UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Hudson River
PCBs SUPERFUND SITE

Engineering Performance Standards

Technical Basis and Implementation of the Resuspension Standard

April 2004

Volume 2 of 5

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Volume 2: Technical Basis of the Performance Standard for Dredging Resuspension

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ATTACHMENTS

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List of Acronyms

ADCP	Acoustic Doppler current profiler
AMN	Water treatment facility (*formerly known as* SRMT)
ARARs	Applicable or Relevant and Appropriate Requirements
ATL	Atlantic Testing Labs
CAB	Cellulose Acetate Butyrate
CAMU	Corrective Action Management Unit
Cat 350	Caterpillar Model 350
CDF	Confined Disposal Facility
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CF	cubic feet
cfs	cubic feet per second
CLP	Contract Laboratory Program
cm	centimeter
CPR	Canadian Pacific Railroad
CSO	Combined Sewer Overflow
CU	certification unit
CWA	Clean Water Act
cy	cubic yard(s)
DDT	Dichlorodiphenyltricholorethane
DEFT	Decision Error Feasibility Trials
DGPS	Differential Global Positioning System
DMC	Dredging Management Cells
DNAPL	Dense Non-Aqueous Phase Liquid
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DQOs	Data Quality Objectives
DSI	Downstream of the dredge area inside the silt curtain
DSO	Downstream of the dredge area outside the silt curtain
EDI	Equal Discharge Interval
EMP	Environmental Monitoring Plan
EPS	Engineering Performance Standards
EQUIL	Software model used to determine chemical equilibrium between the particle-bound solid and the water column or aqueous phase
ESG	ESG Manufacturing, LLC
EWI	Equal Width Interval
FIELDS	Field Environmental Decision Support
FISHRAND	USEPA's peer-reviewed bioaccumulation model

FJI	Fort James Water Intake
fps	feet per second
FRRAT	Fox River Remediation Advisory Team
FS	Feasibility Study
ft	foot
ft^2	square feet
GE	General Electric Company
GEHR	General Electric Hudson River
GCL	Geosynthetic Clay Liner
g/cc	grams per cubic centimeter
g/day	grams per day
GIS	Geographic Information Systems
GM	General Motors
gpm	gallons per minute
GPS	Global Positioning System
HDPE	High Density Polyethylene
HUDTOX	USEPA's peer-reviewed fate and transport model
IDEM	Indiana Department of Environmental Management
JMP	a commercial software package for statistical analysis
kg/day	kilograms per day
lbs	pounds
LWA	length-weighted average
MCL	Maximum Contaminant Level
MCT	Maximum Cumulative Transport
MDEQ	Michigan Department of Environmental Quality
MDS	ESG Manufacturing model #. For example, MDS-177-10
MFE	Mark for Further Evaluation
MGD	million gallons per day
ug/L	micrograms per liter
mg/kg	milligrams per kilogram (equivalent to ppm)
mg/L	milligrams per liter
MPA	Mass per Unit Area
MVUE	minimum unbiased estimator of the mean
ng/L	nanograms per liter
NBH	New Bedford Harbor
NJDEP	New Jersey Department of Environmental Protection
NPDES	National Pollution Discharge Elimination System
NPL	National Priorities List

NTCRA	Non-Time-Critical Removal Action
NTU(s)	Nephelometric Turbidity Units
NYSDEC	New York State Department of Environmental Conservation
NYSDOH	New York State Department of Health
OBS	Optical Backscatter Sensor
O&M	Operations and Maintenance
PAHs	Polycyclic Aromatic Hydrocarbons
PCBs	Polychlorinated Biphenyls
PCDFs	Polychlorinated Dibenzofurans
pcf	pounds per cubic foot
PL	Prediction Limit
ppm	part per million (equivalent to mg/kg)
PVC	Polyvinyl Chloride
Q-Q	Quantile-Quantile
QA/QC	Quality Assurance / Quality Control
QAPP	Quality Assurance Project Plan
QRT	Quality Review Team
RCRA	Resource Conservation and Recovery Act
RDP	Radial Dig Pattern
RI	Remedial Investigation
RI/FS	Remedial Investigation/Feasibility Study
RM	River Mile
RMC	Reynolds Metals Company
ROD	Record of Decision
RS	Responsiveness Summary
Site	Hudson River PCBs Superfund Site
SLRP	St. Lawrence Reduction Plant
SMU	Sediment Management Unit
SOP	Standard Operating Procedure
SPI	Sediment Profile Imaging
SQV	Sediment Quality Value
SRMT	St. Regis Mohawk Tribe Water treatment facility (*former name for* AMN)
SSAP	Sediment Sampling and Analysis Program
SSO	Side-stream of the dredge area outside of the silt curtain
SVOCs	Semi-Volatile Organic Compounds
TAT	Turn-around Time
TDBF	Total Dibenzofurans
TG	turbidity generating unit
TI	Thompson Island
TIP	Thompson Island Pool

TM	turbidity monitoring
TOC	Total Organic Carbon
Tri+	PCBs containing three or more chlorines
TSCA	Toxic Substances Control Act
TSS	Total Suspended Solids
UCL	Upper Confidence Limit
USACE	United States Army Corps of Engineers
USEPA	United States Environmental Protection Agency
USGS	United States Geological Survey
USI	Upstream of the dredge area outside the silt curtain
USO	Upstream of dredge area outside the silt curtain
USS	US Steel
VOC	Volatile Organic Compound
WDNR	Wisconsin Department of Natural Resources
WINOPS	Dredge-positioning software system used to guide the removal of contaminated sediment
WPDES	Wisconsin Pollutant Discharge Elimination System
WSU	Wright State University
WTP	Water Treatment Plant

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Volume 2: Technical Basis of the Performance Standard for Dredging Resuspension

1.0 Technical Background and Approach

This section provides a brief summary of the standard for reference throughout this volume of the text (subsection 1.1), identifies the basis for the standard as specified in the ROD, (subsection 1.2), defines terms used in this volume (subsection 1.3); identifies additional contaminants (subsection 1.4); discusses remedial design considerations (subsection 1.5); and provides an overview of case studies applicable to the approach (subsection 1.6) that are presented in detail in Volume 5 - Appendix.

1.1 Summary Statement of the Standard

A brief summary of the Resuspension Standard is included in this volume for convenience. A thorough statement of this standard is provided in Volume 1. In the formulation of the performance standard, several action levels were established so that remediation-related problems can be quickly identified and corrected before criteria are exceeded that would require temporarily halting the dredging operations. The resuspension criteria include Total PCB concentration, Total and Tri+ PCB[1] load, and suspended solids concentration thresholds. These criteria are defined in Table 1-1.

The Resuspension Standard includes criteria for both PCBs and suspended solids for both near-field and far-field conditions, which are defined as follows:

- Near-field conditions are those within a few hundred meters of the remedial operation. Only suspended solids criteria are applicable to the near-field stations.
- Far-field conditions are those at specific, permanent monitoring locations that are located at least one mile downstream of the remedial operation. Both PCBs and suspended solids criteria are applicable to the far-field stations.

Figures 1-1 and 1-2 depict the location of the near-field and far-field monitoring stations.

Compliance with the resuspension criteria is tested through monitoring. Tables 1-2, 1-3 and 1-4 contain the compliance monitoring requirements for this program. In addition to compliance monitoring, there are sampling requirements in the form of special studies to gather information that can be used to further refine elements of the standard. These studies include:

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[1] Total PCBs refers to the sum of all measurable PCB congeners in a sample, while Tri+ PCBs refers to the sum of PCB congeners containing three or more chlorine atoms.

- Near-field PCB Release Mechanism (Dissolved vs. Particulate)
- Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement
- Development of Far-Field Real-Time Suspended Solids Surrogate Measure
- Non-Target, Downstream Area Contamination

Implementation of the monitoring program is specified in Section 4, as are the required engineering contingencies in the event of exceedance of the resuspension criteria.

1.2 Record of Decision

As part of USEPA's responsibilities during the remedial design for the Hudson River PCBs site, the agency will develop an engineering performance standard that addresses the release and downstream transport of PCBs due to dredging operations. As specified in the Hudson River ROD (USEPA, 2002a):

> Performance standards will address (but may not be limited to) resuspension rates during dredging… These performance standards will be enforceable, and based on objective environmental and scientific criteria. The standards will promote accountability and ensure that the cleanup meets the human health and environmental protection objectives of the ROD. (ROD, page 88)

This standard is to be applied during the Phase 1 dredging effort and revised as necessary at the end of Phase 1 to reflect knowledge gained from the first year of dredging activities, as stated in the ROD:

> …The information and experience gained during the first phase of dredging will be used to evaluate and determine compliance with the performance standards. Further, the data gathered will enable EPA to determine if adjustments are needed to operations in the succeeding phase of dredging, or if performance standards need to be reevaluated. (ROD § 13.1, page 97)

The need for a performance standard concerning the release and downstream transport of PCBs was recognized in the ROD:

> …Although precautions to minimize resuspension will be taken, it is likely that there will be a localized temporary increase in suspended PCB concentrations in the water column and possibly in fish PCB body burdens. (ROD § 11.5, page 85)

This Resuspension Standard provides criteria to minimize the release of PCBs that are consistent with the rates of release anticipated in the ROD, while at the same time facilitating the removal of PCB-contaminated sediments from the river bottom. Like the residual and productivity performance standards, the ultimate goal of this standard is to:

> …ensure that dredging operations are performed in the most efficacious manner, consistent with the environmental and public health goals of the project. (ROD § 11.5, page 85)

The ROD also identifies several applicable or relevant and appropriate requirements (ARARs), and recognizes the need to conform to these federal and state requirements for water quality. These guidelines were considered, to the extent appropriate.

1.3 Definitions

Dredging is fundamentally a subaqueous earthmoving action. Just as ground-based earthmoving operations generate dust, dredging generates sediment particles that are released into the water column. Further, just as air currents spread dust from a construction site, ambient water currents transport resuspended sediments downstream. Resuspended sediments with particulate-associated PCBs increase water column PCB concentration, just as contaminated dust particles contribute to the total concentration of airborne contaminants.

In order to clearly describe the PCB release and downstream transport related to dredging, the following terms have been defined relative to the operation and distance downstream:

- ***Resuspension production rate***. Dredging-related disturbances suspend PCB-bearing sediments in the water column. The rate at which this occurs is the *resuspension production rate.*

- ***Resuspension release rate***. Since most of the sediments to be remediated in the Upper Hudson are fine sands, a significant fraction and often the majority of the small amount of material that escapes the dredge will settle in the immediate vicinity of the dredge. Materials that remain in the water column are then transported away by river currents. The rate of sediment transport in the immediate vicinity of the dredge is defined as the *resuspension release rate.*

- ***Dissolved-phase PCBs***. As suspended solids are transported away from the dredge, they will continue to settle, at the same time releasing a portion of their PCB burden into the water column, where the PCB is no longer bound to a solid particle. PCBs located within the water column but not bound to a solid particle are defined as *dissolved-phase PCBs* (smaller than 0.7 microns).

- ***Particulate PCBs***. As suspended solids are transported away from the dredge, they will continue to settle, while at the same time PCBs bound to the solid particles will be released into the water column. PCBs that are not released into the water column and continue to be bound with the suspended solids are defined as *particulate PCBs.*

Most of this settling takes place within a few hundred yards of the dredge. Given the extensive area of remediation in the Upper Hudson and its focus on depositional areas, it is expected that much of the material settling in the vicinity of the dredge will be collected during subsequent dredging passes.

- ***Resuspension export rate***. Beyond roughly one mile, further PCB removal from the water column by particle settling becomes small, and most of the PCBs in the water column are likely to travel long distances before being removed or captured by baseline geochemical processes such as volatilization or aerobic degradation. The rate at which PCBs are transported beyond one mile is defined as the *resuspension export rate*. It is this rate of PCB loss, with its potential for downstream impacts, that is the focus of the resuspension discussion in the ROD.

PCB loss due to resuspension requires both disturbance and downstream transport of PCBs from the source.

- ***PCB loss due to resuspension***. For the purposes of this performance standard, *PCB loss due to resuspension*, as stated in the ROD, is defined as the resuspension export rate just described. The standard addresses the net export of PCBs resulting from any activity related to the removal of PCB-contaminated sediments from the river bottom. This definition includes PCB export resulting from the dredging operation itself and from dredging-related boat movements, materials handling, and other activities. This definition requires both the disturbance and the downstream transport of PCBs from the source.

  The Resuspension Standard does not regulate resuspension within engineered control barriers, except for unacceptable downstream export.

  An important point is that the standard does not directly address the resuspension release rate or the resuspension production rate. These rates are considered only indirectly to the extent that they produce an export of PCBs beyond a distance of one mile downstream of dredging activity. Similarly, The standard does not regulate resuspension within engineered control barriers (*e.g.*, silt curtains), other than the extent to which resuspension within the barriers results in unacceptable export of PCBs downstream.

- ***Net export of PCBs to the Lower Hudson***. The *net export of PCBs to the Lower Hudson* is defined as the PCB resuspension export rate at the Waterford-Lock 1 Station, *i.e*., the load of PCBs at this location that is attributable to dredging-related activities. The Waterford-Lock 1 station was selected because it is downstream of the target areas identified in the feasibility study (FS) (USEPA, 2000b) but upstream of the Mohawk River, which was shown to be a minor but measurable source of PCBs to the Lower Hudson River (USEPA, 1997). The Federal Dam, which is the lower boundary of the Upper River, was not chosen because this location is downstream of the Mohawk River.

It is important to note that resuspension of sediments also results from other natural processes (*e.g.*, bioturbation and high-flow events) and anthropogenic processes (*e.g.*, the movement and actions of other vessels in the river). For instance, sediments are resuspended by propeller action during recreational boating activities or commercial shipping. Resuspension and any ensuing PCB export by these processes are accounted for by use of the baseline monitoring water column PCB concentrations in the development of the action levels.

In recognition of the nature of PCB release via resuspension, the Resuspension Standard addresses two areas with respect to dredging, the near-field area and the far-field area.

- ***Near-field area*** The *near-field area* is defined as the region in the immediate vicinity of the remedial operation, nominally extending from 100 feet (ft) upstream to 1 mile downstream of the remedial operation. This area represents the region of the water column most directly impacted by the remedial operation. The production of suspended solids by the dredge yields a resuspension release rate that controls local PCB levels in the water column. Resuspension and settling superimposed on the flowing river result in heterogeneous water column conditions in this area, making monitoring difficult. Each remedial operation has its own near-field area, although they can readily overlap, if deployed in the same vicinity.

Near-field area: the region in the immediate vicinity of the dredging, from 100 ft upstream to 1 mile downstream of the operation.

- ***Far-field area*** The *far-field area* is the region well downstream of the remedial operations, beginning no less than 1 mile downstream of the dredging operation. Typically, by this distance downstream, the majority of particle settling related to dredging-related activities is expected to have occurred. Additionally, there has been sufficient travel time that water column conditions can be expected to be relatively homogeneous and, therefore, can be sampled in a representative manner with a manageable level of effort. At this point, PCBs in the water column resulting from dredging constitute the resuspension export rate and are considered to be available to contaminate downstream regions.

Far-field area: the region well downstream of the dredging, no less than 1 mile downstream of the operation.

1.4 Contaminants of Concern in Addition to PCBs

Although much of the data collected for the Hudson River focuses on PCBs because these were selected as the contaminants of concern during the RI/FS, other contaminants (including dioxins and metals) may also be of concern in sections of the river. This performance standard does not address these contaminants. New York State is developing substantive water quality certification requirements for the environmental dredging pursuant to the federal Clean Water Act. The water column concentrations of compounds with certification requirements will be monitored during the remediation.

1.5 Remedial Design Consideration

Development of the performance standard for PCB loss due to resuspension will be done prior to the acquisition of the design support sampling, baseline monitoring sampling and the remedial design. As such, some broad and basic assumptions about the remedial design are required in order to construct the standard. The performance standard only specifies that the design must be able to achieve the performance standard; the standard does not dictate any other specifics of the remedial design. The equipment and procedures selected by the design team will be constrained in no other way by this standard.

As an example, the limits on the spread of resuspended sediments that may be afforded by the use of silt curtains or other barriers will not be considered in the development of the standard. The design team will determine whether these measures are required. Technologies and procedures that may be utilized to control resuspension are described and are based on an examination of the results from case studies and the analyses prepared for the Hudson River FS.

1.6 Case Studies

Preparation of the Resuspension Performance Standard included a review of previous monitoring programs associated with environmental dredging efforts. Review of historical case studies was conducted for both PCBs and suspended solids (turbidity or suspended solids). These studies provided a useful perspective on both the extent of dredging-related releases and the techniques used to monitor the dredging operation. While the Resuspension Standard was developed to be specific to the conditions of the Hudson River, these historical studies provided useful data used to support the selected criteria and requirements.

The PCB resuspension analysis that was completed for the *Responsiveness Summary (RS) of the Record of Decision* (USEPA, 2002a) provides detailed information on specific studies of PCB release. This work has been augmented here by the inclusion of a review of dredging-related turbidity issues. The applicable information from the case studies is summarized as appropriate under subsection 2.2, Supporting Analyses. A discussion of the case studies can be found in Appendix A to the Draft Engineering Performance Standard (provided under separate cover). Table 1-5 contains a brief summary of project information for the case studies reviewed for this standard.

2.0 Supporting Analyses

Supporting analyses were conducted during preparation of the Resuspension Standard to address and resolve issues pertaining to the impact of dredging and PCB transport from the dredge area to downstream locations. These analyses were completed to gather information and to gain an understanding on the following issues:

- What levels of turbidity or suspended solids have been observed at other environmental dredging sites? (Subsection 2.2.1)

- Does a correlation exist between suspended solids, turbidity and PCBs, so one can be a surrogate indicator of the other? (Subsection 2.1)

- What levels of PCB release have been observed at other environmental dredging sites? (Subsection 2.2)

- What are the baseline levels and variability of suspended solids and Total PCBs in the Hudson River water column? (Subsection 2.3)

- What is the upper bound baseline contaminant concentration per month or per season in the Hudson River? (Subsection 2.3)

- How will releases due to dredging be quantified relative to the ongoing releases from the sediments? (Subsection 2.4)

- How does the anticipated solids release from dredging compare to the baseline levels? (Subsection 2.4)

- By what mechanisms will dissolved PCBs be released and how does this compare with particulate PCB levels? (Subsection 2.5)

- Does the release of dissolved PCBs represent a significant impact that may occur from dredging? (Subsection 2.5)

- What would be considered a significant release (*i.e.*, resuspension export rate) from the dredging operation? (Subsection 2.6)

- How may potential releases affect human health and ecological risks? (Subsection 2.6)

- How much PCB may be released during dredging (*i.e.*, resuspension production and release rates)? (Subsection 2.7)

- At what rate will resuspended sediment settle out of the water column? (Subsection 2.7)

- How far downstream will the settling of resuspended material occur? (Subsection 2.7)

- How much material will be deposited and what is impact on the deposition areas outside of the targeted (dredged) areas? (Subsection 2.7)

- Where should monitoring be conducted to measure PCB mass loss from dredging? (Subsections 2.1 and 2.6)

- How far from the dredge should water quality monitoring be conducted and what parameters should be measured? (Subsections 2.1 and 2.7)

To address these issues, supporting analyses were completed to define a basis on which the standard could be established. Several of these issues were addressed as part of the analyses completed for the ROD. Other issues required further analysis. This section briefly summarizes these analyses and the conclusions drawn. Extensive descriptions of the analyses completed specifically for this standard can be found in the attachments to this document (Attachments A to G).

2.1 Turbidity and Suspended Solids at Other Sites

An evaluation was conducted to gather data concerning turbidity and suspended solids from completed dredging projects as well as current and design-phase dredging projects. The review of the available sites is extensively documented in Appendix A (Volume 4 of 4). Dredge sites previously researched during preparation of the Hudson River FS report and the Hudson River RS report were also included in this study. Among the issues addressed by this evaluation are the following:

- What levels of turbidity or suspended solids have been observed at other dredging sites?

- Does a correlation exist among suspended solids, turbidity, and PCBs, so that one can be a surrogate indicator of the other?

- How far from the dredge should water quality monitoring be conducted and what parameters should be measured?

These issues are specifically addressed in subsections 2.2.1 to 2.2.3, respectively. Table 1-5 provides a brief summary of the various sites where dredging-related turbidity or suspended solids data were available.

2.1.1 Reported Levels of Turbidity and Suspended Solids

In most dredging studies, turbidity was the main monitoring parameter.

In most dredging studies, turbidity was the main monitoring parameter. In several instances, data were also collected to correlate turbidity with suspended solids, with varying degrees of success. As to the absolute values of turbidity or suspended solids reported, most studies only noted the instances where conditions exceeded the site-specific criteria. This information is useful in that it can provide some examples of turbidity extremes related to dredging.

In most instances, the main area of turbidity or suspended solids monitoring was conducted in the near field, as defined previously. This is discussed further in subsection 2.2.3. In general, probe measurements or sample collection were most often performed within 1,000 ft of the dredging operation, although data were also obtained further away.

With regard to turbidity criteria, the review of case studies indicated that typical turbidity criteria were established at levels between 25 and 50 nephelometric turbidity units (NTU) above background levels. However, although many studies noted that turbidity monitoring was conducted during dredging operations, no turbidity threshold was provided in the reports, nor were data available for review. Instead, the reports concluded that turbidity never exceeded background levels. However, useful information on turbidity levels was obtained from some sites, as discussed below.

For New Bedford Harbor remediation in the lower harbor area, the turbidity standard was set at 50 NTU above background levels, 300 ft from the dredge. It was indicated that the 50 NTU standard was reached infrequently and further action was not needed since this level was not detected 600 ft from the dredge.

At the General Motors (GM) Central Foundry Division site (St. Lawrence River, Massena, New York), the turbidity threshold was set at 28 NTU. Turbidity measurements were periodically taken upstream and downstream of the dredge. When the value downstream exceeded the upstream value by 28 NTU, real-time turbidity measurements continued until the exceedance ended. Prolonged exceedances required modifications to the waterborne remediation activities until the problem was rectified.

During dredging at the GM Massena site, 18 of 923 turbidity samples exceeded the action level of 28 NTU above background (ranging from 31 to 127 NTU). These exceedances were observed at a depth of 1 ft below the water surface (except for one measurement at 9 ft). The duration of the exceedance was generally reported to be two to eight minutes, with two exceedances that lasted for 15 minutes and 45 minutes, respectively.

Both the reported values and the near-field turbidity criteria suggest maximum turbidity values around 25 to 50 NTU above baseline conditions. Few sites routinely reported all of their data, making further conclusions as to turbidity levels difficult. Suspended solids data were even more rare, and in most cases were assumed to correlate with turbidity.

2.1.2 Correlations Among Turbidity, Suspended Solids and PCBs

Information with regard to turbidity, suspended solids and Total PCB data and associated correlations was examined where available. Little data were available for most sites. However, for three dredging projects, an attempt was made to correlate collected data and draw a conclusion. In all three instances, however, the correlations were between turbidity and suspended solids. No correlations were reported between PCBs and either the turbidity or suspended solids parameter.

At the GM Massena site, bench scale tests were conducted prior to dredging to develop a relationship between suspended solids and turbidity. The following correlation was developed for overall conditions, including elevated suspended solids results (*i.e.*, >300 milligrams per liter [mg/L]):

$$\text{Turbidity (NTU)} = 7.3745+(0.611058 \times \text{SS}) + (0.00094375 \times \text{SS}^2);\ r^2=0.941$$

where: SS = the suspended solids concentration in mg/L.

Based on a regression analysis completed on the data set generated from the bench scale tests to determine whether a relationship existed between suspended solids and turbidity at lower concentrations (*i.e.*, when suspended solids values are less than 60 mg/L and turbidity values are less than 60 NTU), the foregoing equation was simplified to the following relationship by applying a linear fit curve to the plotted data set at lower concentrations, as indicated previously:

$$\text{SS (mg/L)} = [0.63 \times (\text{Turbidity})] + 6.8;\ r^2 = 0.43$$

where: Turbidity = the turbidity reading in NTU

Using this relationship, it was concluded that a turbidity value of 28 NTU corresponded to a suspended solids concentration of less than 25 mg/L. It should be noted that this relationship was the basis of the turbidity standard of 28 NTUs set for the dredging project. It can be concluded, in essence, that GM Massena's threshold was not only to maintain a turbidity of less than 28 NTU, but it was also to maintain a suspended solids concentration of 25 mg/L or less.

At the Cumberland Bay remediation site (Lake Champlain, New York), a technical specification set for the contractor was the development of a site-specific correlation between suspended solids and turbidity. This relationship was expected to yield action levels for the more easily measured parameter, turbidity, which in turn could be readily correlated to suspended solids action levels during the dredging operation. To accomplish this, the contractor performed bench scale tests prior to initiating dredging. The end result was that a reliable suspended solids-turbidity correlation could not be determined. This was attributed to unforeseen factors related to algae blooms and light refraction, which caused turbidity to vary in a way that precluded its direct correlation to suspended solids.

A similar series of bench scale tests was conducted prior to dredging at the Fox River Deposit N dredging site (Kimberly, Wisconsin). In addition to the tests correlating turbidity with suspended solids, studies were conducted to determine sediment resuspension and settling rates. The first steps were to submerge a 1-ft-thick aliquot of Deposit N sediment under 5 ft of river water and introduce forced air into the system to agitate it. Water samples were collected for turbidity and suspended solids analyses, and sediment settling rates were observed within the system.

The results of this study produced the following relationship between turbidity and suspended solids:

$$SS = -1.27 + 1.313 \times \text{Turbidity}; \quad r^2 = 0.98$$

Where:

SS = suspended solids in mg/L

Turbidity = turbidity in NTU

As a result of this relationship, suspended solids were estimated in the field during dredging based on real-time turbidity measurements.

Given the success observed for the two riverine sites, it may be possible to generate a site-specific relationship between turbidity and suspended solids for the Hudson River during Phase 1, or with a laboratory test prior to Phase 1.

2.1.3 Turbidity and Suspended Solids Monitoring

At the dredging projects examined, the locations of near-field monitoring generally included water quality monitoring stations upstream of the dredge, downstream of the dredge and to the side of the dredge (a side-stream station). At sites where containment such as sheet piling or turbidity barriers was deployed, monitoring stations were placed at the aforementioned locations outside of the containment area. Inside the containment area there were generally no monitors. If there were monitors, they did not have a specific threshold level to adhere to, but instead were used to evaluate the dredge operation itself. At sites where dredging was not contained, the monitor was located an average of 300 ft from the dredge. Monitoring locations for several of the larger sites examined are described below.

At the New Bedford Harbor Hot Spot dredging site, water quality monitoring stations were situated 300 ft from the dredge. This 300-ft radial area was referred to as the “mixing zone,” an area where environmental impacts were not directly monitored. There were no set threshold levels within the 300-ft area surrounding the dredge, as it was assumed that solids settling out within this radius from the dredge would not result in an adverse impact to the harbor. However, beyond 300 ft, it was assumed that solids would have the potential to impact downstream resources.

Another project at New Bedford Harbor, the dredging of the lower harbor, utilized the concept of the 300-ft mixing zone as well. For this project, a turbidity threshold of 50 NTU was set at the 300-ft distance from the dredge, as noted previously. In the event that the 50 NTU threshold was exceeded at this location, additional turbidity monitoring was required 300 ft from the location at which the exceedance was detected (*i.e.*, 600 ft from the dredge) to confirm the reading and assess the magnitude of the plume.

Many of the Commencement Bay dredging projects, located off the coast of Washington State, also utilized the concept of the mixing zone. No containment was used due to the tidally influenced waterways; however, monitoring was conducted at the limit of the mixing zone, which was typically established 300 ft from the dredge to ensure compliance with state and federal waterway regulations.

At the Grand Calumet River, Indiana, remediation site, monitoring is planned at locations both upstream and downstream, 300 ft from the dredge.

During dredging operations at the GM Massena site, water quality monitoring stations were positioned between 200 and 400 ft downstream of the sheet piling that enclosed the remedial operations.

Much of the available data on turbidity and suspended solids monitoring is focused in the near-field region, where turbidity measurement is the primary parameter. Monitoring locations are typically located 300 ft from the operation, with additional monitoring performed at greater distances on a less-frequent basis. These locations appear to have been selected based on professional judgment. Monitoring at these locations appears to have successfully measured the suspended solids transport from the vicinity of the remedial operations.

2.2 PCB Releases at Other Dredging Sites

PCB releases at other dredging sites were extensively explored as part of the RS for the ROD (White Paper – *Resuspension of PCBs During Dredging*, USEPA, 2002a). As part of this review, three sites were found to have sufficient PCB data to permit an examination of the rate of PCB release (see Table 2-1). Since the completion of the RS, no other sites have been found that have data to support a similar analysis. For two of these sites, GE Hudson Falls and New Bedford Harbor Hot Spots, monitoring around the location was sufficient to permit an estimate of the mass of PCB transported away from the site (*i.e.*, out of the near-field region).

This loading information was combined with information regarding the mass of PCBs removed to provide an estimate of the fraction of PCB lost. As noted in the white paper, the rates of loss observed for these sites (0.36% and 0.13%, respectively) are in close agreement with the 0.13% estimate presented in the FS for the Hudson River based on a dredging release model.

As discussed at length in the white paper, there were specific issues on sample collection techniques and sampling locations that compromised the data from the Fox River study in terms of developing a flux estimate. The PCB loss estimated for this site was 2.2%. In particular, the close proximity of the monitoring location to the dredging operation during portions of the study (less than 0.25 mile) was a significant factor impacting the data. These results suggest that much greater separation between source and sampling location is needed in order to correctly represent dredging-related losses. Nonetheless, although the magnitude of loss estimated is considered to be an overestimate, the rate of loss estimated by the US Geological Survey (USGS) for this site was considered in the modeling analysis in the RS, as well as later in this document.

2.3 Hudson River Water Column Concentration Analysis

Extensive study of PCB levels in the Hudson River was conducted during the Reassessment RI/FS; however, these analyses were focused on understanding the sources of existing loads and concentrations within the river. For the purposes of establishing a standard for PCB losses due to resuspension, it became necessary to develop a basis for distinguishing between dredging-related and preexisting baseline conditions. To this end, an analysis of the mean and variation of monthly conditions in the Upper Hudson was conducted using data obtained primarily through the ongoing post-construction remnant deposits monitoring program conducted by GE under a consent decree with USEPA. These data were also combined with flow data routinely recorded by USGS to provide estimates of PCB loads in the Upper Hudson.

The analyses, details of which are presented in Attachment A, were primarily intended to address the following two issues:

- What are the baseline levels and variability of suspended solids and Total PCBs in the Hudson River water column?
- What is the upper bound baseline contaminant concentration per month or per season in the Hudson River?

By establishing baseline concentrations and loads as well as the inherent variability of these parameters, it becomes possible to discern the additional contributions of PCBs originating with the remedial operations. That is, by establishing baseline conditions, deviations from these conditions can be identified and attributed to dredging-related releases as appropriate.

The following section briefly summarizes Attachment A of this report. The quantitative answers to the two issues cited above are found in the tables of the attachment and are not repeated here.

Post-1996 data collected by GE in the ongoing weekly sampling program were used in the baseline calculations, since they represent the most comprehensive water column dataset and probably best reflect the current conditions in the Hudson River. Baseline conditions for suspended solids and Total PCB data were analyzed from this data set.

Three of GE's monitoring stations were analyzed for these purposes:

- Rogers Island (Fort Edward)
- Thompson Island Dam (TI Dam)
- Schuylerville

Results for both the PRW2 and the TID-West stations at TI Dam were examined separately. The data from Rogers Island is considered characteristic of concentrations and loads originating upstream of the remediation area. The TI Dam and Schuylerville stations are representative of conditions within the remediation area and are therefore important far-field monitoring locations. Although these data are extensive, however, the data may not be completely representative of the river conditions because of the sampling and analytical methods employed.

The examination was limited to the months of May through November, representing the expected dredging season. The data were examined on a monthly basis, in recognition of the significant month-to-month variation in conditions documented in the Reassessment RI/FS (refer to Appendix D1 of the FS). The analysis included the statistical characterization of each month for each station, establishing a basis for estimation of the mean and the variance of the population as a whole. Correlations with flow were examined as well and applied when significant and useful. Minor correlations with flow were ignored if the magnitude of the change in concentration or load was small.

Using these statistics, the following values were established for each month and station for both PCBs and suspended solids:

- The arithmetic average for a particular month

- The 95th%ile upper confidence limit (95% UCL) on the average value for the month

Data for adjacent months were combined when no significant difference was found between means and seasonal conditions were deemed similar (*e.g.*, May and June, October and November). The formula applied to estimate these factors was dependent on the underlying distribution of the data (*i.e.*, normal, lognormal, or non-parametric). Attachment A, Table 2, of this document contains a summary of these results.

June yielded the maximum concentrations in suspended solids at all stations; maximum PCB concentrations were observed in both May and June; and maximum upper confidence limits for suspended solids also occurred exclusively in June. Maximum upper confidence limits for PCBs proved to be less systematic.

The baseline concentrations and loads presented in Attachment A can be used as a basis to evaluate dredging resuspension during the remedial operation. At a minimum, daily Total and Tri+ PCB measurements will be obtained at the far-field stations. These results will be compared to the baseline values to determine whether the dredging-related releases are in excess of the load-based criteria. Similarly, suspended solids will also be used to identify dredging-related releases. In this instance, continuous or multiple daily measurements will be used to estimate the net suspended solids increase at the far-field stations. Net suspended solids increases above baseline will be considered indicative of dredging-related releases. See subsection 4.1 for implementation details.

Water column concentrations may on occasion be elevated above the upper confidence limits due to baseline processes, but it is unlikely that the concentrations will be elevated above these levels for sustained periods of time without an obvious cause (such as a flood event).

Each far-field station specified in the standard will be monitored during the baseline monitoring program. These baseline data will be used to revise the estimates of the averages and 95% UCLs at all stations and will form the basis for identifying dredging-related releases in Phase 1.

2.4 Resuspension Sensitivity Analysis

During the dredging operation, adequate monitoring will be essential to demonstrate that the resuspension criteria are adhered to and to verify that minimal downstream transport of PCBs occurs. An analysis was conducted to examine the impacts of plausible dredging releases relative to the estimated monthly baseline concentrations. Ultimately, this analysis was needed to address portions of the following issues:

- How will releases due to dredging be quantified relative to the ongoing releases from the sediments?
- How does the anticipated solids release from dredging compare to the baseline levels?

Baseline concentrations and variances were examined for two of the main far-field monitoring stations that established an average monthly concentration and an upper bound on the monthly mean concentration.

Two analyses are summarized in this section that have a direct bearing on this analysis. In Attachment A, baseline concentrations and variances were examined for two of the main far-field monitoring stations, the TI Dam and Schuylerville. This analysis established an average monthly concentration and an upper bound on monthly mean concentrations. These data were then used in an analysis to estimate monthly loads for PCBs. A second important piece of information with respect to the estimated fractions of PCB mass that may be exported during dredging may be found in subsection 2.2. Values in case studies listed in Table 2-1 correspond to 0.13%, 0.36%, and 2.2% of the PCB mass removed. These values can be translated into an absolute mass export rate for the Upper Hudson remediation, as follows:

$$F_{dredge} = \frac{M_{UH}}{5\,yrs \times 7\frac{mo}{yr} \times \frac{30\,days}{1mo} 14\frac{hr}{day}} \times L_{dredge} \times \frac{1{,}000g}{1kg}$$

where: F_{dredge} = dredging resuspension export rate (or flux) in g/hr

M_{UH} = mass of PCBs in the sediments of the Upper Hudson to be removed by dredging (69,800 kg or 150,000 lbs) in kg

5 yrs = period of remediation (half year production in first and last dredging seasons with four full-production-rate years in between)[2]

7 mo/yr = dredging season per year

30 days/mo = days per month

14 hr/day = expected mean dredging period per day

L_{dredge} = dredging resuspension export rate as a fraction of removal (unitless)

By this formula, the three percentages given above (0.13%, 0.36%, and 2.2%) translate to PCB export rates of 6, 17, and 104 grams per hour (g/hour) of dredge operation, respectively. These values are comparable in magnitude to the nominal baseline daily flux of PCBs during the dredging season, generally ranging from 20 to 80 g/hr.[3] Thus the lower end of the possible export rates will be difficult to observe relative to the magnitude and variability of baseline fluxes as demonstrated in the variations discussed in Attachment A. In light of this observation, three nominal resuspension export rates were explored in this analysis: 0.5%, 1.0%, and 2.5%. These translate to 24, 47, and 119 g/hr respectively (or nominally 300, 600, and 1,600 g/day on a 14 hour/day basis).

Recognizing the anticipated range in river conditions over the dredging season, the analysis was conducted for Total PCBs in the Upper Hudson River over a wide range of river flow rates (2,000 to 10,000 cubic feet per second [cfs]). The suspended solids increase in the water column was estimated based on:

- Volume of sediment removed, the density of the sediment
- Dredging-induced resuspension export rate

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[2] This removal rate represents the target removal schedule in the Productivity Performance Standard.

[3] This range is based on a range of flows from 3,000 to 5,000 cfs and a water column concentration of 75 to 150 ng/L, typical of conditions in the TI Pool in June and July.

- Flow rate
- Length of the dredging season

Similarly, the Total PCB increase in the water column was computed as a function of:

- Mass of Total PCBs to be removed
- Dredging-induced resuspension export rate
- River flow rate
- Length of the dredging season

These results are presented in Attachment B of this performance standard. Because dredging-related export is calculated as a net addition of PCB or suspended solids (mass per unit time), the additional flux is independent of the river flow; however, the estimated increase in water column concentration will vary inversely with flow. For these estimates, dredging releases were not considered to be flow-dependent but rather to result from spillage, equipment handling, etc., all of which are independent of flow.

These estimated increases in concentration were then translated into a dredging-induced suspended solids and Total PCB concentrations in the river system. This was computed by adding the system's baseline variation of suspended solids and Total PCB concentrations (the estimated baseline concentrations) to the estimated increase in concentration (loading) as a result of solids loss from the dredging operation. Comparison of these potential in-river suspended solids and Total PCB concentrations were evaluated against the estimated suspended solids and Total PCB monthly baseline concentrations to determine the level of "significant" increase in the river system over baseline concentrations that signals an unacceptable dredging-related impact.

This analysis was completed for both monitoring stations at the TI Dam and for the Schuylerville monitoring station. Attachment B provides a detailed analysis for each monitoring station. The analysis identified periods of the dredging season wherein 600 g/day PCB export rate loading from the dredging operation would increase the Total PCB water column levels to a concentration just below 350 ng/L at the Schuylerville monitoring station. These elevated Total PCB water column concentrations were estimated for the months of May and June during low-flow conditions at the Schuylerville monitoring stations. Similar values were estimated for the TID-PRW2 station. Concentrations exceeding 350 ng/L were calculated for the TID-West station at low flow. In all three instances, however, the data may not be truly representative of the river conditions at the location, in light of concerns over collection techniques. Thus, any conclusions drawn from the data are tentative.

With the exception of estimated Total PCB concentrations during the months of May and June during low-flow conditions, it was concluded that 300 g/day and 600 g/day releases of Total PCBs due to dredging will correspond, overall, with a Total PCB concentration in the water column of less than 300 ng/L Total PCBs on average. This indicates that concentrations can be maintained below the 350 ng/L criterion of the Control Level. Generally, this analysis identified problematic times of year during the dredging season wherein extra care will need to be taken to maintain minimal releases from the dredge to avoid exceedance of the Total PCB concentration resuspension criteria. These results also suggest that if low-flow conditions occur during the months of May and June, less-contaminated areas might be chosen for remediation in favor of more highly contaminated areas.

A sensitivity analysis was conducted on the annual PCB loading baseline to evaluate the impact associated with a dredging-induced PCB loading into the water column. This analysis was completed to evaluate whether the remediation of the Upper Hudson via dredging will have a measurable impact on the annual PCB loads. The baseline annual PCB loading was estimated for each of the monitoring stations for the period of 1992 through 2000 and compared to the dredging-induced PCB loading, assuming PCB export rates of 300 g/day, 600 g/day, and 2,300 g/day. The 2,300 g/day value corresponds to load conditions at the Resuspension Standard threshold for Total PCBs of 500 ng/L.

A sensitivity analysis conducted on the annual PCB loading baseline evaluated the impact of dredging-induced PCB loading into the water column.

Assuming that dredging work would occur seven days per week and that the increase in concentrations would occur only during the 14-hour-per-day working period, the dredging-induced PCB loading for each of these scenarios was computed as a function of the following:

- Volume of sediment removed
- Total PCB concentration on the solids
- Induced Total PCB flux
- Section of the river being remediated

This analysis is presented in Attachment B of this document.

Comparison of the baseline annual PCB loading to the dredging-induced PCB loading for the three scenarios indicated that a well-controlled dredging project at full production (export of 300 g/day Total PCBs from dredging) would release less than 65 kg per year Total PCBs into the river as a result of the remediation, and that a 600 g/day Total PCB export rate from dredging would result in an annual loading of about 130 kg per year Total PCBs.

Analysis indicated:
A well-controlled dredging project exporting 300 g/day Total PCBs would release < 65 kg per year Total PCBs into the river.

A 600 g/day Total PCB export rate from dredging would result in approx. 130 kg/yr annual loading of Total PCBs to the river.

The Resuspension Standard threshold would result in an annual loading of 500 kg/year into the river. It can be seen that these rates of mass loss begin to become significant relative to the baseline annual loads. It was concluded that an annual dredging-induced 65

The Resuspension Standard threshold results in a 500 kg/year annual loading of Total PCBs to the river.

kg/year Total PCB loading is a relatively small fraction of the baseline load to the river in most years, and that the Total PCB load induced by the Resuspension Standard threshold is similar to PCB loadings that occurred in the early 1990s. This rate of export will be controlled through limits on the seasonal and daily rates of dredging-induced PCB export to prevent excessive PCB loss when the baseline PCB concentrations are low and the concentration criteria would allow higher export rates.

It is concluded from this analysis that the PCB concentration and load criteria established for the Resuspension Standard and action levels are protective of the river system and would generate Total PCB concentrations typically within the baseline variability of the river system.

Conclusions:
Annual dredging-induced 65 kg/yr Total PCB loading is relatively small fraction of baseline annual load to the river.

Resuspension Standard criteria and action levels are protective of the river system.

2.5 Dissolved-Phase Releases

Evidence has been reported from the Fox River study (USGS, 2000) to suggest that a large dissolved-phase release of PCBs is possible in the absence of any apparent increase in the water column loading of suspended solids. As a result, theoretical analyses were conducted to assess the potential mechanisms by which dissolved PCBs could be released into the water column. An attempt was then made to quantify the potential release of PCBs in the dissolved phase. The following issues were explored through theoretical analyses to estimate a quantity of PCBs that may be released into the river system in the dissolved phase:

- By what mechanisms will dissolved PCBs be released and how does this compare with particulate PCB levels?

- Does the release of dissolved PCBs represent a significant impact that may occur from dredging?

To some degree, resuspended solids lost from the dredge will release their PCB burden into the dissolved phase as the solids concentrations attempt to establish equilibrium. PCBs will continue to move from the particulate phase on the resuspended solid to the dissolved phase in the water column until a steady state is reached, a process that is otherwise known as establishing equilibrium.

PCBs move from the particulate phase on the resuspended solids to a dissolved state until a steady state, or equilibrium, is reached in the water column.

Once equilibrium is reached, the PCB concentration on the resuspended solid can be estimated, as well as the concentration of PCBs in the dissolved phase. Impacts of resuspension downstream of the dredging area can now be determined, since the PCB flux from the dredging area has been quantified. In addition, the quantity of dissolved phase PCBs released into the water column may have a significant impact on the water column quality, depending on the concentration and quantity of the dissolved-phase release.

There are two basic pathways by which dissolved-phase PCBs can be released into the water column:

- Through direct releases of pore water to the overlying water column as a result of the dredge's making a cut into the sediment
- Directly from a solids release/loss into the water column from dredging

Once solids are displaced into the water column, PCBs begin to partition from the particulate phase to the dissolved phase in an attempt to reach equilibrium within the system. In the event that the suspended solids added to the water column are of sufficient mass and contamination level, the dissolved-phase concentration will rise markedly. These analyses are described in detail in Attachment C to this document. A summary of the analyses assumptions, methodology, and conclusions are presented below.

The first theoretical model analyzed was the three-phase partitioning model, which was examined to evaluate conclusions drawn from PCB-loss calculations estimated for dredging conducted at the Fox River dredging sites. Specifically, the reported fraction of total mass loss as dissolved phase during dredging was approximately 1% of the total mass removed (USGS, 2000).

The three-phase partitioning model presented here assumes that the contaminant, PCBs, reaches equilibrium among particulate, truly dissolved, and dissolved organic carbon (DOC)-bound phases. This model was employed on a mass of contaminant-per volume of sediment basis. The three-phase partitioning model was evaluated using the Hudson River data. Detailed analysis and parameters used for this model can be found in Section 2 of Attachment C.

It was determined, using the three-phase equilibrium model, that the Hudson River sediment pore water contains very little of the *in situ* sediment PCB mass. More specifically, the three-phase partitioning model indicated that the dissolved phase represents 0.002% of the Tri+ fraction of PCBs relative to the sediment-bound PCB fraction of 99.998%. For the mono- and di-homologue fractions, the dissolved phase represents 0.004%, as compared to the sediment-bound PCB fraction of 99.996%.

These percentages of dissolved-phase PCBs per sediment-bound PCBs were then used to estimate the number of pore water volumes that would need to be displaced to achieve a 1% mass loss, as reported from the Fox River case study. The number of pore water volumes is computed as the proportion of water-to-sediment volume or the desired mass to be lost (1%) over the mass available in a single pore water volume (either 0.002% for Tri+ or 0.004% for mono- and di-chlorobiphenyls).

This computation estimated that 420 volumes of pore water would need to be released for the Tri+ fraction, or 210 cubic yards (cy) of water per cy of sediment, assuming the sediment are half water and half sediment. For the mono- and di-chlorobiphenyls, approximately 250 pore water volumes would need to be released, or 125 cy of water, assuming the sediment is half water and half sediment. It was concluded from this analysis that a direct loss of PCBs to the water column from the dissolved phase through the pore water would be highly unlikely, because such a large volume of water must be displaced to result in a measurable release of dissolved PCBs.

The amount of displaced pore water needed to achieve a measurable release of dissolved-phase PCBs is so high that direct loss of PCBs to the water column through pore water is highly unlikely.

Another analysis was the application of the two-phase partitioning model to estimate the distribution of the dissolved-phase PCBs to the total concentration of PCBs in the water column due to dredging. This analysis was conducted to evaluate whether it is sufficient to simply measure whole-water PCBs during dredging or whether the dissolved phase must also be measured if it is representative of a significant concentration. This model assumes equilibrium exists between the dissolved-phase fraction and the suspended phase fraction.

Data collected in the GE float surveys show that sediments continue to release PCBs to the water column throughout the year even when low-flow conditions exist and no observable resuspension is occurring in the system. Thus, for this analysis, a scenario was assumed in which a suspended solids concentration of 1 mg/L would be temporarily added to the system as a result of dredging. It was thought that evaluating the magnitude of PCBs in the water column for this scenario would allow for a preliminary evaluation as to whether the effects of dredging could be distinguished from the baseline river conditions.

In fact, the estimated fraction of dissolved phase PCBs estimated for the dredging-induced scenario in which suspended solids was released into the water column was similar to background concentrations. The fraction of dissolved phase to total water column PCB concentration for both background and after dredging is similar, on the order of 0.9. It was concluded that it is not possible to distinguish the effect of dredging by simply comparing the fraction of the dissolved phase increase in the water column.

Both of the foregoing analyses assume that the solids and dissolved phase PCBs reached equilibrium. Recent studies have indicated, however, that full chemical equilibrium may not be reached since the desorption rates of hydrophobic chemicals from sediment tends to be slow. It is thought that the residence time of a resuspended particle in the water column from dredging is relatively short (*i.e.*, on the order of hours). Assuming a few hours' residence time, it is not likely that the PCBs will reach equilibrium. In response to this concern, a literature review was conducted to obtain data on desorption equilibrium and kinetics of PCBs so this analysis could be carried out and evaluated.

The PCBs desorption rate constants reported in the literature are homologue-based, except for those of Carrol, et al. (1994), who used an untreated PCB that was comprised of 60% to 70% mono- and di-chlorinated biphenyls. The desorption rate constants were determined to vary between 4.2 x 10^{-4} to 0.2 hr^{-1}. The reported rate constants correspond to a half-life of approximately 3 to 1,700 hours and equilibrium times of 26 hours to 980 days. Given the length of time that it takes the PCBs to reach equilibrium, as described by these rate constants, it was concluded that it is highly unlikely that there will be large amounts of dissolved-phase PCBs released as a result of dredging. To validate this statement, the reported desorption rate constants were applied to the Hudson River sediment and dredging conditions. Applying these values into a kinetic rate equation, it was estimated that the dissolved-phase PCB released due to dredging may range from 7.6 x 10^{-5} to 3.2 ng/L, which is approximately 0.04 to 18% of the whole-water PCB concentration. These estimates indicate that the amount of dissolved-phase PCBs introduced into the system will be relatively small and comparable to background concentrations.

The theoretical analyses conclude that the release of a large amount of dissolved-phase PCBs is unlikely to occur as a result of dredging. It is possible to assess these results using field measurements of dissolved and suspended PCB concentrations in the water column during dredging, using the case study data. Measurements of dissolved- and particulate-phase PCBs were collected during the predesign field test conducted at the New Bedford Harbor during August 2000 (USACE, 2001).

The particulate PCB and suspended solids measurements taken during the dredging at New Bedford Harbor show patterns of concentrations similar to what would be expected during the remediation. At the point of dredging, the particulate PCB concentrations are elevated by a factor of about ten over the upstream conditions, but within 1,000 ft downstream of the dredge, the concentrations were only slightly greater than the highest measured upstream concentration. Turbidity levels drop off quickly with distance to upstream monitoring point conditions.

The dissolved-phase PCB concentrations at the dredge are again about ten times larger than the upstream concentrations but these concentrations drop off quickly into the range of the upstream samples. The upstream PCBs concentrations are about 60% dissolved. At the dredge this value drops to below 20%, indicating that PCBs released via dredging are primarily solids-bound. Downstream of the dredge the% of dissolved-phase PCBs is more variable but remain less than the 60% fraction at the upstream location. This variability in the downstream samples is mirrored in the particulate PCB and suspended solids measurements.

These results of this study are consistent with a mechanism of PCB release through the suspension of contaminated solids. This conclusion is more convincing in light of the high concentrations in New Bedford Harbor (860 ppm on average in the top 0 to 1 foot segment) relative to the Hudson River (approximately 50 ppm on average in the Thompson Island Pool [TI Pool]).

2.6 Far-Field Modeling

To study the long-term impacts of dredging, far-field modeling was used to simulate water column, sediment and fish Tri+ PCB concentrations in the Upper and Lower Hudson River as a result of the dredging operation. The far-field model was applied to determine the following:

- What would be considered a significant release (*i.e.*, resuspension export rate) from the dredging operation?

- How may potential releases affect long-term human health and ecological risks?

- What would be the short-term impact of an accidental release on the public water supply?

The modeling efforts were focused on examining the impact of running the dredging operation at the specified action levels in the Resuspension Standard. The water column, sediment, and fish Total PCB concentrations were forecasted using USEPA's peer-reviewed, coupled, quantitative models for PCB fate, transport, and bioaccumulation in the Upper Hudson River, HUDTOX and FISHRAND, which were developed for the Reassessment RI/FS.

HUDTOX was developed to simulate PCB transport and fate for the 40 miles of the Upper Hudson River from Fort Edward to Troy, New York. HUDTOX is a fate and transport model that is based on the principle of conservation of mass. The fate and transport model simulates PCBs in the water column and sediment bed, but not in fish.

For the prediction of the future fish PCB body burdens, the FISHRAND model was used. FISHRAND is a mechanistic time-varying model incorporating probability distributions. It predicts probability distributions of expected concentrations in fish based on mechanistic mass-balance principles, an understanding of PCB uptake and elimination, and information on the feeding preferences of the fish species of interest. Detailed descriptions of HUDTOX and FISHRAND models can be found in the *Revised Baseline Modeling Report* (USEPA, 2000c).

For the Lower Hudson River, the Farley *et al*. (1999) fate and transport model was used. The water and sediment concentrations from the Farley fate and transport model were used as input for FISHRAND to generate the PCB body burden estimates for fish species examined in the Lower Hudson.

As part of the modeling effort for the Resuspension Standard, the following scenarios were simulated using HUDTOX, FISHRAND, and Farley models:

- Dredging scenario with no resuspension release rate (HUDTOX run number d004).

- Dredging scenario with a net increase in Total PCB mass export of 300 g/day at the far-field monitoring stations (run number sr02). This essentially simulates the Evaluation Level of the Resuspension Standard.

- Dredging scenario with a net increase in Total PCB mass export of 600 g/day at the far-field monitoring stations (run number sr01). This corresponds to the Control Level of the Resuspension Standard.

- Dredging scenario with a maximum Total PCB concentration of 350 ng/L at the far-field monitoring stations (run number sr04). This corresponds to the Control Level of the Resuspension Standard.

- Dredging scenario with an accidental release during the 600 g/day dredging operation conditions.

Table 2-2 contains a list of completed model runs used in this report. Unlike the previous modeling efforts performed for the RS for the ROD (USEPA, 2002a), the model simulations completed for the Resuspension Standard track the sediment being resuspended as a result of dredging. The dredging scenarios with resuspension release were simulated with additional solids and Tri+ PCB loading to the model segments. In addition to simulating the "best estimate" of PCB resuspension release during dredging, the dredging schedule was shifted from 2004 to 2006, as seen in the start years listed in Table 2-3.

The resuspension scenarios in the foregoing bullets are specified as the PCB export rate at the far-field monitoring stations. Due to the nature of the HUDTOX model structure, PCB loads cannot be readily specified at far-field locations (*i.e.*, specifying the resuspension export rate). Rather, the input of PCBs is specified as an input load at a location within the river, equivalent to a resuspension release rate. In order to create a correctly loaded HUDTOX run, it is first necessary to estimate the local resuspension release rate from the dredging operation; that is, the rate of Total PCB and solids transport at the downstream end of the dredge plume. At this location most of the solids that are going to settle out will have settled out and the suspended solids will more closely resemble those simulated by HUDTOX.

Unfortunately, there is no direct way to establish the relationship between the resuspension release and export rates prior to running the models. To estimate the suspended solids flux input loading term for HUDTOX, a near-field model was developed (TSS-Chem) based in part on the work by Kuo and Hayes (1991). The Total PCB input loading term for HUDTOX (the resuspension release rate) was derived iteratively so as to obtain the desired PCB export rate at the far-field monitoring location. The resuspension release rate was obtained by checking the resuspension export rate (output from HUDTOX) until the model output gave the desired Total PCB export rate. Once the resuspension release rate that created the desired resuspension export rate was obtained, the corresponding suspended solids flux associated with the Total PCB release rate was estimated using TSS-Chem model. Detailed descriptions of the TSS-Chem and HUDTOX models and their use are provided in Attachment D.

Appendix D contains a complete discussion on the effects of different formulations for suspended solids flux input to the model. From this study, it was concluded that the PCB export rate is not particularly sensitive to the amount of solids (suspended solids flux) loaded with the PCBs. A scenario with no solids added to the model segments increases the Total PCB export rate minimally (less than 15%) compared to the scenario with the suspended solids flux added derived from the one-mile plume scenario of the TSS-Chem model.

The PCB export rate is not particularly sensitive to the amount of solids (suspended solids flux) loaded with the PCBs.

Figures 2-1 through 2-3 present comparisons of predicted HUDTOX Tri+ PCB concentrations in the water column at various locations throughout the Upper Hudson River for the monitored natural attenuation (MNA), no resuspension, and three action level scenarios over a 70-year forecast period.

The effect of running the dredging operations at the Evaluation Level (300 g/day) and the Control Level (600 g/day) on predicted water column Tri+ PCB concentrations is largely confined to the six-year active dredging period (2006 through 2011). Outside of the period of scheduled dredging (2012 and later), impacts on water column Tri+ PCB concentrations are minimal. However, in River Section 3 only, running the dredging operations at the Control Level or 350 ng/L (or 1,600 g/day) results in significantly higher water column concentrations during the dredging period and slightly elevated water column concentrations for approximately ten years after completion.

The cumulative Tri+ PCB load at Waterford as forecasted by HUDTOX was used to determine what would be considered a significant release (*i.e.*, resuspension export rate) from the dredging operation. Figure 2-4 shows the Tri+ PCB load forecasts for several load conditions. The lower bound will be the ideal conditions of dredging, where there are no sediments being spilled (no resuspension) and the upper bound will be the MNA scenario. The 300 g/day scenario was only simulated through 2020. From the figure, it was shown that the Tri+ PCB load for this scenario crosses the MNA by the completion of dredging (2011).

The HUDTOX forecast for the Tri+ PCB load from the 600 g/day scenario remained higher than the MNA for a little longer, approximately four years after completion of dredging operations (2015). However, HUDTOX forecasts showed that Tri+ PCB cumulative loads for both 300 g/day and 600g/day scenarios would be lower than the MNA. This suggests that these two scenarios would yield acceptable loads to the Lower River. HUDTOX results for the 350 ng/L scenario showed that cumulative Tri+ PCB loads will go below the MNA cumulative loads for the 70-year forecast period. This suggests that

HUDTOX forecasts showed that Tri+ PCB cumulative loads for both 300 g/day and 600g/day scenarios would be lower than the MNA, suggesting acceptable loads to the Lower River.

by running the dredging operations at the Control Level of 350 ng/L for the entire program, significantly more Tri+ PCB mass will be transported to the Lower River relative to the MNA scenario, yielding an unacceptable amount of release.

Similar conclusions can be drawn for the Total PCB load estimates, although longer periods are estimated until the 300 g/day and 600 g/day dredging scenarios cross the MNA trajectory. These forecasts are considered less certain, however, since the models do not directly simulate Total PCBs, but rather Tri+ PCBs. The Total PCB estimates are based on estimates of Tri+ to Total PCBs in the resuspended sediments (refer to the *White Paper – Relationship Between Tri+ and Total PCBs* in the RS for more details [USEPA, 2002a]).

In addition to giving an indication of significant release, the results from HUDTOX runs may also provide an indication of the water column concentrations for the different dredging scenarios. Figures 2-5 through 2-7 show the whole water, dissolved phase, and particulate phase Total PCB concentration for the 300 g/day, 600 g/day, and 350 ng/L scenarios during the dredging period (2006 to 2011).

The HUDTOX model predicted that by running the dredging operations at the Evaluation Level (Total PCB flux of 300 g/day), the mean whole water column Total PCB concentrations at the TI Dam would be less than 160 ng/L. At Schuylerville and Waterford, the HUDTOX model predicted that the whole water column concentrations would average less than 120 and 80 ng/L, respectively (Figure 2-5). The water column Total PCB concentrations as a result of running the dredging operations at 600 g/day would be higher than those of the 300 g/day scenario, as expected. The mean whole water Total PCB concentrations at the TI Dam during the dredging period (2006 to 2011) for the 600 g/day scenario are predicted to be less than 250 ng/L except for few days in June 2008 (Figure 2-6). The whole water Total PCB concentrations at the Schuylerville and Waterford monitoring stations are predicted to be lower than 200 and 150 ng/L, respectively.

For the 350 ng/L scenario, as expected, the HUDTOX forecast shows that on average, the whole water Total PCB concentrations will be approximately 350 ng/L (Figure 2-7). The predicted Total PCB concentrations in the water column during River Section 2 dredging are higher than 350 ng/L because the forecast flow used in the model during that dredging period (August 16 to November 30, 2009) is about 15% lower than the historical average flow based on the USGS data. Therefore, the higher concentrations are expected. However, the average concentration during the entire dredging period for River Section 2 (August 16 to November 30, 2009 and May 1 to August 15, 2010) is expected to be around 380 ng/L.

Figure 2-8 depicts the annual species-weighted fish body burdens for human fish consumption at RM 189, 184, and 154. The fish concentrations used are the species-weighted averages, based on Connelly *et al*. (1992), and are considered to represent a reasonable ingestion scenario among the three fish species consumed to any significant extent by human receptors (anglers) (USEPA, 2000a):

- Largemouth bass – 47%
- Brown bullhead – 44 %
- Yellow perch – 9%

FISHRAND fish body burdens forecasts for the MNA, no resuspension, 350 ng/L Total PCBs, and 600 g/day Total PCBs scenarios were plotted in the figure. The 300 g/day scenario was not simulated since the Tri+ PCB loads to the Lower River are lower than both the 600 g/day and 350 ng/L scenarios. FISHRAND modeling results for the Upper River show that the impact of the 600 g/day scenario on fish tissue concentrations is largely confined to the dredging period in River Sections 1 and 2 (Figure 2-8), similar to the water column results from the HUDTOX model. In River Section 3, the impact to the fish tissue concentrations lasts about three years beyond the dredging period to approximately 2014.

The forecast results from the different dredging scenarios indicated that the impacts to fish tissue concentration would largely be short-term (*i.e.*, confined to the years during the dredging period) for River Section 1, even for the 350 ng/L scenario. The impact of the 350 ng/L scenario is slightly longer lasting in River Section 2 compared to that for River Section 1 (Figure 2-8).

Long-term human health and ecological risks are discussed in the following subsection.

2.6.1 Human Health and Ecological Receptor Risks

This subsection compares long-term risks (*i.e.*, after completion of dredging) from consumption of PCB-contaminated fish to anglers and ecological receptors (as represented by the river otter [*Lutra canadensis*]) under the following scenarios:

- No resuspension
- 350 ng/L Total PCBs
- 600 g/day Total PCBs
- Monitored natural attenuation scenarios

Risks were calculated with exposure durations beginning one year after the year in which dredging will be completed in the each section of the river and the average of the upper river (Table 2-3). Exposure durations (*e.g.*, 40 years for evaluating cancer risks to the reasonably maximally exposed [RME] adult angler, 7 years for evaluating non-cancer health hazards to the RME adult angler) and all other risk assumptions, locations, toxicity values, receptors, and fate, transport, and bioaccumulation models used here are the same as those used for baseline conditions throughout the Hudson River PCBs RI/FS in the *Revised Human Health Risk Assessment*, the *Revised Baseline Ecological Risk Assessment*, the FS, and the ROD Responsiveness Summary reports.

The fate and transport and bioaccumulation of PCBs in the upper river were predicted as Tri+ PCB concentrations using the HUDTOX and FISHRAND models. The Tri+ PCB group includes the PCB compounds that are most toxic to fish, wildlife, and humans and is considered to capture the majority of toxicity associated with PCB compounds. PCB contamination in fish tissue from the Hudson River has been shown to consist almost exclusively of Tri+ PCBs, with average values ranging from 98% to nearly 100% (USEPA, 2002).

The Revised HHRA and ERA (USEPA, 2000a and 2000e, respectively) have shown ingestion of fish to account for most of the risk to human and ecological receptors; therefore, the use of Tri+ PCBs for risk assessment modeling requires no revisions for comparison to available toxicological literature for PCB effects expressed as total PCBs or Aroclors.

The risk-based remediation goal (RG) for the protection of human health is 0.05 mg/kg PCBs in fish fillet.

Table 2-4 presents annual species-weighted fish fillet Tri+ PCB concentrations in the Upper Hudson River, as compared to the risk-based remediation goal (RG) for the protection of human health of 0.05 mg/kg PCBs in fish fillet. That RG is based on non-cancer hazard indices for the RME adult fish consumption rate of one half-pound meal per week and is protective of cancer risks as well. Other target concentrations presented are 0.2 mg/kg PCBs in fish fillet, protective at a fish consumption rate of one half-pound meal per month, and 0.4 mg/kg PCBs in fish fillet, protective of the central tendency (CT) or average angler who consumes one half-pound meal every two months.

The time to reach human health fish target concentrations of 0.2 mg/kg Tri+ PCB and 0.4 mg/kg Tri+ PCB in the Upper Hudson River was shorter for all resuspension scenarios as compared to monitored natural attenuation in the upper river as a whole and in River Sections 1 and 2 (Table 2-5). In River Section 3, all active remediation scenarios achieved the RG of 0.05 mg/kg Tri+ PCB prior to MNA. The greatest differences seen in the time to achieve fish target concentrations between the active remediation scenarios and MNA were seen in River Section 1, where the MNA scenarios took up to 17 years longer to achieve some target concentrations, while the smallest differences were seen between scenarios in River Section 3.

Using fish fillet concentrations based upon the three resuspension scenarios (*i.e.*, no resuspension, 350 ng/L, and 600 g/day), human health fish consumption cancer risks and non-cancer hazards show at least a 50% reduction in the upper river as a whole, Section 1 (River Mile 189), and Section 2 (River Mile 184) compared to monitored natural attenuation for both RME and average exposures (Tables 2-6 and 2-7). Risk reductions in Section 3 were seen for the no resuspension and 600 g/day scenarios as compared to monitored natural attenuation, but not for the 350 ng/L Total PCB scenario.

Based on site-specific angler surveys, the *Human Health Risk Assessment* (USEPA, 2000a) determined that Mid-Hudson River anglers have a different diet than anglers in the upper river:

- Brown bullhead – 53%
- Largemouth bass – 15%
- Yellow perch – 1.4%
- White perch – 7.6%
- Striped bass – 23%

Striped bass concentrations were not modeled for resuspension scenarios and therefore human health cancer risks and non-cancer hazards for Mid-Hudson River anglers could not be calculated. To provide an estimate of relative risks amongst the resuspension scenarios, angler intake was calculated using fish concentrations from the FISHRAND model. Striped bass intake was proportionally divided between the remaining fish species (i.e., 69% brown bullhead, 19% largemouth bass, 2.0% yellow perch, and 10% white perch) and white perch concentrations from the FISHRAND Model were used in the absence of Farley Model data.

Calculated fish exposure concentrations were used only for comparison between alternatives and do not represent predicted intake concentrations based on mid-river angler consumption patterns. As expected, fewer differences were seen between the resuspension scenarios in the lower river than in the upper river. Long-term cancer risks and non-cancer hazards differed by a maximum of 32%. The no resuspension and 600 g/day Total PCBs scenarios showed the greatest risk reductions as compared to monitored natural attenuation scenario. The 350 ng/L Total PCBs showed lower and sometimes no reductions in risk, owing to elevated concentrations of PCBs predicted in fish tissues for several years following dredging operations (Figure 2-9).

Risks to ecological receptors, as represented by the river otter, were evaluated by examining largemouth bass whole fish PCB concentrations. In the Upper Hudson River the lowest-observed-adverse-effect-level (LOAEL) target levels were reached within the modeling timeframe for the upper river as a whole and in Section 3 for all scenarios (Table 2-8). In the upper river as a whole, all resuspension scenarios reached the LOAEL target level of 0.3 PCBs mg/kg 17 years prior to the MNA scenario (Table 2-9). Ecological target levels were not reached within the modeling timeframe for Sections 1 and 2 of the river. In Section 3, all scenarios reached the LOAEL target level within five years of one another.

Largemouth bass PCB concentrations in the Lower Hudson River were lower under all resuspension scenarios than under the MNA scenario (Table 2-10). The LOAEL PCB target concentration in largemouth bass was reached 4 to 11 years sooner under the various resuspension scenarios than under MNA in various sections of the lower river (Table 2-11).

Conclusion:
Human health and environmental impacts from dredging are predicted to be

Resuspension may temporarily increase PCB concentrations locally, resulting in slight increases in fish PCB concentrations. However, human health non-cancer hazards and cancer risks and ecological risks were calculated to be well below those under the MNA scenario. Minor differences were seen between the various resuspension scenarios, indicating the human health and environmental impacts from dredging are predicted to be minimal, particularly since levels of resuspension approaching the performance criteria are expected to occur on an intermittent, rather than continuing basis.

2.6.2 Accidental Release Short-Term Impacts

HUDTOX was used to model an accidental release scenario to demonstrate the short-term and long-term impacts to the public water intakes downstream of the incident. The following accidental release scenario was analyzed:

- A hopper barge containing 870 tons of silty sand (barge capacity is 1000 tons, with 87% sediment and 13% water) that has been removed by mechanical dredging from River Section 2 is damaged and releases the entire load in the area just above Lock 1.
- The contents fall in a mound and no effort is made to remove or contain the material.
- Over a period of one week, the entire load is swept downstream.
- The background concentrations are at the 600 g/day Total PCB flux at the River Section 3 monitoring location.
- For this scenario, an additional release of 113,000 kg/day suspended solids is anticipated, with a baseline condition of 20,000 kg/day for a one-week period (from July 1 through 7, 2011).

This scenario is quite conservative in that the average concentration from River Section 2 is higher than in the TI Pool. This is because areas with mass per unit area greater than 10 g/m^2 are targeted in this river section, whereas in the TI Pool, areas greater than 3 g/m^2 are targeted. The hopper barge was used because it has a larger capacity than the deck barge (200 tons) that was also proposed in the FS. The location of the accident is just above the public water intakes at Halfmoon and Waterford, minimizing the opportunity for reductions to the water column concentration resulting from settling and dilution.

Because a mechanical dredge is assumed to have removed the sediment, nearly the entire weight of the release would be attributed to sediment, with little dilution with water. The already elevated water column concentrations result in water column concentrations at the public water intakes greater than the MCL. This scenario is also conservative from the realistic standpoint that a spill of this magnitude would almost certainly be contained within hours of occurrence.

HUDTOX provided the whole water, particulate-bound, and dissolved-phase PCB concentrations in the water column. The model predicted that the accidental release scenario results in a short-term increase of the whole water Total PCBs above the MCL in the water column at Waterford (Figure 2-10); however, the highest dissolved phase Total PCB concentration was less than 350 ng/L (Figure 2-10). Because HUDTOX assumed instantaneous attainment of PCB equilibrium between the dissolved and suspended phases, the dissolved-phase PCB concentrations are overestimated, providing an additional conservative assumption.

While the Total PCB concentration entering the public water intake would be in excess of the federal and state MCL, it is likely that the concentration in the influent would be greatly reduced by minimal treatment because approximately 850 ng/L of the total 1,150 ng/L Total PCB peak concentration would be attributed to the suspended phase. Assuming that the bulk of the contaminated suspended solids would be removed by filtration, the delivered concentration without further treatment would be closer to the dissolved-phase PCB concentration of 300 ng/L. Thus, the water output from the plant would still meet the federal MCL of 500 ng/L.

As previously noted, the dissolved phase PCB concentrations estimated by HUDTOX are already biased high. The dissolved phase PCB concentrations would probably be further reduced by activated carbon treatment, which is currently implemented at the Waterford public water intake. This analysis suggests that the concentration reaching the public would be substantially less than the MCL even in the event of an accidental release in the vicinity of the intakes as described in the hypothetical accidental release scenario.

While this analysis suggests that the planned operations are unlikely to impact the public water supplies in the event of an accident, further consideration on the protection of public water supplies and the requisite monitoring will be given in the development of a community health and safety plan (CHSP).

2.7 Near-Field Modeling

Two models (CSTR-Chem and TSS-Chem) were developed to estimate the conditions within 1 mile downstream of the dredge head. These near-field models were used to estimate the suspended solids and Total PCB plumes resulting from resuspension of solids. The models were useful in identifying the most appropriate location for the placement of water column monitoring stations in the near-field and provided an estimate of solids transported into the far-field. In addition, the TSS-Chem model was used to estimate the effects of settled material on sediment concentrations within the near-field.

2.7.1 CSTR-Chem and TSS-Chem

CSTR-Chem and TSS-Chem models were developed and utilized for the near-field modeling effort to estimate the transport and concentration of suspended solids and Total PCBs from the dredge head to the far-field region (approximately one mile downstream of the dredge head).

2.7.1.1 CSTR-Chem

CSTR-Chem is used to model the area immediately around the dredge. The model is based on an ideal reactor configuration consisting of a continuous stirred tank reactor (hence CSTR). This construct represents a means to simplify the mathematical modeling of constituent concentrations in the immediate vicinity of the dredge head. CSTR-Chem assumes that a constant flow influent with a known constant concentration (*i.e.*, upstream river water) is instantaneously mixed as it enters a confined, well-mixed tank (*e.g.*, the region immediately around the dredge head). Physical and chemical reactions occur while the water is within the ideal tank and the tank effluent is at the same flow as the influent and at the uniform concentration within the tank.

The CSTR concept is most appropriate to the analysis of dredging operations because turbulence in the area of the dredge, coupled with ambient flows, may be assumed to produce mixed conditions similar to that in an ideal tank reactor. A complete discussion of the CSTR-Chem and TSS-Chem model development is presented in Attachment D.

The input for the CSTR-Chem is model is the subsequent resuspension rate. Since solids will settle within this area, the solids flux out will not be equal to the resuspension production rate of solids. The rate at which solids exit the immediate dredge area is termed the source strength. The source strength represents the solids available for downstream transport and is the input for the TSS-Chem model. However, since the TSS-Chem model simulates a point source and CSTR-Chem has a non-zero width, the two models cannot be directly linked. Nevertheless, CSTR-Chem can still be used to provide for input to TSS-Chem, particularly with regard to the dissolved PCB concentration and the silt fraction.

2.7.1.2 TSS-Chem

The TSS-Chem model has two components:

- A Gaussian plume transport model that describes the dispersion and settling of the particles downstream
- A geochemical component that uses two-phase partitioning of PCBs from solids into the dissolved phase taking into account a kinetic desorption rate

TSS-Chem utilizes the same solids transport equations for a mechanical dredge as DREDGE (Kuo and Hayes, 1991), outlined in Appendix E.6 of the FS and the White Paper – *Resuspension of PCBs During Dredging* (USEPA, 2002a). The TSS-Chem model was used to estimate PCB water column conditions downstream of the dredge across the width of the river up to a distance of one mile. TSS-Chem is useful for the near-field downstream transport of solids and PCBs but is inadequate in estimating the net contribution of solids and dissolved and suspended phase PCBs to the water column in the immediate vicinity of the dredging operations (*i.e.*, relating the resuspension production rate to the source strength). For this purpose, the CSTR-Chem model was developed.

2.7.1.3 Desorption Rate Input to the Models

One of the important input parameters in the CSTR-Chem and TSS-Chem models is the desorption rate constant. The conclusions drawn from CSTR-Chem and TSS-Chem models depend on an accurate desorption rate constant assumption. An extensive literature review on the PCB desorption rate constant was conducted for the Resuspension Standard and is presented in Attachment C. Due to lack of knowledge on the amount of “labile” (fast) and “non-labile” (slow) fractions in the dredged material, only fast desorption rate constants are considered in this study in order to provide a conservative (upper bound) estimate of the amount of PCBs that partition into the dissolved phase. The rate of desorption used for TSS-Chem and CSTR-Chem is 0.2 hr^{-1}. This desorption rate was applied to the difference between the PCB concentration of the suspended sediments and the equilibrium concentration by allowing more PCBs to remain in the water column with the existing soluble PCB concentration. Attachment D contains additional detail on the two-phase partitioning equations.

2.7.1.4 Applicability of the Models

Applicability of the CSTR-Chem model depends upon the presence of near-field conditions that can reasonably be represented as well mixed; it is important that the diameter of the cylindrical area that is approximated as a CSTR should reflect the extent to which well-mixed conditions exist. For the purposes of this analysis, a CSTR width of 10 meters (m) is used. Buckets that may be used in the Hudson River project are generally 2 to 3 m in diameter closed and somewhat larger when open. It was assumed that velocities induced by bucket movement could extend across most of a 10-m width used in this analysis.

The CSTR-Chem results suggest that under transient partitioning conditions, which are expected within the CSTR, the PCB releases from dredging operations will generally be less than 1% dissolved. The model results also suggest there is no significant loss of silt particles from the settling within the CSTR. The results of the CSTR-Chem model were used to develop the assumptions made concerning the source strength of the TSS-Chem model. The results indicated that:

- When the dissolved fractions estimated by the CSTR-Chem were input into the TSS-Chem, the results did not significantly vary from runs that had no initial dissolved phase.

- The silt fraction within the sediments is the only parameter that significantly affected the TSS-Chem PCB flux at one mile.

Incorporating these model observations, the TSS-Chem model was used to simulate the near-field dredging operations, from just beyond the dredge head to a one-mile distance downstream. Attachment D contains a more detailed discussion on the relationship between the TSS-Chem model assumptions and the CSTR-Chem.

