8	18.4	4.40	2.08E+00	1.53E+00
68	22-ID	4	Deep	22	4.56E+02	2.17E+04	2.10E-02	0.630	40.3	39.6	20.2	5.00	1.76E+00	1.11E+00
69	23-ID	4	Deep	23	3.09E+02	1.94E+04	1.59E-02	0.490	20.4	52.3	27.3	6.10	5.75E+00	2.82E+00
70	24-ID	4	Deep	24	5.92E+03	6.86E+04	8.63E-02	0.579	26.5	53.2	20.3	6.80	7.12E+00	4.13E+00
71	S020	4	Deep	25	5.27E+04	3.27E+05	1.61E-01	0.539	37.3	44.3	18.4	5.50	1.71E+01	9.21E+00
72	S021	4	Deep	25	2.00E+04	1.24E+05	1.61E-01	0.779	28.9	54.2	16.9	4.00	1.95E+01	1.52E+01
73	S022	4	Deep	25	1.62E+04	9.10E+04	1.78E-01	0.680	27.5	48.5	24.1	5.80	3.06E+01	2.08E+01
74	S023	4	Deep	25	1.39E+04	1.08E+05	1.28E-01	0.947	22.3	56.6	21.1	2.80	2.18E+00	2.06E+00
75	S024	4	Deep	25	1.31E+04	8.69E+04	1.51E-01	0.625	32.9	46.6	20.6	5.60	1.99E+01	1.24E+01
76	S025	4	Deep	25	1.00E+04	8.60E+04	1.17E-01	1.020	27.9	51.5	20.6	2.70	8.77E+00	8.95E+00
77	S026	4	Deep	26	1.02E+03	9.70E+03	1.05E-01	0.798	18.9	61.5	19.6	2.80	6.26E+00	4.99E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
78	S027	4	Deep	26	6.18E+02	9.10E+03	6.79E-02	0.759	25.3	52.6	22.1	3.50	6.24E+00	4.73E+00
79	S028	4	Deep	26	5.05E+03	4.69E+04	1.08E-01	0.729	21.8	60.9	17.3	3.30	1.69E+01	1.23E+01
80	S029	4	Deep	26	1.46E+04	7.74E+04	1.89E-01	0.772	32.1	47.0	20.9	3.50	1.39E+01	1.07E+01
81	S030	4	Deep	26	1.88E+02	3.90E+03	4.82E-02	0.703	25.0	57.8	17.2	3.70	2.13E+01	1.50E+01
82	S031	4	Deep	26	1.15E+02	4.20E+03	2.74E-02	1.050	29.2	45.5	25.3	1.30	6.48E+00	6.81E+00
83	S032	4	Deep	27	3.07E+03	2.96E+04	1.04E-01	0.863	32.4	50.5	17.1	4.30	1.16E+01	9.96E+00
84	S033	4	Deep	27	3.99E+02	1.57E+04	2.54E-02	0.641	40.3	41.5	18.2	5.10	7.29E+00	4.67E+00
85	S034	4	Deep	27	1.09E+04	5.95E+04	1.84E-01	0.849	37.5	45.6	17.0	4.00	1.14E+01	9.68E+00
86	S035	4	Deep	27	1.38E+04	7.33E+04	1.89E-01	0.631	38.1	41.4	20.5	5.00	6.67E+00	4.21E+00
87	S036	4	Deep	27	2.70E-01	3.00E+02	9.00E-04	0.938	38.1	38.9	23.0	2.50	9.57E+00	8.97E+00
88	S037	4	Deep	27	6.76E+02	8.90E+03	7.59E-02	0.776	25.5	48.3	26.2	3.40	1.53E+00	1.19E+00
89	S038	4	Deep	28	3.01E+03	2.90E+04	1.04E-01	0.729	50.7	37.8	11.5	3.40	1.79E+01	1.31E+01
90	S039	4	Deep	28	1.54E+03	1.52E+04	1.01E-01	0.801	14.3	63.0	22.7	3.20	1.17E+01	9.40E+00
91	S040	4	Deep	28	1.54E+04	8.81E+04	1.75E-01	0.643	45.4	38.0	16.6	5.10	1.65E+01	1.06E+01
92	S041	4	Deep	28	2.17E+04	1.22E+05	1.78E-01	0.744	30.3	52.1	17.6	3.90	1.62E+01	1.21E+01
93	S042	4	Deep	28	6.12E+02	1.40E+04	4.37E-02	0.808	46.1	38.4	15.5	3.70	1.34E+01	1.08E+01
94	S043	4	Deep	28	7.40E+03	6.37E+04	1.16E-01	0.941	36.3	47.5	16.3	2.10	9.66E-01	9.09E-01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
95	S044	4	Deep	29	9.95E+03	8.03E+04	1.24E-01	0.592	34.4	48.3	17.4	4.20	2.54E+00	1.50E+00
96	S045	4	Deep	29	2.64E+04	1.60E+05	1.65E-01	0.509	22.8	58.0	19.2	5.20	1.08E+01	5.49E+00
97	S046	4	Deep	29	2.80E+04	1.61E+05	1.75E-01	0.635	29.3	53.9	16.8	4.40	3.03E+00	1.93E+00
98	S047	4	Deep	29	3.00E+04	1.51E+05	1.99E-01	0.476	31.5	49.9	18.6	6.80	1.00E+01	4.78E+00
99	S048	4	Deep	29	2.93E+04	1.68E+05	1.74E-01	0.721	48.2	38.0	13.8	3.80	1.11E+01	7.98E+00
100	S049	4	Deep	29	4.05E+04	2.31E+05	1.75E-01	0.516	43.7	41.3	15.0	4.60	1.10E+01	5.67E+00
101	S050	4	Deep	30	4.29E+03	2.37E+04	1.81E-01	0.922	21.2	58.9	19.9	2.90	3.88E-01	3.57E-01
102	S051	4	Deep	30	4.57E+03	2.36E+04	1.94E-01	0.877	48.8	39.4	11.8	2.90	1.30E+01	1.14E+01
103	S052	4	Deep	30	1.80E+04	9.70E+04	1.86E-01	0.612	24.1	59.4	16.5	5.60	2.46E+00	1.51E+00
104	S053	4	Deep	30	1.57E+04	8.84E+04	1.77E-01	0.582	20.9	61.5	17.6	4.60	5.93E+00	3.45E+00
105	S054	4	Deep	30	2.14E+03	2.63E+04	8.13E-02	0.559	37.4	49.1	13.6	4.80	2.16E+00	1.21E+00
106	S055	4	Deep	30	1.60E+02	4.80E+03	3.33E-02	0.493	17.3	65.1	17.6	5.10	5.69E+00	2.80E+00
107	S056	4	Deep	31	1.29E+04	6.55E+04	1.97E-01	0.484	29.3	53.4	17.4	6.50	3.56E+01	1.73E+01
108	S057	4	Deep	31	1.64E+04	8.35E+04	1.97E-01	0.520	27.9	51.1	21.1	6.70	1.90E+01	9.86E+00
109	S058	4	Deep	31	5.99E+03	3.06E+04	1.96E-01	0.477	33.0	49.9	17.1	6.00	1.52E+01	7.25E+00
110	S059	4	Deep	31	4.95E+03	2.60E+04	1.91E-01	0.702	31.6	42.3	26.1	4.30	7.25E+00	5.09E+00
111	S060	4	Deep	31	4.35E+02	9.00E+03	4.83E-02	0.532	29.7	52.7	17.6	5.60	1.49E+01	7.91E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
112	S061	4	Deep	31	6.50E+03	3.81E+04	1.71E-01	0.750	37.1	42.6	20.3	3.10	6.93E+00	5.20E+00
113	S062	4	Deep	32	4.26E+03	3.32E+04	1.28E-01	0.494	23.0	58.2	18.9	7.10	5.84E+00	2.89E+00
114	S063	4	Deep	32	9.20E+02	4.60E+03	2.00E-01	0.804	37.5	47.8	14.8	4.10	4.02E+00	3.23E+00
115	S064	4	Deep	32	1.90E+02	4.40E+03	4.31E-02	0.569	28.5	52.8	18.7	6.10	5.21E+00	2.96E+00
116	S065	4	Deep	32	7.12E+03	3.56E+04	2.00E-01	0.768	34.8	50.2	15.0	4.50	1.02E+01	7.82E+00
118	S067	4	Deep	32	1.70E+03	8.50E+03	2.00E-01	0.590	24.1	59.3	16.6	5.90	2.29E+01	1.35E+01
119	S068	4	Deep	33	1.00E+03	5.00E+03	2.00E-01	0.520	22.8	58.5	18.7	5.90	4.24E+00	2.20E+00
120	S069	4	Deep	33	6.00E+01	3.00E+02	2.00E-01	0.543	30.9	51.5	17.6	5.90	1.13E+01	6.11E+00
121	S070	4	Deep	33	1.64E+04	8.22E+04	2.00E-01	0.492	26.8	54.9	18.3	6.30	1.12E+01	5.51E+00
122	S071	4	Deep	33	7.82E+03	3.91E+04	2.00E-01	0.569	35.0	48.8	16.3	5.60	1.63E+01	9.25E+00
123	S072	4	Deep	33	4.60E+02	2.30E+03	2.00E-01	0.585	31.9	51.5	16.6	5.90	2.07E+01	1.21E+01
124	S073	4	Deep	33	8.40E+02	4.20E+03	2.00E-01	0.718	39.9	45.0	15.1	5.10	2.22E+01	1.59E+01
125	S074	4	Deep	34	1.00E+02	5.00E+02	2.00E-01	0.630	49.1	38.2	12.8	4.90	9.50E+00	5.98E+00
126	S075	4	Deep	34	4.00E+01	2.00E+02	2.00E-01	1.050	22.9	51.7	25.4	2.60	1.13E+01	1.18E+01
127	S076	4	Deep	34	7.28E+03	3.64E+04	2.00E-01	0.611	50.3	38.0	11.7	5.00	7.29E+00	4.46E+00
128	S077	4	Deep	34	5.60E+03	2.80E+04	2.00E-01	0.873	40.2	46.6	13.3	3.50	1.22E+01	1.07E+01
129	S078	4	Deep	34	5.40E+02	2.70E+03	2.00E-01	0.599	50.9	38.5	10.6	5.10	4.83E+00	2.89E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
130	S079	4	Deep	34	4.40E+02	2.20E+03	2.00E-01	0.801	37.9	51.0	11.1	3.40	1.19E+01	9.56E+00
131	S080	4	Deep	35	1.04E+03	5.20E+03	2.00E-01	0.785	50.8	35.1	14.2	4.10	2.21E+00	1.73E+00
132	S081	4	Deep	35	2.40E+02	1.20E+03	2.00E-01	0.703	40.9	45.0	14.2	5.30	1.18E+01	8.27E+00
133	S082	4	Deep	35	7.22E+03	3.61E+04	2.00E-01	0.755	43.9	42.4	13.7	4.00	3.23E+00	2.44E+00
134	S083	4	Deep	35	5.86E+03	2.93E+04	2.00E-01	0.765	40.9	43.7	15.4	5.10	8.87E+00	6.79E+00
135	S084	4	Deep	35	1.02E+03	5.10E+03	2.00E-01	0.739	35.8	49.7	14.5	3.90	3.81E+00	2.81E+00
136	S085	4	Deep	35	7.20E+02	3.60E+03	2.00E-01	0.806	39.8	44.3	16.0	5.10	7.90E+00	6.37E+00
137	S086	4	Deep	36	1.70E+03	8.50E+03	2.00E-01	0.745	32.8	52.9	14.3	5.10	1.73E+01	1.29E+01
138	S087	4	Deep	36	8.00E+02	4.00E+03	2.00E-01	0.936	22.0	54.4	23.6	4.20	1.09E+01	1.02E+01
139	S088	4	Deep	36	6.38E+03	3.19E+04	2.00E-01	0.849	36.4	50.2	13.4	3.90	1.75E+01	1.48E+01
140	S089	4	Deep	36	2.20E+03	1.10E+04	2.00E-01	0.899	13.7	56.9	29.4	5.00	9.34E+00	8.39E+00
141	S090	4	Deep	36	1.00E+03	5.00E+03	2.00E-01	1.020	36.1	50.2	13.7	2.60	1.68E+01	1.72E+01
142	S091	4	Deep	36	2.60E+02	1.30E+03	2.00E-01	0.814	27.3	49.9	22.8	5.00	8.11E+00	6.60E+00
143	S092	4	Deep	37	6.00E+01	3.00E+02	2.00E-01	0.477	25.6	54.8	19.5	4.50	4.26E+00	2.03E+00
144	S093	4	Deep	37	6.80E+02	3.40E+03	2.00E-01	0.920	52.4	30.6	17.0	3.20	1.13E+00	1.04E+00
145	S094	4	Deep	37	1.01E+04	5.04E+04	2.00E-01	0.498	27.4	52.0	20.6	5.30	3.82E+00	1.90E+00
146	S095	4	Deep	37	5.86E+03	2.93E+04	2.00E-01	1.130	58.7	26.8	14.5	2.30	1.28E+00	1.44E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
147	S096	4	Deep	37	2.30E+03	1.15E+04	2.00E-01	0.400	29.3	55.6	15.2	5.70	3.06E+00	1.22E+00
148	S097	4	Deep	37	9.40E+02	4.70E+03	2.00E-01	1.020	53.0	31.4	15.7	2.60	1.57E+00	1.61E+00
149	S098	4	Deep	38	5.60E+02	2.80E+03	2.00E-01	0.938	40.9	37.7	21.4	2.60	2.83E-01	2.65E-01
150	S099	4	Deep	38	1.82E+03	9.10E+03	2.00E-01	1.190	64.5	24.7	10.8	1.50	2.10E-01	2.51E-01
151	S100	4	Deep	38	5.76E+03	2.88E+04	2.00E-01	1.100	49.3	32.4	18.3	2.20	5.70E-01	6.25E-01
152	S101	4	Deep	38	5.58E+03	2.79E+04	2.00E-01	1.140	56.2	30.7	13.1	1.70	4.22E-01	4.81E-01
153	S102	4	Deep	38	7.20E+02	3.60E+03	2.00E-01	1.380	62.4	24.6	13.1	1.50	9.86E-01	1.36E+00
154	S103	4	Deep	38	7.60E+02	3.80E+03	2.00E-01	0.965	41.0	44.6	14.4	2.00	6.87E-01	6.63E-01
156	S105	4	Deep	39	5.07E+02	3.30E+03	1.54E-01	0.863	43.3	34.4	22.3	2.70	6.97E-01	6.02E-01
157	S106	4	Deep	39	1.88E+03	2.84E+04	6.62E-02	0.818	48.0	34.9	17.1	1.60	4.68E-01	3.83E-01
158	S107	4	Deep	39	7.12E+03	3.56E+04	2.00E-01	0.766	45.3	32.9	21.8	3.20	8.70E-01	6.66E-01
159	S108	4	Deep	39	2.32E+03	1.16E+04	2.00E-01	0.810	41.8	46.8	11.4	1.90	3.58E-01	2.90E-01
160	S109	4	Deep	39	1.68E+03	8.40E+03	2.00E-01	0.773	41.6	44.1	14.4	2.90	4.22E-01	3.26E-01
161	S110	4	Deep	40	1.44E+03	7.20E+03	2.00E-01	0.807	33.0	49.1	18.0	3.90	2.09E+00	1.69E+00
162	S111	4	Deep	40	9.20E+02	4.60E+03	2.00E-01	0.537	36.7	50.1	13.2	6.00	1.51E+00	8.09E-01
163	S112	4	Deep	40	7.98E+03	3.99E+04	2.00E-01	0.625	22.1	60.5	17.5	4.60	1.77E+00	1.11E+00
164	S113	4	Deep	40	8.08E+03	4.04E+04	2.00E-01	0.555	32.4	54.2	13.5	5.90	1.51E+00	8.41E-01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
165	S114	4	Deep	40	9.40E+02	4.70E+03	2.00E-01	0.752	28.0	51.6	20.4	3.80	1.79E+00	1.35E+00
166	S115	4	Deep	40	5.97E+02	7.30E+03	8.18E-02	0.687	31.4	52.7	15.9	5.80	1.45E+00	9.95E-01
1	02-A	5	Deep	2	3.61E+04	1.10E+05	3.29E-01	0.528	41.0	42.6	16.4	6.50	1.67E+01	8.80E+00
2	01-B	5	Deep	1	4.74E+03	5.87E+04	8.07E-02	1.240	57.5	29.8	12.7	2.50	2.90E+01	3.60E+01
3	03-C	5	Deep	3	1.28E+04	6.86E+04	1.86E-01	0.506	29.9	47.9	22.2	6.70	4.71E+00	2.38E+00
4	04-D	5	Deep	4	2.13E+03	4.49E+04	4.75E-02	0.681	58.1	34.8	7.1	6.60	2.26E+00	1.54E+00
5	03-Pg	5	Deep	3	4.46E+03	4.19E+04	1.07E-01	0.382	46.1	46.3	7.6	8.80	5.30E+00	2.02E+00
6	04-Pg	5	Deep	4	4.73E+03	3.52E+04	1.34E-01	0.417	60.1	33.2	6.7	9.90	1.69E+01	7.06E+00
7	04-E	5	Deep	4	1.23E+04	8.18E+04	1.50E-01	0.673	30.9	52.5	16.6	7.00	6.22E-01	4.18E-01
8	05-E	5	Deep	5	2.19E+05	6.40E+05	3.43E-01	0.458	25.5	54.4	20.1	6.00	1.15E+00	5.25E-01
9	06-E	5	Deep	6	1.18E+05	3.92E+05	3.01E-01	0.436	19.9	54.0	26.1	7.30	1.20E+00	5.24E-01
10	07-E	5	Deep	7	5.70E+04	2.40E+05	2.38E-01	0.485	27.0	50.9	22.1	7.40	9.29E-01	4.51E-01
11	06-F	5	Deep	6	2.43E+04	1.03E+05	2.36E-01	0.343	25.3	52.0	22.7	14.00	1.97E-01	6.76E-02
12	08-G	5	Deep	8	2.94E+03	1.93E+04	1.52E-01	0.630	54.4	32.1	13.6	3.80	0.00E+00	0.00E+00
14	09-I	5	Deep	9	3.23E+02	6.90E+03	4.68E-02	0.529	14.2	61.2	24.7	5.70	0.00E+00	0.00E+00
15	09-J	5	Deep	9	1.14E+01	1.60E+03	7.10E-03	0.634	22.6	57.8	19.7	3.70	0.00E+00	0.00E+00
18	10-M	5	Deep	10	1.19E+01	1.20E+03	9.90E-03	0.454	8.5	62.1	29.4	5.60	5.16E+00	2.34E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
19	10-N	5	Deep	10	1.40E+02	3.50E+03	4.01E-02	0.601	51.5	37.0	11.5	8.30	5.68E+01	3.42E+01
20	10-O	5	Deep	10	1.64E+03	9.50E+03	1.72E-01	0.668	64.4	25.9	9.8	6.70	4.70E+01	3.14E+01
21	10-P	5	Deep	10	5.55E+03	2.14E+04	2.60E-01	0.968	46.2	39.7	14.1	2.40	3.13E+00	3.03E+00
23	10-R	5	Deep	10	4.63E+01	1.80E+03	2.57E-02	0.954	35.4	43.3	21.3	8.50	4.99E+00	4.76E+00
24	11-S	5	Deep	11	1.28E+04	1.04E+05	1.23E-01	0.599	63.3	23.6	13.1	8.10	0.00E+00	0.00E+00
25	12-T	5	Deep	12	2.23E+03	1.18E+04	1.89E-01	0.532	91.1	4.0	4.9	8.20	3.74E+00	1.99E+00
26	12-U	5	Deep	12	2.19E+02	3.80E+03	5.76E-02	0.474	35.4	48.5	16.2	6.60	0.00E+00	0.00E+00
27	13-V	5	Deep	13	1.64E+03	9.80E+03	1.68E-01	0.520	52.8	36.3	10.9	4.40	7.22E-01	3.76E-01
28	13-W	5	Deep	13	5.02E+04	2.38E+05	2.11E-01	0.573	53.2	32.7	14.1	4.20	1.02E+00	5.83E-01
29	14-W	5	Deep	14	3.21E+04	1.31E+05	2.44E-01	0.682	48.6	35.0	16.4	3.50	4.76E+00	3.24E+00
30	13-X	5	Deep	13	1.68E+04	8.28E+04	2.03E-01	0.537	40.2	48.2	11.6	4.70	2.90E-01	1.56E-01
31	14-X	5	Deep	14	1.46E+04	6.32E+04	2.31E-01	0.424	25.1	57.2	17.7	5.30	4.09E+00	1.73E+00
32	14-Y	5	Deep	14	5.85E+00	1.30E+03	4.50E-03	0.660	47.6	37.6	14.7	2.50	5.80E+00	3.83E+00
33	14-Z	5	Deep	14	8.59E+02	8.60E+03	9.99E-02	0.695	28.6	48.5	22.9	2.20	0.00E+00	0.00E+00
36	15-CC	5	Deep	15	1.11E+04	5.20E+04	2.13E-01	0.781	30.2	21.3	48.5	1.90	0.00E+00	0.00E+00
37	18-DD	5	Deep	18	2.37E+04	1.00E+05	2.36E-01	0.641	31.9	42.7	25.3	4.60	2.45E+00	1.57E+00
38	19-EE	5	Deep	19	4.21E+04	1.60E+05	2.63E-01	0.706	54.1	32.0	13.9	4.00	6.26E-01	4.42E-01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
39	20-EE	5	Deep	20	1.75E+05	5.31E+05	3.29E-01	0.537	32.1	49.0	18.9	5.70	2.93E+00	1.57E+00
40	21-EE	5	Deep	21	2.52E+05	6.48E+05	3.88E-01	0.508	35.6	44.2	20.2	5.70	2.44E+00	1.24E+00
41	22-EE	5	Deep	22	1.16E+05	3.13E+05	3.71E-01	0.474	24.2	52.6	23.3	6.10	1.98E+00	9.40E-01
42	23-EE	5	Deep	23	8.98E+04	2.69E+05	3.34E-01	0.504	23.5	51.1	25.5	6.30	2.33E+00	1.17E+00
43	24-EE	5	Deep	24	5.51E+04	1.45E+05	3.81E-01	0.659	29.5	49.9	20.7	7.30	5.04E+00	3.32E+00
44	23-FF	5	Deep	23	6.63E+01	1.70E+03	3.90E-02	0.360	3.4	62.4	34.2	5.90	1.62E+00	5.84E-01
45	24-GG	5	Deep	24	3.29E+03	1.41E+04	2.34E-01	0.392	24.3	56.1	19.6	6.50	1.03E+01	4.04E+00
46	24-HH	5	Deep	24	4.06E+03	2.19E+04	1.85E-01	0.593	23.2	55.1	21.7	6.00	2.58E+00	1.53E+00
48	02-ID	5	Deep	2	2.20E-01	1.10E+03	2.00E-04	0.789	44.4	27.7	27.9	5.20	1.42E+01	1.12E+01
49	03-ID	5	Deep	3	2.74E+01	5.70E+03	4.80E-03	0.751	65.0	24.9	10.1	6.60	9.64E+00	7.24E+00
50	04-ID	5	Deep	4	8.58E+02	3.25E+04	2.64E-02	0.557	59.0	31.6	9.4	7.10	4.02E+00	2.24E+00
51	05-ID	5	Deep	5	3.98E+01	3.40E+03	1.17E-02	0.531	32.1	48.3	19.6	6.90	5.94E-01	3.16E-01
52	06-ID	5	Deep	6	1.40E+01	3.50E+03	4.00E-03	0.522	17.3	49.7	33.0	9.10	9.73E-01	5.08E-01
53	07-ID	5	Deep	7	7.18E+02	1.04E+04	6.90E-02	0.459	27.3	48.5	24.3	7.00	1.86E-01	8.53E-02
56	10-ID	5	Deep	10	3.08E+00	3.30E+03	9.00E-04	0.658	43.6	39.4	17.0	7.60	3.02E+01	1.99E+01
59	13-ID	5	Deep	13	3.87E+01	7.30E+03	5.30E-03	1.020	76.5	15.9	7.7	4.10	8.80E-01	8.96E-01
60	14-ID	5	Deep	14	1.22E+01	2.60E+03	4.70E-03	0.629	37.5	45.1	17.4	3.20	5.59E+00	3.52E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
61	15-ID	5	Deep	15	2.70E-01	2.70E+03	1.00E-04	0.878	47.6	26.4	26.1	1.60	0.00E+00	0.00E+00
62	16-ID	5	Deep	16	4.12E+02	1.61E+04	2.56E-02	1.380	86.3	4.4	9.3	0.80	0.00E+00	0.00E+00
64	18-ID	5	Deep	18	8.00E-02	8.00E+02	1.00E-04	0.738	51.9	29.8	18.4	4.40	2.20E+00	1.62E+00
68	22-ID	5	Deep	22	2.04E+00	3.40E+03	6.00E-04	0.630	40.3	39.6	20.2	5.00	1.55E+00	9.73E-01
69	23-ID	5	Deep	23	1.08E+01	1.90E+03	5.70E-03	0.490	20.4	52.3	27.3	6.10	1.77E+00	8.68E-01
70	24-ID	5	Deep	24	9.58E+03	5.85E+04	1.64E-01	0.579	26.5	53.2	20.3	6.80	5.84E+00	3.38E+00
71	S020	5	Deep	25	1.03E+05	3.02E+05	3.40E-01	0.539	37.3	44.3	18.4	5.50	1.22E+01	6.55E+00
72	S021	5	Deep	25	3.79E+04	1.14E+05	3.32E-01	0.779	28.9	54.2	16.9	4.00	5.12E+00	3.99E+00
73	S022	5	Deep	25	2.43E+04	8.26E+04	2.94E-01	0.680	27.5	48.5	24.1	5.80	2.96E+01	2.01E+01
74	S023	5	Deep	25	1.41E+04	7.83E+04	1.80E-01	0.947	22.3	56.6	21.1	2.80	1.76E+00	1.66E+00
75	S024	5	Deep	25	1.96E+04	7.32E+04	2.68E-01	0.625	32.9	46.6	20.6	5.60	2.33E+01	1.46E+01
76	S025	5	Deep	25	1.54E+04	7.23E+04	2.12E-01	1.020	27.9	51.5	20.6	2.70	7.37E+00	7.52E+00
77	S026	5	Deep	26	1.28E+03	7.40E+03	1.73E-01	0.798	18.9	61.5	19.6	2.80	4.43E+00	3.53E+00
78	S027	5	Deep	26	1.38E+02	3.80E+03	3.63E-02	0.759	25.3	52.6	22.1	3.50	2.44E+00	1.85E+00
79	S028	5	Deep	26	4.84E+03	3.16E+04	1.53E-01	0.729	21.8	60.9	17.3	3.30	1.40E+01	1.02E+01
80	S029	5	Deep	26	3.08E+04	7.47E+04	4.13E-01	0.772	32.1	47.0	20.9	3.50	7.13E+00	5.50E+00
81	S030	5	Deep	26	1.15E+02	2.70E+03	4.25E-02	0.703	25.0	57.8	17.2	3.70	1.77E+01	1.24E+01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
82	S031	5	Deep	26	4.48E+01	1.90E+03	2.36E-02	1.050	29.2	45.5	25.3	1.30	1.07E+01	1.13E+01
83	S032	5	Deep	27	2.84E+03	1.94E+04	1.47E-01	0.863	32.4	50.5	17.1	4.30	1.01E+01	8.70E+00
84	S033	5	Deep	27	2.04E+00	1.20E+03	1.70E-03	0.641	40.3	41.5	18.2	5.10	5.77E+00	3.70E+00
85	S034	5	Deep	27	2.16E+04	5.41E+04	4.00E-01	0.849	37.5	45.6	17.0	4.00	9.81E+00	8.33E+00
86	S035	5	Deep	27	2.63E+04	6.65E+04	3.95E-01	0.631	38.1	41.4	20.5	5.00	6.48E+00	4.08E+00
88	S037	5	Deep	27	7.28E+02	6.20E+03	1.17E-01	0.776	25.5	48.3	26.2	3.40	1.54E+00	1.20E+00
89	S038	5	Deep	28	4.29E+03	2.29E+04	1.87E-01	0.729	50.7	37.8	11.5	3.40	7.12E+00	5.19E+00
90	S039	5	Deep	28	1.94E+03	1.21E+04	1.60E-01	0.801	14.3	63.0	22.7	3.20	1.16E+01	9.27E+00
91	S040	5	Deep	28	2.87E+04	8.13E+04	3.53E-01	0.643	45.4	38.0	16.6	5.10	1.56E+01	1.00E+01
92	S041	5	Deep	28	4.33E+04	1.15E+05	3.77E-01	0.744	30.3	52.1	17.6	3.90	2.29E+01	1.70E+01
93	S042	5	Deep	28	5.70E+02	1.05E+04	5.43E-02	0.808	46.1	38.4	15.5	3.70	2.21E+01	1.78E+01
94	S043	5	Deep	28	1.21E+04	5.82E+04	2.08E-01	0.941	36.3	47.5	16.3	2.10	5.95E+00	5.60E+00
95	S044	5	Deep	29	1.25E+04	6.16E+04	2.03E-01	0.592	34.4	48.3	17.4	4.20	2.10E+00	1.24E+00
96	S045	5	Deep	29	5.04E+04	1.46E+05	3.46E-01	0.509	22.8	58.0	19.2	5.20	1.53E+01	7.80E+00
97	S046	5	Deep	29	4.93E+04	1.44E+05	3.43E-01	0.635	29.3	53.9	16.8	4.40	1.84E+00	1.17E+00
98	S047	5	Deep	29	7.20E+04	1.50E+05	4.80E-01	0.476	31.5	49.9	18.6	6.80	1.43E+01	6.80E+00
99	S048	5	Deep	29	6.08E+04	1.58E+05	3.86E-01	0.721	48.2	38.0	13.8	3.80	5.99E+00	4.32E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
100	S049	5	Deep	29	8.09E+04	2.11E+05	3.84E-01	0.516	43.7	41.3	15.0	4.60	1.20E+01	6.19E+00
101	S050	5	Deep	30	7.10E+03	2.17E+04	3.27E-01	0.922	21.2	58.9	19.9	2.90	8.99E-01	8.29E-01
102	S051	5	Deep	30	1.09E+04	2.35E+04	4.62E-01	0.877	48.8	39.4	11.8	2.90	1.07E+01	9.42E+00
103	S052	5	Deep	30	4.11E+04	9.46E+04	4.35E-01	0.612	24.1	59.4	16.5	5.60	9.62E+00	5.88E+00
104	S053	5	Deep	30	3.28E+04	8.42E+04	3.89E-01	0.582	20.9	61.5	17.6	4.60	2.80E+00	1.63E+00
105	S054	5	Deep	30	3.70E+03	2.22E+04	1.67E-01	0.559	37.4	49.1	13.6	4.80	5.64E+00	3.15E+00
106	S055	5	Deep	30	4.58E+01	2.50E+03	1.83E-02	0.493	17.3	65.1	17.6	5.10	4.90E+00	2.41E+00
107	S056	5	Deep	31	3.08E+04	6.47E+04	4.76E-01	0.484	29.3	53.4	17.4	6.50	4.38E+01	2.12E+01
108	S057	5	Deep	31	4.01E+04	8.24E+04	4.86E-01	0.520	27.9	51.1	21.1	6.70	4.18E+01	2.17E+01
109	S058	5	Deep	31	1.37E+04	2.97E+04	4.63E-01	0.477	33.0	49.9	17.1	6.00	1.88E+01	8.98E+00
110	S059	5	Deep	31	1.16E+04	2.57E+04	4.51E-01	0.702	31.6	42.3	26.1	4.30	1.37E+01	9.62E+00
111	S060	5	Deep	31	4.67E+02	6.20E+03	7.53E-02	0.532	29.7	52.7	17.6	5.60	2.12E+01	1.13E+01
112	S061	5	Deep	31	1.10E+04	3.47E+04	3.17E-01	0.750	37.1	42.6	20.3	3.10	1.31E+01	9.85E+00
113	S062	5	Deep	32	8.51E+03	3.05E+04	2.79E-01	0.494	23.0	58.2	18.9	7.10	1.51E+01	7.46E+00
114	S063	5	Deep	32	2.30E+03	4.60E+03	5.00E-01	0.804	37.5	47.8	14.8	4.10	3.26E+00	2.62E+00
115	S064	5	Deep	32	2.74E+02	3.60E+03	7.61E-02	0.569	28.5	52.8	18.7	6.10	1.57E+01	8.92E+00
116	S065	5	Deep	32	1.78E+04	3.56E+04	5.00E-01	0.768	34.8	50.2	15.0	4.50	7.59E+00	5.83E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
118	S067	5	Deep	32	4.25E+03	8.50E+03	5.00E-01	0.590	24.1	59.3	16.6	5.90	1.69E+01	9.98E+00
119	S068	5	Deep	33	2.50E+03	5.00E+03	5.00E-01	0.520	22.8	58.5	18.7	5.90	6.65E+00	3.45E+00
120	S069	5	Deep	33	1.50E+02	3.00E+02	5.00E-01	0.543	30.9	51.5	17.6	5.90	1.44E+01	7.84E+00
121	S070	5	Deep	33	4.11E+04	8.22E+04	5.00E-01	0.492	26.8	54.9	18.3	6.30	1.43E+01	7.01E+00
122	S071	5	Deep	33	1.96E+04	3.91E+04	5.00E-01	0.569	35.0	48.8	16.3	5.60	1.61E+01	9.17E+00
123	S072	5	Deep	33	1.15E+03	2.30E+03	5.00E-01	0.585	31.9	51.5	16.6	5.90	2.02E+01	1.18E+01
124	S073	5	Deep	33	2.10E+03	4.20E+03	5.00E-01	0.718	39.9	45.0	15.1	5.10	2.09E+01	1.50E+01
125	S074	5	Deep	34	2.50E+02	5.00E+02	5.00E-01	0.630	49.1	38.2	12.8	4.90	6.39E+00	4.02E+00
126	S075	5	Deep	34	1.00E+02	2.00E+02	5.00E-01	1.050	22.9	51.7	25.4	2.60	2.86E+00	2.99E+00
127	S076	5	Deep	34	1.82E+04	3.64E+04	5.00E-01	0.611	50.3	38.0	11.7	5.00	5.82E+00	3.55E+00
128	S077	5	Deep	34	1.40E+04	2.80E+04	5.00E-01	0.873	40.2	46.6	13.3	3.50	1.98E+00	1.73E+00
129	S078	5	Deep	34	1.35E+03	2.70E+03	5.00E-01	0.599	50.9	38.5	10.6	5.10	4.98E+00	2.99E+00
130	S079	5	Deep	34	1.10E+03	2.20E+03	5.00E-01	0.801	37.9	51.0	11.1	3.40	3.25E+00	2.61E+00
131	S080	5	Deep	35	2.60E+03	5.20E+03	5.00E-01	0.785	50.8	35.1	14.2	4.10	2.23E+00	1.75E+00
132	S081	5	Deep	35	6.00E+02	1.20E+03	5.00E-01	0.703	40.9	45.0	14.2	5.30	1.58E+01	1.11E+01
133	S082	5	Deep	35	1.81E+04	3.61E+04	5.00E-01	0.755	43.9	42.4	13.7	4.00	3.25E+00	2.45E+00
134	S083	5	Deep	35	1.47E+04	2.93E+04	5.00E-01	0.765	40.9	43.7	15.4	5.10	1.53E+01	1.17E+01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
135	S084	5	Deep	35	2.55E+03	5.10E+03	5.00E-01	0.739	35.8	49.7	14.5	3.90	3.87E+00	2.86E+00
136	S085	5	Deep	35	1.80E+03	3.60E+03	5.00E-01	0.806	39.8	44.3	16.0	5.10	1.62E+01	1.31E+01
137	S086	5	Deep	36	4.25E+03	8.50E+03	5.00E-01	0.745	32.8	52.9	14.3	5.10	1.84E+01	1.37E+01
138	S087	5	Deep	36	2.00E+03	4.00E+03	5.00E-01	0.936	22.0	54.4	23.6	4.20	1.16E+01	1.08E+01
139	S088	5	Deep	36	7.82E+03	2.27E+04	3.45E-01	0.849	36.4	50.2	13.4	3.90	1.86E+01	1.58E+01
140	S089	5	Deep	36	5.01E+03	1.05E+04	4.77E-01	0.899	13.7	56.9	29.4	5.00	9.85E+00	8.85E+00
142	S091	5	Deep	36	1.39E+02	6.00E+02	2.31E-01	0.814	27.3	49.9	22.8	5.00	8.58E+00	6.99E+00
143	S092	5	Deep	37	1.50E+02	3.00E+02	5.00E-01	0.477	25.6	54.8	19.5	4.50	4.38E+00	2.09E+00
144	S093	5	Deep	37	1.70E+03	3.40E+03	5.00E-01	0.920	52.4	30.6	17.0	3.20	1.22E+00	1.12E+00
145	S094	5	Deep	37	2.23E+04	5.04E+04	4.43E-01	0.498	27.4	52.0	20.6	5.30	3.92E+00	1.95E+00
146	S095	5	Deep	37	1.45E+04	2.93E+04	4.96E-01	1.130	58.7	26.8	14.5	2.30	1.32E+00	1.49E+00
147	S096	5	Deep	37	5.51E+03	1.15E+04	4.79E-01	0.400	29.3	55.6	15.2	5.70	3.14E+00	1.26E+00
148	S097	5	Deep	37	2.35E+03	4.70E+03	5.00E-01	1.020	53.0	31.4	15.7	2.60	1.53E+00	1.56E+00
149	S098	5	Deep	38	1.40E+03	2.80E+03	5.00E-01	0.938	40.9	37.7	21.4	2.60	1.27E-01	1.19E-01
150	S099	5	Deep	38	4.55E+03	9.10E+03	5.00E-01	1.190	64.5	24.7	10.8	1.50	1.82E-01	2.17E-01
151	S100	5	Deep	38	1.44E+04	2.88E+04	5.00E-01	1.100	49.3	32.4	18.3	2.20	9.47E-02	1.04E-01
152	S101	5	Deep	38	1.40E+04	2.79E+04	5.00E-01	1.140	56.2	30.7	13.1	1.70	4.24E-01	4.83E-01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
153	S102	5	Deep	38	1.80E+03	3.60E+03	5.00E-01	1.380	62.4	24.6	13.1	1.50	8.05E-02	1.11E-01
154	S103	5	Deep	38	1.90E+03	3.80E+03	5.00E-01	0.965	41.0	44.6	14.4	2.00	9.20E-01	8.88E-01
156	S105	5	Deep	39	1.24E+03	3.30E+03	3.74E-01	0.863	43.3	34.4	22.3	2.70	5.91E-01	5.10E-01
157	S106	5	Deep	39	1.45E+03	9.40E+03	1.54E-01	0.818	48.0	34.9	17.1	1.60	5.64E-01	4.61E-01
158	S107	5	Deep	39	7.50E+03	3.56E+04	2.11E-01	0.766	45.3	32.9	21.8	3.20	7.24E-01	5.54E-01
159	S108	5	Deep	39	5.09E+03	1.16E+04	4.39E-01	0.810	41.8	46.8	11.4	1.90	4.69E-01	3.80E-01
160	S109	5	Deep	39	2.90E+03	8.40E+03	3.45E-01	0.773	41.6	44.1	14.4	2.90	3.77E-01	2.91E-01
161	S110	5	Deep	40	3.60E+03	7.20E+03	5.00E-01	0.807	33.0	49.1	18.0	3.90	1.41E+00	1.14E+00
162	S111	5	Deep	40	2.30E+03	4.60E+03	5.00E-01	0.537	36.7	50.1	13.2	6.00	7.42E-01	3.99E-01
163	S112	5	Deep	40	2.00E+04	3.99E+04	5.00E-01	0.625	22.1	60.5	17.5	4.60	1.29E+00	8.03E-01
164	S113	5	Deep	40	2.02E+04	4.04E+04	5.00E-01	0.555	32.4	54.2	13.5	5.90	8.96E-01	4.98E-01
165	S114	5	Deep	40	1.90E+03	4.70E+03	4.05E-01	0.752	28.0	51.6	20.4	3.80	1.26E+00	9.46E-01
166	S115	5	Deep	40	1.16E+03	6.40E+03	1.81E-01	0.687	31.4	52.7	15.9	5.80	7.95E-01	5.47E-01
1	02-A	6	Deep	2	3.67E+03	8.90E+04	4.12E-02	0.528	41.0	42.6	16.4	6.50	1.87E+00	9.85E-01
2	01-B	6	Deep	1	2.70E+01	7.10E+03	3.80E-03	1.240	57.5	29.8	12.7	2.50	4.07E+00	5.06E+00
3	03-C	6	Deep	3	3.08E+02	2.28E+04	1.35E-02	0.506	29.9	47.9	22.2	6.70	1.45E-01	7.34E-02
4	04-D	6	Deep	4	1.09E+01	5.20E+03	2.10E-03	0.681	58.1	34.8	7.1	6.60	3.53E-01	2.40E-01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
5	03-Pg	6	Deep	3	1.19E+03	1.85E+04	6.44E-02	0.382	46.1	46.3	7.6	8.80	1.57E+01	5.97E+00
6	04-Pg	6	Deep	4	1.24E+03	1.78E+04	6.96E-02	0.417	60.1	33.2	6.7	9.90	3.67E+01	1.53E+01
7	04-E	6	Deep	4	1.54E+03	4.03E+04	3.82E-02	0.673	30.9	52.5	16.6	7.00	4.80E-01	3.23E-01
8	05-E	6	Deep	5	2.60E+04	4.96E+05	5.25E-02	0.458	25.5	54.4	20.1	6.00	1.04E-01	4.78E-02
9	06-E	6	Deep	6	1.21E+04	3.19E+05	3.78E-02	0.436	19.9	54.0	26.1	7.30	5.00E-02	2.18E-02
10	07-E	6	Deep	7	3.25E+03	1.34E+05	2.42E-02	0.485	27.0	50.9	22.1	7.40	0.00E+00	0.00E+00
11	06-F	6	Deep	6	1.33E+03	5.65E+04	2.35E-02	0.343	25.3	52.0	22.7	14.00	5.00E-02	1.72E-02
12	08-G	6	Deep	8	6.12E+01	6.00E+03	1.02E-02	0.630	54.4	32.1	13.6	3.80	0.00E+00	0.00E+00
14	09-I	6	Deep	9	3.60E-01	4.00E+02	9.00E-04	0.529	14.2	61.2	24.7	5.70	0.00E+00	0.00E+00
19	10-N	6	Deep	10	1.96E+00	7.00E+02	2.80E-03	0.601	51.5	37.0	11.5	8.30	6.99E+01	4.20E+01
20	10-O	6	Deep	10	5.47E+01	3.80E+03	1.44E-02	0.668	64.4	25.9	9.8	6.70	6.39E+01	4.26E+01
21	10-P	6	Deep	10	2.75E+02	1.11E+04	2.48E-02	0.968	46.2	39.7	14.1	2.40	2.47E+00	2.39E+00
25	12-T	6	Deep	12	9.10E+01	5.20E+03	1.75E-02	0.532	91.1	4.0	4.9	8.20	0.00E+00	0.00E+00
26	12-U	6	Deep	12	1.00E+00	5.00E+02	2.00E-03	0.474	35.4	48.5	16.2	6.60	0.00E+00	0.00E+00
27	13-V	6	Deep	13	9.92E+01	5.80E+03	1.71E-02	0.520	52.8	36.3	10.9	4.40	4.00E-02	2.08E-02
28	13-W	6	Deep	13	1.75E+03	9.72E+04	1.80E-02	0.573	53.2	32.7	14.1	4.20	4.00E-02	2.29E-02
29	14-W	6	Deep	14	1.18E+03	5.56E+04	2.12E-02	0.682	48.6	35.0	16.4	3.50	4.00E-02	2.73E-02