2.7.2 Near-field Model Results

Near-field modeling was performed to address the following issues:

- How much PCBs may be released during dredging?
- How far from the dredge should water quality monitoring be conducted?
- At what rate will resuspended sediment settle out of the water column?
- How far downstream will the settling occur?
- How much material will be deposited and what is the impact on the deposition areas outside of the targeted (dredged) areas?

2.7.2.1 Solids and PCB Load HUDTOX Inputs

TSS-Chem was used to estimate solids and PCB loads for input to the HUDTOX model. Conditions at one mile were taken for input to the HUDTOX model, recognizing the difference in model scales. As outlined in Appendix E.6 of the FS (USEPA, 2000b) and *White Paper - Resuspension of PCBs During Dredging* (USEPA, 2002a), the average resuspension rate is based on a combination of field data from other sites and a resuspension model. The downstream transport rates (source strengths) only apply to silts and finer particles within the sediment (65% of cohesive and 20% of non-cohesive sediments for the Hudson River). The use of only silts does not significantly affect the PCB flux estimates because the silt resuspension rate, essentially equal to the silt source strength, is the driving source term for the PCB flux downstream

The production rates for the average source strength calculations were based on a total of five full production dredging seasons, using the estimated amount of sediment removal necessary and the time limitations involved. Each source strength estimate was run through TSS-Chem to calculate the resulting flux and concentration increases at one mile.

Table 2-12 contains the production rates, source strengths, and results are shown in. The average source strength was estimated at approximately 0.7 to 0.9 kg/s. For the various river sections these source strengths corresponded to PCB fluxes of approximately 80 to 210 g/day at one mile. The variation in the PCB fluxes for the different river sections is mainly caused by the different sediment concentrations. The highest flux is from dredging activities in River Section 2, which has a sediment concentration roughly 2.2 times greater than River Section 1.

2.7.2.2 Solids Transport Simulation

The TSS-Chem model was used to simulate the solids transport in the water column due to dredging operations up to one mile downstream. Simulations were performed for the 300 g/day, 600 g/day, 350 ng/L and 500 ng/L scenarios. The results suggest that the water column at one mile downstream of the dredge head has a significant amount of dissolved phase, but the suspended solids phase is still dominant (Figure 2-11). The fraction of dissolved phase Total PCB is greater for scenarios with lower amounts of solids introduced to the water column (*i.e.*, lower resuspension rates and source strengths) (Table 2-13).

For example, for the 300 g/day scenario, which has the lowest SS flux range from 0.3 to 1.3 kg/s at the dredge head, the TSS-Chem predicted that the fraction of dissolved phase Total PCBs one mile downstream of the dredge head ranges from 0.2 to 0.4 (Table 2-13). The 500 ng/L scenario has the highest amount of solids introduced to the water column (ranges from 3 to 9 kg/s at the dredge head). For this scenario, the TSS-Chem model results showed that the fraction of dissolved phase Total PCB in the water column ranges only from 0.05 to 0.1.

According to the TSS-Chem model results, the suspended solids concentration decreases and the width of plume increases as the solids are transported downstream. The suspended solids concentration at 300 m downstream is about one-quarter to one-third of the concentration at 50 m downstream, while the width of the plume at 300 m downstream is about twice the plume width at 50 m downstream. The greater width of the plume at 300 m suggests that this location may be easier to monitor using a stationary, continuous reading suspended solids sensor. It is also likely that by this distance downstream, water column concentrations of suspended solids will be more homogeneous. As a result, in an attempt to balance between the wider, more homogeneous plume conditions farther downstream and the easier identification of the center of the plume, 300 m downstream of the dredge head was chosen as the location of a primary near-field monitoring station.

The time that the particles remain suspended is primarily a function of the sediment type. Generally, silt particles will remain suspended longer than coarse particles. In the near-field models, the rate at which particles fall through the water column is determined by the particle settling velocity. Different settling velocities are defined for fine and coarse particles in the models. Attachment D contains a summary of settling velocities from various studies. For most of the studies, Stokes' Law was the theoretical basis for estimating the settling velocity of sand particles. This approach is appropriate for discrete particles that do not aggregate and was applied to the coarse material in the near-field models.

Stokes' Law only applies to discrete particles settling and does not account for flocculation during settling. Flocculation increases the rate at which silts settle from the water column, but the rate of flocculation depends on site-specific conditions and sediment properties. Therefore, silt settling velocities presented in QEA's report (1999) for Hudson River sediments were used in the near-field models, since these values were derived for Hudson River conditions and included the effects of flocculation.

The TSS-Chem results indicate that with a flow rate of 4,000 cfs, approximately 30 m downstream from the dredge head most of the coarse material has settled to the bottom of the river. At this distance, the coarse material is less than 0.1% of the net suspended solids from dredging. Since the coarse material settles much faster than the silts, it does not contribute significantly to PCB loads and concentrations at one mile. The results also suggest that there is a significant amount of settling within one mile downstream of the dredge head. The amount of Total PCBs being introduced to the water column from the dredge head is reduced by approximately 80% in River Section 1 and approximately 70% for River Sections 2 and 3 at one mile downstream of the dredge head (Table 2-13). For example, in River Section 1, when the amount of Total PCBs added to the water column due to dredging is 1,700 g/day, the load at one mile is approximately 400 g/day.

2.7.3 PCB Deposition Immediately Downstream at the Dredge Operations

If the suspended solids that settle onto the riverbed during transport downstream are contaminated, PCB mass and concentration will be added to the surrounding downstream areas. Using the modeled suspended solids concentrations in the water column downstream of the dredge, with the associated PCB concentration on the suspended solids, it is possible to estimate the increase in PCB mass in these areas. The increase in mass per unit area and the length-weighted average concentration of the top 6-in bioavailable layer were used to measure the effect of the settled material. Since these areas are outside of the target areas, the settled particles are not scheduled for removal.

If the suspended solids that settle onto the riverbed during transport downstream are contaminated, PCB mass and concentration will be added to the surrounding downstream areas.

The spatial distribution of the settled contamination will vary according to the shape of the target area and the rate of dredging. For this estimate, the target area is assumed to be 5 acres, 200 ft across, and approximately 1,100 ft long, because the areas of contamination are typically located in the shoals of the river and are narrow. From the FS, the time needed to dredge a 5-acre area with 1-m depth of contamination would take 15 days, operating 14 hours per day. It is assumed that the dredge will move in 50 ft increments across and down the target area. With these assumptions, the dredge will relocate approximately every two hours. To simulate the deposition of settled material, the amount of PCB mass per unit area, the mass of the settled material, and the thickness of the settled material that is deposited in two hours downstream at each modeled location is added on a grid as the dredge moves across and down the area.

Spatial distribution of the settled contamination will vary according to the shape of the target area and the rate of dredging.

The TSS-Chem results for each river section and action levels were used to estimate the additional mass per unit area and length-weighted average concentration approximately two acres downstream of the target area. The remediation could operate continuously at the Evaluation Level of 300 g/day and the Control Level of 600 g/day, but not the Control Level of 350 ng/L. The results are shown in Table 2-14.

The ROD defines 1 mg/kg as the acceptable residual concentration; the length-weighted area concentrations were calculated assuming that the PCB concentration in

The ROD defines 1 mg/kg as the acceptable residual concentration.

the sediment underlying the settled material is 1 mg/kg. In the two acres below the target area in River Section 2, for example, the concentrations range from 2 to 9 mg/kg.

These increases suggest that dredging should proceed from upstream to downstream if no silt barriers are in place, so that the dredge inside the target areas can capture settled material. Also, silt barriers may be needed to prevent the spread of contamination to areas downstream of the target areas have already been dredged or are not selected for remediation, as this settled material is likely to be unconsolidated and may be easily resuspended under higher flow conditions.

2.8 Relationship Among the Resuspension Production, Release, and Export Rates

During dredging operations, it is necessary to specify the near-field load to the water column that would yield the targeted export rates (*i.e.*, resuspension criteria) at the far-field stations. In order to estimate these loads, computer models were utilized to provide a relationship between the far-field and the near-field dredging-induced PCB transport and loss. The TSS-Chem and HUDTOX models were used to represent and link the resuspension production (at the dredge-head), release and export rates. The resuspension release rate (and source strength) in the region from the dredge to a distance of one mile is represented by the TSS-Chem model. The resuspension export rate in the region beyond one mile is represented by HUDTOX.

The TSS-Chem and HUDTOX models were used to examine the:

- Amount of sediment being suspended in the water column at the dredge head.
- Suspended solids and Total PCB flux at one mile downstream of the dredge head.
- Total PCB flux at the far-field monitoring stations for the 300 g/day, 600 g/day, and 350 ng/L scenarios.

Table 2-12 shows the resuspension production, release, and export rates for the simulations. Because HUDTOX predicted different rates of export for different reaches of the river given the same PCB release rate, the TSS-Chem model was run under different conditions so as to yield a consistent output from HUDTOX *(e.g.*, 600 g/day, 350 ng/L) for all river sections.

2.8.1 300 g/day Export Rate Scenario

To create a 300 g/day export rate of Total PCBs at the TI Dam, approx. 900-1,700 g/day Total PCBs would need to be suspended in bulk sediment, depending on distance between dredge head and monitoring station.

From the results, it was predicted that in order to create an export rate of 300 g/day of Total PCBs at the TI Dam, the amount of Total PCBs in bulk sediments that needs to be suspended is approximately 900 to 1,700 g/day, depending on the location of the dredge-head to the monitoring stations. The farther the dredge is from the far-field monitoring location, the greater the amount of solids and PCBs that would need to be suspended into the water column (Table 2-12).

Resuspension production rates that create an export rate of 300 g/day are on the order of 2% to 3% of the removal rate of Total PCBs via dredging. That means that in River Sections 2 and 3, the following amounts of Total PCBs in bulk sediment would need to be suspended from the water column are as follows:

- River Section 2: 1,000 g/day Total PCBs
- River Section 3: approximately 1300 g/day when the dredge head is farther away from the far-field monitoring location; around 1,000 g/day when the dredge head moves closer (downstream) to the monitoring station

Overall, the Total PCB resuspension export fraction relative to the PCB resuspension production rate for the 300 g/day scenario is estimated to range from 0.17 to 0.34.

2.8.2 600 g/day Export Rate Scenario

To obtain an export rate of 600 g/day Total PCBs, the amounts of Total PCB mass that would need to be suspended into the water column in the three river sections are as follows:

- River Section 1: from 3,000 to 4,000 g/day (on the order 5% to 6% of the Total PCB removal rate via dredging)
- River Section 2: approximately 2,000 g/day (approximately 2% of the Total PCB removal rate via dredging)
- River Section 3: approximately 2,000 to 3,000 g/day (on the order of 2% of the Total PCB removal rate by dredging)

Overall, the Total PCB export fraction relative to the PCB resuspension production rate for the 600 g/day scenario is estimated to range from 0.17 to 0.31, similar to that for the 300 g/day scenario.

2.8.3 350 ng/L Total PCB Concentration Scenario

The 350 ng/L Total PCB concentration at the far-field monitoring stations scenario was also simulated. The Total PCB fluxes at the TI Dam, Schuylerville and Waterford that would represent the 350 ng/L are 1,200, 2,000, and 2,300 g/day, respectively. The resuspension production rates, *i.e.*, the g/day volume of Total PCB mass that would need to be suspended to the water column to create an export rate of 350 ng/L Total PCB concentrations, are as follows:

- At the TI Dam: approximately 6,000 to 7,600 g/day (approximately 10% to 13% of the Total PCB removal rate via dredging)
- River Section 2: approximately 7,000 to 8,300 g/day (approximately 6% to 7% of the Total PCB removal rate via dredging)
- River Section 3: approximately 8,400 to 11,000 g/day (approximately 15% to 19% of Total PCB removal rate via dredging)

These resuspension production rates are approximately 19% to 24% of the Total PCB removal rate via dredging. The Total PCB export fraction for this scenario ranges from 0.16 to 0.28.

2.8.4 500 ng/L Total PCB Concentration Scenario

Modeling results suggest that from 16% to 29% of the PCB mass removed during dredging would have to be spilled to yield a 500 ng/L condition in the river.

The 500 ng/L Total PCB condition was only simulated by TSS-Chem model, without a subsequent HUDTOX model forecast. As a result, the Total PCB fluxes at the far-field monitoring stations were extrapolated based on the 500 ng/L input conditions and the results of the previous HUDTOX simulations. The TSS-Chem results for the 500 ng/L scenario suggest that the Total PCB export fraction of the resuspension production rate ranges from 0.16 to 0.29 (*i.e.,* 16% to 29% of the PCB mass removed would have to be spilled to yield a 500 ng/L condition in the river). To obtain 500 ng/L Total PCB concentration at the far-field monitoring station, g/day Total PCB mass that would need to be suspended to the water column would be as follows:

- River Section 1: approximately 10,000 to 13,000 g/day (approximately 17% to 23% of the Total PCBs removal rate via dredging).
- River Section 2: approximately 9,300 to 11,000 g/day (approximately 8% to 9% of the Total PCBs removal rate via dredging)
- River Section 3, approximately 13,000 to 16,600 g/day (approximately 23% to 29% of the Total PCBs removal rate via dredging)

Sediment spillage at levels that would be required in order to have long-term impact on downstream receptors and conditions is unlikely and well beyond what is expected for standard environmental dredging practices

These model calculations yield an important conclusion concerning criteria developed for the Resuspension Standard. While the model analysis of the concentrations and loads that comprise the standard show relatively little long-term impact on downstream receptors and conditions, the amount of sediment spillage required to attain these levels is quite large. Spillage at these levels is unlikely and certainly well beyond what is expected for standard environmental dredging practices. Based on these analyses, compliance with the Resuspension Standard appears to be attainable, including the lowest action criteria.

2.9 Review of Applicable or Relevant and Appropriate Requirements (ARARs)

The evaluation of potentially applicable federal and state water quality standards for the purpose of the performance standard development was based on work previously done for the ROD) for the Hudson River PCBs Site (USEPA, 2001). In the ROD, seven chemical-specific ARARs for PCBs were identified:

500 ng/L	Federal MCL [40 CFR § 141.61] and NYS MCL [10 NYCRR, Chapter I, Part 5, Section 5.1.52, Table 3]
90 ng/L	NYS standard for protection of human health and drinking water sources [6 NYCRR Parts 700 through 706]
30 ng/L	Federal Water Quality Criterion (FWQC) criteria continuous concentration (CCC) for saltwater [Aroclor-specific 40 CFR § 131.36]
14 ng/L	Federal Water Quality Criterion (FWQC) criteria continuous concentration (CCC) for freshwater [Aroclor-specific 40 CFR § 131.36]
1 ng/L	Federal Ambient Water Quality Criterion for Navigable Waters [40 CFR § 129.105(a)(4)]
0.12 ng/L	NYS standard for protection of wildlife [6 NYCRR Parts 700 through 706]
0.001 ng/L	NYS standard for protection of human consumers of fish [6 NYCRR Parts 700 through 706]

Of these criteria, USEPA waived the three lowest concentration standards (0.001 ng/L to 1 ng/L) due to technical impracticality (USEPA, 2001), as it is technically impractical to reach these concentration levels in the Hudson River with the continuing input from the upstream sources. As long as the water column Total PCB concentrations are below the federal and state MCL (500 ng/L), protection of human health will be achieved. Only the 500 ng/L total PCB standard is not regularly exceeded by the main stem Upper Hudson River stations downstream of Rogers Island under existing (baseline) conditions; therefore, the other ARARs were not applied in the development of the Resuspension Standard. No other chemical-specific criteria were identified as ARARs or To-Be-Considered criteria (TBCs) in the ROD or the RRI/FS *Feasibility Study* (USEPA, 2000b).

As long as the water column PCB concentrations are below the 500 ng/L federal and state MCL, protection of human health will be achieved.

Additional surface water quality criteria were considered for parameters that may be impacted by the remediation. These parameters are pH, dissolved oxygen (DO), and turbidity. NYS guidelines [6 NYCRR Parts 700 through 706] set the following standards:

pH	6.5 to 8.5 for Class A surface water
DO	Not less than a daily average of 6 mg/L for trout bearing waters; not less than 5 mg/L for non-trout bearing waters; and

Turbidity No criteria for surface water

Specific resuspension criteria have not been established for these water quality parameters. The water quality parameter data will be used for comparison to the continuously monitored data at both the near-field and far-field stations. These standards may be used as resuspension criteria in Phase 2, if appropriate.

2.10 Summary of Supporting Analyses

Numerous analyses were completed in support of this performance standard. Review of case studies have provided examples for the way the issue of resuspension of contaminated material has been handled at other sites leading to development of the elements of this standard, including resuspension criteria and monitoring and engineering contingencies. The calculations described suggest that the standard is achievable and, if complied with, will be protective of the environment and human health.

The context for these analyses will be evident in Section 3, Discussion of Rationale. A brief synopsis of the supporting analyses follows.

2.10.1 Turbidity and Suspended Solids at Other Sites

A surrogate measurement of suspended solids concentrations such as turbidity may become an important real-time indicator of PCB concentration levels, if it is proven in Phase 1 that the primary mechanism of contaminant release from the remediation is resuspension of sediment. Turbidity measurements are instantaneous, whereas analyses for suspended solids or PCBs are more time-consuming and limit the time available to warn downstream water supplies in the event of an exceedance of the standard.

Turbidity may become an important real-time indicator of PCB concentration levels, if Phase 1remediation indicate that the primary mechanism of contaminant release is resuspension of sediment.

Case studies were reviewed to provide an indication of turbidity and suspended solids concentrations in the water column and the thresholds that were established at these sites to limit resuspension. Because suspended solids measurements are needed for comparison to resuspension criteria, a correlation must be developed between suspended solids and a surrogate before a surrogate measurement could be used for this purpose. Review of case studies and literature indicates that such correlations are site-specific, have been established at other sites, and could potentially be developed for the Hudson River. The case studies described the configuration of monitors relative to the remedial operations. This information was considered when specifying the near-field monitoring locations required by the standard.

2.10.2 PCB Releases at Other Sites

The case studies also provided information with which to calculate the amount of PCB released from other dredging sites. The rate of loss provides another indication of what a reasonable load-based resuspension criterion would be. These estimates of loss can also be used to determine the average increase in water column concentration during the remediation. Estimated rates of contaminant loss from other sites are 0.13%, 0.36%, and 2.2%.

2.10.3 Hudson River Water Column Concentration Analysis

Approximately five years of baseline water column PCB concentration data are available. Although there are concerns over the quality of these data due to the sampling methods and analytical methods used, estimates of the average expected water column PCB can be made. These values can be compared directly to the PCB concentration-based resuspension criteria to indicate whether, in some months, the PCB concentration may routinely approach the standard, even without the added impact of the suspension. The results indicate that the average PCB water column concentrations will be less than the concentration-based resuspension criteria, although in some months it is expected that the criteria would be exceeded on occasion.

2.10.4 Resuspension Sensitivity Analysis

The resuspension sensitivity analysis was built on the Hudson River water column concentration analyses by adding the estimated increase in concentration for a given increase in PCB load on to the estimated baseline PCB water column concentrations. This analysis suggests that the load-based resuspension criteria will not routinely elevate the water column concentration over the concentration-based criteria. The results indicate that the average PCB water column concentrations during dredging will be less than the concentration-based resuspension criteria, although in some months it is expected that the criteria would be exceeded on occasion. Variability in the water column concentrations may on occasion result in exceedance of the load-based criteria, although the true dredging-related releases are below the 300 g/day and 600 g/day Total PCB limits.

2.10.5 Dissolved-Phase Releases

A dissolved-phase PCB release undetected by a surrogate measure such as turbidity or suspended solids is not possible.

Concerns were raised during the public comment period for the Hudson River ROD that dissolved-phase PCB concentrations could be significant during remediation of PCB-contaminated sediment, and that a release of this kind could not be detected by a surrogate measure such as suspended solids or turbidity. The calculations described in subsection 2.5 indicate that a release of this kind would not be possible without an associated suspended solids release, because the bulk of the PCB contamination is bound to the sediment and there is not a sufficient amount of PCBs dissolved in the pore water to cause a substantial release.

2.10.6 Far-Field Modeling

The impacts of allowing the remediation to continue at the levels indicated by the resuspension criteria were determined through model simulation, using the fate, transport, and bioaccumulation models developed during the Reassessment RI/FS phase for this purpose. The results indicate that operation at the total PCB load-based resuspension criteria, which are the only criteria at which the remediation could operate for extended periods of time, will result in short-term impacts to the environment during the remediation, but will have little impact on the fish tissue concentrations post-dredging. Analysis of a hypothetical accidental release scenario in the vicinity of the Upper Hudson River public water intakes (subsection 2.6.2) indicated that although the concentrations entering the intake would be greater than the MCL, minimal water treatment would be sufficient to reduce the concentrations below the MCL.

2.10.7 Near-Field Modeling

Models of surface water concentrations in the vicinity of the dredge were developed to:

- Determine the amount of PCBs released from the dredging operation.
- Predict the downstream water column concentrations.
- Calculate the area in which the resuspended material would settle and the increase in PCB concentration in that area.
- Identify the appropriate locations for near-field monitoring.

The modeling indicated that the PCBs released by the dredge would be largely suspended phase. The amount of dissolved PCBs increased to a limited extent as the plume traveled downstream, but this process is slow because of the small coefficient of desorption. The relative amount of dissolved-phase to suspended-phase PCBs increases as the solids settle. Settling of contaminated material downstream of the dredge has the potential to raise surface concentrations substantially. This would be of concern if the area were not subsequently dredged, and may indicate the need for containment if this condition were verified. The results of these models suggest both the locations of the far-field and near-field monitoring points relative to the remedial operations and the suspended solids near-field resuspension criteria.

2.10.8 Relationship Among the Resuspension Production, Release, and Export Rates

The Total PCB load-based resuspension criteria were based on engineering judgment and the balance of several factors, including the:

- Best engineering estimate of resuspension production and export.
- Minimum detectable PCB load increase.
- Load defined by the water column concentration criteria.
- Impact of load on fish tissue recovery.
- Delivery of Total PCBs and Tri+ PCBs to the Lower Hudson.

Subsection 2.8 contains a detailed description of the selection process for the load-based criteria. A series of models was used to examine the relationship among the resuspension production, release, and export rates. The model calculations yield an important conclusion concerning the relationship between the resuspension production rate and the performance standard criteria. While the model analysis of the concentrations and loads that comprise the standards show relatively little long-term impact on downstream receptors and conditions, the amount of sediment spillage required to attain these levels is quite large. Spillage at these levels is certainly well beyond what is likely, given standard environmental dredging practices.

2.10.9 Review of Applicable or Relevant and Appropriate Requirements (ARARs)

Federal and state surface water quality guidelines were reviewed to determine if these regulations would provide a concentration level that was achievable during the remediation and protective of human health. The federal and state MCL of 500 ng/L total PCBs met these criteria.

3.0 Rationale for the Standard

3.1 Development of the Basic Goals and Resuspension Criteria

The performance standard for PCB losses due to resuspension is unique among the engineering performance standards in that the basic criteria are not defined in the ROD. Unlike the Production and Residuals Standards that have basic goals defined in the ROD (*i.e.,* approximately 2.65M cubic yards in six years and 1 mg/kg Tri+ PCB, respectively), the performance standard for PCB losses due to resuspension must justify both the ultimate numerical goals as well as the required implementation.

The remedial action objectives (RAOs) provide the ultimate basis for the development of the Resuspension Standard. As discussed in the 2002 ROD (USEPA, 2002a):

> [the] RAOs address the protection of human health and protection of the environment. (ROD § 9.1, page 50)

The RAO specifically addressed by this Resuspension Standard is the following:

> Minimize the long-term downstream transport of PCBs in the river. (ROD § 9.1, page 51)

In the ROD, the goal of the Resuspension Standard for PCB losses is defined in the following context:

> …Analysis of yearly sediment resuspension rates, as well as resuspension quantities during yearly high flow events, shows the expected resuspension due to dredging to be well within the variability that normally occurs on a yearly basis. The performance standards and attendant monitoring program, that are developed and peer reviewed during design, will ensure that dredging operations are performed in the most efficacious manner, consistent with the environmental and public health goals of the project. (ROD § 11.5, page 85)

And again:

> …Sampling and monitoring programs will be developed and implemented during the design, construction and post-construction phases to…determine releases during dredging…. These monitoring programs will include sampling of biota, water and sediment such that both short- and long-term impacts to the Upper and Lower Hudson River environs, as a result of the remedial actions undertaken, can be determined and evaluated. EPA will increase monitoring of water supply intakes during each project construction phase to identify and address possible impacts on water supplies drawn for drinking water. The locations, frequency and other aspects of monitoring of the water supplies in the Upper and Lower

> Hudson will be developed with public input and in consultation with New York State during remedial design. (ROD § 13.3, page 99)

Controlling the export of PCBs during the remediation will keep the water column concentrations close to current baseline levels and, by extension, keep fish tissue concentrations close to baseline levels during the remediation. In short, the goal of the standard is to ***minimize PCB losses during dredging to reduce risks to human and ecological health by controlling PCB exposure concentrations in drinking water and fish tissue.***

3.1.1 Development of Water Column Concentration Criteria for PCBs

As discussed in subsection 2.9, there are seven applicable chemical-specific ARARs for PCBs. Of these, the three lowest concentration standards (0.001 ng/L to 1 ng/L Total PCBs) were waived in the ROD, because it is technically impractical to reach theses levels in the Hudson River with continuing input from the upstream sources. Three of the remaining ARARs are concentrations that fall within the range of baseline conditions (14 ng/L to 90 ng/L Total PCBs) and cannot be considered for resuspension criteria during the remediation.

Only the 500 ng/L Total PCB MCL is a practical limit for use as a resuspension criterion, because this concentration generally falls outside of the baseline concentrations. The standard is written to permit a short-term increase in water column concentrations as long as the long-term goals of the remedy as defined in the ROD are met.

Only the 500 ng/L Total PCB MCL is a practical limit for use as a resuspension criterion, because this concentration generally falls outside of the baseline concentrations.

The river sediments are currently the primary source of the contamination in the Upper Hudson River and the removal of sediments is essential for the long-term benefit of the river. Additionally, removal of PCB-contaminated sediments will provide benefit to the remediated portions of the river during the remediation. As such, a limited amount of resuspension will be permitted because the benefits to the river outweigh the short-term impacts from dredging. This is consistent with the USEPA sediment principles recently promulgated by the Office of Solid Waste and Emergency Response (USEPA, 2002c).

Best management practices (BMPs) were considered as a basis for the standard. BMPs that could be implemented include structural and non-structural practices. Structural practices include:

- Containment.
- Shoreline restoration.
- Placement of backfill prior to removal of containment.

Non-structural practices include:

- Cessation of work at velocities above a set rate.
- Minimization of the use of boats with the potential to produce significant prop wash.

Structural practices are not required by this standard, because the locations where there is need for these practices should be identified during the design, when all available data can be fully analyzed. Similarly for non-structural practices, these requirements are specific to the equipment chosen and specific local conditions and are better set as requirements during the design. The cost, impact on productivity, and effectiveness of these practices should be carefully weighed prior to setting these requirements. It is expected that the design will include some best management practices to achieve compliance with the standard, but these will not be specifically required by the standard. Ulitimately, this standard is peformance-based and not prescriptive so as to encourage engineering innovation to protect the environment, optimize operations and complete the remediation as quickly as possible.

The most important ARAR for drinking water supplies is the federal maximum contamination limit, or MCL, for drinking water supplies, 500 ng/L Total PCBs[4]. This ARAR establishes the first of two objectives for the Resuspension Standard:

3.1.1.1 Objective 1 Development of Primary Criteria for Drinking Water

Drinking Water: Maintain PCB concentrations in raw water at drinking water intakes at levels less than the federal MCL of 500 ng/L.

The Resuspension Standard takes a conservative approach and is structured to achieve acceptable water column concentrations in raw water, regardless of WTP capability.

Objective 1 establishes a numerical limit on PCB concentrations in the Upper Hudson. Adherence to this level provides assurance that no public water supplies will be adversely impacted by the remediation, regardless of a given water treatment plant's (WTP's) ability to treat PCB-bearing water. Most of the WTPs potentially affected by the remediation have treatment systems that can reduce the concentration of PCBs in the finished water, although the current degree of reduction is unknown. For this reason, this standard will take the more conservative approach and not rely on this capability. Instead, this standard will be structured such that compliance with the standard achieves acceptable water column concentrations in the raw water.

Based on this objective, PCB export must be sufficiently controlled so as to prevent exceedance of the 500 ng/L Total PCBs level at the water supply intakes at Waterford and Halfmoon, New York, the first public water supply intakes downstream of the remedial areas. While dilution and degradation can be expected to reduce PCB concentrations in the water column during transit from River Sections 1 and 2 to the

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[4] The New York State MCL is also 0.0005 mg/L Total PCBs (500 ng/L).

public water intakes, these processes cannot be relied upon while dredging in River Section 3. Thus, dredging in River Section 3 requires that PCB export due to dredging not result in water column concentrations in excess of the federal MCL. As a conservative approach for the protection of the water supplies, this same concentration level (500 ng/L Total PCB) is applied at all far-field monitoring locations and is the standard for water column concentrations (*i.e.*, the Resuspension Standard threshold).

An action level concentration limit of 350 ng/L, below the 500 ng/L federal MCL, will serve as a trigger for additional monitoring and engineering controls.

An action level criterion was also derived from Objective 1. Although the 500 ng/L level represents a level not to be exceeded, there is need for an action level below the MCL. Specifically, it is desirable to keep water column concentrations below the federal MCL while still meeting the productivity goals of the remedial operation. To this end, a second concentration limit of 350 ng/L Total PCBs was established. This value represents 70% of the MCL value and serves as a trigger for additional monitoring. This limit can also be derived from statistical considerations based on the variability of the water column concentrations and the analytical uncertainty in the PCB measurements, as described below.

No estimate exists of the likely variability of water column PCB concentrations in the Upper Hudson due to dredging. The variability of baseline conditions can be substituted as an initial estimate, or surrogate, although it is likely that dredging-related variability will be greater than the baseline variability. For the analysis that follows, the baseline variability of the Schuylerville station will be used. In order to scale this variability, the ratio of the standard deviation to the mean, (*i.e.*, the coefficient of variance $\left\lfloor \frac{\sigma}{\overline{\overline{X}}} \right\rfloor$) will be used. For this location, based on the GE data set, the coefficient of variance (CV) is approximately 0.35. The 95th percentile is approximately 2 CVs, or 0.70 of the value. For the value of 500 ng/L Total PCB, this represents ± 350 ng/L Total PCB with a lower 95th percentile of 150 ng/L.

As can be seen in the table of baseline data in Table 3-1, this value is near or within the range of baseline variability and is thus not useful as an action level threshold.

As an alternative, it is also possible to determine a value that has no more than a 5% probability that the actual value is 500 ng/L Total PCB. That is, determine a threshold value based on the same CV such that 500 ng/L is the 95th percentile upper bound.

This is given as:

$$Y + 0.7 * Y = 500$$

where

Y = the threshold value

0.7 = 2*CV.

In this case, Y has a value of 294 ng/L, lower than the selected value of 350 ng/L.

If the Control Level were to require a response based on a single value, then this value, nominally 300 ng/L, might be a preferable choice over 350 ng//L. However, the Control Level is based on a one-week average, representing the mean of seven measurements. For an average, the upper and lower bounds are based on the standard error and not the standard deviation.

The ratio of the standard error (SE) to the mean becomes

$$\frac{SE}{\overline{X}} = \frac{\sigma / \sqrt{7}}{\overline{X}} = \frac{C_V}{\sqrt{7}} = \frac{0.35}{2.65} = 0.13$$

where 7 is the number of samples in the seven-day running average. In this instance, the equation for the threshold value using 2*SE becomes:

$$Y + 0.26 * Y = 500$$

This yields a threshold value of 397 ng/L. The selected value of 350 ng/L falls in the center of the two threshold estimates and is considered a good initial value for the program, given the unknown variance associated with dredging-related PCB concentrations.

Analytical precision must also be considered as it pertains to water column measurements. The precision of the historical analyses is quite good. At the Schuylerville station, the historical blind duplicate pairs yielded a median relative percent difference (RPD) of 8.1% and a mean RPD of 12.7% (see Figure 3-1). Ninety percent of all pairs had an RPD less than 22%. For an actual concentration of 350 ng/L, the mean RPD would suggest a possible analytical range of uncertainty of 328 ng/L to 372 ng/L (actual value + RPD/2). On this basis, the analytical variability should not limit the applicability of the 350 ng/L threshold value.

Engineering evaluations and improvements are required if the average concentration increase is 350 ng/L or higher for a week. These activities are required to identify and correct any potential problems that may cause a subsequent exceedance of the federal MCL, thus causing a possible disruption in the operations and requiring contingency actions on the part of the municipal water suppliers. This concentration threshold is defined as a Control Level criterion.

Compliance with these resuspension criteria at the far-field stations attains the objective and protects public water supplies during the remedial efforts. These criteria are designed to limit short-term impacts, since the river will deliver any resuspended PCBs to the downstream water supplies at Waterford and Halfmoon in a matter of days. However, the ROD clearly is also concerned with the impacts to fish and downstream consumers of fish. This concern requires a longer perspective, since fish integrate their exposure to PCBs over both time and area. Thus, fish tissue concentrations are likely to be more affected by a long, steady loss of PCBs than a single large release event. A second objective can be defined specific to this issue, as discussed in the following section.

3.1.1.2 Objective 2 Development of Primary Criteria for PCB Loads

Fish Tissue: Minimize long-term net export of PCBs from dredged areas to control temporary increases in fish tissue concentrations.

Short-term release of PCBs can be tolerated as long as the long-term average continues to satisfy the Resuspension Standard criteria.

Objective 2 addresses the need to limit the impact of the remediation on the anticipated recovery of river after the remedial dredging is completed. This objective recognizes that the export of PCBs during dredging has the potential to slow the rate of recovery for fish body burdens and related exposures if it is sufficiently large. However, this objective also recognizes that it is primarily the long-term release of PCBs that has the potential to create an adverse impact. Short-term releases can be tolerated so long as the long-term average continues to satisfy the criteria.

In general, short-term releases are of the time scale of hours to days, while long-term releases are considered in terms of several weeks to months or longer. Thus, from the perspective of the ROD, the short-term releases are manageable so long as the eventual recovery of the river is not compromised. As noted in the ROD (USEPA 2002a):

> Although precautions to minimize resuspension will be taken, it is likely that there will be localized temporary increases in suspended PCB concentrations in the water column and possibly on fish PCB body burdens. (ROD § 11.5, page 85)

This objective can be approached from two perspectives:

- Ideal rate of PCB export
- Acceptable maximum rate of PCB export

The ideal rate is obviously no PCB release at all. However, this is also unattainable. The case study analysis presented in subsection 2.2 and the resuspension analysis presented in the RS (USEPA, 2002b) provide some useful target values, however. The two sites examined in subsection 2.2, the GE Hudson Falls remediation and the New Bedford Harbor Hot Spot remediation, achieved net PCB export rates of 0.36% and 0.13%, respectively, relative to the mass of PCBs removed. These percentages translate to Total PCB resuspension export rates of 240 and 86 g/day of operation, or 50 and 18 kg/yr on an annual basis for the remediation of the Hudson, respectively. These annual values represent only a small fraction of the annual baseline load of 260 to 400 kg/yr observed for the period 1996-2002 (see Figure 7 of Attachment B). Export at this level is unlikely to have any discernable impact on fish tissue concentrations, given the baseline variability.

In developing the load criteria for the standard, several different perspectives were examined to make the standard meaningful (*i.e.*, not too high) and achievable (*i.e.*, not too low). These include the following:

- Best engineering estimate of resuspension production and export
- Minimum detectable PCB load increase
- Loads defined by the water column concentration criteria of 350 and 500 ng/L Total PCBs
- Impact of load on fish tissue recovery
- Delivery of Total PCBs and Tri+ PCBs to the Lower Hudson (*i.e.*, Waterford load)

Each of these perspectives has the potential to provide some level of constraint on the selection of a PCB load criterion. Each is discussed below.

Best Engineering Estimate of Resuspension Production and Export

The best engineering estimate in the FS and RS estimated a Total PCB export rate of approximately 86 g/day (18 kg/yr), or 0.13% of the PCB mass to be removed from the river bottom.

The analysis presented in Appendix E.6 of the feasibility study (USEPA, 2000b) and in the responsiveness summary (USEPA, 2002b) provided an initial engineering estimate of the rate of PCB release from the dredge operation. The analysis estimated a resuspension production rate and a resuspension release rate, yielding an estimated Total PCB export rate of approximately 86 g/day (18 kg annually), or 0.13% of the PCB mass to be removed from the river bottom (69,800 kg).

The best engineering estimate analysis for the Resuspension Standard estimates a Total PCB export rate of approximately 90 g/day (19 kg/yr) or 0.14% of the PCB mass to be removed from the river bottom – only slightly higher.

In the preparation of the Resuspension Standard, the initial model analysis of suspended solids transport has been expanded and improved to more realistically represent conditions as well as to account for the kinetics of PCB dissolution. These results were discussed previously in subsection 2.7, and a detailed discussion is provided in Attachment D. These analyses confirm the results initially presented in the FS (USEPA, 2000b). The current analysis estimates a PCB export rate only slightly greater than the original estimate, at 90 g/day (19 kg annually[5]) or about 0.14% of the PCB mass to be removed. Based on these results, a best engineering estimate of approximately 20 kg per dredging season was selected as the target load value.

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[5] The target PCB export rate of 19 kg/year represents a daily resuspension export rate of 90 g/day, assuming a 210-day dredging season (May through November) and seven days per week of operation. This is conservative in that operations less than seven days per week would effectively result in lower average daily export rates.

Although a target level of 90 g/day Total PCB would appear a desirable target (the analysis presented in the FS shows this loading rate to have a negligible[6] impact on the recovery of fish tissue concentrations throughout the river), this value does not account for activities other than the dredge operation. Boat movements, debris removal, barrier installation and removal, and other activities related to the dredging operation all have the potential to release PCBs, but are difficult to quantitate. Hence, a set of criteria is needed to define reasonable upper limits for dredging-related releases based on estimated impacts to the river. Much of the analysis described in subsection 2.2 was completed with the intention of providing input to the selection of these limits.

Minimum Detectable PCB Load Increase

An important limitation in selecting the PCB load criteria is the ability to measure the net increase in load due to dredging activities. Several considerations must be addressed in this regard. The selection of the far-field locations as the main PCB monitoring locations is a direct result of this concern. Baseline loads of PCBs originating from the sediments are similar in magnitude to those expected from dredging. Much of the sediment initially added to the water column will rapidly settle, releasing little or no PCBs. Hence the ability to detect a net PCB load increase in the poorly mixed region around the dredge operation (*i.e.*, at the near-field monitoring stations) is difficult and highly uncertain. For this reason, PCB monitoring will be conducted well away from the dredging operation (*i.e.*, far-field monitoring), where the net PCB load should be more stable and can be detected over baseline conditions.

Because it is unlikely that PCB export below 300 g/day (65 kg Total PCBs per yr) can be differentiated from baseline conditions, this value represents the minimum observable PCB export rate, or load.

As discussed in subsection 2.4 and Attachment B, this approach does have a limit on the ability to measure PCB export at a far-field station. Based on the historical variability observed in the available data, it is unlikely that PCB export below 300 g/day (65 kg Total PCBs annually[7]) can be differentiated from baseline conditions. This value then provides a minimum observable PCB export rate or load. Notably, the target load for PCB export due to dredging previously provided falls below the detectable load rate. Thus, if the best engineering estimate of an approximate 20 kg/dredging season export rate is achieved, there will be no measurable increase in PCB export. From a monitoring perspective, the goal for dredging is no observable increase in PCB load above baseline.

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[6] A negligible impact in the Upper Hudson is defined as a forecast fish tissue concentration difference relative to the no-resuspension dredging scenario of 0.5 mg/kg or less within 5 years after the cessation of dredging.

[7] This rate of PCB export corresponds to slightly less than 0.5% of the estimated mass of PCBs to be removed.

Loads Defined by the Water Column Concentration Criteria of 350 and 500 ng/L Total PCBs

The federal MCL provides a means to obtain an upper bound on the annual and daily load rate. If daily Total PCB concentrations remain at a monthly average concentration of 500 ng/L throughout the dredging season, the PCB export load can be calculated from the difference between 500 ng/L and the average baseline concentration for the month. This calculation yields an export rate of about 2,300 g/day (500 kg annually[8]). The 350 ng/L Total PCB resuspension criterion also provides a basis for a loading estimate.

1,600 g/day (340 kg annually) represents the likely maximum load derived from water column concentration criteria.

To maintain a weekly average concentration of 350 ng/L Total PCBs, the resuspension export rate must be approximately 1,600 g/day (340 kg annually[9]). For the purposes of this standard, the Control Level is expected to be the maximum operating condition, since concentrations above this level will require engineering improvements to reduce the releases. From this consideration, 1,600 g/day (340 kg annually) represents the likely maximum annual load that can be derived from the water column concentration criteria. This level cannot be maintained indefinitely, however, because the load-based limits are set at lower values [600 g/day].

Impact of Load on Fish Tissue Recovery

The ability to measure a net increase in PCB export relative to baseline conditions and the water concentration criteria provide potential bounding criteria for an acceptable export rate. However, it is still necessary to demonstrate that export rates at these levels do not substantively alter the recovery period of the river as measured by the decline in PCB concentrations in fish tissue. The model simulation for the best engineering estimate for resuspension presented in the responsiveness summary is the basis for comparison[10]. To investigate this, a series of model forecasts were conducted at resuspension release rates (near-field) and resuspension export rates (far-field) derived from the load considerations discussed in the foregoing subsections. The model runs dealing with long-range forecasts are summarized in subsection 2.6. The near-field model analysis is summarized in subsection 2.7. A complete discussion of the supporting model analyses is provided in Attachment D. Table 2-4 lists the completed model runs along with brief descriptive information.

Due to the inherent nature of the HUDTOX model structures, PCB loads cannot be readily specified at far-field locations. Rather, the input of PCBs is specified as an input load at a location within the river, equivalent to a resuspension release rate. For the

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[8] This rate of PCB export corresponds to about 3.8% of the PCB mass to be removed.

[9] This rate of PCB export corresponds to about 2.4% of the PCB mass to be removed.

[10] Since the completion of the Feasibility Study, various factors and considerations have lead to a suggested start date for the remediation of 2006, instead of 2004 as originally planned. Since the best estimate simulation prepared for the Feasibility Study was barely discernable above the “no resuspension” simulation, the simulations prepared here were simply compared against a revised “no resuspension” result, reflecting the later start date. The 90 g/day best estimate condition was not rerun.

supporting model runs, the resuspension release rate was derived iteratively, by estimating the resuspension release rate (input to the model) and then checking the resuspension export rate (the model output) until the model output met the desired criteria. This process was necessary in order to make the model match the potential control criteria at the planned monitoring locations. These iterations also took into account the different river sections, with their corresponding target sediment properties (*i.e.*, silt fraction), PCB concentrations and hydrodynamics. The simulations also account for the changes in dredging location as the remediation progresses.

For example, to simulate the 350 ng/L Total PCB condition (*i.e.*, the Control Level threshold for the entire dredging program), it was necessary to provide the following loads in the three river sections:

- River Section 1: approximately 1,550 g/day Total PCBs and 56,000 kg/day of sediment
- River Section 2: approximately 2,300 g/day Total PCBs and 35,000 kg/day of sediment
- River Section 3: approximately 2,800 g/day Total PCB and 94,500 kg/day of sediments.[11]

These PCB and sediment loads reflect the differences in PCB concentration, river flow and monitoring locations among the three river sections. PCB and sediment loads had to be further varied to reflect the year-to-year movements of the dredges within each river section. As would be expected, less resuspension was necessary to achieve a specified PCB concentration or load at the far-field station the closer the dredge was to the station.

Model simulations for the 350 ng/L Total PCBs scenario were run to examine the impact of this criterion on the recovery of the river, using the recovery of fish tissue concentrations as the main measure (see Figures 2-8 and 2-9). This scenario showed some fish body burden increases during dredging but negligible[12] changes to fish tissue trajectories during the post-dredging period. After noting the negligible impact of the 350 ng/L scenario, there was no need to run a 300 g/day scenario since its impact would clearly be much less.

A 600 g/day Total PCBs scenario was run, based on its selection as a load criterion (see below). As expected, the 350 ng/L scenario has a greater impact than the 600 g/day scenario. However, both model runs indicate negligible[13] changes in fish tissue concentrations in regions downstream of the dredging. Within five years of the

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[11] To put the suspended solids values in perspective, at a nominal flow rate of 4,000 cfs and 2 to 4 mg/L of suspended solids, the Hudson transports 20,000 to 40,000 kg of solids per day, respectively.

[12] A negligible impact in the Upper Hudson is defined as a forecast fish tissue concentration difference relative to the no-resuspension dredging scenario of 0.5 mg/kg or less within 5 years after the cessation of dredging. In the Lower Hudson, it is defined as a forecast fish tissue concentration difference relative to the no-resuspension dredging scenario of 0.05 mg/kg or less within 15 years after the cessation of dredging. Note that in the Lower Hudson, fish tissue concentration forecasts always agree within 0.5 mg/kg except for one year during the dredging period for the 350 ng/L scenario at River Mile 152.

[13] See footnote 12.

completion of dredging there is little discernable impact from the dredging releases based on the fish tissue forecasts. The model results suggest that compliance with the water concentration criteria previously developed (*i.e.*, 350 ng/L and 500 ng/L) will also minimize dredging impacts to the long-term recovery of the river.

Within five years of completion of dredging, there is little discernable impact from dredging releases, based on the fish tissue forecasts.

Delivery of Total PCBs and Tri+ PCBs to the Lower Hudson

In addition to recovery of the river as measured by fish tissue concentrations, impacts to the river due to dredging can also be gauged by the absolute mass of PCBs released. For this comparison, both Total PCBs and Tri+ PCBs are considered. The emphasis is placed on the estimated Tri+ PCB releases, however, since this is the fraction of PCBs that is bioaccumulative. This fraction is also far better understood from the perspective of sediment inventory and geochemical processes (the USEPA models simulate Tri+ PCBs).

As noted previously, the main consideration in developing a load standard is to minimize the release of PCBs. For this reason, the cumulative PCB load at Waterford, as forecast by the HUDTOX model, provides a useful gauge of any suggested loading standard. In this instance, the ideal condition is that given by the no resuspension scenario for the selected remedy. The upper bound would be the load delivered by the original monitored natural attenuation scenario (MNA). The forecast for acceptable load criteria would fall between the MNA and the no resuspension scenario.

The Tri+ PCB load forecasts for several load conditions are presented in Figure 2-4. The lowest curve, representing the least amount of PCBs transported downstream, represents the no resuspension scenario. MNA is also indicated on the figure. Because of the dredging-related PCB releases, all scenarios except no resuspension exceed the MNA forecast during the dredging period. Unlike the lower PCB release scenarios (see the upper diagram in Figure 2-4), the forecast curve corresponding to the 350 ng/L criteria never crosses over the MNA curve, indicating that setting the loading standard on the basis of this water concentration criterion would deliver significantly more Tri+ PCB mass to the Lower Hudson than MNA.

The 300 g/day scenario, equivalent to 100 g/day Tri+ PCBs (run to 2020), crosses the MNA curve just before the cessation of dredging. While this scenario was not run for the full forecast period, it is evident that the Tri+ PCB load level for the 300 g/day scenario would deliver much less Tri+ than the MNA. Also shown on the figure is a forecast curve for a Tri+ PCB load for the 600 g/day scenario, equivalent to 200 g/day Tri+ PCBs[14]. This curve also crosses the MNA forecast, just after the completion of dredging. On the basis of this analysis, both the 300 and a 600 g/day load standards would yield acceptable Tri+ PCB loads to the Lower Hudson.

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[14] This load is equivalent to 130 kg/year of Total PCB and 44 kg/yr of Tri + PCBs, or slightly less than 1% of the estimated mass of Total PCBs to be removed.

The impacts of the possible load criteria were also examined for Total PCBs, as illustrated in the lower diagram of Figure 2-4. These Total PCB curves are considered less certain, since the EPA models were developed to simulate Tri+ PCBs and not Total PCBs. Nonetheless they provide some guidance. The results from this analysis also show an unacceptably high Total PCB load to the Lower Hudson, based on the 350 ng/L criterion. Both the 300 and the 600 g/day forecasts show less total load delivered to the Lower Hudson than MNA, although the equivalence points occur later in time. The 600 g/day forecast crosses MNA about 20 years after the completion of dredging. The overall load difference between the 600 g/day scenario and MNA is relatively small, such that an increase in the daily load to 700 g/day would probably exceed the MNA curve. Given the uncertainties in the Total PCB estimates, the Tri+ PCB forecasts are considered the more reliable gauge among these scenarios.

Selection of a Load-Based Criterion

Taking into account the various considerations described above, it is clear that the target load of 90 g/day is not measurable, and the load equivalent to 350 ng/L delivers an unacceptably large mass of PCBs to the Lower Hudson. None of the load scenarios chosen as criteria yield an unacceptable impact on fish tissue concentrations, so this gauge is not useful here. The need to control PCB loads to the Lower Hudson provides the strictest limitation in the selection of a load criterion. This criterion is primarily based on Tri+ PCBs, the form of PCBs simulated by USEPA's models. Total PCB restrictions are more uncertain in this regard since they were not the focus of USEPA's models.

While no exact value results from this analysis, it is clear that the loading standard must fall between the ability to measure it (*i.e.*, 300 g Total PCBs/day detection threshold) and the 350 ng/L-based load of 1,600 g/day, which results in unacceptable loads to the Lower Hudson.

The loading standard must fall between the ability to measure – 300 g Total PCBs/day) and the 350 ng/L-based load of 1,600 g/day that results in unacceptable loads to the Lower Hudson.

A load of 300 g Total PCBs/day has been selected as a resuspension criterion, because it represents a best management practices goal. A load of 600 g/day, representing 130 kg annually, is the daily equivalent of the maximum allowable annual load and is also selected as a load criterion. It is twice the load detection threshold and therefore measurable. It is less than the 350 ng/L – 1,600 g/day condition and results in acceptable Tri+ and Total PCB load increases to the Lower Hudson.[15] In term of absolute loads, the 130 kg/year represents slightly more than a 40% increase in the mean annual load at Schuylerville (300 kg/yr for 1998-2002). Added to this value, the load increase would yield 430 kg/yr, which is just beyond the observed range at Schuylerville between 1998 and 2002 (180 to 410 kg/yr).

Relative to TI Dam loads, this 600 g/day load increase represents a 40% to 90% increase in the observed loads (TID West and TID-PRW, respectively) for 1996 to 2002. More importantly though, this load represents a nearly seven-fold increase relative to the best

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[15] As was noted previously, the Total PCB load is not considered a robust constraint due to its uncertainty.

engineering estimate of 90 g/day, thus providing a reasonable allowance for other dredging-related releases (*e.g.*, boat traffic and debris removal). Yet as noted above, this load increment would have negligible[16] impacts on the long-term river recovery, generating only brief (one-to-two-year) increases in fish tissue concentrations relative to the MNA scenario.

Based on these considerations, the value of 600 g/day has been selected as the primary load criterion: 600 g/day is equivalent to 650 kg load loss over the entire remediation and 65 kg/yr in Phase 1 assuming half the targeted production rate will be achieved.

600 g/day, the daily equivalent of a 650 kg load loss over the entire remediaion and 65 kg/yr in Phase 1, has been selected as the primary load criterion.

Long-term maximum load loss limits of 650 kg Total PCBs and 220 kg Tri+ PCBs for the entire remediation have been derived from review of the model predictions. Adherence to these limits is important for the recovery of the river and protection of the Lower Hudson River. These limits have not been included as resuspension criteria directly, because these are end-of-remediation goals that do not fit within the performance standard structure. Indirectly these limits are implemented over shorter times frames, with daily limits for Total PCBs and Tri+ PCBs at 600 g/day and 200 g/day, respectively, and Phase 1 dredge season and annual limits of 65 kg and 22 kg, respectively, for the Phase 1 dredge season. As long as the load-based resuspension criteria are adhered to, the long-term load loss limit will not be exceeded.

Because Tri+ PCBs are the most important component of Total PCBs for the recovery of fish tissue concentrations, a load criterion is desired for this parameter as well. This criterion is simply derived from the Total PCB load criterion and the observation that the Total PCB to Tri+ PCBs ratio in the sediments is approximately 3:1. Since sediments are the main form of release of PCBs, it is expected that the net addition of Tri+ PCBs will be one-third that of Total PCBs, yielding a primary criterion for Tri+ PCBs of 200 g/day.

The primary load criterion for Tri+ PCBs is 200 g/day, one-third that of Total PCBs.

The last consideration for selecting the load-based criteria is the time frame over which these apply. Taking into consideration the long-term nature of the load impacts and the likely high degree of short-term variability, the criteria should be based on longer-term conditions in order to avoid major disruptions to the operation due to short-term exceedances. For this reason, the Evaluation Level and Control Level load criteria will be measured over seven-day periods by constructing a running average of Tri+ and Total PCB loads at all far-field stations for the entire dredging season.

Evaluation and Control Level load criteria will be measured over 7-day periods by constructing a running average of Tri+ and Total PCB loads at all far-field stations for the entire dredging season.

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[16] A negligible effect in the Upper Hudson is defined as a forecast fish tissue concentration difference relative to the no-resuspension dredging scenario of 0.5 mg/kg or less within 5 years after the cessation of dredging.

3.2 Rationale for a Tiered Approach

A tiered approach provides for additional sampling and appropriate engineering controls as PCB levels rise, thereby avoiding the need to cease dredging operations.

The actions levels (Evaluation Level, and Control Level) were developed to facilitate a steady level of remedial activities while still providing environmental protection. The tiered approach is intended to require additional sampling and engineering controls as PCB levels rise above those predicted by the best engineering analysis. This tiered approach provides action levels to trigger monitoring contingencies and implementation of additional engineering controls and thereby avoid a complete cessation in the operation. It is the intention of this standard to both minimize PCB losses and facilitate uninterrupted remedial operations.

In this approach, monitoring requirements will increase as the action levels are exceeded to provide data to clarify the nature of the PCB losses. These data can then be used to direct engineering control improvements while dredging operations continue unabated. The monitoring requirements will have no effect on dredging operations and productivity since there is no affect on the equipment and crews involved.

3.2.1 PCB Considerations

In developing the tiers of the standard, the need to control PCB export must be balanced with the need to comply with the federal standard. As extensively discussed in Attachments A and B, baseline water column PCB concentrations vary from month to month, necessarily complicating the structure of the standard. Based on these concerns, the PCB component of the Evaluation Level is a flux-based action level. The Control Level has both flux-based and concentration-based PCB criteria. Exceedance of absolute concentrations for the flux-based criteria at the Evaluation Level is not a concern in this instance. The purpose of the Evaluation Level is to control PCB export and potential long-term impacts to the recovery of the river.

The PCB concentration-based criterion of 350 ng/L is included in the Control Level to address the concern over exposure to PCBs through public water supplies as the MCL is approached. The duration for the exceedance is one week, based on a seven-day average in acknowledgement of the anticipated variability in water column conditions. As previously discussed, the federal MCL of 500 ng/L Total PCBs represents an absolute maximum concentration, the exceedance of which will cause the temporary halting of the remedial operations following confirmation of the concentration.

Exceedance of the Control Level 350 ng/L Total PCBs means the MCL is being approached and serves as an effective trigger for engineering controls.

The Control Level at 350 ng/L Total PCBs will be the effective maximum allowable level, since exceedance of this level means that the absolute maximum is being approached and that extra efforts are required to control PCB export. By requiring operations to maintain water column conditions below this value (350 ng/L Total PCBs), the Control Level provides a relatively large window of protection, decreasing the likelihood of a 500 ng/L Total PCB event.

When concentrations exceed 350 ng/L Total PCBs on average for one week or more, engineering evaluations and engineering improvements become mandatory until riverine conditions falling below the Control Level are achieved. Notably, months with high baseline concentrations will have relatively little “room to spare” and may require tight controls on the dredging operations to comply with this criterion. Exceedance of the Control Level may prompt temporary cessation of operations as deemed necessary by USEPA.

The monitoring and engineering requirements of the Control Level reflect the gravity of the exceedances. The increased sampling frequency is needed to have sufficient confidence in the results. These results may prompt costly engineering improvements if exceedance of the criteria is demonstrated. Extensive monitoring requirements and mandatory engineering controls are needed at this level to quickly identify the problems and render a solution, thereby avoiding a cessation of the dredging operation.

Exceedance of the 500 ng/L Total PCBs Resuspension Standard threshold requires cessation of operations if confirmed by sampling.

Exceedance of the Resuspension Standard threshold (500 ng/L Total PCBs) will require a cessation of operations if the exceedance is confirmed by samples collected the following day. If dredging-related PCB concentrations and loads increase gradually, there should have been at least two attempts (one for each of the two lower action levels) to understand and control any resuspension problem prior to the exceedance of the 500 ng/L threshold. Alternatively, a rapid rise in PCB concentration from baseline to more than 500 ng/L represents an unexpected and poorly understood event. In either case (*i.e.,* exceedance of the Resuspension Standard threshold), temporary halting of operations is required since conditions are clearly not as anticipated and may have significant consequences.

3.2.2 Suspended Solids Considerations

While PCB concentrations and loads are clearly the most important focus of this standard, determination of PCB conditions in the river is time-consuming, with a significant lag between the collection of samples and the availability of preliminary (draft) data. For this reason, it is desirable to measure and monitor parameters that correlate with PCBs and can be determined readily. Suspended solids, in particular, fit this requirement and have been selected for monitoring as well. Suspended solids measurements are reflective of short-term conditions, since the concentrations will vary rapidly in response to sediment disturbances. For this reason the suspended solids criteria will be derived from the water column concentration criteria described in subsection

3.1.1. Acceptable suspended solids concentrations were developed for both near-field and far-field conditions.

To further support the development of the suspended solids criteria, near-field conditions were simulated using a Gaussian plume model (TSS-Chem) to estimate the impact of various resuspension release rates. This analysis, summarized in subsection 2.7 and described in Attachment D, indicates that resuspension release rates corresponding to PCB loads of 300 to 2,000 g/day are rapidly reduced in the near-field region, with resulting PCB export rates at the far-field stations two to six times less than the release rates.

Resuspension release rates corresponding to PCB loads of 300 to 2,000 g/day are rapidly reduced in the near-field region, with resulting PCB export rates at the far-field stations 2 to 6 times less.

This analysis included an estimation of kinetically controlled PCB desorption, suggesting relatively minimal rates of dissolved-phase PCB release in the immediate vicinity of the dredge. In the region between 10 and 1,000 m downstream of the dredge, PCB loads steadily diminish while gradually decreasing the fraction borne by suspended matter relative to the dissolved phase. At the point of departure from the near-field region, PCB loads are primarily dissolved-phase, but overall the loads are substantively reduced compared to the immediate dredge area.

It can be concluded that downstream export of PCBs (at one mile beyond the dredge operation) is unlikely to exceed the 300 g/day Total PCB Control Level on a regular basis. Furthermore, the analysis of suspended solids release and PCB desorption, presented in subsection 2.5 and Attachment C, indicates the resuspension process alone controls the PCB release within the dredging region. The creation of dissolved-phase releases by processes other than PCB desorption from suspended solids is highly unlikely, further supporting the focus of this performance standard on solids-related release mechanisms. This assumption will be tested by the separate phase PCB analyses to be completed as part of a special study.

Analysis supports focusing the Resuspension Standard on solids-related release mechanisms, as it is apparent that the resuspension process alone controls PCB release within the dredging region.

Suspended solids criteria were developed for the Evaluation and Control Levels to provide a means to identify potentially significant PCB releases more rapidly. In most instances, suspended solids exceedances will necessitate additional PCB monitoring, which in turn should identify whether the PCB criteria are being exceeded. While these suspended solids criteria will require additional monitoring, it is the PCB concentrations, not the suspended solids concentrations, that will trigger the need for additional engineering controls. The additional monitoring will be limited to the far-field monitoring requirements for the nearest representative far-field station, with the sampling timed to capture the plume causing the exceedance. Near-field suspended solids sampling frequency will remain as a continuous surrogate measurement (turbidity) with an added suspended solids measurement (*i.e.*, 2 samples per day) to be obtained only at the noncompliant nodes..

3.2.3 Near-field Suspended Solids Criteria

Derivation of the suspended solids action levels is described in detail in Attachment D and briefly summarized here. The near-field suspended solids action levels were derived using the TSS-Chem model to simulate suspended solids conditions corresponding to the PCB concentration resuspension criteria.

The same suspended solids values are used for both the Evaluation and Control Level; only the duration of the exceedance varies between the levels.

For the Evaluation and Control Levels, suspended solids thresholds represent average suspended solids concentrations 300 m downstream of the dredge that would yield a Total PCB concentration exceeding 350 ng/L at the far-field station. The same suspended solids values are used for both action levels; only the duration of the exceedance varies between the levels. This was done to simplify the monitoring while still maintaining the ability to identify significant events.

A location of 300 m downstream was selected since the model suggests a plume width of 50 m and a relatively homogeneous water column at this distance. At this distance, it should be easy to reliably maintain a sensor in the plume and also minimize moment-to-moment variability in suspended solids measurements. If barriers are installed, this station will be placed 150 m downstream of the barrier. At these locations, a sustained concentration of 100 mg/L suspended solids in River Sections 1 or 3, and 60 mg/L suspended solids in River Section 2 will trigger an exceedance of either the Evaluation Level or the Control Level, depending on the duration of the exceedance.

Additional monitoring will be required at a location closer to the dredge to provide the operator with real-time information on the effectiveness of the dredge operations and the suspended solids controls. A distance of 100 m downstream of the dredge was selected as sufficiently downstream to provide some level of mixing and smoothing of the suspended solids signal while still being close enough to provide rapid feedback to the dredging operation. Feedback may be crucial in identifying operations or actions that cause excessive turbidity but can also be controlled to minimize water quality impacts.

Another station will be located 10 m to the side of the dredge nearest the channel. At these locations, a sustained concentration of 700 mg/L suspended solids will trigger an exceedance of the Evaluation Level. If barriers are in place, these stations will not have an associated resuspension criterion. In all cases, adjustment of the monitoring locations will be considered if alternate sites can be shown to be more effective to the monitoring goals.

Unlike the PCB criteria, the near-field suspended solids criteria should be prorated among all the active dredge operations in a given area, but for Phase 1, the concentration criteria for the suspended solids will apply to each operation individually.

3.2.4 Far-Field Suspended Solids Criteria

Far-field suspended solids criteria were developed for the Evaluation and Control Levels, reflecting the decreased sensitivity of suspended solids measurements at the far-field monitoring station. The suspended solids at the far-field stations are derived from the far-field PCB resuspension standard. The far-field suspended solids criterion was developed by simply calculating the amount of suspended solids that can result in a net increase of PCB concentration above the primary PCB criterion, assuming that the PCB concentration on the suspended solids is the same as on the dredged sediment The 500 ng/L far-field Total PCBs standard was used as a basis to calulate the suspended solids criteria for the far-field stations.

Assuming the baseline level of PCB concentration is approximately 100 ng/L Total PCBs, the net PCB concentration increase will be 400 ng/L Total PCBs. As stated in the responsiveness summary, the average Total PCB concentration on the dredged sediment across the three river sections is about 34 ppm. Based on these values, the increase in suspended solids concentration above baseline is calculated to be about 12 mg/L. This increase in suspended solids concentration must occur across the entire river and not just within the dredge plume for the associated PCB concentration increase to occur. This level (12 mg/L suspended solids increase) is close to baseline variability, however.

Considering the uncertainty in the calculation assumptions as well as the baseline variability in suspended solids concentration, a value twice 12 mg/L, *i.e.*, 24 mg/L, was also selected. As a result, the Control Level uses 24 mg/L suspended solids as the far-field suspended solids criterion. The Evaluation Level uses approximately half of this value (12 mg/L suspended solids), with a shorter duration. The periods of exceedance are the same as those for the near-field suspended solids action levels. The increased monitoring requirements will be limited to the nearest downstream far-field station, with the sample collection timed in order to capture the plume.

Due to the variable conditions within the river over time, some action levels may conflict with one another, particularly in May and June when baseline concentrations are relatively high. In these instances, the Control Level criteria for Total PCB concentration may be exceeded even though the Total PCB load does not exceed the Control Level criteria. The concentration-based action levels will govern the response, since these levels are intended to provide protection for the downstream public water supplies and therefore represent the more protective criteria in these instances.

Similarly, the suspended solids criteria may identify potentially important PCB concentration or load conditions that are not verified by subsequent PCB sampling and analysis. Exceedance of the suspended solids criteria prompts limited additional far-field sampling to determine the PCB concentration in the plume as it reaches the far-field station. These additional samples are incorporated in the equations used to determine whether the water quality levels are in compliance with the standard (subsection 4.1). In all cases, exceedances of the action level criteria by any parameter (*i.e.,* Total PCBs, Tri+ PCBs, or suspended matter) will spur additional monitoring requirements in order to have a sufficient number of samples from which decisions can be made from the data with confidence.

3.3 Monitoring Rationale

The rational for the standards describe above supports the framework and criteria which form the Resuspension Performance Standard. Monitoring to verfy comliance or excedance of the standard criteria is an integral part of the framework. This section presents the overall rationale for the monitoring program as it is currently configured. Significant adjustments to the monitoring program can only be made after the impacts of the adjustments are evaluated in one or more special studies. Adjustments to certain portions of the monitoring program may prompt evaluation of other aspects of the sampling and possible revision of the resuspension criteria. For example, an alternate monitoring program using automatic samplers to collect the PCB samples is presented in Section 4.

As noted in the ROD (USEPA, 2002a), the export of PCBs from the dredging area to regions downstream is the ultimate concern of this performance standard, since it affects both fish and public water supplies. Thus, the most important monitoring stations are those that monitor the rate of PCB export downstream. This increase in PCB export can be best and most easily measured at sufficient distance downstream of the dredging operation so that the river can homogenize the water column inputs from dredging. This distance should also be sufficient to avoid the inclusion of solids suspended during dredging that will settle in close proximity to the dredging operation and thus not represent a source to regions downstream.

Based on historical evidence as well as concerns highlighted by the Fox River study (USGS, 2000), these stations will be used for direct comparison with the Resuspension Standard criteria only when the stations are at least one mile downstream of the dredging operations. Baseline PCB conditions will be well characterized at these locations, allowing the load increase due to dredging-related operations to be measured. In the near field, the baseline is not characterized and may be highly variable.

Since the dredging program extends over nearly 30 miles, with potentially impacted downstream water supplies as far away as 100 miles from the TI Dam, the far-field monitoring program will consist of several major monitoring locations that can be readily and regularly occupied to obtain water column samples for PCB analysis. It is important to measure the PCB concentrations and the PCB mass loading from each of the river sections. In addition to showing how much mass is exported from each of the river sections, the size of the region subjected to the PCB export can be determined. Additionally, water treatment plants downstream can be notified in the event of a large release.

3.3.1 Far-Field Concerns

Because of the importance of the Hudson River as a public water supply and the need to assure public safety, daily samples will be collected at all far-field monitoring stations. Discrete samples will be collected from each station to represent the entire river cross section (*e.g.,* an equal-discharge representation of the river's cross section). The samples must be collected to represent the dredging period. That is, samples from an affected water parcel at each far-field station must be collected. Without consideration for time-of-travel between the remedial operations and the representative far-field station, false low values may be obtained and potentially large releases may go unidentified, even though samples will be collected daily under routine monitoring. (Note that this does not imply the requirement of strict time-of-travel sampling, only that the samples should be collected when it can be reasonably expected that dredging-related water quality impacts can be captured by sampling at each downstream far-field station.) The daily discrete routine monitoring will include the following variables:

- Total and Tri+ PCBs (whole water[17], congener-specific, low detection limits)
- Suspended solids
- Dissolved organic carbon (DOC)
- Organic carbon on suspended solids (weight loss on ignition on suspended solids, or similar measurement)
- Temperature
- pH
- Dissolved oxygen (DO)
- Conductivity

In situ probes are required for the following:

- Turbidity (continuous)
- Suspended solids size distribution via a particle counter (continuous at nearest far-field station only)

The discrete samples for PCBs are clearly required to document compliance with the far-field action level criteria and the Resuspension Standard threshold. The suspended solids, DOC, and organic carbon on suspended solids are all needed to support the interpretation of the PCB data, particularly when action levels are exceeded. The continuous reading parameters are needed as supporting information to confirm a minimal impact of

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[17] Whole water samples require separation of dissolved and suspended matter fractions for separate extraction. Extracts may be combined into a single analysis.

dredging on water quality as well as to prompt additional PCB sampling in the event of a substantive suspended solids release.

The daily discrete monitoring parameter analytical methods must be sufficiently sensitive to avoid non-detect values at most stations and provide data that can characterize PCB concentrations during both routine and unusual conditions. In general, the analytical methods chosen for the monitoring program must meet or exceed the specifications of the methods used to develop the baseline water column concentration data. As discussed in further detail in the next section, the frequency and type of samples will be adjusted as action levels are exceeded. For example, the frequency of PCB sampling will be increased to as often as four times per day.

In addition to the daily discrete sample collection, two other forms of sampling will be included at these stations. Specifically, continuous suspended solids monitoring by means of turbidity and particle counters and the use of an integrating PCB sample (*e.g.*, an Isco sampler) will also be required. A surrogate relationship must be developed for suspended solids using a real-time measurement (turbidity or particle counter). These measurements will be conducted continuously and recorded on a regular basis for use within the same day. The surrogate relationship must be developed prior to Phase 1 and maintained throughout the program.

An integrating PCB sampler will be required as well to provide an alternate measurement basis for water column PCB concentrations. These sampling techniques provide a useful integration of water column loads over time and can be compared to historical measurements (to be collected during the remedial design) or simply to the prior months' data. The data from the integrating PCB sample can be used to document changes in PCB export from the dredging operations to the extent the changes occur in between daily discrete samples. The results can be compared to the more quantitative but instantaneous daily measurements of PCB concentration to generate a rough estimate of PCB transport.

More importantly, these samplers provide a long-term integration of PCB load, monitoring the relatively long periods of time between the daily sampling events. This information serves to confirm that river conditions as captured by the daily discrete samples are representative of general river conditions. These samplers do not provide real-time data but rather confirm that the discrete samples are providing a useful measure of average conditions. These samplers will be deployed in a manner similar to the regular water column points, (*i.e.*, multiple points in the river cross section will be sampled to obtain a representative sample where possible). These samples will be collected biweekly at the five Upper River main stem stations from Rogers Island to Waterford.

3.3.2 Near-Field Concerns

Local variation prevents useful monitoring of PCBs in the immediate vicinity (near-field) of the dredging operation. From the float studies conducted by GE in the late 1990s, it is clear that the PCB concentrations in the water column can increase greatly over relatively short distances from exposure to the contaminated sediments. Near-field downstream monitoring of the PCB concentrations cannot distinguish between the contribution resulting from resuspension during dredging and the contribution from the sediments. Additionally, the time lag between sample collection and the availability of PCB data (normally at least 24 hours, even with an accelerated turn-around time) preclude the use of PCB measurement as a real-time monitor of dredging operations. The ROD acknowledges that the water quality may be reduced in the short term, to allow the remediation to result in attainment of the long-term goals. Therefore, it is not useful to implementconcentration criteria in the near field, given the high spatial and temporal variability as well as the delayed receipt of information.

The near-field monitoring program is designed to provide a real-time measure of conditions around the dredging operation. It is designed recognizing that the far-field monitoring program cannot provide direct feedback to the dredge operators concerning the day-to-day operation of the equipment and engineering controls. For this reason, near-field monitoring will entail continuous measurement of turbidity through the use of electronic sensors (see Attachment F) to allow real-time response to changing conditions and dredge operator activities.

Using electronic sensors for continuous measuring of turbidity the near-field monitoring program will provide a real-time gauge of conditions around the dredging operation.

A surrogate relationship between turbidity and suspended solids must be developed and maintained throughout the program. Suspended solids samples will be collected daily to assess the predictive capability of the surrogate relationship. Suspended solids sampling only increases to once per three hours if the surrogate relationship fails to provide a sufficiently conservative estimate of the TSS concentrations. The criteria for the surrogate relationship are provided in Section 4.

The near-field monitoring program is not intended to provide quantitative measures of PCB loss from the dredging operations but rather to provide a more sensitive qualitative measure of the possible impacts of various dredging activities. These results will be used in coordination with far-field turbidity, suspended solids, and PCB monitoring so that acceptable levels of near-field turbidity can be developed from the net effects observed downstream.

The near-field monitoring program will include suspended solids and turbidity monitoring both upstream and downstream of the dredging operation, so that dredging-related turbidity and associated suspended solids can be identified. Sensors will be deployed at specific distances downstream of the dredging operation that have been determined based on information available in the literature as well as on results of the near-field modeling analysis described in Attachment D. In addition to direct sensor measurements, daily discrete particle counter suspended solids measurement will also be collected *in situ* to provide analytical confirmation of the sensors.

Real-time turbidity and suspended solids monitoring provides the best means of minimizing suspended solids and PCB release.

The near-field monitoring program provides the best opportunity to obtain real-time results that can be used to guide the dredging operations and to identify activities that may result in unacceptable releases of PCBs from the sediments. While PCB monitoring is the ultimate measure of downstream impacts, the real-time turbidity and suspended solids monitoring provides the best means of minimizing suspended solids and PCB release.

While the use of turbidity or suspended solids monitoring provides valuable real-time data, there are some issues that need to be considered in the design of the monitoring program and interpretation of the data. Besides the straightforward issues of sample accuracy and representativeness, the installation of backfill concurrent with the dredging operation may serve to confound the turbidity and suspended solids signals. To the extent that backfill creates large amounts of turbidity, it is possible that the contribution of dredging-related turbidity or suspended solids may be indiscernible. The expected close proximity of dredging and backfill operations will make it difficult to estimate the suspended solids load upstream of dredging but downstream of the backfilling. Thus, measurement of the local impact of dredging by suspended solids monitoring may be compromised. This is addressed to the extent possible by placing a suspended solids and turbidity monitoring station just upstream of each dredging operation. It is, however, expected that backfilling operations will not always coincide with dredging, which would simplify the suspended solids monitoring during these intervals.

Further refinement of the near-field and far-field suspended solids criteria is anticipated at the completion of Phase 1, and possibly during Phase 1 if appropriate. Pending the results of Phase 1, suspended solids criteria may be developed that may require engineering evaluations or improvements. (As currently constructed, the Resuspension Performance Standard only requires an engineering action in response to PCB-based exceedances.)

In summary, both PCB and suspended solids monitoring have limitations that affect the usefulness of the data. For PCBs, the time lag between sampling and the availability of the data as well as the baseline release of PCBs limit the measurement sensitivity. For suspended solids, the near-field heterogeneity, the sensitivity of the surrogate measurement and the impact of backfilling resuspension potentially confound the measurement. Nonetheless, these measures taken together can provide a rigorous basis on which to monitor downstream transport and compliance with the Resuspension Standard.

3.4 Data Quality Objectives

The monitoring plan for the Resuspension Performance Standard is summarized in Tables 1-2, 1-3 and 1-4. The main objectives of the monitoring plan are described in the following subsections, along with the techniques intended to satisfy these objectives. This analysis represents an initial analysis of the DQOs that will undergo subsequent refinement during preparation of the quality assurance plans for dredging-related monitoring. As such, it is expected that the monitoring requirements developed for the standard represent a minimum level of monitoring and that additional sampling beyond these requirements will be needed to completely understand the nature of any dredging-related release.

These monitoring requirements, therefore, are primarily intended to document compliance with the various criteria of the Resuspension Standard. Special studies, as outlined in Section 4.0 will provide information to verify assumptions made about the behavior of the contaminant releases due to dredging (*e.g.*, PCB dissolution, suspended solids settling and dissipation). Information collected to verify these assumptions during the Phase 1 period should serve to improve the monitoring program during Phase 2 in several ways. The Phase 1 data should permit identification of the most effective monitoring locations and monitoring techniques as well as those that are not useful. This information may also permit a reduction in the frequency and complexity of monitoring during Phase 2.

Subsections 3.4.1 to 3.4.3 contain a discussion of the main DQOs and a discussion of the sampling approaches needed to satisfy each objective. Subsection 3.4.4 provides a summary of the analyses that confirm the adequacy of the sampling frequencies required as part of the routine and non-routine monitoring programs. More detail is provided in Attachment G. These analyses, which conform to USEPA methods for assessing statistical uncertainty (USEPA, 2000f), cover only routine monitoring and the minimum levels of contingency monitoring as defined in the Resuspension Standard. Additional monitoring related to the required engineering studies at the Concern and Control Levels (as well as exceedance of the standard threshold) may be required, depending on the anticipated cause of the exceedance. These may be conducted as a part of the engineering evaluations. The design of these additional monitoring programs may occur during the remedial design period. It is also likely that monitoring plans will need to be developed by the contractor during the dredging operation in response to observations made at the time.

A particular limitation to the analysis summarized in subsection 3.4.4 is lack of information on the variance of river conditions in response to dredging-related releases. Little data exist on which to develop the estimate of variance. As a result, the variation of baseline conditions was used as a means to estimate the variance for dredging operations. These estimates for sampling requirements and the associated error rates will require review once additional data become available during Phase 1.

3.4.1 Objectives for Far-Field Monitoring in the Upper Hudson

The far-field monitoring program in the Upper Hudson River addresses several DQOs. This program is the primary monitoring effort for the protection of public water supplies and for determining the magnitude of long-term PCB releases. Following the statement of each data quality objective is a discussion of the sampling techniques to be used to satisfy the objective.

3.4.1.1 Objective I

Provide a set of data to demonstrate compliance with the Total PCB concentration components of the Resuspension Standard (*i.e.*, the 350 ng/L criterion for the Control Levels and the 500 ng/L criterion for the standard threshold).

- Dredging-related operations are expected to occur throughout the Upper Hudson between Fort Edward and Waterford. Hence, dredging-related PCB releases may occur over the entire region as well. In particular, while the majority of dredging is focused north of Schuylerville, boat traffic and other operations are expected to occur downstream of Schuylerville. Thus, PCB concentrations must be monitored throughout the Upper Hudson River. Additionally, PCB release due to dredging is not expected to be constant with time but is expected to vary substantively over time. Thus, discrete grab samples collected at one station at one point in the day may miss more substantial release events occurring at other times. As the river carries these releases, natural mixing and dispersion will serve to homogenize PCB concentrations to some degree, spreading them out and making it easier to collect representative samples at locations farther downstream. Multiple stations, therefore, provide the ability to capture conditions representing a longer period of time.

  Note that the desire to obtain many samples from the river to characterize conditions must be tempered by the availability of laboratories to analyze the samples. For this reason, sampling under routine conditions (expected to be the majority of the conditions while dredging) will only require daily samples from the far-field stations plus a limited number of longer-term integrated samples (see Table 1-2). This consideration also recognizes the need to obtain and analyze samples sufficiently rapidly to address Objective II below. An alternative to these discrete samples is the collection of daily composite samples, integrated over a 24-hour period at each station. These samples still require the collection of a cross section composite for each day. Additional sampling will be required if 24-hour composites are collected when certain resuspension criteria are exceeded.

- It is necessary to correctly characterize the PCB concentration throughout the river cross section, recognizing that both baseline and dredging-related releases create heterogeneous PCB concentrations. This has been extensively demonstrated by the paired sample data

Because both baseline and dredging-related releases create heterogeneous PCB concentrations, It is necessary to correctly characterize the PCB concentration throughout the river cross section.

collected at TID-West and TID-PRW2. For this reason, at least five points are required at each sampling station, based on equal width or equal discharge considerations as given by USGS guidance (USGS, 2002). Multiple points are required for discrete samples as well as the alternative daily composite samples.

- To support the use of discrete samples as representative of mean river conditions, it is also necessary to obtain integrated samples. These samples will serve to demonstrate compliance with the standard during periods between discrete samples. Integrated samples will cover two-week intervals during routine monitoring, providing a longer perspective on PCB transport and concentration with relatively little increase in the total number of PCB analyses. Rapid turnaround of results is not needed for the integrated samples because these samples take longer to collect. The resulting PCB average concentrations provide confirmation of data obtained from daily discrete samples. As such, these results are needed during Phase 1 to provide supporting data for the discrete samples. If the viability of the discrete sampling program is confirmed, these samples may be dropped or greatly reduced during Phase 2.

- Samples must be collected at sufficient frequency to provide a reasonable statistical certainty that conditions are in compliance with the Resuspension Standard criteria. Higher statistical uncertainty is acceptable when concentrations are well below the standard criteria. As the action levels and the standard threshold are approached, sampling frequency must be increased to provide greater certainty that conditions are still in compliance. In particular, it is important to minimize the false negative error, the error of accepting conditions to be in compliance when in reality they are not. The issue of sampling frequency is discussed in subsection 3.4.4 and Attachment G more extensively.

- Analytical methods for the monitoring program must meet or exceed the specifications for the baseline monitoring program to provide sufficient precision, sensitivity, accuracy, and representativeness. The monitoring results from the baseline program are a basis of comparison for the Resuspension Standard and must be consistent.

3.4.1.2 Objective II

Provide a means to rapidly assess water column Total PCB levels so that the USEPA can advise public water suppliers when water column concentrations are expected to approach or exceed the federal MCL (*i.e.*, 500 ng/L) during the remediation.

In this manner, public water suppliers can take contingency actions, if needed, to maintain safe water for their users. Appurtenant to this objective, determine the relationship of dredging-related PCB contamination at the upstream far-field stations (TI Dam and Schuylerville) to that at the downstream far-field stations (Stillwater and Waterford) in order to use the far-field stations near the remediation as predictors of downstream concentrations entering the public water intakes.

There are several aspects of the monitoring plan that are required to achieve these closely related objectives. These are described below.

- Measurements of PCB concentrations at all Upper Hudson far-field stations are needed on a daily basis to identify possible exceedances of the standard threshold and any action level criteria. These data satisfy both components of this objective, since the data will document the PCB concentrations and also serve as a database to resolve the relationship between upstream and downstream PCB concentration increases related to dredging.

- Reduced turnaround time for PCB samples from the two far-field stations nearest to the dredging operations is required. During Phase 1 these stations will probably be TI Dam and Schuylerville, although the Phase 1 dredging area has not yet been defined. The results from sampling at these stations will be used to assess the need to warn the public water supplies that the concentrations entering the intakes may be elevated. The travel time between remediation activities in River Sections 1 and 2 and the Waterford public water supply intakes is generally at least two days, although during high flow events, the travel time is shorter. Thus, in order to have information from the primary dredging areas in time to provide a warning to the downstream intakes, a turn-around time of 24 hours or less is required for the samples obtained from the two nearest downstream far-field stations. (Note that because the turn-around time for PCB analysis is 24-hours, it is also important to develop a real-time indicator of elevated contaminant levels.)

- While actual PCB measurements provide the most certain basis for assessing PCB loads and concentrations, these cannot be obtained in real-time. Resuspension of contaminated sediment is thought to be the primary mechanism of dredging-related contamination release. When verified, suspended solids monitoring provides one of the best means of warning the public water supplies of potential exceedances, since it provides the longest lead time between knowledge of the release and its arrival at the downstream intakes.

  Additionally, as the dredging operations move farther downstream, suspended solids monitoring will provide the only real-time data for the protection of downstream impacts. Specifically in River Section 3, there will be insufficient time to collect, analyze, and evaluate a PCB sample and still warn the downstream intakes. As a result, the standard requires that a surrogate measure of suspended solids concentrations (turbidity or laser particle counter) be developed and maintained throughout the remediation. Samples will be collected once a day for suspended solids analysis to provide confirmation of the surrogate results. Each week, the measured suspended solids results will be compared to the predicted values to determine if the surrogate is providing sufficiently accurate results, based on a statistical analysis. (See Section 4 for details of these special studies.)

- Frequent suspended solids measurements (every three hours) will only be required when the surrogate measurements for suspended solids are not providing a conservative measurement. A modified method for suspended solids analysis will be specified to permit a short turn-around time (three hours). Co-located samples will be collected for both the modified method for suspended solids and the unmodified method that is based on ASTM 3977-97 once a day as to assess the accuracy of the modified method.

- At the far-field stations, monitoring for suspended solids via a surrogate is conducted on a 24-hour-per-day basis.

3.4.1.2.1 Objective III

Provide a set of data to demonstrate compliance with the Total PCB load components of the Resuspension Standard (*i.e.*, 300 g/day and 600 g/day).

- As stated in subsection 3.4.1.1 Objective I, dredging-related operations are expected to occur throughout the Upper Hudson between Fort Edward and Waterford, increasing PCB loads as well as concentrations. PCB loads, however, represent a longer-term concern since the associated impacts will take longer to occur and thus require a sustained level of loading in order to occur. A high frequency of monitoring in Phase 1 can provide an opportunity to identify substantive increases in load soon after occurring so that the root cause can be identified and long term impacts avoided. To this end, the monitoring frequency required to satisfy the concentration criteria is expected to also satisfy this objective.

- Since PCB loads over time are the primary concern of this objective, it is desirable to obtain integrative samples for this objective as well. For this reason, integrative samples will be obtained at the four main far-field stations during Phase 1, as discussed under Objective I. These will provide confirmation of the initial conclusions drawn regarding PCB loads based on the more frequent discrete samples.

- Data on river discharge is also needed to address load considerations. Data from the USGS stations at Fort Edward and Waterford will be used to this end. In the event that the USGS discontinues these stations, data on flow must be obtained by an alternate means. Additional data on meteorological conditions must be obtained to supplement the USGS data and permit an accurate representation of flows at the stations not monitored by the USGS.

- Sample collection must be timed to capture the impacted water column. If samples were collected each day from the nearest far-field station at the onset of the operations, it is unlikely that the water collected would show the dredging-related impacts. The plume will

> *Sample collection must be timed to capture the impacted water column.*

widen and lengthen as it travels downstream, making it more likely that the downstream stations will capture dredging-related impacts. (This is not, however, a time-of-travel sampling. Although the parcel of water sampled must be impacted, the same parcel of water need not be tracked as it passes down the river.)

- Equal discharge increment (EDI) or equal width increment (EWI) sampling as defined by USGS will be required. This type of sampling method is required to capture a representative cross-sectional sample. A single center channel station will not be sufficient, because extensive natural mixing across the channel is unlikely in most of the Upper Hudson and plumes confined to the shoreline by river hydrodynamics will not be accurately represented, resulting in low-biased results.

3.4.1.3 Objective IV

Determine the primary means of PCB release via dredging-related activities. (Verify that dissolved phase releases are minimal as estimated by modeling and that the primary mechanism of release is suspension of sediment.)

- During the public comment period on the Hudson River ROD, concerns were raised that dredging of PCB contaminated sediment could release a substantial amount of dissolved-phase PCBs. Calculations to determine whether and how such a release could occur (Attachments C and D) have indicated that this scenario cannot occur and that the primary release mechanism would be resuspension of contaminated sediment. This mechanism would be accompanied by an increase in suspended solids concentration and could be tracked in the near field.

  Though convincing, the calculations done to determine the primary mechanism of release need to be verified in order to be certain that the goals of the ROD can be achieved (long-term recovery of the river, protection of the environment and human heath). This will be accomplished by a special study, which will characterize dissolved-phase and suspended-phase Total PCB concentrations in the vicinity of dredging operations. Several of these studies will be conducted to characterize the releases for various concentration ranges, sediment types and dredging equipment. Samples will be collected daily for a week at each selected location to provide a sufficient number of samples given the high degree of variability in the near-field conditions. More details of this special study are provided in Section 4.

  Dredging is not expected to release substantial amounts of dissolved-phase PCBs directly. A special study will assess the primary release mechanism in the vicinity of the dredging operation.

  The objective of the special study is to determine whether there is a substantial dissolved-phase release from the remedial operations consistent with that estimated by the USGS at the Fox River site. The study will not be designed to quantify a low-level dissolved-phase release; hence, it will not be necessary to extensively characterize the baseline conditions in these areas. A station upstream from the remedial operations will be monitored for comparison.

Additional parameters will be required to aid in the interpretation of the split phase data. Dissolved organic carbon, suspended organic carbon, suspended solids, turbidity, and temperature provide an indication of the distribution of dissolved-phase and suspended-phase PCBs. These parameters will also be measured for the discrete samples collected during routine monitoring and contingency monitoring. In this manner, changes in these supplemental parameters may help identify the nature of the mechanism responsible for the PCB release throughout Phase 1, assuming equilibrium has been reached.

3.4.1.4 Objective V

Determine the baseline Total PCB levels entering River Section 1 from upstream sources.

- PCBs entering River Section 1 should be identified so as to differentiate these additional concentrations from the releases occurring downstream. Based on monitoring data from the past five years, PCBs have been at non-detect or low concentrations entering River Section 1. However, changes in upstream conditions such as construction at the source areas could result in higher PCB concentrations entering the TI Pool. Monitoring at Bakers Falls and Rogers Island for PCBs will be required to identify such situations. If the contribution from upstream sources were to increase, the Bakers Falls and Rogers Island results should document this occurrence and provide a basis to adjust the dredging-related load contribution.

  This information will help to avoid an unnecessary enforcement of the engineering or monitoring contingencies of the standard and should be done on a case-by-case basis. The sampling frequency will be once per week at Bakers Falls and once per day at Rogers Island. With USEPA's approval, the frequency at Rogers Island may be further reduced if these concentrations are shown to be consistently low relative to dredging-related releases.

- Both Bakers Falls and Rogers Island stations are needed for this purpose. An important assumption in the ROD was the continued reduction of the releases from the GE Hudson Falls facility. Differences in PCB concentration and load between these two stations will be used to document this process. In the event that these data are collected as part of other remedial activities upstream of Rogers Island, these data do not have to be duplicated by the dredging-related monitoring. However, these data must meet the data quality objectives defined here and in the subsequent quality assurance plans issued for the Resuspension Standard.

- Detection limits for Total PCBs for these data must achieve equal or better reporting limits as those achieved for the remedial design baseline monitoring program, approximately 4.0 ng/L for an eight-liter sample. Lower reporting limits (*i.e.*, less than 4 ng/L) will be required if sample results at Rogers Island routinely fall below the reporting limit since accurate quantitation of this load is an integral part of the long-term monitoring program.

- Additional data will be required to aid in the interpretation of downstream data. Baseline levels of DOC, suspended organic carbon, suspended solids, and temperature are needed to characterize the changes in these parameters that may be caused by dredging-related activities. Dissolved oxygen measurements will be taken at Rogers Island for the same purpose.

- Since baseline conditions should not change in response to dredging-related releases, the frequency of baseline monitoring does not increase in response to action level or threshold exceedances.

Baseline conditions should not change in response to dredging-related releases; thus baseline monitoring frequency does not increase in response to action level or threshold exceedances.

3.4.1.5 Objective VI

Determine ancillary remediation-related effects on the river (*e.g.*, barge traffic-related resuspension, spillage during transit or off-loading of sediment) that may occur in areas that are not captured by the nearest representative far-field station.

During Phase 1, the remediation will probably be limited to the TI Pool. Once the material is dredged it will be conveyed to another location for further processing and shipping to a landfill. This destination may not be in the TI Pool, resulting in transport of contaminated material throughout stretches of the Hudson River by barge or pipeline. To verify that the transport of material is not causing the release of PCB contamination to an extent that would cause exceedance of the resuspension criteria, sampling will be required at each Upper Hudson River far-field station (except Bakers Falls) at least once per day.

3.4.1.6 Objective VII

Verify that the water column PCB concentrations developed from the grab samples adequately characterize the average concentration.

- Discrete grab samples will be used for comparison to the PCB flux and concentration resuspension criteria. The Resuspension Standard requires that samples must be timed to capture the impacted water column, increasing the likelihood that the samples will be representative of the dredging-related impacts. As described in subsection 3.4.4, the sampling frequency is sufficient to compare the results of the analyses to the resuspension criteria with confidence, but this analysis is based on an assumption of the variability of the water column concentrations. This estimate of variability is derived from the baseline conditions, which do not include the added variability of the dredging-related releases. This added variability could change within a day as different operations are completed and different dredge operators are employed.

To verify that the grab samples are sufficiently indicative of average river conditions, integrating samplers are required for deployment periods ranging from two weeks under routine monitoring to one day under Control Level monitoring. Integrating samplers cannot entirely replace the required grab samples at TI Dam and Schuylerville, even if all other DQOs are met by this sampling method, because it will be important to have some measure of the upper and lower bound concentrations that are occurring in the river as well as the average condition near the remedial operations.

- Integrating samplers are required for daily measurements in place of discrete grab sampling at Stillwater and Waterford at the Concern and Control Level monitoring as well. This sampling method is used because of the concern that the water column concentrations are approaching the MCL. Integrating samples are used here instead of multiple grab samples to reduce the overall number of PCB analyses while still obtaining data on PCB concentrations over a 24-hour period.

3.4.1.7 Objective VIII

Confirm the exceedance of the action level criteria as well as the standard criterion.

- Sampling frequency must be increased to verify exceedances of the resuspension criteria. At lower levels of exceedance, the consequences of error in deciding whether the resuspension criteria have been exceeded are less serious than at higher levels of exceedance. Hence, a higher level of decision uncertainty is acceptable at exceedances involving the lower action levels. At the Evaluation Level, the concern is adherence to best practices and long-term PCB release impacts, concerns that do not require a rapid (*i.e.,* 24-hour) response. At PCB concentrations close to or above the Resuspension Standard, public water supplies could be impacted and a shutdown of the dredging operations may be required. Thus, a greater level of certainty is required when the consequences are greater. This is the primary reason for requiring increased frequency of sampling in the standard. The development and level of certainty provided by the various sampling regimes are further discussed in subsection 3.4.4.

- An increase in monitoring frequency will be required as a contingency at the two representative far-field stations during Phase 1. These stations provide the best opportunity to document river conditions in response to dredging-related releases and also provide a warning to downstream public water supply intakes. With the uncertainty related to dredging-related releases, the second station will confirm the observations of the nearest far-field station and thus provide a sound basis for whatever response actions are required.

- Monitoring of the downstream far-field stations (Stillwater and Waterford) for PCBs will be changed to daily integrated sampling to capture the average concentrations that would be entering the public water supply, while PCB concentrations collected from stations nearer to the remediation may be approaching the resuspension standard threshold. Data from the integrated far-field samples provide further subsequent confirmation of the estimated concentrations based on conditions closer to the dredging operations.

  Results from these downstream stations can be used to refine the means of predicting the PCB concentrations that will enter the public water supplies based on the concentrations measured nearer to the remediation. These results will indicate the degree to which the PCB concentrations dissipate as the water column passes downstream. The switch from a daily discrete sample to an integrated sample reflects the need to characterize the entire day's water conditions while minimizing the number of samples collected, so that results can be made rapidly available and interpreted.

3.4.1.8 Objective IX

Confirm Alternate Monitoring Programs.

The monitoring program outlined in Tables 1-2, 1-3 and 1-4 has been constructed around the standard. It may be possible to employ alternate monitoring techniques. However, the ability of alternate monitoring programs to achieve the data quality objectives must be demonstrated. Modifications to the resuspension criteria and required actions if exceeded may be required as well in response to the changes. This will be the subject of a special study. Details are provided in Section 4.

3.4.1.9 Objective X

Measure the parameters with precision, accuracy, representativeness, comparability, **completeness and sensitivity that is equivalent to the baseline monitoring program specifications**.

- Analytical methods for the monitoring program must meet or exceed the specifications for the baseline monitoring program to provide sufficient precision, sensitivity, accuracy, representativeness, comparability, completeness and sensitivity. The monitoring results from the baseline program are a basis of comparison for the resuspension standard and must be consistent.

- Sample collection and sample handling must be consistent with the approach taken during baseline.

- As verification of these methods it will be necessary to have performance evaluation PE samples. The purposes of these samples will be to determine that the results for multiple laboratories are consistent in terms of both accuracy and precision. The PE samples will be used to verify that the congener distribution identified among the laboratories is consistent.

An exception to this objective will be the specification of a modified analytical method for suspended solids that will permit the results to be available in three hours.

3.4.2 Objectives for Near-Field Monitoring in the Upper Hudson

3.4.2.1 Objective XI

Provide a real-time indication of suspended solids release in the near field.

A real-time indication of the amount of suspended solids in the water column in the near field will aid the dredge operators in minimizing the release of suspended solids and associated PCBs during the remediation. This monitoring will also provide the earliest evidence for a substantive PCB release and allow further response by direct PCB measurements downstream. To this end, turbidity monitors will be placed around each dredging or debris area undergoing remediation. Information from these monitors will provide continuous feedback to the operators, allowing real-time adjustments to be made to the operations as needed.

3.4.2.2 Objective XII

Determine the amount of suspended solids released by the remedial operations to provide an indication of PCB export.

- Calculations presented in Attachment C indicate that the primary release mechanism of dredging-related contamination is resuspension of contaminated sediment. Thus, an increase in suspended solids should correlate with an increase in PCB contamination. The standard requires that a surrogate relationship be developed for suspended solids concentrations in the near field and maintained throughout Phase 1. Samples will be collected daily for suspended solids analysis as a means of assessing the surrogate relationship. Samples will be collected twice daily for suspended solids analysis if there is an exceedance of the suspended solids criteria. This increase in susppended solids sampling is limited to the noncompliant nodes. If the continuous reading surrogate (*e.g.*, turbidity) fails to adequately predict suspended solids concentrations, samples will be collected every three hours for suspended solids analysis until an adequate surrogate relationship is developed. More details are provided in Section 4 on this special study.

- Near-field sampling is limited to the hours of operation, with some pre- and post-dredging sampling.

- Exceedance of the near-field criteria prompts limited far-field sampling for PCB analysis (and supporting analyses) at the nearest downstream representative far-field station. These data, combined with the results of the far-field PCB analytical results, can be used to develop a relationship between suspended solids and PCB concentrations, and also provide a means of adjusting the suspended solids-based resuspension criteria, although a predictive correlation is not expected due to the heterogeneity of the sediment concentrations.

3.4.2.3 Objective XIII

Verify that the NYSDEC surface water quality regulations are not violated during the remediation.

NYSDEC has water quality standards for pH and dissolved oxygen (DO). At both the near-field and far-field stations, pH and DO will be monitored discretely each time a sample is collected. These parameters, plus conductivity, will also provide a measure of quality assurance for the data collected.

3.4.3 Additional Monitoring Objectives

3.4.3.1 Objective XIV

Monitoring in the Lower Hudson: Determine the extent of short-term impacts to the Lower Hudson River and examine the effect of Upper Hudson dredging activities on Lower Hudson PCB concentrations.

- The monitoring program for the Lower Hudson is designed to measure the short-term impacts to the freshwater portion of the river (previously referred to as the Mid-Hudson River during the Reassessment) resulting from the remediation. The sampling requirements in the Lower Hudson are not designed for comparison to the resuspension criteria. This is addressed by the frequent sampling at Waterford, which will be extrapolated to conditions downstream.

  Requirements for additional monitoring at the public water supply intakes will be prepared as part of the community health and safety plan (CHASP) currently under public review. The Lower Hudson stations are intended to characterize general water column conditions in response to elevated PCB concentrations and loads originating from dredging. These stations consist of a single center channel location that can be readily reoccupied. Cross sectional sampling is not required, since flow is not unidirectional and thus flux cannot easily be estimated.

- The frequency of sampling is increased in the Lower Hudson in response to greater loads and concentrations in the Upper Hudson, *e.g.*, when the concentration at Troy is expected to exceed 350 ng/L Total PCBs. This is done to examine Lower Hudson conditions in response to these loads, part of documenting recovery of the river.

The monitoring program for the Lower Hudson will measure short-term impacts to the freshwater portion of the river (referred to as the Mid-Hudson River during the Reassessment) resulting from the remediation.

3.4.3.2 Objective XV

Verify the selection of the monitoring locations.

The locations of the far-field and near-field monitoring stations were selected based on several considerations, including near-field and far-field monitoring, ease of access, and level of planned dredging activities. The suspended solids and PCB analyses will be used to verify that these locations are appropriate. Monitoring of the far-field station less than one mile from the remediation will be required even though the PCB measurements will not be used for comparison to resuspension criteria during Phase 1. These results will determine whether the station is heavily impacted by the nearby remediation and will validate the requirement that far-field stations be more than one mile from the remediation. (Monitoring for compliance with the far-field net suspended solids resuspension criteria will be required each day, no matter how close the remediation is to the far-field stations.)

3.4.3.3 Objective XVI

Non-Target Area Monitoring: Determine the degree and extent of contamination resulting from the remedial operations downstream from the target areas.

- A special study will be conducted to measure the amount of resuspended material that has settled in the immediate downstream areas and is a potential source of future contamination of the water column and downstream surficial sediment. The primary DQO for this study is to determine the extent of contamination in terms of spatial extent, concentration and mass of Tri+ PCB contamination deposited in non-target near-field areas downstream from the dredged target areas.

- This study is needed because contaminated material may be disturbed by the remedial operations and move downstream along the bottom of the river, only to be identified by the water column monitoring during the next high flow event of sufficient force to transport the material. The near-field suspended solids monitoring is not conservative with regard to this issue because these criteria are based on the assumption that a single dredge meets the full production, when it is likely that several dredges will be required. Resuspension due to several dredges can theoretically create more local deposition because of settling between dredge operations. The near-field suspended solids criteria were established based on a single large plume since this approach is conservative for PCB dissolution and thus maximum PCB transport. Therefore, it is not sufficient to assume that compliance with the resuspension criteria means that the loss from the remedial operations will not create an unacceptable degree of contamination downstream.

- To address this objective, a special study will be conducted to measure the amount of resuspended material that settles in the downstream areas and that may act as a potential source of future contamination to the water column and downstream surficial sediment. Each study areas will be located downstream of a dredging area and will be approximately five acres in size. Samplers (*e.g.*, sediment traps) will be installed at multiple locations prior to the start of the dredging in the area under study. The exact number of locations per study area will be determined as part of the sampling plan development. At each sample location two or more co-located sediment traps will be deployed. Sediment accumulated in one of the samplers at each location will be collected and sent for analysis once the dredging in the area is completed, including any redredging attempts. Sediment accumulated in the second set of samplers will be collected at a higher frequency (perhaps weekly) to examine the relationship between various dredging operations and sediment accumulation.

- The study will be conducted at several target areas to determine the degree and extent of contamination over a range of conditions. The selected areas must represent a range of sediment textures, contamination levels and remedial equipment.

- Measurement techniques will include suspended solids mass, PCBs, and other pertinent variables. The techniques employed will meet or exceed the specification for the analytical and sampling methods with the SSAP.

3.4.4 Statistical Justification of the Sampling Frequency

The adequacy of the sampling frequencies required as part of the routine monitoring programs was examined using the USEPA defined methods for assessing statistical uncertainty (USEPA, 2000). The analyses cover only routine monitoring and the minimum levels of contingency monitoring as defined in the Resuspension Standard.

The final sampling requirements for the standard were developed using USEPA's Decision Error Feasibility Trials Software (DEFT) (USEPA, 2001), a program to estimate sampling requirements based on a project-specific error rate. The results of this analysis are presented in Table 3-2.

As defined in DEFT:

- A *false acceptance* decision error occurs when the sample data lead to a decision that the baseline condition is probably true when it is really false.

- A *false rejection* decision error occurs when the limited amount of sample data lead to a decision that the baseline condition is probably false when it is really true.

- The *gray region* is a range of true parameter values within the alternative condition near the action level where it is "too close to call."

The analysis of the various criteria and acceptable gray region around each criterion yielded the results shown in Table 3-2. The table is organized by measurement type (*i.e.,* PCB and suspended solids). False acceptances were minimized because this is the more serious error. For all criteria except the confirmation of the 500 ng/L exceedance, the null hypothesis assumed that river conditions were in compliance.

Decisions that are more critical generally require a large number of samples and have greater certainty than the less critical decisions.

In general, decisions that are more critical (*e.g.,* confirmation of exceedance of the Resuspension Standard which requires shut down, or exceedance of the Control Level, which requires intense monitoring and engineering responses) require a large number of samples and have greater certainty than the less critical decisions. For the suspended solids measurements, it is clear from this analysis that the implementation of a continuous monitor capable of estimating suspended solids concentrations will be needed to have a reasonable amount of certainty in these decisions. The low level of certainty is tolerable only because any decisions made as a result of exceedance of the suspended solids will be confirmed by measurements of PCB concentrations in the impacted water column.

Table 3-2 shows that the higher level of sampling associated with the higher action levels and the Resuspension Standard yield low false error rates, as expected, reflecting the need to be accurate before taking costly actions or improvements. In some instances, the false rejection rate is fairly high, indicating that additional sampling may be unnecessarily triggered. However, this represents a protective approach from the perspective of the safety of the public water supplies. Additionally, the higher monitoring rates will quickly confirm the need to remain at the action level thought to be exceeded.

Higher error rates are estimated in transitions from routine conditions to the Evaluation and Control Levels, reflecting the relative low sampling rate required for routine sampling. Also shown in the table is the one-week confirmation result (*i.e.,* the error rate for the combination of one week of routine monitoring and one week at the action level). In each instance the false acceptance error is brought below 5%, thereby confirming the need to sample at the higher rate or indicating that sampling at the routine rate may be resumed.

The results for monitoring requirements for exceedance of the standard demonstrate the need for the intensive sampling specified. In this instance, the river is assumed be in exceedance of the standard. Four additional discrete samples (Table 3-2) do not provide sufficient certainty given that the next day’s decision will involve the temporary halting of the dredging operations, a costly choice. However, by collecting hourly composites, the power of the same four analyses is greatly improved and the 5% false acceptance rate is attained. Table 3-2 also shows the results for the long-term integrative samples. These samples will serve to confirm the results of daily routine monitoring or to demonstrate the need for more frequent sampling. The results assume the automated collection of eight samples per day over a one- to two-week period.

The results for suspended solids illustrate the need to use a continuous sampling system such as a turbidity probe. In the lower portion of the table, results for the discrete sampling program are compared with those that can be achieved with a continuous probe recorded once every 15 minutes. In almost all cases, the continuous reading probe provides more than an order of magnitude of improvement in the expected error rate. Better rates can be achieved with the continuous probes by simply recording more frequently.

It has been demonstrated that continuous reading turbidity probes provide more than an order of magnitude of improvement in the expected error rate.

Note that this analysis does not consider any uncertainty introduced by use of a probe over discrete samples. Nonetheless, given a semi-quantitatve relationship between the probe and actual suspended solids levels, it is highly likely that the probes will provide a substantial reduction in the expected error rates for suspended solids monitoring, thereby reducing unnecessary additional PCB sampling prompted by a false indication.

Table 3-3 contains the following information related to use of the automatic sampler:

- Summary of the various criteria
- Associated gray region
- Sampling frequency required by the resuspension standard
- False acceptance and false rejection levels for Total PCB sampling requirements when the automatic sampler is used

Using the automatic sampler, the error rates for most of the sampling requirements are less than 1%. The highest error rate was about 2% for the false rejection of the sampling requirement from evaluation to control level. However, this value is still below 5% error rate. This analysis shows that, theoretically, the power of the sampling program for Total PCBs using automatic sampler is greatly improved. In actuality, an alternate monitoring program that is primarily based on sample collection via automatic samplers will only be as good as the implementation. There are numerous challenges associated with such a program that must be carefully worked through during a special study. See Section 4 for more information.

3.5 Summary of Rationale

The rationale for the performance standard for PCB loss due to resuspension has its basis in the goals outlined in the ROD (USEPA, 2002a). The need to protect downstream fish and fish consumers and the need to protect public water supply intakes define the objectives for the standard. Action levels were derived from consideration of ARARs for the site and RAOs from the ROD, as well as the ability to detect a net increase in PCB loads. These criteria were shown by modeling analysis to produce little change in downstream fish tissue recovery, further supporting their use as action levels.

The rationale for the performance standard for PCB loss due to resuspension has its basis in the goals outlined in the ROD.

Specifically, PCB releases commensurate with 500 ng/L Total PCB had no substantive impact on the fish recovery once dredging operations were completed.

Ultimately the RAO concerning the transport of PCBs to the Lower Hudson provided the lowest upper bound on the acceptable amount of PCB loss (*i.e.*, 600 g/day Total PCB or 650 kg Total PCB over the entire period of dredging). Additional action levels were needed to provide a tiered series of action levels with an increasing amount of contingencies as the action levels are exceeded. The criteria, monitoring requirements, and engineering contingencies are all designed with the intention of identifying and correcting minor problems in the dredging operation while keeping the dredging operation functioning smoothly and steadily.

Due to the variable conditions within the river over time, the Total PCB concentrations may be greater than 350 ng/L Total PCBs, even though the load-based criteria are not exceeded. This results from elevated baseline conditions and is most likely to occur in May and June. The concentration-based action levels will govern, since these action levels are intended to provide short-term protection for the downstream public water supplies and therefore represent the more protective criteria in these instances. It is also possible that the suspended solids criteria may indicate elevated PCB concentrations that are not verified by subsequent PCB sampling and analysis. This is recognized in the standard by requiring only additional sampling of the impacted water column at the nearest representative far-field station for comparison against the resuspension criteria as outlined in subsection 4.1.

4.0 Implementation of the Performance Standard for Dredging Resuspension

The Resuspension Performance Standard consists of the standard threshold and associated action levels, monitoring requirements and engineering requirements. The implementation of the action levels is described in subsection 4.1. Compliance monitoring requirements including measurement techniques, monitoring locations and other specifics are described in subsection 4.2. The procedures to revert to lower action levels or routine monitoring are presented in subsection 4.3 The requirements for the special studies are defined in subsection 4.4. For engineering contingencies, the engineering evaluations, technologies for controlling releases that may be implemented, and the requirements of the standard regarding engineering contingencies are described in subsection 4.5. Reporting requirements are described in subsection 4.6.

Flowcharts depicting the implementation of the Resuspension Standard are provided in Figures 4-1, 4-2 and 4-3 for the near-field suspended solids criteria, far-field Total PCBs and far-field suspended solids. These flowcharts are a simplified depiction of the interaction between the three aspects of the standard: action levels, monitoring and engineering controls. To fully implement the Resuspension Standard the specifications provided throughout this document must be upheld.

4.1 Resuspension Criteria

This subsection contains details of the implementation of the standard. Table 1-1 contains the requirements and criteria of the standard in tabular form. Implementation of the Resuspension Standard will necessarily require monitoring for the parameters of concern. Daily measurements of suspended solids and PCB concentrations can then be compared with the appropriate action level or the Resuspension Standard threshold. Load-based criteria require more than a simple measure of concentration, since flow must be incorporated into the load estimate. Comparisons to the resuspension criteria must be made on a daily basis for each of the Upper Hudson far-field stations. This will include assessment of the load and concentration seven-day averages and the total load loss for the season vs. the productivity rate.

If dredging occurs in more than one river section, effectively creating two "nearest" far-field stations, this standard applies in the same manner to both stations.

Note that in the event that dredging occurs in more than one river section, effectively creating two "nearest" far-field stations, this standard is applied in the same manner to both stations. That is, the near-field concentration criteria apply to both stations equally. Given the various uncertainties in load estimation, no "pro-rating" of the standard for the upper station will be required, although the dredge operators should consider doing so, as needed. This means that any of the far-field stations can dictate response actions.

The Total PCB load-based criteria will be assessed using the results of the baseline monitoring program, which is scheduled to begin in 2004. Historical data collected prior to the baseline period will be incorporated into the analysis of the baseline data if a relationship between the historical and current baseline data can be developed. Estimates of flow will be derived from USGS gauging stations currently operating in the Upper Hudson, along with data from additional stations developed for this monitoring program (*e.g.*, Schuylerville). As noted previously, the load-based criteria will also be adjusted to reflect the anticipated dredging period length with the maximum allowable net release of 650 kg Total PCBs[18] or 220 kg Tri+ PCB over baseline for the duration of the remediation.

Both of the action levels have associated load-based criteria. To simplify review of the monitoring results and avoid additional computations during the remediation, the load-based criteria will be converted to look-up tables of concentrations that correspond to various load-based levels as a function of river flow and month. Examples of these tables for Total PCBs at the Schuylerville station are included as Tables 4-1 and 4-2 for the Evaluation Level and Control Level far-field net Total PCB load, respectively. The tables were developed using the existing GE data for this location. However, as mentioned previously, the existing water column data from the Upper Hudson are limited in applicability,[19] and were used to provide a preliminary set of values for these tables. Final values for these tables for both Total PCBs and Tri+ PCBs will be developed from the baseline monitoring program. Exceedance of the final values to be developed for these tables from the baseline monitoring program for a given month and given flow will constitute exceedance of the corresponding action level.

Both the Evaluation Level and Control Level contain far-field criteria based on 7-day running averages. These averages are to be calculated daily for comparison against the appropriate criteria on a daily basis. Similarly, both action levels contain near-field suspended solids criteria based on 3-hour, 6-hour or daily running averages. These averages are to be calculated throughout the day on a three hour basis to determine compliance.

For all flux estimates, the load calculation may be corrected for contributions originating upstream of the remediation area (*i.e.*, above Rogers Island) in the event that loads from this region are above the levels typically observed. See Section 4.1.2.7 for the means of adjusting for a significant difference in the upstream loads.

In the event that dredging operations move to a location less than one mile upstream of a far-field monitoring point, the next downstream far-field station becomes the

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[18] A daily rate of PCB loading can be derived consistent with the attainment of the recommended Target Cumulative Volume as specified in the Productivity Standard and the cumulative PCB mass delivery to the Lower Hudson. The daily load figure as well as an annual load goal should be prorated according to the production rate planned in the Production Schedule to be submitted annually to USEPA.

[19] Single point monitoring locations at Thompson Island Dam and Schuylerville or any of the far-field stations are not adequate (*i.e.*, not sufficiently representative of river conditions) for the purposes of estimating recent baseline load conditions. A cross-sectional composite sample is required, as will be obtained during both the baseline monitoring and the remedial monitoring programs for this purpose.

representative far-field station for the operation. The nearer far-field station will continue to be monitored, not to judge compliance with the standard, but rather to evaluate the requirement that the far-field station be more than one mile from the remedial operations for the monitoring data to be comparable to the resuspension criteria.

If dredging operations move to less than one mile upstream of a far-field monitoring point, the next downstream far-field station becomes the representative far-field station for the operation.

For exceedance of suspended solids criteria at either near-field or far-field locations, the impacted water column must be sampled at the far-field station to determine the concentration of PCBs in the plume. Suspended solids and turbidity measurements collected from the representative far-field station will document that the sample has been collected from the plume.[20]

In the subsections that follow, the text describes the details of each of the action levels and the threshold. Equations provided in the sections below are the basis for comparing the monitoring results to the resuspension criteria.

4.1.1 Evaluation Level

4.1.1.1 Far-Field Net Total PCB Load

The net increase in Total PCB mass transport due to dredging-related activities at any downstream far-field monitoring station exceeds 300 g/day for a seven-day running average.

The far-field net Total PCB load is a load-based criterion (300 grams per day), as opposed to a concentration-based action level (PCB concentration criteria [ng/L]), and is calculated after taking into account the pre-existing baseline loads of Total PCBs. This criterion applies only to the monitoring stations of the Upper Hudson, where a PCB load can be readily estimated. The formula to estimate the dredging-related release using the seven-day running average concentration is as follows:

$$F_7 = \left(\overline{C_{ffs}} - \overline{C_{bl}}\right) \times Q_7 \times T_{d7} \times \frac{0.02832\,m^3}{ft^3} \times \frac{3600s}{hr} \times \frac{1g}{10^9\,ng} \times \frac{1000L}{m^3} \tag{4-1}$$

where:

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[20] The standard requires that a real-time surrogate be developed and maintained to estimate suspended solids concentrations at the near-field and far-field stations. There may be times when the surrogate fails to predict suspended solids concentrations conservatively and samples will be collected every three hours for suspended solids analysis to measure compliance with the standard.

F_7 = Seven-day average load of Total PCBs at the far-field station due to dredging-related activities in g/day

$\overline{C_{ffs}}$ = Flow-weighted average concentration of Total PCBs at the far-field station as measured during the prior seven-day routine discrete sampling in ng/L.

This is given as:

$$\overline{C_{ffs}} = \frac{\sum_{j=1}^{7} C_{ffs_j} \times Q_j}{\sum_{j=1}^{7} Q_j} \qquad (4\text{-}2)$$

where:

C_{ffs} = The Total PCB concentration at the far-field station for day j. If more than one sample is collected in a day due to exceedance of the near-field or far-field criteria, the arithmetic average of all the measurements will be used.

Q_j = The daily average flow at the far-field station for day j,

$\overline{C_{bl}}$ = Estimated 95% upper confidence limit (UCL) of the arithmetic mean baseline concentration of Total PCBs at the far-field station for the month in which the sample was collected, in ng/L. Initial estimates for these values are given in Table 4-3.

This value is determined from baseline monitoring data and represents the upper bound for the average concentration at the far-field station in the absence of dredging. Where the 95% UCL varies within the 7-day period of interest (*e.g.*, at the end of a month), time-weighted average 95% UCL is calculated as the sum of each day's 95% UCL dividing by the number of days.

Q_7 = Seven-day average flow at the far-field station, determined either by direct measurement or estimated from USGS gauging stations, in cfs

T_{d7} = Average period of dredging operations per day for the seven-day period, in hours/day, as follows:

$$T_{d7} = \frac{\sum_{j=1}^{7} T_{d_j}}{7} \qquad (4\text{-}3)$$

where: T_{d_j} = The period of dredging operations for day j in hours.

If F_7 is 300 g/day Total PCBs or greater, this is considered to be an exceedance of the Evaluation Level. This formula is intended to identify a mean loading of Total PCBs due to dredging in excess of the action level. The 95% UCL of the water column PCB concentrations at each station and month is chosen to represent baseline concentrations ($\overline{C_{bl}}$), because this is a comparison to the average condition for a short duration. The confidence limit indicates the probability or likelihood that the interval contains the true population value.

Because the seven-day average value will be compared to the monthly mean, it is appropriate to estimate the range of values that may contain the mean. Values that fall outside this range are unlikely to be part of the original population of baseline values; therefore, these PCB export levels are likely to represent a dredging-related release of PCBs. Note that this and all PCB load standards may be adjusted for the production rate as described in subsection 4.1.2.7.

4.1.1.2 Far-Field Net Tri+ PCB Load

The net increase in Tri+ PCB mass transport due to dredging-related activities at any downstream far-field monitoring station exceeds 100 g/day day for a seven-day running average.

Equations 4-1, 4-2, and 4-3 will be used to calculate the far-field net Tri+ PCB load at each Upper River mainstem station on a daily basis by substituting the daily Tri+ PCB concentrations and baseline Tri+ PCB 95% UCL values for the Total PCB concentrations. Baseline Tri+ PCB concentrations have not been calculated for this report, but the Tri+ PCB 95% UCLs will be calculated using the data collected during the Baseline Monitoring Program. An F_7 value of 100 g/day Tri+ PCBs or greater constitutes an exceedance of the Evaluation Level.

4.1.1.3 Far-Field Average Net Suspended Solids Concentration

The sustained suspended solids concentration above ambient conditions at a far-field station exceeds 12 mg/L. To exceed this criterion, this condition must exist on average for 6 hours or a period corresponding to the daily dredging period (whichever is shorter). Suspended solids are measured continuously by turbidity (or an alternate surrogate) or every three hours by discrete samples.

The net increase in suspended solids concentration over baseline levels will be calculated during the daily dredging period for each main stem Upper River far-field station. If the suspended solids concentration is estimated continuously using a surrogate, the six-hour running average net increase will be calculated throughout the daily dredging period. If the suspended solids concentration is measured by discrete samples at three-hour intervals, the net increase will be calculated throughout the day for each six-hour interval as the data become available from the laboratory. The suspended solids data must be available within three hours of sample collection (three-hour turnaround time using a modified method for suspended solids analysis). The net increase in suspended solids is calculated as follows:

$$\text{Net Increase in Suspended Solids (mg/L)} = C_{avg} - C_{baseline} \tag{4-4}$$

where:

C_{avg} = Arithmetic average suspended solids concentration for the time interval at the far-field station

$C_{baselin}$ $_{e}$ Arithmetic average baseline suspended solids concentration for the same far-field station and month (based on the baseline monitoring program results)

Suspended solids contributions from the tributaries will appear to be dredging-related increases in suspended solids. This criterion may be waived with USEPA review if the increase in suspended solids can be traced to meteorological events. The baseline concentrations at each station will be developed from the results of the baseline monitoring program.

The Evaluation Level is exceeded if the net increase in suspended solids concentration is 12 mg/L or greater. Exceedance of this criterion prompts Evaluation Level sampling at one far-field station. The station will be chosen to measure the Total PCB concentration in the suspended solids plume in order to determine whether additional actions need to be taken. Sample collection will be timed to measure the concentration of PCBs in the impacted water column. The frequency of this sampling will be equivalent to that defined in Table 1-2 for the representative stations (TI Dam and Schuylerville). Only the grab sample will be collected for this purpose.

The Evaluation Level is exceeded if the net increase in suspended solids concentration is 12 mg/L or greater at any far-field station.

4.1.1.4 Near-Field Net Suspended Solids Concentration 300 m Downstream

The sustained suspended solids concentration above ambient conditions at a location 300 m downstream (i.e., near-field monitoring) of the dredging operation or 150 m downstream from any suspended solids control measure (e.g., silt curtain) exceeds 100 mg/L for River Sections 1 and 3 and 60 mg/L for River Section 2. To exceed this criterion, this condition must exist on average for six hours or for the daily dredging period (whichever is shorter). Suspended solids are measured continuously by surrogate or every three hours by discrete samples.

The net increase in suspended solids concentration between the upstream near-field station and the downstream near-field stations will be calculated during the daily dredging period for each remedial operation. Without barriers, these near-field stations will be located approximately 300 m downstream of the dredge. With barriers, these stations will be located approximately 150 m downstream of the barrier. If the suspended solids concentration is estimated continuously using turbidity or any other surrogate, the six-hour running average net increase will be calculated throughout the daily dredging period. If the suspended solids concentration is measured by discrete samples at three-hour intervals, the net increase will be calculated throughout the day for each six-hour interval as the data become available from the laboratory. The suspended solids analysis will require a three-hour turnaround time (using a modified method for suspended solids). The net increase in suspended solids is calculated as follows:

$$Net\ \ Increase\ \ In\ \ SS_{near-field} = C_{avg} - C_{up} \tag{4-5}$$

where:

C_{up} = The arithmetic average upstream near-field station concentration over the time interval

C_{avg} = The arithmetic average downstream concentration over the time interval. Samples will be collected from two stations located 300 m downstream. The average concentration from each location over the time period will be calculated separately and the higher average concentration will be chosen for use in this equation

Evaluation Level exceedances are as follows:

- River Sections 1 and 3: at a net increase in suspended solids concentration of 100 mg/L or higher
- River Section 2: at a net increase in suspended solids concentration 60 mg/L or higher

Exceedance of this criterion prompts Evaluation Level sampling at the nearest representative far-field station. Sample collection will be timed to measure the concentration of PCBs in the impacted water column.

Each near-field 300 m station (150 m station with barriers) will be compared to either 100 mg/L or 60 mg/L, depending on the location of the remediation during Phase 1, while the behavior of the system is tested. In Phase 2, when multiple dredging operations are conducted simultaneously within the same section of the river, the sum of the concentrations measured at the near-field station may be compared to the criteria, because this approach is in keeping with the development of the criteria. This criterion may be waived with USEPA review if the increase in suspended solids can be traced to meteorological events.

4.1.1.5 Near-Field Net Suspended Solids Concentration 100 m Downstream and at the Side Channel Station Without Barriers

> *The sustained suspended solids concentration above ambient conditions at the near-field side channel station or the 100 m downstream station exceeds 700 mg/L. To exceed this criterion, this condition must exist for more than three hours on average measured continuously or a confirmed occurrence of a concentration greater than 700 mg/L when suspended solids are measured every three hours by discrete samples.*

Without barriers, the average suspended solids concentration over the time period at the upstream near-field stations for a remedial operation will be subtracted from the average suspended solids concentration over the same time period at the 100 m downstream station to get the net suspended solids concentration. Also, the average suspended solids concentration over the time period at the upstream near-field stations for a remedial operation will be subtracted from the average suspended solids concentration over the same time period at the side channel station to get the net suspended solids concentration.[21]

Exceedance of this criterion prompts Evaluation Level sampling at the nearest representative far-field station.

If the suspended solids concentration is estimated continuously using turbidity as a surrogate, a three-hour average net suspended concentration of 700 mg/L or higher is an exceedance. If the suspended solids concentration is measured by discrete samples at three-hour intervals, two consecutive samples of 700 mg/L or higher is an exceedance. Exceedance of this criterion prompts Evaluation Level sampling at the nearest representative far-field station. Sample collection will be timed to measure the concentration of PCBs in the impacted water column.

The net suspended solids concentration at each near-field 100 m station or side channel station will be compared to 700 mg/L while the remediation is in Phase 1. In Phase 2, when multiple dredging operations are conducted simultaneously within the same section of the river, the sum of the concentrations measured at the near-field 100 m stations (or side channel station) may be compared to 700 mg/L, because this approach is more in conformance with the development of the criterion. This criterion may be waived with USEPA review if the increase in suspended solids can be traced to meteorological events.

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[21] Note that this standard also applies to the 300 m station in the unlikely event that a 700 mg/L event occurs at that location, but does not affect the 100 m and side channel stations.

4.1.2 Control Level

4.1.2.1 Far-Field Total PCB Concentration

The Total PCB concentration during dredging-related activities at any downstream far-field monitoring station exceeds 350 ng/L for a seven-day running average.

The arithmetic average of the past seven days' monitoring will be calculated on a daily basis for each of the Upper River mainstem far-field stations. For each station, a day will be represented by a single value. If more than one sample is collected in a day for a station, the arithmetic average of the Total PCB measurements for a station will be used as a single day's concentration in the seven-day average. If the arithmetic average of the Total PCB concentration is 350 ng/L or higher at a far-field station, this is considered to be an exceedance of the Control Level.

4.1.2.2 Far-Field Net Total PCB Load

The net increase in Total PCB mass transport due to dredging-related activities at any downstream far-field monitoring station exceeds 600 g/day on average over a seven-day period.

The far-field net Total PCB load will be calculated using Equations 4-1, 4-2, and 4-3 on a daily basis. A seven-day Total PCB load of 600 g/day or higher constitutes an exceedance of the Control Level.

4.1.2.3 Far-Field Net Tri+ PCB Load

The net increase in Tri+ PCB mass transport due to dredging-related activities at any downstream far-field monitoring station exceeds 200 g/day on average over a seven-day period.

Equations 4-1, 4-2 and 4-3 will be used to calculate the far-field net Tri+ PCB load at each Upper River mainstem station on a daily basis by substituting the daily Tri+ PCB concentrations and baseline Tri+ PCB 95% UCL values for the Total PCB concentrations. Baseline Tri+ PCB concentrations have not been calculated for this report, but the Tri+ PCB 95% UCLs will be calculated using the data collected during the baseline monitoring Program. An F_7 value of 200 g/day Tri+ PCBs or greater constitutes an exceedance of the Control Level.

4.1.2.4 Far-Field Average Net Suspended Solids Concentration

> *The sustained suspended solids concentration above ambient conditions at a far-field station exceeds 24 mg/L. To exceed this criterion, this condition must exist for a period corresponding to the daily dredging period (six hours or longer) or 24 hours if the operation runs continuously (whichever is shorter) on average. Suspended solids are measured continuously by surrogate or every three hours by discrete samples.*

The net increase in suspended solids concentration between far-field stations will be calculated on a daily basis for each mainstem Upper River far-field station as soon as the data become available (within 3 hours of sample collection). The net increase in suspended solids concentration will be estimated for the daily dredging period (longer than 6 hours) or for 24 hours if dredging is continuous. Equation 4-4 can be used to calculate the net increase in suspended solids for the time period of concern.

Suspended solids contributions from the tributaries will appear to be dredging-related increases in suspended solids. This criterion may be waived if the increase in suspended solids can be traced to meteorological events.

> *The Control Level is exceeded if the net increase in suspended solids concentration is 24 mg/L or greater at any far-field station.*

The Control Level is exceeded if the net increase in suspended solids concentration is 24 mg/L or greater. Exceedance of this criterion prompts Control Level sampling at one far-field station. The station will be chosen to measure the Total PCB concentration in the suspended solids plume in order to determine if additional actions need to be taken. Sample collection will be timed to measure the concentration of PCBs in the impacted water column. The frequency of this sampling will be equivalent to that defined in Table 1-2 for the representative stations (TI Dam and Schuylerville). Only the grab sample will be collected for this purpose.

4.1.2.5 Near-Field Net Suspended Solids Concentration 300 m Downstream

> *The sustained suspended solids concentration above ambient conditions at a location 300 meters downstream (i.e., near-field monitoring) of the dredging operation or 150 meters downstream from any suspended solids control measure (e.g., silt curtain) exceeds 100 mg/L for River Sections 1 and 3 and 60 mg/L for River Section 2. To exceed this criterion, this condition must exist for a period corresponding to the daily dredging period (6 hours or longer) or 24 hours if the operation runs continuously (whichever is shorter) on average. Suspended solids are measured continuously by surrogate or every three hours by discrete samples.*

The net increase in suspended solids concentration between the upstream near-field station and the downstream near-field stations will be calculated during the daily dredging period for each remedial operation. Without barriers, these near-field stations will be located approximately 300 m downstream of the dredge. With barriers, these stations will be located approximately 150 m downstream of the barrier. The net increase in suspended solids concentration will be estimated for the daily dredging period (longer than 6 hours) or 24 hours if dredging is continuous. Equation 4-5 can be used to calculate the net increase in suspended solids for the time interval of concern.

Control Level exceedances are as follows:

- River Sections 1 and 3: at a net increase of 100 mg/L or higher in suspended solids concentration
- River Section 2: at a net increase of 60 mg/L or higher in suspended solids concentration

Exceedance of this criterion prompts Control Level sampling at the nearest representative far-field station. Sample collection will be timed to measure the concentration of PCBs in the impacted water column.

Each near-field 300 m station (150 m station without barriers) will be compared to either 100 mg/L or 60 mg/L, depending on the location of the remediation during Phase 1 while the behavior of the system is tested. In Phase 2, when multiple dredging operations are conducted simultaneously within the same section of the river, the sum of the concentrations measured at the near-field stations may be compared to the criterion, because this approach is in conformance with the development of the criterion. This criterion may be waived if the increase in suspended solids can be traced to meteorological events.

4.1.2.6 Far-Field Net PCB Seasonal Load

The net increase in PCB mass transport due to dredging-related activities measured at the downstream far-field monitoring stations exceeds 65 kg/year Total PCBs or22 kg/year Tri+ PCBs.

The model projections indicate that no more than 650 kg of dredging-related Total PCBs or 220 kg of dredging-related Tri+ PCBs will be exported during the period of remediation. This is prorated according to the anticipated rate of PCB inventory removal for a season (see subsection 4.1.2.7). During Phase 1, it is anticipated that one-tenth of the PCB inventory will be targeted for removal. Therefore, only one-tenth of this allowable Total PCB load (*i.e.,* 65 kg) or Tri+ PCB load (*i.e.,* 22 kg) will be the maximum allowable release of PCBs during Phase 1, assuming the target production rate is met. Assuming the target productivity schedule is followed, this value rises to 130 kg/yr Total PCBs or 44 kg/yr Tri+ PCBs during Phase 2.

The formula to estimate the dredging-related release to date is:

$$F_{todate} = \left(\overline{C_{ffst}} - \overline{C_{blt}}\right) \times Q_{todate} \times T_{todate} \times \frac{0.02832\, m^3}{ft^3} \times \frac{3600\, s}{hr} \times \frac{1 g}{10^9\, ng} \times \frac{1000\, L}{m^3} \tag{4-6}$$

where:

F_{todate} = load loss of Total PCBs at the far-field station for the dredging period to date due to dredging-related activities in g/day

$\overline{C_{ffst}}$ = flow-weighted average concentration of Total PCBs at the far-field station as measured from the start of the dredging period to date in ng/L. For once per day sampling, this is given as:

$$\overline{C_{ffst}} = \frac{\sum_{j=1}^{n} C_{ffst_j} \times Q_j}{\sum_{j=1}^{n} Q_j} \tag{4-7}$$

where:

C_{ffst_j} = Total PCB concentration at the far-field station for day j. If more than one sample is collected in a day, the arithmetic average of all the measurements will be used

Q_j = daily average flow at the far-field station for day j

n = number of days from the start of dredging period

$\overline{C_{blt}}$ = Estimated arithmetic mean baseline concentration of Total PCBs at the far-field station for the period in which the sample was collected, in ng/L. This value is determined from baseline monitoring data. Time-weighted averages are calculated as the sum of the arithmetic average for each day dividing by the number of days

Q_{todate} = average flow at the far-field station, determined either by direct measurement or estimated from USGS gauging stations, in cfs

T_{todate} = average period of dredging operations per day for the time period, in hours/day, as follows:

$$T_{todate} = \frac{\sum_{j=1}^{n} T_{d_j}}{n} \qquad (4\text{-}8)$$

where: T_{d_j} = The period of dredging operations for day j in hours.

The allowable F_{todate} in Phase I is 65 kg of Total PCBs if the total PCB mass anticipated to be dredged is 10 percent of the total PCB mass remediated as estimated in the FS (USEPA, 2001). If the production rate is different than 10 percent, the PCB load loss may be adjusted for production rate as described in subsection 4.1.2.7. This formula is intended to identify the amount of loading of Total PCBs due to dredging from the start of the dredging period to the day of measurement. It is based on the collection of grab samples, hence the correction for the daily period of operation. If sampling is conducted on an alternate basis (*i.e.,* composites), this formula will require adjustment to reflect this. The load loss of the Total PCB at the far-field stations will be compared to the allowable load loss for the dredging season.

4.1.2.7 Adjustment to the Load-Based Thresholds

The production rate will be reviewed on a weekly basis. The allowable Total PCB load loss for the season will be adjusted if this target rate is not met using the following equation:

$$AllowableSeasonalTotalPCBLoss(kg) = \frac{m}{M} \cdot 650(kg) \quad (4\text{-}9)$$

where:

m = Total PCB mass anticipated to be dredged in a season (kg)

M = Total PCB mass to be dredged in the remediation (kg), 70,000 kg as estimated in the FS (USEPA, 2001)

The allowable seven-day Total PCB load loss thresholds will be revised if the production rate varies from the anticipated value or the operation schedule differs from that assumed for this report. This revision is to be calculated once per dredging season (*i.e.,* the 7-day running average criterion is set once per season). The equation for estimating the allowable Total PCB load loss is as follows:

$$Load_{TPCB,allowable} = \frac{m_{dredged}}{P_{t\arg et} * T} * Load_{threshold} \qquad (4\text{-}10)$$

where:

m_{dredge} = Total PCB mass dredged within a period, kg

P_{target} = Targeted production rate, kg/hour. This is given as:

$$P_{target} = \frac{M}{T_d * D_{year} * Y} \qquad \text{(4-11)}$$

where:

M = Total PCB mass targeted to be dredged in the remediation (kg), 70,000 kg as estimated in FS (USEPA, 2001)

T_d = assumed average period of dredging operations per day, 14 hours/day

D_{year} = assumed number of days in one dredging season, 210 days/season

Y = number of dredging seasons during the remediation

$Load_{threshold}$ = Total PCB load thresholds specified in action levels, such as 300 g/day and 600 g/day

The load calculation may be corrected for contributions originating upstream of the remediation (*i.e.,* above Rogers Island) in the event that loads from this region fall above levels typically observed. See subsection 4.1.4.3.

4.1.3 Resuspension Standard Threshold

Resuspension Standard threshold is a confirmed occurrence of 500 ng/L Total PCBs, measured at any main stem far-field station. To exceed the standard threshold, an initial result greater than or equal to 500 ng/L Total PCBs must be confirmed by the average concentration of four samples collected within 48 hours of the first sample. The standard threshold does not apply to far-field station measurements if the station is within one mile of the remediation.

4.1.4 Calculation Details

4.1.4.1 Calculation of Total and Tri+ PCBs from Congener Data

To estimate the Tri+ PCB and Total PCB concentrations from congener data the following equations will be used:

$$\text{Tri+PCBs} = \sum_{i=1}^{n} Congeners_{Tri+,i} \qquad \text{(4-12)}$$

where:

$Congener_{Tri+,i}$ = Concentrations for PCB congeners with three or more chlorine atoms measured

$$\text{Total PCBs} = \sum_{i=1}^{n} Congeners_{all,i} \qquad (4\text{-}13)$$

where:

$Congener_{all,i}$ = Concentrations for PCB congeners measured

4.1.4.2 Non-Detect Values

Half the detection limit will be substituted for nondetect values in the formulas.

4.1.4.3 Upstream Source Concentrations

To identify the load contributions originating upstream of the remediation area (i.e., above Rogers Island), the 7-day running average of the Total PCBs should be used and compared to the monthly baseline average obtained from the baseline monitoring program. Appropriate means test should be used when comparing the 7-day running average to the baseline monthly average. Prior to performing the means test, the following should be considered:

- Normality – test for normality of the data, either using W-Test for n<=50 or Kolmogorov-Smirnov Test for n>50.
- Data transformation – repeat the test for normality on transformed data for parameters that are no normally distributed.
- Homogeneity of variance – test for homogeneity of variance using Levene's test.

After considering the above criteria, perform the appropriate one-tailed means test comparison:

- For normally distributed data, t-test should be used if the variance is homogeneous, otherwise approximate t-test should be used.
- For data that are not normally distributed, the non-parametric Mann-Whitney U test should be used.

After the means test is performed, the downstream load calculations may be corrected by subtracting the load obtained from the difference between the average concentrations. The additional load originating from upstream source can be calculated as follows:

$$F_{RI} = \left(\overline{C_{RI}} - \overline{C_{RIbl}}\right) \times Q_{ff} \times T_{d7} \times \frac{0.02832\,m^3}{ft^3} \times \frac{3600s}{hr} \times \frac{1g}{10^9 ng} \times \frac{1000L}{m^3} \qquad (4\text{-}14)$$

where: F_{RI} = Average additional load of Total PCBs originating from upstream source in g/day,

$\overline{C_{RI}}$ = Seven-day average concentration of Total PCBs from upstream source (above Rogers Island) in ng/L.

$\overline{C_{RIbl}}$ = Baseline monthly average concentration of Total PCBs from Baseline Monitoring Program.

Q_{ff} = Average flow at the far-field station, determined either by direct measurement or estimated from USGS gauging stations, in cfs, and

T_{d7} = Average period of dredging operations per day for the seven-day period, in hours/day, as defined in equation 3.3.

The corrected downstream load is then:

$$F_{7corr} = F_7 - F_{RI} \qquad (4\text{-}15)$$

where: F_{7corr} = Corrected load at the far-field station in g/day.

F_7 = Seven-day average load of Total PCBs at the far-field station due to dredging-related activities in g/day.

F_{RI} = Average additional load of Total PCBs originating from upstream source in g/day.

4.2 Monitoring Plan for Compliance with the Standard

Implementation of the monitoring program for compliance is provided in the subsections 4.2 and 4.3. Measurement techniques, monitoring locations, parameters, sampling frequency and requirements of the standard are provided. Attachment F provides a description of measurement techniques for the continuous monitoring requirements. Some of the more stringent aspects of this monitoring program, such as the need to have a real-time surrogate measurement of suspended solids to provide a warning of elevated contaminant levels, may be relaxed after Phase 1. A clear rationale for each element of the monitoring plan is presented in Section 3. Additional monitoring in the form of special studies is required to gather information that can be used to refine the standard. This is described in subsection 4.4.

4.2.1 Measurement Technologies

Sampling techniques and technologies have been reviewed to select the appropriate means of obtaining the monitoring data needed to confirm adherence to the standard. The far-field monitoring will be similar to the baseline monitoring program implemented during the remedial design period (2003 – 2005). The near-field monitoring will have a reduced set of parameters and has little relation to previous sampling efforts. Some additional components will be required to give a full picture of the conditions during dredging *(e.g.,* continuous monitoring for PCBs), but will not be assessed against the action levels in Phase 1.

Instruments that provide an instantaneous measure of water column conditions will be used for the following parameters:

- Turbidity
- Dissolved oxygen
- Temperature
- pH
- Conductivity
- Laser particle counters

Continuous measurement of water column conditions will be made for:

- Turbidity
- Laser particle counters
- Integrating sampler for PCBs (continuous sampler)

The analytical methods will need to be sensitive enough to measure water column concentrations at each station. This is most important for PCBs. For Total and Tri+ PCBs, a congener-specific method with a detection limit low enough to detect expected PCB congener concentrations at Bakers Falls, Rogers Island, and Waterford is required.

4.2.2 Consistency with the Baseline Monitoring Program

There will be several monitoring programs developed throughout the remediation. The primary programs are:

- Baseline
- Remedial
- Long-term

To capture a consistent picture of the site conditions, there must be consistency throughout the programs on key issues. Two items that must be carefully chosen are the measurement techniques (analytical or direct reading) and the locations of

Measurement techniques and stations or substation locations must be carefully selected.

the stations or substations.

The analytical methods chosen for this program must meet or exceed the specifications of the methods used in the baseline monitoring program in terms of precision, sensitivity, accuracy, representativeness, comparability, completeness and sensitivity. The only exception to this requirement will be the modified method specified for TSS to allow a reduced turn-around time. The same analytical methods chosen for each station will be maintained at each station throughout the program for consistency.

Data collected during baseline monitoring will be the means of differentiating dredging-related loads from baseline loads.

The same stations must be occupied during the remediation as during the baseline monitoring program. Any change to the location or method of collection will result in changes to the resulting data that cannot be easily accounted for, confounding estimates of PCB conditions. The data collected during baseline monitoring will be the means of differentiating dredging-related loads from baseline loads. A correction would need to be applied to the baseline data to properly determine compliance with the load-based resuspension criteria, but there is no basis for developing this correction factor. Therefore, it is essential to maintain the same monitoring locations and sampling methods.

Two important aspects of the baseline monitoring program are the equal discharge interval sampling method and the requirement that samples collected from the water column cannot be split among multiple sample jars. These requirements must be maintained for the resuspension standard monitoring program.

4.2.3 Compliance Monitoring Programs

Monitoring will be required for at least the remedial operations listed below. Other operations related to dredging may be included as well:

- Dredging
- Debris removal
- Resuspension control equipment removal
- Off loading to the processing facility
- Cap placement
- Backfill placement
- Installation of containment devices other than silt curtains (sheet piling and other structural devices requiring heavy equipment operation and disturbance of the river bottom)
- Shoreline excavation and restoration

The following remedial operation will not require near-field monitoring:

- Silt curtain placement

4.2.3.1 Far-Field Monitoring

The far-field stations will be used to monitor water column conditions in the Upper and Lower Hudson River. These results are needed for comparison to the baseline water column concentrations to estimate the magnitude of any dredging-related release. Due to the anticipated extent of remediation and associated barge traffic, dredging-related releases may not be limited to a single area; thus, monitoring of multiple stations is anticipated throughout the dredging period.

The parameters of primary interest are PCBs and related parameters including turbidity, suspended solids, DOC, and suspended OC. A surrogate real-time measure of suspended solids will be used as an indicator of dredging-related releases, assuming the mechanism for increased PCB concentrations from dredging operations will involve the resuspension of contaminated sediment. DOC and suspended OC describe the dissolved and suspended matter distribution of PCBs in the water column. These parameters also may be useful in determining the source of elevated concentrations.

A surrogate real-time measure of suspended solids will be used as an indicator of dredging-related releases, assuming the mechanism for increased PCB concentrations associated with dredging will be resuspension of contaminated sediment.

Discrete Samples

The far-field Upper Hudson River sampling will require the measurement of PCB congeners, suspended solids, and OC by taking discrete, cross-sectional grab samples. These measurements are necessary to assess the impacts of the dredging operations and to provide a basis for a warning system for the downstream water intakes. The required sampling in the Lower Hudson River is similar to the far-field Upper Hudson River sampling, but is more limited in the extent and frequency of sampling. Data from these samples will identify increased impacts to the Lower Hudson River from dredging and be compared to resuspension criteria.

Unless stated otherwise, the monitoring and sampling at each station will be performed using equal discharge increment (EDI) sampling for the Phase 1 monitoring program. Equal width increment (EWI) sampling techniques may be considered for an alternate Phase 2 monitoring program. The EDI or EWI methods usually result in a composite sample that represents the discharge-weighted concentrations of the stream cross-section for the parameter that is being monitored or sampled. The EDI and EWI methods are used to divide a selected cross section of a stream into increments having a specified volume of flow or width.

The samples will be integrated both vertically and horizontally. The term vertical refers to that location within the increment at which the sampler or the measurement probe is lowered and raised through the water column. EWI verticals are located at the midpoint of each width increment. EDI verticals are located at the centroid, which is a point within each increment at which stream discharge is equal on either side of the vertical. If properly implemented, EDI and EWI methods should yield identical results. These sampling methods will be applied for all parameters measured in the water column.

Daily average flow rates at each far-field station will be recorded for comparison of the discrete sample measurements to the load-based criteria.

Continuous Integrating Samplers for PCBs

Continuous integrating samplers will be set up at the far-field stations between Fort Edward and Waterford. These samplers will be used throughout the dredging program to integrate PCB loads and concentrations over time, providing a measure of PCBs releases between the discrete samples. Integrating data over time intervals in the periods between the discrete water column samples will enable identification of dredging-related releases, including dissolved-phase PCBs that cannot otherwise be identified by examining surrogate measurements such as suspended solids. The Phase 1 results may be used to develop resuspension criteria for Phase 2.

Continuous Monitoring for Suspended Solids Surrogate at the Representative Far-Field Stations

The suspended solids will be continuously monitored via surrogate direct reading monitors (*e.g.*, laser diffraction-based particle counters and turbidity monitors). A special study will be conducted to determine an initial surrogate relationship (see subsection 4.4) that will allow the suspended solids concentrations to be estimated in real time, which provides a warning system for downstream water intakes in the Hudson River. The real-time estimates of suspended solids will be compared to measured values from samples collected once per day at each station. At least three substations must be monitored (one in the channel, one on each shoal), but preferably, five or six substations will be occupied in the same manner as the Baseline Monitoring Program sampling.

If the relationship between surrogate and TSS does not provide sufficiently accurate estimates of TSS, samples will be collected for suspended solids analysis every three hours with a three-hour turn-around (using a modified TSS method) for compliance to the standard until an appropriate surrogate relationship is developed and implemented. In the event of an exceedance of the suspended solids resuspension criteria based on the surrogate measurement, TSS samples will be collected for confirmation twice a day at the station with the exceedance.

All continuous monitors will be checked daily for problems such as bio-fouling and damage.

Suspended Solids Collection at Other Downstream Far-Field Stations

The standard requires that samples be collected for suspended solids analysis every 3 hours on a 24-hour basis at the downstream far-field stations, excluding the representative far-field station. These samples will be collected by means of automatic samplers placed in the cross-section of the river. At a minimum, there will be one center channel station and two shoal stations, one on each side of the river, but preferably these samplers will be deployed in a manner that is consistent with EDI. The samplers must be capable of collecting and storing a series of three hour composite samples. The samples will be collected twice a day. The turnaround time for these results will be 12-hours. Decontamination procedures must be developed for these samplers that meet with USEPA approval.

Monitoring Parameters Without Resuspension Criteria

Monitoring parameters required by the performance standard (*i.e.*, discrete measures taken whenever samples are collected for PCB or suspended solids analysis), but not compared to resuspension criteria, are:

- Temperature – because the distribution of PCB concentrations between the dissolved and suspended phases is partially dependent on water column temperature.
- pH – to provide a measure of quality assurance by comparing values to the New York State surface water standard (6.5 to 8.5 [6 NYCRR part 703.3])
- Conductivity – to provide a measure of quality assurance
- DO - because high suspended solids could exert a demand on oxygen levels, which is potentially damaging to biota in the region of the dredge.

4.2.3.2 Near-Field Monitoring

Monitoring in the near field will be performed to determine the suspended solids releases. This will include both continuous measurements of surrogates and discrete samples.

Continuous monitoring for a suspended solids surrogate is required to address two goals of the Phase 1 standard:

- To provide a real-time measure of conditions surrounding the dredging operation
- To provide feedback to the dredge operator

The real-time measure provides an immediate signal to the dredge operator in the event of an unexpected release. It also provides the dredge operator with feedback in the form of information on the amount of resuspension resulting from various dredge manipulations. Using this information, the dredge operator is expected to optimize the manipulations of the dredge to avoid unnecessary resuspension. Based on this need, continuous reading probes must be deployed in the near field even if their output does not yield a sufficiently useful estimate of TSS.

The continuous suspended solids monitoring consists of monitoring suspended solids via surrogate direct reading monitors (*e.g.*, turbidity monitors) at each near-field station. A special study will be conducted to determine an initial surrogate relationship (see subsection 4.4). This relationship will allow the suspended solids concentrations to be estimated in real time based on the continuous reading probes. The real-time estimates of suspended solids will be compared to measured values from samples collected once per day at each station.

If the relationship between surrogate and suspended solids is not sufficiently protective of the various action level criteria, samples will be collected for suspended solids analysis every three hours with a three-hour turnaround (using a modified TSS method) for compliance to the standard until an appropriate surrogate relationship is developed and implemented. In the event of an exceedance of the suspended solids resuspension criteria based on surrogate readings, samples will be collected for confirmation twice a day at the station with the exceedance.

Continuous monitors will be deployed such that the measurements are made from the middle of the water column (halfway between the river bottom and the water surface).

Continuous monitors will be checked daily for problems such as bio-fouling and damage.

Daily particle counter measurements will be required at each near-field monitoring location. This will provide an additional means of relating a real-time measurement to suspended solids.

4.2.4 Monitoring Locations

The monitoring plan has two baseline stations (Bakers Falls and Rogers Island), four Upper Hudson far-field stations, and two Lower Hudson far-field stations. In addition, each dredging operation has 5 near-field stations.

4.2.4.1 Far-field Monitoring

The following stations, locations of which are shown in Figure 1-2, comprise the far-field monitoring stations for the Upper Hudson River:

- TI Dam[22]
- Schuylerville
- Stillwater
- Waterford

Two upstream baseline stations will be monitored in the Upper Hudson River:

- Bakers Falls
- Rogers Island

The Bakers Falls and Rogers Island stations represent baseline conditions for the remediation area and thus need to be monitored regularly to avoid confusion between

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[22] The Thompson Island Dam station will be a true cross-sectional station, as opposed to the historical TID West or PRW2 stations.

dredging-related releases and those that may have occurred upstream. The frequency of monitoring at Bakers Falls will be less than that at Rogers Island, if the Bakers Falls station continues to exhibit low baseline levels of PCBs and suspended solids relative to Rogers Island conditions.

In the Lower Hudson River, the following stations will be monitored:

- Albany
- Poughkeepsie

In addition to these Lower Hudson River stations, a monitoring station will also be required on the Mohawk River at Cohoes to estimate PCB loads from the Mohawk watershed. This station will be used in conjunction with the measurements at the Lower Hudson River monitoring locations to aid in identifying the fraction of any PCB load increase from the Mohawk River, as opposed to the Upper Hudson River remedial activities.

The daily (and any continuous) measurements at the far-field stations must reflect the river cross section at the monitoring location by using EDI (USGS, 2002). At least five locations will be monitored in each cross section. Discrete samples in the cross section may be composited, but continuous reading devices (*i.e.*, turbidity) are required at multiple locations in the cross section.

4.2.4.2 Near-Field Monitoring Locations

Near-field monitoring locations are associated with individual remedial operations and move as the operation moves. The data from these locations have two principal objectives: provide feedback to the dredge operator and, provide a measure of suspended solids release from the operation. Each remedial operation requires five monitoring locations, which are arranged as shown in Figure 1-1 and described as follows:

- One station located approximately 100 m upstream of the dredging operation will monitor water quality conditions entering the dredging area to establish ambient background conditions.

- One station located 10 m to the channel side of the dredging operation will monitor local boat traffic impacts.

- One station located 100 m downstream of the dredging operation or 50 m downstream of the most exterior silt control barrier will monitor the dredge plume.

- Two stations located 300 m downstream of the dredging operation or 150 m downstream of the most exterior silt control barrier will monitor the dredge plume.