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
30	13-X	6	Deep	13	7.41E+02	3.92E+04	1.89E-02	0.537	40.2	48.2	11.6	4.70	4.00E-02	2.15E-02
31	14-X	6	Deep	14	8.17E+02	3.63E+04	2.25E-02	0.424	25.1	57.2	17.7	5.30	4.00E-02	1.69E-02
33	14-Z	6	Deep	14	9.36E+00	1.80E+03	5.20E-03	0.695	28.6	48.5	22.9	2.20	0.00E+00	0.00E+00
36	15-CC	6	Deep	15	3.62E+02	2.08E+04	1.74E-02	0.781	30.2	21.3	48.5	1.90	0.00E+00	0.00E+00
37	18-DD	6	Deep	18	3.36E+02	2.67E+04	1.26E-02	0.641	31.9	42.7	25.3	4.60	1.40E-01	8.97E-02
38	19-EE	6	Deep	19	2.28E+03	8.72E+04	2.61E-02	0.706	54.1	32.0	13.9	4.00	9.71E-01	6.86E-01
39	20-EE	6	Deep	20	1.08E+04	3.23E+05	3.35E-02	0.537	32.1	49.0	18.9	5.70	1.66E-01	8.91E-02
40	21-EE	6	Deep	21	2.77E+04	5.53E+05	5.01E-02	0.508	35.6	44.2	20.2	5.70	2.51E-01	1.28E-01
41	22-EE	6	Deep	22	9.75E+03	2.28E+05	4.28E-02	0.474	24.2	52.6	23.3	6.10	1.79E-01	8.50E-02
42	23-EE	6	Deep	23	9.02E+03	1.88E+05	4.80E-02	0.504	23.5	51.1	25.5	6.30	3.46E-01	1.74E-01
43	24-EE	6	Deep	24	3.36E+04	1.16E+05	2.90E-01	0.659	29.5	49.9	20.7	7.30	1.31E-01	8.60E-02
45	24-GG	6	Deep	24	1.01E+03	7.90E+03	1.28E-01	0.392	24.3	56.1	19.6	6.50	1.58E+00	6.20E-01
46	24-HH	6	Deep	24	1.41E+03	1.23E+04	1.15E-01	0.593	23.2	55.1	21.7	6.00	1.84E-01	1.09E-01
49	03-ID	6	Deep	3	1.68E+00	1.40E+03	1.20E-03	0.751	65.0	24.9	10.1	6.60	5.32E+00	4.00E+00
50	04-ID	6	Deep	4	8.06E+01	1.28E+04	6.30E-03	0.557	59.0	31.6	9.4	7.10	1.20E+01	6.69E+00
51	05-ID	6	Deep	5	6.24E+00	2.40E+03	2.60E-03	0.531	32.1	48.3	19.6	6.90	2.14E-01	1.14E-01
53	07-ID	6	Deep	7	6.48E+01	8.20E+03	7.90E-03	0.459	27.3	48.5	24.3	7.00	0.00E+00	0.00E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
59	13-ID	6	Deep	13	5.00E-02	5.00E+02	1.00E-04	1.020	76.5	15.9	7.7	4.10	4.00E-02	4.08E-02
62	16-ID	6	Deep	16	5.80E+01	1.61E+04	3.60E-03	1.380	86.3	4.4	9.3	0.80	0.00E+00	0.00E+00
69	23-ID	6	Deep	23	1.44E+00	8.00E+02	1.80E-03	0.490	20.4	52.3	27.3	6.10	3.71E-01	1.82E-01
70	24-ID	6	Deep	24	4.10E+03	3.90E+04	1.05E-01	0.579	26.5	53.2	20.3	6.80	2.71E+00	1.57E+00
71	S020	6	Deep	25	5.19E+04	2.28E+05	2.27E-01	0.539	37.3	44.3	18.4	5.50	9.17E+00	4.94E+00
72	S021	6	Deep	25	1.76E+04	8.17E+04	2.16E-01	0.779	28.9	54.2	16.9	4.00	4.86E+00	3.78E+00
73	S022	6	Deep	25	8.77E+03	4.69E+04	1.87E-01	0.680	27.5	48.5	24.1	5.80	2.92E+01	1.99E+01
74	S023	6	Deep	25	1.75E+03	2.64E+04	6.64E-02	0.947	22.3	56.6	21.1	2.80	3.15E+00	2.98E+00
75	S024	6	Deep	25	9.94E+03	4.88E+04	2.04E-01	0.625	32.9	46.6	20.6	5.60	2.27E+01	1.42E+01
76	S025	6	Deep	25	6.58E+03	4.51E+04	1.46E-01	1.020	27.9	51.5	20.6	2.70	4.50E+00	4.60E+00
77	S026	6	Deep	26	1.45E+02	2.90E+03	5.01E-02	0.798	18.9	61.5	19.6	2.80	3.81E+00	3.04E+00
79	S028	6	Deep	26	8.86E+02	1.47E+04	6.03E-02	0.729	21.8	60.9	17.3	3.30	1.21E+01	8.82E+00
80	S029	6	Deep	26	1.28E+04	5.33E+04	2.41E-01	0.772	32.1	47.0	20.9	3.50	5.34E+00	4.12E+00
81	S030	6	Deep	26	1.60E-01	2.00E+02	8.00E-04	0.703	25.0	57.8	17.2	3.70	1.52E+01	1.07E+01
82	S031	6	Deep	26	9.00E-02	1.00E+02	9.00E-04	1.050	29.2	45.5	25.3	1.30	9.00E+00	9.46E+00
83	S032	6	Deep	27	5.04E+02	9.70E+03	5.20E-02	0.863	32.4	50.5	17.1	4.30	5.11E+00	4.40E+00
85	S034	6	Deep	27	1.27E+04	4.34E+04	2.93E-01	0.849	37.5	45.6	17.0	4.00	3.70E+00	3.14E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
86	S035	6	Deep	27	1.17E+04	4.77E+04	2.45E-01	0.631	38.1	41.4	20.5	5.00	1.30E+01	8.20E+00
88	S037	6	Deep	27	1.59E+02	3.20E+03	4.96E-02	0.776	25.5	48.3	26.2	3.40	1.50E+00	1.16E+00
89	S038	6	Deep	28	1.46E+03	1.40E+04	1.04E-01	0.729	50.7	37.8	11.5	3.40	4.75E+00	3.46E+00
90	S039	6	Deep	28	3.56E+02	5.10E+03	6.98E-02	0.801	14.3	63.0	22.7	3.20	7.44E+00	5.96E+00
91	S040	6	Deep	28	1.35E+04	5.60E+04	2.41E-01	0.643	45.4	38.0	16.6	5.10	1.54E+01	9.89E+00
92	S041	6	Deep	28	1.60E+04	7.86E+04	2.03E-01	0.744	30.3	52.1	17.6	3.90	1.60E+01	1.19E+01
93	S042	6	Deep	28	1.22E+01	1.80E+03	6.80E-03	0.808	46.1	38.4	15.5	3.70	1.91E+01	1.54E+01
94	S043	6	Deep	28	1.58E+03	2.53E+04	6.25E-02	0.941	36.3	47.5	16.3	2.10	5.08E+00	4.78E+00
95	S044	6	Deep	29	4.43E+03	3.58E+04	1.24E-01	0.592	34.4	48.3	17.4	4.20	2.47E+00	1.46E+00
96	S045	6	Deep	29	2.48E+04	1.08E+05	2.30E-01	0.509	22.8	58.0	19.2	5.20	7.27E+00	3.70E+00
97	S046	6	Deep	29	1.99E+04	9.50E+04	2.10E-01	0.635	29.3	53.9	16.8	4.40	3.61E+00	2.29E+00
98	S047	6	Deep	29	5.37E+04	1.35E+05	3.98E-01	0.476	31.5	49.9	18.6	6.80	1.28E+01	6.09E+00
99	S048	6	Deep	29	3.32E+04	1.29E+05	2.58E-01	0.721	48.2	38.0	13.8	3.80	3.02E+00	2.18E+00
100	S049	6	Deep	29	5.68E+04	1.78E+05	3.20E-01	0.516	43.7	41.3	15.0	4.60	1.47E+01	7.58E+00
101	S050	6	Deep	30	1.64E+03	1.09E+04	1.50E-01	0.922	21.2	58.9	19.9	2.90	1.09E+00	1.00E+00
102	S051	6	Deep	30	5.67E+03	2.08E+04	2.73E-01	0.877	48.8	39.4	11.8	2.90	7.39E+00	6.48E+00
103	S052	6	Deep	30	3.20E+04	8.51E+04	3.76E-01	0.612	24.1	59.4	16.5	5.60	1.32E+01	8.08E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
104	S053	6	Deep	30	1.77E+04	6.42E+04	2.75E-01	0.582	20.9	61.5	17.6	4.60	2.48E+00	1.44E+00
105	S054	6	Deep	30	1.81E+03	1.65E+04	1.10E-01	0.559	37.4	49.1	13.6	4.80	7.32E+00	4.09E+00
107	S056	6	Deep	31	2.72E+04	6.12E+04	4.44E-01	0.484	29.3	53.4	17.4	6.50	3.94E+01	1.91E+01
108	S057	6	Deep	31	3.81E+04	8.13E+04	4.68E-01	0.520	27.9	51.1	21.1	6.70	3.31E+01	1.72E+01
109	S058	6	Deep	31	1.20E+04	2.83E+04	4.23E-01	0.477	33.0	49.9	17.1	6.00	1.97E+01	9.39E+00
110	S059	6	Deep	31	6.94E+03	2.30E+04	3.02E-01	0.702	31.6	42.3	26.1	4.30	1.11E+01	7.82E+00
111	S060	6	Deep	31	1.04E+02	3.40E+03	3.07E-02	0.532	29.7	52.7	17.6	5.60	2.09E+01	1.11E+01
112	S061	6	Deep	31	4.62E+03	2.40E+04	1.92E-01	0.750	37.1	42.6	20.3	3.10	1.06E+01	7.96E+00
113	S062	6	Deep	32	5.68E+03	2.51E+04	2.26E-01	0.494	23.0	58.2	18.9	7.10	3.00E+01	1.48E+01
114	S063	6	Deep	32	2.30E+03	4.60E+03	5.00E-01	0.804	37.5	47.8	14.8	4.10	2.82E+00	2.27E+00
115	S064	6	Deep	32	3.80E+01	1.90E+03	2.00E-02	0.569	28.5	52.8	18.7	6.10	2.03E+01	1.15E+01
116	S065	6	Deep	32	1.78E+04	3.56E+04	5.00E-01	0.768	34.8	50.2	15.0	4.50	6.20E+00	4.76E+00
118	S067	6	Deep	32	4.25E+03	8.50E+03	5.00E-01	0.590	24.1	59.3	16.6	5.90	1.31E+01	7.70E+00
119	S068	6	Deep	33	2.50E+03	5.00E+03	5.00E-01	0.520	22.8	58.5	18.7	5.90	6.26E+00	3.25E+00
120	S069	6	Deep	33	1.50E+02	3.00E+02	5.00E-01	0.543	30.9	51.5	17.6	5.90	1.50E+01	8.16E+00
121	S070	6	Deep	33	4.11E+04	8.22E+04	5.00E-01	0.492	26.8	54.9	18.3	6.30	1.38E+01	6.81E+00
122	S071	6	Deep	33	1.96E+04	3.91E+04	5.00E-01	0.569	35.0	48.8	16.3	5.60	1.39E+01	7.92E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
123	S072	6	Deep	33	1.15E+03	2.30E+03	5.00E-01	0.585	31.9	51.5	16.6	5.90	1.79E+01	1.04E+01
124	S073	6	Deep	33	2.10E+03	4.20E+03	5.00E-01	0.718	39.9	45.0	15.1	5.10	1.53E+01	1.10E+01
125	S074	6	Deep	34	2.50E+02	5.00E+02	5.00E-01	0.630	49.1	38.2	12.8	4.90	6.70E+00	4.22E+00
126	S075	6	Deep	34	4.00E+01	2.00E+02	2.00E-01	1.050	22.9	51.7	25.4	2.60	9.75E-01	1.02E+00
127	S076	6	Deep	34	1.82E+04	3.64E+04	5.00E-01	0.611	50.3	38.0	11.7	5.00	6.34E+00	3.87E+00
128	S077	6	Deep	34	6.35E+03	2.80E+04	2.27E-01	0.873	40.2	46.6	13.3	3.50	9.76E-01	8.52E-01
129	S078	6	Deep	34	1.35E+03	2.70E+03	5.00E-01	0.599	50.9	38.5	10.6	5.10	5.71E+00	3.42E+00
130	S079	6	Deep	34	4.70E+02	2.20E+03	2.14E-01	0.801	37.9	51.0	11.1	3.40	1.01E+00	8.11E-01
131	S080	6	Deep	35	2.60E+03	5.20E+03	5.00E-01	0.785	50.8	35.1	14.2	4.10	1.59E+00	1.25E+00
132	S081	6	Deep	35	6.00E+02	1.20E+03	5.00E-01	0.703	40.9	45.0	14.2	5.30	1.43E+01	1.00E+01
133	S082	6	Deep	35	1.69E+04	3.61E+04	4.68E-01	0.755	43.9	42.4	13.7	4.00	1.50E+00	1.13E+00
134	S083	6	Deep	35	1.47E+04	2.93E+04	5.00E-01	0.765	40.9	43.7	15.4	5.10	1.28E+01	9.78E+00
135	S084	6	Deep	35	2.02E+03	5.10E+03	3.97E-01	0.739	35.8	49.7	14.5	3.90	1.07E+00	7.90E-01
136	S085	6	Deep	35	1.80E+03	3.60E+03	5.00E-01	0.806	39.8	44.3	16.0	5.10	1.30E+01	1.05E+01
137	S086	6	Deep	36	4.25E+03	8.50E+03	5.00E-01	0.745	32.8	52.9	14.3	5.10	1.81E+01	1.35E+01
138	S087	6	Deep	36	2.00E+03	4.00E+03	5.00E-01	0.936	22.0	54.4	23.6	4.20	1.15E+01	1.07E+01
139	S088	6	Deep	36	6.81E+03	2.12E+04	3.21E-01	0.849	36.4	50.2	13.4	3.90	1.83E+01	1.55E+01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
140	S089	6	Deep	36	4.52E+03	1.05E+04	4.31E-01	0.899	13.7	56.9	29.4	5.00	9.90E+00	8.90E+00
142	S091	6	Deep	36	1.11E+02	6.00E+02	1.85E-01	0.814	27.3	49.9	22.8	5.00	8.71E+00	7.09E+00
143	S092	6	Deep	37	3.00E+01	3.00E+02	1.00E-01	0.477	25.6	54.8	19.5	4.50	5.00E+00	2.39E+00
144	S093	6	Deep	37	3.40E+02	3.40E+03	1.00E-01	0.920	52.4	30.6	17.0	3.20	1.68E+00	1.55E+00
145	S094	6	Deep	37	4.19E+03	2.16E+04	1.94E-01	0.498	27.4	52.0	20.6	5.30	3.90E+00	1.94E+00
146	S095	6	Deep	37	4.32E+03	2.92E+04	1.48E-01	1.130	58.7	26.8	14.5	2.30	2.24E+00	2.53E+00
147	S096	6	Deep	37	3.55E+03	9.10E+03	3.91E-01	0.400	29.3	55.6	15.2	5.70	3.14E+00	1.26E+00
148	S097	6	Deep	37	9.40E+02	4.70E+03	2.00E-01	1.020	53.0	31.4	15.7	2.60	1.85E+00	1.89E+00
149	S098	6	Deep	38	5.60E+02	2.80E+03	2.00E-01	0.938	40.9	37.7	21.4	2.60	1.36E+00	1.28E+00
150	S099	6	Deep	38	4.55E+03	9.10E+03	5.00E-01	1.190	64.5	24.7	10.8	1.50	1.79E-01	2.13E-01
151	S100	6	Deep	38	5.76E+03	2.88E+04	2.00E-01	1.100	49.3	32.4	18.3	2.20	8.96E-01	9.81E-01
152	S101	6	Deep	38	1.40E+04	2.79E+04	5.00E-01	1.140	56.2	30.7	13.1	1.70	5.11E-01	5.83E-01
153	S102	6	Deep	38	7.20E+02	3.60E+03	2.00E-01	1.380	62.4	24.6	13.1	1.50	6.07E-01	8.38E-01
154	S103	6	Deep	38	1.90E+03	3.80E+03	5.00E-01	0.965	41.0	44.6	14.4	2.00	1.17E+00	1.13E+00
156	S105	6	Deep	39	9.53E+02	3.20E+03	2.98E-01	0.863	43.3	34.4	22.3	2.70	1.44E+00	1.24E+00
157	S106	6	Deep	39	6.55E+02	6.10E+03	1.07E-01	0.818	48.0	34.9	17.1	1.60	1.10E+00	8.95E-01
158	S107	6	Deep	39	3.70E+02	6.30E+03	5.87E-02	0.766	45.3	32.9	21.8	3.20	1.45E+00	1.11E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
159	S108	6	Deep	39	8.73E+02	4.50E+03	1.94E-01	0.810	41.8	46.8	11.4	1.90	1.25E+00	1.01E+00
161	S110	6	Deep	40	3.00E+03	7.20E+03	4.17E-01	0.807	33.0	49.1	18.0	3.90	1.41E+00	1.14E+00
162	S111	6	Deep	40	2.30E+03	4.60E+03	5.00E-01	0.537	36.7	50.1	13.2	6.00	6.84E-01	3.67E-01
163	S112	6	Deep	40	1.88E+04	3.99E+04	4.71E-01	0.625	22.1	60.5	17.5	4.60	1.30E+00	8.12E-01
164	S113	6	Deep	40	2.02E+04	4.04E+04	5.00E-01	0.555	32.4	54.2	13.5	5.90	8.38E-01	4.65E-01
165	S114	6	Deep	40	1.11E+03	3.30E+03	3.36E-01	0.752	28.0	51.6	20.4	3.80	1.40E+00	1.06E+00
166	S115	6	Deep	40	7.12E+02	5.10E+03	1.40E-01	0.687	31.4	52.7	15.9	5.80	5.17E-01	3.55E-01
5	03-Pg	7	Deep	3	3.21E+02	1.23E+04	2.61E-02	0.382	46.1	46.3	7.6	8.80	5.41E+00	2.07E+00
6	04-Pg	7	Deep	4	6.38E+01	5.50E+03	1.16E-02	0.417	60.1	33.2	6.7	9.90	4.56E+00	1.90E+00
7	04-E	7	Deep	4	9.36E+00	3.60E+03	2.60E-03	0.673	30.9	52.5	16.6	7.00	9.45E-01	6.36E-01
8	05-E	7	Deep	5	9.36E+00	7.80E+03	1.20E-03	0.458	25.5	54.4	20.1	6.00	2.63E-02	1.21E-02
42	23-EE	7	Deep	23	5.85E+01	6.80E+03	8.60E-03	0.504	23.5	51.1	25.5	6.30	4.53E-02	2.28E-02
43	24-EE	7	Deep	24	1.44E+04	8.27E+04	1.75E-01	0.659	29.5	49.9	20.7	7.30	6.70E-02	4.42E-02
45	24-GG	7	Deep	24	1.70E+02	4.30E+03	3.95E-02	0.392	24.3	56.1	19.6	6.50	3.24E-01	1.27E-01
46	24-HH	7	Deep	24	4.68E+02	7.80E+03	6.00E-02	0.593	23.2	55.1	21.7	6.00	1.44E-01	8.51E-02
49	03-ID	7	Deep	3	2.00E-02	2.00E+02	1.00E-04	0.751	65.0	24.9	10.1	6.60	8.43E+00	6.33E+00
50	04-ID	7	Deep	4	4.00E-01	1.00E+03	4.00E-04	0.557	59.0	31.6	9.4	7.10	3.65E+00	2.03E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
70	24-ID	7	Deep	24	1.30E+03	2.49E+04	5.20E-02	0.579	26.5	53.2	20.3	6.80	6.37E-01	3.69E-01
71	S020	7	Deep	25	1.02E+04	1.14E+05	8.94E-02	0.539	37.3	44.3	18.4	5.50	4.96E+00	2.68E+00
72	S021	7	Deep	25	5.48E+03	4.71E+04	1.16E-01	0.779	28.9	54.2	16.9	4.00	2.84E-01	2.21E-01
73	S022	7	Deep	25	3.81E+03	2.94E+04	1.30E-01	0.680	27.5	48.5	24.1	5.80	2.70E+01	1.83E+01
74	S023	7	Deep	25	5.67E+02	1.42E+04	3.99E-02	0.947	22.3	56.6	21.1	2.80	3.75E-01	3.55E-01
75	S024	7	Deep	25	5.39E+03	3.84E+04	1.40E-01	0.625	32.9	46.6	20.6	5.60	1.99E+01	1.24E+01
76	S025	7	Deep	25	3.07E+03	3.38E+04	9.07E-02	1.020	27.9	51.5	20.6	2.70	4.07E-01	4.15E-01
77	S026	7	Deep	26	7.00E-02	1.00E+02	7.00E-04	0.798	18.9	61.5	19.6	2.80	8.08E-01	6.44E-01
79	S028	7	Deep	26	4.06E+01	3.20E+03	1.27E-02	0.729	21.8	60.9	17.3	3.30	7.42E-01	5.41E-01
80	S029	7	Deep	26	2.49E+03	2.50E+04	9.95E-02	0.772	32.1	47.0	20.9	3.50	1.39E+00	1.07E+00
83	S032	7	Deep	27	2.47E+00	1.30E+03	1.90E-03	0.863	32.4	50.5	17.1	4.30	3.42E+00	2.95E+00
85	S034	7	Deep	27	3.02E+03	2.52E+04	1.20E-01	0.849	37.5	45.6	17.0	4.00	5.34E-01	4.53E-01
86	S035	7	Deep	27	3.69E+03	2.80E+04	1.32E-01	0.631	38.1	41.4	20.5	5.00	2.30E+01	1.45E+01
88	S037	7	Deep	27	1.33E+01	1.20E+03	1.11E-02	0.776	25.5	48.3	26.2	3.40	1.45E+00	1.12E+00
89	S038	7	Deep	28	3.03E+02	7.60E+03	3.99E-02	0.729	50.7	37.8	11.5	3.40	8.29E+00	6.04E+00
90	S039	7	Deep	28	5.88E+00	1.20E+03	4.90E-03	0.801	14.3	63.0	22.7	3.20	2.52E+00	2.01E+00
91	S040	7	Deep	28	4.06E+03	3.51E+04	1.16E-01	0.643	45.4	38.0	16.6	5.10	1.30E+01	8.38E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
92	S041	7	Deep	28	2.83E+03	3.40E+04	8.33E-02	0.744	30.3	52.1	17.6	3.90	1.52E+00	1.13E+00
93	S042	7	Deep	28	2.00E-02	2.00E+02	1.00E-04	0.808	46.1	38.4	15.5	3.70	7.22E+00	5.84E+00
94	S043	7	Deep	28	4.00E-02	4.00E+02	1.00E-04	0.941	36.3	47.5	16.3	2.10	1.98E+00	1.86E+00
95	S044	7	Deep	29	1.02E+03	2.10E+04	4.85E-02	0.592	34.4	48.3	17.4	4.20	1.79E+00	1.06E+00
96	S045	7	Deep	29	4.75E+03	5.59E+04	8.50E-02	0.509	22.8	58.0	19.2	5.20	2.90E+00	1.47E+00
97	S046	7	Deep	29	6.48E+03	5.40E+04	1.20E-01	0.635	29.3	53.9	16.8	4.40	3.78E+00	2.40E+00
98	S047	7	Deep	29	2.73E+04	1.02E+05	2.67E-01	0.476	31.5	49.9	18.6	6.80	5.33E+00	2.54E+00
99	S048	7	Deep	29	5.89E+03	6.11E+04	9.64E-02	0.721	48.2	38.0	13.8	3.80	4.59E-01	3.31E-01
100	S049	7	Deep	29	2.77E+04	1.38E+05	2.00E-01	0.516	43.7	41.3	15.0	4.60	4.25E+00	2.19E+00
101	S050	7	Deep	30	4.68E+01	3.00E+03	1.56E-02	0.922	21.2	58.9	19.9	2.90	1.68E+01	1.55E+01
102	S051	7	Deep	30	3.91E+02	6.10E+03	6.41E-02	0.877	48.8	39.4	11.8	2.90	1.74E+01	1.52E+01
103	S052	7	Deep	30	1.82E+04	6.55E+04	2.77E-01	0.612	24.1	59.4	16.5	5.60	1.72E+01	1.05E+01
104	S053	7	Deep	30	7.33E+03	4.35E+04	1.69E-01	0.582	20.9	61.5	17.6	4.60	5.32E+00	3.10E+00
105	S054	7	Deep	30	3.75E+02	9.20E+03	4.08E-02	0.559	37.4	49.1	13.6	4.80	1.59E+01	8.86E+00
107	S056	7	Deep	31	2.18E+04	5.72E+04	3.80E-01	0.484	29.3	53.4	17.4	6.50	2.97E+01	1.44E+01
108	S057	7	Deep	31	3.06E+04	7.62E+04	4.01E-01	0.520	27.9	51.1	21.1	6.70	2.97E+01	1.54E+01
109	S058	7	Deep	31	9.09E+03	2.50E+04	3.64E-01	0.477	33.0	49.9	17.1	6.00	1.76E+01	8.38E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
110	S059	7	Deep	31	6.91E+02	9.20E+03	7.51E-02	0.702	31.6	42.3	26.1	4.30	8.03E+00	5.64E+00
111	S060	7	Deep	31	5.22E+00	9.00E+02	5.80E-03	0.532	29.7	52.7	17.6	5.60	1.72E+01	9.14E+00
112	S061	7	Deep	31	5.24E+02	9.40E+03	5.57E-02	0.750	37.1	42.6	20.3	3.10	7.36E+00	5.52E+00
113	S062	7	Deep	32	3.89E+03	2.06E+04	1.89E-01	0.494	23.0	58.2	18.9	7.10	3.57E+01	1.76E+01
114	S063	7	Deep	32	2.30E+03	4.60E+03	5.00E-01	0.804	37.5	47.8	14.8	4.10	1.15E+00	9.28E-01
115	S064	7	Deep	32	6.00E-02	1.00E+02	6.00E-04	0.569	28.5	52.8	18.7	6.10	1.94E+01	1.11E+01
116	S065	7	Deep	32	1.68E+04	3.56E+04	4.72E-01	0.768	34.8	50.2	15.0	4.50	8.73E-01	6.70E-01
118	S067	7	Deep	32	3.46E+03	8.50E+03	4.07E-01	0.590	24.1	59.3	16.6	5.90	9.60E-01	5.66E-01
119	S068	7	Deep	33	2.50E+03	5.00E+03	5.00E-01	0.520	22.8	58.5	18.7	5.90	1.30E+01	6.74E+00
120	S069	7	Deep	33	1.50E+02	3.00E+02	5.00E-01	0.543	30.9	51.5	17.6	5.90	2.50E+01	1.36E+01
121	S070	7	Deep	33	3.98E+04	8.22E+04	4.84E-01	0.492	26.8	54.9	18.3	6.30	1.90E+01	9.35E+00
122	S071	7	Deep	33	1.96E+04	3.91E+04	5.00E-01	0.569	35.0	48.8	16.3	5.60	1.29E+01	7.37E+00
123	S072	7	Deep	33	9.20E+02	2.30E+03	4.00E-01	0.585	31.9	51.5	16.6	5.90	1.20E+01	7.00E+00
124	S073	7	Deep	33	2.10E+03	4.20E+03	5.00E-01	0.718	39.9	45.0	15.1	5.10	5.33E+00	3.82E+00
125	S074	7	Deep	34	2.50E+02	5.00E+02	5.00E-01	0.630	49.1	38.2	12.8	4.90	2.21E+00	1.39E+00
127	S076	7	Deep	34	1.82E+04	3.64E+04	5.00E-01	0.611	50.3	38.0	11.7	5.00	2.96E+00	1.81E+00
128	S077	7	Deep	34	9.00E+01	2.40E+03	3.75E-02	0.873	40.2	46.6	13.3	3.50	2.32E+00	2.02E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
129	S078	7	Deep	34	1.35E+03	2.70E+03	5.00E-01	0.599	50.9	38.5	10.6	5.10	3.95E+00	2.37E+00
130	S079	7	Deep	34	2.27E+00	1.00E+02	2.27E-02	0.801	37.9	51.0	11.1	3.40	1.99E+00	1.59E+00
131	S080	7	Deep	35	8.09E+02	2.90E+03	2.79E-01	0.785	50.8	35.1	14.2	4.10	3.49E-01	2.74E-01
132	S081	7	Deep	35	4.17E+02	1.00E+03	4.17E-01	0.703	40.9	45.0	14.2	5.30	3.22E+00	2.27E+00
133	S082	7	Deep	35	3.03E+03	1.56E+04	1.94E-01	0.755	43.9	42.4	13.7	4.00	8.25E-01	6.23E-01
134	S083	7	Deep	35	1.15E+04	2.59E+04	4.42E-01	0.765	40.9	43.7	15.4	5.10	4.68E+00	3.58E+00
136	S085	7	Deep	35	1.80E+03	3.60E+03	5.00E-01	0.806	39.8	44.3	16.0	5.10	5.43E+00	4.38E+00
137	S086	7	Deep	36	3.41E+03	8.50E+03	4.01E-01	0.745	32.8	52.9	14.3	5.10	9.47E-01	7.06E-01
138	S087	7	Deep	36	1.20E+03	4.00E+03	3.00E-01	0.936	22.0	54.4	23.6	4.20	1.96E+00	1.83E+00
139	S088	7	Deep	36	5.32E+03	1.97E+04	2.70E-01	0.849	36.4	50.2	13.4	3.90	8.90E-01	7.56E-01
140	S089	7	Deep	36	9.49E+02	5.90E+03	1.61E-01	0.899	13.7	56.9	29.4	5.00	2.41E+00	2.16E+00
145	S094	7	Deep	37	1.09E+03	1.42E+04	7.67E-02	0.498	27.4	52.0	20.6	5.30	2.90E+00	1.44E+00
147	S096	7	Deep	37	1.77E+03	8.40E+03	2.11E-01	0.400	29.3	55.6	15.2	5.70	2.90E+00	1.16E+00
161	S110	7	Deep	40	3.96E+00	1.20E+03	3.30E-03	0.807	33.0	49.1	18.0	3.90	7.00E+00	5.65E+00
162	S111	7	Deep	40	2.14E+03	4.60E+03	4.66E-01	0.537	36.7	50.1	13.2	6.00	8.33E+00	4.47E+00
163	S112	7	Deep	40	4.43E+03	2.82E+04	1.57E-01	0.625	22.1	60.5	17.5	4.60	7.30E+00	4.56E+00
164	S113	7	Deep	40	1.62E+04	4.04E+04	4.01E-01	0.555	32.4	54.2	13.5	5.90	8.32E+00	4.62E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
165	S114	7	Deep	40	2.97E+02	2.80E+03	1.06E-01	0.752	28.0	51.6	20.4	3.80	5.29E+00	3.98E+00
166	S115	7	Deep	40	4.71E+02	4.30E+03	1.10E-01	0.687	31.4	52.7	15.9	5.80	8.33E+00	5.72E+00
5	03-Pg	8	Deep	3	1.44E+00	1.20E+03	1.20E-03	0.382	46.1	46.3	7.6	8.80	1.72E+00	6.55E-01
6	04-Pg	8	Deep	4	6.00E-02	2.00E+02	3.00E-04	0.417	60.1	33.2	6.7	9.90	1.49E+00	6.19E-01
42	23-EE	8	Deep	23	2.54E+01	4.80E+03	5.30E-03	0.504	23.5	51.1	25.5	6.30	2.43E-02	1.22E-02
43	24-EE	8	Deep	24	1.37E+03	3.28E+04	4.18E-02	0.659	29.5	49.9	20.7	7.30	3.40E-02	2.24E-02
45	24-GG	8	Deep	24	3.00E-01	5.00E+02	6.00E-04	0.392	24.3	56.1	19.6	6.50	1.26E-01	4.94E-02
46	24-HH	8	Deep	24	6.03E+01	3.70E+03	1.63E-02	0.593	23.2	55.1	21.7	6.00	8.62E-02	5.11E-02
70	24-ID	8	Deep	24	4.96E+01	6.20E+03	8.00E-03	0.579	26.5	53.2	20.3	6.80	9.74E-02	5.64E-02
71	S020	8	Deep	25	1.79E+03	4.41E+04	4.05E-02	0.539	37.3	44.3	18.4	5.50	8.06E+00	4.35E+00
72	S021	8	Deep	25	1.26E+03	2.47E+04	5.09E-02	0.779	28.9	54.2	16.9	4.00	5.24E-01	4.08E-01
73	S022	8	Deep	25	2.00E+03	2.10E+04	9.52E-02	0.680	27.5	48.5	24.1	5.80	3.02E+01	2.05E+01
74	S023	8	Deep	25	1.60E+02	8.40E+03	1.91E-02	0.947	22.3	56.6	21.1	2.80	6.07E-01	5.74E-01
75	S024	8	Deep	25	2.23E+03	2.36E+04	9.45E-02	0.625	32.9	46.6	20.6	5.60	1.67E+01	1.05E+01
76	S025	8	Deep	25	4.87E+02	1.45E+04	3.36E-02	1.020	27.9	51.5	20.6	2.70	3.23E-01	3.29E-01
79	S028	8	Deep	26	4.56E+00	1.20E+03	3.80E-03	0.729	21.8	60.9	17.3	3.30	5.65E-01	4.12E-01
80	S029	8	Deep	26	1.80E+02	7.60E+03	2.37E-02	0.772	32.1	47.0	20.9	3.50	2.69E-01	2.08E-01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
85	S034	8	Deep	27	2.81E+02	7.00E+03	4.01E-02	0.849	37.5	45.6	17.0	4.00	1.81E-01	1.53E-01
86	S035	8	Deep	27	7.99E+02	1.26E+04	6.34E-02	0.631	38.1	41.4	20.5	5.00	8.99E+00	5.67E+00
89	S038	8	Deep	28	2.21E+01	2.30E+03	9.60E-03	0.729	50.7	37.8	11.5	3.40	2.25E+00	1.64E+00
91	S040	8	Deep	28	8.99E+02	1.56E+04	5.76E-02	0.643	45.4	38.0	16.6	5.10	4.92E+00	3.17E+00
92	S041	8	Deep	28	2.63E+02	1.21E+04	2.17E-02	0.744	30.3	52.1	17.6	3.90	1.35E+00	1.00E+00
95	S044	8	Deep	29	5.20E+01	4.30E+03	1.21E-02	0.592	34.4	48.3	17.4	4.20	1.56E+00	9.21E-01
96	S045	8	Deep	29	2.01E+02	1.25E+04	1.61E-02	0.509	22.8	58.0	19.2	5.20	1.24E+00	6.30E-01
97	S046	8	Deep	29	1.67E+03	3.04E+04	5.50E-02	0.635	29.3	53.9	16.8	4.40	5.68E+00	3.61E+00
98	S047	8	Deep	29	9.66E+03	6.51E+04	1.48E-01	0.476	31.5	49.9	18.6	6.80	5.69E+00	2.70E+00
99	S048	8	Deep	29	4.26E+02	1.67E+04	2.55E-02	0.721	48.2	38.0	13.8	3.80	3.01E+00	2.17E+00
100	S049	8	Deep	29	6.02E+03	6.98E+04	8.63E-02	0.516	43.7	41.3	15.0	4.60	2.24E+00	1.16E+00
102	S051	8	Deep	30	1.04E+01	1.20E+03	8.70E-03	0.877	48.8	39.4	11.8	2.90	2.05E+01	1.79E+01
103	S052	8	Deep	30	6.56E+03	4.74E+04	1.38E-01	0.612	24.1	59.4	16.5	5.60	9.22E+00	5.64E+00
104	S053	8	Deep	30	9.18E+02	1.94E+04	4.73E-02	0.582	20.9	61.5	17.6	4.60	6.72E+00	3.91E+00
105	S054	8	Deep	30	3.06E+00	1.70E+03	1.80E-03	0.559	37.4	49.1	13.6	4.80	8.39E+00	4.69E+00
107	S056	8	Deep	31	1.00E+04	4.11E+04	2.44E-01	0.484	29.3	53.4	17.4	6.50	2.72E+01	1.32E+01
108	S057	8	Deep	31	1.17E+04	5.42E+04	2.15E-01	0.520	27.9	51.1	21.1	6.70	3.62E+01	1.88E+01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
109	S058	8	Deep	31	5.15E+03	2.03E+04	2.54E-01	0.477	33.0	49.9	17.1	6.00	1.76E+01	8.41E+00
110	S059	8	Deep	31	6.00E-01	3.00E+02	2.00E-03	0.702	31.6	42.3	26.1	4.30	2.15E+01	1.51E+01
111	S060	8	Deep	31	4.00E-02	1.00E+02	4.00E-04	0.532	29.7	52.7	17.6	5.60	2.26E+01	1.20E+01
112	S061	8	Deep	31	1.24E+01	1.80E+03	6.90E-03	0.750	37.1	42.6	20.3	3.10	3.32E+01	2.49E+01
113	S062	8	Deep	32	2.94E+03	1.76E+04	1.67E-01	0.494	23.0	58.2	18.9	7.10	1.42E+01	7.02E+00
114	S063	8	Deep	32	2.30E+03	4.60E+03	5.00E-01	0.804	37.5	47.8	14.8	4.10	1.97E+00	1.59E+00
116	S065	8	Deep	32	9.21E+03	2.56E+04	3.60E-01	0.768	34.8	50.2	15.0	4.50	2.12E+00	1.63E+00
118	S067	8	Deep	32	2.12E+01	6.00E+02	3.53E-02	0.590	24.1	59.3	16.6	5.90	8.10E+00	4.78E+00
119	S068	8	Deep	33	2.56E+02	1.60E+03	1.60E-01	0.520	22.8	58.5	18.7	5.90	3.44E+01	1.79E+01
120	S069	8	Deep	33	7.00E+01	3.00E+02	2.33E-01	0.543	30.9	51.5	17.6	5.90	2.33E+01	1.27E+01
121	S070	8	Deep	33	1.51E+04	5.12E+04	2.94E-01	0.492	26.8	54.9	18.3	6.30	3.11E+01	1.53E+01
122	S071	8	Deep	33	1.46E+04	3.91E+04	3.72E-01	0.569	35.0	48.8	16.3	5.60	1.16E+01	6.60E+00
124	S073	8	Deep	33	2.10E+03	4.20E+03	5.00E-01	0.718	39.9	45.0	15.1	5.10	4.46E+00	3.20E+00
125	S074	8	Deep	34	5.00E+01	5.00E+02	1.00E-01	0.630	49.1	38.2	12.8	4.90	1.40E+00	8.79E-01
127	S076	8	Deep	34	1.17E+04	3.64E+04	3.21E-01	0.611	50.3	38.0	11.7	5.00	1.85E+00	1.13E+00
128	S077	8	Deep	34	4.91E+01	1.80E+03	2.73E-02	0.873	40.2	46.6	13.3	3.50	1.46E+00	1.27E+00
129	S078	8	Deep	34	1.35E+03	2.70E+03	5.00E-01	0.599	50.9	38.5	10.6	5.10	2.45E+00	1.47E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
130	S079	8	Deep	34	2.27E+00	1.00E+02	2.27E-02	0.801	37.9	51.0	11.1	3.40	1.25E+00	1.01E+00
131	S080	8	Deep	35	8.09E+02	2.90E+03	2.79E-01	0.785	50.8	35.1	14.2	4.10	1.81E-01	1.42E-01
132	S081	8	Deep	35	4.17E+02	1.00E+03	4.17E-01	0.703	40.9	45.0	14.2	5.30	1.58E+00	1.11E+00
133	S082	8	Deep	35	1.85E+03	1.23E+04	1.51E-01	0.755	43.9	42.4	13.7	4.00	3.80E-01	2.87E-01
134	S083	8	Deep	35	1.15E+04	2.59E+04	4.42E-01	0.765	40.9	43.7	15.4	5.10	2.08E+00	1.59E+00
136	S085	8	Deep	35	1.80E+03	3.60E+03	5.00E-01	0.806	39.8	44.3	16.0	5.10	2.34E+00	1.89E+00
137	S086	8	Deep	36	1.09E+03	4.30E+03	2.53E-01	0.745	32.8	52.9	14.3	5.10	8.21E-01	6.12E-01
139	S088	8	Deep	36	3.16E+03	1.42E+04	2.23E-01	0.849	36.4	50.2	13.4	3.90	7.89E-01	6.70E-01
162	S111	8	Deep	40	1.83E+03	4.10E+03	4.46E-01	0.537	36.7	50.1	13.2	6.00	1.10E+01	5.91E+00
163	S112	8	Deep	40	4.90E+01	2.50E+03	1.96E-02	0.625	22.1	60.5	17.5	4.60	1.10E+01	6.88E+00
164	S113	8	Deep	40	3.42E+03	2.09E+04	1.64E-01	0.555	32.4	54.2	13.5	5.90	1.10E+01	6.11E+00
166	S115	8	Deep	40	6.29E+01	2.90E+03	2.17E-02	0.687	31.4	52.7	15.9	5.80	1.10E+01	7.56E+00
42	23-EE	9	Deep	23	2.40E+00	2.40E+03	1.00E-03	0.504	23.5	51.1	25.5	6.30	2.23E-02	1.12E-02
43	24-EE	9	Deep	24	4.40E+00	2.20E+03	2.00E-03	0.659	29.5	49.9	20.7	7.30	3.15E-02	2.08E-02
71	S020	9	Deep	25	3.02E+02	2.17E+04	1.39E-02	0.539	37.3	44.3	18.4	5.50	1.52E+01	8.22E+00
72	S021	9	Deep	25	3.12E+01	6.50E+03	4.80E-03	0.779	28.9	54.2	16.9	4.00	2.88E+00	2.24E+00
73	S022	9	Deep	25	1.49E+03	1.76E+04	8.44E-02	0.680	27.5	48.5	24.1	5.80	3.85E+01	2.62E+01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
74	S023	9	Deep	25	2.14E+01	3.50E+03	6.10E-03	0.947	22.3	56.6	21.1	2.80	6.57E-01	6.22E-01
75	S024	9	Deep	25	1.10E+03	1.76E+04	6.27E-02	0.625	32.9	46.6	20.6	5.60	2.03E+01	1.27E+01
76	S025	9	Deep	25	4.16E+01	5.20E+03	8.00E-03	1.020	27.9	51.5	20.6	2.70	3.64E-01	3.71E-01
79	S028	9	Deep	26	8.00E-02	2.00E+02	4.00E-04	0.729	21.8	60.9	17.3	3.30	9.34E-02	6.81E-02
80	S029	9	Deep	26	9.60E-01	8.00E+02	1.20E-03	0.772	32.1	47.0	20.9	3.50	1.66E-01	1.28E-01
85	S034	9	Deep	27	6.17E+01	3.30E+03	1.87E-02	0.849	37.5	45.6	17.0	4.00	1.10E-01	9.33E-02
86	S035	9	Deep	27	1.31E+02	6.00E+03	2.19E-02	0.631	38.1	41.4	20.5	5.00	3.06E+00	1.93E+00
89	S038	9	Deep	28	2.05E+00	5.00E+02	4.10E-03	0.729	50.7	37.8	11.5	3.40	7.09E-01	5.17E-01
91	S040	9	Deep	28	8.01E+01	5.20E+03	1.54E-02	0.643	45.4	38.0	16.6	5.10	1.07E+00	6.88E-01
92	S041	9	Deep	28	1.62E+01	2.80E+03	5.80E-03	0.744	30.3	52.1	17.6	3.90	5.88E-01	4.37E-01
95	S044	9	Deep	29	6.97E+00	1.70E+03	4.10E-03	0.592	34.4	48.3	17.4	4.20	5.52E+00	3.26E+00
96	S045	9	Deep	29	2.04E+00	1.70E+03	1.20E-03	0.509	22.8	58.0	19.2	5.20	1.24E+00	6.33E-01
97	S046	9	Deep	29	7.57E+01	8.80E+03	8.60E-03	0.635	29.3	53.9	16.8	4.40	4.64E+00	2.94E+00
98	S047	9	Deep	29	7.61E+02	2.48E+04	3.07E-02	0.476	31.5	49.9	18.6	6.80	3.02E+00	1.44E+00
99	S048	9	Deep	29	6.90E+01	6.70E+03	1.03E-02	0.721	48.2	38.0	13.8	3.80	1.12E+00	8.10E-01
100	S049	9	Deep	29	1.06E+02	1.34E+04	7.90E-03	0.516	43.7	41.3	15.0	4.60	1.28E+00	6.59E-01
102	S051	9	Deep	30	2.00E-01	1.00E+02	2.00E-03	0.877	48.8	39.4	11.8	2.90	2.87E+01	2.52E+01