The locations and associated criteria were chosen using the TSS-Chem model assuming that a single dredging operation was achieving full production (refer to Attachment D of this report). If control barriers are installed, the five stations will be placed outside of the barrier. A sixth location within the barrier is required in the controlled area downstream of the dredge. While there is no standard for this inner station, it is needed to develop a relationship between conditions inside the silt barriers and the near-field monitoring stations downstream. The distances from the remedial operations are approximate and the location of the near-field stations may be changed in the field to better capture the plume, if USEPA approves the change.

It is acknowledged that the location of remedial operations and control barriers will be determined during the design. As a result, the location of the near-field monitoring stations can only be anticipated in this standard, but will be reviewed as a part of the design. Work plans developed for the remediation must specify a means of verifying that the downstream monitors are placed to capture the plume. The acoustic doppler current profiler (ADCP) may be useful in this regard. With changing river conditions and movement of the dredge, periodic adjustment of the monitoring locations will be required.

Work plans developed for the remediation must specify a means of verifying that the downstream monitors are placed to capture the plume.

4.2.5 Potential for Reduction in the Near-Field Monitoring Locations

In order to provide an accurate representation of the suspended solids around the dredging operations, all five monitoring (or six with containment barriers) are necessary. However, if remedial operations are located in close proximity to one another, it may not be feasible to maintain all of the locations since they may pose a safety concern to the technicians or they will be within the working area for a downstream operation. In this case, monitoring locations may be dropped at the discretion of the construction manager for as long as this condition exists.

Such decisions must be documented in the weekly reports. At this time, it is anticipated that stations will be dropped only if the remedial operations are located on the same side of the river. A more prescriptive definition of the conditions when dropping a station would be appropriate cannot be developed at this time, because this is contingent on design specifications, including equipment types and schedule, that are not presently available.

A possible example of conditions in which the number of stations can be reduced is when remedial operations are conducted within 600 m (0.25 mile) of each other on the same side of the river. This is the distance initially prescribed between the upstream station and the farthest downstream stations, assuming no containment. In this situation, the monitoring locations of the upstream operation would fall within the work zone of the downstream operation. To remedy this, one or more of the downstream monitoring locations for the upstream operation may be dropped. Additionally, the remaining stations may serve as both downstream monitors for the upstream operation as well as baseline monitors for the downstream operation.

If the operations are sufficiently close (*i.e.*, within 0.25 miles and on the same side of the river), the USEPA field coordinator may approve the monitoring of the two operations as a single unit, thus halving the monitoring requirements. A similar configuration may occur for contained areas, but the revisions to the monitoring program cannot be specified, without further information to be developed during the design.

4.2.6 Frequency and Parameters

Tables 1-2, 1-3, and 1-4 contain the parameters and frequency of sampling required by the Resuspension Standard for routine monitoring and each action level. The parameters required are constant throughout, but the sampling method or analytical technique may differ in some instances. The sampling frequency varies by station and action level.

4.2.6.1 Analytical Methods for Suspended Solids

Suspended solids measurements are required at both near-field and far-field stations. While a surrogate measurement of suspended solids concentrations is in use for compliance with the standard, a method equivalent to ASTM method 3977-97 will be used with a turnaround time of 12 hours. This method will be equivalent to the suspended solids analysis specified for the baseline monitoring program. A second modified method will be specified that will allow an estimate of suspended solids concentrations to be made with a three-hour turnaround time. Modifications to the standard method to permit a reduced turnaround time may include:

- Collection of a larger sample volume when suspended solids are visibly low
- Reduction in drying time
- Higher drying temperature
- Field filtration

Co-located samples for both the standard and modified suspended solids methods will be collected at a frequency of once per day for the first month of operation. The samples should be collected from a range of concentrations to permit a full comparison of the methods. If the methods are in good agreement (relative percent difference is less than 30%), the sampling frequency for co-located samples by the full ASTM method may be reduced.

4.2.6.2 Sampling Methods for Suspended Solids

Suspended soilids samples will be collected for confirmation of the surrogate measurements and compliance monitoring (in place of the surrogate measurements), and in support of the PCB analyses. The collection method for confirmation of the surrogate measurements will differ in that the sample must collected at the location of the turbidity sensor. For the far-field stations, the volume that is equivalent to the percentage of discharge that a continuous monitor represents must be acquired for each substation. The collection method for compliance monitoring will be vertically integrated samples at each near-field station or compliance with the EDI method at the far-field station. The sampling for supporting information for PCB analyses will be consistent with the PCB sample collection process.

No splitting of water samples is permissible for any measurements that must accurately reflect the suspended solids content. If duplicate samples are required, the sample bottles for the duplicate and sample analysis can be deployed at once or in series to generate co-located samples. Sample bottles for PCB and suspended solids analysis should be deployed simultaneously if possible.

No splitting of water samples is permissible for any measurements that must accurately reflect the suspended solids content.

4.2.6.3 Far-field Monitoring Parameters and Frequency

Table 4-4 presents the relevant information for each parameter that will be monitored as part of the far-field Upper Hudson River program. PCB congeners will be analyzed using the Green Bay method or an equivalent method. Attachment F-2 provides a synopsis of PCB analytical methods and associated detection limits. As stated above, the analysis for suspended solids will be conducted using a method equivalent to ASTM method 3977-97. The entire sample collected will be used for the suspended solids and PCB analyses.

All measurement techniques require sufficient sensitivity to avoid non-detect values at most stations. For PCB congeners, low detection limits will be required at Bakers Falls, Rogers Islands, and Waterford. Discrete samples must be collected from a potentially impacted water parcel as it passes the station, although samples from different stations do not need to be timed to correspond to the same water parcel.

The type of integrating sampler will be determined during design. Analysis for DOC, suspended OC, and suspended solids will be required in addition to PCB congeners for these samples, if this is appropriate for the type of sampler chosen.

The standard requires that samples for suspended solids be collected every three hours continuously at each of the far-field stations, but that at the near representative far-field station, a surrogate relationship will be developed to have a real-time indication of the suspended solids concentrations. If suspended solids analyses for compliance have a turn-around time of 12 hours at all other far-field stations, but if samples are collected for compliance at the representative near-field station (*e.g.,* TI Dam if dredging is limited to the TI Pool), the turn-around time is three hours. It will be permissible to use an integrated sampler to collect the eight samples per day for suspended solids (if the sampler is capable of collecting eight separate samples over time) and sending all eight samples to the laboratory once per day. This will greatly reduce the labor requirements for the monitoring program.

Whole water samples for PCB analysis must include a process to extract PCBs from the dissolved and suspended phases separately, using matrix-specific extraction and cleanup methods used for the Reassessment RI/FS or similar methods demonstrated to be capable of achieving equivalent extraction efficiencies. Justification for this approach is provided in Attachment F-3. Analyses may be done on the combined extracts.

Routine and non-routine monitoring of the 6 Upper River mainstem stations will both require the same analysis, but sampling method and frequency will vary with the station and action level.

Routine monitoring of the six Upper River mainstem stations will consist of grab samples and continuous monitoring. Non-routine monitoring will require the same analyses, but the sampling method and frequency will vary with the station and action level. Grab samples will be composited from five or six samples in the cross section using the EDI sample collection method and consistent with the approach taken during the baseline monitoring program. Continuous monitors will be located in at least three locations (on channel station and two shoal stations), although it would be preferable to have the stations deployed consistent with EDI or EWI locations.

At Bakers Falls, one whole water PCB sample will be collected per week. DOC, suspended OC, and suspended solids will be measured for these samples. The surface water quality parameters to be measured are as follows:

- Turbidity
- Temperature
- pH
- Conductivity
- DO

Routine and non-routine monitoring are the same for this station. Laboratory results must be available within 72 hours of the collection of the sample. This station will be sampled from only one location in the cross section.

At Rogers Island, one whole water PCB sample will be collected per day. DOC, suspended OC, and suspended solids will be measured for these samples. Surface water quality parameters to be measured continuously are as follows:

- Turbidity
- Temperature
- pH
- Conductivity

Dissolved oxygen measurements will be made along with each grab sample collected for suspended solids. Samples will be collected for suspended solids every 3 hours, 24 hours per day. An integrating sampler will be deployed continuously for a two-week period throughout the construction season. The turn-around time for the PCB analysis is 72 hours from the collection of the sample. Routine and non-routine monitoring are the same for this station. The monitoring frequency at Rogers Island may be reduced to weekly for all parameters except suspended solids, if the data will not be used to monitor for releases from the upstream sources that could be interpreted as releases from the remediation. Reduction in frequency at this station will require approval from USEPA.

USEPA has not yet identified the location of the Phase 1 dredging. Assuming that the remediation will be limited to the northern end of the TI Dam during Phase 1, there will be two representative stations that are sampled with a shorter turn-around and a higher frequency for monitoring contingencies: the TI Dam and Schuylerville stations.

During Phase 1, the Stillwater and Waterford stations will be monitored to measure the PCB concentrations entering the Upper Hudson River public water treatment plants in Halfmoon and Waterford, and to confirm or adjust the means of by which Total PCB concentrations for the Waterford station have been estimated based on the concentrations at the upstream stations. This information will be important during Phase 1 to understand the behavior of the system, but the frequency of sampling at these downstream locations will most likely be reduced in Phase 2.

Routine monitoring for the four Upper River far-field stations from the TI Dam to Waterford will be identical to the monitoring at Rogers Island, with some exceptions:

- Suspended solids will be continuously monitored with a particle counter at these stations.
- Grab sample laboratory results for parameters other than suspended solids must be available within 24 hours of the collection of the sample for the TI Dam and Schuylerville.
- The nearest representative station, which would be the TI Dam station if dredging is conducted in the TI Pool throughout Phase 1, will be required to have a surrogate relationship for suspended solids concentrations in place of the suspended solids sampling.

Non-routine monitoring at the two representative stations (TI Dam and Schuylerville) will increase in frequency for the PCB, DOC, suspended OC, and suspended solids samples, and the PCB analyses will be on the dissolved and suspended phases instead of whole water. For the Evaluation Level, the samples will be collected twice a day. For the Control Level samples will be collected three times a day. For the Resuspension Standard threshold, the samples will be collected four times a day, but will be composited from samples collected hourly over one six-hour period.

The deployment period for the integrating sampler will also vary. For the Evaluation Level, the deployment period is the same as for routine monitoring. For the Control Level, the integrating sampler will be deployed for periods of one week. For the Resuspension Standard threshold, the integrating sampler will be deployed for one-day periods.

The sampling frequency and turn-around time is unchanged from routine monitoring for the Evaluation Level for Stillwater and Waterford, the farthest downstream stations. The sampling method changes for the Control Level from discrete grab samples to daily integrating samples to capture the average concentration in what could be a rapidly changing environment.

Sampling frequency and turn-around time for Stillwater and Waterford is the same as routine monitoring for the Evaluation Level but changes from discrete grab samples to daily integrating samples for the Control Level.

The analytical results will be required within 24 hours for the Control Level. This shorter turn-around time requirement is warranted for this action level because the Total PCB concentration could be approaching the Resuspension Standard threshold, or because the PCB load loss to the Lower Hudson River has exceeded the allowable rate for an extended period of time. For the Resuspension Standard threshold, these stations will be sampled four times a day for:

- Whole water PCBs
- DOC
- Suspended OC
- Suspended solids
- Surface water quality

In addition, an integrating sampler will be deployed for one-day periods. The turn-around time for PCB analyses from the integrating sampler will only be specified where the information is needed quickly for comparison to the resuspension criteria. For the Resuspension Standard, the turn-round times will be 24 hours for the two representative far-field stations (TI Dam and Schuylerville stations) and the stations farther downstream (Stillwater and Waterford stations). For the Concern and Control Levels at Stillwater and Waterford, the turn-around times will be 72 hours and 24 hours, respectively.

These monitoring contingencies are for remediation of River Section 1 more than one mile upstream from the TI Dam monitoring location. If dredging were conducted in River Sections 2 and 3, the two stations downstream of the dredging will have the parameters, frequency, sampling methods, and turn-around times associated with the TI Dam and Schuylerville as described above, and stations below these stations will have the parameters, frequency, sampling methods and turn-around times associated with Stillwater and Waterford, also as described above.

If the remediation is conducted in more than one river section, more than two stations are representative. If there were an accidental release in a section that was not undergoing remediation at that time, the two stations at least one mile downstream of the accidental release would be representative until the situation was resolved. Representative stations must always be more than one mile downstream from the source of the resuspended material. In the event that a far-field suspended solids resuspension criterion is exceeded, the far-field station would be monitored for PCBs.

In the event that a far-field suspended solids resuspension criterion is exceeded, the far-field station would be monitored for PCBs.

Exceedance of Evaluation Level criteria will prompt far-field Evaluation Level discrete sample monitoring requirements. Exceedance of Control Level criteria will prompt far-field Control Level monitoring discrete sample monitoring requirements. This additional far-field sampling will be limited to the nearest downstream representative far-field station or the next downstream station, depending on the location of the plume causing the exceedance. Sample collection will be timed to capture the plume. The frequency, parameters and sampling methods will be the same as those defined for the TI Dam and Schuylerville in Table 1-2.

If the monitoring requirements change because of exceedance of a resuspension criterion or reverting to lower action levels, the deployment period of the continuous integrating samplers may change before completion of the period. If the deployment period is reduced, the sample already collected will be sent for analysis. If the deployment period is extended, the sampling period can be extended to match the new requirements.

Affirmation Sampling

Integrating PCB samplers are required to verify whether the grab samples are sufficiently indicative of average river conditions. The deployment for the integrating sampler varies from routine monitoring to different action levels. For routine monitoring and evaluation level, the deployment periods are once every two weeks. At the control level, the integrating sampler deployment periods at TID and Schuylerville are increased to once a week. For Stillwater and Waterford far-field stations, the deployment periods are increased to once a day at the control level. Similarly, at the resuspension standard threshold, the deployment periods are once a day for all the far-field stations.

To ensure that the grab samples represent the average river conditions, the appropriate means test comparison of the grab samples to the integrated samples need to be performed. To perform the means test comparison, the following should be considered:

- Normality – test for normality of the data, either using the W-Test for n<=50 or the D'Agostino Test for n>50.
- Data transformation – repeat the test for normality on transformed data for parameters that are not normally distributed.

After considering the above criteria, perform the appropriate one-tailed means test comparison:

- For normally distributed data, t-test should be used if the variance is homogeneous, otherwise approximate t-test should be used.
- For not normally distributed data, the non-parametric Mann-Whitney U test should be used.

If the means test results indicate that the mean of the grab samples is not statistically different from the corresponding integrating samples, the sampling frequencies and approach for both the grab and integrating samplers are appropriate. On the other hand, if the means test indicate that the mean of the grab samples is statistically different from the mean of the integrating samples, additional study for both integrating and grab samples needs to be performed to assess the adequacy of the grab and integrating samples.

4.2.6.4 Lower Hudson River and the Mohawk River at Cohoes

Far-field stations in the Lower Hudson River and at one location in the Mohawk River will require routine monitoring. Sampling at these stations will include the analysis of PCBs congeners, DOC, suspended OC, and suspended solids. The samples will be whole water, not split phase. Discrete measurements will be made for the following:

- Surface water quality measurements for turbidity
- Temperature
- pH
- Conductivity
- DO

The results of the analyses will be required within 72 hours. Samples will be collected every four weeks under routine monitoring. (This low frequency is contingent on the results of the baseline monitoring program showing Total PCB concentrations less than 100 ng/L on average to allow a margin of safety for the public water supplies.) The Mohawk River station will be sampled using EDI, but only a single center-channel station is required for the Lower Hudson River stations.

Non-routine monitoring at these locations will be triggered by an estimated Total PCB concentration of 350 ng/L or higher at Waterford or Troy. The first round of non-routine monitoring will be timed to capture the parcel of water that triggered the non-routine Lower Hudson River and Mohawk River monitoring.

The concentration is estimated using the following equation:

$$C_{Lower\ \ Hudson} = C_{Far-field} \times \frac{Q_{Far-field}}{Q_{Troy}} \qquad \text{(4-16)}$$

where:

C_{Troy} = Estimated water column concentration Troy

$C_{Far\text{-}field}$ = Measured water column concentration at the far-field station

$Q_{Far\text{-}field}$ = Instantaneous flow at the far-field station (cfs) at the time of sample collection

Q_{Troy} = Instantaneous flow over Federal Dam at Troy

4.2.6.5 Near-field Monitoring

Routine Sampling for Compliance

The parameters that are monitored in the near field are summarized in Table 4-5 along with the relevant information for each parameter. The standard requires that a surrogate real time measurement for suspended solids be developed and maintained throughout the program for compliance with the near-field resuspension criteria. It is expected that turbidity will be the surrogate measure chosen.

Each near-field station will have continuous monitoring for turbidity, temperature, and conductivity for one hour prior to beginning remedial operations and for at least two hours after the operation ceases. This applies to the five stations required if there are no barriers installed, and to all six stations if barriers are installed. The information from these monitors will provide immediate feedback to the dredge operator.

Confirmation Sampling of the Surrogate

Samples will be collected daily from each near-field monitoring location for confirmation of the surrogate relationship. The ability of the surrogate to adequately predict the suspended solids concentrations will be assessed on a daily basis. The criteria and method for assessing the surrogate relationship is provided in Section 4.4. If the resuspension criteria are exceeded at a near-field monitoring station, two samples will be collected per day for confirmation of the surrogate.

In the event that the surrogate fails to adequately predict the suspended solids concentrations, samples will be collected every three hours and analyzed for suspended solids using the modified method with a three-hour turn-around. Vertically integrated samples will be collected from each near-field station every three hours with the results of the analysis available within three hours. These results will be compared to the resuspension criteria. One sample from each near-field station will be collected one-hour prior to beginning the remedial operations at a location.

After completing the remedial operation, at least two samples collected one hour apart will be used to confirm that the suspended solids concentrations have stabilized. This will require the sampling to continue for at least another four to five hours because of the three-hour turn-around time on the analyses. More samples will be required if the suspended solids concentrations have not stabilized two hours after completing the remedial operation. If the remediation is halted due to hazardous conditions such as thunderstorm, the near-field monitoring to show that the suspended solids concentrations have stabilized will not be required.

After completing the remedial operation, at least two samples collected one hour apart for four to five hours will be used to confirm that the suspended solids concentrations have stabilized.

Other Parameters

Discrete laser particle counter measurements will be made on any samples collected for suspended solids analysis.

At both the near-field and far-field stations, pH and DO will be monitored discretely each time a sample is collected.

Exceedance of the Near-Field Resuspension Criteria

Exceedance of near-field Evaluation Level suspended solids criteria will prompt far-field Evaluation Level monitoring. Similarly, exceedance of near-field Control Level suspended solids criteria will prompt far-field Control Level monitoring. This additional sampling will be limited to the nearest downstream representative far-field station and timed to capture the plume from the remedial operation. The frequency, parameters and sampling methods will be the same as those defined for the TI Dam and Schuylerville, as shown in Table 1-2.

Engineering Evaluations

Additional sampling in the near field may be conducted as a part of the engineering evaluations. Samples for PCB analysis may be collected in the vicinity of the dredges or in other areas affected by the remediation. The same sampling and analytical methods will be used for comparison to the near-field and far-field data.

4.3 Reverting to Lower Action Levels

Any reduction in monitoring requires approval from USEPA before the changes are made. USEPA may approve a reduction in the level of monitoring when the following occurs for Total PCB criteria:

- For the exceedance of a Control Level concentration criterion, the running average concentration must fall below the action level for one week before the contingencies can be relaxed.

- For the exceedance of a Evaluation or Control Level seven-day running average load-based criterion, the running average load level must fall below the action level for one week before the contingencies can be relaxed.

- Following exceedance of Resuspension Standard threshold, temporary halting of in-river operations, and modification of the remedial operation, Control Level monitoring requirements will commence unless otherwise instructed by USEPA.

- Routine monitoring will resume in the Lower Hudson after non-routine monitoring has confirmed that the concentrations in the Lower Hudson are below 350 ng/L Total PCBs and the estimated concentration at Waterford and Troy have fallen below 350 ng/L Total PCBs for at least two days.

- When suspended solids criteria are exceeded, the suspended solids concentrations must fall below the action level for one day before USEPA may approve a reduction in the level of monitoring and the contingencies can be relaxed.

During temporary halting of in-river remedial operations, routine monitoring of the Upper River far-field stations will continue. If the operations are temporarily halted, monitoring in the Lower Hudson will continue at non-routine frequency until the requirements listed above are met.

4.4 Special Studies

The monitoring programs for the resuspension and residual standards are organized to separate sampling necessary to measure compliance with the standard from sampling efforts needed to evaluate and refine the implementation of the standard. This has been accomplished by designating the second category of sampling efforts as “special studies.” The special studies will be conducted for limited periods of time to gather information for specific conditions that may be encountered during the remediation or to develop an alternate strategy for monitoring. Specific conditions may include different dredge types, contaminant concentration ranges, and varying sediment textures. Each of these studies is integral to the Phase 1 evaluation, the development of Phase 2, and is also tied to compliance issues.

There are a total of five special studies for the resuspension standard. These are as follows:

- Near-field PCB Release Mechanism (Near-field PCB Concentrations)
- Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement for the Near-field and Far-field Stations (Bench Scale)
- Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement for the Near-field and Far-field Stations (Full Scale)
- Non-Target, Downstream Area Contamination
- Phase 2 Monitoring Plan

The main components of each of these studies is described below.

4.4.1 Near-Field PCB Concentrations

A special study will be conducted in the near field to characterize the nature of PCB release due to dredging-related activities, specifically to evaluate whether the PCB release due to these activities occurs as the result of dissolved-phase or suspended-matter phase releases. Data from this study will be used to evaluate the use of suspended solids as a useful surrogate to identify PCB releases. Suspended solids will be a useful predictor of PCB exceedances if the nature of the release is primarily resuspension of suspended-phase PCBs. Following are some of the specifics that pertain to the Near-Field PCB Concentrations Study.

4.4.1.1 Duration

Each study will last for a full work week (six or seven days) in each selected area. The duration for the study of debris removal may be reduced if the debris removal is completed in less than a week.

4.4.1.2 Sample Collection

The study will entail daily sample collection for each study area during the week of investigation. This should allow for the collection of a sufficient number of samples to distinguish dredging-related conditions from variations in the water column due to baseline conditions.

The sampling locations will be arrayed in two transects located 100 ft and 200 ft downstream of the dredge and will also include one upstream location. If there is containment around the dredge, one composite sample consisting of three discrete locations will be collected from within the containment and the transects will be located just downstream of the containment and 100 ft downstream.

Each transect will contain five sample locations. If the water depth is greater than 10 ft, two samples will be collected from each location (0 to 10 ft and deeper than 10 ft). A sample will also be collected from a station 50 ft upstream from the dredge. Figure 1-1 depicts the layout of the monitoring stations. The location of the sampling stations may be adjusted with the approval of the USEPA’s field coordinator.

The plume will be identified at the transect locations using ADCP. This will be done with a second boat that will continuously monitor for the location of the plume during the sample collection. The signal from the ADCP increases markedly once the edge of the plume is encountered.

4.4.1.3 Sample Handling

Vertically integrated samples will be collected following EDI techniques to represent the area around the dredge (not the entire river width) and composited. Each sample (comprised of several vertically integrated sampling nodes) will be filtered in the field as soon as possible from the time of collection. Filtering of the sample must be completed within two hours of collection. Samples will be collected in separate bottles at each substation for each parameter measured. No samples will be split.

4.4.1.4 Analytical and Direct Reading Methods

The following parameters will be measured on each sample:

- PCB congener analysis (dissolved and suspended phases)
- Suspended organic carbon
- Dissolved organic carbon
- Suspended Solids

Turnaround times must be assigned to allow sufficient amount of time to meet the reporting requirements.

Measurements with a probe will be made at each substation for:

- Turbidity
- Temperature
- pH
- Conductivity
- Laser-based particle size distribution

All measurements will be analytically consistent with the far-field monitoring program.

4.4.1.5 Definition of the Study Areas

Near-field total PCBs will be measured at several locations to determine the nature of PCB releases for different sediment types (cohesive and non-cohesive), concentration ranges, and dredge types. A near-field study will also be conducted during at least one debris removal event.

Table 4-6 summarizes the possible areas for special study in the near field to characterize the nature of PCB release due to dredging-related activities. The areas were chosen based on:

- Type of sediment as classified by the side scan sonar.
- Type of sediment as classified by ASTM Method D422.
- Range of Tri+ PCB entire core length weighted averages (LWAs) concentration.

Draft dredge area boundaries were used to guide the selection of the possible study areas. (Note that these dredge area boundaries have not been approved by the USEPA; however, while the boundaries have not been approved, the identified locations are expected to be included in the final delineation of dredge areas and so were identified for this special study.) Figure 4-4 shows the possible study areas, sediment type as classified by side scan sonar, and the Tri+ PCB LWA range. Figure 4-5 shows the possible study areas and different types of sediment as classified by ASTM Method D422. Of the 13 possible study areas depicted, 5 areas are recommended for the special study (Table 4-7). Selection of these 5 study areas did not take into consideration other engineering factors and the type of equipment that will be used for dredging; therefore, the final selection of study areas may be different. The final selection of the study areas will be determined upon USEPA approval of the *Phase I Intermediate Design Report*.

4.4.2 Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement For the Near-Field and Far-Field Stations (Bench Scale)

Laboratory studies correlating the direct measurement of suspended solids (i.e., TSS analyses) and turbidity-based field measurements (or another surrogate real-time measure of suspended solids) are required such that the near-field and the far-field suspended solids analyses can be replaced with a surrogate real-time measure of suspended solids. The need for a real-time measurement is evident from the sample frequency analysis, which demonstrates that given the variability in baseline suspended solids concentrations, samples will be collected every 15 minutes to monitor a suspended solids release with sufficient confidence. This can only be achieved with a direct reading field measurement device. These analyses will provide a link between the direct but time-consuming measurement of suspended solids and surrogate suspended solids measurements, which can be performed continuously and remotely with the use of a buoyed monitoring station (or another equivalent method for the far-field stations).

4.4.2.1 Near Field

The relationship between suspended solids concentrations and turbidity for the Hudson River Remediation is expected to be an evolving one, with the relationship potentially changing over time as different sediments and hydrodynamic conditions are encountered. Additionally, near-field requirements will be different due to the stronger suspended solids and turbidity signals near the dredge operation. The concerns dictate the need for separate study goals appropriate to near-field and far field conditions. It also necessitates the need to review and revise the relationships as new field data are obtained.

For these reasons, the initial near-field suspended solids bench scale study must focus on the sediments of the Phase 1 target areas. Subsequently, the daily sampling of near-field TSS along with turbidity must be used to verify the initial relationship or slowly modify the relationship.

4.4.2.2 Far-Field

The development of a surrogate for suspended solids in the far-field must also be included in this special study. At a distance of 1 mile from the dredge, it will be difficult to discern a simple increase in suspended solids concentration due to dredging given the baseline variability and the small increase of concern (12 to 24 mg/L). To this end, the far-field monitoring will include laser-based particle counters or equivalent to provide data on the distribution of particle sizes in the water column in addition to the turbidity monitors. The distribution of particle sizes due to dredging is expected to be quite different from baseline, due in part to the different fractions of organic matter in the sediments *vs.* normal water column conditions. Based on these observations, it should be possible to discern a rise in TSS approaching the threshold due to baseline variability from a rise due to dredging resuspension. The combination of increased suspended solids concentrations and turbidity along with a change in particle size distribution should provide the most accurate signal of dredging-related releases and the need to sample. Given this approach, it will also be necessary to collect data on the natural range of particle size distributions under baseline prior to dredging (as part of baseline monitoring).

4.4.2.3 Study Procedures

The procedures to do this study are described in guidance from the US Army Corps of Engineers (Thackston and Palermo, 2000). Both the USACE Long Tube Settling Test and batch tests as per Earhart (1984) will be conducted. However, the procedures involving long tube settling tests for compression are not needed, which should reduce the time required for the study.

4.4.2.4 Selection of Sediment Characteristics for the Study

Hudson River sediments will be collected from a number of locations in each river section to encompass the range of sediment types that will be encountered while dredging. This range of samples should provide a basis to examine the relationship between direct measurement of suspended solids and turbidity measurements and permit turbidity to serve as a surrogate of suspended solids measurement for a broad range of sediment types.

This study will characterize the response for a minimum of three sediment types (silt, fine sand and medium sand) by collecting at least 8 separate samples of each sediment class. Samples must have median diameters consistent with their intended class (*e.g.,* silt must fall between 5 and 75 um median diameter) and have that class as the major fraction in the sample.

4.4.2.5 Duration

A typical bench scale test can be conducted within a week. The initial study will be conducted prior to the beginning of Phase 1. Subsequent bench scale tests may be conducted if a surrogate measurement fails to predict suspended solids concentrations with sufficient accuracy. See Section 4.4.3 for more information.

4.4.3 Develop and Maintain of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement For the Near-Field and Far-Field Stations (Full Scale)

This special study addresses the means by which the surrogate relationship for suspended solids will be evaluated and updated using the confirmatory sample data. Surrogate relationships for the near-field and far-field monitoring stations will be developed initially using only laboratory methods as described above. It is expected, however, that field samples of TSS and estimates based on the surrogate relationship will deviate somewhat from the laboratory-based relationships. Thus, it is necessary to continually review and revise the relationships as new field data are obtained. At first, the evolution will transition the relationship to represent field conditions. However, these relationships are expected to evolve throughout the program as different sediment and hydrodynamic conditions are encountered.

Daily confirmatory samples will be collected at near-field and far-field stations under normal conditions. If there is an exceedance of the suspended solids-based resuspension criteria, the rate of confirmatory sampling increases to two per day at the station with the exceedance. These daily samples will be used to verify the initial relationship and eventually modify it. Over time, the daily monitoring requirements should provide a large data set with which to examine and establish a field-specific suspended solids-turbidity relationship.

Statistical approaches will be used to evaluate data as it is collected, determine if the TSS-Turbidity relationship should be modified, and refine the relationship based upon the new data. This assessment will be conducted separately for the near-field and far-field surrogate relationships.

Statistical Assessment

To verify that the surrogate relationship from the field data does not deviate significantly from the initial relationship developed in the laboratory, statistical tests need to be performed. Additionally, as the data set of field measurements grows, the combined field and laboratory data can be combined into a single data for the purposes of defining the relationship. The following statistical tests may be used:

- Examine the proportion of the field data that falls within the 95 percent confidence bounds of the predictive relationship . The confidence bounds are those for the prediction interval from the regression. The confidence interval for an individual point prediction, y_0, is given by:

$$y_0 \pm \frac{t_{n-2}}{\sqrt{n-2}} s_{y.x} \sqrt{\frac{n+1+n(x_0 - \bar{x})^2}{s_x^2}}$$

where:

y_0 = individual measured total suspended solids (TSS) concentration of the field sampling,
n = number of paired TSS and surrogate measurement pairs of the laboratory-based data,
x_0 = individual turbidity value,
$\bar{x}$ = average predicted TSS concentration estimated from the regression,

s_x^2 = variance of predicted TSS concentration estimated from the regression,

t_{n-2} = approximately 1.96 for 95 percent confidence intervals and large sample size (Normal approximation),

$s_{y.x}$ = standard deviation of the TSS, given by $\sqrt{\frac{\sum\left(TSS_{predictied} - TSS_{field}\right)^2}{n}}$

where:

$TSS_{predicted}$ = predicted TSS concentration estimated from the regression,

TSS_{field} = measured TSS concentrations.

The above equation will give the fraction of measured suspended solids concentrations that fall within the 95 percent confidence limits of the regression. If more than 10 percent of the measured suspended solids concentrations data fall outside the 95 percent confidence limits, it is considered to be a poor fit.

- Chow's F test (Fisher, 1970) can test whether the parameters for two data sets (e.g., the initial laboratory data versus a collection of field measurements) are significant. It requires calculating the error sum of squares or sum of squared residuals (SSEs) for regression models on each of the data sets individually and an SSE for a regression on the pooled data. The comparison is made by forming an F statistic with k and (t_1+t_2-2k) degrees of freedom, formed as (Kennedy, 1979):

$$F = \frac{[SSE(constrained) - SSE(unconstrained)]/k}{SSE(unconstrained)/(t_1 + t_2 - 2k)}$$

where

$SSE(unconstrained)$ = the sum of the SSEs from the two separate regressions,

$SSE(constrained)$ = the SSE from the regression of the pooled data,

$$SSE = \sum\left(Y - \hat{Y}\right)^2$$

Where: Y = measured TSS concentrations and

$\hat{Y}$ = predicted TSS concentrations.

t_1 = the number of observations in the first sample set,

t_2 = the number of observations in the second sample set, and

k = the number of parameters in the model, including the intercept term.

The resulting statistic can then be compared to a tabulation of the *F* distribution with *k* and (*t1+ t2 - 2k*) degrees of freedom to test the hypothesis that parameters have changed significantly between data sets 1 and 2. If the calculated F statistic exceeds the critical value F, the null hypothesis (no change in the regression lines) can be rejected. An *F* statistic with a 95 percent probability of occurring can be considered indicative of a significant difference in the parameters, and by inference, a difference between the laboratory and field relationships.

- Theil's U statistic that gives a measure of the consistency between the forecasts (e.g., field data predictions using the initial surrogate relationship model) and the data used to develop the forecasts. It ranges from 0 to 1, with 0 indicating perfect predictions. The variance of the U statistics can be approximated (for U less than 0.3) as U^2/T, where T is the number of samples in the "forecast." The U statistic is defined as (Pindyck and Rubinfeld, 1981):

$$U = \frac{\sqrt{\frac{1}{T}\sum(Y_t^s - Y_t^a)^2}}{\sqrt{\frac{1}{T}\sum(Y_t^s)^2} + \sqrt{\frac{1}{T}\sum(Y_t^a)^2}}$$

where

Y_t^s = simulated TSS value for observation t,
Y_t^a = actual TSS value of the observation t, and
T = total number of observations.

The numerator of *U* is simply the root mean square simulation error, but the scaling of the denominator is such that *U* always falls between 0 and 1. The U statistics may also be decomposed into portions attributed to bias or systematic error (U^m), variance or ability of the model to replicate the degree of variability in the variable of interest (U^s), and covariance or unsystematic error (U^c). These *proportions of inequality*, which sum to 1, are defined as:

Bias Error $$U^m = \frac{(\overline{Y}^s - \overline{Y}^a)^2}{(1/T)\sum(Y_t^s - Y_{t^a}^a)^2}$$

Variance Error $$U^s = \frac{(\sigma_s - \sigma_a)^2}{(1/T)\sum(Y_t^s - Y_{t^a}^a)^2}$$

Covariance Error $$U^c = \frac{2(1-\rho)\sigma_s\sigma_a}{(1/T)\sum(Y_t^s - Y_t^a)^2}$$

where:

$\bar{Y}^s$ = the mean of the series of the simulated TSS Y_t^s,
$\bar{Y}^a$ = the mean of the series of actual TSS Y_t^a,
σ_s = the standard deviation of the series Y_t^s,
σ_a = the standard deviation of the series Y_t^a,
ρ = the correlation coefficient of the two series.

When U is non-zero, a desirable evaluation of a model will show that the non-zero component is dominantly attributable to the covariance or unsystematic component, which represents non-controllable random variability. Weight on the bias component indicates that the linear relationship differs between the two data sets. Weight on the variance component indicates that the difference is attributable primarily to differing variances between the two data sets.

For the purposes of the TSS-turbidity relationship, consistency in the relationship would be exhibited by a high U^c component and low values for U^m and U^s. Values of U^m and U^s over 0.2 are indicative of a significant difference between the laboratory and field relationships.

Low Bias Assessment

In addition to the statistical tests, the measured suspended solids concentration data need to be checked for low bias compared to the surrogate regression. If 75 percent of the measured suspended solids data falls under the regression for 4 days out of 7 days, it is recommended that the surrogate relationship be reassessed.

Evaluation

The statistical tests and the comparison of the field data to the current surrogate relationship need to be performed daily. The frequency of assessing the data may be lowered in Phase 2, if appropriate. Data from confirmation suspended solids sampling collected during the previous seven days (if applicable to current operating conditions) will be compared to the data used to develop and maintain the surrogate relationship. This data will initially be composed initially of the bench scale test results. When Phase 1 begins and confirmatory samples for suspended solids are collected, these results will be compared to the bench scale results in the manner described below.

- If Chow’s F, Theil’s U and the low bias assessments, show the surrogate relationship to be in compliance, continue use of the surrogate for evaluation of the suspended solids based resuspension standard.

- If Chow’s F or Theil’s U statistics fail, and there is no low bias, the surrogate relationship is in compliance, but the data from the previous day should not be used to reassess the current regression. It is recommended that the regression be reassessed.

- If Chow’s F or Theil’s U statistics fail, and there is no low bias, the surrogate relationship is not in compliance. It is required that the regression be reassessed.

The regression will be re-evaluated weekly to capture the information from the field results and adjust the means of calculating the suspended solids concentrations from the surrogate. Daily measurements will be evaluated in terms of the existing relationship.

Reassessment of the Surrogate Relationship

In the event that the reassessment of the surrogate relationship is needed, there are two options. Sediment in the current area could be collected and a bench scale study that conforms to the special study described in Section 4.4.2 could be conducted. This method is preferred. Alternatively, the confirmatory samples for suspended solids can be assessed to determine if a revised surrogate measurement can be derived from the available data. Until a revised surrogate regression can be derived and approved by USEPA, samples will be collected every three hours for suspended solids analysis with three hour turnaround (using the modified method for suspended solids) and used for compliance with the standard. This sampling will apply to either the near-field or the far-field, depending on which surrogate relationship needs reevaluation.

4.4.3.1 Duration

This study will be conducted throughout Phase 1. It is likely that this study will be maintained in some form throughout the remediation, because the surrogate relationships are likely to require adjustment as the remediation moves throughout the river.

4.4.4 Phase 2 Monitoring Plan

This study will be conducted to demonstrate the feasibility and implementability of alternated monitoring programs that are proposed for Phase 2 of the remediation. The study will determine if the alternate program fully meets the data quality objectives defined for the Resuspension Standard monitoring program. The results of the study will be used to adjust the resuspension criteria, monitoring program and engineering contingencies for the Phase 2 standard.

4.4.4.1 Definition of the Study Areas

The Phase 2 Monitoring Program would need to be implemented at all stations where changes to the Phase 1 Montioring Program are proposed.

4.4.4.2 Duration

The Phase 2 monitoring plan must be implemented for enough time to allow potential problems with the alternate sampling methods to be identified. The program must be in use during the month of full production, but the extent to which the duration of the study will extend beyond that period will depend on the details of the Phase 2 monitoring plan.

Alternate monitoring programs with more challenging aspects may require longer periods of implemention.

4.4.4.3 Assessment of Data

The data acquired during this study will be compare to the results of the Phase 1 monitoring program to determine if the alternate program succeeds in achieving the data quality objectives defined for the Phase 1 program. The study will be reviewed to determine if there are implementation issues that require alteration. The reliability of the alternate program will be assessed.

4.4.4.4 Automatic Samplers for PCB Sample Collection

An alterative to the Phase 1 monitoring plan that may be contemplated would be use of automatic sampling devices to collect the PCB samples under routine conditions. Once a fuller understanding of the nature of contaminant release is acquired through the monitoring program as written is acquired, a well designed monitoring that included the use of automatic samplers for collection of the PCBs could conceivably be of benefit providing more temporal coverage and may reduce costs.

Specific Requirements

While conceptually reasonable, there are aspects associated with the use of automatic samplers that may make implementation difficult. For instance:

- How will these samplers be maintained to ensure that samples are always being collected and the instruments have not clogged?
- If piping is needed, how will the integrity of the pipes be maintained?
- If piping is needed, how will the system be designed to avoid settling of suspended mater in the pipe?
- How will the samplers be decontaminated between samples?
- How will the samplers be protected from boat traffic and still collect representative samples from the cross-section?

Some specific requirements of an alternate monitoring program that includes automatic samplers are:

- The stations must be in the same location as the baseline monitoring program,.
- Samples must be collected in a manner that is compliant with EDI or EWI.
- The reliability of the system must be demonstrated.
- Decontamination procedures must be demonstrated.
- A comprehensive maintenance plan must be developed.

Resultant Changes to the Standard

Use of automatic samplers to collect PCBs may prompt changes to other aspects of the standard. The resuspension criteria, aspects of the near-field and far-field monitoring program and engineering contingencies would need to be evaluated.

The higher sampling frequency that can be achieved with composite sampling would provide a more reliable measurement of the water column concentration. Assuming that the issues identified above can be overcome, there would be more certainty in these measurements and the period in which an exceedance of the resupsension criteria can be known would be reduced. Table 4-8 shows a possible revision to the resuspension criteria should PCB samples be collected with automatic samplers. The time period for each PCB-based resuspension criteria has been reduced from seven days to time periods of two to four days, which are derived from considerations of statistical certainty. The engineering contingencies and monitoring contingencies associated with these exceedances would need to be re-evaluated. The time frames for implementation of engineering contingencies would also need to be re-evaluated.

If the Phase 2 Monitoring Program demonstrated that this means of sampling were acceptable, alterations would be made to the Phase 2 Resuspension Standard criteria in light of the information acquired during Phase 1.

4.4.5 Non-Target, Downstream Area Contamination

This study will examine the amount of resuspended material that has settled in the local downstream areas of the dredging operation and could act as a potential source of future contamination of the water column and downstream surficial sediment. The primary data quality objective for this study is to determine the extent of contamination in terms of spatial extent, concentration and mass of Tri+PCB contamination deposited downstream from the dredged target areas in non-target areas.

The data acquired from this study will be used to determine if the resuspension controls are adequately limiting downstream transport of contamination. A basis for this determination may be a comparison to the thresholds for MPA and surface concentrations provided in the ROD. If the local downstream areas are exceeding these criteria, the resuspension controls will require evaluation. Another consideration will be the amount of mass that is transported downstream near the bottom of the river.

4.4.5.1 Definition of the Study Areas

Study areas will be identified in the same manner as the Near-Field PCBs special study (Section 4.4.1.5). The study area will cover approximately five acres. In addition to these specifications, the area downstream area will not be rock or gravel as defined by the side scan sonar. Because these areas will be located in the Phase 1 dredge zones, the areas that are sampled may not be non-target areas as defined by the dredge line delineations, but will be studied to have this information early on in the project.

4.4.5.2 Duration

The studies will be conducted throughout Phase 1.

4.4.5.3 Sampler Deployment and Collection

Sediment traps or equivalent equipment will be deployed in the study area. Sediment traps will be deployed at the rate of eight per five-acre area. The sediment traps will be laid out on a triangular grid. The sediment traps will be co-located (approximately 10 ft apart). This will allow one of the co-located sediment traps to be sampled each week, while the other remains in place for the duration of the study and is sampled at the end. The sediment traps will be installed at the start of the dredging in the area under study.

4.4.5.4 Sample Handling

Suspended sediments collected in the trap will be weighed to determine mass collected and then homogenized for subsequent organic carbon and PCB analysis. PCB analysis for the short deployment traps may not be possible if a limited mass of sediment is obtained.

4.4.5.5 Analytical Methods

The following parameters will be measured on each sample:

- Sediment mass collected
- Organic carbon content
- PCB congener analysis

The following field measurements will be recorded:

- Date and time of deployment
- Date and time of sample collection
- Depth of sediment in the sediment trap
- Approximate distance from the dredge operation.

All measurements will meet or exceed the analytical specifications for the SSAP program.

4.4.5.6 Definition of the Study Areas

The areas to be studied will be identified in a similar manner to the Near-Field PCBs special study (Section 4.4.1.). Each study area will cover approximately five acres downstream from an area undergoing remediation. In addition to these specifications, the downstream study area will not include rock or gravel as defined by the side scan sonar, since these are generally poor depositional zones and unlikely to accumulate sediment from the dredge. Because these areas will be located downstream of the Phase 1 dredge zones, the areas that are sampled may not be non-target areas as defined by the dredge line delineations. This is not a concern since the Phase 1 downstream areas are typically depositional and should provide a conservative estimate of the amount of deposition that can occur over non-target areas.

4.4.6 Further Development of the Special Studies

The special studies will be further developed and specific implementation details documented in work plans and quality assurance project plans developed during the design phase. Modification of some aspects of the special studies as outlined may be permissible as long as the objectives of the studies can be achieved. All modifications to the programs as outlined in this document will require USEPA review and approval.

4.5 Engineering Contingencies

For the Hudson River remediation, engineering contingencies must be considered for the dredging operation if the action levels are exceeded:

Engineering contingencies must be considered for the dredging operation if the action levels are exceeded.

- Engineering contingencies will be recommended for consideration when the Evaluation Level is exceeded by any measure (*i.e.*, suspended solids or PCBs, near-field or far-field).

- Engineering contingencies will be required and implemented if the Total PCB or Tri+ PCB concentrations exceed the Control Level or the Resuspension Standard (500 ng/L Total PCBs), based on monitoring results at the far-field stations for PCB load- or concentration-based criteria, not suspended solids criteria.

- If the Control Level or the Resuspension Standard threshold is exceeded, an adjustment to the remedial operation is mandatory.

- If the Evaluation Level, the lower tier action level, is exceeded, an adjustment to the operation is optional.

Additional monitoring is mandatory when any of the action levels criteria parameter (*i.e.*, Total PCBs, Tri+ PCBs, or suspended solids) is exceeded. Engineering evaluations of the source of the exceedance are also required when the Control Level or the Resuspension Standard threshold is exceeded.

The performance standard requires increased monitoring contingencies, engineering evaluations, and modification of remedial operations for exceedance of the action levels. Subsections 4.2 and 4.3 describe the monitoring contingencies. This section describes the engineering evaluations, suggested technologies to control resuspension, and the requirements of the standard in this regard. These engineering evaluations and technologies are described in general terms here, but will be specified during the remedial design and possibly modified during the remedial operation.

Recommended and required engineering contingencies are listed below for each action level and the Resuspension Standard threshold.

- **Evaluation Level**

  - Evaluate and identify any problems.
  - Examine boat traffic patterns near the dredges.
  - Examine sediment transfer pipelines for leaks.
  - Recommend engineering evaluations near the dredges and barges.
  - Perform other such engineering evaluations as appropriate.
  - Recommend PCB sample collection in the near-field or other areas of the operation as a part of an engineering evaluation.

- **Control Level**

  - Initiate mandatory engineering evaluation and continual adjustments to dredging operations until the Evaluation Level or better is attained.
  - Evaluate and identify any problems.
  - Consider change in resupension controls, dredge operation, or dredge type.
  - Consider implementing additional resuspension controls.
  - Consider changing location and rescheduling more highly contaminated areas for later in the year (applies to May and June only), if all other options are not effective.
  - Temporarily cease operations if required.

- **Resuspension Standard**

  - Mandatory cessation of all operations in the river is required if Total PCB concentration levels in excess of 500 ng/L Total PCBs are confirmed by next day's samples.
  - Restart requires engineering evaluation and USEPA approval.

4.5.1 Timeframe for Implementing Engineering Evaluations and Engineering Improvements

The time frame for the initiation and completion of engineering evaluations and implementation of the engineering solutions must be specified as part of the remedial design. The actual implementation schedule in the field is subject to USEPA review and oversight. It is anticipated that engineering evaluations will begin immediately upon receipt of data indicating the exceedance of a criterion. It is similarly anticipated that the required engineering contingencies should begin as soon as possible so as to minimize PCB releases. At a minimum, engineering contingency actions should begin within a week of an exceedance, assuming conditions remain in exceedance. In the case of a temporary halt of the operations, an evaluation should be completed with five days. In the event of a temporary cessation, every effort should be made to correct the problem and minimize the length of time of the stoppage.

4.5.2 Engineering Evaluations

Engineering evaluations are required for exceedance of the Control Level and Resuspension Standard and recommended but not required for exceedance of the Evaluation Level.

The engineering evaluation includes the study of all dredge-related operations and supporting components, including review of the dredging operation, barrier installation, and sediment transportation system. Engineering evaluations are required for exceedance of the Control Level and Resuspension Standard and recommended but not required for exceedance of the Evaluation Level.

Exceedance of the suspended solids criteria must be confirmed by PCB measurements before actions other than increased monitoring are required. The evaluation and review of the dredging operation should include additional turbidity measurements in the vicinity of the dredge, barge, pipeline, etc., and will be conducted to evaluate the possible source(s) and mechanism(s) causing the exceedance. An engineering evaluation will include the following as needed:

- Examination of the containment barrier, if it is in use, for leaks and stability
- Examination of the sediment transport pipeline, if a hydraulic dredge is used
- Examination of the barge loading system and barge integrity, if barges are used
- Examination of the turbidity associated with the sediment transport barges and other support vehicles
- Analysis of near-field water column samples for Total PCBs, as well as analysis of samples from other locations such as along the sediment transport pipeline, the channel, etc.

The evaluation will be briefly documented in a report with approach, results, and conclusions for submittal to USEPA. Submittal of a report is mandatory in cases where USEPA must approve modifications to the remediation or give approval to resume operations following temporary halting of remedial operations.

4.5.3 Implementation of Control Technologies

This subsection discusses engineering contingencies recommended for consideration in the event of an exceedance of the Control Level or Resuspension Standard. The contingencies consist of implementation of specific control technologies and apply to remedial operations. A more detailed description of these technologies is provided in Attachment E to the Resuspension Standard. Use of these contingencies resulted primarily from the review of relevant case studies (See Volume 5) and from research done during preparation of the Hudson River FS Report (USEPA, 2000b).

4.5.3.1 Remedial Operations

Barriers and modifications to operations and equipment are the principal and most useful methods for reducing the suspended solids and PCB concentrations downstream of the dredging operation.

Barriers

Barrier types reviewed in Attachment E include:

- Fixed structural barriers such as sheet piling.
- Non-structural barriers such as silt curtains and silt screens.
- Portable barriers systems such as the Portadam^{TM} and Aqua-Barrier^{TM} systems.
- Air bates.
- Control zone technology.

If a barrier system has been implemented, but action levels are still exceeded, further steps that can be considered include the following:

- Monitor or inspect the barrier for leaks
- Identify and correct problems with the installation
- Change the barrier material to a more effective material such as high density polyethylene (HDPE)
- Install multiple layers of barriers
- Fasten the barrier to the river bottom

Operation and Equipment Modifications

Operation and equipment modifications that may reduce the generation of suspended sediments include:

- Limiting/reducing boat speeds to reduce prop wash.
- Restricting the size of boats that can be used in certain areas.
- Loading barges to less than capacity where necessary to reduce draft.
- Use of smaller, shallow draft boats to transport crew members and inspection personnel to and from the dredges.

- Selection of an alternate dredge with a lower resuspension rate.
- Selection of another means of placing backfill/capping materials.
- Scheduling changes to the dredge plan/pattern to avoid remediation of highly contaminated areas during times of year when background PCB concentrations are high (applies to May and June only).

4.5.4 Requirements of the Standard

The standard provides a series of action levels by which the severity of the dredging-related release can be measured and quantified. As an action level is exceeded, engineering evaluations and engineering solutions will be suggested or required, based on the level of the exceedance. This tiered level of enforcement is set up to allow for the remediation to be conducted continuously without operation near the Resuspension Standard threshold, thus avoiding subsequent temporary halting of remedial operations due to a confirmed exceedance.

In summary, the Resuspension Standard requires the following:

Action Level	**Monitoring Contingencies Required***	**Engineering Evaluation Required**	**Engineering Contingencies Required**
Evaluation	Yes	Recommended	No
Control	Yes	Yes	Yes
Resuspension Standard Threshold	Yes	Yes	Yes

* Monitoring requirements for suspended solids exceedances limited for the far-field monitoring to only one or two stations, in order to capture the PCB concentrations in the impacted water column.

4.5.5 Settled Contaminated Material and the Need for Resuspension Barriers

The near-field modeling results presented in subection 2.6 and Attachment D indicate that a substantial amount of the suspended solids will settle in the immediate vicinity of the dredge. In particular, coarse-grained sediments settle very rapidly and so will most likely be captured by a subsequent dredging pass. However, fine-grained sediments may remain in the water column sufficiently long to settle beyond the areas selected to be dredged.

While modeling analysis does not show these additions to be significant in terms of long-distance transport, the redeposited sediments may potentially create small regions of elevated contamination just outside the remedial areas. This could elevate the PCB concentration of the river bed surficial sediments downstream of the remediation to concentration levels that are unacceptable even for the least stringent PCB load-based action level (300 g/day).

The potential for redeposition leads to the conclusion that, where appropriate, resuspension barriers of some type should be considered to contain the resuspended material within the target areas and control the spread of contaminated material.

The potential for redeposition indicates that, where appropriate, resuspension barriers should be considered.

The need for these controls is suggested by evidence obtained from the dredging on the Grasse River. Rising concentrations of cesium-137 and PCB in the surface layer sediment downstream were observed as part of the post-dredge sampling of the Grasse River non-time critical removal action (NTCRA). As shown in Figure 4-6, cesium-137 increases in the uppermost layers of all four cores collected downstream of the dredging operation. The surface layer sediment represents the most recently deposited material. In term of natural variation, the concentration for cesium-137 is not expected to increase since its source (atmospheric weapons testing) no longer exists. This significant increase is consistent with the release and redeposition of older sediments containing high levels of cesium-137 as a result of dredging operations. The relatively thin layer suggests this is not a significant redeposition on the scale of miles (the distance among the cores) but does demonstrate its occurrence.

PCBs do not show as much response as Cesium 137 in the Grasse River sediment, but evidence of a recent PCB release is clear in one core (18M). This core shows significantly elevated PCB concentrations at the surface, also consistent with a suspended solids release. The elevated PCB levels associated with this core may also reflect the generally higher PCB levels in recently deposited sediments, suggesting that the location may collect more of the fine-grained, PCB-contaminated sediments than the other coring locations. Notably, the triple silt barriers used at this site were not fastened to the river bottom, potentially permitting resuspended material to travel beneath them and move downstream. While these data cannot be construed as proof, this does do suggest that suspended solids settling estimates warrant further consideration. Some form of sediment monitoring outside the target areas will be required. Sediment monitoring for this purpose is required in one of the special studies discussed previously, the Non-Target Area Contamination study.

These data also suggest that dredging should generally proceed from upstream to downstream, or the associated redeposition will recontaminate remediated areas. Where resuspension barriers are used, the water flow rate within the barriers is expected to be greatly reduced, thereby significantly reducing this problem.

Dredging should generally proceed from upstream to downstream, or the associated redeposition will recontaminate remediated areas.

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Additional references are provided in the attachments.

Tables

Table 1-1
Resuspension Criteria[1]

Parameter		Resuspension Standard Threshold		Control Level[2]		Evaluation Level	
		Limit	Duration	Limit	Duration	Limit	Duration
Far-Field PCB Concentration	Total PCBs	500 ng/L	Confirmed Occurrence [8]	350 ng/L	7-day running average		
Far-Field Net PCB Load[3]	Total PCBs			65 kg/year[4]	Dredging Season		
	Tri+ PCBs			22 kg/year[4]			
	Total PCBs			600 g/day	7-day running average	300 g/day	7-day running average
	Tri+ PCBs			200 g/day		100 g/day	
Far-Field Net Suspended Solids Concentration[5,6]	All Sections			24 mg/L	Daily dredging period (> 6 hrs.) OR 24 hrs. on average	12 mg/L	6-hour running average net increase OR average net increase in the daily dredging period if the dredging period is less than 6 hrs.
Near-Field (300 m) Net Suspended Solids Concentration[7]	Sections 1 & 3			100 mg/L	Daily dredging period (> 6 hrs.) OR 24 hrs. on average	100 mg/L	6-hour running average net increase OR average net increase in the daily dredging period if the dredging period is less than 6 hrs.
	Sections 2			60 mg/L		60 mg/L	
Near-Field (100 m and Channel-Side) Net Suspended Solids Concentration[7]	All Sections					700 mg/L	3 continuous hrs. running average.

Notes:
1. Implemention of the criteria is described in Section 3.
2. Engineering contingencies for the Control Level will include temporary cessation of the operation.
3. Net increases in PCB load or suspended solids concentration refers to dredging related releases over baseline as defined in the text.
4. During Phase 1, half of the anticipated average production rate will be achieved. As a result, the total allowable export for Phase 1 is half of the fullscale value of 130 kg/year for a total of 650 kg for the entire program. This is equivalent to the 600 g/day Total PCB release at the target productivity schedule, during the dredging season from May to November. The Tri+ PCB values are 22 kg/year for Phase 1, 44 kg/year for full scale production and 220 kg for the entire program.
5. The increased far-field monitoring required for exceedance of suspended solids criteria must include a sample timed so as to capture the suspended solids plume's arrival at the far-field station.
6. The monitoring requirements for exceedance of the suspended solids action levels are increased frequency sampling at the nearest far field station. The increased frequency at this station will be the same as the frequency required for the PCB action levels.
7. All remedial operations will be monitored in the near-field during Phase 1, including backfilling.
8. Exceedance of the Resuspension Standard must be confirmed by the 4 samples that are collected once a concentration greater than 500 ng/L Total PCB is detected. The average of the 5 sample concentrations is compared to the Resuspension Standard. The Resuspension Standard is exceeded if the average

Table 1-2
Sampling Requirements on a Weekly Basis - Upper River Far-Field Stations

Routine Monitoring Number of Samples per Week	PCB Lab Turn-Around Time (hr.)	Laboratory Analyses					Probe		
		Congener-Specific PCBs Whole Water	DOC & Susp. OC	SS	TSS (1/3-hours)_	Integrating Sampler for PCBs	Turbidity	Do, Temp., Ph, Cond.	Laser Particle Counter
RM 197.0 - Bakers Falls Bridge	72	1	1	1			Discrete		
RM 194.2 - Fort Edward	72	7	7.5	7.5	56	0.5	Continous	Discrete	Discrete[5]
RM 188.5 - TI Dam_	24	7	7.5	7.5	56	0.5	Continous	Discrete	None
RM 181.4 - Schuylerville_	24	7	7.5	7.5	56	0.5	Continous	Discrete	None
RM 163.5 - Stillwater	72	7	7.5	7.5	56	0.5	Continous	Discrete	None
RM 156.5 – Waterford	72	7	7.5	7.5	56	0.5	Continous	Discrete	None
Samples/Week		36	38.5	38.5	280	2.5			
PCB analyses/week		**38.5 or 5.5 /day**							

Evaluation Level Number of Samples per Week	PCB Lab Turn-Around Time (hr.)	Laboratory Analyses					Probe		
		Congener-Specific PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)_	Integrating Sampler for PCBs	Turbidity	Do, Temp., Ph, Cond.	Laser Particle Counter
RM 197.0 - Bakers Falls Bridge	72	1	1	1			Discrete		
RM 194.2 - Fort Edward	72	7	7.5	7.5	56	0.5	Continous	Discrete	Discrete[5]
RM 188.5 - TI Dam_	24	14	14.5	14.5	56	0.5	Continous	Discrete	None
RM 181.4 - Schuylerville_	24	14	14.5	14.5	56	0.5	Continous	Discrete	None
RM 163.5 - Stillwater	72	7	7.5	7.5	56	0.5	Continous	Discrete	None
RM 156.5 – Waterford	72	7	7.5	7.5	56	0.5	Continous	Discrete	None
Samples/Week		50	52.5	52.5	280	2.5			
PCB analyses/week		**52.5 or 7.5 /day**							

Control Level Number of Samples per Week	PCB Lab Turn-Around Time (hr.)	Laboratory Analyses					Probe		
		Congener-Specific PCBs Whole Water	DOC & Susp. OC	SS	TSS (1/3-hours)_	Integrating Sampler for PCBs	Turbidity	Do, Temp., Ph, Cond.	Laser Particle Counter
RM 197.0 - Bakers Falls Bridge	72	1	1	1			Discrete		
RM 194.2 - Fort Edward	72	7	7.5	7.5	56	0.5	Continous	Discrete	Discrete[5]
RM 188.5 - TI Dam_	24	21	22	22	56	1	Continous	Discrete	None
RM 181.4 - Schuylerville_	24	21	22	22	56	1	Continous	Discrete	None
RM 163.5 - Stillwater_	24		7	7	56	7	Continous	Discrete	None
RM 156.5 – Waterford_	24		7	7	56	7	Continous	Discrete	None
Samples/Week		50	66.5	66.5	280	16.5			
PCB analyses/week		**66.5 or 9.5 /day**							

Threshold[4] Number of Samples per Day Only	PCB Lab Turn-Around Time (hr.)	Laboratory Analyses					Probe		
		Congener-Specific PCBs Whole Water	DOC & Susp. OC	SS	TSS (1/3-hours)_	Integrating Sampler for PCBs	Turbidity	Do, Temp., Ph, Cond.	Laser Particle Counter
RM 197.0 - Bakers Falls Bridge	72	1	1	1			Discrete		
RM 194.2 - Fort Edward	72	1	1	1	8	1/2-weeks	Continous	Discrete	Discrete[5]
RM 188.5 - TI Dam_,_	24	4	5	5	8	1	Continous	Discrete	None
RM 181.4 - Schuylerville_,_	24	4	5	5	8	1	Continous	Discrete	None
RM 163.5 - Stillwater_	24	4	5	5	8	1	Continous	Discrete	None
RM 156.5 – Waterford_	24	4	5	5	8	1	Continous	Discrete	None
Samples/day		18	22	22	40	4			
PCB analyses/day		**22 /day**							

Note:

1. TI Dam and Schuylerville will be representative stations while the dredging is ongoing in the Phase 1 areas and will be sampled more intensely. Samples will be composited from hourly grab samples for theResuspension Standard threshold at these two stations.

2. TSS sampling every 3- hours will be required for compliance at the nearest representative far-field stations only if the semi-quantative relationship between TSS and a surrogate is not sufficiently conservative (See Section 4). Samples collected at the other stations will have 12-hour turnaround.

3. The turnaround time for PCB analyses from the integrating sampler will only be specified when the information is needed quickly for comparison to the resuspension criteria. For the Resuspension Standard the integrating sample turnaround times will be 24-hours for the two representative far-field stations (TI Dam and Schuylerville stations) and 72-hours for the stations farther downstream (Stillwater and Waterford stations). For the Control Level at Stillwater and Waterford, the turnaround times will be 72-hours and 24-hours, respectively.

4. The monitoring for the Resuspension Standard threshold is required for one day only for verification of the elevated concentration.

5. Continuous laser particle analysis is required only ar the nearest far-field station to the dredge operation. For the purpose of this table, the Phase-1 area was assumed to occur in the TIP

Table 1-3
Sampling Requirements on a Weekly Basis - Lower River Far-Field Stations

Lower River Sampling Requirements on a Weekly Basis

Routine Monitoring [1]	Lab Turn-Around Time (hr.)	Laboratory Analyses			Probe	
		Congener-specific PCBs Whole Water	DOC & Susp. OC	SS	Turbidity, Temp., pH, Cond.	Dissolved Oxygen
Mohawk River at Cohoes	72	0.25	0.25	0.25	0.25	0.25
RM 140 - Albany	72	0.25	0.25	0.25	0.25	0.25
RM 77 - Highland	72	0.25	0.25	0.25	0.25	0.25
Samples/Week		0.75	0.75	0.75	0.75	0.75

Non-Routine Monitoring [2]	Lab Turn-Around Time (hr.)	Laboratory Analyses			Probe	
		Congener-specific PCBs Whole Water	DOC & Susp. OC	SS	Turbidity, Temp., pH, Cond.	Dissolved Oxygen
Mohawk River at Cohoes	24	1	1	1	1	1
RM 140 - Albany	24	1	1	1	1	1
RM 77 - Highland	24	1	1	1	1	1
Samples/Week		3	3	3	3	3

Notes:

1. Routine monitoring samples for the Lower Hudson stations are collected once per month.

Table 1-4
Sampling Requirements on a Weekly Basis - Upper River Near-Field Stations

Near-Field Sampling Requirements on a Weekly Basis [1, 2, 3, 4]
Routine Monitoring (Use of continuous reading probe to indicate suspended solids concentrations.)

No. of Operations	No. of SS Laboratory Analyses [5] per week	No. of Discrete Measurements by Laser Particle Counter per week	No. of Continuous Monitors
1	35	35	5
2	70	70	10
3	105	105	15
4	140	140	20
5	175	175	25
6	210	210	30
7	245	245	35
8	280	280	40
9	315	315	45
10	350	350	50

Non-Routine Monitoring (If the surrogate analysis fails to predict TSS concentrations adequately.)[1, 5, 6]

No. of Operations	Number of SS Laboratory Samples with 3-Hour Turn-Around, per Week					Discrete Probe Measurements for Turbidity & Laser Particle Counter (No. per week)
	Number of Stations (where surrogate is out of compliance) 1	2	3	4	All Stations[7] 5	
1	49	98	147	196	245	35
2	98	196	294	392	490	70
3	147	294	441	588	735	105
4	196	392	588	784	980	140
5	245	490	735	980	1,225	175
6	294	588	882	1,176	1,470	210
7	343	686	1,029	1,372	1,715	245
8	392	784	1,176	1,568	1,960	280
9	441	882	1,323	1,764	2,205	315
10	490	980	1,470	1,960	2,450	350

Notes:

1. A surrogate must be established to determine compliance with the TSS based resuspension criteria. Only if this surrogate relationship fails to adequately predict TSS concentrations will sampling for TSS concentrations every 3-hours with a 3-hour turnaround be required. If compliance is based on TSS samples, 1 sample will be collected an hour prior to beginning of the operation and at least 3 samples will be collected at 1-hour intervals after completing for the day.
2. One TSS samples will be collected per day per station to confirm the surrogate semi-quantitative relationship.

3. If a TSS resuspension criteria is exceeded at a monitoring station, two TSS samples will be collected per day at that station to confirm the surrogate semi-quantitative relationship.
4. Turbidity, temperature, pH, conductivity and dissolved oxygen will be monitored continuously at each of the five near-field stations.

5. Assumed hours of operation: 14 hours of dredging per 24 hours of operation per day for the quantities above.
6. Exceedence of a suspended solids criteria will also prompt monitoring at the representative far-field station nearest to the location of the exceedence at the frequency of sampling indicated for the action level.

7. If containment is used in an area, 6 stations will be required, increasing the total

Table 1 - 5
Case Study Resuspension Summary Table

Project/Site Name	Dates of Operation	Project Setting	Water Quality Parameters Monitored	Water Quality Standard	Water Quality Monitoring Stations	Water Quality Measurements Reported During Dredging
Fox River: Kimberly, Wisconsin Deposit N	November 1998 to December 1998 (Phase I); August 1999 to November 1999 (Phase II)	Riverine	Turbidity, TSS, and PCBs	Turbidity - Threshold limit based on hourly average value; Specific threshold not stated in materials reviewed; PCBs- water column concentrations compared to pre-dredge concentrations and upstream samples versus downstream samples compared-specific threshold not indicated	Real time turbidity monitoring at 6 stations: (1) upstream, (1) side gradient, (1) downstream, (1) at ILP water intake, (1) at the ILP effluent discharge, and (1) within the contained dredge area. Measured turbidity at 50% total water depth	Average PCB water column concentration during Phase I (1998) downstream of dredging was 11 ng/L compared to an average upstream measured concentration of 3.2 ng/L during dredging. Baseline concentration before Phase I was 5.0 ng/L. Average downstream PCB concentration during Phase II (1999) was 24 ng/L compared to an average upstream PCB concentration of 14 ng/L. Minor differences between upstream and downstream turbidity during dredging. No apparent difference in TSS data collected upstream and downstream of the dredge was noted from measurements collected during dredging.
Fox River: Green Bay, Wisconsin SMU 56/57 Phase I	August to December 1999 (Phase I)	Riverine	Turbidity, TSS, and PCBs	Not indicated in documents reviewed	Real time turbidity monitoring at 6 locations: (1) upstream dredge outside turbidity barrier;(1) upstream dredge inside turbidity barrier;(1) side stream dredge outside turbidity barrier;(1) downstream dredge outside turbidity barrier;(1) downstream dredge inside turbidity barrier; (1) at Fort James water intake - Each meter located in water column at 50-60% of the water depth for location	Average PCB water column concentration downstream of the dredge was 90 ng/L compared to an upstream concentration of 51 ng/L during dredging and a baseline concentration prior to dredging of 52 ng/L. Turbidity monitors downstream of the dredge, outside the silt curtain were indicative of periodic turbidity increases. TSS samples only showed minor differences between the upstream and downstream locations. Monthly averaged turbidity data indicated that a high turbidity of 41 NTU occurred during the first month of dredging (August) downstream of the dredge, outside the silt curtain.
Fox River: Green Bay, Wisconsin SMU 56/57 Phase II	August 2000 to November 2000 (Phase II)	Riverine	Turbidity, TSS, and PCBs	Turbidity - Reached threshold if downstream turbidity reading was two or more times higher than the upstream reading and cause was related to dredging; Specific PCB threshold not indicated in documents reviewed	Real time turbidity monitoring at 3 locations: (1) upstream of silt curtain at the Fort James water intake; (1) 10-ft downstream of the silt curtain; and (1) 50-ft downstream of the silt curtain	Upstream and downstream turbidity values never varied by more than a factor of two during dredging. Contractor did not perform PCB water column monitoring since turbidity threshold was neve exceeded however PCB water column sampling was performed by the USGS.
Manistique River, Michigan	1995 - 1999	Riverine	Turbidity, TSS, and PCBs	TSS concentration less than 2X the background turbidity within 50-feet of the dredge head; Literature reviewed stated that this level was achieved within 10-feet of the dredge head. PCB water quality threshold not stated in literature reviewed. It was noted that PCB concentrations were compared to pre-dredge water column PCB concentrations	For 1997 Dredging: seven samples from one station near dredge; one sample from upstream; six samples from a station downstream; and two samples from a station outside of the dredge area. For 1998: 9 samples from station upstream of dredge; 8 samples from locations downstream of dredge- distance and exact location not specified.	In 1997: avg. PCB water column concentrations outside dredge area was 0.37mg/L and avg. [PCB] downstream of dredge was 0.23 mg/l compared to pre-dredge concentration of 0.001 mg/L. The background sample collected during this event was 0.062 mg/L PCBs. In 1998: Avg. upstream [PCB] was 0.093 mg/L and the average [PCB] downstream was 0.066 mg/L.
Reynolds Metals: St. Lawrence River, Massena. NY	April 2001 through November 2001	Riverine	Turbidity and water column samples (PCBs , PAHs, and PCDFs); TSS was not measured in this project.	Turbidity action level of 25 NTU above the background level, which was derived based on 28 NTU action level used at GM Massena. The action levels for water column samples were 2 ug/L of PCBs, 0.2 ug/L for PAHs and detectable PCDFs above the practical quantitation limit (PQL).	Monitoring was conducted at different locations for each project phase (sheetpile installation, dredging, capping, and sheet pile removal); All locations identified in Final Case Study Table (Appendix A of th Resuspension standard). For dredging: (4) stations outside the sheet piling- one upcurrent (100ft from the active dredge) and 3 down current stations (10, 150 and 300 ft from the sheet pile wall closest to the dredge being monitored). Within the sheetpiling-Water Quality was monitored at 12 to 19 different stations based on dredge location.	Outside the sheet piling : Turbidity during dredging ranged between 0.5 to 1.5 NTUs. During dredging, water column PCB concentrations ranged between 0.05 to 0.53 ug/L. and PAH and PCDF were non-detect in samples analyzed
GM Massena: St. Lawrence River, Massena, NY	May 1995 through December 1995	Riverine	Turbidity, PCBs, PAHs	Action level was selected based on a 1994 site-specific bench-scale laboratory correlation between TSS and turbidity, and experience in previous dredging projects. Downstream turbidity 28 NTUs above background corresponded to a downstream TSS of 25 mg/L above background. For PCBS: 2 ug/L (at downstream monitoring locations)	Visual observations and real-time turbidity monitoring at 3 locations: 50 feet upstream of western extent of control system, two between 200 feet and 400 feet downstream of easternmost active installations. Measurements collected from 50% water depth. Water column sampling at the same two downstream locations as the turbidity measurements.	In 18 out of 923 turbidity samples, the 28 NTU action level was exceeded (31-127 NTU) at 1-ft below the water surface for a duration of 2-8 minutes, on average, however 2 exceedances lasted for 15 minutes and 45 minutes respectively. Exceedance determined to be a result of water overflow from the dredge area over the sheet piling due to inadequate height/installation. PCBs monitored at same station as turbidity. High PCB concentrations correlated with times where high turbidity (> 28 NTU) measured. Filtered [PCB] ranged between 0.94-2.4 ug/L and unfiltered ranged between 4.51 to 9.84 ug/L. These PCB measurements collected at end of Phase I after sheet piling removed.
Cumberland Bay: New York	April 1999 to May 2000	Western side of Lake Champlain	TSS, turbidity and PCB	Turbidity was used only to alert the operators of a potential re-suspension problem-not associated with an action level.**Operational Monitoring**: TSS 25 mg/L above background. **Compliance Monitoring** (outside turbidity barrier): TSS 4 mg/L above background. When TSS action level was exceeded, dredging was suspended or modified.	**Operational Monitoring**: Real-time turbidity monitoring in 2 locations: on dredge head and using a float that trailed behind the dredge. **Compliance Monitoring:** Four OBS-3 sensor stations which changed for each active work zone: one sensor in a background location (near breakwater) and three sensors outside the perimeter of the work zone silt curtain (an additional temporary sensor was located near Georgia-Pacific's industrial water intake). **Documentation Monitoring:** Six fixed turbidity monitoring (TM) buoys (in 1999 outside perimeter turbidity curtain; 2000 locations different).	Documentation reviewed indicated that the TSS levels were not exceeded and dredging was never suspended.
United Heckathorn: Parr Canal and Lauritzen Channel on the San Francisco Bay	August 1996 through March 1997	Bay area - shipping inlet/slip	TSS and Contaminants of Concern: DDT and Dieldrin	Surface water: Dieldrin 0.14ng/L and DDT 0.59ng/L both based on EPA AWQ (Ambient water Quality criteria) and also based on human health standards (risk)	Four water quality sampling stations- Locations were established both upstream and downstream of area being dredged and downstream/outside channel/ship inlet/slip in the harbor and bay at both ends	Data not available in documents reviewed for water quality data during dredging however it was noted that the area is extremely turbid naturally due to ship traffic; Post-dredge water quality data collected 4-months after dredging indicated concentrations equal to or greater than predredge conditions. This was a result of incomplete dredging near banks and around structures. Dredging not a success at this site and further action to be taken.