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
103	S052	9	Deep	30	4.60E+02	1.42E+04	3.24E-02	0.612	24.1	59.4	16.5	5.60	1.39E+01	8.50E+00
104	S053	9	Deep	30	3.67E+01	3.90E+03	9.40E-03	0.582	20.9	61.5	17.6	4.60	1.33E+01	7.72E+00
107	S056	9	Deep	31	2.87E+03	2.26E+04	1.27E-01	0.484	29.3	53.4	17.4	6.50	3.06E+01	1.48E+01
108	S057	9	Deep	31	2.67E+03	2.50E+04	1.07E-01	0.520	27.9	51.1	21.1	6.70	1.69E+01	8.77E+00
109	S058	9	Deep	31	6.40E+02	1.05E+04	6.09E-02	0.477	33.0	49.9	17.1	6.00	1.65E+01	7.87E+00
112	S061	9	Deep	31	2.00E-02	1.00E+02	2.00E-04	0.750	37.1	42.6	20.3	3.10	1.66E+01	1.24E+01
113	S062	9	Deep	32	2.39E+03	1.59E+04	1.50E-01	0.494	23.0	58.2	18.9	7.10	3.47E+00	1.72E+00
114	S063	9	Deep	32	4.60E+02	4.60E+03	1.00E-01	0.804	37.5	47.8	14.8	4.10	1.09E+00	8.80E-01
116	S065	9	Deep	32	1.84E+03	2.56E+04	7.19E-02	0.768	34.8	50.2	15.0	4.50	1.26E+00	9.65E-01
118	S067	9	Deep	32	4.26E+00	6.00E+02	7.10E-03	0.590	24.1	59.3	16.6	5.90	4.92E+00	2.90E+00
119	S068	9	Deep	33	2.56E+02	1.60E+03	1.60E-01	0.520	22.8	58.5	18.7	5.90	1.83E+01	9.49E+00
120	S069	9	Deep	33	1.67E+01	1.00E+02	1.67E-01	0.543	30.9	51.5	17.6	5.90	1.77E+01	9.59E+00
121	S070	9	Deep	33	1.05E+04	4.84E+04	2.16E-01	0.492	26.8	54.9	18.3	6.30	1.75E+01	8.61E+00
122	S071	9	Deep	33	3.84E+03	2.66E+04	1.44E-01	0.569	35.0	48.8	16.3	5.60	9.36E+00	5.33E+00
124	S073	9	Deep	33	4.20E+02	4.20E+03	1.00E-01	0.718	39.9	45.0	15.1	5.10	2.79E+00	2.00E+00
127	S076	9	Deep	34	5.50E+03	2.01E+04	2.74E-01	0.611	50.3	38.0	11.7	5.00	2.94E+00	1.80E+00
128	S077	9	Deep	34	1.69E+01	1.40E+03	1.21E-02	0.873	40.2	46.6	13.3	3.50	2.80E+00	2.44E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
129	S078	9	Deep	34	1.35E+03	2.70E+03	5.00E-01	0.599	50.9	38.5	10.6	5.10	2.89E+00	1.73E+00
130	S079	9	Deep	34	2.27E+00	1.00E+02	2.27E-02	0.801	37.9	51.0	11.1	3.40	5.41E+00	4.33E+00
131	S080	9	Deep	35	3.23E+02	2.90E+03	1.12E-01	0.785	50.8	35.1	14.2	4.10	5.37E-01	4.22E-01
132	S081	9	Deep	35	4.17E+02	1.00E+03	4.17E-01	0.703	40.9	45.0	14.2	5.30	1.25E-01	8.77E-02
133	S082	9	Deep	35	4.18E+02	9.40E+03	4.45E-02	0.755	43.9	42.4	13.7	4.00	5.40E-01	4.08E-01
134	S083	9	Deep	35	1.15E+04	2.59E+04	4.42E-01	0.765	40.9	43.7	15.4	5.10	1.33E-01	1.01E-01
136	S085	9	Deep	35	1.80E+03	3.60E+03	5.00E-01	0.806	39.8	44.3	16.0	5.10	1.36E-01	1.10E-01
137	S086	9	Deep	36	1.09E+03	4.30E+03	2.53E-01	0.745	32.8	52.9	14.3	5.10	1.11E-01	8.29E-02
139	S088	9	Deep	36	3.16E+03	1.42E+04	2.23E-01	0.849	36.4	50.2	13.4	3.90	1.11E-01	9.40E-02
162	S111	9	Deep	40	3.65E+02	4.10E+03	8.91E-02	0.537	36.7	50.1	13.2	6.00	1.10E+01	5.91E+00
163	S112	9	Deep	40	5.00E-01	5.00E+02	1.00E-03	0.625	22.1	60.5	17.5	4.60	1.10E+01	6.88E+00
164	S113	9	Deep	40	1.44E+02	6.30E+03	2.29E-02	0.555	32.4	54.2	13.5	5.90	1.10E+01	6.11E+00
71	S020	10	Deep	25	4.42E+01	6.60E+03	6.70E-03	0.539	37.3	44.3	18.4	5.50	2.44E+01	1.32E+01
73	S022	10	Deep	25	4.71E+03	1.59E+04	2.96E-01	0.680	27.5	48.5	24.1	5.80	2.56E+01	1.74E+01
75	S024	10	Deep	25	3.23E+02	9.50E+03	3.40E-02	0.625	32.9	46.6	20.6	5.60	1.19E+01	7.46E+00
85	S034	10	Deep	27	1.13E+01	1.80E+03	6.30E-03	0.849	37.5	45.6	17.0	4.00	5.30E+00	4.50E+00
86	S035	10	Deep	27	1.17E+01	1.80E+03	6.50E-03	0.631	38.1	41.4	20.5	5.00	6.05E+00	3.81E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
89	S038	10	Deep	28	4.50E-01	3.00E+02	1.50E-03	0.729	50.7	37.8	11.5	3.40	6.35E-01	4.63E-01
91	S040	10	Deep	28	2.46E+01	2.10E+03	1.17E-02	0.643	45.4	38.0	16.6	5.10	1.21E+00	7.76E-01
97	S046	10	Deep	29	1.08E+00	6.00E+02	1.80E-03	0.635	29.3	53.9	16.8	4.40	6.07E-01	3.85E-01
98	S047	10	Deep	29	5.58E+00	1.80E+03	3.10E-03	0.476	31.5	49.9	18.6	6.80	1.11E+00	5.27E-01
99	S048	10	Deep	29	7.35E+00	2.10E+03	3.50E-03	0.721	48.2	38.0	13.8	3.80	5.97E-01	4.31E-01
100	S049	10	Deep	29	2.40E-01	8.00E+02	3.00E-04	0.516	43.7	41.3	15.0	4.60	1.39E+00	7.18E-01
102	S051	10	Deep	30	1.00E-01	1.00E+02	1.00E-03	0.877	48.8	39.4	11.8	2.90	2.37E+01	2.08E+01
103	S052	10	Deep	30	1.35E+00	9.00E+02	1.50E-03	0.612	24.1	59.4	16.5	5.60	1.38E+01	8.46E+00
104	S053	10	Deep	30	2.40E-01	6.00E+02	4.00E-04	0.582	20.9	61.5	17.6	4.60	2.15E+01	1.25E+01
107	S056	10	Deep	31	1.98E+03	1.31E+04	1.51E-01	0.484	29.3	53.4	17.4	6.50	2.24E+01	1.08E+01
108	S057	10	Deep	31	5.09E+02	1.13E+04	4.50E-02	0.520	27.9	51.1	21.1	6.70	1.03E+01	5.38E+00
109	S058	10	Deep	31	7.00E+00	5.00E+02	1.40E-02	0.477	33.0	49.9	17.1	6.00	2.28E+01	1.09E+01
113	S062	10	Deep	32	4.45E+03	1.43E+04	3.11E-01	0.494	23.0	58.2	18.9	7.10	1.06E+00	5.22E-01
119	S068	10	Deep	33	8.19E+02	1.60E+03	5.12E-01	0.520	22.8	58.5	18.7	5.90	2.15E+01	1.11E+01
120	S069	10	Deep	33	5.33E+01	1.00E+02	5.33E-01	0.543	30.9	51.5	17.6	5.90	1.83E+01	9.92E+00
121	S070	10	Deep	33	6.94E+03	2.07E+04	3.35E-01	0.492	26.8	54.9	18.3	6.30	2.13E+01	1.04E+01
122	S071	10	Deep	33	2.04E+03	7.10E+03	2.88E-01	0.569	35.0	48.8	16.3	5.60	1.58E+01	8.99E+00

Stack Number	Identifier	Layer	Segment Number	Overlying Water Segment	Volume (m3)	Area (m2)	Thickness (m)	Bulk Density (kg/L)	Coarse (%)	Medium (%)	Fine (%)	TOC (%)	PCB (mg/kg)	PCB (mg/L)
127	S076	10	Deep	34	7.32E+03	1.96E+04	3.73E-01	0.611	50.3	38.0	11.7	5.00	2.98E+00	1.82E+00
128	S077	10	Deep	34	1.00E+00	2.00E+02	5.00E-03	0.873	40.2	46.6	13.3	3.50	2.79E+00	2.43E+00
129	S078	10	Deep	34	1.89E+03	2.70E+03	7.00E-01	0.599	50.9	38.5	10.6	5.10	2.90E+00	1.74E+00
130	S079	10	Deep	34	3.18E+00	1.00E+02	3.18E-02	0.801	37.9	51.0	11.1	3.40	4.93E+00	3.95E+00
132	S081	10	Deep	35	3.33E+02	1.00E+03	3.33E-01	0.703	40.9	45.0	14.2	5.30	1.25E-01	8.77E-02
134	S083	10	Deep	35	6.31E+02	6.80E+03	9.28E-02	0.765	40.9	43.7	15.4	5.10	1.33E-01	1.01E-01
137	S086	10	Deep	36	8.70E+02	4.30E+03	2.02E-01	0.745	32.8	52.9	14.3	5.10	1.11E-01	8.29E-02
139	S088	10	Deep	36	2.53E+03	1.42E+04	1.78E-01	0.849	36.4	50.2	13.4	3.90	1.11E-01	9.40E-02
164	S113	10	Deep	40	2.00E-02	2.00E+02	1.00E-04	0.555	32.4	54.2	13.5	5.90	0.00E+00	0.00E+00