Table 1 - 5
Case Study Resuspension Summary Table

Project/Site Name	Dates of Operation	Project Setting	Water Quality Parameters Monitored	Water Quality Standard	Water Quality Monitoring Stations	Water Quality Measurements Reported During Dredging
Grand Calumet River, Indiana	Dredging Began November 2002 (currently in progress)	Riverine	Level 1: Flow, total ammonia, specific conductance, DO, pH, sulfides, temp., and turbidity monitored daily by multi-parameter automatic data logger system; Level 2: microtox chemical testing for acute and chronic toxicity; Level 3: chemical monitoring for total ammonia, pH, sulfides, temp, free cyanide, hardness oil and grease, TSS, dissolved aluminum, dissolved copper, dissolved lead, total mercury, dissolved zinc, select VOCs, and total PCBs; Each Level Monitoring is conducted concurrently at a pre-set frequency. A contingency plan exists for each Level monitoring in the event that a high measurement is recorded.	IDEM (Indiana Department of Environmental Management) chronic and acute state surface water criteria	(1) upstream background sampling location; (1) located near mid-channel 200-yd downstream from open water dredge; (1) downstream sampling site below 5-mile dredge area; (1) proposed sample location for verification analysis located 200-yd upstream of open water dredging in cell c	Data Not yet available; dredging currently underway
New Bedford Harbor (Hot Spots), New Bedford, Massachusetts	April 1994 to September 1995	Estuary/Bay	PCBs (24-hr turn-around) and metals. PCBs (Total PCBs: dissolved and particulate tested separately and summed).	PCBs: 1.3 mg/L determined by a pilot study and a Maximum cumulative transport (MCT) of PCBs during the entire operation of 240 Kg PCBs.	Down current locations: 50 ft, 300 ft, 700 ft, and 1,000 ft. from dredging area. Background measurements: ~ 1,000 ft up-current of dredging operations. Sampling depth: ~ mid-depth in the water column.	By the end of project, a total PCB transport of 57 kg was reported. Thus, the MCL was not exceeded. Toxicity tests completed during dredging were not indicative of acute toxicity and PCB accumulation in mussels was not significantly greater then predredge measurements.
New Bedford Harbor (Pre-Design Field Test), New Bedford, Massachusetts	Demonstration Project in August 2000	Estuary/Bay	TSS, turbidity and PCBs (dissolved and particulate, PCB congeners)	PCBs: No set limit since background concentrations exceeded Federal criteria however did set the maximum Cumulative Transport (MCT) for PCB loss from dredging at the limit of mixing zone (300 ft from the dredge) of 400 kg PCBs throughout entire dredging project. Turbidity: 50 NTU above background at limit of mixing zone (300 ft from the dredge)	2 Monitoring stations 300 ft away from dredge; additional sampling as required 600 ft from dredge. Background measurements ~ 1,000 ft up-current of dredging operations.	Turbidity measurements exceeded the 50 NTU threshold infrequently at the 300-ft limit of the mixing zone and no further action was taken. Bioassay tests completed when turbidity exceeded 50 NTU were not indicative of an ecological impact.
Commencement Bay: Hylebos Waterway	Small hot spot dredging October 2002; Full-scale dredging begun 2003	Tidal Waterway	Turbidity and dissolved oxygen (system currently exhibits a low dissolved oxygen level and managers do not want dredging to deplete it any further)	It is anticipated that the turbidity standard wil be set at either 20 NTU or 50 NTU over background.	2 anticipated monitoring stations; one near dredge head and one at the limit of the mixing zone (300-ft from the dredge)	Data not yet available.
Commencement Bay: Thea, Foss, Wheeler, Osgood Waterway	Full-scale dredging begun 2003	Tidal Waterway	Turbidity however water quality monitoring plan still in design	It is anticipated that the turbidity standard wil be set at either 20 NTU or 50 NTU over background.	2 anticipated monitoring stations; one near dredge head and one at the limit of the mixing zone (300-ft from the dredge)	Data not yet available.

Table 2-1
Summary of Case Studies for PCB Losses Due to Dredging

Project	Period of Dredging	Total PCBs Removed (kg)	Total PCBs Resuspension Loss (kg)	Percentage Lost (%)
GE Hudson Falls Dredging	Oct.-Dec. 1997, Aug.-Nov. 1998	3,890	14	0.36%
New Bedford Harbor Hot Spots	1994-1995	43,700	57	0.13%
Fox River Deposit N	Nov. - Dec. 1998 (Phase I) Aug. -Dec.1999 (Phase II)	111	4.20	3.5% - 14% (1)
Fox River SMU 56/57	Aug. - Nov. 1999 (Phase I)	1,490	22	2.2% (2)

Notes:

(1) Average Daily Percentage Loss varied over dredge season based on dredge location and uncertainty associated with PCB removal estimation.

(2) PCB Percentage Loss based on USGS study while other values taken from the SMU 56/57 Final Summary report (September 2001).

Table 2-2
Far-Field Forecast Model Runs Completed for the Performance Standard

Scenario [5]	Description	Rate of PCB Release [1] g/day (kg/yr) [3]	Period of Dredging	Start Year	Completed Simulations [4]			
					Upper Hudson		Lower Hudson	
					HUDTOX	FISHRAND	Farley	FISHRAND
-	MNA	NA	-	-	x	x	x	x
-	No resuspension	0 (0)	6	2004	x	x	x	x
d004	No resuspension	0 (0)	6	2006	X	X	X	X
-	2.5% Export[2]	1,700 (350)	6	2004	x	x	x	x
sr01	300 g/day	300 (70)	6	2006	X	X	X	X
sr02	600 g/day	600 (130)		2006	X	X	X	X
sr04	350 ng/L	1,600 (340)	6	2006	X	X	X	X
-	Accidental Release	600 (130)	6	2006	X			

Notes:

1. All PCB resuspension scenarios were based on a resuspension release rate (near-field release) at the specified percentage of dredging loss unless noted otherwise.
2. The model run included with the Responsiveness Summary for the ROD is effectively a 2.5 percent export scenario since all PCBs were loaded as dissolved phase. See text for further discussion.
3. The rates are based on 7 months of operation, 7 days per week at 14 hours per day.
4. x = completed for ROD
   X = completed for this report
5. The d004 and sr01 and sr04 and sr0x series of scenarios were created during the development of the performance standards.

Table 2-3
Upper Hudson Conceptual Dredging Schedule

Sediment removal season	Dredging Location	Speed of operation
May 1 - Nov. 1, 2006	Sec. 1	half
May 1 - Nov. 30, 2007	Sec. 1	full
May 1 - Nov. 30, 2008	Sec. 1	full
May 1 - Aug. 15, 2009	Sec. 1	full
Aug. 16 - Nov. 30, 2009	Sec. 2	full
May 1 - Aug. 15, 2010	Sec. 2	full
Aug. 16 - Nov. 30, 2010	Sec. 3	full
May 1 - Aug. 15, 2011	Sec. 3	full

Table 2-4
Species-Weighted Fish Fillet Average PCB Concentration (in mg/kg)

	No Resuspension (d004)				350 ng/L (sr04)				600 g/day (sr01)				Monitored Natural Attenuation			
Year	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)
1998	3.317	6.813	9.271	1.537	3.316	6.807	9.276	1.537	3.316	6.807	9.276	1.537	3.353	6.774	9.659	1.529
1999	3.328	6.908	9.406	1.510	3.328	6.909	9.410	1.509	3.328	6.909	9.410	1.509	3.212	6.621	8.877	1.501
2000	2.866	5.747	8.346	1.300	2.865	5.751	8.338	1.300	2.865	5.751	8.338	1.300	2.791	5.563	8.028	1.292
2001	2.582	5.098	7.588	1.177	2.583	5.104	7.585	1.177	2.583	5.104	7.585	1.177	2.504	4.924	7.210	1.171
2002	2.370	4.841	6.925	1.053	2.372	4.848	6.924	1.054	2.372	4.848	6.924	1.054	2.301	4.705	6.571	1.047
2003	2.182	4.340	6.471	0.978	2.182	4.338	6.474	0.978	2.182	4.338	6.474	0.978	2.129	4.290	6.090	0.980
2004	2.290	5.285	6.356	0.946	2.290	5.286	6.354	0.946	2.290	5.286	6.354	0.946	2.204	5.084	5.934	0.942
2005	1.905	3.912	5.712	0.816	1.911	3.910	5.740	0.821	1.908	3.909	5.726	0.819	1.852	3.739	5.523	0.812
2006	1.617	2.996	5.119	0.716	1.703	3.111	5.350	0.770	1.666	3.076	5.237	0.746	1.574	2.890	4.904	0.716
2007	1.487	2.838	4.669	0.647	1.709	3.461	5.141	0.739	1.614	3.225	4.920	0.697	1.474	2.862	4.489	0.654
2008	1.297	2.318	4.226	0.571	1.673	3.762	4.743	0.694	1.525	3.216	4.582	0.634	1.371	2.774	4.168	0.586
2009	0.964	1.573	2.949	0.489	1.323	2.317	3.769	0.687	1.106	1.907	3.140	0.583	1.262	2.616	3.877	0.519
2010	0.595	0.899	1.355	***0.398***	0.928	1.012	1.835	0.753	0.707	0.943	1.411	0.535	1.116	2.321	3.533	0.440
2011	0.447	0.661	0.847	0.332	0.817	0.736	1.122	0.781	0.568	0.697	0.901	0.483	0.971	1.921	3.164	***0.388***
2012	0.404	0.723	0.786	0.269	0.631	0.774	0.999	0.537	0.469	0.747	0.818	***0.350***	0.878	1.851	2.879	0.324
2013	***0.342***	0.568	0.717	0.229	0.515	0.600	0.883	0.433	***0.389***	0.572	0.734	0.291	0.791	1.682	2.601	0.287
2014	0.318	0.593	0.669	***0.199***	0.453	0.602	0.803	***0.361***	0.353	0.582	0.675	0.248	0.742	1.666	2.396	0.258
2015	0.289	0.520	0.638	0.178	***0.400***	0.524	0.751	0.312	0.316	0.506	0.638	0.219	0.686	1.535	2.229	0.237
2016	0.294	0.586	0.651	0.170	0.391	0.589	0.750	0.287	0.317	0.573	0.648	0.205	0.680	1.610	2.126	0.231
2017	0.296	0.671	0.612	0.161	0.379	0.672	0.704	0.260	0.315	0.660	0.610	***0.190***	0.649	1.573	1.978	0.221
2018	0.272	0.606	0.574	0.149	0.344	0.605	0.665	0.233	0.289	0.595	0.577	0.173	0.593	1.437	1.765	0.210
2019	0.281	0.710	0.567	0.140	0.341	0.702	0.656	0.210	0.295	0.694	0.572	0.161	0.577	1.497	1.619	***0.200***
2020	0.243	0.584	0.502	0.125	0.292	0.579	0.584	***0.180***	0.253	0.571	0.507	0.142	0.512	1.270	1.480	0.182
2021	0.217	0.471	0.482	0.117	0.260	0.468	0.557	0.164	0.226	0.459	0.486	0.131	0.460	1.080	1.365	0.171
2022	0.215	0.476	0.477	0.114	0.253	0.473	0.548	0.155	0.222	0.464	0.482	0.126	0.450	1.093	1.296	0.166
2023	0.216	0.529	0.454	0.108	0.247	0.524	0.514	0.142	0.222	0.517	0.461	0.118	0.435	1.088	1.225	0.158
2024	***0.195***	0.484	0.417	0.094	0.219	0.480	0.463	0.122	***0.200***	0.474	0.427	0.102	***0.385***	0.939	1.123	0.139
2025	0.176	0.415	***0.391***	0.088	***0.196***	0.413	0.426	0.110	0.181	0.406	0.402	0.094	0.350	0.842	1.019	0.129
2026	0.163	***0.357***	0.377	0.084	0.180	0.355	0.405	0.103	0.166	***0.347***	***0.388***	0.089	0.325	0.757	0.952	0.124
2027	0.183	0.490	0.380	0.083	0.197	0.488	0.403	0.100	0.186	0.483	0.387	0.088	0.339	0.888	0.920	0.121
2028	0.177	0.509	0.353	0.076	0.189	0.508	***0.371***	0.090	0.179	0.504	0.353	0.080	0.322	0.863	0.875	0.111
2029	0.158	0.414	0.337	0.072	0.168	0.412	0.351	0.084	0.159	0.407	0.332	0.076	0.287	0.720	0.801	0.105
2030	0.143	0.326	0.326	0.072	0.152	***0.325***	0.342	0.082	0.143	0.320	0.322	0.075	0.261	0.620	0.735	0.103
2031	0.151	0.422	0.303	0.067	0.159	0.421	0.320	0.075	0.152	0.418	0.302	0.069	0.257	0.679	0.675	0.095
2032	0.138	0.362	0.288	0.064	0.145	0.362	0.305	0.071	0.139	0.357	0.289	0.066	0.234	0.602	0.610	0.091
2033	0.133	0.349	0.277	0.061	0.138	0.349	0.295	0.066	0.133	0.343	0.279	0.063	0.219	0.560	0.564	0.086
2034	0.132	0.368	0.259	0.060	0.134	0.368	0.276	0.060	0.132	0.366	0.261	0.059	0.208	0.545	0.521	0.082
2035	0.123	0.279	0.249	0.068	0.116	0.279	0.266	0.056	0.114	0.275	0.251	0.055	***0.191***	0.443	0.475	0.089
2036	0.148	0.356	0.242	0.087	0.124	0.356	0.258	0.051	0.125	0.352	0.244	0.055	0.209	0.504	0.446	0.104
2037	0.137	0.297	0.234	0.086	0.115	0.298	0.250	0.053	0.125	0.295	0.237	0.070	0.190	0.427	0.410	0.101
2038	0.140	0.337	0.221	0.083	0.130	0.337	0.235	0.068	0.140	0.335	0.224	0.083	0.189	0.456	***0.386***	0.098
2039	0.128	0.270	0.214	0.083	0.132	0.271	0.227	0.087	0.131	0.268	0.218	0.087	0.173	0.382	0.363	0.096

Table 2-4
Species-Weighted Fish Fillet Average PCB Concentration (in mg/kg)

2040	0.124	0.262	0.214	0.079	0.132	0.262	0.225	0.087	0.128	0.260	0.217	0.085	0.164	0.352	0.346	0.092
2041	0.140	0.359	0.219	0.079	0.150	0.360	0.228	0.091	0.146	0.358	0.222	0.087	0.180	0.461	0.347	0.092
2042	0.143	0.400	0.223	0.074	0.153	0.401	0.229	0.087	0.148	0.399	0.225	0.081	0.178	0.486	0.337	0.084
2043	0.123	0.318	0.202	0.068	0.132	0.318	0.206	0.080	0.129	0.320	0.205	0.075	0.155	***0.386***	0.316	0.078
2044	0.108	0.245	***0.191***	0.064	0.114	0.246	***0.193***	0.073	0.114	0.256	***0.195***	0.069	0.136	0.301	0.289	0.074
2045	0.112	0.282	0.190	0.063	0.118	0.283	0.191	0.070	0.118	0.301	0.194	0.066	0.137	0.329	0.278	0.071
2046	0.105	0.258	0.184	0.058	0.109	0.256	0.184	0.064	0.110	0.273	0.187	0.062	0.131	0.319	0.269	0.067
2047	0.109	0.284	0.187	0.058	0.112	0.271	0.187	0.065	0.112	0.285	0.190	0.062	0.153	0.474	0.261	0.066
2048	0.115	0.329	0.188	0.057	0.118	0.318	0.187	0.064	0.116	0.316	0.190	0.061	0.175	0.612	0.263	0.066
2049	0.116	0.339	0.190	0.055	0.120	0.340	0.189	0.062	0.117	0.328	0.192	0.059	0.166	0.574	0.259	0.063
2050	0.105	0.289	0.183	0.052	0.109	0.290	0.182	0.057	0.106	0.283	0.185	0.055	0.151	0.498	0.251	0.060
2051	0.101	0.286	0.180	***0.047***	0.104	0.287	0.178	0.052	0.104	0.294	0.182	***0.050***	0.140	0.457	0.242	0.055
2052	0.094	0.244	0.181	0.047	0.097	0.246	0.180	0.051	0.099	0.263	0.184	0.049	0.130	0.402	0.236	0.054
2053	0.113	0.359	0.187	0.048	0.116	0.359	0.185	0.052	0.118	0.379	0.189	0.050	0.146	0.494	0.244	0.055
2054	0.105	0.311	0.185	0.047	0.107	0.311	0.184	0.050	0.109	0.327	0.187	0.049	0.134	0.430	0.235	0.053
2055	0.098	0.274	0.182	0.045	0.100	0.274	0.180	***0.048***	0.101	0.287	0.183	0.047	0.125	0.383	0.231	0.052
2056	0.105	0.307	0.195	0.046	0.106	0.307	0.193	0.048	0.108	0.322	0.195	0.047	0.129	0.407	0.233	0.051
2057	0.105	0.323	0.185	0.045	0.107	0.324	0.183	0.047	0.108	0.337	0.186	0.046	0.126	0.397	0.231	0.050
2058	0.095	0.253	0.188	0.045	0.096	0.253	0.186	0.047	0.097	0.264	0.188	0.046	0.116	0.337	0.226	0.050
2059	0.109	0.356	0.181	0.043	0.110	0.356	0.181	0.045	0.111	0.366	0.182	0.044	0.127	0.422	0.228	***0.047***
2060	0.091	0.256	0.175	0.040	0.092	0.256	0.175	0.042	0.093	0.266	0.175	0.041	0.106	0.316	0.209	0.044
2061	0.086	0.234	0.169	0.040	0.087	0.233	0.169	0.042	0.087	0.241	0.169	0.041	0.100	0.286	***0.200***	0.043
2062	0.091	0.261	0.171	0.040	0.091	0.261	0.170	0.042	0.092	0.268	0.170	0.041	0.102	0.297	0.197	0.043
2063	0.091	0.261	0.172	0.041	0.091	0.260	0.171	0.041	0.092	0.266	0.171	0.041	0.101	0.296	0.196	0.043
2064	0.093	0.268	0.175	0.041	0.093	0.268	0.174	0.042	0.094	0.273	0.175	0.042	0.103	0.306	0.196	0.044
2065	0.092	0.255	0.178	0.043	0.093	0.255	0.177	0.043	0.093	0.260	0.177	0.043	0.100	0.283	0.195	0.045
2066	0.105	0.353	0.172	0.041	0.105	0.353	0.171	0.041	0.106	0.358	0.171	0.041	0.113	0.377	0.195	0.043
2067	0.095	0.275	0.180	0.042	0.095	0.275	0.179	0.042	0.096	0.279	0.179	0.043	0.101	0.301	0.183	0.044

BOLD-ITALICIZED - First occurrence of species-weighted fish fillet average PCB concentration below risk-based remediation goal of 0.05 mg/kg. Target concentrations of 0.2 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/month) and 0.4 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/ 2 months) are also italicized.

Upper Hudson River average is weighted by river section length. River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 2-5

Modeled Year-of-Compliance with Human Health Risk Assessment-Based Concentrations for various Resu Resuspension Scenarios

	No Resuspension (d004)	350 ng/L (sr04)	600 g/day (sr01)	MNA
Upper River Average				
Human Health risk-based RG 0.05 mg/kg	>2067	>2067	>2067	>2067
Fish Target Concentration 0.2 mg/kg	2024	2025	2024	2035
Fish Target Concentration 0.4 mg/kg	2013	2015	2013	2024
River Section 1- RM 189				
Human Health risk-based RG 0.05 mg/kg	>2067	>2067	>2067	>2067
Fish Target Concentration 0.2 mg/kg	>2067	>2067	>2067	>2067
Fish Target Concentration 0.4 mg/kg	2026	2030	2026	2043
River Section 2- RM 184				
Human Health risk-based RG 0.05 mg/kg	>2067	>2067	>2067	>2067
Fish Target Concentration 0.2 mg/kg	2044	2044	2044	2061
Fish Target Concentration 0.4 mg/kg	2025	2028	2026	2038
River Section 3- RM 154				
Human Health RG 0.05 mg/kg	2051	2055	2051	2059
Fish Target Concentration 0.2 mg/kg	2014	2020	2017	2019
Fish Target Concentration 0.4 mg/kg	2010	2014	2012	2011

Note: RG = risk-based remediation goal

Upper Hudson River average is weighted by river section length. River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 2-6
Estimated Non-cancer Indices via Long Term Fish Ingestion for Several Resuspension scenarios-Adult Angler and Upper Hudson Fish

Remedial Alternative	PCB Conc. in Fish (mg/kg ww)	Intake (Non-Cancer) (mg/kg-day)	Reference Dose (mg/kg-day)	Hazard Index
Reasonable Maximum Exposure				
Upper Hudson Average				
No Resuspension d004	0.30	1.4E-04	2.0E-05	6.9
350 ng/L sr04	0.58	2.6E-04	2.0E-05	13
600 g/day sr01	0.50	2.3E-04	2.0E-05	11
MNA	1.4	6.4E-04	2.0E-05	32
River Section 1 (RM 189)				
No Resuspension d004	0.62	2.8E-04	2.0E-05	14
350 ng/L sr04	0.64	2.9E-04	2.0E-05	15
600 g/day sr01	0.62	2.8E-04	2.0E-05	14
MNA	1.7	7.7E-04	2.0E-05	39
River Section 2 (RM 184)				
No Resuspension d004	0.66	3.0E-04	2.0E-05	15
350 ng/L sr04	0.79	3.6E-04	2.0E-05	18
600 g/day sr01	0.67	3.1E-04	2.0E-05	15
MNA	2.3	1.0E-03	2.0E-05	52
River Section 3 (RM 154)				
No Resuspension d004	0.18	8.0E-05	2.0E-05	4.0
350 ng/L sr04	0.30	1.4E-04	2.0E-05	6.8
600 g/day sr01	0.21	9.7E-05	2.0E-05	4.8
MNA	0.23	1.1E-04	2.0E-05	5.4
Central Tendency				
Upper Hudson Average				
No Resuspension d004	0.27	1.2E-05	2.0E-05	0.6
350 ng/L sr04	0.52	2.4E-05	2.0E-05	1.2
600 g/day sr01	0.46	2.1E-05	2.0E-05	1.0
MNA	1.2	5.5E-05	2.0E-05	2.8
River Section 1 (RM 189)				
No Resuspension d004	0.60	2.7E-05	2.0E-05	1.4
350 ng/L sr04	0.61	2.8E-05	2.0E-05	1.4
600 g/day sr01	0.59	2.7E-05	2.0E-05	1.4
MNA	1.50	6.9E-05	2.0E-05	3.5
River Section 2 (RM 184)				
No Resuspension d004	0.59	2.7E-05	2.0E-05	1.4
350 ng/L sr04	0.70	3.2E-05	2.0E-05	1.6
600 g/day sr01	0.60	2.7E-05	2.0E-05	1.4
MNA	1.9	8.7E-05	2.0E-05	4.4
River Section 3 (RM 154)				
No Resuspension d004	0.15	6.8E-06	2.0E-05	0.3
350 ng/L sr04	0.24	1.1E-05	2.0E-05	0.5
600 g/day sr01	0.18	8.0E-06	2.0E-05	0.4
MNA	0.21	9.4E-06	2.0E-05	0.5

Notes: The RME non-cancer exposure time frame is seven years, while the CT time frame is 12 years.
Upper Hudson River average is weighted by river section length. River Section 1: 6.3 miles = 15.4%;
River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 2-7
Estimated cancer Indices via Long Term Fish Ingestion for Several Resuspension scenarios- Adult Angler and Upper Hudson Fish

Remedial Alternative	PCB Conc. in Fish (mg/kg ww)	Intake (Cancer) (mg/kg-day)	Cancer Slope Factor (mg/kg-day)	Cancer Risk
Reasonable Maximum Exposure				
Upper Hudson Average				
No Resuspension d004	0.18	4.6E-05	2	9.3E-05
350 ng/L sr04	0.32	8.3E-05	2	1.7E-04
600 g/day sr01	0.30	7.7E-05	2	1.5E-04
MNA	0.60	1.7E-04	2	3.3E-04
River Section 1 (RM 189)				
No Resuspension d004	0.43	1.1E-04	2	2.2E-04
350 ng/L sr04	0.43	1.1E-04	2	2.2E-04
600 g/day sr01	0.42	1.1E-04	2	2.2E-04
MNA	0.86	2.2E-04	2	4.5E-04
River Section 2 (RM 184)				
No Resuspension d004	0.36	9.3E-05	2	1.9E-04
350 ng/L sr04	0.40	1.0E-04	2	2.1E-04
600 g/day sr01	0.36	9.4E-05	2	1.9E-04
MNA	0.90	2.4E-04	2	4.9E-04
River Section 3 (RM 154)				
No Resuspension d004	0.09	2.4E-05	2	4.8E-05
350 ng/L sr04	0.12	3.2E-05	2	6.4E-05
600 g/day sr01	0.10	2.7E-05	2	5.3E-05
MNA	0.12	3.2E-05	2	6.4E-05
Central Tendency				
Upper Hudson Average				
No Resuspension d004	0.27	2.1E-06	1	2.1E-06
350 ng/L sr04	0.52	4.0E-06	1	4.0E-06
600 g/day sr01	0.46	3.6E-06	1	3.6E-06
MNA	1.2	9.5E-06	1	9.5E-06
River Section 1 (RM 189)				
No Resuspension d004	0.60	4.7E-06	1	4.7E-06
350 ng/L sr04	0.61	4.8E-06	1	4.8E-06
600 g/day sr01	0.59	4.7E-06	1	4.7E-06
MNA	1.5	1.2E-05	1	1.2E-05
River Section 2 (RM 184)				
No Resuspension d004	0.59	4.7E-06	1	4.7E-06
350 ng/L sr04	0.70	5.5E-06	1	5.5E-06
600 g/day sr01	0.60	4.7E-06	1	4.7E-06
MNA	1.9	1.5E-05	1	1.5E-05
River Section 3 (RM 154)				
No Resuspension d004	0.15	1.2E-06	1	1.2E-06
350 ng/L sr04	0.24	1.9E-06	1	1.9E-06
600 g/day sr01	0.18	1.4E-06	1	1.4E-06
MNA	0.21	1.6E-06	1	1.6E-06

Notes: The RME cancer exposure time frame is 40 years, while the CT time frame is 12 years.
Upper Hudson River average is weighted by river section length. River Section 1: 6.3 miles = 15.4%;
River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 2-8
Upper Hudson River Average Largemouth Bass (Whole Fish) PCB Concentration (in mg/kg)

Year	No Resuspension (d004)				Total PCB 350 ng/L (sr04)				Total PCB 600 g/day (sr01)				Monitored Natural Attenuation			
	Upper River Average	Section 1 (RM 189)	Section 2 (RM 184)	Section 3 (RM 154)	Upper River Average	Section 1 (RM 189)	Section 2 (RM 184)	Section 3 (RM 154)	Upper River Average	Section 1 (RM 189)	Section 2 (RM 184)	Section 3 (RM 154)	Upper River Average	Section 1 (RM 189)	Section 2 (RM 184)	Section 3 (RM 154)
1998	7.13	16.73	17.22	3.33	7.13	16.70	17.24	3.33	7.13	16.70	17.24	3.33	7.19	16.61	18.04	3.29
1999	7.04	17.11	16.80	3.20	7.04	17.12	16.83	3.20	7.04	17.12	16.83	3.20	6.76	16.16	15.91	3.17
2000	5.84	13.71	14.51	2.66	5.84	13.74	14.47	2.66	5.84	13.74	14.47	2.66	5.74	13.09	14.57	2.64
2001	5.29	12.01	13.33	2.47	5.30	12.04	13.32	2.47	5.30	12.04	13.32	2.47	5.13	11.34	12.94	2.45
2002	4.91	11.63	12.30	2.20	4.92	11.66	12.29	2.20	4.92	11.66	12.29	2.20	4.76	11.11	11.84	2.18
2003	4.43	10.12	11.39	2.01	4.43	10.11	11.40	2.01	4.43	10.11	11.40	2.01	4.33	9.92	10.73	2.03
2004	5.12	14.37	11.49	2.04	5.12	14.38	11.48	2.04	5.12	14.38	11.48	2.04	4.88	13.63	10.57	2.02
2005	3.94	9.68	9.91	1.67	3.95	9.67	9.97	1.68	3.94	9.67	9.95	1.68	3.85	9.04	10.09	1.66
2006	3.14	6.44	8.80	1.45	3.38	6.61	9.48	1.63	3.28	6.57	9.17	1.55	3.06	5.97	8.70	1.46
2007	2.96	6.45	8.04	1.33	3.63	8.59	9.25	1.59	3.35	7.78	8.73	1.47	2.96	6.39	7.95	1.36
2008	2.59	5.37	7.38	1.17	3.88	11.02	8.77	1.51	3.40	9.02	8.30	1.36	2.78	6.45	7.30	1.21
2009	2.00	4.08	5.15	1.02	3.06	6.90	7.31	1.50	2.49	5.39	5.93	1.27	2.60	6.16	6.88	1.10
2010	1.35	2.88	2.56	0.81	2.14	3.17	3.68	1.66	1.65	3.00	2.76	1.17	2.31	5.51	6.40	0.92
2011	1.00	2.02	1.57	0.68	1.94	2.18	2.05	1.86	1.34	2.12	1.67	1.11	1.95	4.24	5.61	0.83
2012	0.94	2.35	1.48	0.55	1.38	2.45	1.85	1.07	1.07	2.41	1.54	0.70	1.78	4.21	5.16	0.68
2013	0.76	1.69	1.30	0.47	1.08	1.75	1.59	0.85	0.85	1.71	1.34	0.59	1.55	3.47	4.60	0.61
2014	0.72	1.80	1.22	0.41	0.97	1.81	1.44	0.71	0.79	1.80	1.23	0.50	1.46	3.49	4.23	0.55
2015	0.64	1.52	1.16	0.37	0.85	1.53	1.35	0.62	0.70	1.51	1.16	0.44	1.33	3.13	3.87	0.50
2016	0.68	1.72	1.26	0.36	0.87	1.72	1.43	0.59	0.73	1.71	1.26	0.43	1.36	3.53	3.65	0.50
2017	0.73	2.17	1.18	0.35	0.89	2.16	1.34	0.54	0.77	2.16	1.18	0.40	1.38	3.73	3.60	0.49
2018	0.66	1.93	1.09	0.32	0.79	1.91	1.24	0.48	0.70	1.92	1.10	0.37	1.24	3.29	3.21	0.46
2019	0.72	2.34	1.13	***0.30***	0.83	2.32	1.28	0.43	0.75	2.33	1.14	0.34	1.25	3.68	2.94	0.43
2020	0.59	1.89	0.92	0.26	0.68	1.86	1.06	0.36	0.61	1.87	0.93	***0.29***	1.08	3.02	2.71	0.38
2021	0.51	1.44	0.90	0.25	0.59	1.43	1.03	0.33	0.53	1.42	0.91	0.27	0.93	2.43	2.40	0.36
2022	0.51	1.43	0.92	0.24	0.58	1.43	1.04	0.33	0.53	1.42	0.93	0.27	0.93	2.51	2.26	0.36
2023	0.54	1.69	0.88	0.24	0.60	1.67	0.98	0.30	0.55	1.68	0.89	0.25	0.94	2.67	2.21	0.35
2024	0.49	1.58	0.79	0.20	0.53	1.57	0.87	***0.25***	0.50	1.57	0.81	0.21	0.82	2.26	2.05	***0.29***
2025	0.43	1.29	0.74	0.19	0.46	1.29	0.80	0.23	0.44	1.28	0.76	0.20	0.73	1.98	1.82	0.28
2026	0.38	1.08	0.71	0.18	0.41	1.07	0.75	0.21	0.39	1.06	0.72	0.19	0.66	1.69	1.68	0.26
2027	0.47	1.60	0.74	0.18	0.50	1.59	0.78	0.21	0.48	1.59	0.75	0.19	0.75	2.29	1.66	0.27
2028	0.46	1.69	0.65	0.16	0.48	1.69	0.68	0.18	0.46	1.69	0.66	0.17	0.73	2.33	1.61	0.23
2029	0.39	1.34	0.63	0.15	0.41	1.33	0.65	0.17	0.40	1.33	0.62	0.16	0.62	1.83	1.44	0.22
2030	0.35	0.99	0.63	0.16	0.36	0.98	0.65	0.18	0.35	0.98	0.62	0.17	0.55	1.45	1.33	0.23
2031	0.40	1.42	0.58	0.15	0.41	1.41	0.61	0.16	0.40	1.41	0.58	0.15	0.59	1.86	1.27	0.21
2032	0.35	1.18	0.55	0.14	0.36	1.18	0.58	0.15	0.35	1.18	0.55	0.14	0.53	1.59	1.13	0.20
2033	0.34	1.14	0.53	0.13	0.35	1.13	0.56	0.14	0.34	1.13	0.53	0.13	0.49	1.47	1.04	0.18
2034	0.34	1.23	0.49	0.13	0.35	1.23	0.52	0.13	0.34	1.23	0.49	0.13	0.48	1.50	0.98	0.17

Table 2-8
Upper Hudson River Average Largemouth Bass (Whole Fish) PCB Concentration (in mg/kg)

2035	***0.29***	0.88	0.47	0.14	***0.28***	0.87	0.50	0.12	***0.28***	0.87	0.48	0.12	0.41	1.12	0.87	0.18
2036	0.40	1.21	0.48	0.22	0.33	1.21	0.50	0.11	0.33	1.20	0.48	0.12	0.51	1.43	0.85	0.26
2037	0.36	0.98	0.46	0.21	0.29	0.98	0.49	0.11	0.32	0.98	0.47	0.15	0.45	1.19	0.75	0.24
2038	0.36	1.13	0.43	0.19	0.33	1.13	0.45	0.14	0.37	1.13	0.43	0.20	0.45	1.32	0.72	0.22
2039	0.33	0.89	0.42	0.19	0.34	0.89	0.44	0.21	0.34	0.89	0.42	0.21	0.41	1.09	0.68	0.22
2040	0.31	0.86	0.42	0.17	0.33	0.86	0.44	0.20	0.32	0.86	0.42	0.19	0.38	0.98	0.63	0.20
2041	0.37	1.23	0.44	0.18	0.40	1.23	0.45	0.22	0.39	1.23	0.44	0.20	0.45	1.42	0.66	0.21
2042	0.39	1.40	0.46	0.16	0.42	1.40	0.47	0.20	0.41	1.40	0.46	0.18	0.46	1.56	0.65	0.19
2043	0.33	1.10	0.39	0.15	0.35	1.10	0.40	0.18	0.34	1.10	0.40	0.16	0.39	1.22	0.62	0.17
2044	0.28	0.82	0.37	0.14	0.29	0.82	0.37	0.16	0.28	0.83	0.37	0.15	0.32	0.88	0.55	0.16
2045	0.30	0.97	0.38	0.14	0.31	0.97	0.38	0.16	0.31	1.00	0.38	0.15	0.34	1.04	0.52	0.16
2046	0.27	0.86	0.36	0.13	0.28	0.86	0.36	0.14	0.28	0.88	0.36	0.14	0.32	0.95	0.51	0.15
2047	0.28	0.93	0.37	0.13	0.29	0.91	0.37	0.14	0.29	0.93	0.37	0.14	0.35	1.17	0.49	0.15
2048	0.30	1.08	0.37	0.13	0.31	1.07	0.37	0.14	0.31	1.07	0.37	0.13	0.39	1.42	0.50	0.15
2049	0.31	1.14	0.39	0.12	0.33	1.15	0.39	0.14	0.32	1.13	0.39	0.13	0.38	1.39	0.50	0.14
2050	0.28	0.96	0.36	0.12	0.29	0.96	0.36	0.13	0.28	0.95	0.37	0.12	0.34	1.21	0.49	0.13
2051	0.27	0.96	0.36	0.10	0.28	0.96	0.36	0.11	0.27	0.96	0.37	0.11	0.32	1.12	0.47	0.12
2052	0.24	0.80	0.36	0.10	0.25	0.80	0.36	0.11	0.25	0.82	0.36	0.11	***0.29***	0.98	0.44	0.12
2053	0.32	1.26	0.38	0.11	0.32	1.26	0.38	0.12	0.33	1.28	0.38	0.11	0.37	1.41	0.49	0.12
2054	0.29	1.08	0.38	0.11	0.29	1.08	0.38	0.11	0.30	1.10	0.38	0.11	0.32	1.18	0.46	0.12
2055	0.26	0.93	0.36	0.10	0.26	0.93	0.36	0.11	0.27	0.95	0.36	0.10	0.30	1.06	0.44	0.11
2056	0.28	1.03	0.41	0.10	0.29	1.02	0.40	0.11	0.29	1.04	0.41	0.10	0.32	1.16	0.45	0.11
2057	0.29	1.14	0.37	0.10	0.30	1.14	0.37	0.10	0.30	1.15	0.37	0.10	0.32	1.17	0.46	0.11
2058	0.25	0.85	0.37	0.10	0.25	0.85	0.37	0.10	0.25	0.87	0.38	0.10	0.27	0.91	0.43	0.11
2059	0.31	1.27	0.36	0.10	0.31	1.26	0.36	0.10	0.31	1.28	0.36	0.10	0.33	1.31	0.46	0.10
2060	0.24	0.88	0.35	0.09	0.25	0.87	0.35	0.09	0.25	0.89	0.35	0.09	0.26	0.93	0.40	0.10
2061	0.23	0.79	0.33	0.09	0.23	0.79	0.33	0.09	0.23	0.80	0.33	0.09	0.25	0.84	0.38	0.09
2062	0.25	0.89	0.34	0.09	0.25	0.89	0.34	0.09	0.25	0.90	0.34	0.09	0.26	0.91	0.38	0.10
2063	0.24	0.89	0.35	0.09	0.25	0.89	0.34	0.09	0.25	0.89	0.35	0.09	0.26	0.91	0.37	0.10
2064	0.25	0.92	0.36	0.09	0.25	0.92	0.36	0.09	0.25	0.92	0.36	0.09	0.27	0.97	0.38	0.10
2065	0.25	0.88	0.36	0.10	0.25	0.87	0.36	0.10	0.25	0.88	0.36	0.10	0.25	0.87	0.38	0.10
2066	0.30	1.25	0.34	0.09	0.30	1.25	0.34	0.09	0.30	1.25	0.34	0.09	0.31	1.26	0.40	0.09
2067	0.26	0.95	0.37	0.09	0.26	0.95	0.37	0.09	0.26	0.95	0.37	0.09	0.27	0.97	0.37	0.10

Notes:

Fish fillets multiplied by 2.5 to obtain whole fish concentrations.

Upper Hudson River average is weighted by river section length. River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

All whole fish PCB concentrations are above target fish concentration of 0.3 mg/kg and/or 0.03 mg/kg based on the river otter lowest-observed-adverse-effects-level (LOAEL) and no-observed-adverse-effects-level (NOAEL), respectively.

Table 2-9
Modeled Year-of-Compliance for River Otter Risk-Based Fish Concentrations Upper Hudson River

River Otter - RI/FS TRVs (whole fish tissue)	Modeled Year of Compliance	
	LOAEL 0.3 PCBs mg/kg	**NOAEL 0.03 PCBs mg/kg**
Upper Hudson River Average		
No Resuspension (d004)	2035	> 2067
Total PCB 350 ng/L (sr04)	2035	> 2067
Total PCB 600 g/day (sr01)	2035	> 2067
Monitored Natural Attenuation	2052	> 2067
Upper Hudson River Section 1		
No Resuspension (d004)	> 2067	> 2067
Total PCB 350 ng/L (sr04)	> 2067	> 2067
Total PCB 600 g/day (sr01)	> 2067	> 2067
Monitored Natural Attenuation	> 2067	> 2067
Upper Hudson River Section 2		
No Resuspension (d004)	> 2067	> 2067
Total PCB 350 ng/L (sr04)	> 2067	> 2067
Total PCB 600 g/day (sr01)	> 2067	> 2067
Monitored Natural Attenuation	> 2067	> 2067
Upper Hudson River Section 3		
No Resuspension (d004)	2019	> 2067
Total PCB 350 ng/L (sr04)	2024	> 2067
Total PCB 600 g/day (sr01)	2020	> 2067
Monitored Natural Attenuation	2024	> 2067

Notes:
First year in which fish target concentrations are achieved are provided.
Upper Hudson River average is weighted by river section length. River Section 1: 6.3 miles = 15.4
River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 2-10
Lower Hudson River Average Largemouth Bass (Whole Fish) PCB Concentration (in mg/kg)

Year	No Resuspension (d004)				Total PCB 350 ng/L (sr04)				Total PCB 600 g/day (sr01)				Monitored Natural Attenuation			
	River Mile 152	River Mile 113	River Mile 90	River Mile 50	River Mile 152	River Mile 113	River Mile 90	River Mile 50	River Mile 152	River Mile 113	River Mile 90	River Mile 50	River Mile 152	River Mile 113	River Mile 90	River Mile 50
1998	7.15	5.21	3.55	3.26	7.15	5.21	3.55	3.26	7.15	5.21	3.55	3.26	7.54	5.30	3.55	3.24
1999	4.53	4.12	3.30	3.01	4.53	4.12	3.30	3.01	4.53	4.12	3.30	3.01	4.37	4.06	3.28	2.99
2000	3.81	3.56	2.93	2.73	3.81	3.56	2.93	2.73	3.81	3.56	2.93	2.73	4.01	3.56	2.91	2.71
2001	4.50	3.54	2.66	2.49	4.50	3.54	2.66	2.49	4.50	3.54	2.66	2.49	4.51	3.54	2.65	2.47
2002	3.97	3.19	2.49	2.31	3.97	3.19	2.49	2.31	3.97	3.19	2.49	2.31	3.91	3.17	2.47	2.28
2003	3.42	2.82	2.26	2.10	3.42	2.82	2.26	2.10	3.42	2.82	2.26	2.10	3.39	2.82	2.25	2.08
2004	2.42	2.26	1.97	1.89	2.42	2.26	1.97	1.89	2.42	2.26	1.97	1.89	2.39	2.23	1.96	1.88
2005	2.27	1.95	1.69	1.67	2.27	1.95	1.69	1.67	2.27	1.95	1.69	1.67	2.25	1.94	1.68	1.66
2006	2.37	1.85	1.49	1.48	2.53	1.89	1.49	1.49	2.49	1.86	1.49	1.49	2.34	1.86	1.49	1.47
2007	1.93	1.71	1.35	1.34	2.37	1.86	1.40	1.36	2.20	1.79	1.38	1.34	1.89	1.70	1.35	1.32
2008	1.54	1.41	1.22	1.20	2.33	1.77	1.33	1.25	1.97	1.60	1.27	1.23	1.57	1.42	1.21	1.20
2009	1.21	1.15	1.06	1.05	2.03	1.53	1.18	1.12	1.62	1.34	1.12	1.08	1.27	1.16	1.06	1.05
2010	1.10	1.02	0.92	0.94	2.55	1.71	1.16	1.06	1.73	1.30	1.02	1.00	1.36	1.13	0.94	0.95
2011	1.25	1.01	0.84	0.86	5.16	2.57	1.35	1.10	2.43	1.49	1.01	0.96	1.63	1.22	0.91	0.89
2012	0.92	0.86	0.75	0.77	2.17	2.06	1.38	1.13	1.32	1.20	0.96	0.90	1.30	1.11	0.86	0.83
2013	1.02	0.82	0.68	0.71	1.78	1.63	1.28	1.11	1.27	1.08	0.88	0.84	1.48	1.13	0.83	0.79
2014	0.86	0.74	0.62	0.64	1.33	1.29	1.12	1.04	1.01	0.92	0.78	0.77	1.27	1.03	0.79	0.74
2015	0.72	0.65	0.56	0.59	1.04	1.04	0.96	0.94	0.82	0.78	0.69	0.70	1.00	0.90	0.73	0.70
2016	0.55	0.53	0.50	0.53	0.76	0.78	0.79	0.83	0.61	0.61	0.60	0.63	0.76	0.72	0.65	0.64
2017	0.46	0.45	0.44	0.48	0.54	0.60	0.65	0.73	0.51	0.51	0.51	0.56	0.68	0.62	0.57	0.59
2018	0.43	0.41	0.39	0.44	0.45	0.50	0.54	0.63	0.47	0.45	0.45	0.50	0.65	0.58	0.51	0.53
2019	0.34	0.35	0.35	0.40	0.35	0.39	0.44	0.54	0.37	0.38	0.39	0.45	0.52	0.50	0.46	0.49
2020	0.42	0.35	0.32	0.36	0.42	0.37	0.38	0.46	0.45	0.37	0.35	0.40	0.68	0.51	0.42	0.44
2021	0.41	0.34	***0.30***	0.34	0.41	0.36	0.34	0.41	0.44	0.36	0.32	0.36	0.63	0.49	0.40	0.41
2022	0.35	0.32	0.29	0.32	0.35	0.33	0.31	0.37	0.37	0.34	0.30	0.34	0.51	0.45	0.38	0.39
2023	0.30	***0.29***	0.27	***0.30***	0.30	***0.29***	***0.28***	0.33	0.32	0.30	***0.28***	0.32	0.46	0.41	0.35	0.37
2024	0.32	0.28	0.25	0.28	0.32	0.28	0.26	0.31	0.33	***0.29***	0.26	***0.30***	0.48	0.40	0.34	0.35
2025	0.35	0.30	0.25	0.27	0.35	0.30	0.26	***0.29***	0.37	0.31	0.26	0.29	0.53	0.43	0.34	0.34
2026	0.33	0.29	0.25	0.27	0.33	0.29	0.25	0.28	0.34	0.29	0.25	0.28	0.48	0.40	0.33	0.33
2027	***0.26***	0.26	0.24	0.26	***0.26***	0.26	0.24	0.27	***0.26***	0.27	0.24	0.27	0.37	0.36	0.32	0.32
2028	0.24	0.24	0.23	0.25	0.24	0.25	0.23	0.26	0.25	0.25	0.23	0.26	0.35	0.34	***0.30***	0.31
2029	0.29	0.25	0.22	0.24	0.29	0.25	0.22	0.25	0.30	0.25	0.22	0.25	0.42	0.34	0.28	***0.30***
2030	0.29	0.25	0.22	0.24	0.29	0.25	0.22	0.24	0.30	0.25	0.22	0.24	0.40	0.34	0.28	0.29
2031	0.25	0.24	0.21	0.23	0.25	0.24	0.21	0.23	0.25	0.24	0.22	0.24	0.34	0.32	0.27	0.28
2032	0.25	0.24	0.21	0.23	0.25	0.24	0.21	0.23	0.26	0.24	0.22	0.24	0.35	0.32	0.27	0.28
2033	0.23	0.23	0.21	0.23	0.23	0.23	0.21	0.23	0.23	0.23	0.21	0.23	0.31	0.30	0.26	0.28
2034	0.22	0.22	0.20	0.22	0.22	0.22	0.20	0.22	0.22	0.22	0.20	0.23	***0.29***	***0.29***	0.25	0.27
2035	0.35	0.25	0.21	0.22	0.35	0.25	0.21	0.22	0.27	0.23	0.20	0.22	0.42	0.33	0.25	0.26

Table 2-10
Lower Hudson River Average Largemouth Bass (Whole Fish) PCB Concentration (in mg/kg)

2036	0.48	0.32	0.23	0.23	0.48	0.32	0.23	0.23	0.23	0.22	0.20	0.22	0.54	0.38	0.27	0.26
2037	0.57	0.39	0.26	0.24	0.57	0.39	0.26	0.24	0.40	0.28	0.21	0.22	0.69	0.46	0.30	0.28
2038	0.58	0.40	0.28	0.26	0.58	0.40	0.28	0.26	0.65	0.38	0.24	0.23	0.65	0.47	0.32	0.29
2039	0.48	0.39	0.29	0.27	0.48	0.39	0.29	0.27	0.56	0.41	0.27	0.25	0.55	0.44	0.33	0.30
2040	0.43	0.37	0.29	0.27	0.43	0.37	0.29	0.27	0.51	0.40	0.29	0.26	0.48	0.42	0.33	0.31
2041	0.30	0.32	0.28	0.27	0.30	0.32	0.28	0.27	0.35	0.35	0.28	0.27	0.35	0.36	0.31	0.30
2042	0.25	0.27	0.26	0.26	0.25	0.27	0.26	0.26	0.29	0.30	0.27	0.27	0.28	0.30	0.28	0.29
2043	0.29	0.26	0.24	0.25	0.29	0.26	0.24	0.25	0.33	0.29	0.25	0.26	0.35	0.30	0.26	0.28
2044	0.35	0.28	0.23	0.24	0.35	0.28	0.23	0.25	0.38	0.31	0.25	0.25	0.42	0.32	0.26	0.27
2045	0.33	0.28	0.23	0.24	0.33	0.28	0.23	0.24	0.34	0.30	0.24	0.25	0.38	0.32	0.26	0.26
2046	0.29	0.26	0.22	0.24	0.29	0.26	0.22	0.24	0.30	0.27	0.23	0.24	0.33	0.30	0.25	0.26

Notes:

Fish fillets multiplied by 2.5 to obtain whole fish concentrations.

All whole fish PCB concentrations are above target fish concentration of 0.3 mg/kg and/or 0.03 mg/kg based on the river otter lowest-observed-adverse-effects-level (LOAEL) and no-observed-adverse-effects-level (NOAEL), respectively.

Table 2-11
Modeled Year-of-Compliance for River Otter Risk-Based Fish Concentrations
Lower Hudson River

	River Otter - RI/FS TRVs (whole fish tissue)	
	LOAEL 0.3 PCBs mg/kg	NOAEL 0.03 PCBs mg/kg
Lower Hudson River RM 152		
No Resuspension (d004)	2027	> 2067
Total PCB 350 ng/L (sr04)	2027	> 2067
Total PCB 600 g/day (sr01)	2027	> 2067
Monitored Natural Attenuation	2034	> 2067
Lower Hudson River RM 113		
No Resuspension (d004)	2023	> 2067
Total PCB 350 ng/L (sr04)	2023	> 2067
Total PCB 600 g/day (sr01)	2024	> 2067
Monitored Natural Attenuation	2034	> 2067
Lower Hudson River RM 90		
No Resuspension (d004)	2021	> 2067
Total PCB 350 ng/L (sr04)	2023	> 2067
Total PCB 600 g/day (sr01)	2023	> 2067
Monitored Natural Attenuation	2028	> 2067
Lower Hudson River RM 50		
No Resuspension (d004)	2023	> 2067
Total PCB 350 ng/L (sr04)	2025	> 2067
Total PCB 600 g/day (sr01)	2024	> 2067
Monitored Natural Attenuation	2029	> 2067

Notes:
First year in which fish target concentrations are achieved are provided.

Table 2-12
Results for Average Dredging-Related Source Strength Estimated Fluxes

	INPUT				TSS-Chem RESULTS				PERCENT LOSS	
	PCB Production rate kg PCB/day	Sediment production rate kg solids/day	Silt Fraction unitless	TSS Silt Source Strength (1,2) (kg/s)	Net TSS Flux at 1 mile (2) (kg/day)	Net Total PCB Flux at 1 mile (2) (g/day)	Net Fraction Dissolved PCBs at 1 mile unitless	Concentration increase at 1 mile (ng/l)	TSS Loss at 1 mile %	PCB Loss at 1 mile %
River Section										
Section 1	57	2,099,921	0.37	0.077	2,303	78	0.35	14	0.11	0.14
Section 2	116	1,857,493	0.48	0.088	2,642	209	0.39	37	0.14	0.18
Section 3	45	1,563,927	0.48	0.074	2,225	81	0.40	14	0.14	0.18

Notes:

1. Source strengths apply to silt and finer particles only
2. Production rates are based on 7 days/week, 14 hours per day, 630 days in Section 1 and 210 days each in River Sections 2 & 3.
3. Values are based on river-wide volumetric flow of 4000 cfs.

Table 2-13
Resuspension Production, Release, and Export Rates from TSS-Chem and HUDTOX Models

TSS-Chem and HUDTOX Simulations

Scenario	Sediment Removal Period	Dredging Location and Monitoring Station	Resuspension Production Rate of Sediment[1] (kg/s)	Resuspension Production Rate of Total PCB[2] (g/day)	Silt Fraction in Dredged Material	Net SS Flux at 1 mile from SS-Chem (kg/s)	Total PCB flux at 1 mile3 from TSS-Chem (Resuspension Release Rate) (g/day)	Fraction Dissolved total PCB from TSS-Chem	Total PCB Flux at Far-field Monitoring Stations from HUDTOX[4] (Resuspension Export Rate) (g/day)	Removal Rate of total PCB via Dredging[6] (g/day)	Removal Rate of Solids via Dredging[7] (kg/s)	Source Strength as Percentage of total PCB Removed[8] (%)	Resuspension Export Rate as Percentage of total PCB Removed[9] (%)	Total PCB Export Fraction - (Resuspension Export Rate/Resuspension Production Rate)
				A			B		C	D		(A/D)	(C/D)	(C/A)
Evaluation Level - 300 g/day total PCB Flux at the Far-Field Monitoring Stations	May 1 - November 30, 2006	Section 1, TID	1.3	1,700	0.37	0.28	410	0.22	320	5.7.E+04	42	3%	0.56%	0.19
	May 1 - November 30, 2007	Section 1, TID	1.3	1,700	0.37	0.27	410	0.22	320	5.7.E+04	42	3%	0.56%	0.19
	May 1 - November 30, 2008	Section 1, TID	1.1	1,500	0.37	0.24	360	0.23	300	5.7.E+04	42	3%	0.53%	0.20
	May 1 - August 15, 2009	Section 1, TID	0.9	1,300	0.37	0.20	310	0.25	310	5.7.E+04	42	2%	0.54%	0.24
	August 16 - November 30, 2009	Section 2, Schuylerville	0.3	1,100	0.48	0.10	360	0.35	330	1.2.E+05	37	1%	0.29%	0.30
	May 1 - August 15, 2010	Section 2, Schuylerville	0.3	900	0.48	0.08	310	0.37	300	1.2.E+05	37	1%	0.26%	0.33
	August 16 - November 30, 2010	Section 3, Waterford	0.9	1,300	0.48	0.25	400	0.25	340	4.5.E+04	31	3%	0.75%	0.26
	May 1 - August 15, 2011	Section 3, Waterford	0.7	1,000	0.48	0.19	310	0.28	340	4.5.E+04	31	2%	0.75%	0.34
Control Level - 600 g/day total PCB Flux at the Far-Field Monitoring Stations	May 1 - November 30, 2006	Section 1, TID	2.6	3,600	0.37	0.57	820	0.15	620	5.7.E+04	42	6%	1.1%	0.17
	May 1 - November 30, 2007	Section 1, TID	2.6	3,600	0.37	0.57	820	0.15	630	5.7.E+04	42	6%	1.1%	0.18
	May 1 - November 30, 2008	Section 1, TID	2.3	3,100	0.37	0.50	720	0.16	620	5.7.E+04	42	6%	1.1%	0.20
	May 1 - August 15, 2009	Section 1, TID	2.0	2,700	0.37	0.43	620	0.18	590	5.7.E+04	42	5%	1.0%	0.22
	August 16 - November 30, 2009	Section 2, Schuylerville	0.7	2,300	0.48	0.21	730	0.29	620	1.2.E+05	37	2%	0.5%	0.27
	May 1 - August 15, 2010	Section 2, Schuylerville	0.6	1,900	0.48	0.17	630	0.30	590	1.2.E+05	37	2%	0.5%	0.31
	August 16 - November 30, 2010	Section 3, Waterford	1.9	2,700	0.48	0.52	810	0.17	660	4.5.E+04	31	6%	1.5%	0.24
	May 1 - August 15, 2011	Section 3, Waterford	1.4	2,100	0.48	0.40	630	0.20	650	4.5.E+04	31	5%	1.4%	0.31
Control Level - 350 ng/L total PCB Concentrations at the Far-Field Monitoring Stations	May 1 - November 30, 2006	Section 1, TID	5.6	7,600	0.37	1.2	1,700	0.09	1,200	5.7.E+04	42	13%	2.1%	0.16
	May 1 - November 30, 2007	Section 1, TID	5.6	7,600	0.37	1.2	1,700	0.09	1,200	5.7.E+04	42	13%	2.1%	0.16
	May 1 - November 30, 2008	Section 1, TID	4.9	6,700	0.37	1.1	1,500	0.10	1,300	5.7.E+04	42	12%	2.3%	0.19
	May 1 - August 15, 2009	Section 1, TID	4.2	5,700	0.37	0.91	1,300	0.11	1,200	5.7.E+04	42	10%	2.1%	0.21
	August 16 - November 30, 2009	Section 2, Schuylerville	2.7	8,300	0.48	0.75	2,500	0.14	2,000	1.2.E+05	37	7%	1.7%	0.24
	May 1 - August 15, 2010	Section 2, Schuylerville	2.3	7,100	0.48	0.64	2,100	0.16	2,000	1.2.E+05	37	6%	1.7%	0.28
	August 16 - November 30, 2010	Section 3, Waterford	7.5	10,900	0.48	2.1	3,100	0.06	2,200	4.5.E+04	31	24%	4.9%	0.20
	May 1 - August 15, 2011	Section 3, Waterford	5.8	8,400	0.48	1.6	2,400	0.07	2,300	4.5.E+04	31	19%	5.1%	0.27

TSS-Chem Simulations Only

Scenario	Sediment Removal Period	Dredging Location and Monitoring Station	Resuspension Production Rate of Sediment[1] (kg/s)	Resuspension Production Rate of Total PCB[2] (g/day)	Silt Fraction in Dredged Material	Net SS Flux at 1 mile from SS-Chem (kg/s)	Total PCB flux at 1 mile3 from TSS-Chem (Resuspension Release Rate) (g/day)	Fraction Dissolved total PCB from TSS-Chem	Total PCB Flux at Monitoring Stations[10] (Resuspension Export Rate) (g/day)	Removal Rate of total PCB via Dredging[6] (g/day)	Removal Rate of Solids via Dredging[7] (kg/s)	Source Strength as Percentage of total PCB Removed[8] (%)	Resuspension Export Rate as Percentage of total PCB Removed[9] (%)	Total PCB Export Fraction - (Resuspension Export Rate/Resuspension Production Rate)
				A			B		C	D		(A/D)	(C/D)	(C/A)
Resuspension Standard - 500 ng/L total PCB Concentrations at the Far-Field Monitoring Stations	May 1 - November 30, 2006	Section 1, TID	9.4	12,800	0.37	2.0	2,800	0.06	2,100	5.7.E+04	42	23%	3.7%	0.16
	May 1 - November 30, 2007	Section 1, TID	9.3	12,700	0.37	2.0	2,800	0.06	2,100	5.7.E+04	42	22%	3.7%	0.17
	May 1 - November 30, 2008	Section 1, TID	8.2	11,200	0.37	1.8	2,500	0.06	2,100	5.7.E+04	42	20%	3.7%	0.19
	May 1 - August 15, 2009	Section 1, TID	7.1	9,600	0.37	1.53	2,100	0.07	2,100	5.7.E+04	42	17%	3.7%	0.22
	August 16 - November 30, 2009	Section 2, Schuylerville	3.5	10,900	0.48	0.99	3,200	0.12	2,700	1.2.E+05	37	9%	2.3%	0.25
	May 1 - August 15, 2010	Section 2, Schuylerville	3.0	9,300	0.48	0.84	2,800	0.13	2,700	1.2.E+05	37	8%	2.3%	0.29
	August 16 - November 30, 2010	Section 3, Waterford	11	16,600	0.48	3.2	4,800	0.04	3,500	4.5.E+04	31	37%	7.7%	0.21
	May 1 - August 15, 2011	Section 3, Waterford	8.8	12,800	0.48	2.5	3,700	0.05	3,500	4.5.E+04	31	28%	7.7%	0.27

Notes:

Numbers are rounded to 2 significant digits.

[1] Source strength represents the amount of solids being suspended to the water column at the dredge-head in kg/s. The value is obtained from the CSTR-Chem model.

[2] Total PCB flux for source strength is obtained by multiplying the solids source strength with the total PCB concentration in the sediment. The total PCB concentration for River Sections 1, 2, and 3 is 27, 62, and 29 mg/kg, respectively.

[3] Net SS flux is the TSS-Chem model result at a distance 1 mile downstream of the dredge-head. This number is also the SS flux input to the HUDTOX model.

[4] Values represent the amount of total PCB flux at the monitoring stations as predicted by HUDTOX.

[5] Total PCB flux is obtained from TSS-Chem model. It is the total PCB flux at 1 mile downstream of the dredge-head. This is also the input total PCB flux to the HUDTOX model.

[6] Removal rate of total PCBs via dredging is based on the total total PCB being removed in each river section (36,000 kg, 24,300 kg, and 9,500 kg of total PCB for River Sections 1, 2, and 3, respectively);
assuming 7days/week, 14 hours/day, 630 days in River Section 1 and 210 days each in River Sections 2 and 3.

[7] Removal rate of solids via dredging is calculated based on the total sediment being removed including overcut (1.5x10^6 cy, 5.8x10^5 cy, and 5.1x10^5 cy of solids in River Sections 1, 2, and 3, respectively);
assuming 7days/week and 14 hours/day, 630 days in River Section 1 and 210 days each in River Sections 2 and 3.

[8] Percentage is calculated as total PCB source strength divide by the total PCB production rate.

[9] Percentage is calculated as total PCB flux at the monitoring station divide by the total PCB production rate.

[10] Total PCB flux values are extrapolated from the previous HUDTOX runs above.

Table 2-14

Increase in PCB Mass from Settled Material 2-Acres Below the Target Area Estimated Using the TSS-Chem Model Results

Management Level	Condition at Far Field Station	River Section	Total PCBs Length-Weighted Average Concentration (mg/kg) (0-6 inches)
Evaluation	300 g/day PCB Mass Loss	1	2.6
Control	600 g/day PCB Mass Loss	1	4.2
Control	350 ng/L	1	6.6
Evaluation	300 g/day PCB Mass Loss	2	2.0
Control	600 g/day PCB Mass Loss	2	3.3
Control	350 ng/L	2	9.1
Evaluation	300 g/day PCB Mass Loss	3	2.2
Control	600 g/day PCB Mass Loss	3	3.5
Control	350 ng/L	3	8.6

1. Mass/Area used to define the lateral extent of dredging in River Sections 1 and 2 is approximately 6.6 g/sq. m and 34 g/sq. m, respectively. In River Section 3, a mass/area was not used to select the areas in this way.

2. The length weighted average concentration was calculated assuming the concentration below the deposited PCBs is 1 mg/kg Total PCBs.

Table 3-1
Upper 95th Percentile Estimates of Total PCB Concentrations at TI Dam and Schuylerville Under Baseline Conditions

Units: ng/L

TID-West	May	June	July	August	Sept.	Oct. & Nov.
Prediction interval	368	368	212	149	119	297

TID-PRW2	May&June Low Flow (<5000 cfs)	May&June High Flow (>5000 cfs)	July and August	Sept.	Oct.	Nov.
Prediction interval	161	68	106	72	92	65

Schuylerville	May and June	July	August	Sept.	Oct.	Nov.
Prediction interval	195	99	107	85	118	107

Table 3-2
Summary of Sampling Frequency Requirements and Expected Error Rates

Analysis	Transition	Detail	Sampling Time Period	Action Level	Number of Samples[1]	Grey Region Limit	False Rejection Error Limit - a (%)	False Acceptance Error Limit - b (%)	Figure Number
Total PCB Sampling Requirements (25% CV)									
Far Field									
	Routine to Evaluation Level	Routine to > 300 g/day	1 week	300 g/day	7 (1 sample/day for 1 week)	400 g/day	7.5	5	1
	Routine to Control Level	Routine to > 600 g/day	1 week	600 g/day	7 (1 sample/day for 1 week)	700 g/day	25	15	2
	Confirmation of the Control Level	Confirmation of > 600 g/day	1 week routine + 1 week	600 g/day	28 (7 samples routine + 21 samples control level)	700 g/day	5	4	3
	Routine to Control Level	Routine to > 350 ng/L	1 week	350 ng/L	7 (1 sample/day for 1 week)	400 ng/L	27.5	20	4
	Confirmation of the Control Level	Confirmation of > 350 ng/L	1 week routine + 1 week	350 ng/L	28 (7 samples routine + 21 samples control level)	400 ng/L	10	5	5
	Evaluation to Control Level	300 g/day to > 600 g/day	1 week evaluation + 1 week	600 g/day	35 (14 samples evaluation level + 21 samples control level)	700 g/day	4	2	6
	Resuspension Standard Threshold	Confirmation of > 500 ng/L[2]	1 day routine + 1 day	500 ng/L	5 (1 sample routine + 4 samples confirmation)	400 ng/L	15	30	7
		Confirmation of > 500 ng/L (24 hours)[2]	1 day	500 ng/L	4 composites of 6 aliquots each	400 ng/L	5	7	8
	Routine to Control Level	Continuous Total PCB 1-week or 2-week deployment	1 week or 2 weeks	350 ng/L	2 composites of 56 aliquots each	400 ng/L	6.5	5	9
Suspended Solids Sampling Requirements (75% CV)									
Far Field									
	Routine to Evaluation Level	Far-field - Baseline to > 12 mg/L	1 day (3 hrs for 24 hrs)	14 mg/L	8 (discrete)	21 mg/L	27.5	12.5	10
			1 day (15 min for 24 hrs)	14 mg/L	96 (continuous)	21 mg/L	0.1	0.1	11
	Routine to Control Level	Far-field - Baseline to > 24 mg/L	1 day (3 hrs for 24 hrs)	26 mg/L	8 (discrete)	39 mg/L	27.5	12.5	12
			1 day (15 min for 24 hrs)	26 mg/L	96 (continuous)	39 mg/L	0.1	0.1	13
	Evaluation to Control Level	Far-field - 12 mg/L to > 24 mg/L	1 day evaluation + 1 day	26 mg/L	16 (discrete)	39 mg/L	15	5	14
			1 day evaluation + 1 day	26 mg/L	192 (continuous)	39 mg/L	0.5	< 0.5	15
Near Field									
	Routine to Control Level	Near Field - River Sections 1 and 3	6 hours (1 sample per 3 hours)	100 mg/L	3 (discrete)	150 mg/L	35	25	16
		Baseline to > 100 mg/L	6 hours (1 sample per 15 min)	100 mg/L	24 (continuous)	150 mg/L	6.6	5	17
	Routine to Control Level	Near Field - River Section 2	6 hours (1 sample per 3 hours)	60 mg/L	3 (discrete)	90 mg/L	35	25	18
		Baseline to > 60 mg/L	6 hours (1 sample per 15 min)	60 mg/L	24 (continuous)	90 mg/L	6.6	5	19
	Evaluation to Control Level	Near Field - River Sections 1 and 3	1 day (3 hrs for 15 hrs)	100 mg/L	5 (discrete)	150 mg/L	27.5	20	20
		Baseline to > 100 mg/L	1 day (15 min for 15 hrs)	100 mg/L	60 (continuous)	150 mg/L	0.7	0.5	21
	Evaluation to Control Level	Near Field - River Section 2	1 day (3 hrs for 15 hrs)	60 mg/L	5 (discrete)	90 mg/L	27.5	20	22
		Baseline to > 60 mg/L	1 day (15 min for 15 hrs)	60 mg/L	60 (continuous)	90 mg/L	0.7	0.5	23
	Routine to Evaluation Level	Near Field	3 hours (1 sample per 3 hours)	700 mg/L	2 (discrete)	1000 mg/L	40	30	24
		Baseline to > 700 mg/L	3 hours (1 sample per 5 min)	700 mg/L	36 (continuous)	1000 mg/L	16.5	5	25

Note

[1] Sampling frequency at the different action level can be found in Table 1-2 of Volume 1 of the document

[2] Null hypothesis for the 500 ng/L assumed that river conditions were not in compliance, for all other action levels, the null hypohesis assumed that river conditions were in compliance. See text for discussions.

Table 3-3
Summary of Sampling Frequency Requirements and Expected Error Rates for Automatic Sampler

Analysis	Transition	Detail	Sampling Time Period	Action Level	Number of Samples	Grey Region Limit	False Rejection Error Limit - a (%)	False Acceptance Error Limit - b (%)	Figure Number
Total PCB Sampling Requirements (25% CV)									
Far Field									
	Routine to Evaluation Level	Routine to > 300 g/day	1 week	300 g/day	7 composites of 24 aliquots each (1 sample/day for 1 week)	400 g/day	0.1	<0.1	29
	Routine to Control Level	Routine to > 600 g/day	1 week	600 g/day	7 composites of 24 aliquots each (1 sample/day for 1 week)	700 g/day	0.5	0.1	30
	Confirmation of the Control Level	Confirmation of > 600 g/day	1 week routine + 3 day	600 g/day	10 (7 samples routine + 3 samples control level)	700 g/day	0.5	<0.5	31
	Routine to Control Level	Routine to > 350 ng/L	1 week	350 ng/L	7 composites of 24 aliquots each (1 sample/day for 1 week)	400 ng/L	1	1	32
	Confirmation of the Control Level	Confirmation of > 350 ng/L	1 week routine + 3 day	350 ng/L	10 (7 samples routine + 3 samples control level)	400 ng/L	0.5	<0.5	33
	Evaluation to Control Level	300 g/day to > 600 g/day	2 day evaluation + 3 day	600 g/day	5 (composite sampling every 1 hour, 1 sample/day)	700 g/day	2	1	34

Table 4-1
Estimated 7-Day Total PCB Concentrations[1] Corresponding to the Evaluation Level (300 g/day) at the Schuylerville Monitoring Station

			Total PCB (ng/L)- Schuylerville Station[2]					
Flow (cfs)	Flow (m^3/s)	Total PCB increase (ng/L)	May & June	July	August	Sept.	Oct.	Nov.
95% UCL Baseline Total PCB Concentration			**121**	**103**	**81**	**60**	**84**	**75**
2,000	57	105	226	208	186	165	189	180
2,500	71	84	205	187	165	144	168	159
3,000	85	70	191	173	151	130	154	145
3,500	99	60	181	163	141	120	144	135
4,000	113	53	174	155	133	113	136	128
4,500	127	47	168	149	127	107	131	122
5,000	142	42	163[3]	145	123	102	126	117
5,500	156	38	160	141	119	98	122	113
6,000	170	35	156	138	116	95	119	110
6,500	184	32	154	135	113	92	116	108
7,000	198	30	151	133	111	90	114	105
7,500	212	28	149	131	109	88	112	103
8,000	227	26	148	129	107	86	110	101
8,500	241	25	146	127	105	85	109	100
9,000	255	23	145[4]	126	104	83	107	99
9,500	269	22	143	125	103	82	106	97
10,000	283	21	142	124	102	81	105	96

Notes:

1. Total PCB concentrations are estimated based on the assumption of a 7-day per week operation, 14 hours per day for May to November (210 days). This is conservative since operating less than 7-days per week would increase the daily allowable Total PCB load. These values will be adjusted to reflect the planned period of operation once it is defined as part of the remedial design.
2. Shaded areas are the concentration at the mean flow for the month, based on flow estimates derived from the USGS flow data (1977-present).
3. Condition for June.
4. Condition for May.
5. The values provided in this table are based on historical data. These values will be revised prior to Phase 1 when baseline monitoring data are available and more is known about the operating schedule and production rate.

Table 4-2

Estimated 7-Day Total PCB Concentrations[1] Corresponding to the Control Level (600 g/day) at the Schuylerville Monitoring Station

			Total PCB (ng/L) - Schuylerville Station[2]					
Flow (cfs)	Flow (m^3/s)	TPCB increase (ng/L)	May & June	July	August	Sept.	Oct.	Nov.
95% UCL Baseline Total PCB Concentration			**121**	**103**	**81**	**60**	**84**	**75**
2,000	57	210	331	313	291	270	294	285
2,500	71	168	289	271	249	228	252	243
3,000	85	140	261	243	221	200	224	215
3,500	99	120	241	223	201	180	204	195
4,000	113	105	226	208	186	165	189	180
4,500	127	93	215	196	174	154	177	169
5,000	142	84	205[3]	187	165	144	168	159
5,500	156	76	198	179	157	137	160	152
6,000	170	70	191	173	151	130	154	145
6,500	184	65	186	167	145	125	149	140
7,000	198	60	181	163	141	120	144	135
7,500	212	56	177	159	137	116	140	131
8,000	227	53	174	155	133	113	136	128
8,500	241	49	171	152	130	110	133	125
9,000	255	47	168[4]	149	127	107	131	122
9,500	269	44	166	147	125	104	128	119
10,000	283	42	163	145	123	102	126	117

Notes:

1. Total PCB concentrations are estimated based on the assumption of a 7-day per week operation, 14 hours per day for May to November (210 days). This is conservative since operating less than 7-days per week would increase the daily allowable PCB load. These values will be adjusted to reflect the planned period of operation once it is defined as part of the remedial design.
2. Shaded areas are the concentration at the mean flow for the month, based on flow estimates derived from the USGS flow data (1977-present).
3. Condition for June.
4. Condition for May.
5. The values provided in this table are based on historical data. These values will be revised prior to Phase 1 when baseline monitoring data are available and more is known about the operating schedule and production rate.

Table 4-3
Estimates of Baseline Concentrations at TI Dam, Schuylerville and Waterford[1]

Preliminary estimate of 95% UCL ($\overline{C_{bl}}$) for use in the equations presented in Section 4.1[1].

Station	Total PCB Concentrations (ng/L)						
	May	June	July	August	September	October	November
TID West[2]	181	205	151	106	83	241	241
TID PRW2[2]	111 [3] 47 [4]	111 [3] 47 [4]	71	71	50	64	45
Schuylerville	121	121	103	81	60	84	75
Waterford[5]	90	90	76	60	44	62	56

Notes:

[1] These values will be revised using the data collected during the baseline monitoring program. Similar values will be determined for Stillwater and Waterford from the baseline monitoring as well.

[2] The actual TID values are expected to fall between those obtain for TID West and TID PRW2.

[3] For flow < 5000 cfs.

[4] For flow > 5000 cfs.

[5] These values were estimated by multiplying the Schuylerville Total PCB concentrations by a dilution factor of 0.74 to account for additional tributary flow to Waterford.

Table 4-4

Far-Field Monitoring - Analytical Details

Parameter	Analytical Method / Instrument	Detection Limit Goal	Method Range	Accuracy	Precision	Sample Size	Holding Time	Sample Container	Preservation
Congener-specific PCBs (Total)	Green Bay or equivalent	0.05 ng/L/congener	Lab-specific and congener-specific	60-150%	40% RPD[1]	1 Liters	5/40[2] days	1 Liter amber glass	Maintain at 4^{o} C (± 2^{o} C)
Congener-specific PCBs (Water)	Green Bay or equivalent	0.05 ng/L/congener	Lab-specific and congener-specific	60-150%	40% RPD	20 Liters	5/40[2] days	4 Liter amber glass	Maintain at 4^{o} C (± 2^{o} C)
Congener-specific PCBs (Particle)	Green Bay or equivalent	1 µg/kg	Lab-specific and congener-specific	60-150%	40% RPD	200-800 mg	5/40[2] days	Amber glass	Maintain at 4^{o} C (± 2^{o} C)
DOC (TOC on filtered water)	Persulfate Digestion (415.2)	0.025 mg/L	50 µg/L to 10 mg/L	90-110%	20% RPD	2 x 40 mL (25 mL minimum)	28 days	VOA vial	Maintain at 4^{o}C H_2SO_4 pH =2
TSS	ASTM D 3977-97	0.5 mg/L (on 1 L sample)	0.5 to 2000 mg/L on 1 L sample	90 - 110%	20% RPD	1 Liter	7 days	4 Liter plastic	Maintain at 4^{o} C (± 2^{o} C)
TSS (using particle counter)	LISST Series	TBD	1.2 to 250 :m	TBD	TBD	25-50 mL	Field	Per instrument requirement	NA
TSS (fast turnaround)	Modified	1.0 mg/L (on 1 L sample)	0.5 to 2000 mg/L on 1 L sample	80 – 120 %	35% RPD	1 Liter	N/A	1 Liter plastic	None
Turbidity	YSI 6-Series	2 NTU	0 to 1000 NTU	± 5% or 3 NTU[3]	5%	25-50 mL	Field	Per instrument requirement	NA
Temperature	YSI 6-Series	0.15^{o} C	-5 to +45 ^{o}C	± 0.15^{o} C	± 0.15^{o} C	25-50 mL	Field	Per instrument requirement	NA
pH	YSI 6-Series	0.2 pH unit	0 to 14 pH units	± 0.2 pH unit	± 0.2 pH unit	25-50 mL	Field	Per instrument requirement	NA
Dissolved Oxygen	YSI 6-Series	0.2 mg/L	0 to 50 mg/L	0-20 mg/L: ± 2% or 0.2 mg/L[3]	15%	25-50 mL	Field	Per instrument requirement	NA
Conductivity	YSI 6-Series	0.001 mS/cm	0 to 100 mS/cm	± 0.5% or 0.001 mS/cm[3]	10%	25-50 mL	Field	Per instrument requirement	NA
TOC on SS – routine EPA 160.4	Volatile solids on SS as surrogate for TOC.	0.5% dry wt based on SS	± 0.3 mg assuming 0.1 mg sensitivity	± 10% or ± 0. 2 mg	± 0.4mg or 10%	100 mg solids based on 0.1 mg sensitivity	Lab	Glass only	NA
TOC for SS – periodic confirm	L Kahn – EPA Region II	0.5 % dry wt basis on SS	100 mg/kg	80 – 120%	RSD < 10 percent on quadruplicate	20 g filtered matter at 0.5%	Lab	Glass only	NA

Notes:

1 RPD = Relative Percent Difference; RPD criteria applicable only where sample concentrations = 5 x the sample reporting limit.