APPENDIX B. ASSESSMENT OF SPATIAL AND TEMPORAL TRENDS IN LOWER FOX RIVER SEDIMENT PCB CONCENTRATIONS

ASSESSMENT OF SPATIAL AND TEMPORAL TRENDS IN LOWER FOX RIVER SEDIMENT PCB CONCENTRATIONS

OVERVIEW

Accurate quantification of spatial and temporal PCB concentration trends in Lower Fox River sediments is complex. PCB concentration data for the river were collected as part of numerous sampling efforts conducted over an 8-year period. These efforts were not specifically designed to estimate PCB concentration trends over time. Sediment cores from each sampling effort were collected at different horizontal and vertical locations, different times, and often analyzed using different analytical techniques and quantitation standards. Differences introduced as a result of spatial heterogeneity, temporal variability, and analytical bias confounds direct analysis and makes clear identification of possible trends challenging. When estimating the scale of possible PCB trends, the nature and influence of these confounding factors must be considered.

Terms used in the sections that follow (e.g. SMU, TM2e, river reach, etc.) are defined in the main body of the report. Sections 2.1, 2.3, 3.2, and 3.3 provide definitions for most terms. River reach definitions are presented in Table 3-2 of Section 3.3.

NATURE AND INFLUENCE OF COUNFOUNDING FACTORS

Spatial Heterogeneity

The spatial heterogeneity of sediment PCB concentrations confounds assessments of trends since samples collected from different locations will likely have different PCB levels regardless of when those samples were collected or how they were analyzed. The heterogeneous nature of PCB concentrations in river sediments is readily apparent. PCB concentrations in Lower Fox River sediment samples collected at the same time and analyzed using the same methods but collected from different horizontal and/or vertical locations differ widely. The patchy distribution of PCBs in Lower Fox River sediments is very likely a reflection variable PCB inputs from multiple sources as well as the distance from and differential rates of transport in the region around each PCB source. For any single sample collection effort, PCB concentrations can vary with location by several orders of magnitude, from near the limit of detection (approximately 0.05 mg/kg) to more than 100 mg/kg. However, as noted in TM2e (WDNR, 1999b), samples were often collected far apart and no single sampling effort necessarily provided a complete assessment of the spatial differences in PCB concentrations. As a result, the patchy nature of PCB concentrations in space may not be fully characterized. For example, the maximum PCB concentration of samples collected in the area around SMU 56/57 (prior to initiation of sediment removal projects) was ~40 mg/kg in 1989, ~400 mg/kg in 1995, and ~700 mg/kg in 1997. In the absence of significant external PCB sources to the river over that time period, it is reasonable to conclude that these apparent temporal differences are in fact spatial differences since the density of samples collected from the area increased with each successive sampling effort. However, changes over time and analytical bias may nonetheless contribute to part of these differences. Consequently, potential spatial trends in sediment PCB concentrations can be somewhat difficult to quantify since some of the apparent differences may be attributable to the confounding factors of temporal variability and analytical bias.

Temporal Variability

The possible temporal variability of sediment PCB concentrations also confounds assessments of trends since samples collected at different times may have different PCB levels regardless of where those samples were collected or how they were analyzed. However, the potential temporal variability of river sediment PCB concentrations may be even more difficult to identify than spatial trends. There were no areas where samples collected at different times were collected at the same horizontal or vertical locations. Further, the vertical location of all samples is uncertain. Sediment core slice depth intervals were only measured from the relative position of the sediment-water interface. The vertical location of samples was not recorded with respect to a fixed datum. As noted in TM2g (WDNR, 1999c) and follow-up efforts presented in Section 4.2.2.1, the position of the sediment-water interface can vary widely over time. This means it is possible that, relative to the sediment-water interface, samples collected from a given specific stratum in one year might be located in a different stratum or not exist at all in subsequent years. Also, PCB concentrations in sediment cores collected during different sampling efforts were generally analyzed using different analytical methods. Given the patchy spatial distribution of PCBs in Lower Fox River sediments and differences in laboratory procedures, it is possible that much of the apparent difference in PCB concentrations over time for any area of sediments may instead be a reflection of spatial heterogeneity or analytical bias.

Analytical Bias

Differences in laboratory analytical techniques and quantitation standards further confound clear identification of spatial and temporal PCB concentration trends. For each sample collection effort, different analytical techniques and quantitation standards were used. These differences can result in a consistent bias in reported PCB concentrations.

While, no comprehensive study examining all possible factors that may contribute to analytical bias has been completed, USEPA explored some of these issues as part of quality assurance efforts for LMMBS efforts (Grace Analytical, 1996). As part of those LMMBS inter-lab bias studies, “snap and shoot” ampules of PCBs dissolved in hexane were analyzed and quantitated at eight different laboratories. The true PCB concentration in each ampule was known from gravimetric determinations. All samples were analyzed according to the same methods. Relative to the known (gravimetric true) total PCB concentration in a standard sample, the mean absolute bias was 25% less than the true value and ranged from -4% to -78%. Note that all determinations were *less* than the true value. Relative to each other, the greatest relative inter-lab bias was -77%. Relative to the mean bias (-25%), inter-lab relative biases ranged from -71% to +28%. The range of biases for individual PCB congener measurements was even larger.

In addition to that USEPA effort, two laboratories participated in a study performed in support of the Deposit N sediment removal project. In that study, each laboratory analyzed a standard according to the laboratory’s procedure as well as the other laboratory’s procedure. By this approach, methodological differences in quantitation were explored. The inter-lab relative bias for analysis of the standard was estimated to exceed 35% (Kuehl, 1999).

In general, these studies indicate that analytical biases exist between data analyzed at different laboratories with different methods. The estimate of the relative bias is approximately ±30%.

This means that on average approximately 30% of any difference in PCB concentrations between samples may be solely attributable to analytical bias. It is also worth noting that these bias studies focused only on instrumentation and quantitation methods. Additional biases can also occur as a result of different sample extraction methods. If differences in sample extraction methods also exist between data sets, the relative bias between samples analyzed by different methods can be on the order of ±50%.

EXPLORATION OF SEDIMENT PCB CONCENTRATION TRENDS

Methodology

Data collected over the period 1989 through 1997 were examined to explore Lower Fox River sediment PCB concentration trends over the model calibration period. An overview of these data is presented in TM2e (WDNR, 1999b). The horizontal locations of sediment PCB sample collection sites are presented in Figures B-1 through B-4. These data were explored following a five-step process:

- First, data for each unique horizontal location were standardized by a thickness-weighted averaging procedure for the vertical layers described in TM2e (WDNR, 1999b): 0-10 cm, 10-30 cm, etc. This standardization was necessary to account for the different sediment core slicing protocols of each data set. This thickness-weighted averaging process was also used during development of TM2e.

- Second, the underlying distribution of the standardized data was assessed using the D'Agostino D statistic as described by Gilbert (1987). D statistic results indicate that the natural logarithms (log) of the Lower Fox River sediment PCB data have a normal distribution. Therefore, all subsequent analysis and statistical tests were performed on the natural log-transformed data. The distribution of the data is presented in Figure B-5.

- Third, analyses were restricted to the standardized data for the 0-10 cm layer. This was necessary to minimize the potential for misidentifying differences in sample vertical location as temporal trends since differences in vertical locations over time between samples cannot be determined from the present data. Differences in vertical locations cannot be determined because: 1) the positions of the sediment-water interface over time were not measured; and 2) sample core slice elevations (from a fixed datum) were not measured. It should be noted that variations in sediment-water interface positions also affect the standardized data for the 0-10 cm layer. However, it is reasonable to examine trends in these data because this layer always represents the bioavailable layer regardless of the magnitude or frequency of sediment-water interface position changes over time or whether sediments comprising this layer were present at some other horizontal or vertical location at some other time.

- Fourth, the horizontal locations of all sample sites were translated to equivalent river positions expressed by the distance upstream of the river mouth as measured along the (curvilinear) axis of river flow. This translation was necessary to ensure a consistent basis to represent sample locations as river orientation varies.

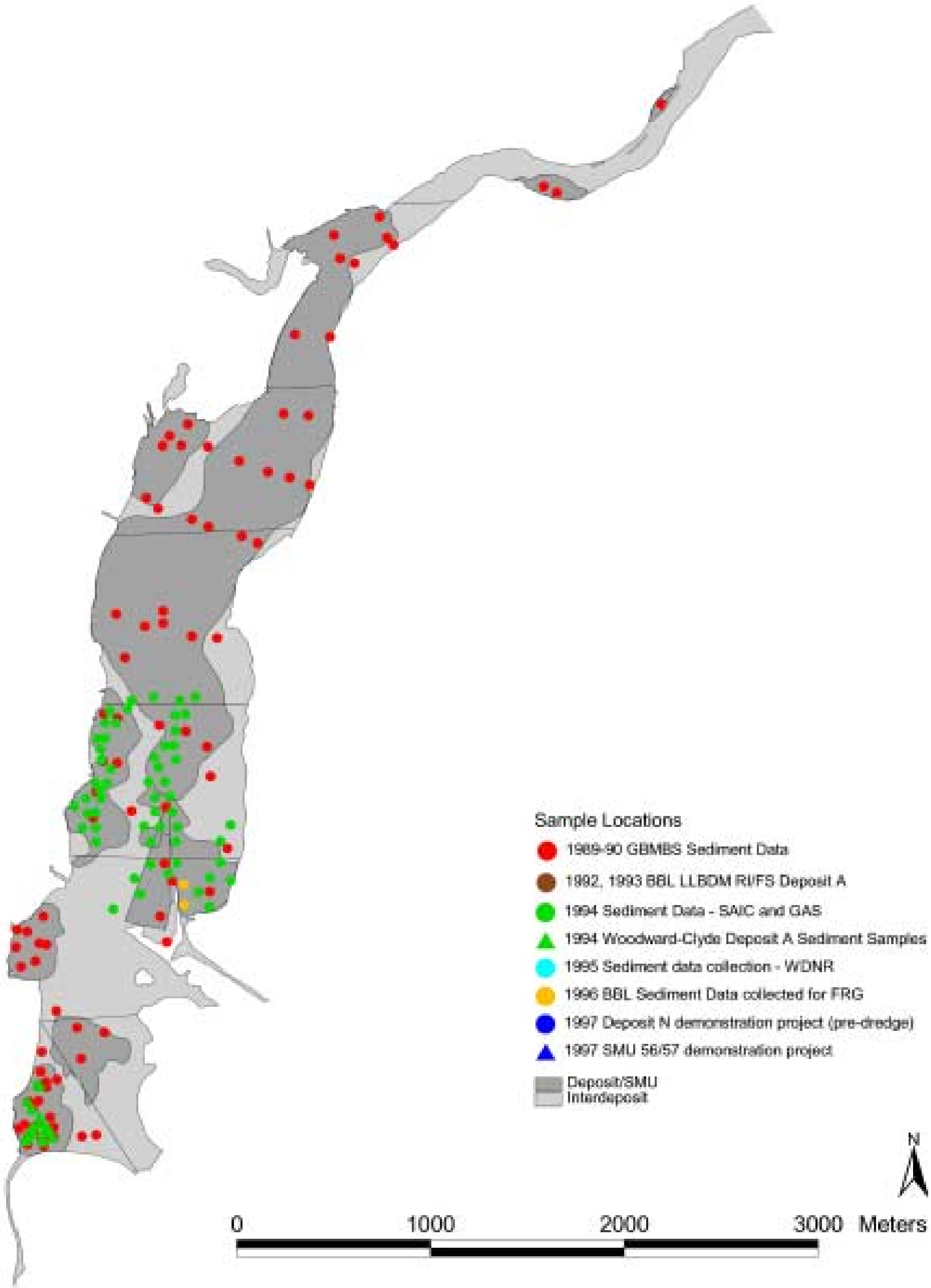

Figure B—1. Lower Fox River sediment PCB sampling sites 1989-1997: Reach 1.

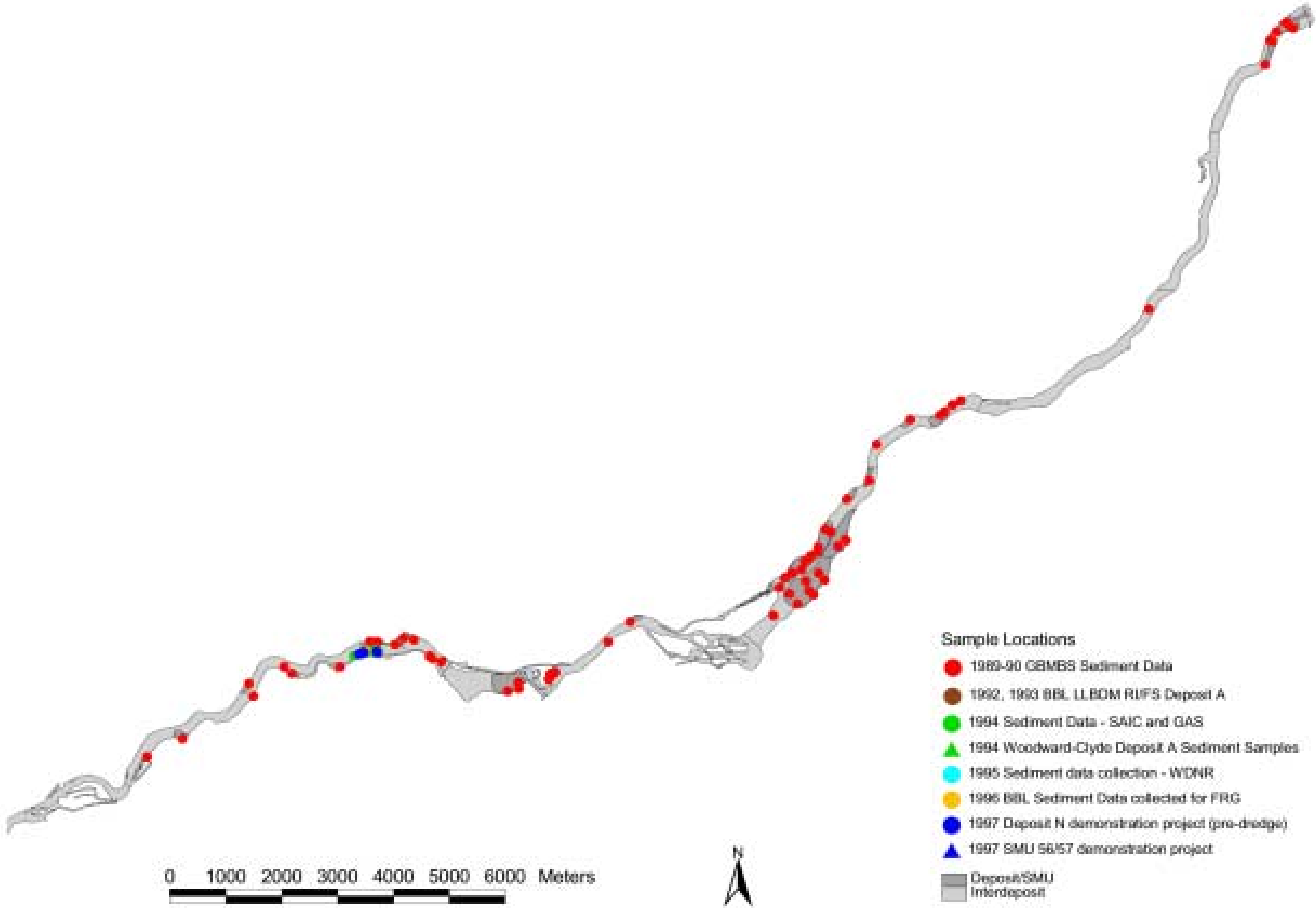

Figure B—2. Lower Fox River sediment PCB sampling sites 1989-1997: Reach 2.

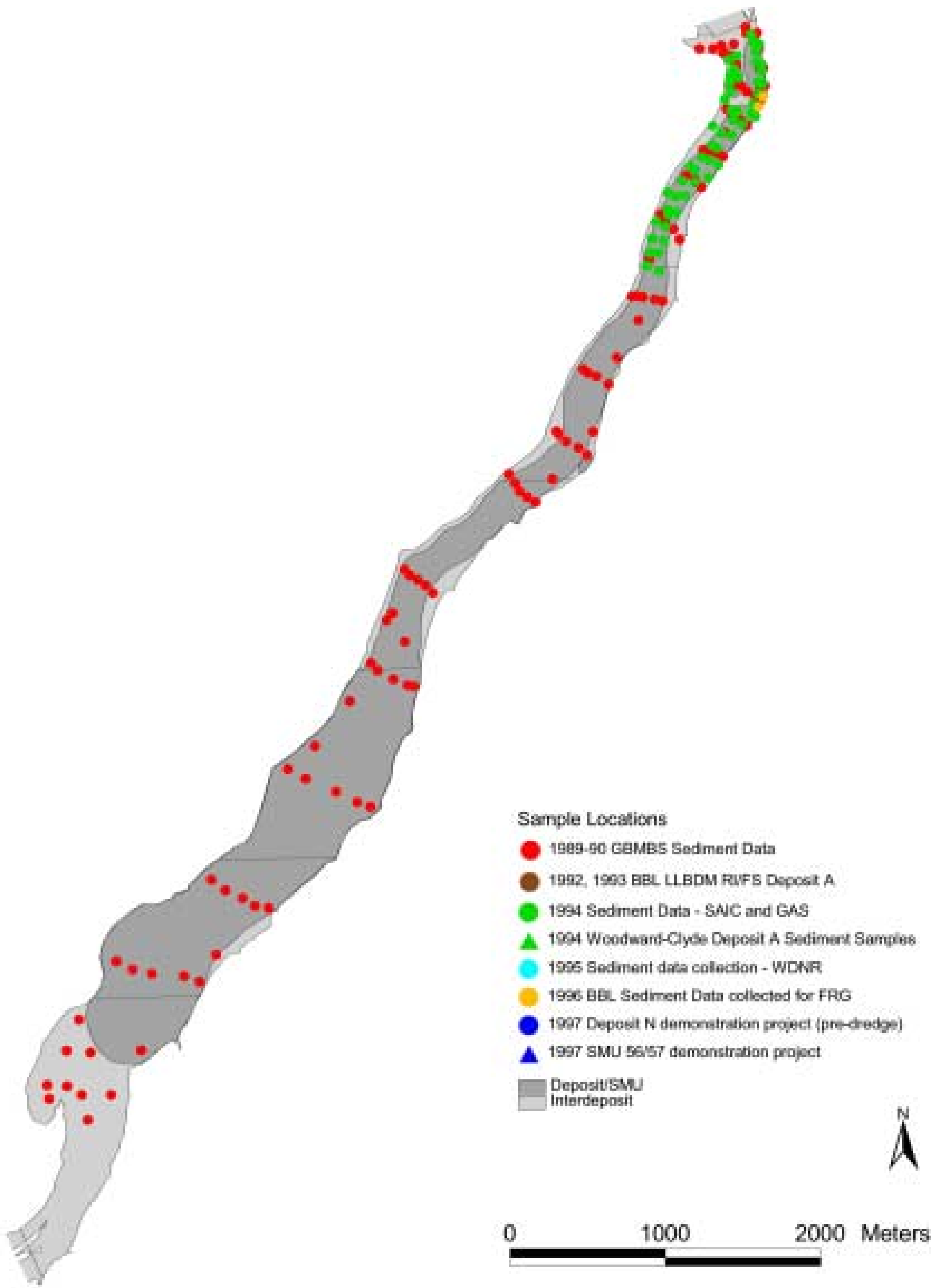

Figure B—3. Lower Fox River sediment PCB sampling sites 1989-1997: Reach 3.

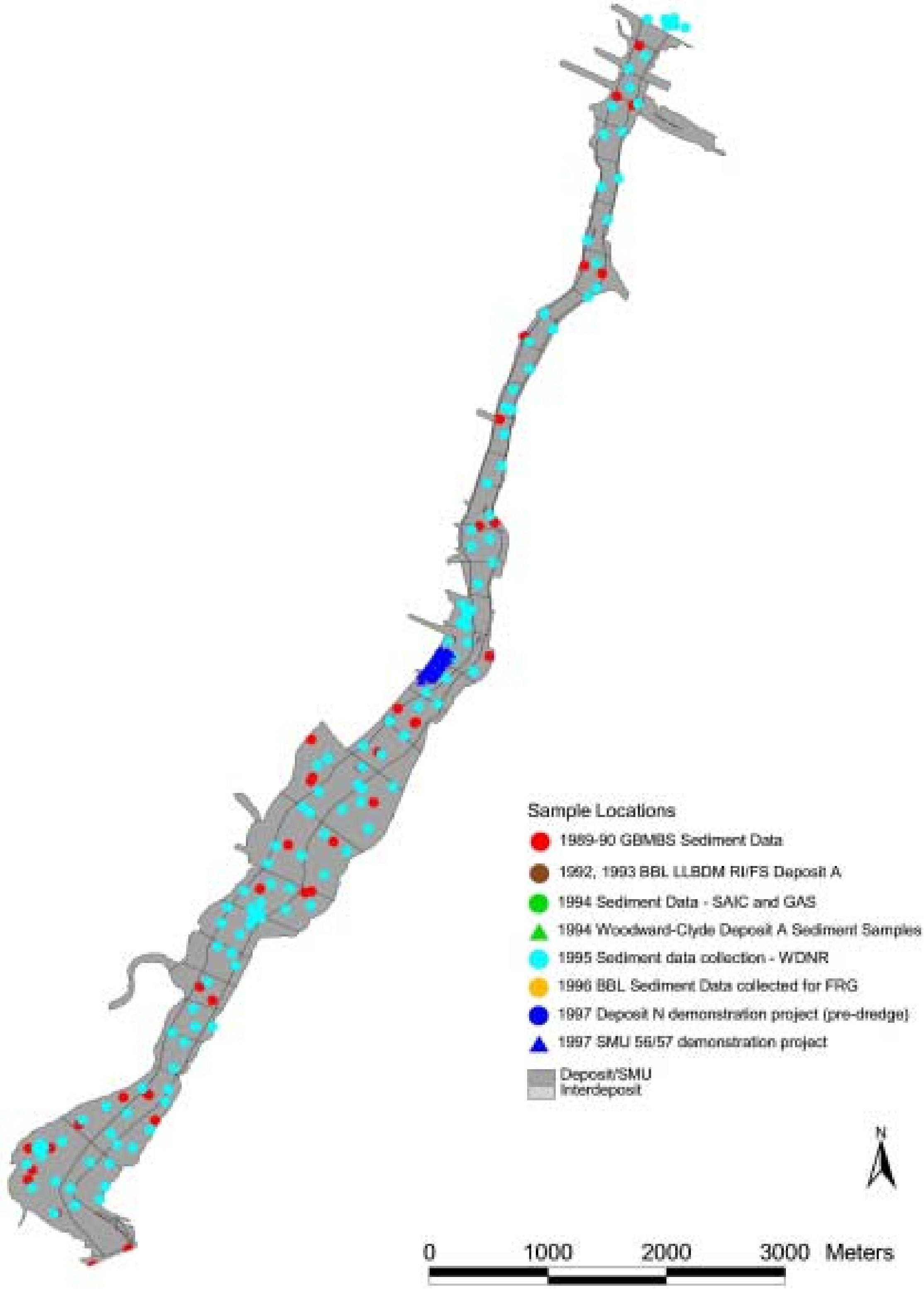

Figure B—4. Lower Fox River sediment PCB sampling sites 1989-1997: Reach 4.

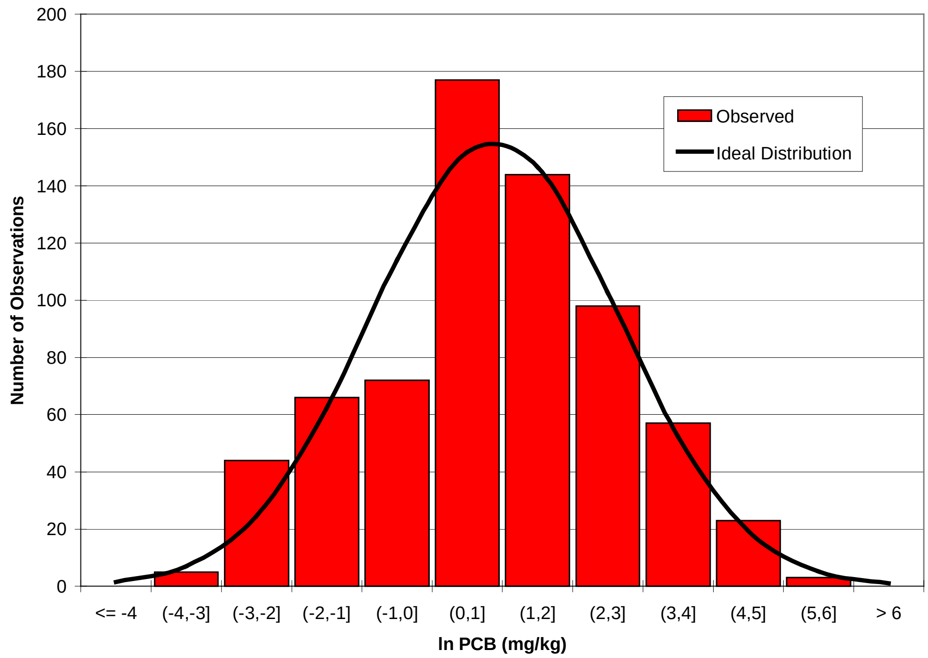

Figure B—5. Distribution of Lower Fox River sediment PCB concentrations (0-10 cm).

- Fifth, PCB concentration trends estimates were developed from statistical analyses. The data were grouped by river reach, river position, and year of sample collection. Analyses were performed for the whole river as well as for each of the four river reaches. For data sets where samples were collected over two calendar years, the first year of the sample collection effort was used to represent the year of collection. For example, 1989 was used to represent the year of collection for all samples collected during the 1989-1990 GBMBS. Spatial and temporal trends were inferred from the results of linear and multiple linear regression analyses of sediment PCB concentration versus river position and year of collection.

Spatial and Temporal Trend Assessment Results

Sediment PCB concentrations as functions of year of sample collection and distance from Lake Winnebago (the upstream boundary of the study area) are presented in Figures B-6 through B-15. Summaries of linear and multiple linear regression analysis results are presented in Tables B-1 and B-2. Note that these results do not account for possible analytical biases.

For the whole river (all observations considered together regardless of the year of collected or location), linear and multiple linear regression analyses suggest a trend of increasing PCB concentration over time (positive slope) and decreasing concentration over space (negative slope). As determined from F-test results, the slopes estimated for time and space variables are statistically significant at the 95% confidence level ($\alpha = 0.05$). However, correlation coefficients (r^2) for these regressions are very low.

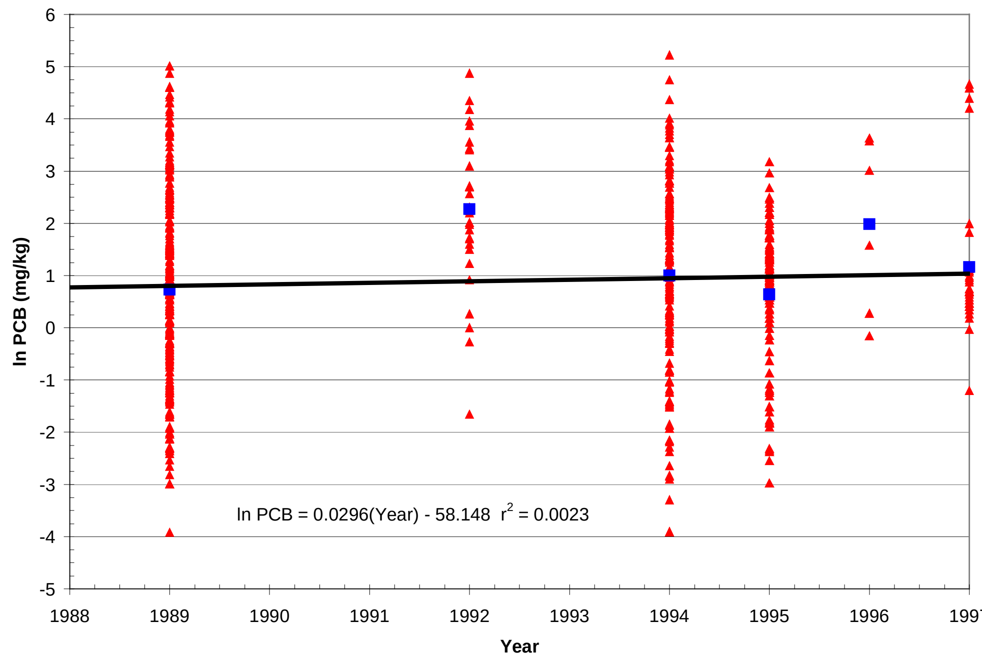

Figure B—6. Surface sediment PCB concentration trend over time: all reaches (0-10 cm).

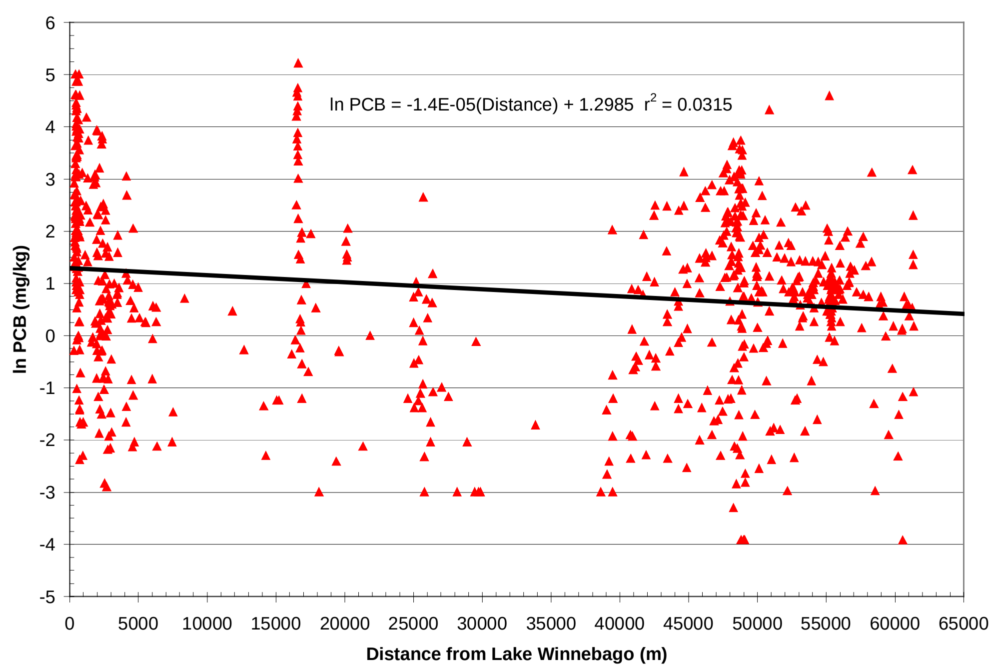

Figure B—7. Surface sediment PCB concentration trend over space: all reaches (0-10 cm).

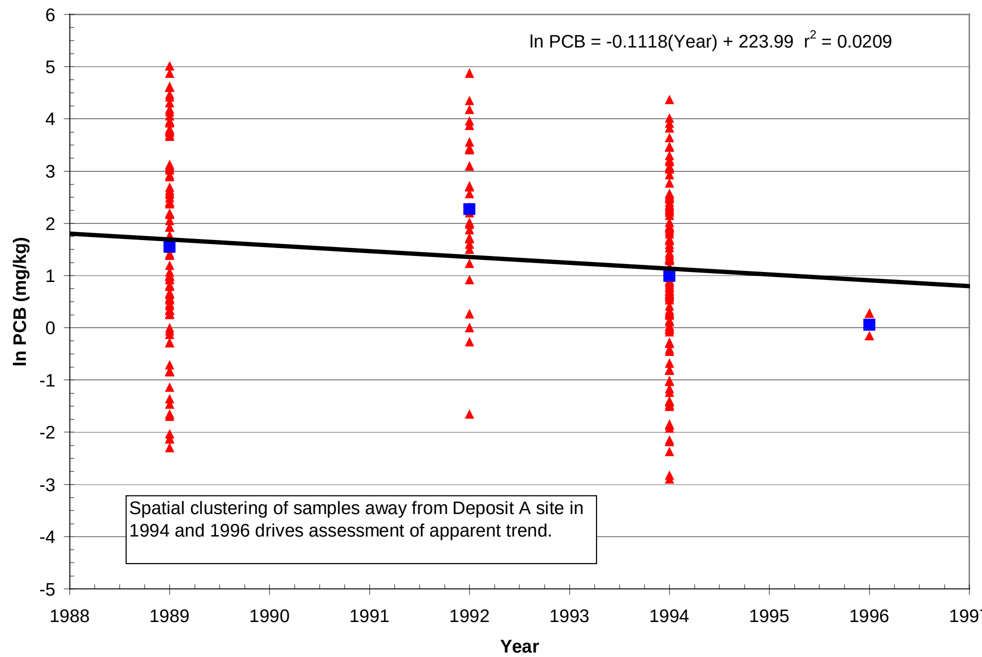

Figure B—8. Surface sediment PCB concentration trend over time: Reach 1 (0-10 cm).

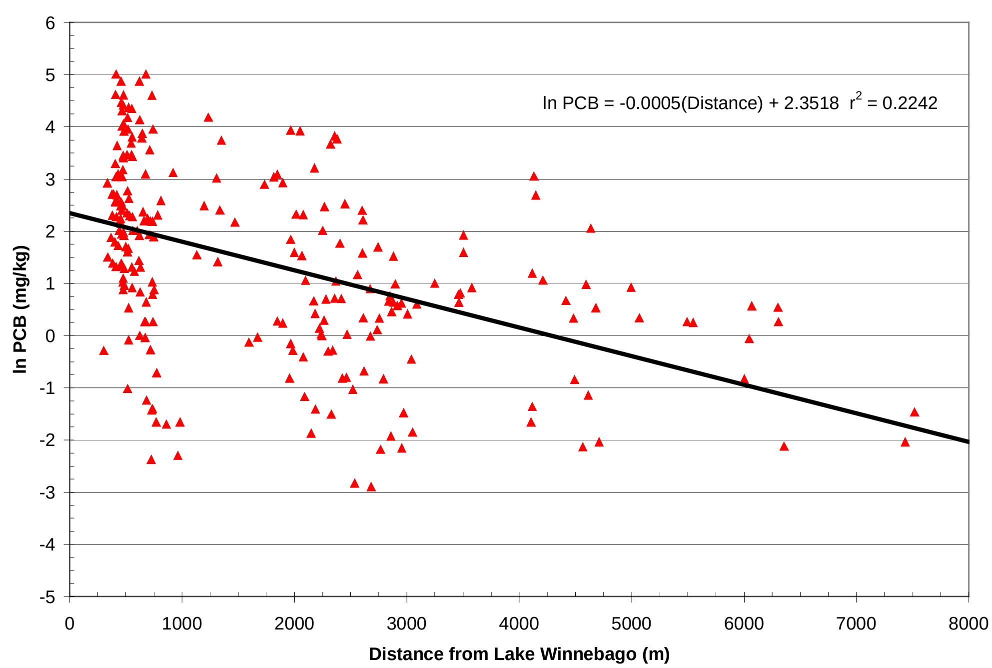

Figure B—9. Surface sediment PCB concentration trend over space: Reach 1 (0-10 cm).

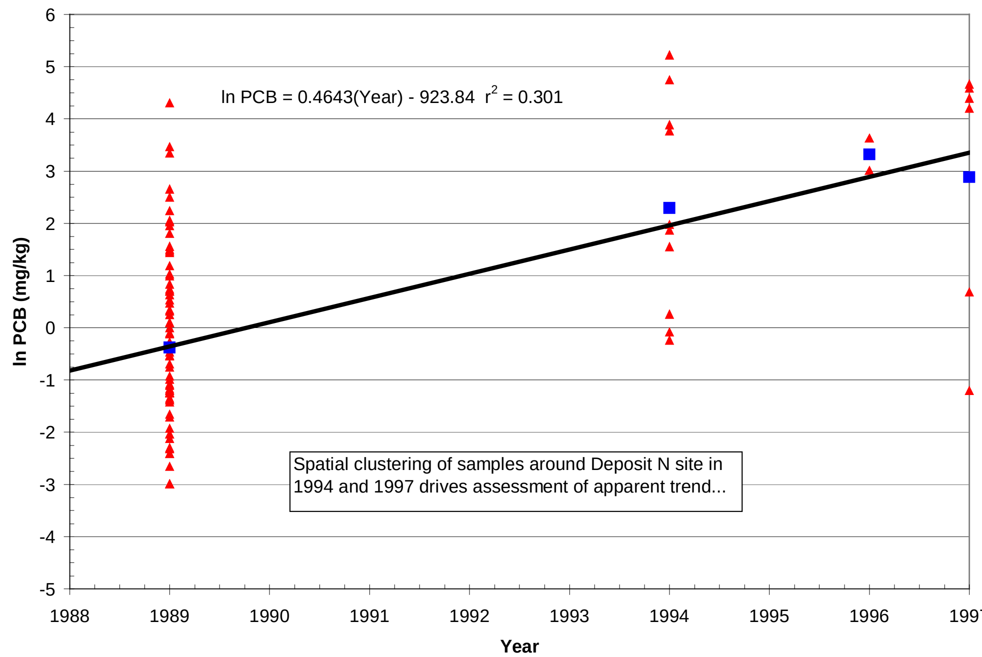

Figure B—10. Surface sediment PCB concentration trend over time: Reach 2 (0-10 cm).

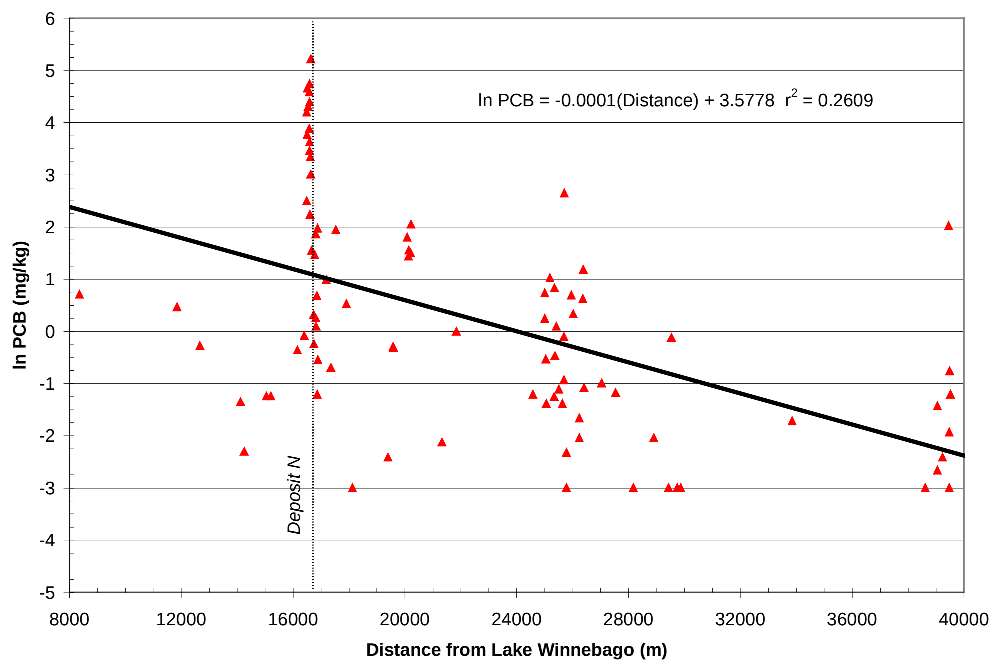

Figure B—11. Surface sediment PCB concentration trend over space: Reach 2 (0-10 cm).