2 Holding times for extraction/analysis from time/date of sample collection.

3 Whichever is greater

NA	Not applicable
TBD	To Be determined
TOC	Total Organic Carbon
ICP	Inductively Coupled Plasma – atomic emission spectrometry
CV	Cold Vapor atomic absorption
SS	Suspended solids (i.e., particulate matter on filter)
mS	milli-siemen

Table 4-5
Near-Field Monitoring - Analytical Details

Parameter		Method Analytical/Direct Reading	Detection Limit	Range	Accuracy	Precision	Sample Size	Holding Time	Sample Container	Preser-vative
Turbidity	Continuous	YSI 6-Series	2 NTU	0-1000 NTU	+/- 5% or 3 NTU	5%	NA	Field	NA	NA
TSS using particle counter	Discrete	LISST Series	TBD	1.2-250 um	TBD	TBD	25-50 mL	Field	NA	NA
TSS Laboratory	Discrete	ASTM D3977-97	0.01 mg/L	20%	LCS 90-110%	NA	TBD	7 days	plastic bottle	4 liter
TSS (fast turnaround)	Modified	1.0 mg/L (on 1 L sample)	0.5 to 2000 mg/L on 1 L sample	80 – 120 %	35% RPD	1 Liter	N/A	1 Liter plastic	None	1 liter
Dissolved Oxygen	Discrete	YSI 6-Series	TBD	0 to 500% air saturation	0-200 % : ±2% air sat. or ±2% of reading, whichever is greater; 200-500%	0.1% air saturation or 1% selectable	NA	Field	NA	NA
Conductivity	Discrete	YSI 6-Series	0.001 mS/cm	0 to 100 mS/cm	± 0.5% or 0.001 mS/cm3	0.1	25-50 mL	Field	NA	NA
Temperature	Discrete	YSI 6-Series	0.15o C	-5 to +45 oC	± 0.15o C	± 0.15o C	25-50 mL	Field	NA	NA

Notes:

1. Analytical Method ASTM D3977-97 Standard test method for determining sediment concentration in water samples.
2. TBD - to be determined

Table 4-6

Possible Study Areas for Nature of Release of PCB

Recommended Study Area	Sediment Type (Side Scan Sonar)	Sediment Type (ASTM Method D422 Classification)	Mean Tri+ PCB Concentrations[1] (mg/kg)
1	IV	CL, SI, FS, MS	10
2	IV	FS, MS	30
3	II	MS	11
4	IV	FS	15
5	IV	CL, SI, FS, MS	39
6	I	SI, FS	15
7	II	FS, MS	14
8	I	SI, FS, MS	8
9	II	FS	13
10	I	CL, SI, FS	14
11	I	FS	12
12	I	CL, SI, FS	15
13	I	CL, SI, FS	28

Note:

[1] Mean Tri+ concentrations are based on the length weighted averages of the entire core at location. Concentration represents the mean of draft dredge areas. Note that the draft dredge area boundaries have not yet been approved by the USEPA.

Table 4-7
Recommended Study Areas for Nature of Release of PCB

Recommended Study Area	Sediment Type (Side Scan Sonar)	Sediment Type (ASTM Method D422 Classification)	Tri+ PCB Entire Core LWA Concentrations (mg/kg)
1	IV	CL, SI, FS, MS	10
2	IV	FS, MS	30
3	II	MS	11
6	I	SI, FS	15
10	I	CL, SI, FS	14

Note:

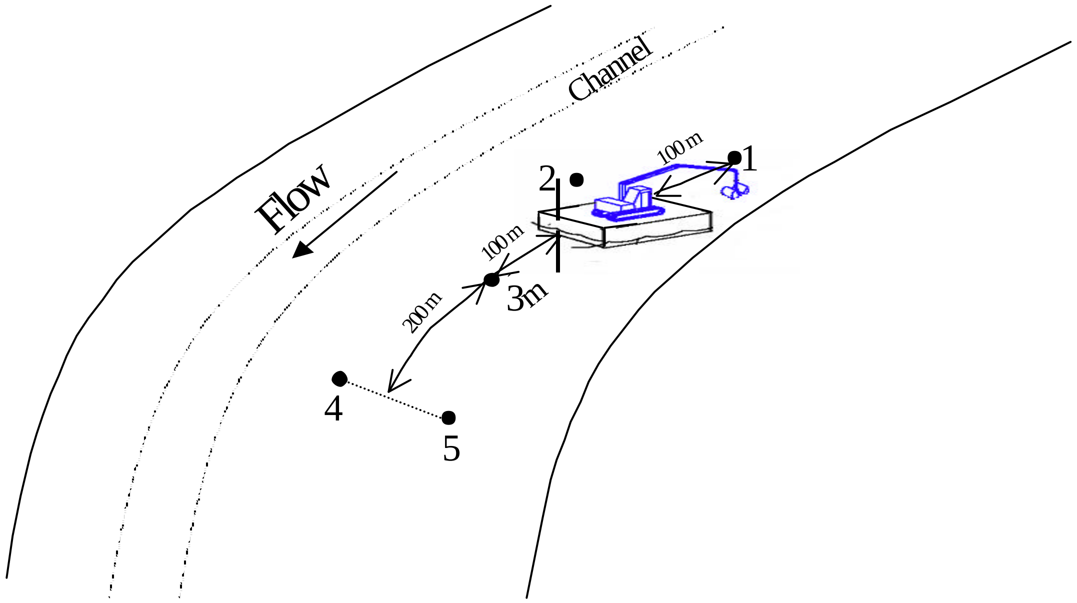
[1] Mean Tri+ concentrations are based on the length weighted averages of the entire core at location. Concentration represents the mean of draft dredge areas. Note that the draft dredge area boundaries have not yet been approved by the USEPA.

Table 4-8
Resuspension Criteria (alternate)[1]

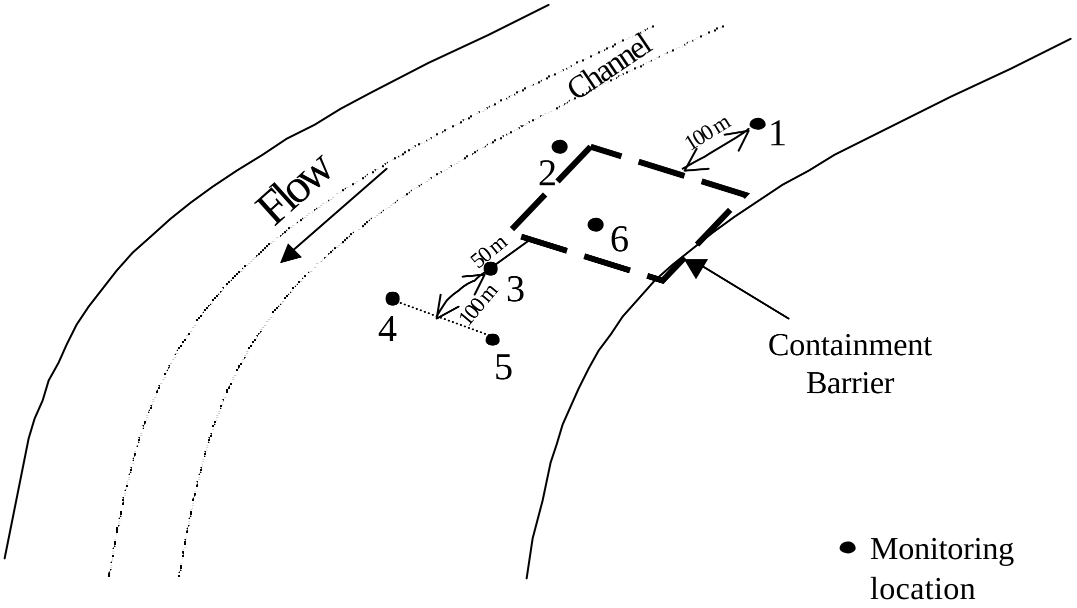
Parameter		**Resuspension Standard Threshold**		**Control Level**		**Evaluation Level**	
		Limit	Duration	Limit	Duration	Limit	Duration
Far-Field PCB Concentration	Total PCBs	500 ng/L	Confirmed Occurrence	350 ng/L	4-day running average (composite sampling every 1 hour, 1 sample/day)		
Far-Field Net PCB Load[3]	Total PCBs			65 kg/year[4]	Dredging Season		
	Total PCBs			600 g/day	3-day running average (composite sampling every 1 hour, 1 sample/day)	300 g/day	2-day running average (composite sampling every 1 hour, 1 sample/day)
	Tri+ PCBs			200 g/day		100 g/day	
Far-Field Net Suspended Solids Concentration[5,6]	All Sections			24 mg/L	Daily dredging period (> 6 hrs.) OR 24 hrs. on average	12 mg/L	6-hour running average net increase OR average net increase in the daily dredging period if the dredging period is less than 6 hrs.
Near-Field (300 m) Net Suspended Solids Concentration[7]	Sections 1 & 3			100 mg/L	Daily dredging period (> 6 hrs.) OR 24 hrs. on average	100 mg/L	6-hour running average net increase OR average net increase in the daily dredging period if the dredging period is less than 6 hrs.
	Sections 2			60 mg/L		60 mg/L	
Near-Field (100 m and Channel-Side) Net Suspended Solids Concentration[7]	All Sections					700 mg/L	3 continuous hrs. running average.

Notes:
1. Implemention of the criteria is described in Section 3.
2. Engineering contingencies for the Control Level will include temporary cessation of the operation.
3. Net increases in PCB load or suspended solids concentration refers to dredging related releases over baseline as defined in the text.
4. During Phase 1, half of the anticipated average production rate will be achieved. As a result, the total allowable export for Phase 1 is half of the fullscale value of 130 kg/year for a total of 650 kg for the entire program. This is equivalent to the 600 g/day Total PCB release at the target productivity schedule, during the dredging season from
5. The increased far-field monitoring required for exceedance of suspended solids criteria must include a sample timed so as to capture the suspended solids plume's arrival at the far-field station.
6. The monitoring requirements for exceedance of the suspended solids action levels are increased frequency sampling at the nearest far field station. The increased frequency at this station will be the same as the frequency required for the PCB action levels.
7. All remedial operations will be monitored in the near-field during Phase 1, including backfilling.

Figures

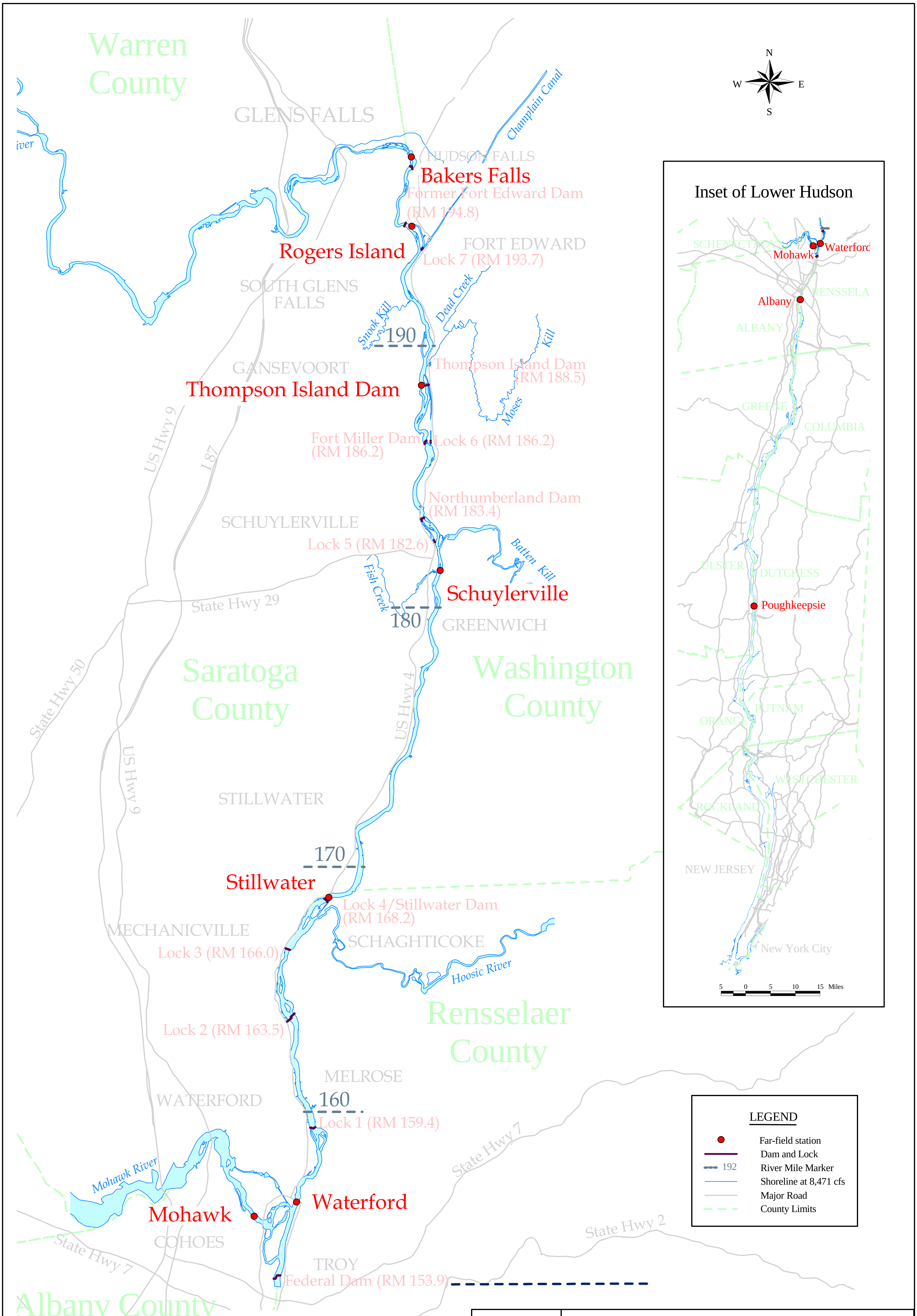


With No Containment Barrier



With Containment Barrier

Figure 1-1
Schematic of Near-field Monitoring Station Locations



TAMS Consultants, Inc.

Hudson River

Figure 1-2

Far-field Water Column Monitoring Stations

Figure 2-1
Comparison Between Upper Hudson River Remediation Scenario Forecasts for Thompson Island Dam

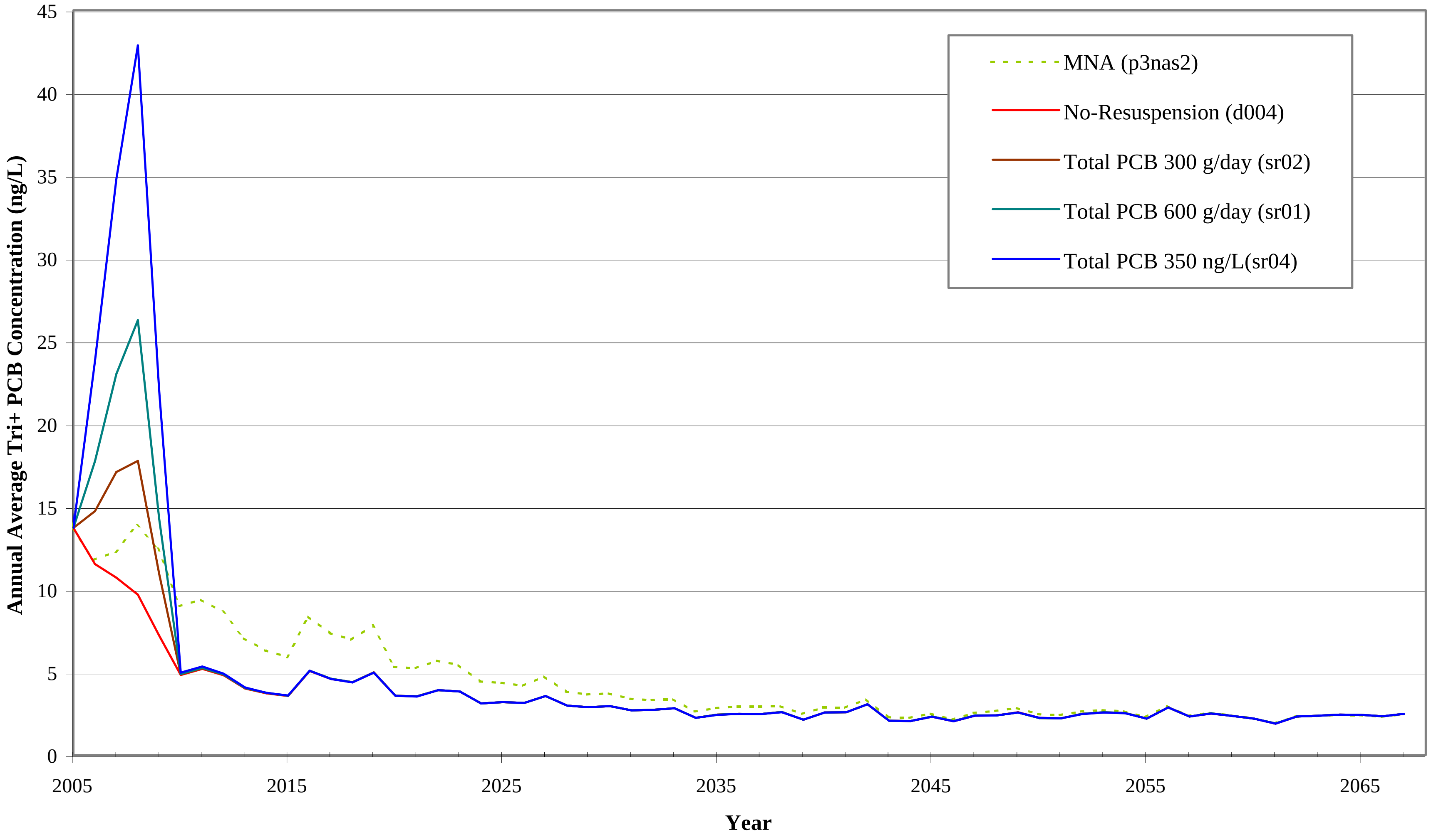


Figure 2-2

Comparison Between Upper Hudson River Remediation Scenario Forecasts for Schuylerville

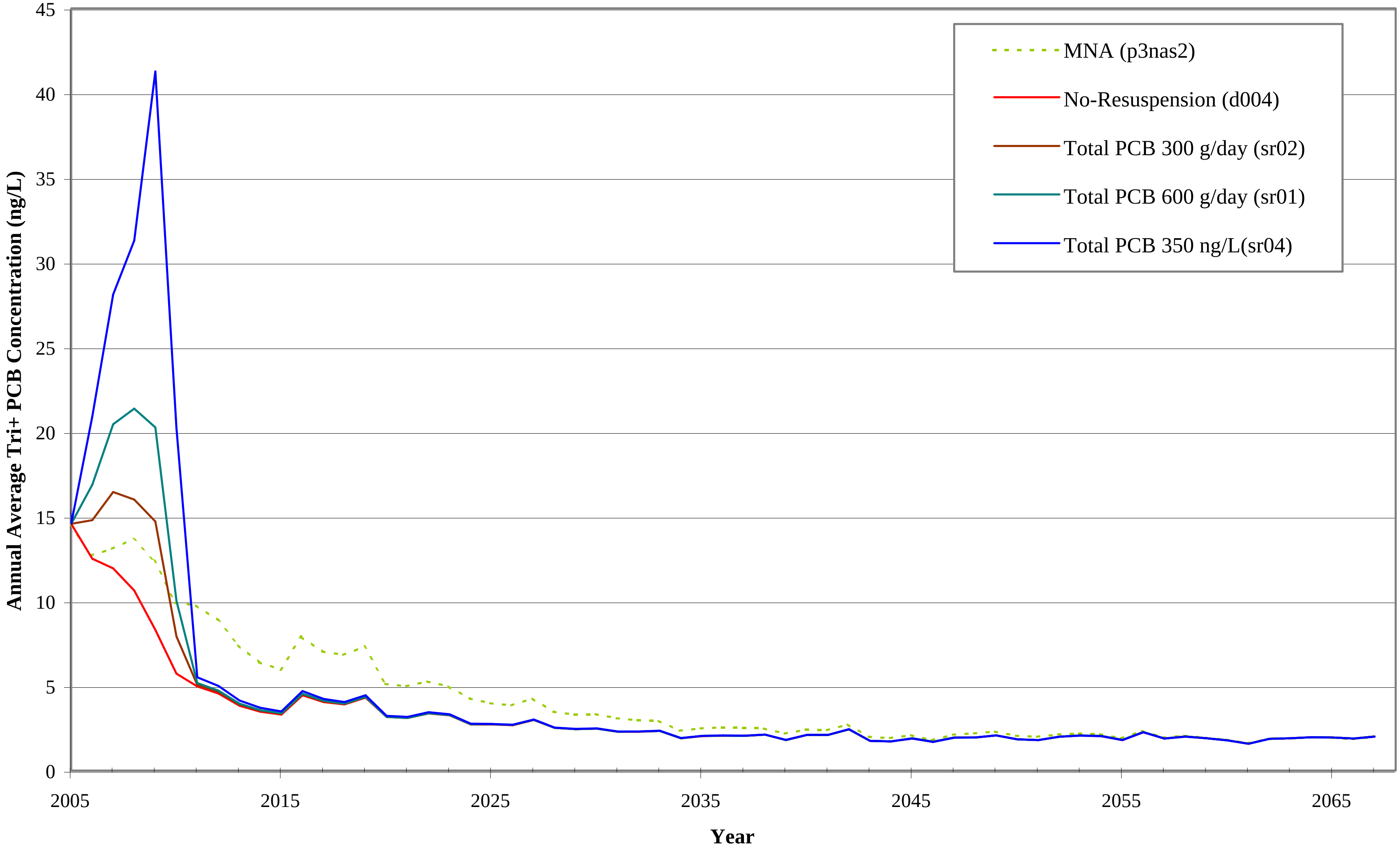


Figure 2-3
Comparison Between Upper Hudson River Remediation Scenario Forecasts for Waterford

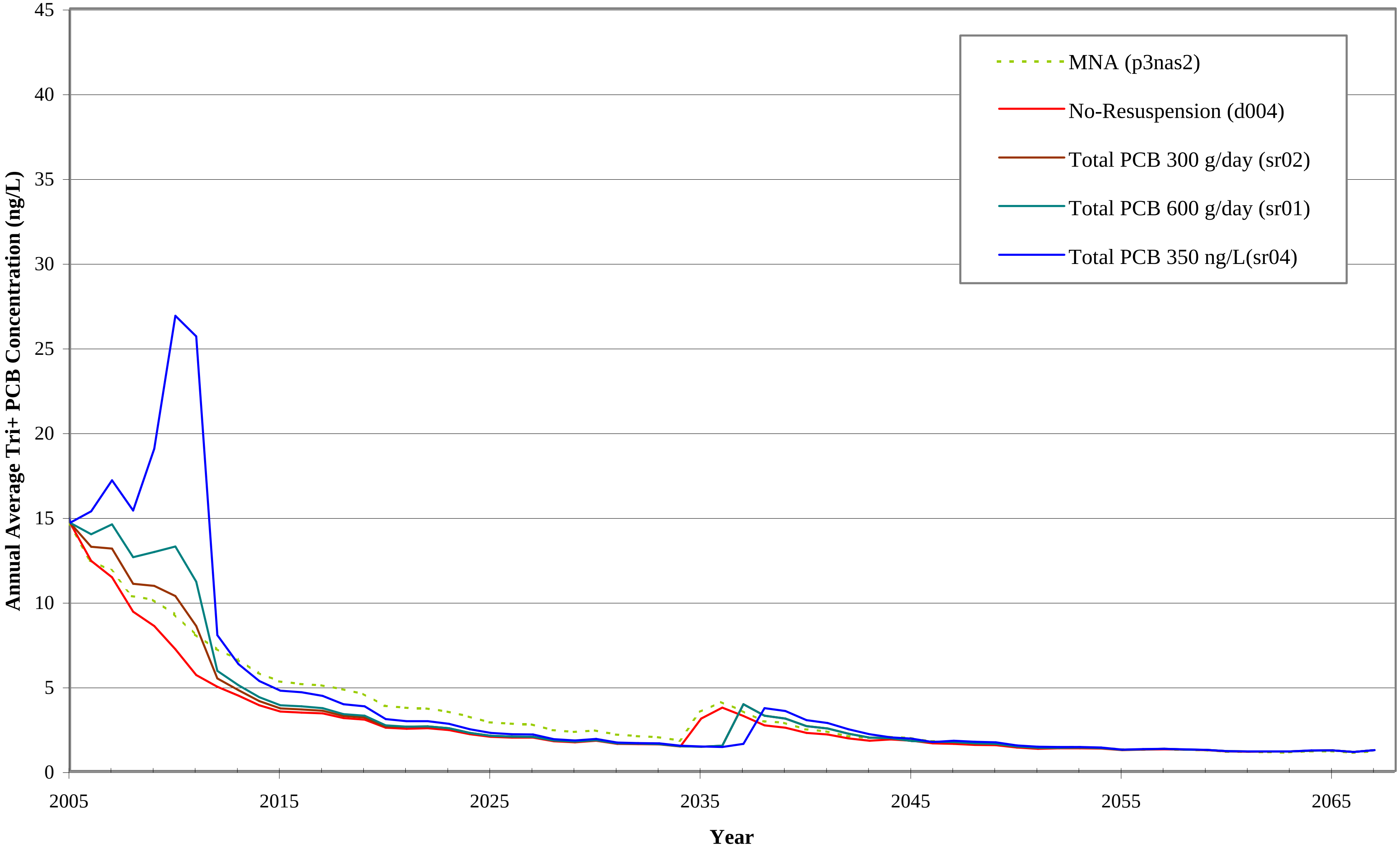
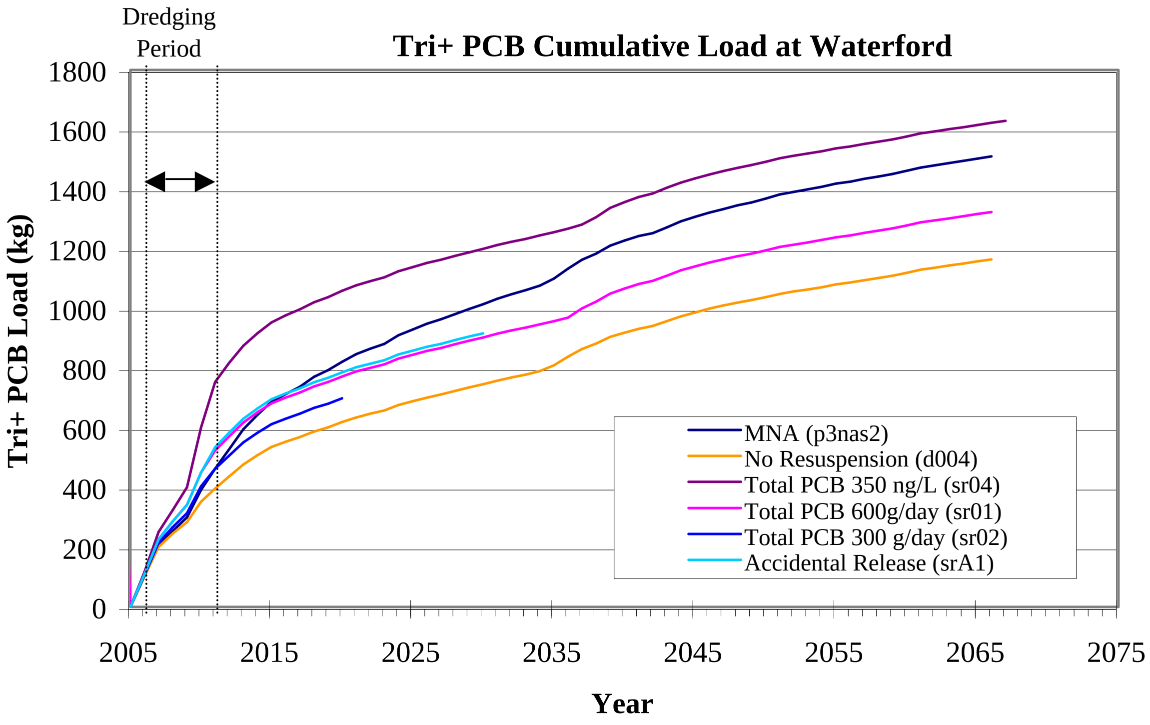


Figure 2-4
Cumulative PCB Loads at Waterford



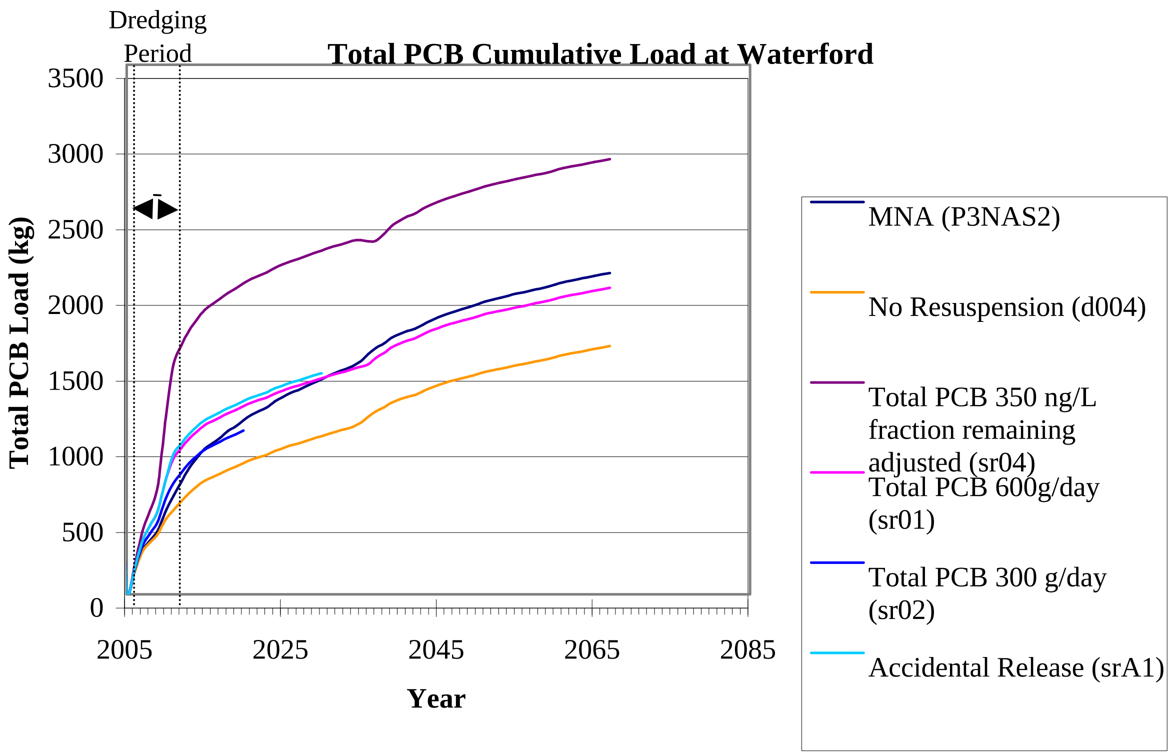
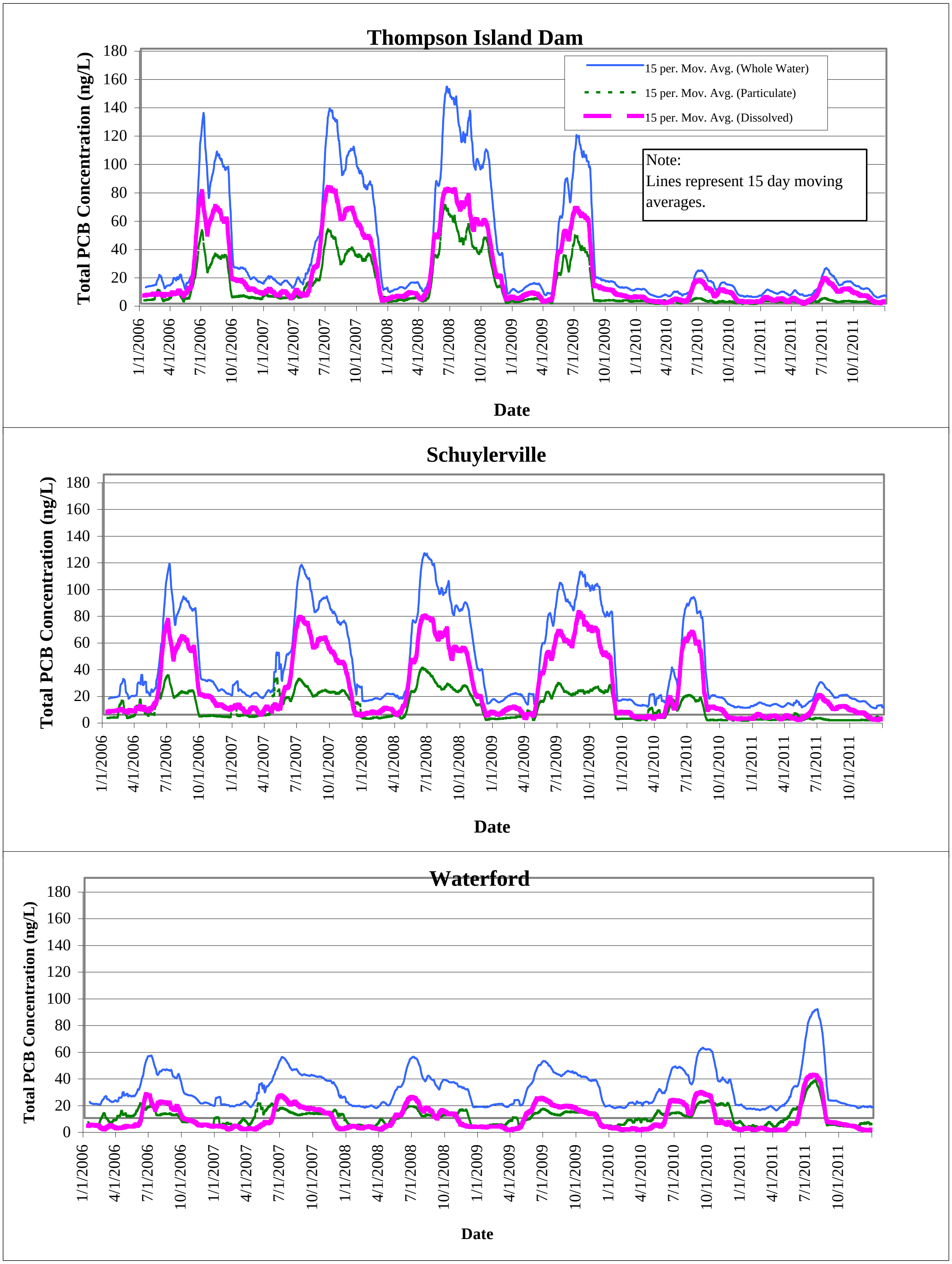


Figure 2-5

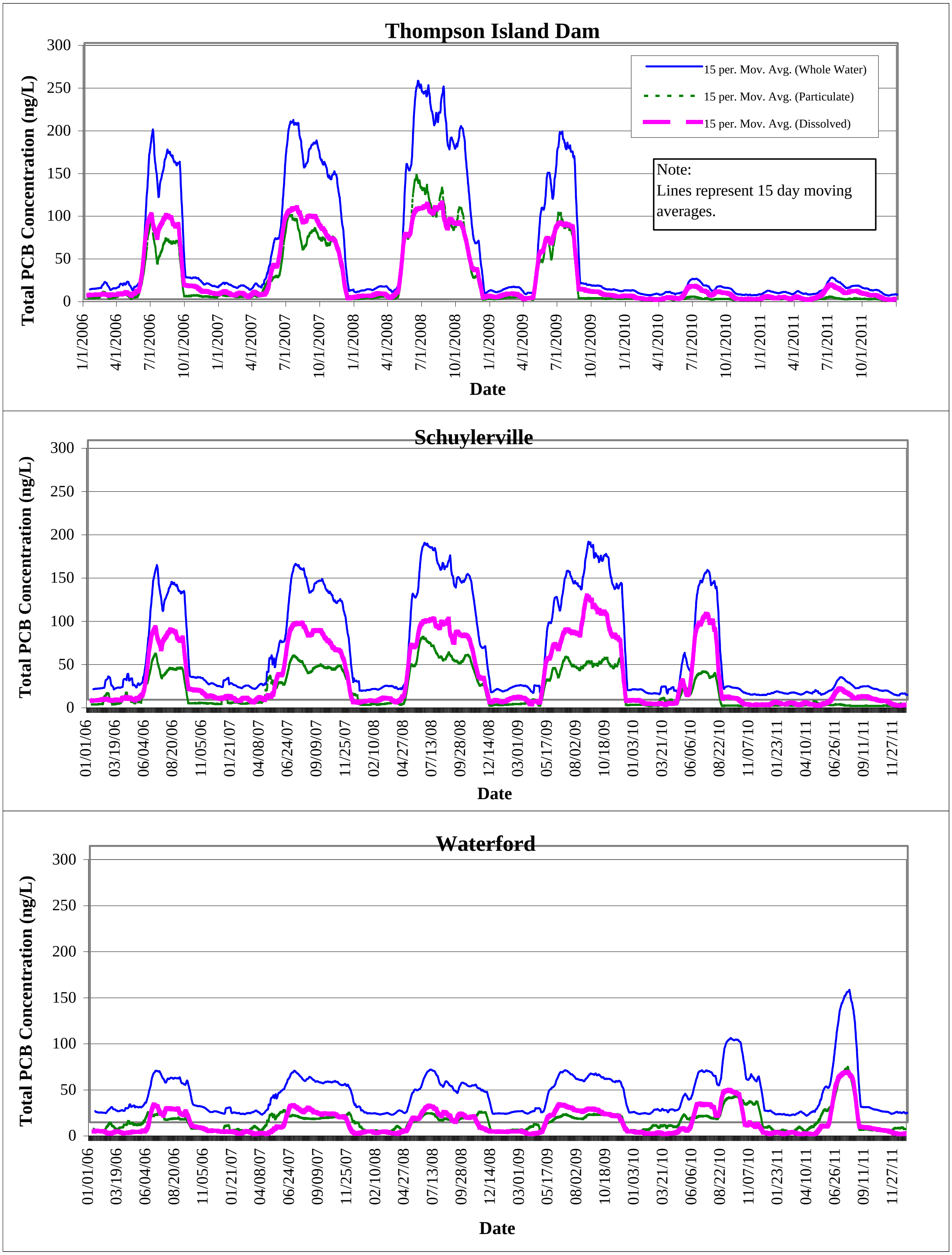
HUDTOX Forecasts of Whole Water, Particulate, and Dissolved Total PCB Concentrations for Evaluation Level - 300 g/day Scenario



Note:
Lines represent 15 day moving averages.

Figure 2-6

HDUTOX Forecasts for Whole Water, Particulate and Dissolved Total PCB Concentration for Control Level - 600 g/day Scenario (sr01)



Note:
Lines represent 15 day moving averages.

Figure 2-7

HUDTOX forecasts for Whole Water, Particulate, and Dissolved Total PCB Concentrations for ControlLevel 350 ng/L Scenario (sr04)

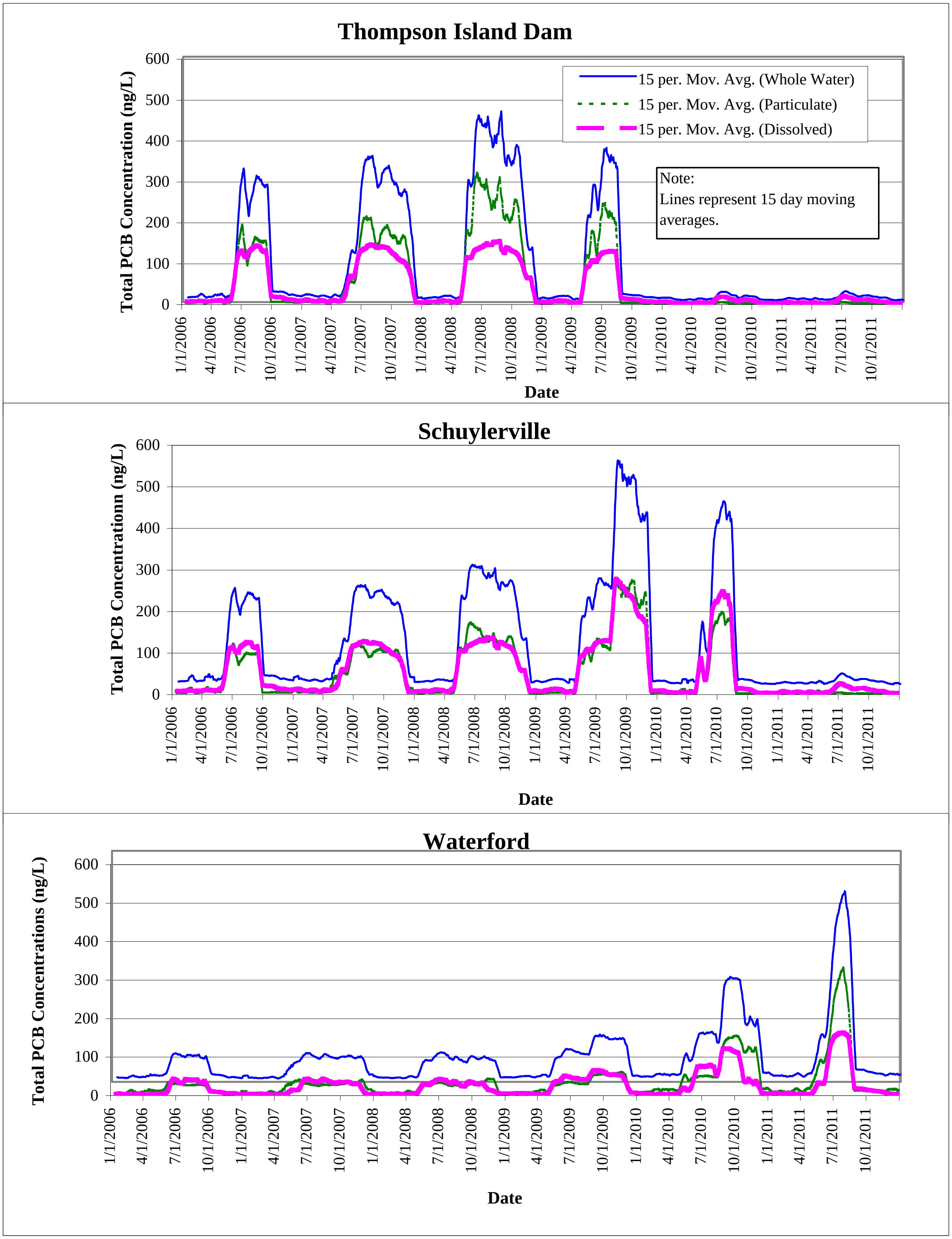
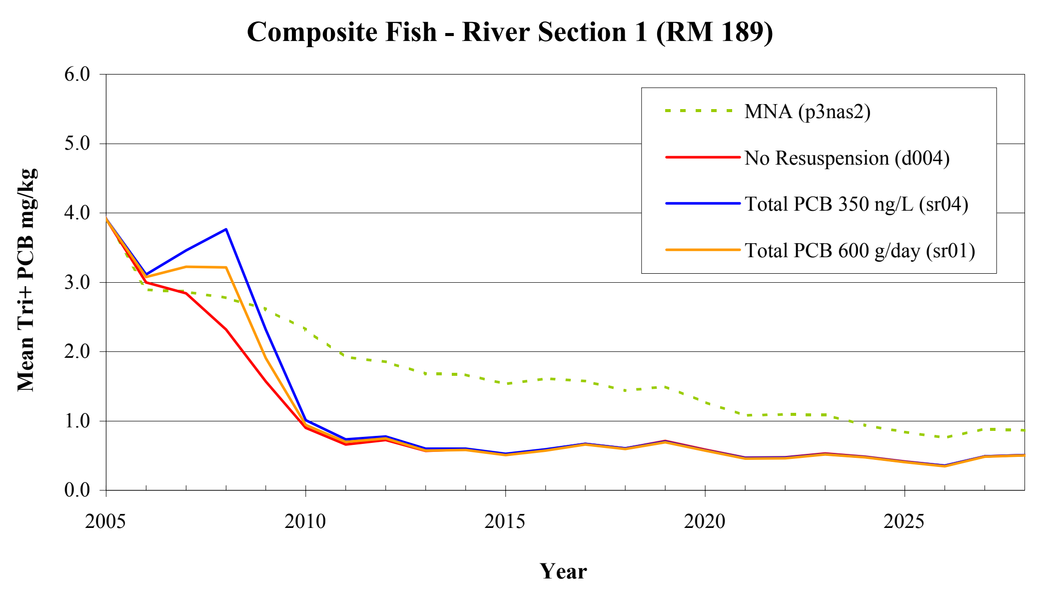
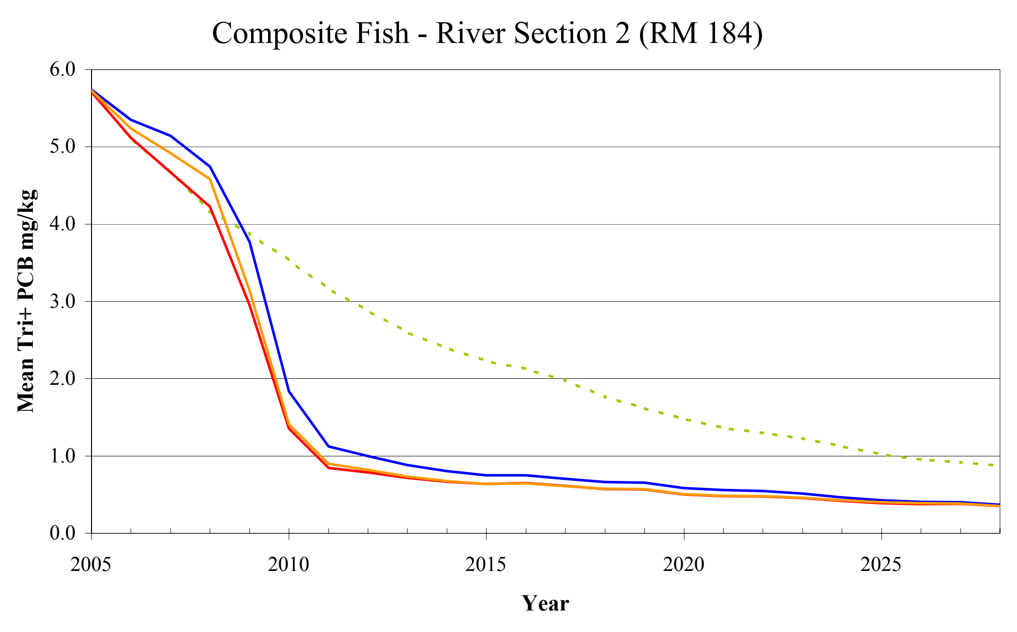


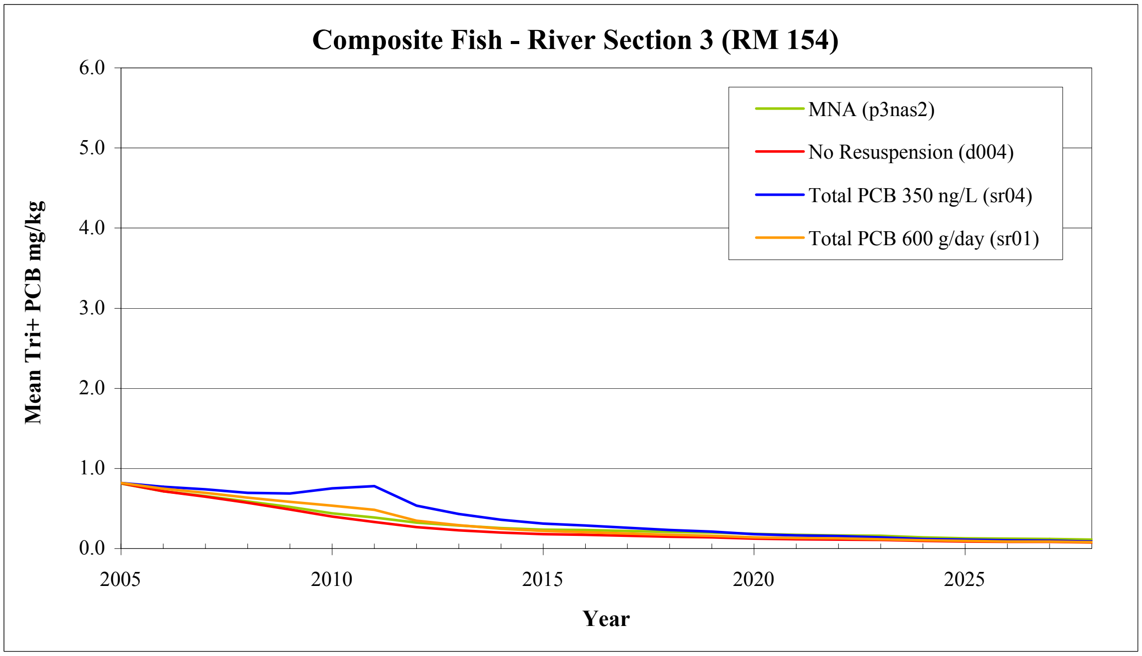
Figure 2-8

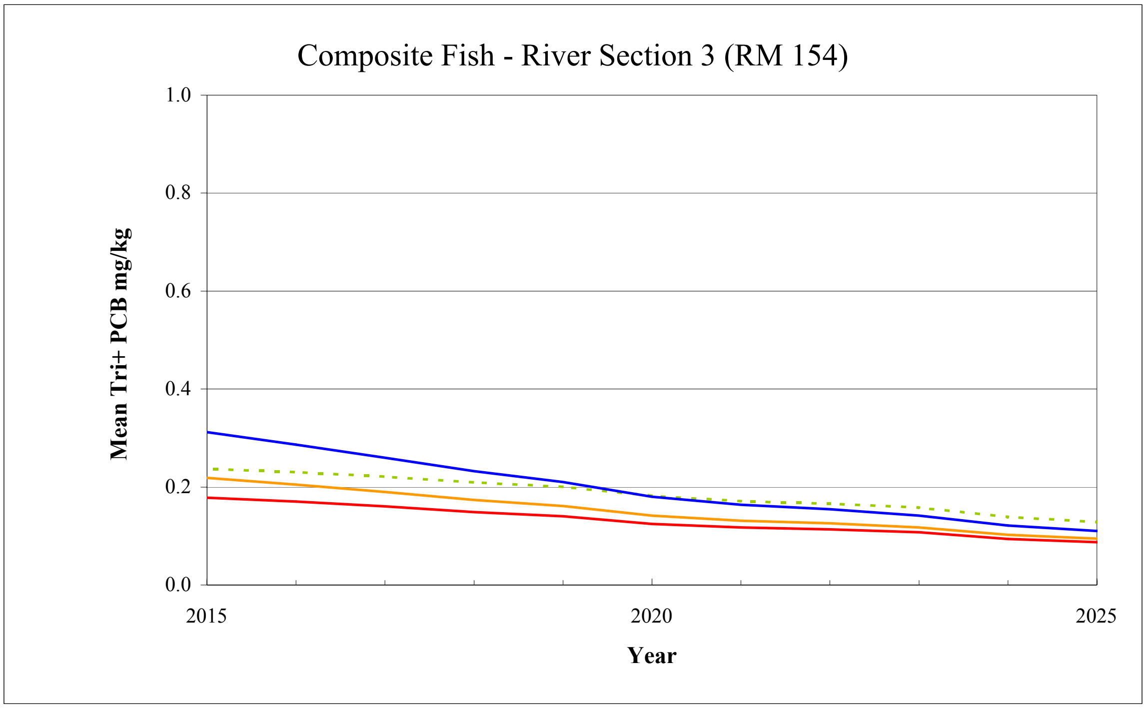




Note:
Fish composite is 47% largemouthbass + 44% brown bullhead + 9% yellow perch

Figure 2-8 (Cont.)
Composite Fish Tissue Concentrations for the Upper River

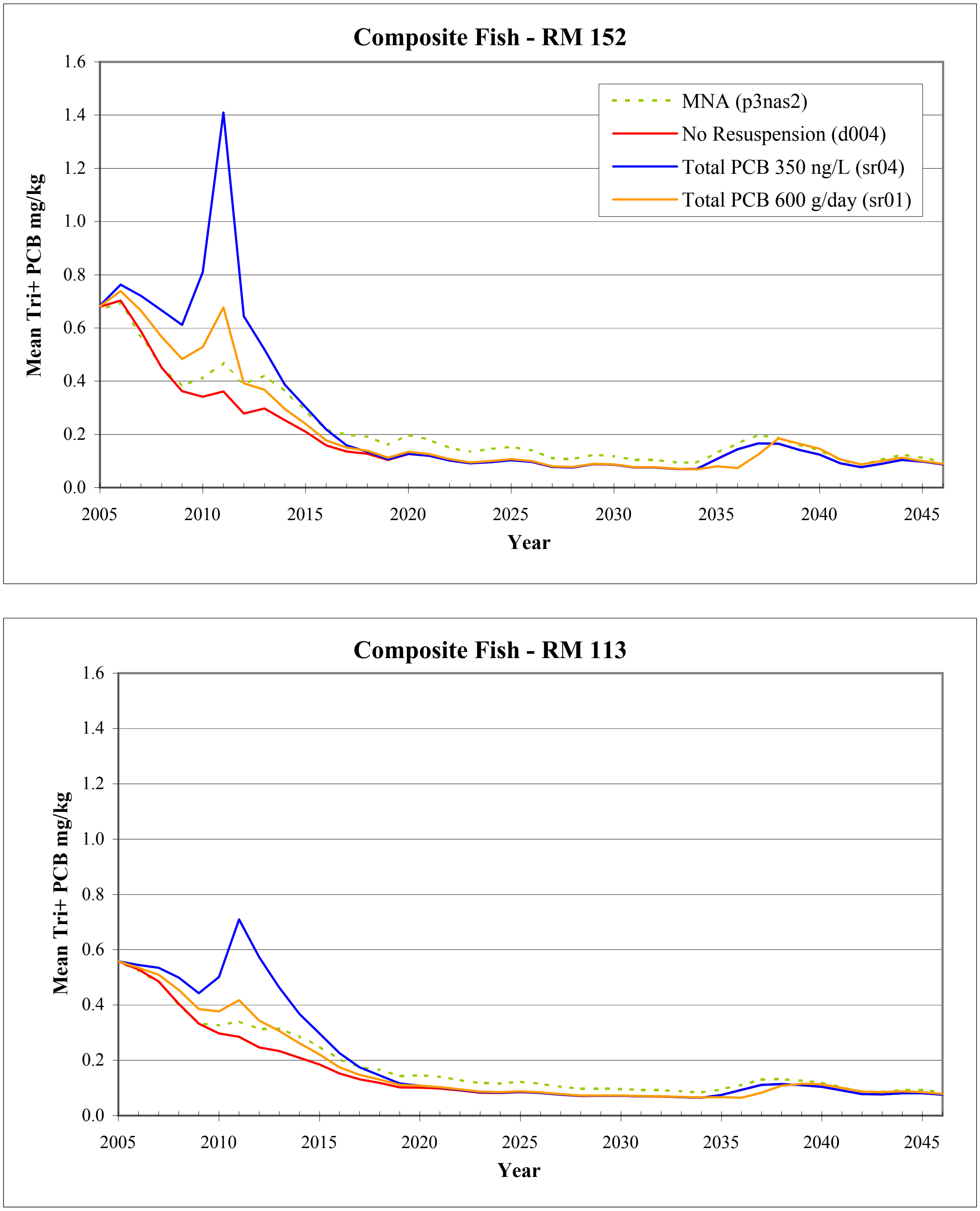




Notes:
Fish composite is 47% largemouthbass + 44% brown bullhead + 9% yellow perch
The bottom figure is portion of the top figure.

Figure 2-9

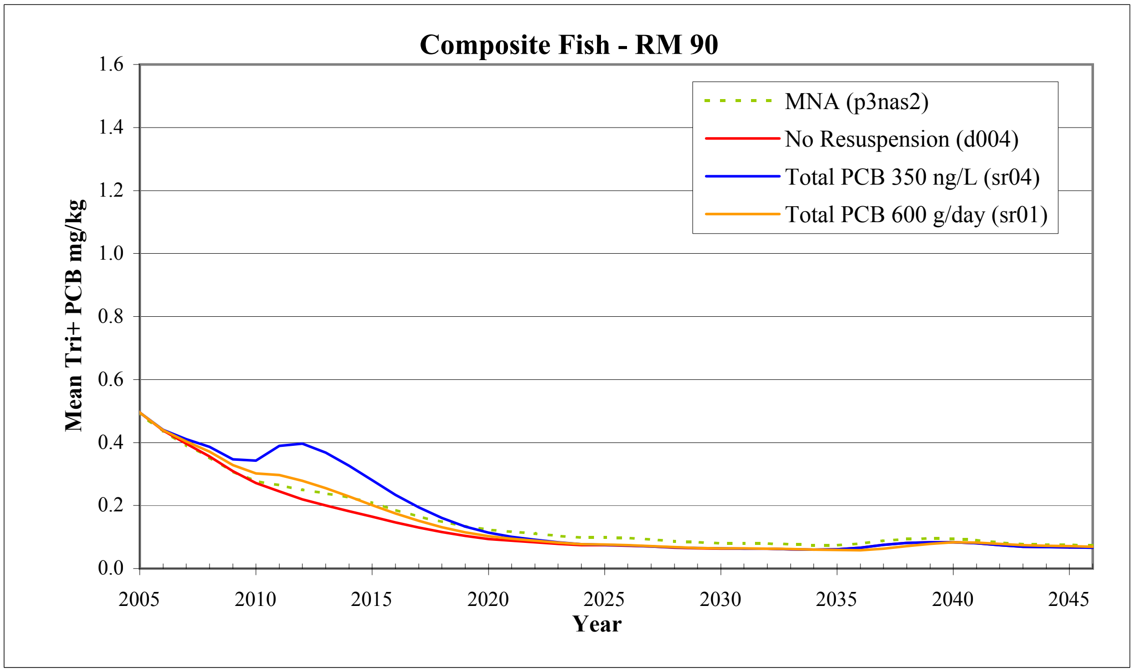
Composite Fish Tissue Concentrations for the Lower River

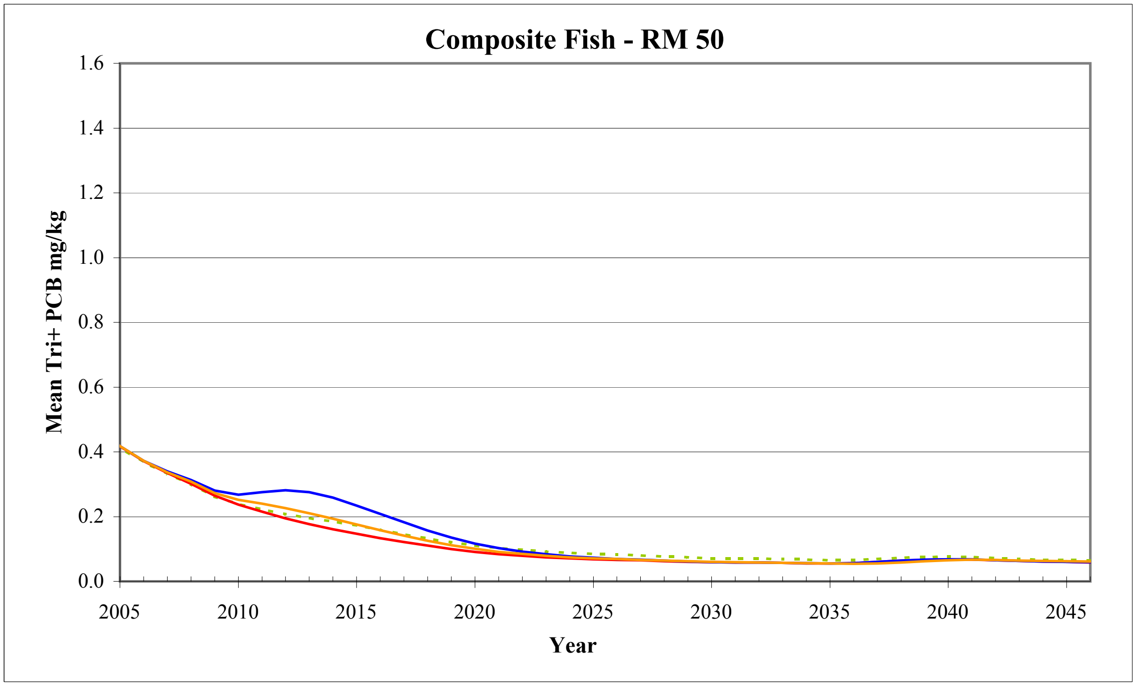


Note:
Fish composite is 47% largemouthbass + 44% brown bullhead + 9% yellow perch

Figure 2-9 (Cont.)

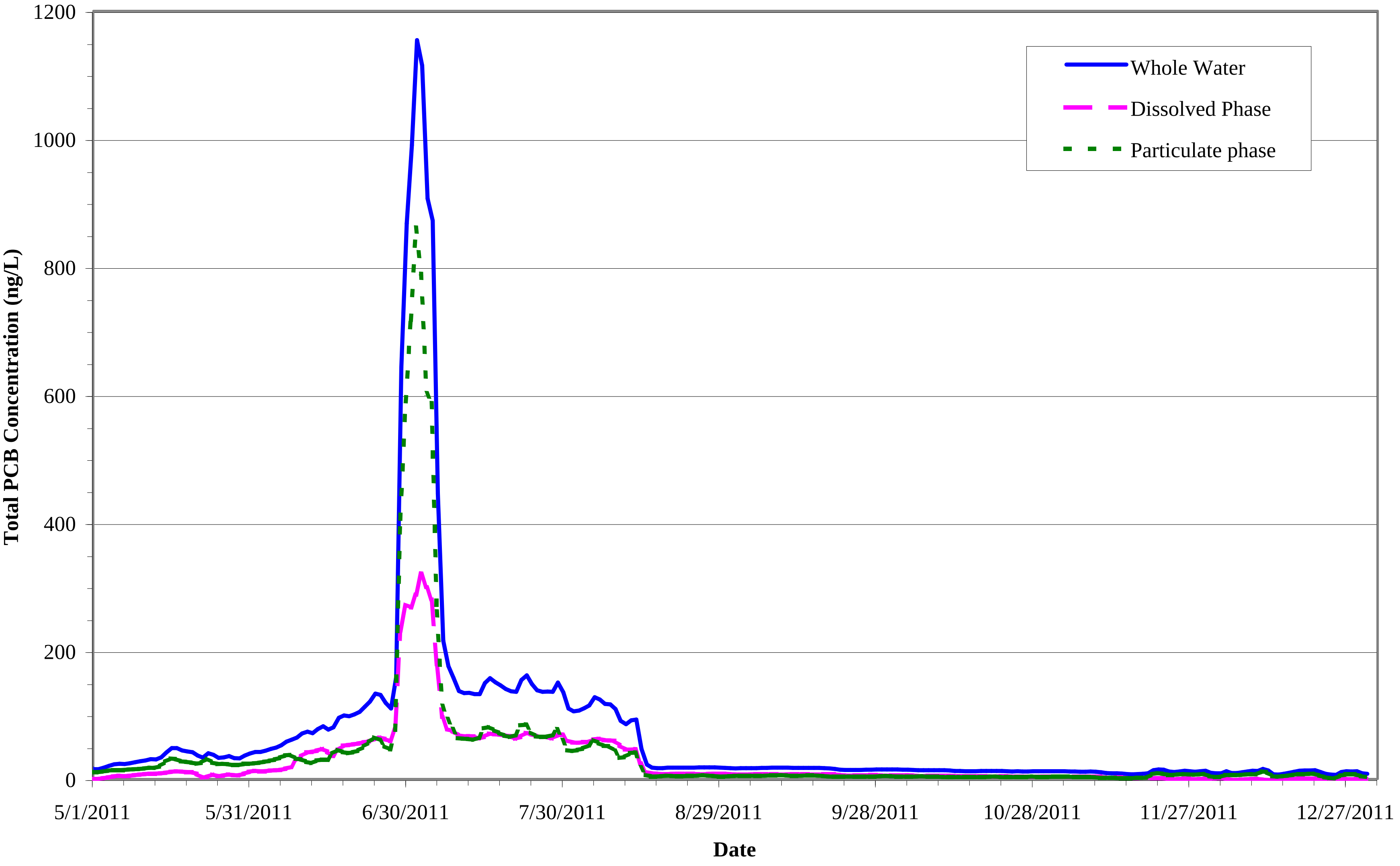
Composite Fish Tissue Concentrations for the Lower River





Note:
Fish composite is 47% largemouthbass + 44% brown bullhead + 9% yellow perch

Figure 2-10
Estimated Total PCB Concentrations at Waterford for the Accidental Release Scenario



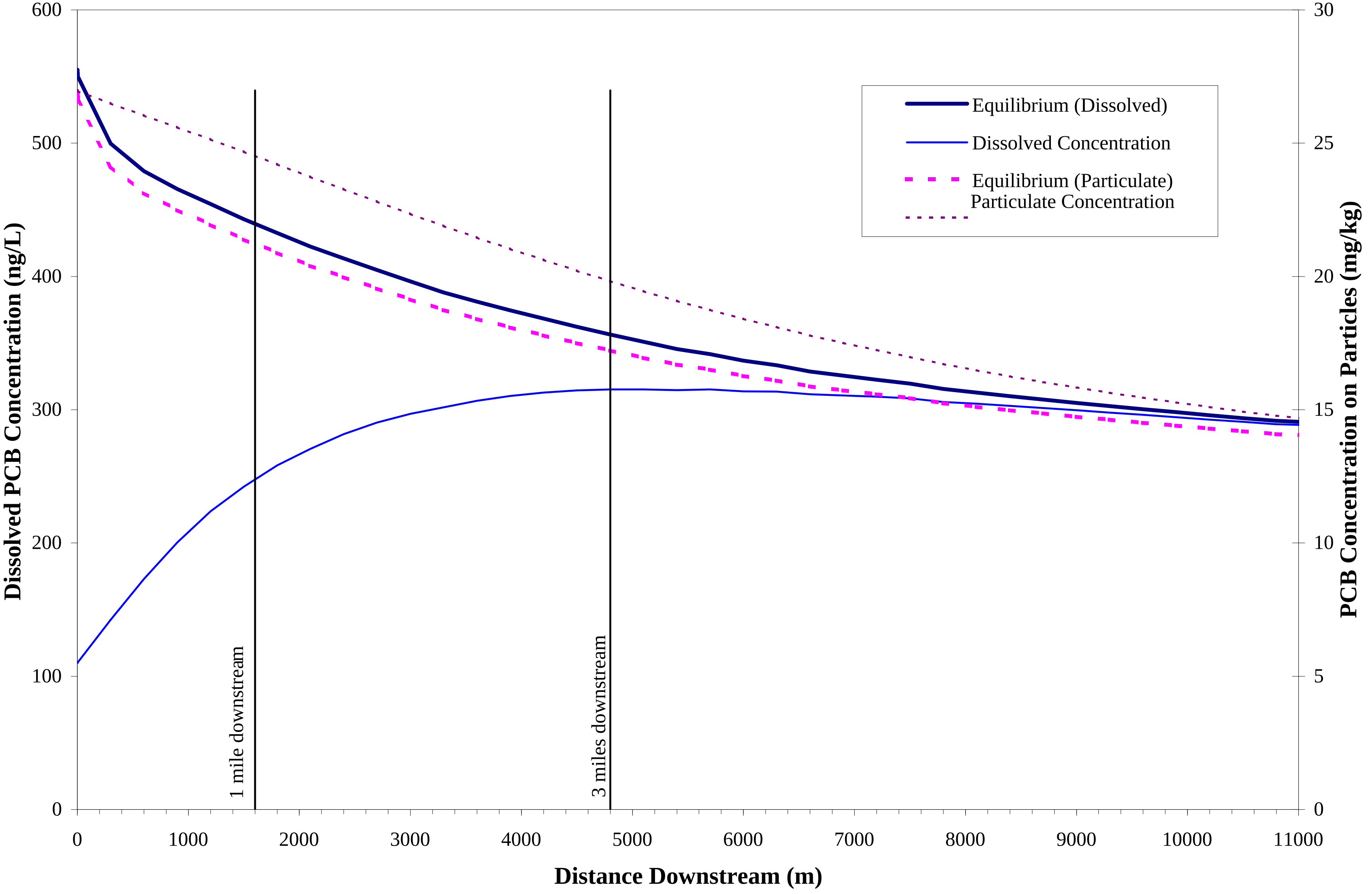
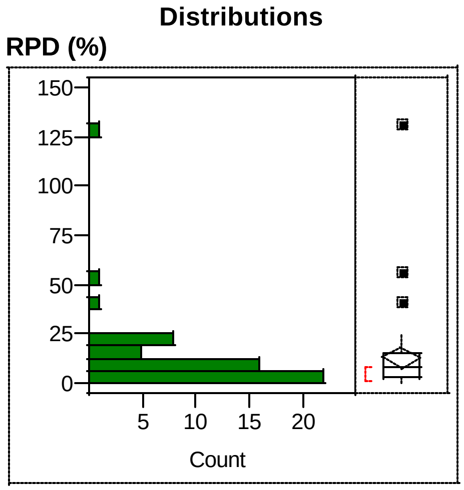


Figure 2-11
PCB Concentrations Downstream of Dredge for 350 ng/L Scenario
Section 1 at 1 mile and 3 miles

Figure 3-1
Examination of Analytical Precision Based on Blind Duplicates

Data from the Schuylerville Station,
GE Data



Quantiles

100.0%	maximum	130.64
99.5%		130.64
97.5%		102.24
90.0%		21.82
75.0%	quartile	15.51
50.0%	median	8.12
25.0%	quartile	2.89
10.0%		1.27
2.5%		0.36
0.5%		0.21
0.0%	minimum	0.21

Moments

Mean	12.7
Std Dev	19.2
Std Err Mean	2.6
upper 95% Mean	17.9
lower 95% Mean	7.4
N	54

Values represent relative percent difference calculated between blind duplicate pairs. See text for additional discussion.

Figure 4-1

Simplified Flow Chart for Near-field SS

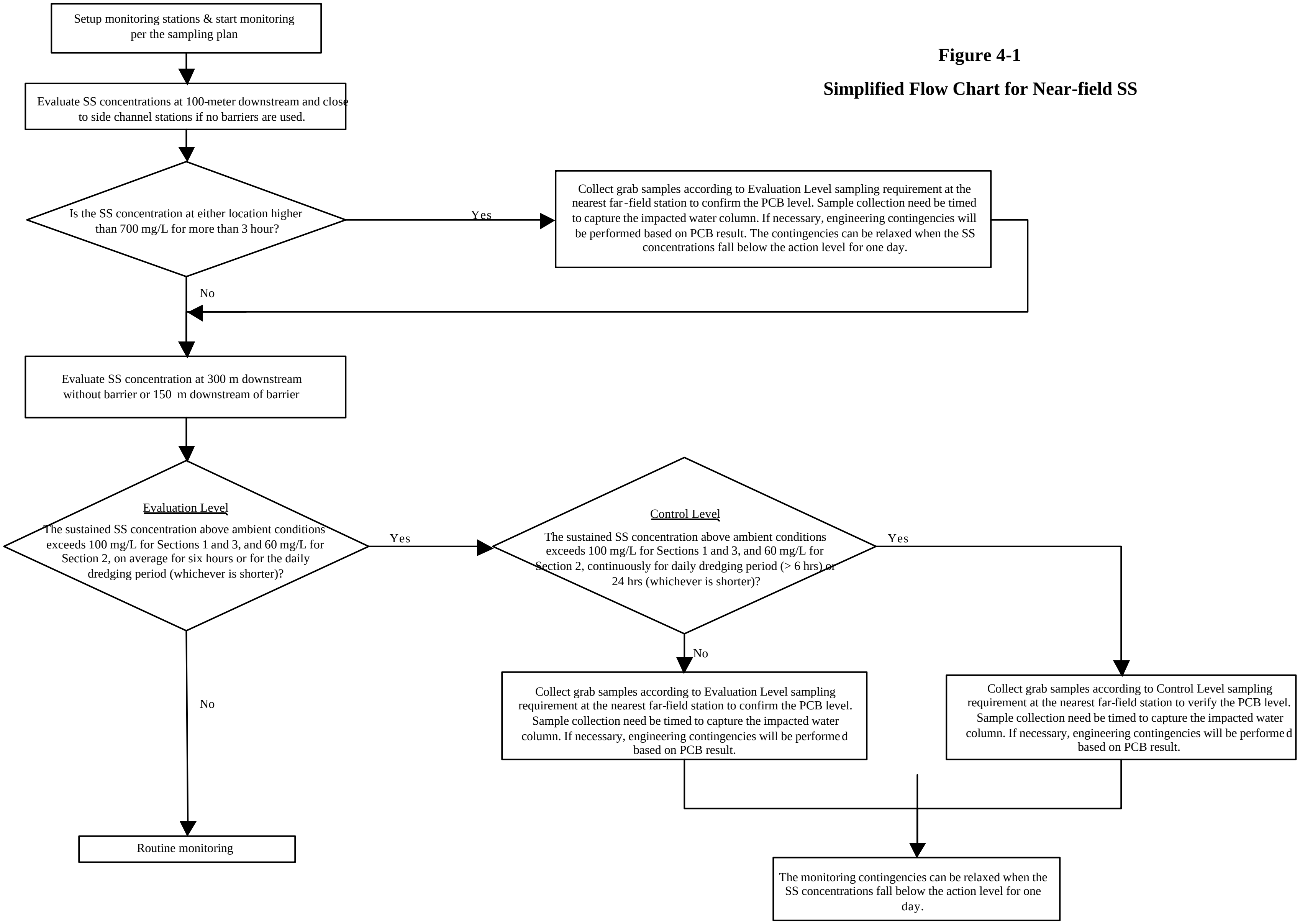
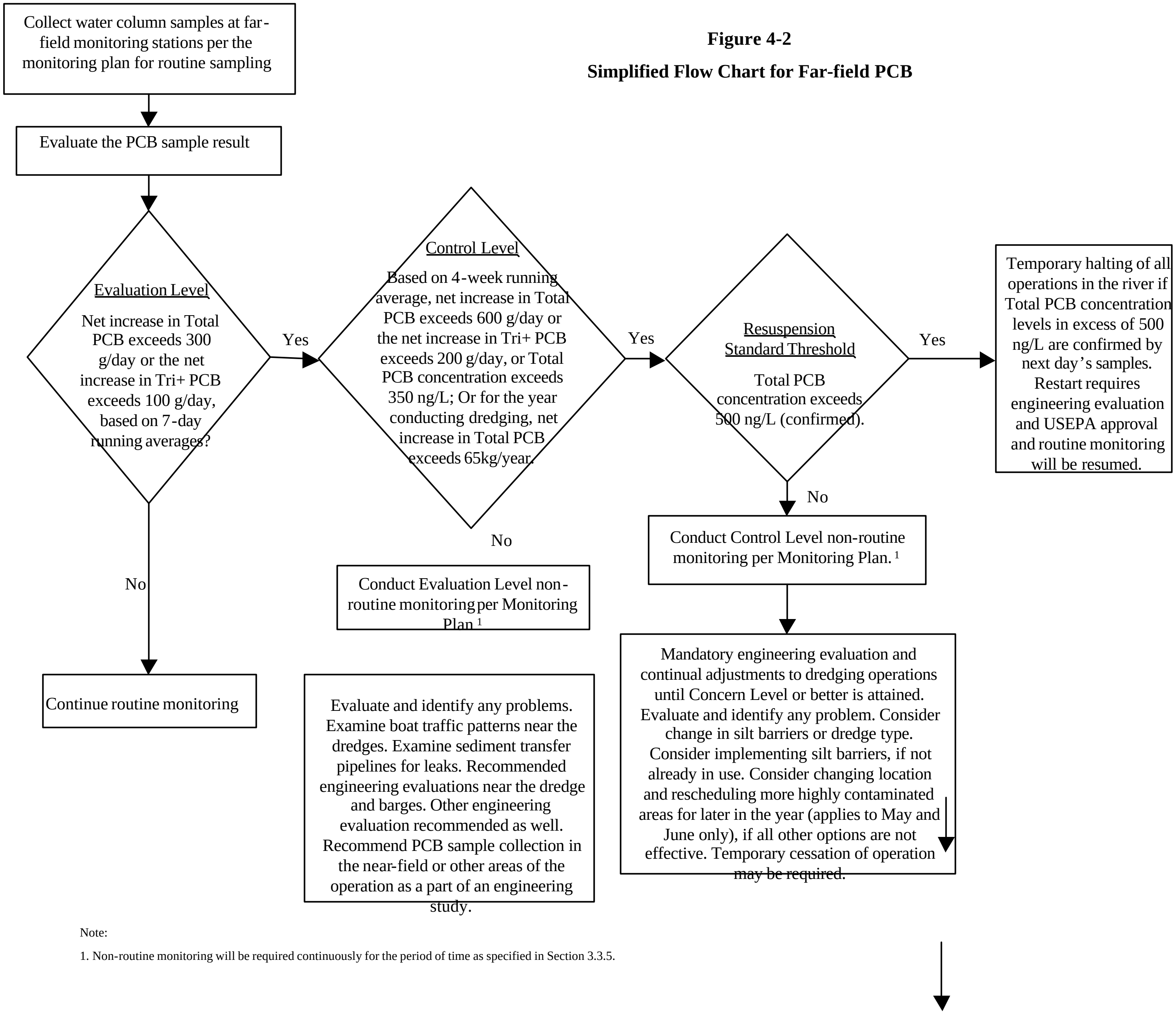


Figure 4-2

Simplified Flow Chart for Far-field PCB



Collect water column samples at far-field monitoring stations per the monitoring plan for routine sampling

Evaluate the PCB sample result

Evaluation Level

Net increase in Total PCB exceeds 300 g/day or the net increase in Tri+ PCB exceeds 100 g/day, based on 7-day running averages?