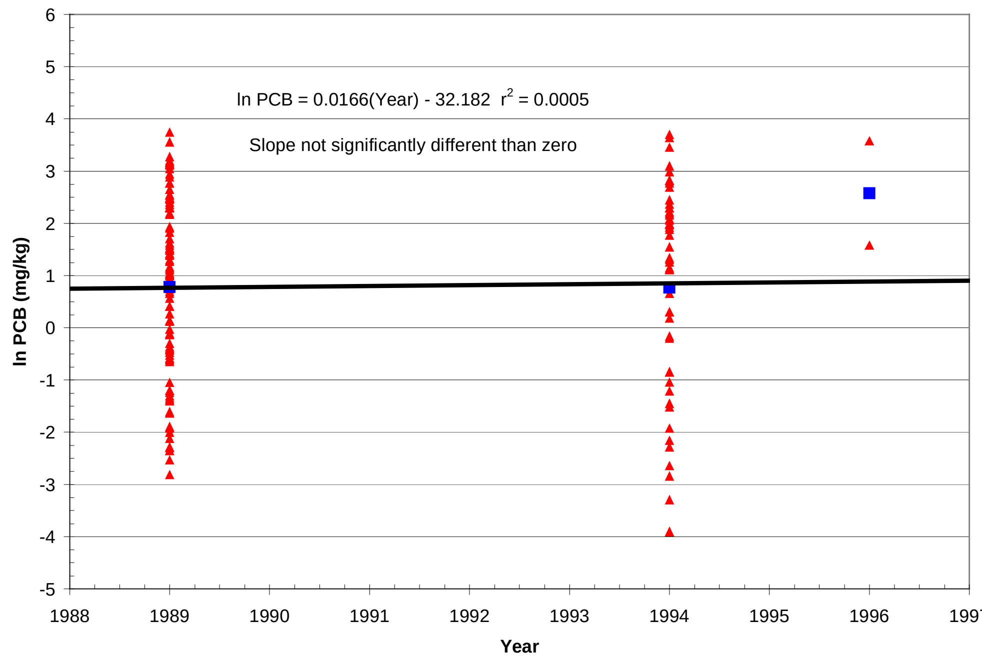

Figure B—12. Surface sediment PCB concentration trend over time: Reach 3 (0-10 cm).

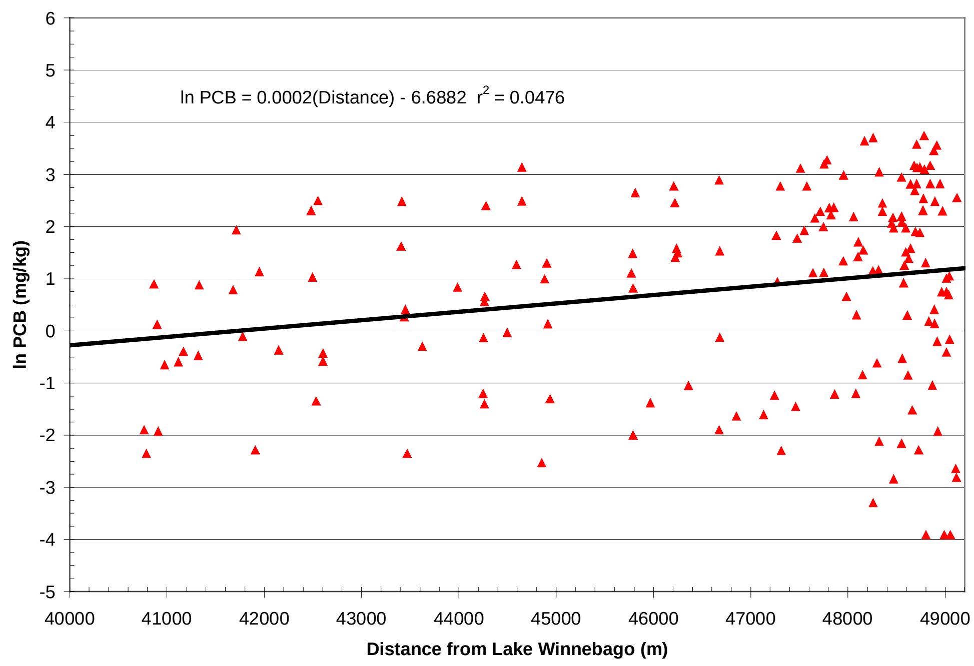

Figure B—13. Surface sediment PCB concentration trend over space: Reach 3 (0-10 cm).

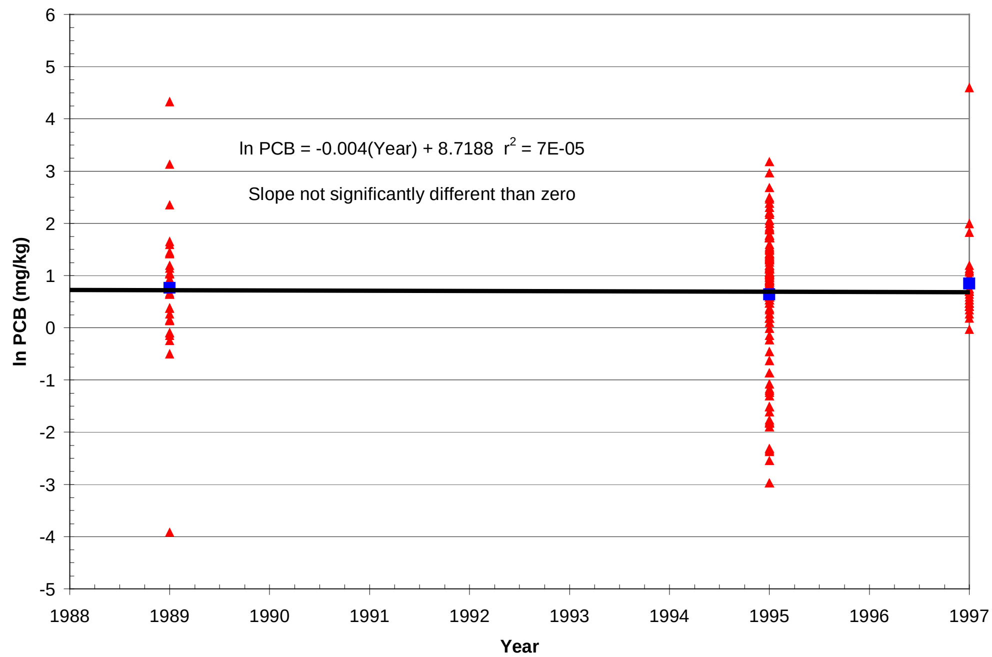

Figure B—14. Surface sediment PCB concentration trend over time: Reach 4 (0-10 cm).

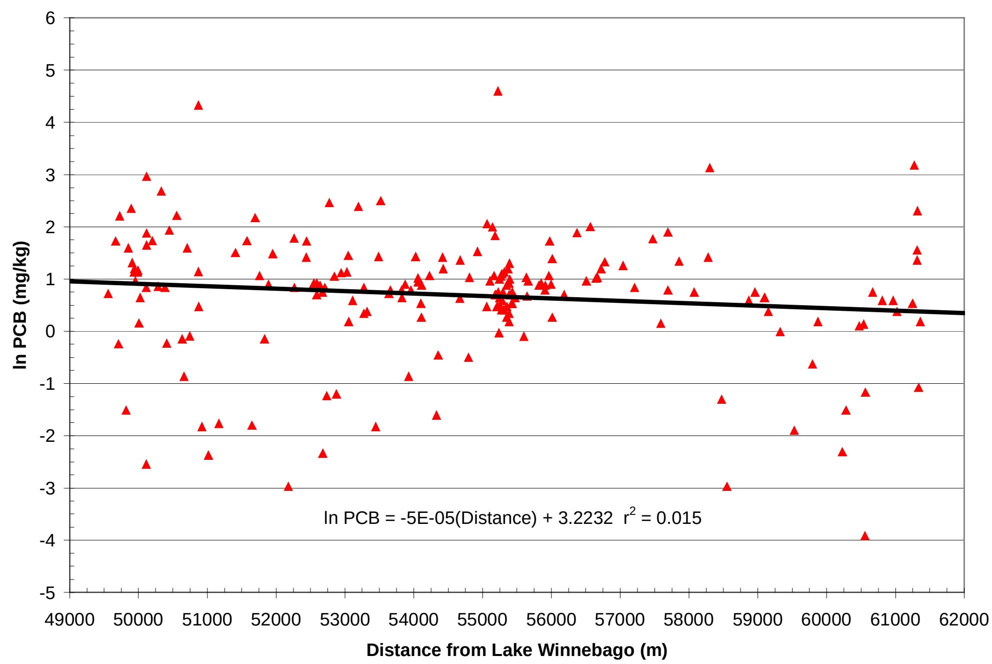

Figure B—15. Surface sediment PCB concentration trend over space: Reach 4 (0-10 cm).

Table B-1. Summary of Lower Fox River sediment PCB concentration linear and multiple linear regression results: 0-10 cm.

Reach	*n*	*Regression Type*	r^2	*significant* ($\alpha = 0.05$)	*Year*				*Distance*			
					m	*-95% CL*[19]	*+95% CL*	*p*	*m*	*-95% CL*	*+95% CL*	*p*
All	689	Linear (time)	0.0023	yes	0.030	-0.016	0.076	0.207	N/A	N/A	N/A	N/A
		Linear (space)	0.0315	yes	N/A	N/A	N/A	N/A	-1.36E-5	-1.92E-5	-7.92E-6	2.78E-6
		Multiple	0.0390	yes	0.055	0.008	0.101	0.020	-1.50E-5	-2.07E-5	-9.23E-6	3.97E-7
1	240	Linear (time)	0.0209	yes	-0.112	-0.209	-0.014	0.025	N/A	N/A	N/A	N/A
		Linear (space)	0.2242	yes	N/A	N/A	N/A	N/A	-5.48E-4	-6.79E-4	-4.18E-4	8.1E-15
		Multiple	0.3247	yes	-0.259	-0.345	-0.173	1.02E-8	-6.76E-4	-8.04E-4	-5.47E-4	7.1E-21
2	92	Linear (time)	0.3010	yes	0.464	0.316	0.612	1.50E-8	N/A	N/A	N/A	N/A
		Linear (space)	0.2609	yes	N/A	N/A	N/A	N/A	-1.49E-4	-2.02E-4	-9.65E-5	1.97E-7
		Multiple	0.4059	yes	0.349	0.200	0.498	1.10E-5	-1.02E-4	-1.54E-4	-5.11E-5	1.45E-4
3	163	Linear (time)	0.0005	no	0.017	-0.103	0.136	0.784	N/A	N/A	N/A	N/A
		Linear (space)	0.0476	yes	N/A	N/A	N/A	N/A	1.60E-4	4.87E-5	2.71E-4	0.0051
		Multiple	0.0570	yes	-0.085	-0.218	0.048	0.209	2.00E-4	7.24E-5	3.27E-4	0.0023
4	194	Linear (time)	7.1E-5	no	-0.004	-0.072	0.064	0.907	N/A	N/A	N/A	N/A
		Linear (space)	0.0150	yes	N/A	N/A	N/A	N/A	-4.63E-5	-9.97E-5	7.16E-6	0.089
		Multiple	0.0150	yes	-9.40E-5	-0.068	0.068	0.998	-4.63E-5	-1.00E-4	7.43E-6	0.091

[19] CL = Confidence Limit

For Reach 1, linear and multiple linear regression analyses suggest a trend of decreasin PCB concentration over time and decreasing concentration over space. As determined from F-test results, the slopes estimated for time and space variables are statistically significant at the 95% confidence level. However, the correlation coefficient for the linear regression with time is very low. In contrast, the correlation coefficient for the linear regression with space is much greater. It is important to note that samples collected in 1992 were collected exclusively from the Deposit A site while most of the 1994 and 1996 samples were collected away from Deposit A.

For Reach 2, linear and multiple linear regression analyses suggests a trend of increasing PCB concentration over time and increasing concentration over space. As determined from F-test results, the slopes estimated for the time and space variables are statistically significant at the 95% confidence level. The correlation coefficients for linear regressions with time and space are moderate. It is important to note that samples collected in 1989 were collected throughout the reach while all 1994 and 1997 samples were collected exclusively from the Deposit N site.

For Reach 3, linear and multiple linear regression analyses suggest a trend of constant PCB concentration over time and increasing concentration over space. As determined from F-test results, the slope estimated for the time variable is not statistically significant (i.e. is not different from zero) at the 95% confidence level. The corresponding correlation coefficient for the linear regression with time is essentially zero. In contrast, the slope estimated for the space variable is statistically significant as determined from F-test results. However, the correlation coefficient for the linear regression with space is nonetheless low.

For Reach 4, linear and multiple linear regression analyses suggest a trend of constant PCB concentration over time and decreasing concentration over space. As determined from F-test results, the slope estimated for the time variable is not statistically significant (i.e. is not different from zero) at the 95% confidence level. The corresponding correlation coefficient for the linear regression with time is essentially zero. In contrast, the slope estimated for the space variable is statistically significant as determined from F-test results. However, the correlation coefficient for the linear regression with space is nonetheless low.

The magnitude of analytical bias was assumed to be ±30% based on the average bias determined from the LMMBS and Deposit N laboratory bias studies.

DISCUSSION

In general, the regression analysis results suggest that sample location explains more of the total observed variability than sample collection year. Sediment PCB concentrations vary widely throughout the river. Therefore, differences in sample locations between years may explain much of any apparent PCB concentration trends over time. This is a key factor to consideration when inferring PCB concentration trends over time from regression results.

In Reach 1, regression results suggest that an apparent trend of decreasing PCB concentrations with time exist. However, this apparent trend may be attributable to shifts in sampling locations that occurred over time. As shown in Figure B-1, samples collected in 1989 were collected throughout the reach. Samples collected in 1992 were collected exclusively from the most heavily contaminated area in the reach (Deposit A). Samples collected in subsequent year were collected from only portions of the reach. In particular, many of the samples collected in later years were obtained from less contaminated areas of the reach. The apparent decreasing concentration trend over time may simply be a reflection of increased sampling effort in less contaminated areas in later years.

In Reach 2, regression results suggest that an apparent trend of increasing PCB concentrations with time exist. This apparent trend may again be attributable to shifts in sampling locations over time. As shown in Figure B-2, samples collected in 1989 were collected at locations throughout the reach. However, all samples collected in subsequent year were collected exclusively from the most heavily contaminated area of the reach (Deposit N). The apparent increasing concentration trend over time may simply be a reflection of increased sampling effort in a more contaminated area in later years.

In Reaches 3 and 4, regression results suggest that no PCB concentration trends with time exist. For these two reaches, the null hypothesis that the slopes for time terms in the regression are zero could not be rejected. However, at least in the case of Reach 4, it should be noted that the samples collected in 1997 were collected exclusively from the most heavily contaminated area of the reach (SMU 56/57).

Nonetheless, when the river is considered as a whole, the regression results suggest that PCB concentrations increase with time and decrease with distance from Lake Winnebago. As already noted, the apparent trend of increasing concentration with time may be a reflection of the shift in sample collection locations towards more extensively contaminated areas over time. The general trend of decreasing concentration with distance is consistent with the discharge history of PCBs to the Lower Fox River.

As described in TM2d (WDNR, 1999a), the majority of the cumulative mass of PCBs released to the river was discharged in Reaches 1 and 2. In these reaches, PCB concentrations tend to decrease with distance while pockets of more heavily contaminated sediment tend to occur in areas around discharge points. Reach 3 differs from upstream areas, as PCB concentrations tend to increase with distance. It is possible that this apparent increasing trend may be a reflection of more extensive sampling efforts and clustering of sample locations in downstream areas of this reach. However, Reach 3 is a large pool area (impoundment) so the trend of increasing PCB concentration with distance may be a reflection of differential particle sorting and transport attributable to the backwater effect of the dam at DePere. In Reach 4, PCB concentrations again tend to decrease with distance with a pocket of more heavily contaminated sediment occurring around a discharge point.

With numerous caveats, the regression analysis results may be used to infer PCB concentration trends. This most straightforward approach is to express the slopes of regression terms for PCB concentration change with time as an annual percentage rate of change. This value and the corresponding upper and lower 95% confidence limits express the uncertainty of the regression results and provide an estimate of the bounds of any apparent concentration trend. The influence of possible analytical bias can also be roughly factored into these trend estimates by assuming that the average lab bias value (±30%) scales the unadjusted trend estimate bounds downward

Table B-2. Inferred PCB concentration trends over time in Lower Fox River surface sediments (0-10 cm) based on multiple linear regression results.

Reach	*Trend Without Analytical Bias*			*Lower Bound Analytical Bias*			*Upper Bound Analytical Bias*		
	Inferred Annual Rate of Change (%)	*Inferred Rate at Lower 95% CL (%)*	*Inferred Rate at Upper 95% CL (%)*	*Inferred Annual Rate of Change (%)*	*Inferred Rate at Lower 95% CL (%)*	*Inferred Rate at Upper 95% CL (%)*	*Inferred Annual Rate of Change (%)*	*Inferred Rate at Lower 95% CL (%)*	*Inferred Rate at Upper 95% CL (%)*
1	-22.8	-29.2	-15.9	-16.0	-20.4	-11.1	-29.7	-37.9	-20.7
2	+41.8	+22.2	+64.6	+29.3	+15.4	+45.2	+54.4	+28.9	+84.0
3	-8.1	-19.6	+4.9	-5.7	-13.7	+3.4	-10.6	-25.4	+6.4
4	0	-6.6	+7.0	0	-4.6	+4.9	0	-8.5	+9.1
All	+5.6	+0.8	+10.6	+3.9	+0.6	+7.4	+7.3	+1.1	+13.8

(smaller trends) or upward (larger trends). For model evaluation purposes, a summary of estimated PCB concentration trends over time is presented in Table B-2. This approach can also be used to draw similar inferences regarding PCB concentration trends as functions of distance.

While it is possible to infer PCB concentration trends, the numerous limitations of such trend inferences must be considered. First, sediment PCB concentrations vary widely by location. Samples collected in different years as part of different sediment coring efforts were not collected from the same locations. Even relatively small shifts in locations over time contribute to differences in observed PCB concentrations. This means that apparent concentration trends over time may really be a reflection of the spatial heterogeneity of sediment PCB concentrations. Second, as evidenced by generally very low correlation coefficient values, the regression results suggest that the year of sample collection describes very little of the variability of sediment PCB concentrations. Assessments of regression result significance often depend on the number of observations. Statistical significance tests will often indicate that a result is significant given a sufficiently large number of observations. This means that a given regression result may be considered statistically significant and still not provide an accurate description of the observed conditions. Third, regression results do not establish causality. Sediment PCB concentrations may change in time or space in response to a variety of processes such as erosion, deposition, physical mixing, or diffusion. Inference of a PCB concentration trend from these regression results does not elucidate which process, or combination of processes, gave rise to the observed conditions. Fourth, extrapolation of inferred trends beyond the date range (1989-1997) (or spatial extent) of the observations may yield unreliable or spurious results. The inferred rates of change may not provide a meaningful basis to hindcast or forecast PCB concentrations in time or project conditions at other locations. For example, inferred changes in sediment PCB concentrations over distance in Reach 4 should not be used to estimate possible spatial trends of sediment PCB concentrations in Green Bay.

CONCLUSIONS

Sediment PCB concentrations in the Lower Fox River vary widely with location. PCB concentrations at nearby sites can differ by more than an order of magnitude. Sediment samples collected in different years as part of different sampling efforts were generally collected from different locations and analyzed at different laboratories using different analysis and quantitation methods. As a consequence it is difficult to distinguish between spatial heterogeneity, temporal variability, and analytical bias in these data. These factors confound inferences regarding potential temporal and spatial PCB concentration trends in Lower Fox River sediments.

Regression analysis results suggest that PCB concentration in Lower Fox River sediments may vary with time and distance. Based on examination of the observations for all reaches, the regression results suggest that PCB concentration increase with time and decrease with distance downstream of Lake Winnebago. On an individual reach basis, the regression results suggest that PCB concentrations can increase or decrease with time. The apparent changes in concentration with time may be a reflection of shifting sampling locations over time. Therefore, differences in sample locations between years may explain much of any apparent PCB concentration that may occur in a reach. The trend of decreasing concentration with distance is generally consistent with the discharge history of PCB to the river as presented in TM2d (WDNR, 1999a).

Analytical bias may significantly contribute to apparent changes in PCB concentrations. Based on interlab comparison studies, the estimate of analytical bias is ±30%. This means that on average approximately 30% of any difference in PCB concentrations between different data sets may be solely attributable to analytical bias. All laboratories reported PCB concentrations were *less* than the true value. Also note that the bias studies focused only on instrumentation and quantitation methods. Additional biases can also occur as a result of different sample extraction methods. If differences in sample extraction methods also exist between data sets, the relative bias between samples analyzed by different methods can be on the order of ±50%.

With numerous caveats, regression analysis results may be used to infer PCB concentration trends. This most straightforward approach is to express the slopes of regression terms for PCB concentration change with time as an annual percentage rate of change. This value and the corresponding upper and lower 95% confidence limits express the uncertainty of the regression results and provide an estimate of the bounds of any apparent concentration trend. The influence of possible analytical bias can also be roughly factored into these trend estimates by assuming that the average lab bias value (±30%) scales the unadjusted trend estimate bounds. Using this approach, the inferred PCB concentration trend for the whole river was +5.6% per year and ranged from near zero to nearly +14% per year. This approach can also be used to draw similar inferences regarding PCB concentration trends as functions of distance.

The numerous limitations of trend inferences must be considered. Sediment PCB concentrations vary widely by location. Samples collected in different years as part of different sediment coring efforts were not collected from the same locations. This means that apparent concentration trends over time may really be a reflection of the spatial heterogeneity of sediment PCB concentrations. Second, the regression results suggest that the year of sample collection describes very little of the variability of sediment PCB concentrations. Even though a given regression result may be considered statistically significant, the regression may not provide an accurate description of observed conditions. Third, regression results do not establish causality. Inference of a PCB concentration trend from these regression results does not elucidate which process, or combination of processes, gave rise to the observed conditions. Fourth, extrapolation of inferred trends beyond the date range (or spatial extent) of the observations may yield unreliable or spurious results. The inferred rates of change may not provide a meaningful basis to hindcast or forecast PCB concentrations in time or project conditions at other locations.

REFERENCES

Gilbert, R.O. 1987. Statistical Methods for Environmental Pollution Monitoring. Van Nostrand Reinhold Company, New York. 320 pp.

Grace Analytical. 1996. Transmittal Memorandum: Final Evaluation of Ultra PE Ampule Results, Organic PE Study #1. Memorandum from Marcia A. Kuehl, LMMB Organic QC Coordinator. Grace Analytical. December 5.