Continue routine monitoring

Control Level

Based on 4-week running average, net increase in Total PCB exceeds 600 g/day or the net increase in Tri+ PCB exceeds 200 g/day, or Total PCB concentration exceeds 350 ng/L; Or for the year conducting dredging, net increase in Total PCB exceeds 65kg/year.

Conduct Evaluation Level non-routine monitoring per Monitoring Plan [1]

Evaluate and identify any problems. Examine boat traffic patterns near the dredges. Examine sediment transfer pipelines for leaks. Recommended engineering evaluations near the dredge and barges. Other engineering evaluation recommended as well. Recommend PCB sample collection in the near-field or other areas of the operation as a part of an engineering study.

Resuspension Standard Threshold

Total PCB concentration exceeds 500 ng/L (confirmed).

Temporary halting of all operations in the river if Total PCB concentration levels in excess of 500 ng/L are confirmed by next day's samples. Restart requires engineering evaluation and USEPA approval and routine monitoring will be resumed.

Conduct Control Level non-routine monitoring per Monitoring Plan. [1]

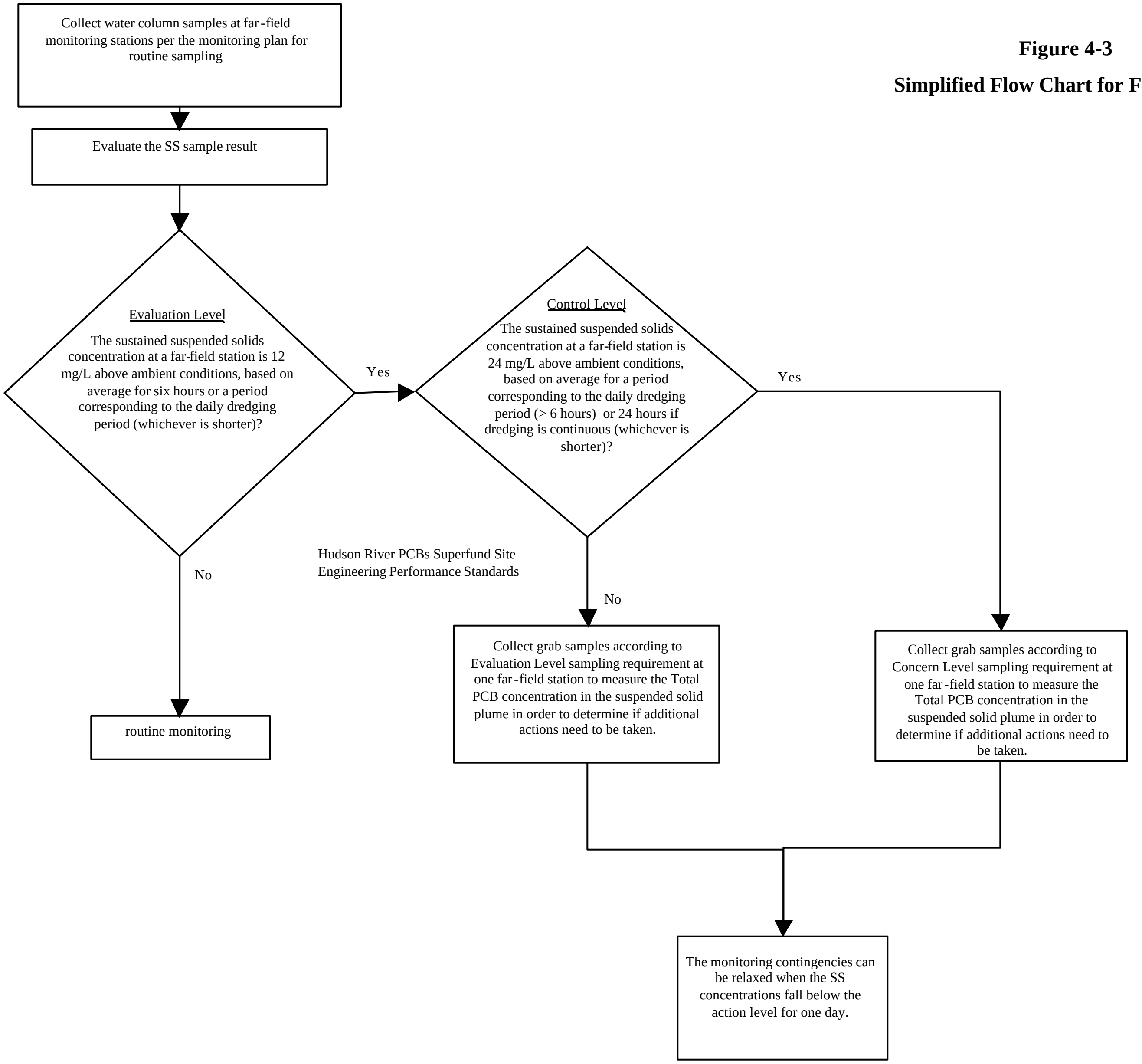
Mandatory engineering evaluation and continual adjustments to dredging operations until Concern Level or better is attained. Evaluate and identify any problem. Consider change in silt barriers or dredge type. Consider implementing silt barriers, if not already in use. Consider changing location and rescheduling more highly contaminated areas for later in the year (applies to May and June only), if all other options are not effective. Temporary cessation of operation may be required.

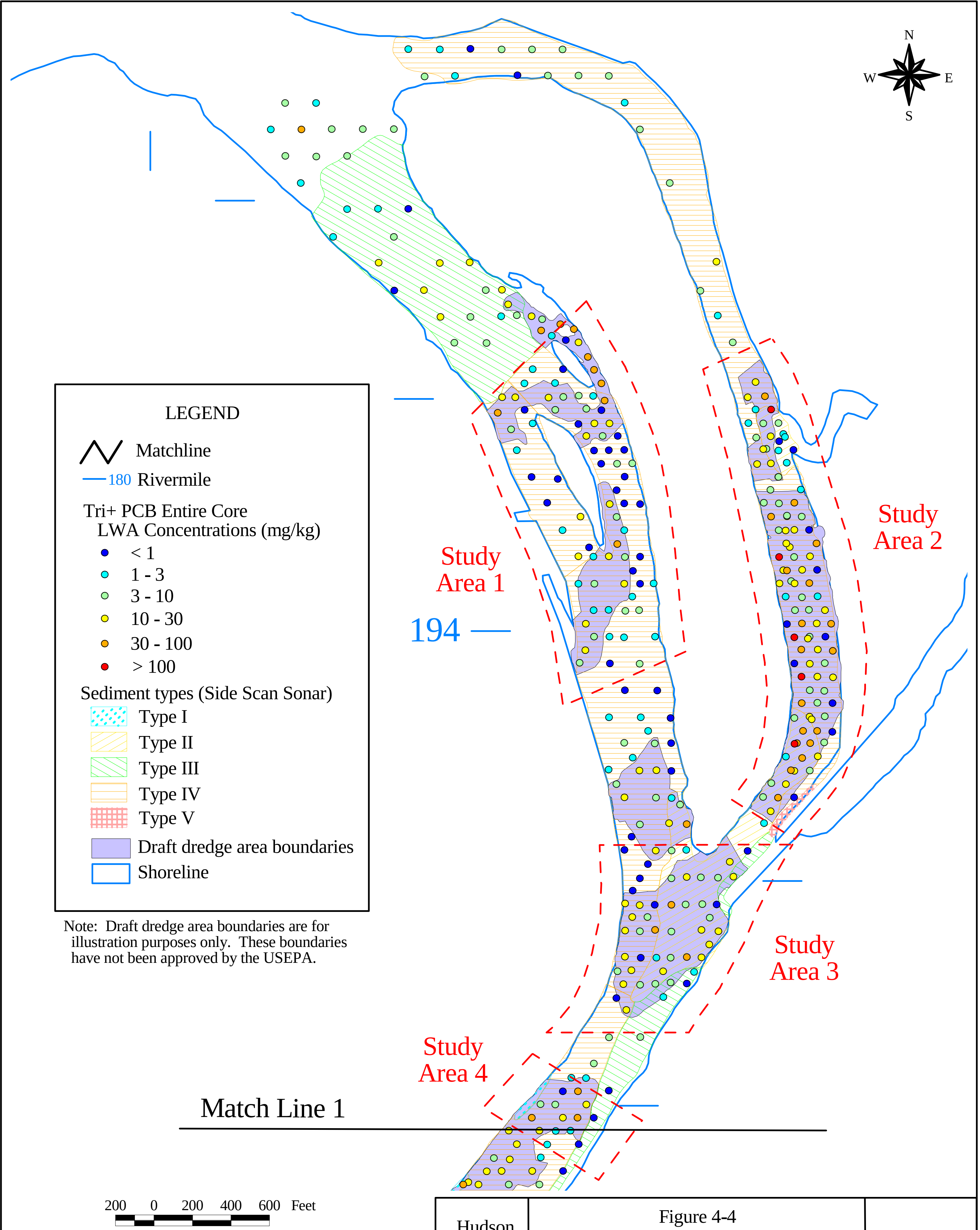
Note:

1. Non-routine monitoring will be required continuously for the period of time as specified in Section 3.3.5.

Figure 4-3

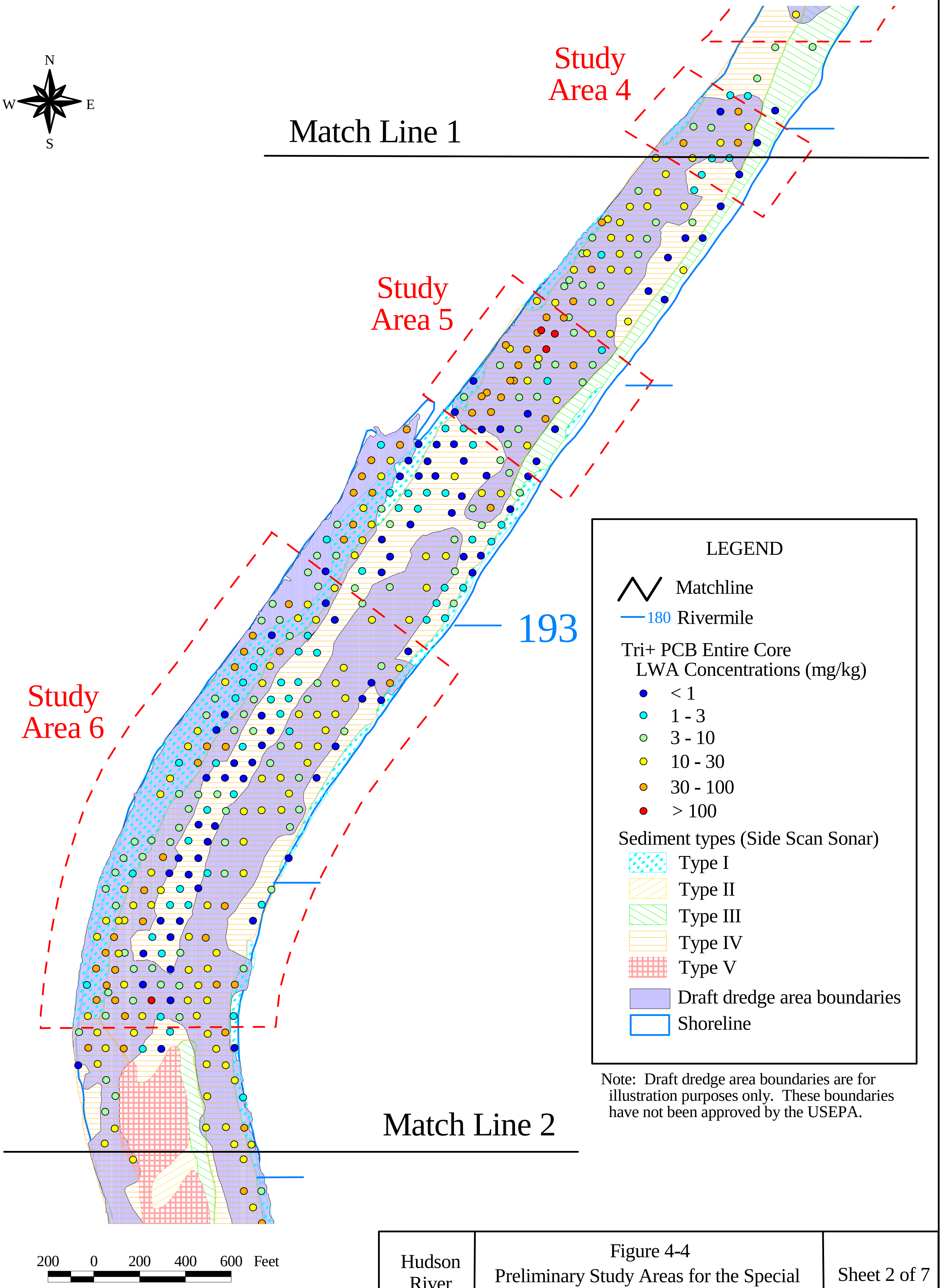
Simplified Flow Chart for Far-field SS





Note: Draft dredge area boundaries are for illustration purposes only. These boundaries have not been approved by the USEPA.

Hudson River	Figure 4-4 Preliminary Study Areas for the Special Studies Showing LWA Concentrations	Sheet 1 of 7



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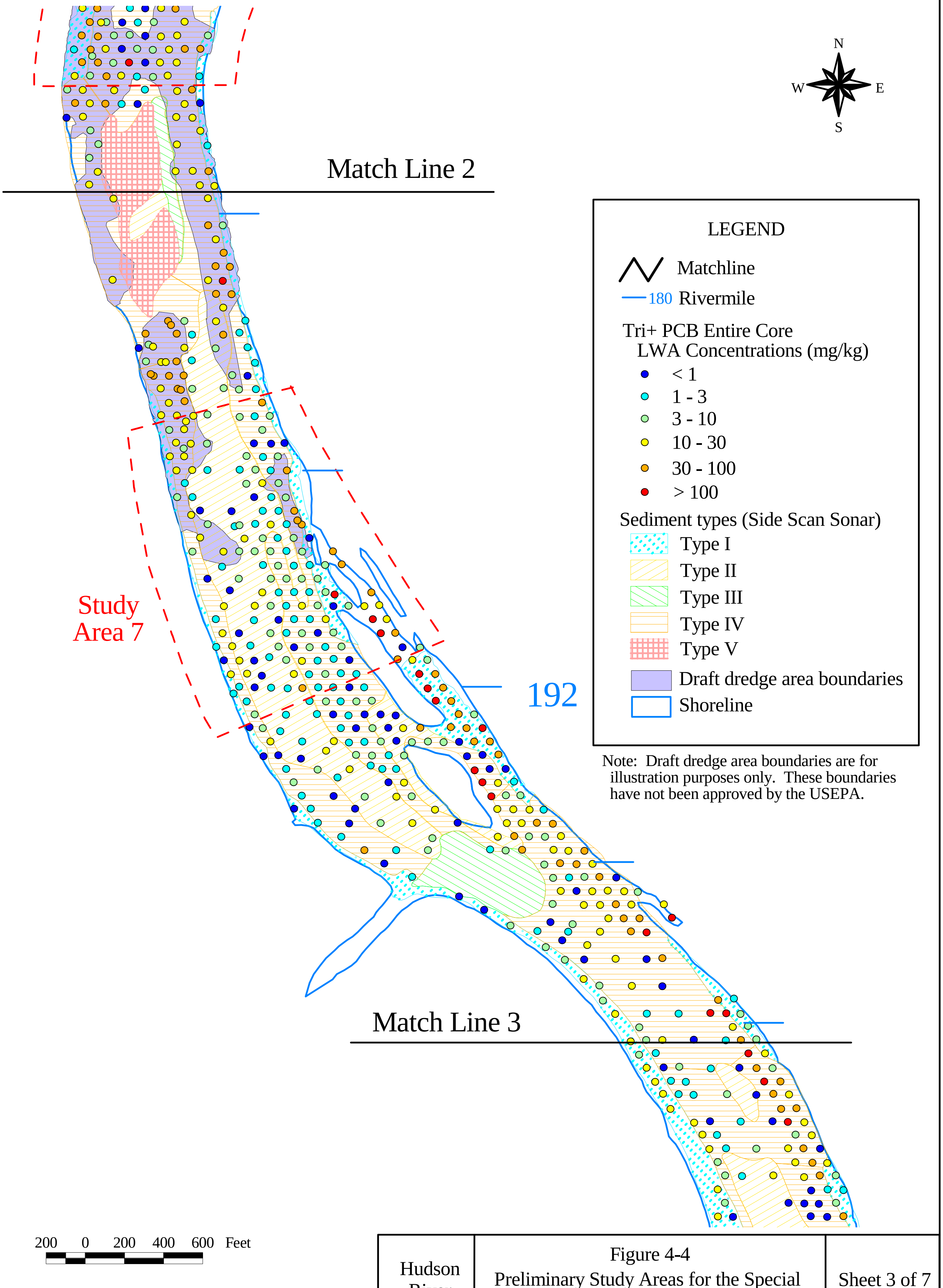
Hudson River	Figure 4-4 Preliminary Study Areas for the Special Studies Showing LWA Concentrations	Sheet 2 of 7



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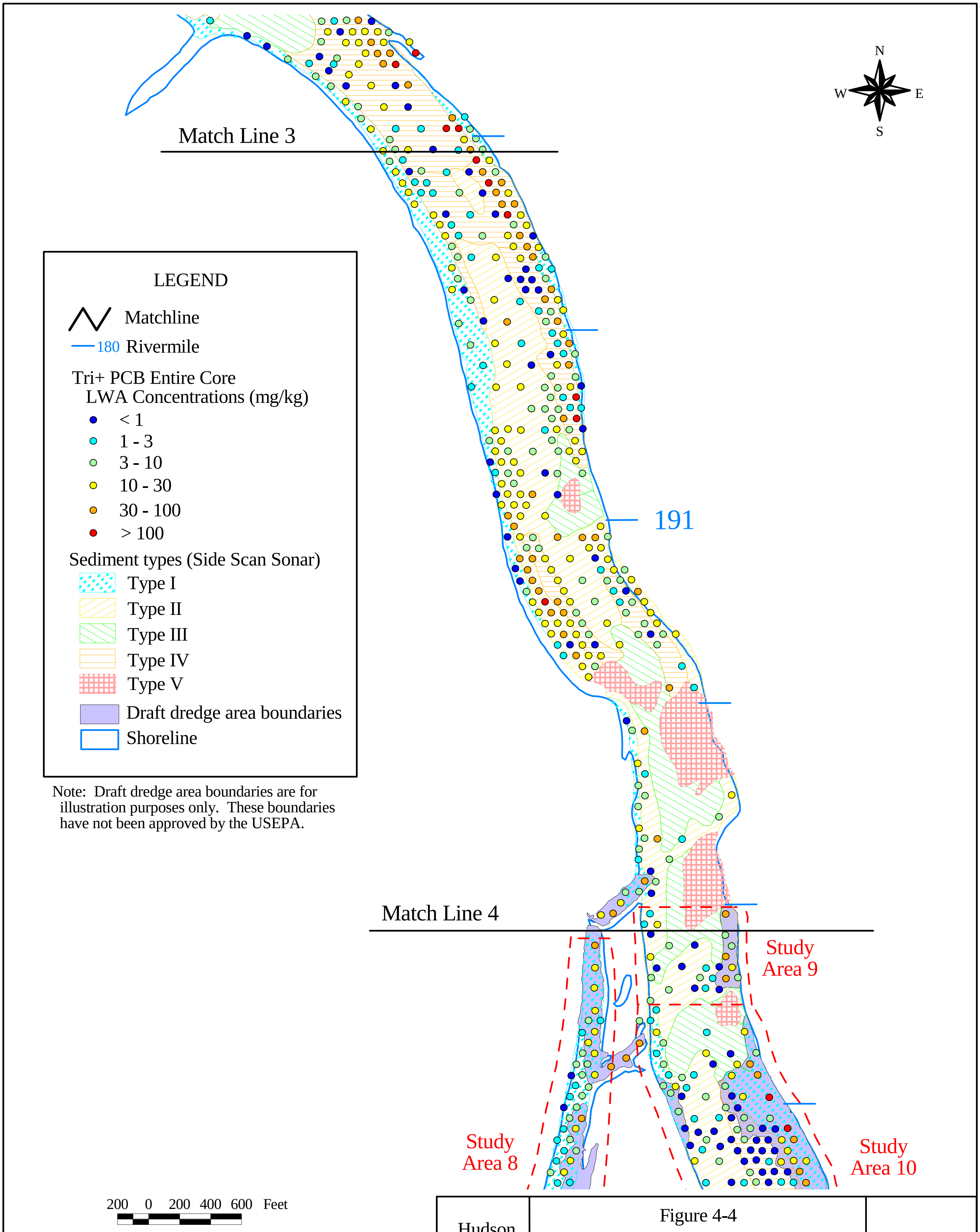
Hudson River	Figure 4-4 Preliminary Study Areas for the Special Studies Showing LWA Concentrations	Sheet 3 of 7



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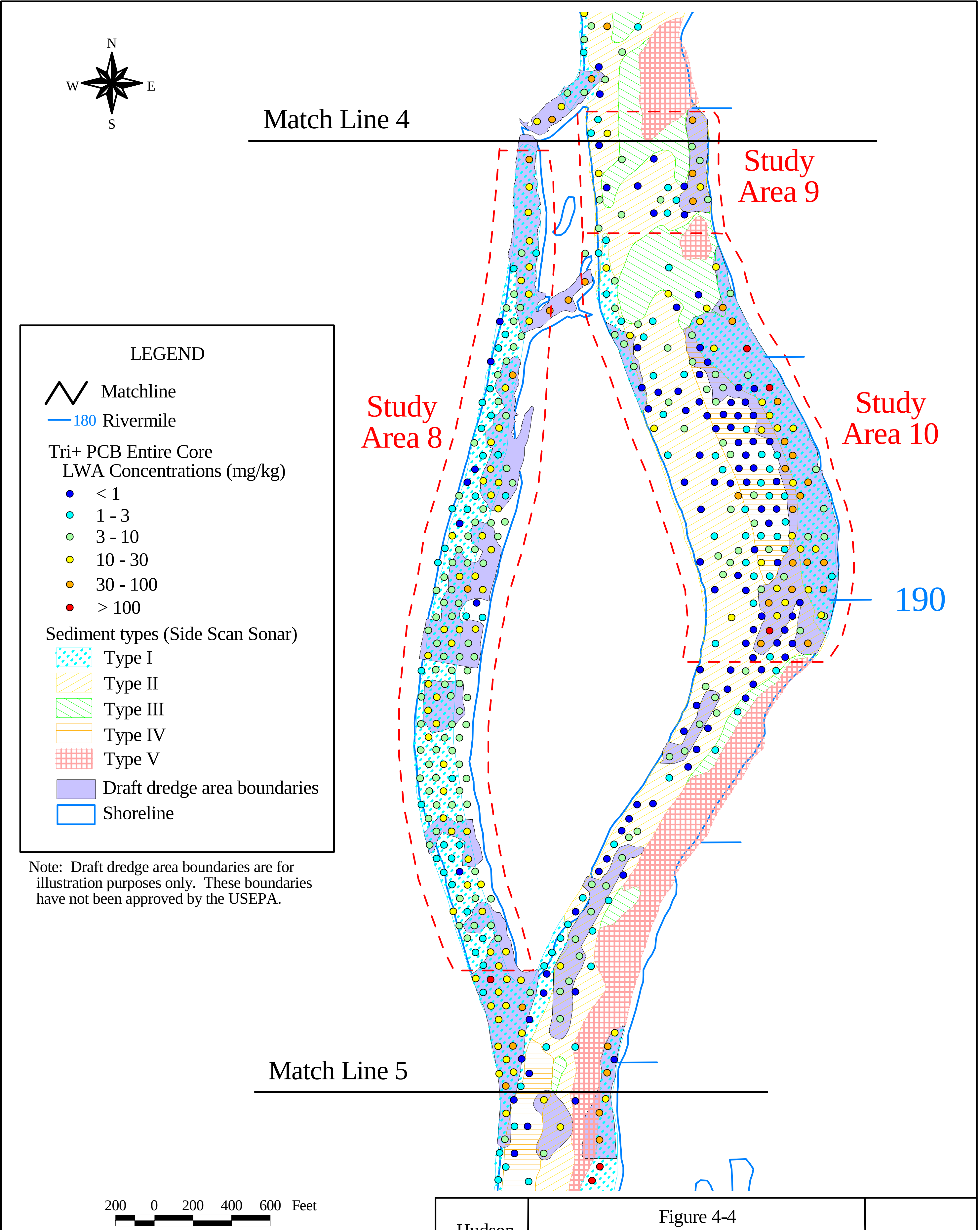
Hudson River	Figure 4-4 Preliminary Study Areas for the Special Studies Showing LWA Concentrations	Sheet 4 of 7



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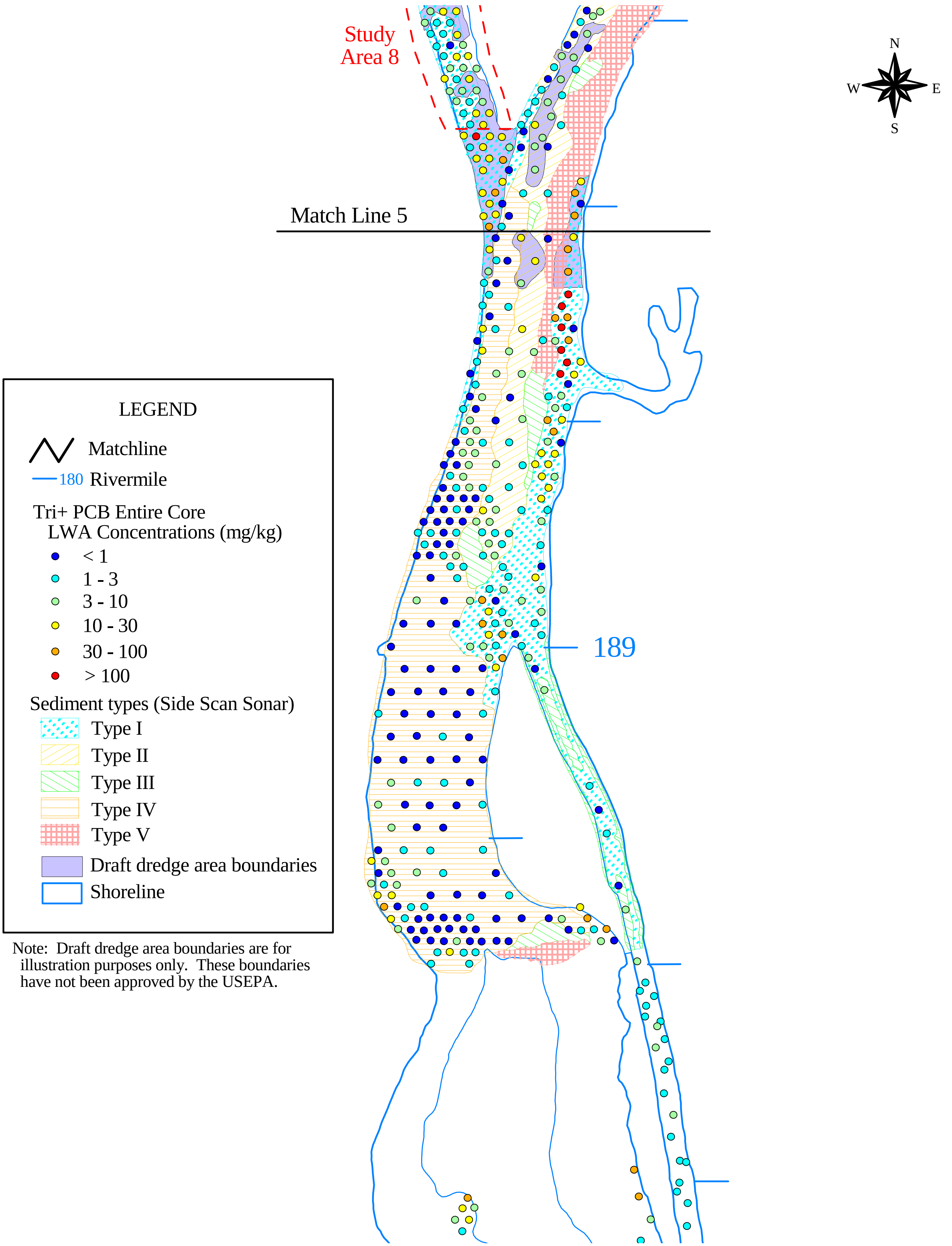
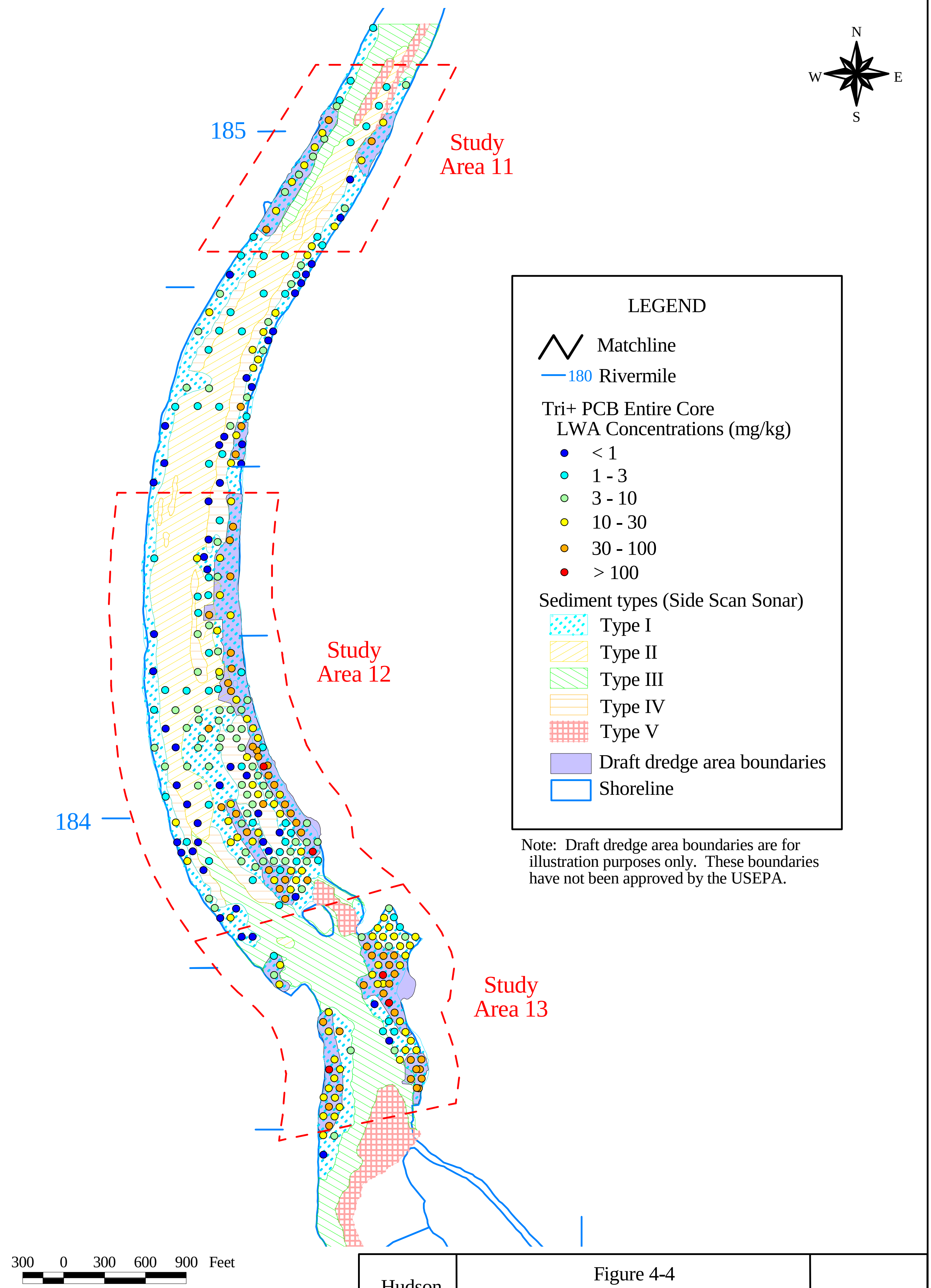
Hudson River	Figure 4-4 Preliminary Study Areas for the Special Studies Showing LWA Concentrations	Sheet 5 of 7



Note: Draft dredge area boundaries are for illustration purposes only. These boundaries have not been approved by the USEPA.

Hudson River	Figure 4-4 Preliminary Study Areas for the Special Studies Showing LWA Concentrations	Sheet 6 of 7



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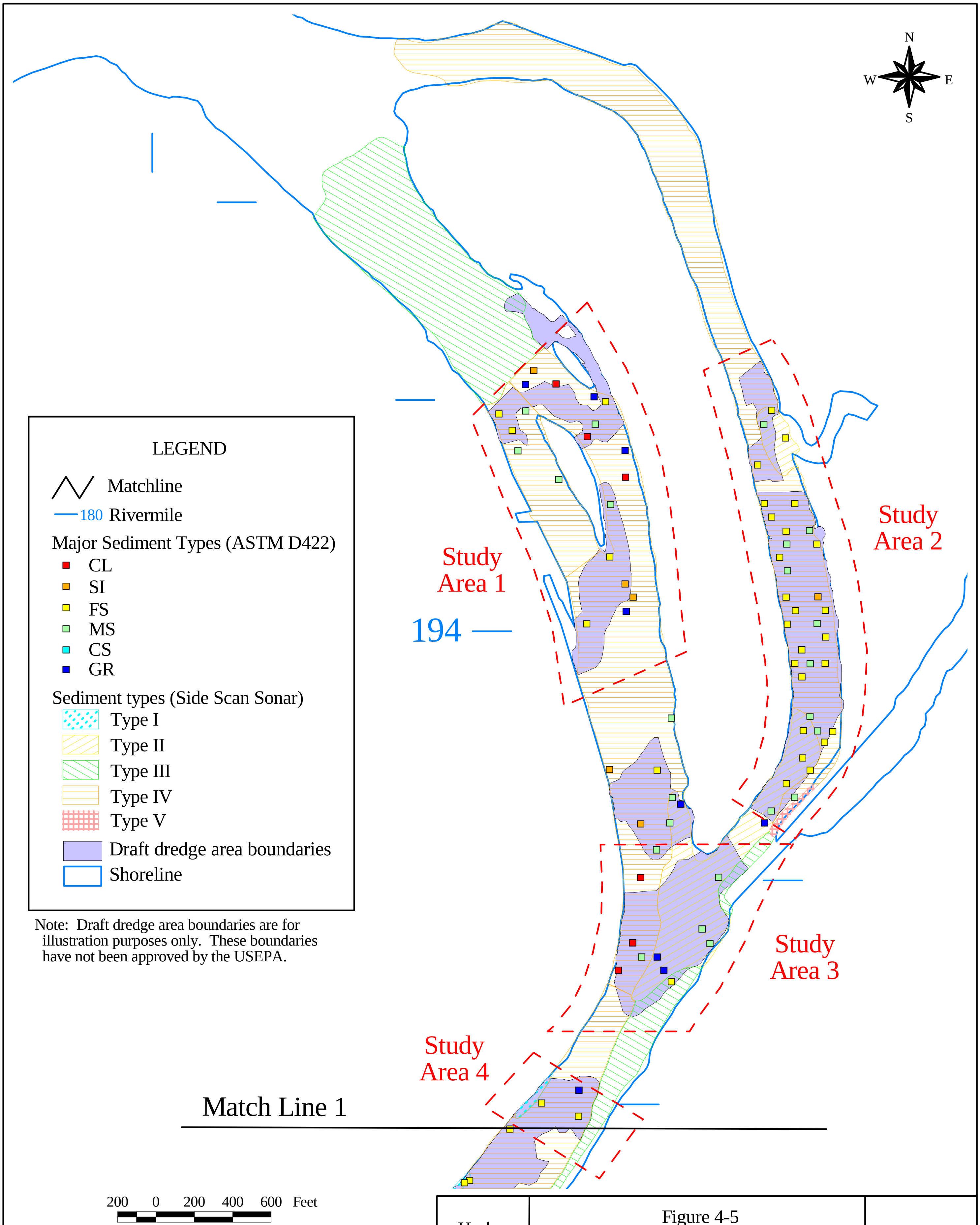
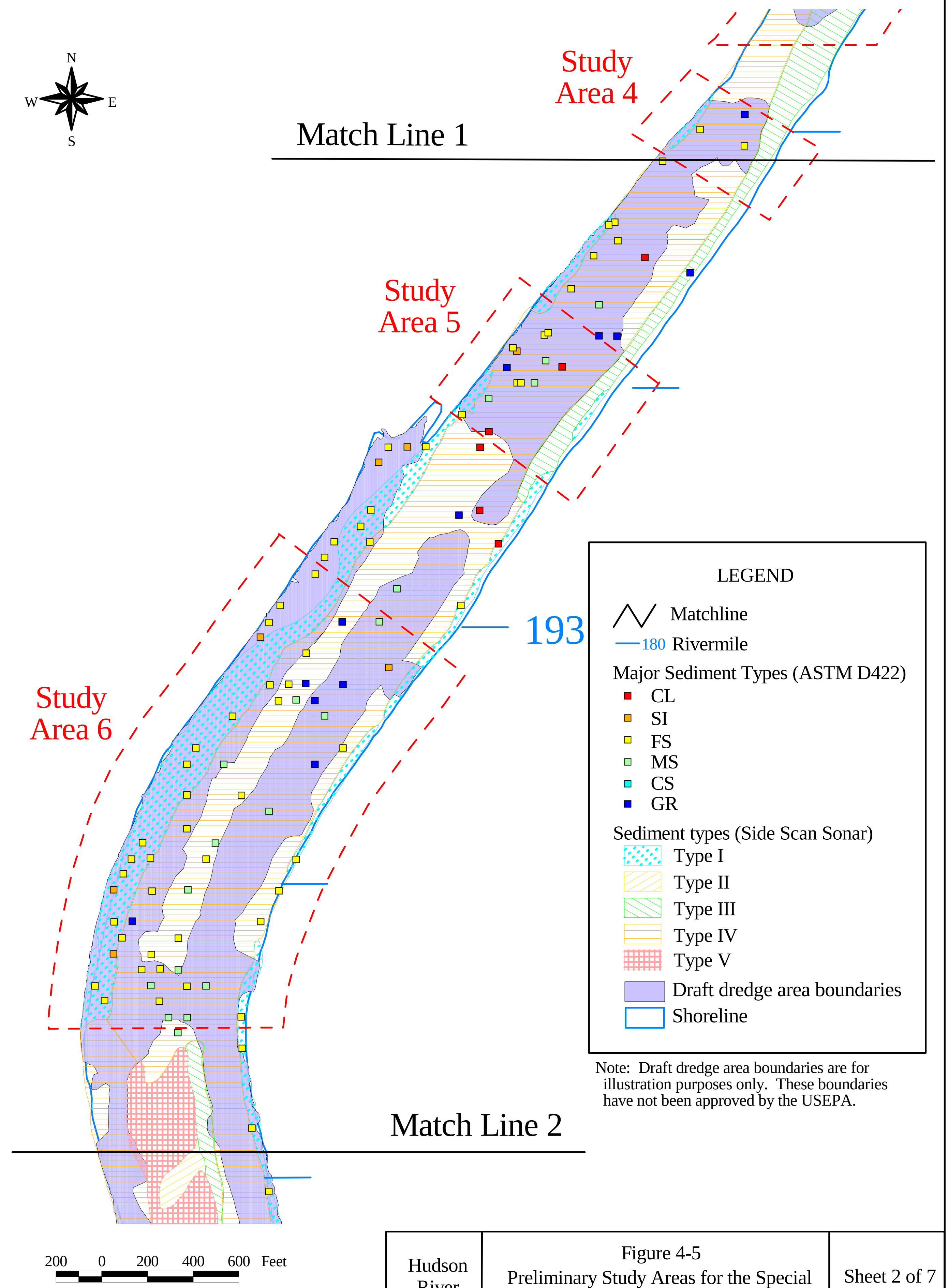
Hudson River	Figure 4-4 Preliminary Study Areas for the Special Studies Showing LWA Concentrations	Sheet 7 of 7



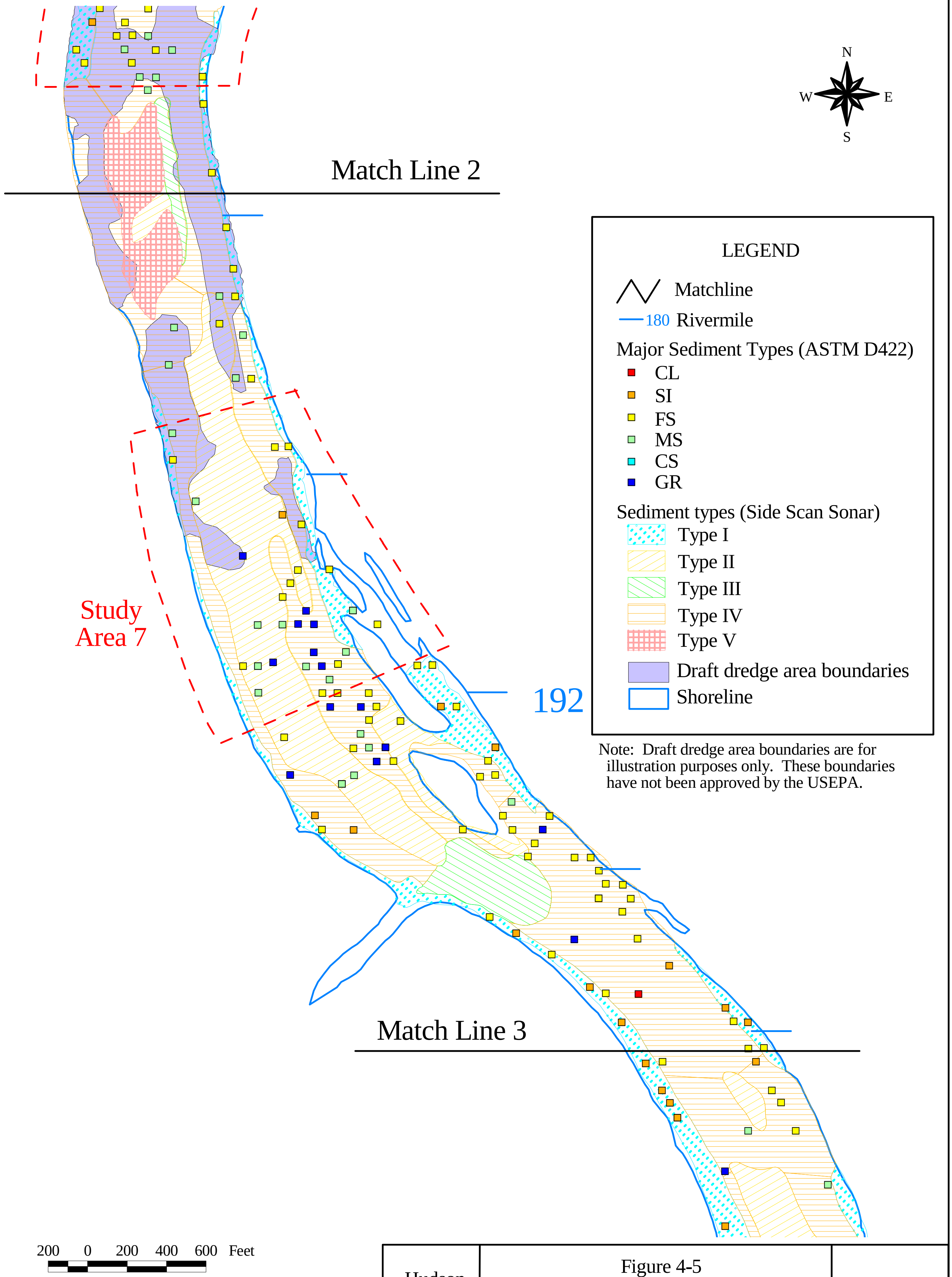
Note: Draft dredge area boundaries are for illustration purposes only. These boundaries have not been approved by the USEPA.

Hudson River	Figure 4-5 Preliminary Study Areas for the Special Studies Showing Sediment Types	Sheet 1 of 7



Note: Draft dredge area boundaries are for illustration purposes only. These boundaries have not been approved by the USEPA.

Hudson River	Figure 4-5 Preliminary Study Areas for the Special Studies Showing Sediment Types	Sheet 2 of 7



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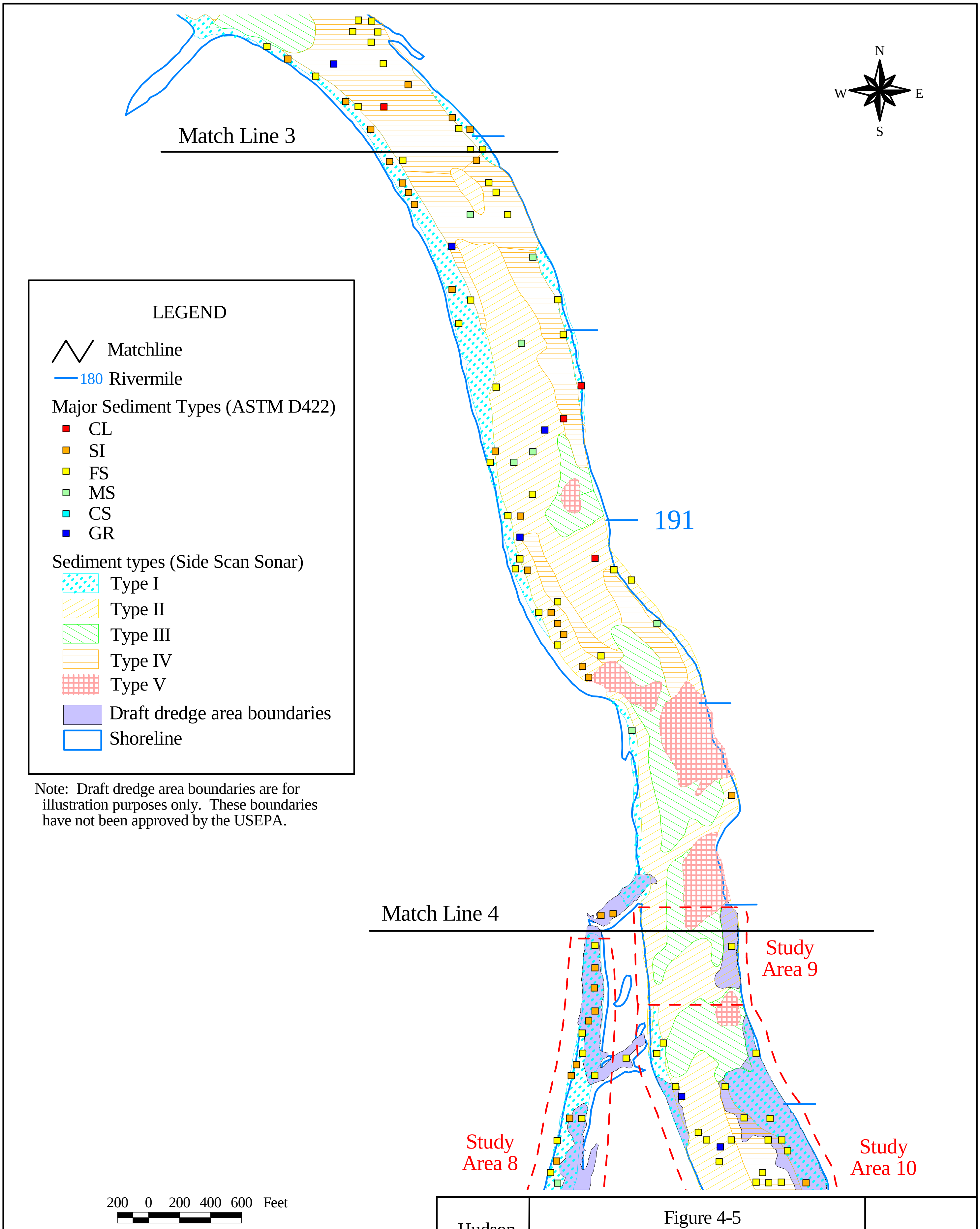
Hudson River

Figure 4-5
Preliminary Study Areas for the Special Studies Showing Sediment Types

Sheet 3 of 7



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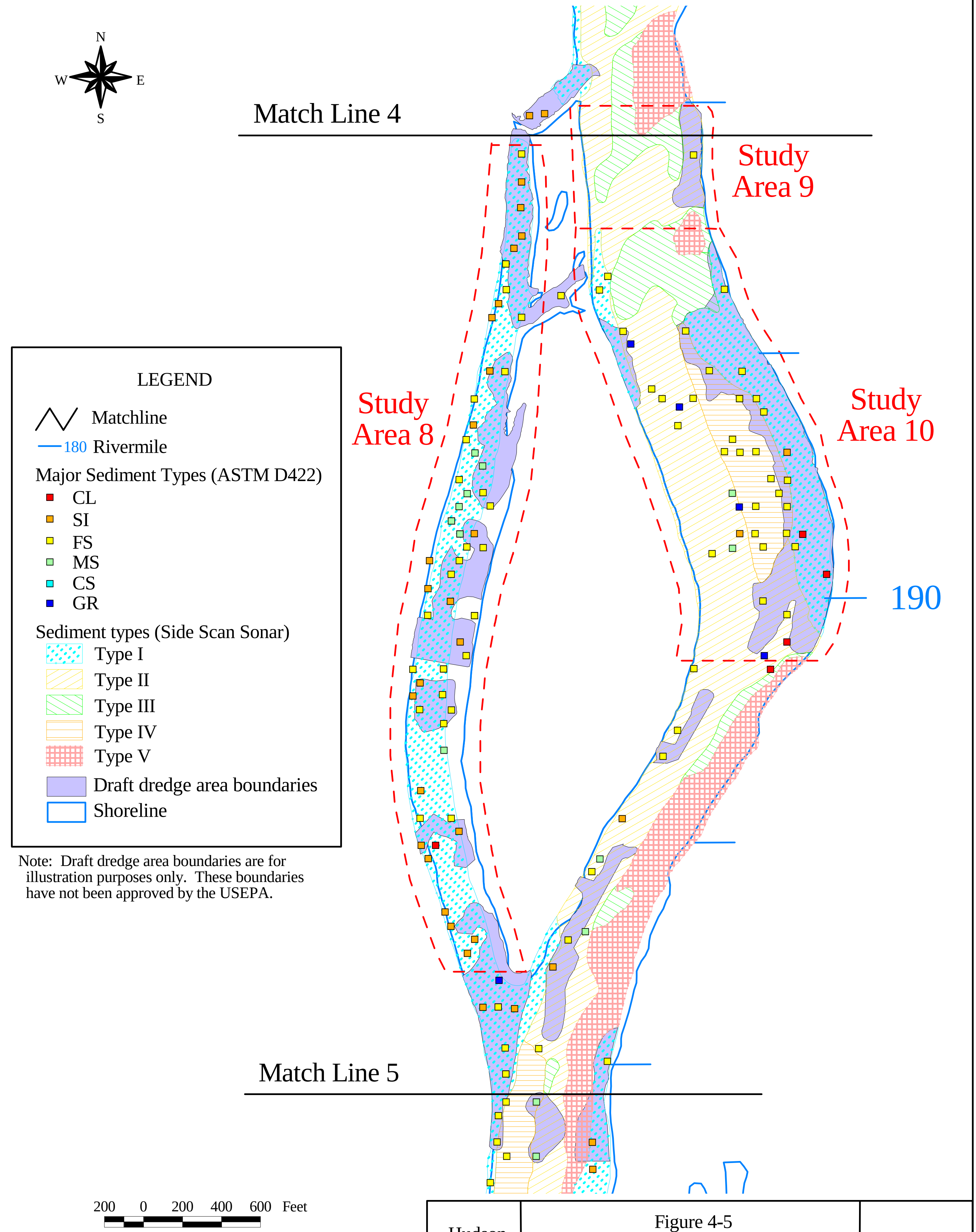
Hudson River

Figure 4-5
Preliminary Study Areas for the Special Studies Showing Sediment Types

Sheet 4 of 7

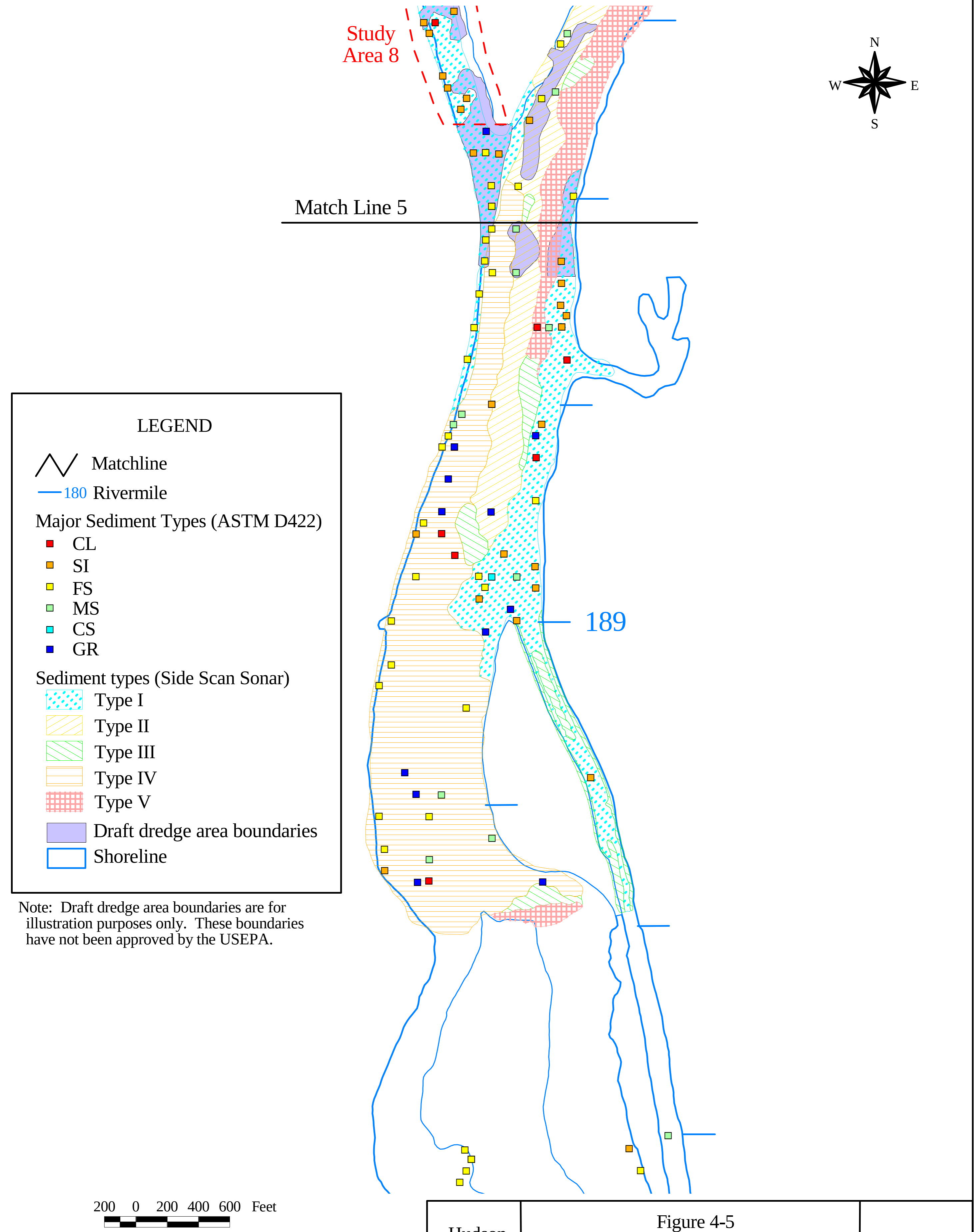


Note: Draft dredge area boundaries are for illustration purposes only. These boundaries have not been approved by the USEPA.

Hudson River

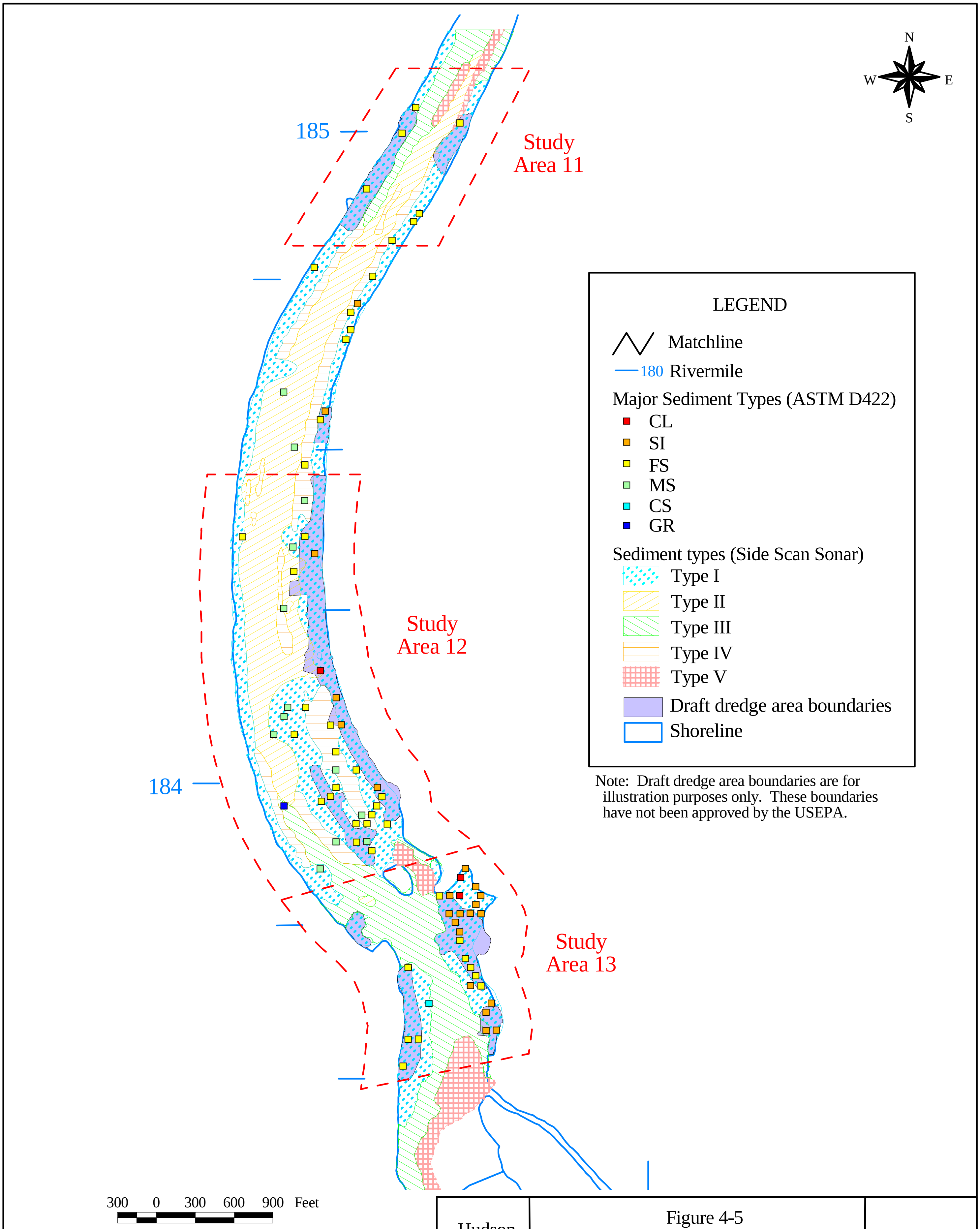
Figure 4-5
Preliminary Study Areas for the Special Studies Showing Sediment Types

Sheet 5 of 7



Note: Draft dredge area boundaries are for illustration purposes only. These boundaries have not been approved by the USEPA.

Hudson River	Figure 4-5 Preliminary Study Areas for the Special Studies Showing Sediment Types	Sheet 6 of 7

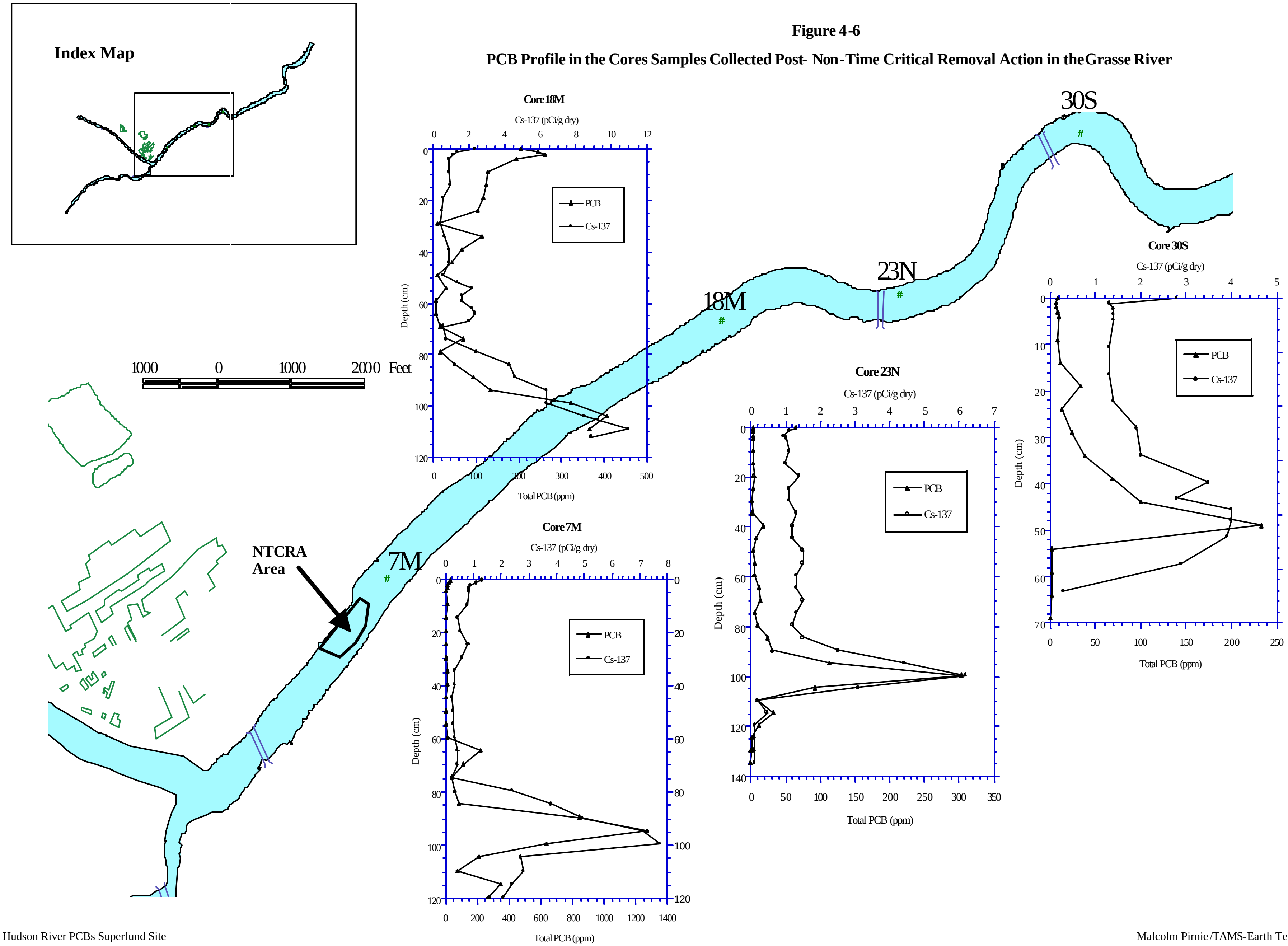


Note: Draft dredge area boundaries are for illustration purposes only. These boundaries have not been approved by the USEPA.

Hudson River	Figure 4-5 Preliminary Study Areas for the Special Studies Showing Sediment Types	Sheet 7 of 7

Figure 4-6

PCB Profile in the Cores Samples Collected Post- Non-Time Critical Removal Action in the Grasse River



Attachment A

Hudson River Water Column Concentration Analysis

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Attachment A

Hudson River Water Column Concentration Analysis

1.0 Introduction

An analysis of the existing total suspended solids (TSS) and PCB concentrations in the water column of the Hudson River was conducted to determine baseline concentrations of TSS and PCBs in the river. These baseline concentrations will be used as a comparison to TSS and PCB concentrations measured during dredging to evaluate the impact o dredging on the water column. However, it should be noted that the baseline and sensitivity calculations provided here will be revised based on the results of the Baseline Monitoring Program. To estimate the baseline concentrations of TSS and total PCBs in the water column, the following tasks were performed:

- Evaluation of the monthly flow rate over the dredging season.
- Review and analysis of existing TSS and PCB data collected by General Electric (GE) since 1996 were.
- Estimation of the baseline PCB and TSS concentrations.

Limitations of the Existing Data

Much of the data analysis planned for the development of the resuspension performance standard focuses on determining the pre-construction variability of contaminant concentrations, or loads, in the water column. Previous studies, notably the *Data Evaluation and Interpretation Report* (DEIR, USEPA, 1997), have shown that the variability of contaminants in the water column changes throughout the year. The variability of contaminants in the water column is greatest during the spring, and it gradually decreases through the summer and into the fall.

For PCBs, the amount of available data is much greater, since nearly weekly sampling was conducted from the early 1990s to the present. But only limited locations were monitored, with the southernmost station located at Lock 5 in Schuylerville. Because the amount of data from stations close to the Mid-Hudson portion of the river is limited, the variability of contaminants in the water column at Waterford (sampled at the Troy Dam) will be inferred from the Upper River stations. This approach is reasonable, but not perfect. The contaminant concentrations at the TI Dam are much more variable than those at the downstream stations because the dam is closer to the contaminant sources. As the contaminant load travels downstream, the “signal” is dampened by dilution from tributary inputs, homogenization, and settling of the contaminants. Thus, if the TI Dam variability is assumed to apply to the Waterford area, the variability will be too high, leading to a performance standard that is less conservative than it should be. Direct measurements of the water column, expected to be provided by future GE sampling, will give a more accurate representation of conditions at the Troy Dam.

Although the dataset for PCBs encompasses most of the 1990s through the present, the data sampled prior to 1996 may not be useable for performance standard development due to the lack of source control at the GE facilities prior to that year. This leaves approximately five years of data at the TI Dam, and less at the other water column stations, for use in the planned evaluation. While this dataset would seem to be sufficient to examine the variability of contaminant concentrations, there are concerns regarding the location of the monitoring stations within the river at the TI Dam and Schuylerville.

- At Schuylerville, the station is located near the Battenkill, but not at a point where contaminant concentrations would be influenced by this tributary's input (the station was not situated where complete mixing would be expected to occur). Because of this, the Schuylerville (Lock 5) station may not fully represent the Hudson River water column concentrations under all conditions. It is hoped that future Schuylerville (Lock 5) samples will be collected from locations in the river where the flows from the Hudson River and the Battenkill are sufficiently homogenized, adopting a standard USGS sampling approach.

- At the TI Dam, both a west wing station and a central channel station are frequently sampled. Both stations have limitations. An analysis performed for the *Responsiveness Summary for the Data Evaluation and Interpretation Report* (USEPA, 1998) on the results in the west wing indicated that the concentrations from this station may be strongly influenced by the nearby sediments, particularly during times of low flow. The center channel station is north (upstream) of the west wing station, and thus does not measure the impact from the side channel sediments near the dam. Also, the center channel is inaccessible during the winter months due to ice cover, so the dataset is limited to the warmer months. Subsequent analysis indicated that the downstream concentrations (Schuylerville) are unlike either station taken separately, but resemble a mix of the concentrations measured at the two stations.

These concerns regarding the existing water column dataset have an impact on the evaluation of water column contaminant variability. It is unclear whether the estimated variability derived only from historic data will be more or less conservative than the actual conditions in the river. If GE adjusts the locations of the monitoring stations during future sampling events, a better measure of variability will be obtained.

2.0 Estimation of Hudson River Flow Rates at Stations Within the Upper Hudson River

Monitoring of resuspension in the water column of the Hudson River during dredging will include the measurement of PCBs at the far-field monitoring locations and measurement of turbidity and TSS at locations near the dredging operation, to ensure that the loss of PCBs from dredging is not occurring at a level greater than the baseline variability of PCBs already present in the water column.

Based on this need, it has been concluded that the far-field monitoring stations will be situated at the downstream limit of each of the three pools during dredging. Of these locations, only three have a long history of water column measurements: the TI Dam, Schuylerville (Lock 5), and Waterford (Troy Dam). For each of these locations, the baseline variability of TSS and PCB loading to the water column must be computed to establish a baseline for monitoring during implementation of the remedy. To determine the baseline variability of PCBs and TSS concentrations at the monitoring locations, the flow rates at these locations are needed.

The USGS monitors the flow rate of the Hudson River at gauges in the following locations:

- At Ft. Edward, along the Hoosic River
- On the Batten Kill before it converges with the Hudson River at Schuylerville,
- On the Hudson River just north of Waterford,
- Within the drainage areas surrounding the Hudson River.

In addition, the flow rate at Stillwater is estimated by the USGS. The flow rates at TI Dam and Schuylerville are not readily available.

Flow rates at the TI Dam and Schuylerville were computed using the drainage-area ratio method and known flow rates from existing USGS gauge stations. Flows were determined for the period 1977 to 2001 to incorporate all flow rate data available at the gauged stations.

Schuylerville Flow Rate Calculation

As shown in Figure 1, the flow rate of the Hudson River as it passes through Schuylerville is equal to the sum of the following:

- The flow rate of the Hudson River measured at the USGS gauge station at Ft. Edward.

- The flow rate measured by USGS at the gauge station along the Batten Kill.

- The flow contribution from this gauged station along the Batten Kill westward to its confluence with the Hudson River.

- The flow rate between Ft. Edward and Schuylerville.

This relationship is described by the following equation:

$$\text{Flow rate at Schuylerville} \equiv F_{schuy} = F_{Ft.Ed} + F_{BKg} + F_{BKung} + \Delta f_{ung\text{-}schuy} \quad \ldots\textit{Equation 1}$$

where $F_{Ft.Ed}$ = Flow at Ft. Edward
F_{BKg} = Flow at the Batten Kill gauge station
F_{Bkung} = Flow within the ungauged section of the Batten Kill
$\Delta f_{ung\text{-}schuy}$ = Change in flow rate of the ungauged section of the Hudson River between Ft Edward and Schuylerville

Using the drainage-area ratio method, the relationship of watershed yield times the drainage area of the watershed was used to compute the corresponding flow rate of the watershed. In the foregoing equation, the flow rate within the ungauged section of the Batten Kill (F_{BKung}) was computed by multiplying the yield of the Batten Kill by the change in watershed area over the ungauged section of the Batten Kill (the difference of the total area of the Batten Kill minus the gauged area along the Batten Kill) before it has its confluence with the Hudson River. This relationship is expressed in Equations 2 and 3, shown below.

$$F_{BKg} = y_{BKg\,*}\, A_{BKg} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\textit{Equation 2}$$

where F_{BKg} = Flow rate at the Batten Kill USGS gauge station
y_{BKg} = Yield for the Batten Kill gauged section of the River
A_{BKg} = Drainage area for the Batten Kill gauged section of the river

$$F_{BKung} = y_{BKg} * A_{BKung} = (F_{BKg}/A_{BKg}) * A_{BKung} \quad \ldots\ldots\ldots\textit{Equation 3}$$

where F_{BKung} = Flow rate for the ungauged section of the Batten Kill
A_{BKung} = Drainage area for the ungauged section of the Batten Kill
$= A_{BK} - A_{BKg}$
A_{BK} = Total drainage area of the Batten Kill

The flow rate contributed by the section of the Hudson River between Ft. Edward and Schuylerville was computed as the change in flow rate between the flow rates measured at Ft. Edward and Stillwater by USGS and both the gauged and ungauged sections of the Batten Kill.

$$\Delta f_{ung\text{-}schuy} = \Delta a_{ung\text{-}schuy} * y_{ung} \quad \ldots\ldots\ldots\ldots\textit{Equation 4}$$

where

$$y_{ung} = (F_{stwtr} - F_{Ft.Ed} - F_{BKg} - F_{BKung})/(A_{stwtr} - A_{Ft.Ed} - A_{BKg} - A_{BKung}) \quad \ldots\ldots\textit{Equation 5}$$

and

$\Delta a_{ung\text{-}schuy} = A_{schuy} - A_{Ft.Ed} - A_{BKg} - A_{Bkung}$ .... *Equation 6*

and

$\Delta f_{ung\text{-}schuy}$ = Change in flow rate of the ungauged section of the Hudson River between Ft. Edward and Schuylerville

$\Delta a_{ung\text{-}schuy}$ = Change in the drainage area of the ungauged section of the Hudson River between Ft. Edward and Schuylerville

y_{ung} = Yield for the ungauged section of the Hudson River between Ft. Edward and Stillwater

F_{stwtr} = USGS estimated flow rate of the Hudson River at Stillwater

A_{stwt} = Drainage Area that enters the Hudson River at Stillwater

$A_{Ft.Ed}$ = Drainage area that enters the Hudson River at Ft. Edward

A_{schuy} = Drainage area that enters the Hudson River at Schuylerville

For select days over the period 1977 through 2001, the estimated flow rates at Stillwater were less than that of Fort Edward. In these instances, the following relationship was used to estimate the flow rate at Schuylerville:

$F_{schuy} = F_{Ft.Ed} + F_{Bkg} + F_{Bkung} + \Delta a_{ung\text{-}schuy} * y_{BKg}$ .... *Equation 7*

Thompson Island Dam Flow Rate Calculation

The flow rate at the TI Dam was computed similarly to the flow rate at Schuylerville; the drainage-area ratio method and the measured flow at the Ft. Edward gauge were used to estimate the flow at the dam. The following equations, Equations 8, 9, and 10, depict the relationships used to predict the flow rate at the TI Dam (F_{TID}):

$F_{TID} = F_{Ft.Ed} + \Delta f_{TID}$ .... *Equation 8*

where

$\Delta f_{TID} = \Delta a_{TID} * y_{ung}$ .... *Equation 9*

and

$\Delta a_{TID} = A_{TID} - A_{Ft.Ed}$ .... *Equation 10*

and

F_{TID} = Flow rate of the Hudson River at the Thompson Island Dam

Δf_{TID} = Change in flow rate along the Hudson River between Ft. Edward and the Thompson Island Dam

Δa_{TID} = Change in the drainage area into the Hudson River between Ft. Edward and the Thompson Island Dam

A_{TID} = Drainage area into the Hudson River at the Thompson Island Dam

For days where data gaps existed at the Ft. Edward USGS gauge station, the flow at Ft. Edward was estimated from the regression equation generated from the plot of the daily runoff yield at Stillwater versus the daily runoff yield at Ft. Edward (Figure 2). This plot generated the following equation that was used to estimate the flow rate at Ft. Edward:

$$F_{Ft.Ed} = 1.05*y_{stwtr}*A_{Ft.Ed}$$ ....*Equation 11*

where y_{stwtr} = Yield for the Hudson River drainage area at Stillwater
and other parameters as defined above

3.0 Baseline TSS and Total PCB Analysis

The major concern associated with the dredging operation is the resuspension of sediment particles that may introduce additional PCB contamination into the water column. The water column PCB concentration will be monitored during dredging operations, and actions will be taken to minimize the impact of resuspension on the river system when the PCB concentration exceeds a certain level/threshold. Previous sampling results indicate that the variability of water column contaminant concentrations in the Hudson River can, to some extent, be attributed to the uncertainty of laboratory analyses. However, the variability in contaminant concentration in the water column is actually primarily the result of variability of the river system. In order to measure the "net" effect of the dredging operation, it is necessary to distinguish the dredging-related contribution of PCB contamination to the water column from the flux of PCBs currently present in the water column. If the new measurements collected during dredging are within the variability determined by the samples collected prior to the onset of dredging activities, it will be assumed that there is no impact from dredging. This poses the question of whether each new observation/sample collected belongs to the populations created from the baseline data and if the new observations generate the same central tendency as the baseline data. To evaluate this question, a statistical analysis was performed over the multiple-year baseline water column data set to investigate the typical condition of the river and to estimate the upper bound and typical PCB contaminant levels representative of the river system.