Kuehl, M. 1999. Technical Memorandum: Congener Standards Comparison for Deposit N Project. Memorandum from Marcia A. Kuehl. MAKuehl Company. August 30.

WDNR. 1999a. Technical Memorandum 2d: Compilation and Estimation of Historical Discharges of Total Suspended Solids and PCB from Lower Fox River Point Sources. Wisconsin Department of Natural Resources, Madison, Wisconsin. February 23.

WDNR. 1999b. Technical Memorandum 2e: Estimation of Lower Fox River Sediment Bed Properties. Wisconsin Department of Natural Resources, Madison, Wisconsin. March 31.

WDNR, 1999c. Technical Memorandum 2g: Quantification of Lower Fox River Sediment Bed Elevation Dynamics through Direct Observations. Wisconsin Department of Natural Resources, Madison, Wisconsin. July 23.

APPENDIX C. LONG-TERM (FUTURE) FORECAST SIMULATION SEDIMENT BED PCB INITIAL CONDITIONS

Table C-0-1. Sediment bed PCB concentration initial conditions: basic set of conditions for long-term (future) simulations.

Stack Number	Identifier	Overlying Water Segment	PCB 0-5 cm (mg/kg)	PCB 5-10 cm (mg/kg)	PCB 10-30 cm (mg/kg)	PCB 30-50 cm (mg/kg)	PCB 50-100 cm (mg/kg)	PCB 100-150 cm (mg/kg)	PCB 150-200 cm (mg/kg)	PCB 200-250 cm (mg/kg)	PCB 250-300 cm (mg/kg)	PCB 300+ cm (mg/kg)
1	02-A	2	9.91	9.91	9.22	3.51	3.28	0.00	0.00	Null	Null	Null
2	01-B	1	1.16	1.16	3.78	15.94	2.34	0.00	0.00	Null	Null	Null
3	03-C	3	5.45	5.45	1.83	0.19	0.32	0.00	0.00	Null	Null	Null
4	04-D	4	1.97	1.97	2.44	3.22	2.52	0.17	0.00	Null	Null	Null
5	03-Pg	3	5.22	5.22	2.79	2.09	10.64	13.43	0.00	0.00	0.00	Null
6	04-Pg	4	13.09	13.09	12.06	12.14	32.21	10.40	0.00	0.00	0.00	Null
7	04-E	4	1.16	1.16	1.12	1.20	0.39	0.33	0.02	0.00	Null	Null
8	05-E	5	3.59	3.59	2.16	0.25	0.26	0.07	0.11	0.00	0.00	Null
9	06-E	6	3.43	3.43	2.57	0.14	0.16	0.15	0.17	Null	Null	Null
10	07-E	7	0.78	0.78	0.34	0.05	0.00	0.00	0.00	Null	Null	Null
11	06-F	6	0.96	0.96	0.45	0.22	0.35	0.15	0.15	Null	Null	Null
12	08-G	8	0.18	0.18	0.11	0.00	0.00	0.00	0.00	Null	Null	Null
13	08-H	8	2.04	2.04	0.66	0.05	Null	Null	Null	Null	Null	Null
14	09-I	9	0.76	0.76	0.19	0.05	0.05	0.00	0.00	Null	Null	Null
15	09-J	9	0.10	0.10	0.08	0.05	0.00	0.00	Null	Null	Null	Null
16	09-K	9	0.26	0.26	0.08	0.00	Null	Null	Null	Null	Null	Null
17	10-L	10	0.29	0.29	0.11	0.00	Null	Null	Null	Null	Null	Null
18	10-M	10	0.70	0.70	0.34	0.05	0.00	0.00	Null	Null	Null	Null
19	10-N	10	14.85	14.85	19.41	14.51	3.14	0.00	0.00	Null	Null	Null
20	10-O	10	1.27	1.27	0.62	0.05	0.00	0.00	0.00	Null	Null	Null
21	10-P	10	1.02	1.02	1.42	1.42	0.45	0.00	0.00	Null	Null	Null

Stack Number	Identifier	Overlying Water Segment	PCB 0-5 cm (mg/kg)	PCB 5-10 cm (mg/kg)	PCB 10-30 cm (mg/kg)	PCB 30-50 cm (mg/kg)	PCB 50-100 cm (mg/kg)	PCB 100-150 cm (mg/kg)	PCB 150-200 cm (mg/kg)	PCB 200-250 cm (mg/kg)	PCB 250-300 cm (mg/kg)	PCB 300+ cm (mg/kg)
22	10-Q	10	1.70	1.70	2.95	7.64	Null	Null	Null	Null	Null	Null
23	10-R	10	0.05	0.05	0.05	0.00	0.00	0.00	Null	Null	Null	Null
24	11-S	11	0.51	0.51	0.09	0.05	0.00	0.00	Null	Null	Null	Null
25	12-T	12	5.51	5.51	4.47	0.05	0.05	0.00	0.00	Null	Null	Null
26	12-U	12	1.00	1.00	0.30	0.00	0.00	0.00	0.00	Null	Null	Null
27	13-V	13	2.09	2.09	0.29	0.00	0.00	0.00	0.00	Null	Null	Null
28	13-W	13	0.25	0.25	0.10	0.09	0.15	0.12	0.10	Null	Null	Null
29	14-W	14	0.37	0.37	0.03	0.03	0.11	0.12	0.00	Null	Null	Null
30	13-X	13	0.19	0.19	0.04	0.05	0.14	0.13	0.12	Null	Null	Null
31	14-X	14	0.13	0.13	0.06	0.09	0.16	0.15	0.15	Null	Null	Null
32	14-Y	14	0.37	0.37	0.11	0.05	0.00	0.00	Null	Null	Null	Null
33	14-Z	14	0.31	0.31	0.06	0.05	0.05	0.00	0.00	Null	Null	Null
34	15-AA	15	0.05	0.05	0.05	0.05	Null	Null	Null	Null	Null	Null
35	15-BB	15	0.13	0.13	0.07	0.05	Null	Null	Null	Null	Null	Null
36	15-CC	15	0.28	0.28	0.08	0.05	0.00	0.00	0.00	Null	Null	Null
37	18-DD	18	0.89	0.89	1.62	3.44	0.24	0.00	0.00	Null	Null	Null
38	19-EE	19	6.99	6.99	1.87	0.10	0.09	0.12	0.12	Null	Null	Null
39	20-EE	20	0.72	0.72	0.15	0.04	0.08	0.12	0.12	Null	Null	Null
40	21-EE	21	0.71	0.71	0.12	0.04	0.08	0.07	0.07	Null	Null	Null
41	22-EE	22	0.49	0.49	0.23	0.08	0.26	0.12	0.12	Null	Null	Null
42	23-EE	23	2.70	2.70	0.76	0.61	1.21	0.11	0.03	0.02	0.00	0.00
43	24-EE	24	8.06	8.06	9.50	9.72	2.81	0.23	0.05	0.03	0.00	0.00
44	23-FF	23	0.28	0.28	0.01	0.07	0.00	0.00	Null	Null	Null	Null

Stack Number	Identifier	Overlying Water Segment	PCB 0-5 cm (mg/kg)	PCB 5-10 cm (mg/kg)	PCB 10-30 cm (mg/kg)	PCB 30-50 cm (mg/kg)	PCB 50-100 cm (mg/kg)	PCB 100-150 cm (mg/kg)	PCB 150-200 cm (mg/kg)	PCB 200-250 cm (mg/kg)	PCB 250-300 cm (mg/kg)	PCB 300+ cm (mg/kg)
45	24-GG	24	8.54	8.54	14.28	16.25	9.69	4.79	0.23	0.03	0.00	Null
46	24-HH	24	7.51	7.51	9.92	10.40	5.43	2.32	0.13	0.03	0.00	Null
47	01-ID	1	2.05	2.05	3.22	2.45	2.27	Null	Null	Null	Null	Null
48	02-ID	2	9.00	9.00	11.45	9.71	3.11	0.00	Null	Null	Null	Null
49	03-ID	3	5.65	5.65	0.87	0.33	0.86	9.78	0.00	0.00	Null	Null
50	04-ID	4	3.26	3.26	4.83	5.62	8.98	4.56	0.02	0.00	Null	Null
51	05-ID	5	1.84	1.84	0.89	0.71	0.49	0.05	0.15	Null	Null	Null
52	06-ID	6	3.12	3.12	3.01	0.23	0.25	0.15	Null	Null	Null	Null
53	07-ID	7	1.01	1.01	0.67	0.06	0.00	0.00	0.00	Null	Null	Null
54	08-ID	8	0.67	0.67	0.39	0.06	0.00	Null	Null	Null	Null	Null
55	09-ID	9	0.70	0.70	0.08	0.05	Null	Null	Null	Null	Null	Null
56	10-ID	10	3.37	3.37	5.06	6.16	6.68	0.00	Null	Null	Null	Null
57	11-ID	11	0.51	0.51	0.07	0.05	0.00	0.00	Null	Null	Null	Null
58	12-ID	12	2.86	2.86	3.15	0.05	0.05	Null	Null	Null	Null	Null
59	13-ID	13	1.07	1.07	0.27	0.07	0.15	0.12	0.11	Null	Null	Null
60	14-ID	14	0.36	0.36	0.07	0.05	0.06	0.14	Null	Null	Null	Null
61	15-ID	15	0.16	0.16	0.07	0.05	0.00	0.00	Null	Null	Null	Null
62	16-ID	16	0.18	0.18	0.00	0.00	0.00	0.00	0.00	Null	Null	Null
63	17-ID	17	0.00	0.00	0.00	0.00	Null	Null	Null	Null	Null	Null
64	18-ID	18	0.16	0.16	0.18	1.08	0.24	0.00	Null	Null	Null	Null
65	19-ID	19	0.51	0.51	1.59	0.45	Null	Null	Null	Null	Null	Null
66	20-ID	20	1.01	1.01	0.38	0.04	Null	Null	Null	Null	Null	Null
67	21-ID	21	0.54	0.54	0.09	0.03	Null	Null	Null	Null	Null	Null

Stack Number	Identifier	Overlying Water Segment	PCB 0-5 cm (mg/kg)	PCB 5-10 cm (mg/kg)	PCB 10-30 cm (mg/kg)	PCB 30-50 cm (mg/kg)	PCB 50-100 cm (mg/kg)	PCB 100-150 cm (mg/kg)	PCB 150-200 cm (mg/kg)	PCB 200-250 cm (mg/kg)	PCB 250-300 cm (mg/kg)	PCB 300+ cm (mg/kg)
68	22-ID	22	0.56	0.56	0.31	0.09	0.26	0.12	Null	Null	Null	Null
69	23-ID	23	3.01	3.01	0.78	0.97	1.28	0.10	0.04	Null	Null	Null
70	24-ID	24	7.09	7.09	8.66	10.52	4.00	1.18	0.10	0.03	0.00	0.00
71	S020	25	6.28	6.28	13.39	17.32	19.53	7.64	4.70	30.00	0.00	0.00
72	S021	25	8.86	8.86	11.48	12.21	1.94	1.53	0.20	21.73	0.05	0.00
73	S022	25	3.34	3.34	23.21	27.55	27.46	34.39	23.52	29.75	0.00	0.00
74	S023	25	0.99	0.99	0.73	0.65	0.13	0.70	0.73	10.46	0.05	0.00
75	S024	25	1.95	1.95	8.41	9.64	14.15	19.28	18.30	29.37	0.00	0.00
76	S025	25	0.74	0.74	0.82	0.35	0.23	0.37	1.95	17.18	0.05	0.00
77	S026	26	1.97	1.97	3.47	4.19	3.00	0.17	0.07	0.09	Null	Null
78	S027	26	5.31	5.31	10.66	2.38	1.97	0.09	Null	Null	Null	Null
79	S028	26	2.36	2.36	7.14	13.59	10.21	0.45	0.09	0.09	0.51	0.00
80	S029	26	5.47	5.47	13.96	6.65	5.48	0.17	0.12	0.12	0.34	0.00
81	S030	26	2.87	2.87	9.85	17.56	14.49	0.62	0.12	Null	Null	Null
82	S031	26	1.30	1.30	4.81	9.74	8.04	0.26	0.17	Null	Null	Null
83	S032	27	4.55	4.55	13.09	9.99	8.74	3.20	0.55	0.43	Null	Null
84	S033	27	2.43	2.43	5.33	4.94	10.31	41.63	Null	Null	Null	Null
85	S034	27	3.44	3.44	13.66	9.79	8.11	0.47	0.11	0.08	0.08	0.00
86	S035	27	2.88	2.88	5.90	6.46	8.87	21.77	3.82	4.57	4.48	28.75
87	S036	27	1.35	1.35	10.27	7.87	6.67	Null	Null	Null	Null	Null
88	S037	27	0.58	0.58	1.26	1.54	1.35	4.52	1.41	3.06	Null	Null
89	S038	28	1.34	1.34	4.53	1.64	1.93	16.35	2.66	2.10	6.77	28.75
90	S039	28	1.53	1.53	7.79	4.99	1.55	0.10	0.08	0.23	Null	Null

Stack Number	Identifier	Overlying Water Segment	PCB 0-5 cm (mg/kg)	PCB 5-10 cm (mg/kg)	PCB 10-30 cm (mg/kg)	PCB 30-50 cm (mg/kg)	PCB 50-100 cm (mg/kg)	PCB 100-150 cm (mg/kg)	PCB 150-200 cm (mg/kg)	PCB 200-250 cm (mg/kg)	PCB 250-300 cm (mg/kg)	PCB 300+ cm (mg/kg)
91	S040	28	2.94	2.94	10.20	14.98	13.46	8.93	1.68	2.15	6.82	28.51
92	S041	28	2.07	2.07	5.11	9.32	5.42	0.51	0.14	0.42	20.59	26.81
93	S042	28	1.56	1.56	7.83	15.49	13.03	2.47	0.55	0.75	Null	Null
94	S043	28	0.88	0.88	0.67	1.02	0.85	0.27	0.12	0.33	Null	Null
95	S044	29	1.01	1.01	2.34	2.17	2.09	2.99	3.41	5.59	22.00	22.01
96	S045	29	1.42	1.42	3.24	5.07	14.61	12.08	3.24	3.05	2.42	2.23
97	S046	29	1.75	1.75	2.83	2.05	2.76	7.16	8.10	4.45	21.12	21.09
98	S047	29	2.19	2.19	7.26	13.68	12.94	6.34	4.98	2.27	2.64	2.15
99	S048	29	6.84	6.84	12.01	9.45	10.81	4.44	0.76	1.03	18.18	18.13
100	S049	29	4.90	4.90	10.43	16.94	13.07	6.25	1.24	0.47	4.56	4.28
101	S050	30	1.60	1.60	0.30	1.07	1.00	8.46	10.06	11.81	Null	Null
102	S051	30	4.45	4.45	12.37	14.28	12.04	10.32	10.98	44.45	27.73	21.78
103	S052	30	2.42	2.42	2.10	13.29	12.01	7.86	12.14	11.87	22.37	18.39
104	S053	30	3.21	3.21	4.99	3.13	2.42	1.29	4.51	42.29	26.35	20.96
105	S054	30	1.19	1.19	4.19	16.63	15.28	8.56	11.19	7.35	22.97	Null
106	S055	30	2.37	2.37	3.79	4.11	4.22	2.39	Null	Null	Null	Null
107	S056	31	4.88	4.88	24.39	44.55	47.85	35.34	24.60	40.91	24.66	20.06
108	S057	31	2.06	2.06	5.17	29.34	59.77	38.78	37.69	16.13	5.01	8.36
109	S058	31	2.67	2.67	10.38	20.40	23.81	20.23	16.62	41.97	24.55	18.40
110	S059	31	1.97	1.97	2.75	7.90	13.73	24.12	22.05	16.24	9.23	Null
111	S060	31	2.42	2.42	6.78	17.08	22.17	25.42	20.89	37.58	22.49	Null
112	S061	31	1.44	1.44	1.47	7.02	12.52	36.53	32.10	21.63	11.59	13.92
113	S062	32	1.64	1.64	2.67	6.41	12.27	32.27	31.58	23.87	5.85	9.35

Stack Number	Identifier	Overlying Water Segment	PCB 0-5 cm (mg/kg)	PCB 5-10 cm (mg/kg)	PCB 10-30 cm (mg/kg)	PCB 30-50 cm (mg/kg)	PCB 50-100 cm (mg/kg)	PCB 100-150 cm (mg/kg)	PCB 150-200 cm (mg/kg)	PCB 200-250 cm (mg/kg)	PCB 250-300 cm (mg/kg)	PCB 300+ cm (mg/kg)
114	S063	32	2.15	2.15	2.76	2.24	2.05	1.15	0.76	3.49	19.51	11.58
115	S064	32	2.54	2.54	3.27	9.59	17.97	30.23	29.38	22.05	Null	Null
116	S065	32	1.87	1.87	2.44	2.04	1.92	1.15	0.89	7.65	16.56	11.88
118	S067	32	1.15	1.15	1.24	1.27	1.33	1.13	0.87	9.69	18.09	8.34
119	S068	33	2.69	2.69	3.41	6.07	7.33	13.04	6.32	5.20	20.00	0.00
120	S069	33	3.25	3.25	9.02	14.09	15.95	24.47	11.74	16.15	20.00	0.00
121	S070	33	3.63	3.63	5.37	10.58	11.99	18.39	9.77	10.14	19.97	8.65
122	S071	33	3.55	3.55	12.33	16.09	15.52	12.91	6.00	8.58	20.00	0.00
123	S072	33	1.92	1.92	3.28	5.46	5.45	5.31	3.30	11.85	Null	Null
124	S073	33	4.12	4.12	14.67	20.55	17.78	5.13	2.37	2.56	20.00	0.00
125	S074	34	3.15	3.15	9.36	6.70	5.71	1.32	1.29	6.26	20.00	Null
126	S075	34	5.10	5.10	8.04	0.91	0.77	0.91	0.87	Null	Null	Null
127	S076	34	2.84	2.84	7.30	6.34	5.51	1.74	1.73	4.20	20.00	0.00
128	S077	34	5.20	5.20	8.74	0.91	0.81	1.37	1.33	3.75	20.00	0.00
129	S078	34	2.57	2.57	4.84	5.72	5.10	2.30	2.30	1.37	20.00	0.00
130	S079	34	5.49	5.49	8.35	0.73	0.67	1.17	1.15	7.51	20.00	0.00
131	S080	35	3.08	3.08	2.05	1.82	1.50	0.07	0.06	0.14	0.00	0.00
132	S081	35	3.03	3.03	2.56	6.95	13.02	6.49	0.24	0.14	0.00	0.00
133	S082	35	3.85	3.85	2.47	1.20	0.99	0.06	0.06	0.15	20.00	0.00
134	S083	35	2.67	2.67	2.15	10.91	13.02	5.87	0.29	0.14	0.00	0.00
135	S084	35	4.77	4.77	2.46	0.35	0.31	0.13	0.06	Null	Null	Null
136	S085	35	2.31	2.31	2.03	14.25	14.09	5.99	0.34	0.14	0.00	0.00
137	S086	36	1.55	1.55	1.54	1.63	7.07	7.96	0.22	0.14	0.00	0.00

Stack Number	Identifier	Overlying Water Segment	PCB 0-5 cm (mg/kg)	PCB 5-10 cm (mg/kg)	PCB 10-30 cm (mg/kg)	PCB 30-50 cm (mg/kg)	PCB 50-100 cm (mg/kg)	PCB 100-150 cm (mg/kg)	PCB 150-200 cm (mg/kg)	PCB 200-250 cm (mg/kg)	PCB 250-300 cm (mg/kg)	PCB 300+ cm (mg/kg)
138	S087	36	0.41	0.41	1.53	1.69	1.73	7.60	0.23	0.14	Null	Null
139	S088	36	1.51	1.51	1.42	2.01	8.28	8.02	0.22	0.14	0.00	0.00
140	S089	36	0.91	0.91	3.86	4.29	4.37	7.62	0.23	0.14	Null	Null
141	S090	36	0.69	0.69	0.50	2.12	6.50	Null	Null	Null	Null	Null
142	S091	36	0.96	0.96	2.77	3.17	3.29	8.00	0.21	Null	Null	Null
143	S092	37	1.85	1.85	2.75	2.65	5.64	6.53	0.34	Null	Null	Null
144	S093	37	0.71	0.71	1.22	1.26	2.14	0.00	0.00	Null	Null	Null
145	S094	37	1.56	1.56	3.13	3.19	4.60	7.89	0.23	0.14	Null	Null
146	S095	37	0.45	0.45	1.10	0.97	1.61	8.13	0.21	Null	Null	Null
147	S096	37	1.26	1.26	2.77	3.00	3.51	8.13	0.21	0.00	Null	Null
148	S097	37	0.24	0.24	1.18	1.31	2.32	0.00	0.00	Null	Null	Null
149	S098	38	0.59	0.59	0.12	0.14	0.14	0.00	0.00	Null	Null	Null
150	S099	38	0.14	0.14	0.20	0.18	0.18	11.00	11.00	Null	Null	Null
151	S100	38	0.79	0.79	0.09	0.10	0.10	0.00	0.00	Null	Null	Null
152	S101	38	0.22	0.22	0.36	0.50	0.50	11.00	11.00	Null	Null	Null
153	S102	38	1.03	1.03	0.08	0.08	0.08	0.00	0.00	Null	Null	Null
154	S103	38	0.22	0.22	0.69	1.16	1.16	11.00	11.00	Null	Null	Null
155	S104	39	1.00	1.00	0.09	0.66	Null	Null	Null	Null	Null	Null
156	S105	39	1.55	1.55	0.67	1.44	1.45	11.00	11.00	Null	Null	Null
157	S106	39	0.78	0.78	0.24	1.09	1.10	11.00	11.00	Null	Null	Null
158	S107	39	1.83	1.83	0.85	1.46	1.48	11.00	11.00	Null	Null	Null
159	S108	39	0.30	0.30	0.35	1.25	1.26	11.00	11.00	Null	Null	Null
160	S109	39	1.13	1.13	0.42	1.41	1.45	11.00	Null	Null	Null	Null

Stack Number	Identifier	Overlying Water Segment	PCB 0-5 cm (mg/kg)	PCB 5-10 cm (mg/kg)	PCB 10-30 cm (mg/kg)	PCB 30-50 cm (mg/kg)	PCB 50-100 cm (mg/kg)	PCB 100-150 cm (mg/kg)	PCB 150-200 cm (mg/kg)	PCB 200-250 cm (mg/kg)	PCB 250-300 cm (mg/kg)	PCB 300+ cm (mg/kg)
161	S110	40	1.82	1.82	2.01	1.47	2.18	11.00	11.00	0.00	Null	Null
162	S111	40	2.01	2.01	1.49	0.60	10.81	11.00	11.00	0.00	0.00	0.00
163	S112	40	1.81	1.81	1.55	1.47	2.41	11.00	11.00	0.00	0.00	0.00
164	S113	40	2.11	2.11	1.39	0.72	9.20	11.00	11.00	0.00	0.00	0.00
165	S114	40	1.83	1.83	1.68	1.49	1.79	11.00	11.00	0.00	Null	Null
166	S115	40	1.07	1.07	1.36	0.31	1.98	11.00	11.00	0.00	0.00	Null