3.1 Methodology

Samples collected by GE during their ongoing weekly sampling program were used to estimate the current PCB water column contamination conditions in the Hudson River. The GE sample results were used because they provide a long record of PCB and TSS concentrations in the Hudson River, have measured PCB concentrations using a congener method, represent the most comprehensive dataset of water column PCB results, and probably best reflect the current situation in the Hudson River. There are some problems with the data collection method that make this data less than representative; the samples were collected from a single centroid sample to represent the cross-section, and the detection limits are not low enough to detect concentrations at all stations throughout the year. Only post-1996 water column samples were used in this analysis (due to the lack of source control at the GE facilities prior to that year) to estimate the baseline conditions in the Hudson River prior to any impact that may result from the dredging operation.

GE has been monitoring the water column situation in the Upper Hudson River at four stations since the early 1990s. These four stations are located at Fort Edward, at the west side of the TI Dam near the shore (TID-West), in the channel section above the TI Dam (TID-PRW2), and at Schuylerville (Lock 5). Data collected at the above-listed stations were investigated in this study to estimate the natural variability of TSS and PCB concentration in the river system at different locations. Daily average flow measured and reported by the USGS was used for PCB and TSS analysis at the Fort Edward station. The flow rate at the other three stations was estimated based on the flow rate at Fort Edward, as described in detail in Section 2.0 of this attachment.

Since the proposed dredging season spans the months of May through November, only data associated with these seven months were examined for distribution and variability herein. As stated in the *Hudson River Feasibility Study Report* (USEPA, 2000), dredging is not expected to be performed during high flow conditions. Therefore, samples with flows greater than 10,000 cfs were excluded from this analysis in order to provide the best estimate of what conditions will be during dredging activities. Field duplicate samples were collected for 1 percent of the total samples taken, and an average concentration was calculated to represent the results of all duplicates. In addition, for cases where multiple samples were collected at different times in the same day, a daily average concentration was calculated and used in this analysis in order to evenly weight each sampling day.

Non-detected values for both TSS and PCBs exist in the GE data set. Typically, when these results are used in a calculation, a value is substituted for the detection limit to estimate the concentration in the sample. Usually, either zero or one-half the detection limit is used in the substitution. In the data reviewed, GE did not provide a detection limit for TSS, and, in some instances, for PCBs. To determine the best estimate of the concentration in the non-detect TSS samples, a concentration of 0.5 mg/L TSS, one-half of the lowest detected TSS concentration, was assigned to the non-detect samples. To determine the best estimate of the concentration in the non-detect PCB samples, half of the reported detection limit for PCBs (5.5 ng/L) was assigned to PCB samples reported as non-detect from the laboratory.

The impact of resuspension on water column PCB concentrations is the focus of concern during the dredging operation. Some PCBs stored in the sediment will be introduced into the water column via resuspended particles. As a result, a change in the TSS concentration can be used as an indicator of a possible increase in the PCB concentration in the water column. There are currently no instruments capable of making reliable measurements of PCBs in-situ. Measurements of PCB concentration must be performed through laboratory analysis and measurement, which can take hours to perform. Due to the inability to obtain real-time PCB concentrations in the water column during dredging, TSS will be used as a surrogate indicator of dreging related releases and thereby PCB release also. Therefore, baseline conditions for both PCB and TSS concentrations were analyzed herein.

Review of the PCB and TSS data collected by GE since 1996 at the Ft. Edward, TID-West, TID-PRW2, and Schuylerville monitoring stations indicated the following:

- Variation exists among different months' data, and
- A single concentration could not be computed for TSS or PCB to represent the background concentration over the seven-month dredging period.

Based on the above, PCB and TSS data were analyzed starting on a monthly basis at each of the four monitoring stations. This monthly variation can be seen in Figures 3 and 4 for the Ft. Edward station; Figures 5 and 6 for the TID-West station; Figures 7 and 8 for the TID-PRW2 station; and in Figures 9 and 10 for the Schuylerville monitoring station.

An example of the data analysis performed for the monthly TSS and PCB data at the above-listed stations follows, using the results from the Schuylerville station.

Figure 11 depicts results from the weekly PCB and TSS water column samples collected at the Schuylerville monitoring station from 1996 through 2001, grouped by month (May through November). The mean TSS and PCB concentrations for each month were calculated and plotted to show the trend of the monthly concentrations. The data indicate that relatively high TSS and PCB concentrations were detected more frequently in May and June as compared to the rest of the study period. PCB data in May and June are distributed over a broader range than the data in the other dredging months. The mean TSS concentration fluctuates for the period of July through September, while the mean PCB concentration declines over that same period. In addition, October’s mean PCB concentration is greater than the mean PCB concentration for September and November.

The data strongly suggests that a single uniform TSS or PCB baseline value cannot be applied to every month. Similar analyses were performed for each of the data sets representative of the other three monitoring stations, and the same conclusion was drawn: that significant difference exists between the data collected at different times of the year, (for example, data collected during a spring month differ significantly from data collected during a summer month), and a uniform baseline value would not be representative of the range of conditions expected to be encountered during the dredging period. The baseline variability of the Hudson River should be addressed by a set of time-specific groupings of the available data in a reasonable way.

There are approximately 20 to 25 data points available for each month. A data group of a smaller size will not permit a reliable statistic analysis result, so one month is the smallest unit to group the data into for this analysis. In addition, it is physically meaningful to generate a baseline number for each month. Statistical analysis was conducted on each of the monthly datasets to determine whether or not it would be appropriate to group data for some months together. JMP (SAS, 1997), a statistical program, was used to perform the statistical analysis. This study included the following:

- Calculation of the minimum, mean, and maximum concentrations for each month

- Calculation of the 10 percent, 25 percent, 75 percent, and 90 percent quantiles

- Use of the Tukey-Kramer Honestly Significant Difference (HSD) to determine whether or not two sets of data are significantly different.

A sample plot for this study of TSS and PCB concentrations measured at the Schuylerville Station over the seven months of interest is shown in Figure 12. Generally speaking, this statistical study allowed months exhibiting insignificantly different means to be grouped. Circles for means that are significantly different either do not intersect or intersect slightly so that the outside angle of intersection is less than 90 degrees. If the circles intersect by an angle of more than 90 degrees, or if they are nested, the means are not significantly different. Figure 12 shows that TSS data for the period of July through November at the Schuylerville station are similar. Thus, data for these "similar" months can be consolidated into one dataset for further analysis to determine a baseline TSS concentration. Figure 12 also indicates that PCB data for the months of May and June are similar and can be consolidated into one dataset.

The studies performed on TSS and PCB data for the Ft. Edward, TID-West, and TID-PRW2 stations allowed the consolidation of several months of data into one dataset in the following cases:

- At the Ft. Edward station: consolidation of TSS data for September through November, and PCB data for July through September and October and November.

- At the TID-West station: consolidation of TSS data for July through October and PCB data for October and November.

- For the TID-PRW2 station: consolidation of TSS data for July through November and PCB data for the months of July and August.

The variability of monthly and consolidated monthly TSS and PCB data was analyzed based on interval estimates. Interval estimates are intervals that have a stated probability of containing the true population value. The intervals are wider for datasets having greater variability. There are two types of interval estimates: the prediction interval (PI) and the confidence interval. The prediction interval indicates the likelihood that a single data point with a specific magnitude comes from the population under study, while the confidence interval indicates the probability or likelihood that the interval contains the true population value. For each of the four monitoring stations, the prediction interval and the 95 percent confidence interval were estimated for each month and consolidated month dataset over the dredging period, since previous analysis of the data indicated that PCB and TSS concentration data varied.

Prediction intervals are computed for a different purpose than confidence intervals. The prediction interval deals with the individual data values as compared to a summary statistic such as the mean. A prediction interval is wider than the corresponding confidence interval because an individual observation is more variable than a summary statistic computed from several observations. Unlike a confidence interval, a prediction interval takes into account the variability of single data points around the median and mean, in addition to the error in estimating the center of the distribution.

In order to judge whether a new observation is likely to have come from the same distribution as previously collected data or, alternatively, from a different distribution, the prediction interval needs to be computed from the existing data and compared to the new observation. Prediction intervals contain 100*(1-a) percent of the data distribution, while 100*a percent are outside of the interval. If a new observation comes from the same distribution as previously collected data, there is a 100*a percent chance that it will lie outside the prediction level. Therefore, being outside of the interval does not "prove" that the new observation is different, just that it is likely to be so. Prediction intervals are used in this study as the upper bound limit for a single incident, and will be used as a baseline for comparison for a single sample result collected during the dredging operation. Sample results obtained during dredging falling above this upper bound limit (the prediction interval) will be assumed to represent some dredging-related release.

In addition to providing the prediction limit which provides an upper bound limit for individual samples, the confidence limit on the average was used as the second layer criterion to control the average of new observations. Therefore, if a group of samples are each below the prediction limit, but the average is above the upper confidence limit, it is likely that the group of samples belong to a different population than the baseline (*i.e.* indicative of dredging related releases).

Considering the possible impact of flow rate on PCB and TSS concentrations, correlations between PCB concentration and flow and between TSS concentration and flow were examined for the dredge season, either monthly or per consolidated set of dredging months, at each station. For each monitoring station, flow was plotted against PCB and TSS water column concentrations. Overall, no correlation was observed between TSS and flow at any of the four monitoring stations.

No correlation between PCB and flow was observed at the Ft. Edward monitoring station, but data indicated that correlations existed between PCB concentration and flow rate during the months of May and June at the TID-West and TID-PRW2 stations. Data for the Schuylerville station also indicated a correlation between PCB and flow for the months of May and June. Statistical data were indicative of these correlations based on a high r-squared value and an observed significant probability that was less than 0.05. The above-described correlations are presented in the following figures: TID-west station (Figure 13), TID-PRW2 station (Figure 14), and Schuylerville station (Figure 15).

For months where PCB data appeared to be correlated with the flow rate, JMP was used to estimate the center confidence and individual confidence of the data corresponding to different flows. The center confidence puts a confidence limit on the predicted central tendency, and the individual confidence interval includes both the variability of the estimates and the variability of the observation itself and is thus appropriate for a prediction interval. The JMP program was able to compute these values while performing a regression analysis between two correlated variables. The lower 95 percent confidence interval is not presented in these plots, since only the upper bound estimates were of interest in this study.

Fit curves estimating the center confidence and individual confidence of the data were generated for the PCB monthly data at the TID-West, TID-PRW2, and Schuylerville monitoring stations for months in which the data indicated a correlation between PCB concentration and flow rate. These fit curves are shown in Table 1. For stations with a defined timeframe where PCBs are correlated with flow, the flow rate was applied to the listed formulas and fit curves to determine the baseline PCB concentration, the prediction interval, and the UCL at different flows. Velocities of 2000 cfs, 4000 cfs, and 8000 cfs were used to calculate the baseline levels, representing the lower bound flow, the average flow, and the upper bound flow, respectively, during dredging operations.

For the monthly and consolidated monthly datasets where a correlation between flow and concentration was not observed, the prediction interval and UCL were estimated solely based on the concentration data.

The upper bound prediction interval was estimated using methods provided by Helsel and Hirsch (Helsel and Hirsch, 2002). Three methods were used to calculate the upper 95th prediction interval on each of the datasets. These methods were the parametric symmetric prediction interval, the parametric asymmetric prediction interval, and the nonparametric prediction interval. Because the goal of this study was to determine the upper bound level of existing data, a one-side prediction interval was applied in all three methods. The nonparametric prediction interval does not require the data to follow any particular distribution shape, while the symmetric prediction interval is calculated based on the assumption that the data follow a normal distribution. The following formula, Equation 12, is used to compute the symmetric prediction interval:

$$PI = \overline{X} + t(0.05, n-1) \cdot \sqrt{s^2 + (s^2 / n)} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{Equation 12}$$

where PI = the upper bound of the prediction interval

$\overline{X}$ = the mean value of the data set (mean concentration for the TSS and PCB data sets)
t = the student's t for alpha equal to 0.05 and n-1 degrees of freedom
s^2 = the variance of the data set
n = number of data points

The parametric asymmetric prediction interval assumes that the data follows a lognormal distribution, and the prediction interval is computed using the formula shown in Equation 13.

$$PI = \exp(\overline{y} + t(0.05, n-1) \cdot \sqrt{s_y^2 + s_y^2 / n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \textit{Equation 13}$$

where y = ln(x), $\overline{y}$ is the mean and s_y^2 is the variance of the logarithms

$\overline{y}$ = the mean logarithm
s^2_y =the variance of the logarithms
n = number of data points

t = the student’s t for alpha equal to 0.05 and n-1 degrees of freedom

The non-parametric prediction interval is computed from statistical analysis of the data and is representative of the 95th percentile of the dataset.

Similarly, three methods were used to estimate the upper bound confidence interval for each dataset based on the distribution of the data. The following formula, Equation 14, was used to compute the 95 percent UCL on datasets exhibiting a normal distribution:

$$UCL = \overline{X} + t\ (s/\sqrt{n}) \qquad \text{……………………………………………} \textit{Equation 14}$$

where $\overline{X}$ = arithmetic mean of the sample data set for the compound of concern,
s = sample standard deviation of the sample data set for the compound of concern,
t = the student’s t statistic for the 95 percent confidence interval for a one tailed distribution. The t-statistic is a function of the number of samples collected, and;
n = number of samples in the data set

For data sets that exhibited a lognormal distribution, the 95 percent UCL was computed using Equation 15, shown below.

$$UCL = EXP\ [\ \overline{X} + 0.50s2 + Hs/\sqrt{n-1}\ ] \qquad \text{……………………………………} \textit{Equation 15}$$

where X = arithmetic average of the natural log-transformed data;
s^2 = variance of the log-transformed data;
s = sample standard deviation of the log-transformed data;
H = H statistic. The H value differs from the t-values because the formula is designed to estimate the UCL on the basis of the log-transformed data. H is a function of the standard deviation of the log-transformed data and the number of samples in the data set. H was taken from a standard table of calculated values (Gilbert, 1987) or linearly interpolated between values given in the table where necessary; and
n = the number of samples in the data set.

For non-parametric data sets, the 95 percent UCL was calculated using ProUCL (USEPA, 2001). ProUCL does provide several types of non-parametric UCLs. As recommended in the User’s Guide for ProUCL, the 95 percent Chebyshev UCL was selected for this analysis since all of the datasets that were neither normally distributed nor lognormally distributed had a standard deviation (σ) less than 1.

The Shapiro-Wilk test (W-test) and D'Agostino's test were used to determine the best data relationship among each of the monthly data sets for all four stations so the prediction interval and the 95 percent UCL could be calculated, based on the determined distribution of the data, using one of the above-listed equations. For months in which the number of samples was less than 50 (n<50), the W-test was used to evaluate the distribution of the dataset. For months in which the number of samples was greater than 50 (n>50), D'Agostino's Test was used to evaluate the distribution of the dataset.

The W-test generates a W-value and an ln-W value, which are then compared to the 5 percent W critical value. If the calculated W-value is greater than this critical value, the distribution is determined to be normal at the 5 percent confidence level. Similarly, if the computed ln-W value is greater than the critical value, then the data distribution is determined to be lognormal. In the event that the computed W-value and ln-W value are both greater than the critical value, the larger computed value (i.e., the W-value or the ln-W value) will determine the data distribution. If both of the computed values (i.e., the W-value and the ln-W value) are less than the critical W value, then the distribution is determined to be non-parametric.

For monthly and consolidated monthly datasets with more than 50 samples, D’Agostino’s test was used to compute a Y-value and an ln-Y value, which are then compared to a range of set critical values. The distribution is considered to be normal when the calculated Y-value is within the range of critical Y-values. The data set is determined to be lognormal when the ln-Y value is within the range of critical ln-Y values. If the computed Y-value and ln-Y value satisfy both the normal distribution and lognormal distribution requirement, then the value representing the smallest absolute value of Y dictates the data distribution. Lastly, if the Y-value and ln-Y-value do not meet the criteria that are indicative of normal or lognormal distribution, then the data set is determined to be non-parametric.

For monthly and consolidated monthly datasets determined to have a normal distribution of data, the prediction interval and the 95 percent UCL were computed from Equations 12 and 14, respectively, to determine the baseline concentrations for TSS and PCB at each station. Similarly, for monthly and consolidated monthly datasets determined to have a lognormal distribution of data, the prediction interval and the 95 percent UCL were computed from Equations 13 and 15, respectively, to determine the baseline concentrations for TSS and PCB at each station. Lastly, as described above, the 95th percentile of the dataset was computed to determine the prediction interval baseline, and ProUCL was used to determine the 95 percent UCL baseline for months and consolidated months where the data were distributed in a non-parametric relationship.

These statistical tests were performed for each of the seven dredging months and consolidated dredging months at each of the four monitoring stations. The results are presented in Table 2, and were indicative of the following at each of the monitoring stations:

- A prediction interval baseline for PCB and TSS per month and consolidated months

- A 95 percent UCL baseline for PCB and TSS per month and consolidated months

The results for each monitoring station are included below, along with a discussion of the estimated baseline concentrations for the dredging season. Ultimately, these baselines will be compared against PCB and TSS measurements made during dredging operations to assess potential dredging-related impacts.

Note that only the samples associated with high flow events were excluded during the data analysis procedure. No data were excluded as outliers. Some elevated values found in the dataset are representative of values that could occur during the remediation, thereby making it inappropriate to treat them as outliers, although in a strict mathematical sense the values might fall into that category. This analysis is also intended to show the approach used to estimate the baseline. The final baseline values will be calculated using Baseline Monitoring Program data, which is scheduled for collection between 2004 and 2005. When the baseline data is available, some outlier analysis methods, such as Dicson analysis and Mahanalobis Distance, may be used to identify the outliers based on engineering judgment in order to provide a baseline level for addressing the Hudson River condition prior to dredging.

For the datasets in which PCBs were determined to be correlated with flow, the prediction interval and UCL of the PCB concentration were estimated using the same method that was used for datasets where concentration is not correlated with flow. The prediction interval and UCL values generated by this method are similar to the results obtained assuming a flow of 4000 cfs and using the equations listed in Table 1. A flow rate of 4000 cfs is assumed to be the average velocity that will be observed during the dredging period. Therefore, the values generated by this simple (no flow involvement) method adequately reflect the PCB concentration under the average river flow conditions.

It was also found that the estimated prediction interval and UCL values calculated for velocities of 2000 cfs and 8000 cfs were approximately within 20 percent of the values calculated for a velocity of 4000 cfs. The 20 percent variance is not a pronounced difference when considering other uncertainties involved in the analysis.

Lastly, it was thought that the measurement of the flow rate and application of the above formulas may be impractical tasks for the dredging operator to perform in the field in order to determine the PCB concentration. A developed baseline with PCB concentrations defined for each month and set of months over the dredging season would be the easiest and the most practical method for field application. It was concluded that the baseline levels (prediction interval and UCL) are all estimated based on the assumption that there is no correlation between flow and concentrations. The flow-independent prediction interval and UCL values are calculated and summarized in Table 2 for each month and consolidated months at each station.

It should be noted that all the analyses listed above are intended to demonstrate the approach used to estimate the baseline. When the new baseline data is available, the same type of analyses will be conducted, and the results may suggest some ways to simplify the process. The baseline level will be finalized based on both the new baseline level data and historic data.

3.2 Results and Discussion

Ft. Edward Monitoring Station

Water quality data for TSS were analyzed individually for May, June, July, and August, and jointly over the period of September through November. PCB data were analyzed individually for May and June, jointly over the period of July through September, and jointly over the period of October and November. These results are shown on Table 2.

As shown in Table 2, data collected for TSS during the months of May, July, and September through November have a normal distribution. In contrast, the data collected for TSS during the month of June has a non-parametric distribution and that collected for August has a lognormal distribution.

Figure 16 indicates that the prediction interval baseline generally tends to correspond to the maximum measured TSS concentration for a particular month, with the exception of months where elevated TSS data points exist. June and August each have one TSS data point that contains one TSS sample result that is more than twice the concentration of all other TSS results obtained for these months. For these two instances, the prediction interval baseline and the 95 percent UCL are representative of the majority of the data. It should also be noted that the 95 percent UCL is greater than the prediction interval for the month of June. However, for all other months, the prediction interval represents the upper limit TSS baseline concentration.

The prediction interval baseline is highest in August, with a concentration of 5.5 mg/L. In the months prior to August, the prediction interval is approximately 4.0 mg/L, on average, while for the remainder of the dredging season, in the months of September through November, the prediction interval decreases to 3.0 mg/L and levels out. The 95 percent UCL baseline follows the same seasonal distribution as the prediction interval, but reaches a maximum concentration of 5.7 mg/L in June. This baseline then decreases by 3 mg/L and fluctuates through July and August, eventually leveling out at 1.8 mg/L during the period of September through November.

The estimated 95 percent UCL baseline for TSS appears to be consistent with the mean TSS data concentration for each month, and the estimated prediction interval appears to be consistent with the upper bound measured TSS concentration for each month, with the exception of June and August where two outlying TSS concentrations exist (as previously discussed). It can be concluded that if a single TSS measurement made during dredging is greater than the prediction interval concentrations, or if the average of a set quantity of measured samples are greater than the 95 percent UCL baseline, the measured TSS concentration is most likely a result of the dredging operation.

An analysis of total PCB data collected during the proposed dredging season at the Ft. Edward monitoring station indicated that all data were representative of a non-parametric distribution. The results are presented in Table 2. The estimated baselines were plotted against the total PCB monthly datasets. These relationships are presented in Figure 17.

Figure 17 indicates that total PCB concentrations measured for this station were greatest in the months of July through August, and that the lowest concentrations were measured during the month of May. Data indicate that the estimated prediction interval baseline corresponds to the upper bound total PCB concentrations measured each month. The prediction interval baseline is the highest for total PCBs during the months of July through September, and lowest total PCB concentration during the month of May. The prediction interval baseline decreases by 15 ng/L from September to October and levels out at 19 ng/L for the period of October through November. It can be concluded that any PCB measurements with a concentration greater than the prediction interval can most likely be attributed to dredging.

The 95 percent UCL baseline result per month is always less than the prediction interval baseline result, and tends to correspond to the mean total PCB concentration per month, as shown in Figure 17. This lowest baseline concentration on the curve occurs during the month of May and the maximum concentration occurs during the month of June. Baseline values occur during the months of July through September, and are lower in concentration than the maximum estimated concentration by approximately 0.4 ng/L. The 95 percent UCL baseline concentration decreases to 10.4 ng/L in October, a result that is 8 ng/L less than the September level. This concentration remains constant during the months of October and November. It can be concluded that if the average of the PCB measurements reported during dredging activities exceeds the 95 percent UCL, it is most likely attributable to the dredging operation.

Thompson Island Dam (TID) Monitoring Stations

There are two GE monitoring stations located at the TI Dam: TID–West, located on the west side of the TI Dam near the shore, and TID-PRW2, located in the channel section of the river near the dam. TSS and total PCB monthly data and consolidated monthly data were analyzed for each of these stations. Subsequently, the prediction interval and the 95 percent UCL baseline were determined for each station’s monthly and monthly consolidated TSS and total PCB data.

TID-West Monitoring Station

As shown in Table 2, TSS data analyzed at the TID-West station exhibited a non-parametric relationship for May and June. A lognormal relationship was determined for consolidated monthly data representing the period July through October and also for the month of November. The estimated prediction interval and 95 percent UCL are shown in Figures 18 and 19.

Figure 18 compares the monthly TSS data at the TID-West station with the estimated prediction interval baseline and the estimated 95 percent UCL baseline. This figure depicts that the prediction interval baseline is always greater than the 95 percent UCL baseline and tends to follow the maximum measured TSS concentration reported for each dredging month. Exceptions to this conclusion exist during months where elevated TSS concentrations exist, in this case May, June, July, and August. In these instances, the prediction interval baseline tends to correspond to a data point midway between the majority of the sample results and the elevated data point (i.e., the prediction interval tends to fall at a data point consistent with the maximum concentration of samples, excluding the outlier for these months). The maximum TSS prediction interval baseline value occurs during the month of May. This baseline decreases through June to approximately 5 mg/L during the month of July. The baseline remains level until October, and then increases slightly to 6.4 mg/L during the month of November.

The 95 percent UCL baseline shown in Figure 18 tends to follow the mean TSS concentration in each dredging month, with a maximum estimated concentration occurring in May and June and a minimum concentration occurring during the months of July through October.

The total PCB data reported for this station follow a lognormal distribution for May, June, August, and September. Total PCB data reported for July were determined to follow a normal distribution, and total PCB data for the period of October through November were determined to represent a non-parametric relationship.

As shown in Figure 19, the estimated prediction interval baseline consists of total PCB concentrations greater than those estimated for the 95 percent UCL baseline. The prediction interval maximum total PCB result occurs during the months of May and June, with a total PCB concentration of approximately 370 ng/L. The prediction interval baseline then decreases through July (211 ng/L) and August (150 ng/L), and reaches a minimum value of 120 ng/L during the month of September. During the months of October and November, the prediction interval baseline total PCB concentration increases to 300 ng/L. It was also noted that the prediction interval tends to be consistent with the maximum total PCB data concentration reported for each dredging month, on average.

The estimated 95 percent UCL baseline for total PCBs at the TID-West station tends to correspond with the mean total PCB concentration for most dredging months, on average. This can be seen in Figure 19. This baseline concentration is approximately 200 ng/L from May to June, and decreases through July (150 ng/L) and August (106 ng/L). The baseline reaches a minimum concentration of 83 ng/L in September, and then increases to a maximum concentration of 241 ng/L during the period of October and November. It is noted that the 95 percent UCL baseline follows the same seasonal variation as the estimated prediction interval baseline.

TID-PRW2 Monitoring Station

TSS data collected at this station exhibited a lognormal distribution for the month of May and for the period of July through November. Data indicated a non-parametric distribution for the month of June.

Figure 20 shows that the estimated prediction interval baseline tends to generally correspond with the maximum monthly TSS concentration for all months, with the exception of May, June, July, and August, where elevated TSS data exist. In these instances, the estimated prediction interval tends to represent the maximum TSS concentration associated with the majority of the data points. The prediction interval baseline concentration reaches a maximum during the month of June (15 mg/L) and decreases to 5 mg/L for the months of July through November.

The estimated 95 percent UCL baseline for TSS, shown in Figure 20, tends to correspond with the monthly mean TSS concentration for all months, with the exception of May and June. The baseline reaches a maximum during June (14 mg/L TSS), and decreases to a concentration of 2 mg/L for the months of July through November.

The total PCB data indicated that the months of May, June, October, and November all exhibited a normal data distribution, and that the datasets for the consolidated months of July and August and the month of September each exhibited a lognormal data distribution.

Figure 21 indicates that the estimated prediction interval fluctuates throughout the proposed dredge season, with a minimum concentration in May and June and a maximum concentration through the period of July and August. The estimated total PCB concentration in September and November are just above the minimum estimated concentration in May and June, but less than the estimated baseline value for the month of October. For most months, with the exception of May and June, the estimated prediction interval baseline tends to correspond with the maximum monthly total PCB concentration. This relationship is not observed during May and June because the total PCB concentration tends to vary with the flow rate. The prediction interval was estimated for a low flow condition of less than 5,000cfs and for a high flow condition greater than 5,000cfs. A greater range of PCB concentrations is evident during May and June. Additionally, Figure 21 indicates that the prediction interval baseline varies during May and June, and that low flow conditions result in a 100-ng/L PCB increase in the water column. It was noted that while the estimated prediction interval value for May and June shown is representative of a flow rate greater than 5,000 cfs, the prediction interval baseline data point is representative for a flow rate less than 5,000 cfs. This is also indicated in Table 2.

The estimated total PCB 95 percent UCL baseline follows the same seasonal trend as the estimated prediction interval baseline. This relationship is presented in Figure 21. The minimum estimated 95 percent UCL baseline concentration of approximately 45 ng/L occurs during May and June. However, under low flow conditions, this value could increase by almost 60 ng/L. This data point is shown on Figure 21. The maximum total PCB 95 percent UCL baseline value of 70 ng/L occurs during July and August. The 95 percent UCL baseline for total PCBs then decreases to 50 ng/L in September, increases to 65 ng/L in October, and decreases during the month of November to a total PCB concentration of 45 ng/L. Generally, the total PCB 95 percent estimated UCL baseline tends to correspond with the mean total PCB concentration for each month.

Schuylerville Monitoring Station

Monthly TSS data for the Schuylerville monitoring station was determined to have a lognormal distribution for May and for the period July through November. As indicated in Figure 22, the prediction interval TSS baseline concentration in May is approximately 7 mg/L, and increases to its maximum value of 11 mg/L during the month of June. The estimated prediction interval baseline then decreases to a TSS concentration of approximately 5 mg/L, where it remains for the period of July through November.

The estimated TSS 95 percent UCL baseline for Schuylerville follows the same seasonal trend as the estimated prediction interval, as shown in Figure 22. The estimated 95 percent UCL baseline reaches a maximum TSS concentration of approximately 10 mg/L during the month of June, and then decreases to a constant TSS concentration of 2 mg/L for the period July through November, representative of the minimum estimated 95 percent UCL baseline TSS concentration.

Total PCB results indicate that data collected for May, June, August, September, and November exhibit a lognormal distribution, and that the total PCBs dataset for the month of July exhibits a non-parametric distribution. Data for the month of October exhibit a normal data distribution.

As shown in Figure 23, both the estimated prediction interval and the 95 percent UCL baseline for total PCBs have a maximum concentration during the months of May and June. Both estimated total PCB baselines then fluctuate through the remainder of the proposed dredge season, with a minimum baseline value for both baseline curves occurring during the month of September and corresponding to a total PCB concentration of 85 ng/ L total PCBs (prediction interval) and 60 ng/L total PCBs (95% UCL baseline). As noted previously at other monitoring stations, the prediction interval baseline tends to be consistent with the maximum monthly total PCB concentration. Except for the months of May and June, the 95 percent UCL baseline tends to be consistent with the mean monthly total PCB concentration.

4.0 References

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Tables

Table 1. PCB versus Flow Correlation Analysis Based on the Fit Curve Generated from Plot

	May and June at TID W	May and June Low Flow (<5000 cfs) at TID PRW2	May and June at Schuylerville
Fit curve	Y = 283.23 - 0.026946x	Y = 186.82 - 0.030192x	Y = 176.19 - 0.012506x
Lower 95% Confidence Limit	Y = 246.5 - 0.015*x - 1.51E-6*x^2	Y = 144 - 8.73E-3*x - 3.56E-6*x^2	Y = 151.16 - 6.97E-3*x - 4.93E-7*x^2
Upper 95% Confidence Limit	Y = 386.95 - 0.0474*x + 1.51E-6*x^2	Y = 229.64 - 5.17E-2*x + 3.56E-6*x^2	Y = 201.22 - 1.80E-2*x +4.93E-7*x^2
Upper 95% Individual Limit	Y = 522.19 - 0.0342*x + 2.85E-7*x^2	Y = 242.14 - 3.72E-2*x + 1.18E-6*x^2	Y = 234 - 0.0138*x + 1.16E-7*x^2

Notes:
Y = PCB concentration
X = Flow (cfs)

Table 2
Statistics Results and Baseline Level of TSS and PCB Concentration at Upper Hudson River Monitoring Stations

	Fort Edward								
	TSS (mg/L)					PCB (ng/L)			
Parameter	May	June	July	August	Sept thru Nov	May	June	July thru Sept.	Oct. & Nov.
n	17	22	21	20	60	25	30	79	48
Minimum Detected	0.5	0.5	0.5	0.5	0.5	5.50	5.50	5.50	5.50
Maximum Detected	4.1	16	4.1	9.3	3.3	18.31	31.41	55.51	21.88
Arithmetic Mean	2	3	2	2	2	9	13	13	8
Standard Deviation	1	3	1	2	1	5	8	11	4
Median	1.9	2.2	2.2	1.95	1.6	5.5	14	12	6
W-Test (n<=50)									
W	0.920	0.429	0.936	0.648		0.657	0.862		0.531
W-LN	0.872	0.783	0.825	0.927		0.641	0.829		0.535
Critical W	0.892	0.911	0.908	0.905		0.918	0.927		0.947
D'Agostino's Test (n>50)									
Y	-1.79	-19.20	-0.20	-10.67	-0.25	-7.33	-1.49	-12.20	-19.66
Yln	-2.19	-8.70	-2.69	-3.16	-1.91	-7.33	-1.15	-3.82	-18.28
UCL 95%	2.2	5.7	2.4	3.1	1.8	12.7	19.7	18.6	10.4
UCL 95% Lognormal	2.6	3.6	3.0	3.1	1.9	10.3	17.3	15.5	8.3
UCL 95% Normal	2.2	4.0	2.4	3.1	1.8	10.2	15.8	15.4	8.6
LCL 95%	1.4	2.2	1.7	1.9	1.4	6.9	10.9	11.6	6.7
LCL 95% Lognormal	1.4	2.2	1.7	1.9	1.4	7.2	11.2	11.6	6.7
LCL 95% Normal	1.4	1.8	1.7	1.7	1.4	6.9	10.9	11.5	6.5
Data Distribution (Normal, Lognormal or non-parametric)	Normal	non-parametric	Normal	Lognormal	Normal	non-parametric	non-parametric	non-parametric	non-parametric
95th percentile	0.5	1.6	3.2	3.7	3.1	16.9	27.7	34.3	19.1
Prediction Interval (Normal)	3.4	8.2	3.9	5.6	3.0	16.8	27.1	31.1	15.1
Prediction Interval (LogNormal)	4.6	6.5	5.8	5.6	3.9	17.5	33.1	32.9	14.0
Prediction interval	3.4	4.2	3.9	5.6	3.0	16.9	27.7	34.3	19.1

Table 2 (cont'd)
Statistics Results and Baseline Level of TSS and PCB Concentration at Upper Hudson River Monitoring Stations

	TID West									
	TSS (mg/L)				PCB (ng/L)					
Parameter	May	June	July thru Oct.	Nov.	May	June	July	August	Sept.	Oct. & Nov.
n	17	24	90	22	24	32	30	29	27	54
Minimum Detected	1.20	1.40	0.50	0.50	24.5	60.1	65.52	49.02	40.00	25.82
Maximum Detected	26.00	36.00	6.50	6.70	813.6	413.4	219.45	164.00	126.25	1424.00
Arithmetic Mean	4	5	2	2	127.6	169.1	138	96	75	127
Standard Deviation	7	7	1	1	160.3	85.8	43	27	22	193
Median	2	3	1	2	81.0	156.5	135	92	73	88
W-Test (n<=50)										
W	0.514	0.454		0.892	0.6	0.9	0.961	0.931	0.962	
W-LN	0.780	0.823		0.930	1.0	0.9	0.943	0.973	0.980	
Critical W	0.892	0.916		0.911			0.927	0.926	0.923	
D'Agostino's Test (n>50)										
Y	-13.07	-18.63	-11.94	-2.89	-14.2	-0.8	0.76	-2.38	-0.42	-34.51
Yln	-4.84	-5.48	-2.12	-1.37	-0.7	0.8	0.10	-1.35	0.18	-8.09
UCL 95%	11.5	11.5	1.9	3.3	181.3	205.3	150.9	105.8	83.1	241.4
UCL 95% Lognormal	6.6	6.2	1.9	3.3	181.3	205.3	154.9	105.8	83.1	134.8
UCL 95% Normal	7.2	7.5	1.8	2.9	183.6	194.8	150.9	104.9	81.9	170.9
LCL 95%	2.6	3.4	1.5	1.9			124.3	88.8	68.2	97.7
LCL 95% Lognormal	2.6	3.4	1.5	1.9	90.5	146.0	124.9	88.8	68.2	97.7
LCL 95% Normal	1.6	2.4	1.4	1.8	71.5	143.4	124.3	88.0	67.6	82.8
Data Distribution (Normal, Lognormal or non-parametric)	non-parametric	non-parametric	Lognormal	Lognormal			Normal	Lognormal	Lognormal	non-parametric
95th percentile	18.8	15.5	3.6	4.3	264.1	280.6	202.2	151.1	113.7	297.4
Prediction Interval (Normal)	16.4	17.8	3.5	4.9	407.9	316.8	211.6	142.7	112.3	453.4
Prediction Interval (LogNormal)	12.6	12.2	3.9	6.4	367.8	368.3	233.3	148.7	119.2	272.1
Prediction interval	18.8	15.5	3.9	6.4	367.8	368.3	211.6	148.7	119.2	297.4

Table 2 (cont'd)
Statistics Results and Baseline Level of TSS and PCB Concentration at Upper Hudson River Monitoring Stations

	TID PRW								
	TSS (mg/L)			PCB (ng/L)					
Parameter	May	June	July thru Nov.	May&June Low Flow (<5000 cfs)	May&June High Flow (>5000 cfs)	July and August	Sept.	Oct.	Nov.
n	14	13	75	19.0	21	40	19	23	20
Minimum Detected	0.50	1.80	0.50	32.0	15.58	28.30	26.20	23.24	20.00
Maximum Detected	24.80	29.50	6.60	166.4	67.05	141.76	65.44	93.26	64.28
Arithmetic Mean	4	5	2	96.8	42	65	44	57	40
Standard Deviation	6	7	1	35.8	15	21	13	20	14
Median	2	3	2	107.1	41	62	44	55	39
W-Test (n<=50)					3.707150762				
W	0.468	0.434		1.0	0.968	0.936	0.929	0.970	0.943
W-LN	0.896	0.729		0.9	0.914	0.992	0.934	0.937	0.924
Critical W	0.874	0.866			0.908	0.940	0.901	0.914	0.905
D'Agostino's Test (n>50)									
Y	-13.66	-13.99	-10.21	0.2	0.14	-2.85	0.43	0.32	0.50
Yln	-3.26	-6.17	-1.73	-0.9	-1.50	-0.41	0.58	-0.79	0.12
UCL 95%	6.5	14.0	2.2	111.1	47.1	70.9	50.1	64.2	45.4
UCL 95% Lognormal	6.5	7.4	2.2	118.9	50.2	70.9	50.1	67.3	47.5
UCL 95% Normal	6.7	8.7	2.1	111.1	47.1	70.3	48.9	64.2	45.4
LCL 95%	2.2	3.2	1.6		36.0	59.4	39.1	50.2	34.4
LCL 95% Lognormal	2.2	3.2	1.6	83.5	36.2	59.4	39.1	50.6	34.9
LCL 95% Normal	0.9	1.4	1.6	82.6	36.0	58.8	38.6	50.2	34.4
Data Distribution (Normal, Lognormal or non-parametric)	Lognormal	non-parametric	Lognormal		Normal	Lognormal	Lognormal	Normal	Normal
95th percentile	12.0	15.0	4.5	148.1	64.0	93.5	64.0	86.3	61.4
Prediction Interval (Normal)	15.1	18.8	4.1	160.5	67.6	101.2	66.7	91.6	65.0
Prediction Interval (LogNormal)	11.7	13.1	4.6	189.6	80.2	106.4	71.8	104.9	73.5
Prediction interval	11.7	15.0	4.6	160.5	67.6	106.4	71.8	91.6	65.0

Table 2 (cont'd)
Statistics Results and Baseline Level of TSS and PCB Concentration at Upper Hudson River Monitoring Stations

	Schuylerville								
	TSS (mg/L)			**PCB (ng/L)**					
Parameter	May	June	July thru Nov.	May and June	July	August	Sept.	Oct.	Nov.
n	10	12	74	34.0	19	21	17	23	22
Minimum Detected	1.60	2.00	0.50	43.0	61.00	50.18	26.30	34.94	38.94
Maximum Detected	8.00	17.50	7.80	211.3	157.18	107.00	78.22	111.64	105.25
Arithmetic Mean	3	5	2	106.5	82	74	52	75	67
Standard Deviation	2	4	1	41.7	20	17	15	24	20
Median	3	3	2	94.9	81	71	49	75	63
W-Test (n<=50)									
W	0.739	0.548		0.9	0.694	0.953	0.948	0.936	0.933
W-LN	0.909	0.813		1.0	0.830	0.971	0.955	0.881	0.965
Critical W	0.842	0.859			0.901	0.908	0.892	0.914	0.911
D'Agostino's Test (n>50)									
Y	-5.08	-10.41	-12.01	-0.5	-9.00	0.04	0.10	0.13	-0.56
Yln	-1.63	-4.31	-1.52	0.6	-5.09	0.59	-0.10	-1.48	0.24
UCL 95%	4.4	9.9	2.2	121.3	102.7	80.6	60.1	83.8	75.2
UCL 95% Lognormal	4.4	6.5	2.2	121.3	89.5	80.6	60.1	88.0	75.2
UCL 95% Normal	4.3	6.8	2.1	118.6	90.3	79.9	58.5	83.8	74.1
LCL 95%	2.5	3.4	1.6		75.8	67.9	46.4	66.5	60.4
LCL 95% Lognormal	2.5	3.4	1.6	95.5	75.8	67.9	46.4	66.8	60.4
LCL 95% Normal	2.1	2.5	1.6	94.4	74.0	67.4	45.8	66.5	59.6
Data Distribution (Normal, Lognormal or non-parametric)	Lognormal	non-parametric	Lognormal	Lognormal	non-parametric	Lognormal	Lognormal	Normal	Lognormal
95th percentile	6.1	10.8	4.4	175.9	98.7	105.0	73.7	108.2	40.0
Prediction Interval (Normal)	6.7	12.4	4.2	178.1	118.7	103.1	79.1	117.6	101.6
Prediction Interval (LogNormal)	7.0	10.8	4.7	194.6	115.9	106.7	85.5	135.7	107.2
Prediction interval	7.0	10.8	4.7	194.6	98.7	106.7	85.5	117.6	107.2

Figures

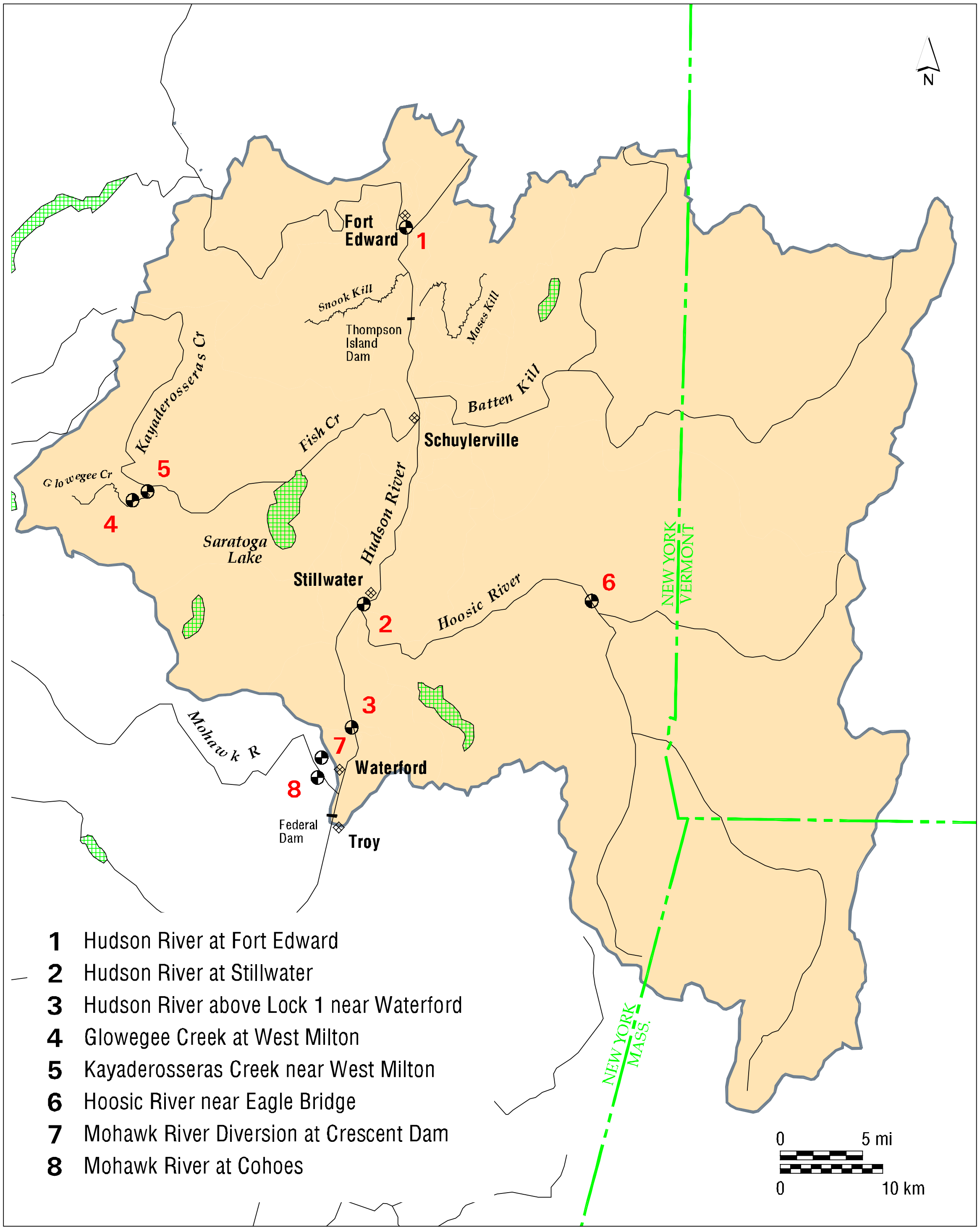


Figure 1. Upper Hudson River Basin USGS Flow Gage Stations Used in HUDTOX Modeling.

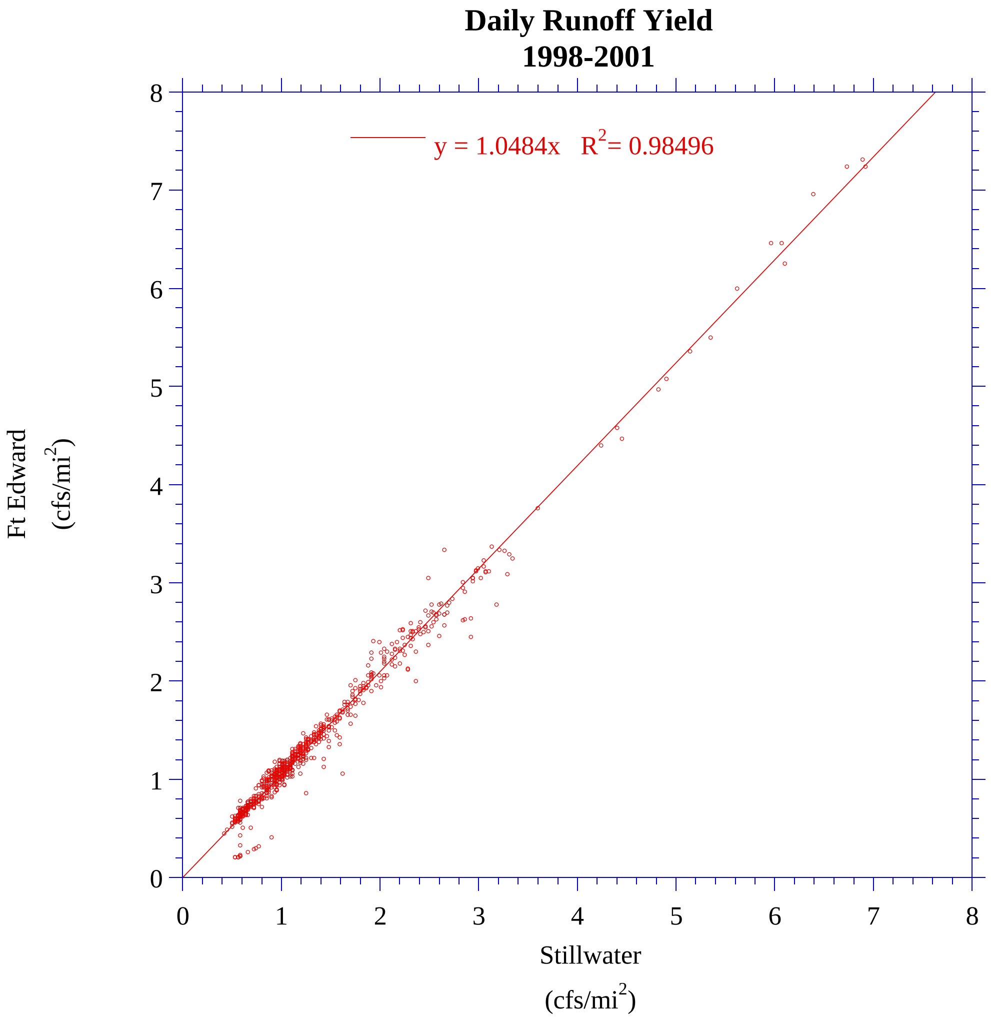


Figure 2. Stillwater versus Ft. Edward Daily Runoff Yield 1998-2001

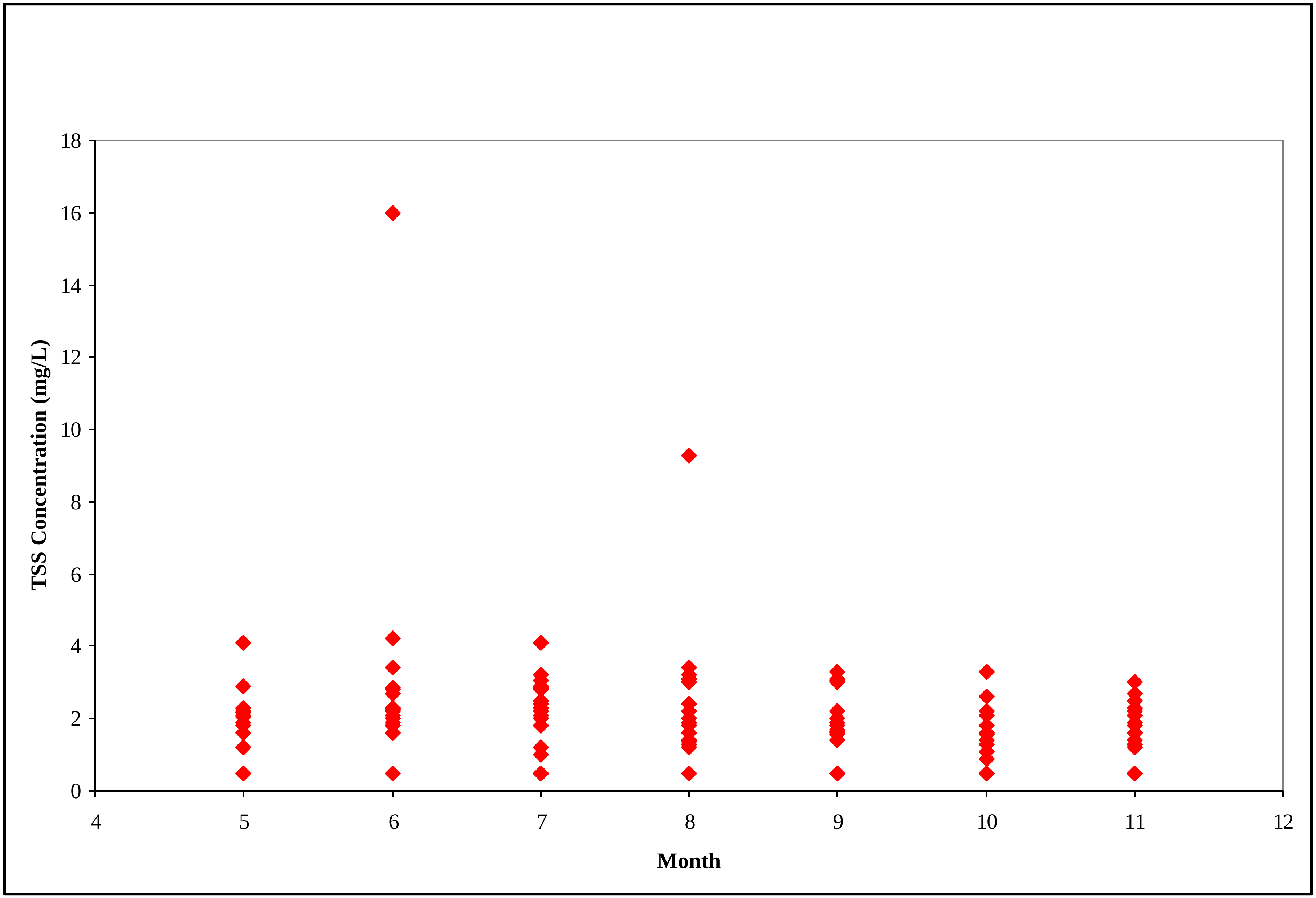


Figure 3. Fort Edward Station Monthly TSS Concentration Variation

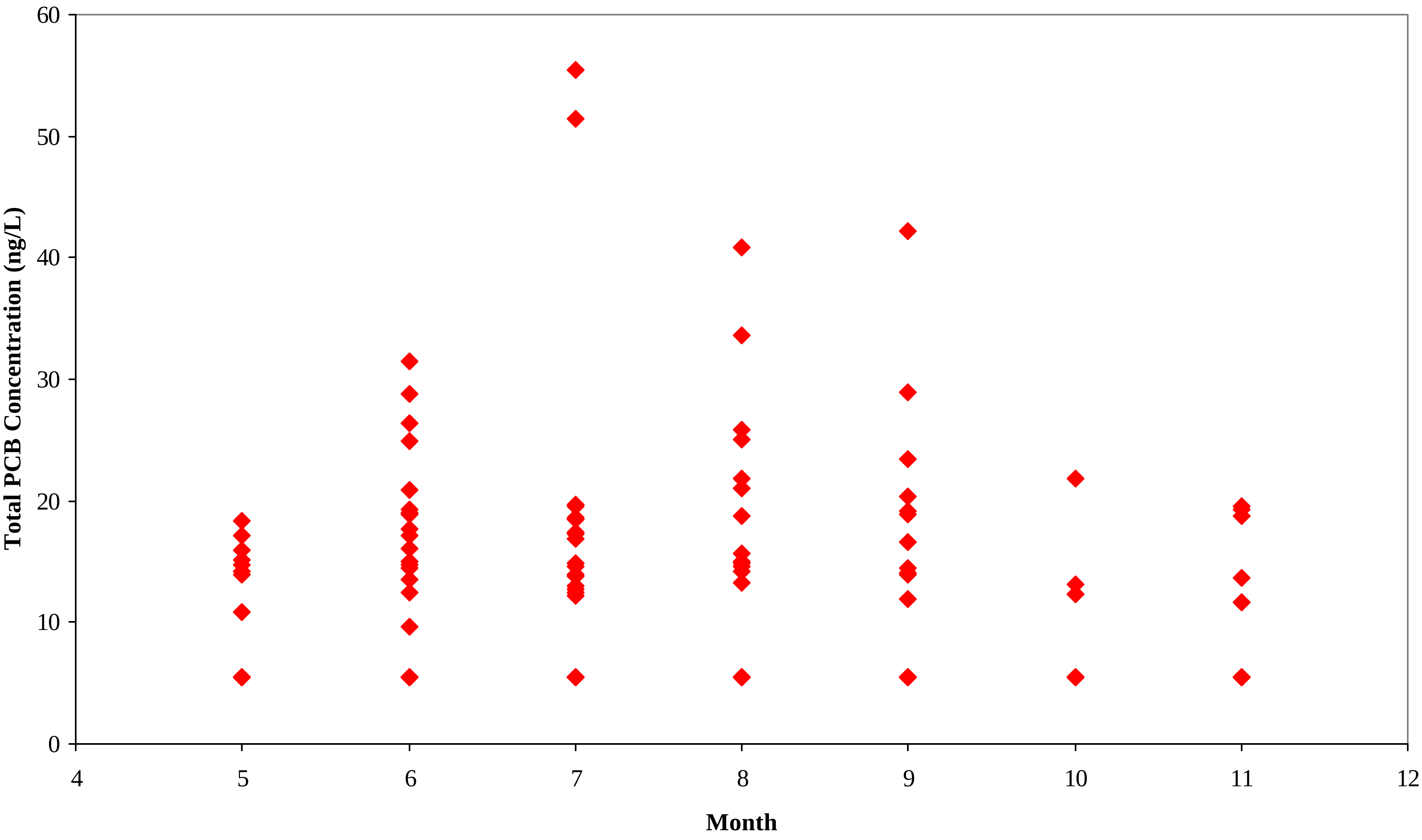


Figure 4. Fort Edward Station Monthly PCB Concentration Variation

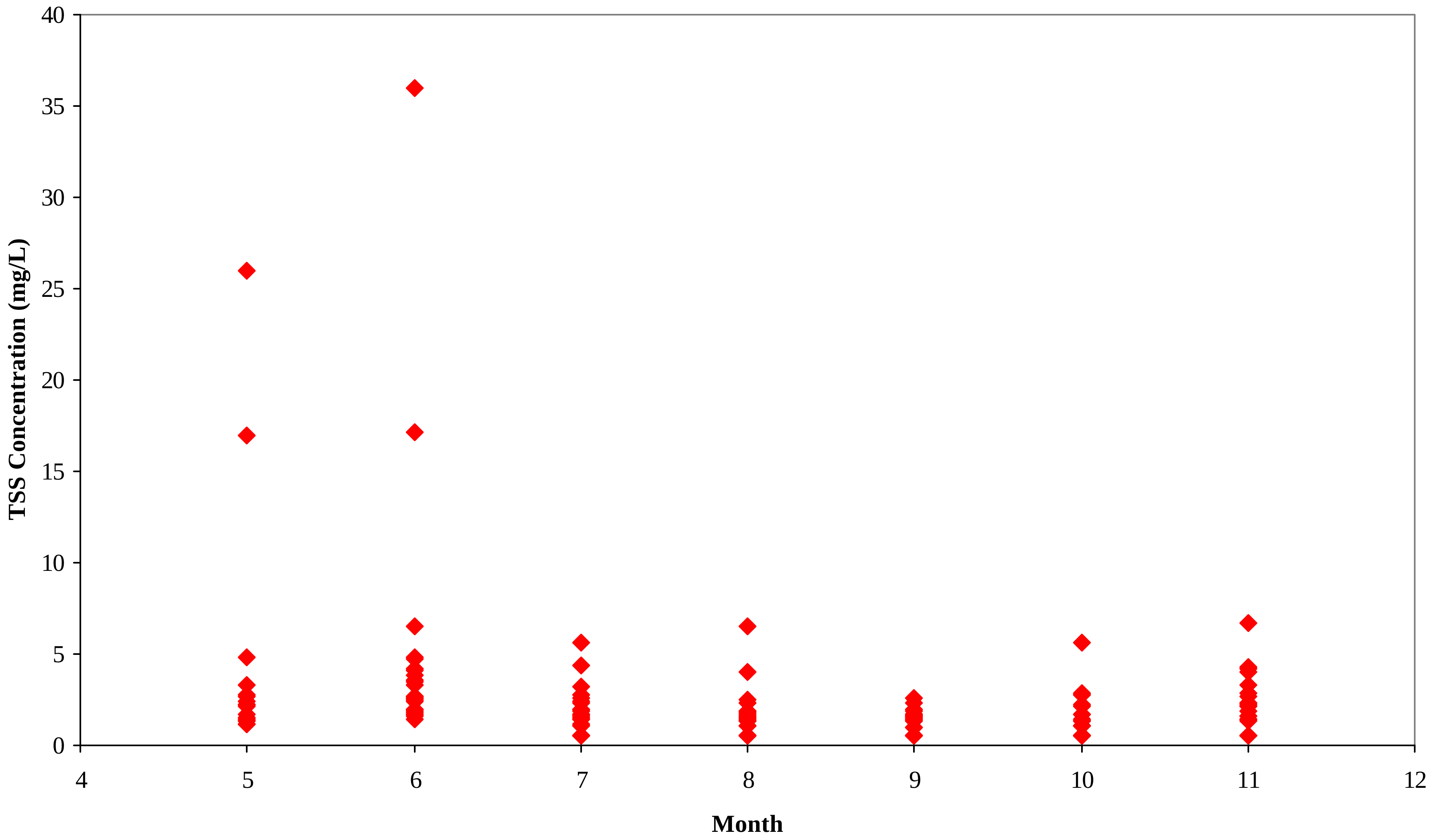


Figure 5. TID-West Station Monthly TSS Concentration Variation

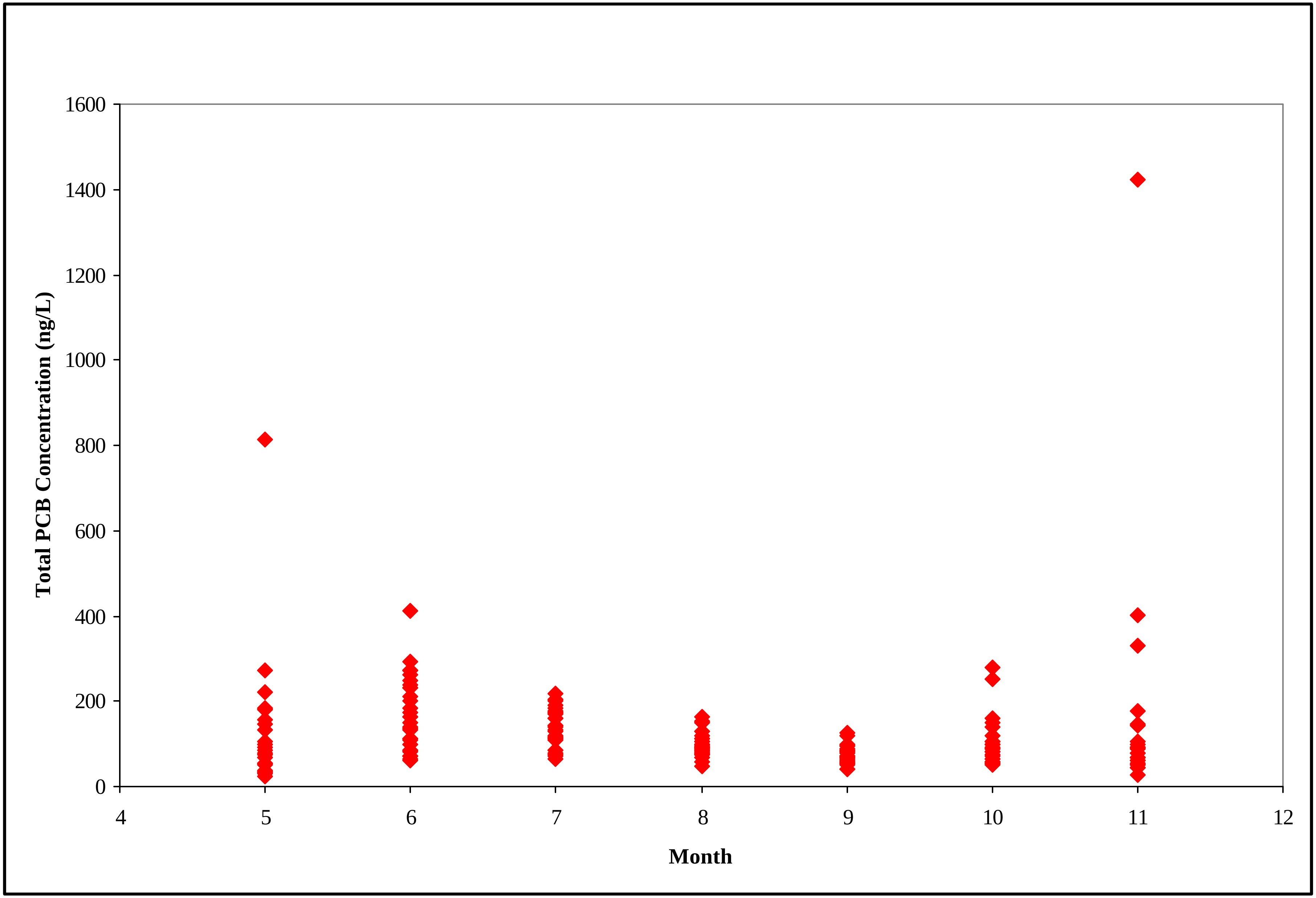


Figure 6. TID-West Station Monthly Total PCB Concentration Variation

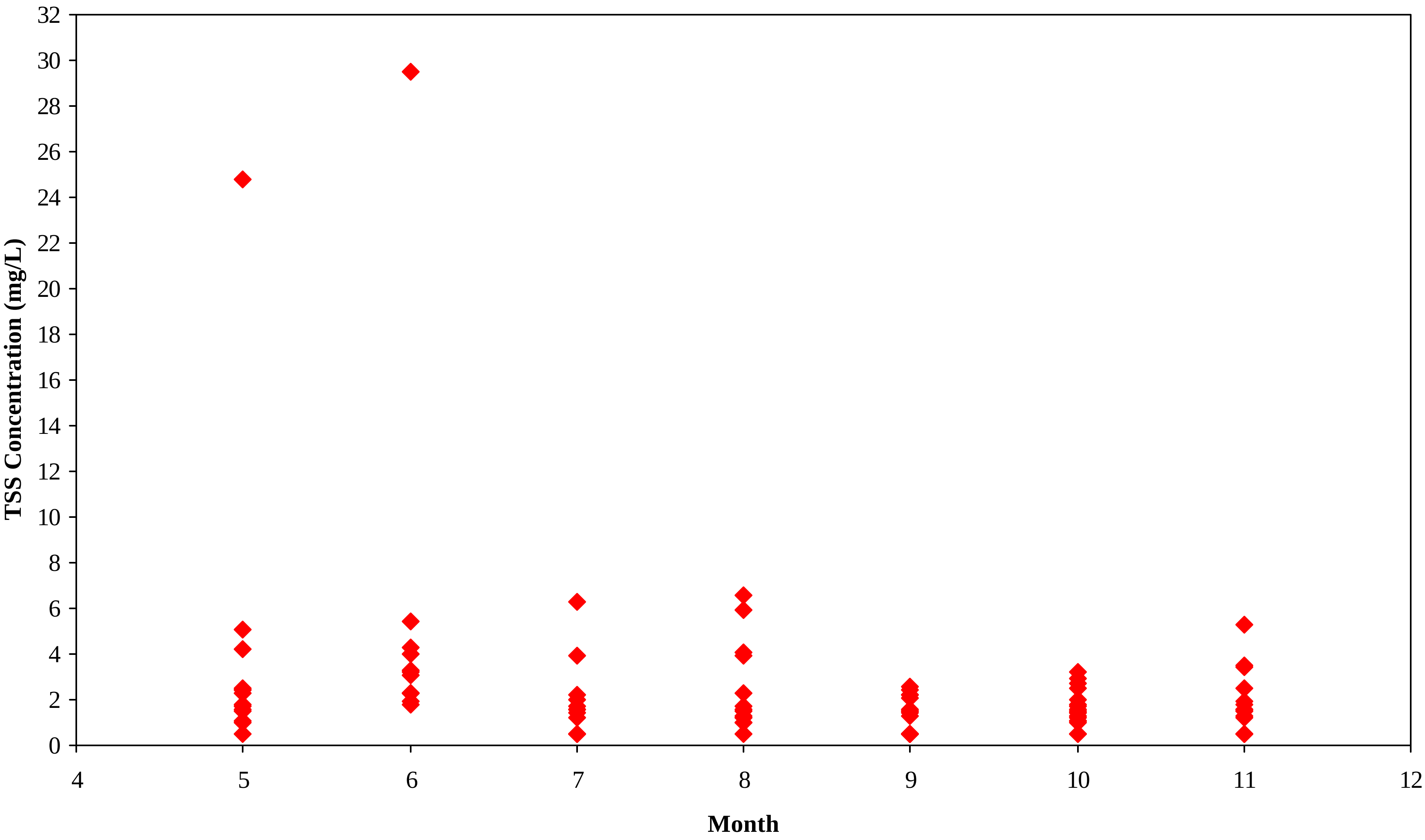


Figure 7. TID-PRW Station Monthly TSS Concentration Variation

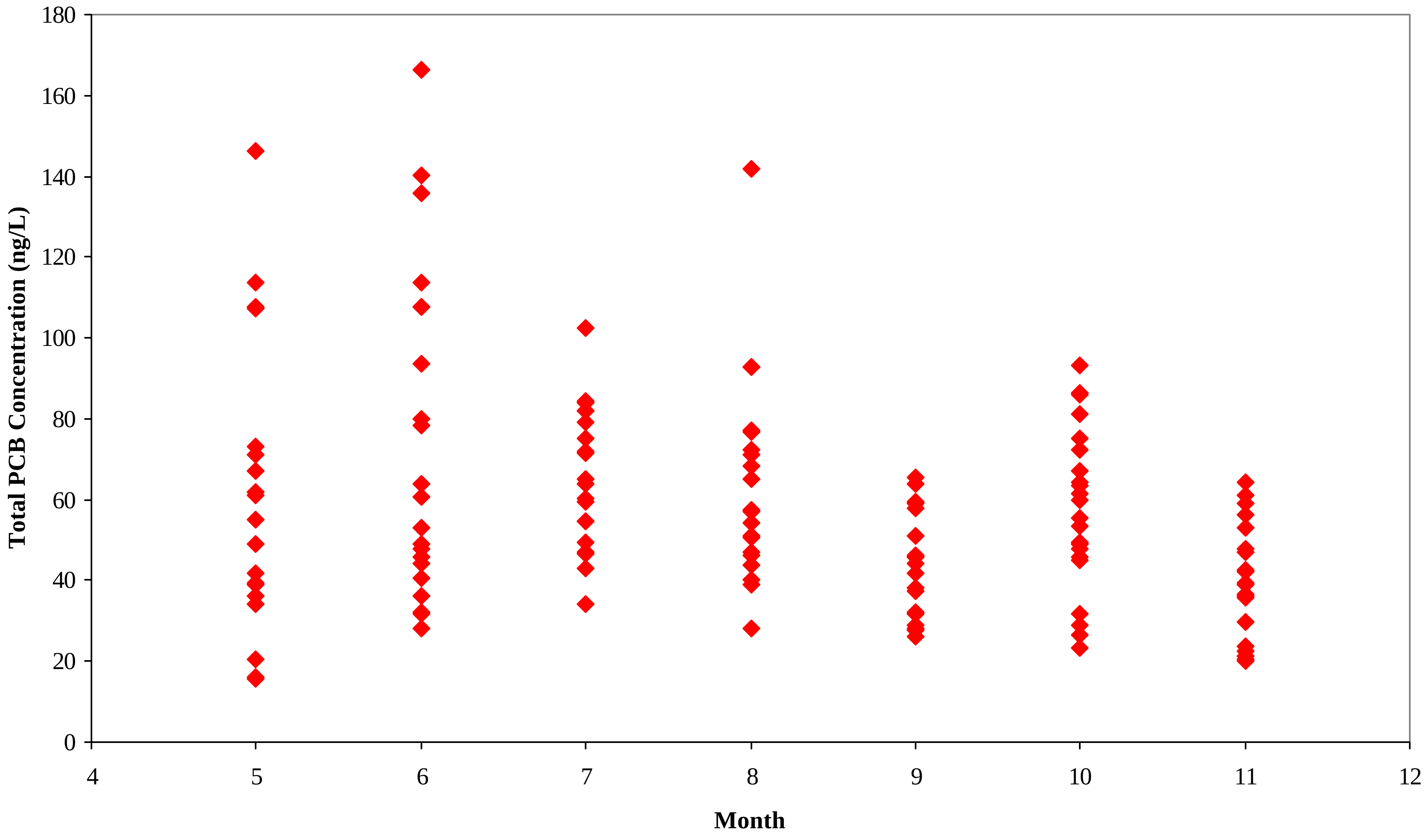


Figure 8. TID-PRW Station Monthly Total PCB Concentration Variation

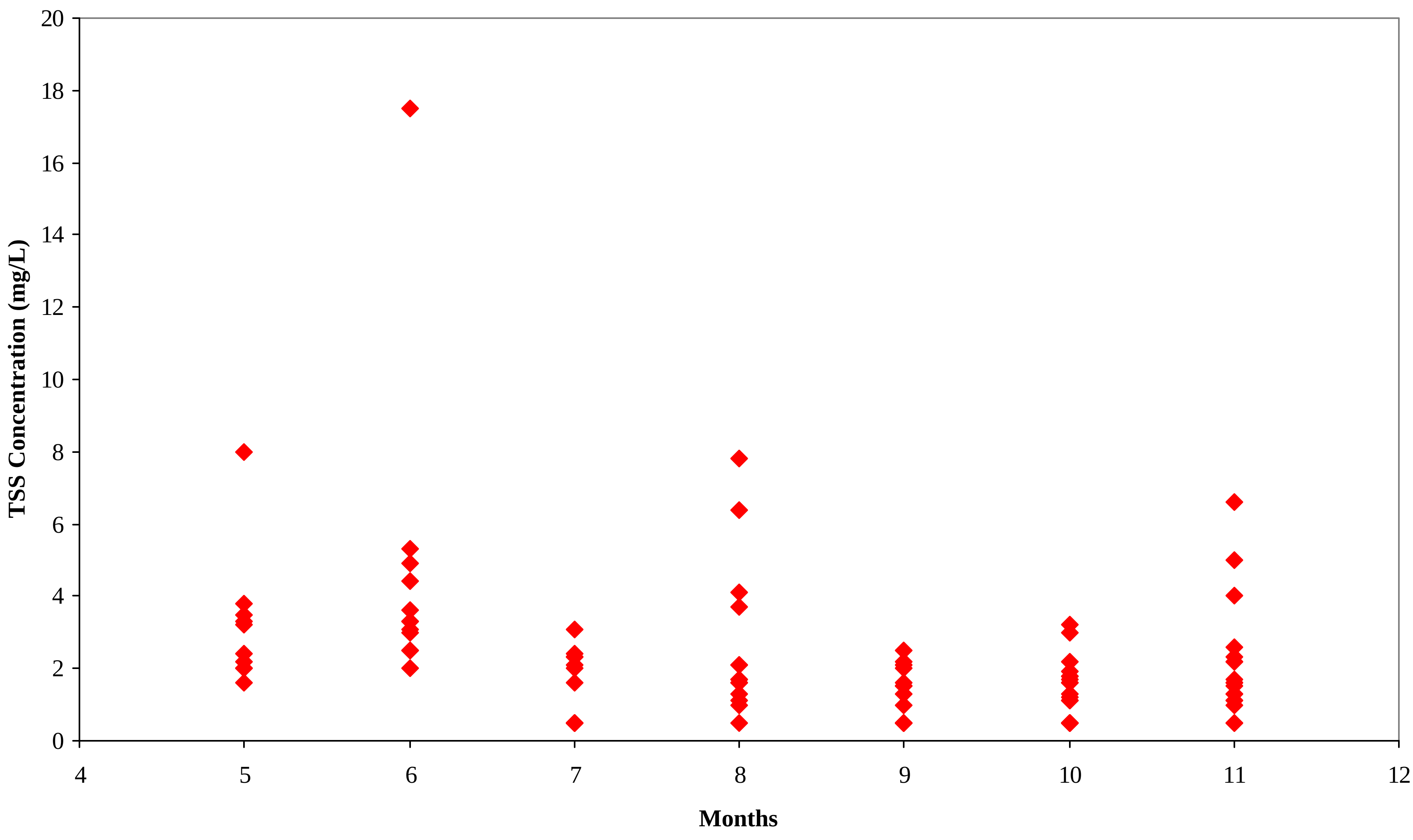


Figure 9. Schuylerville Station Monthly TSS Concentration Variation

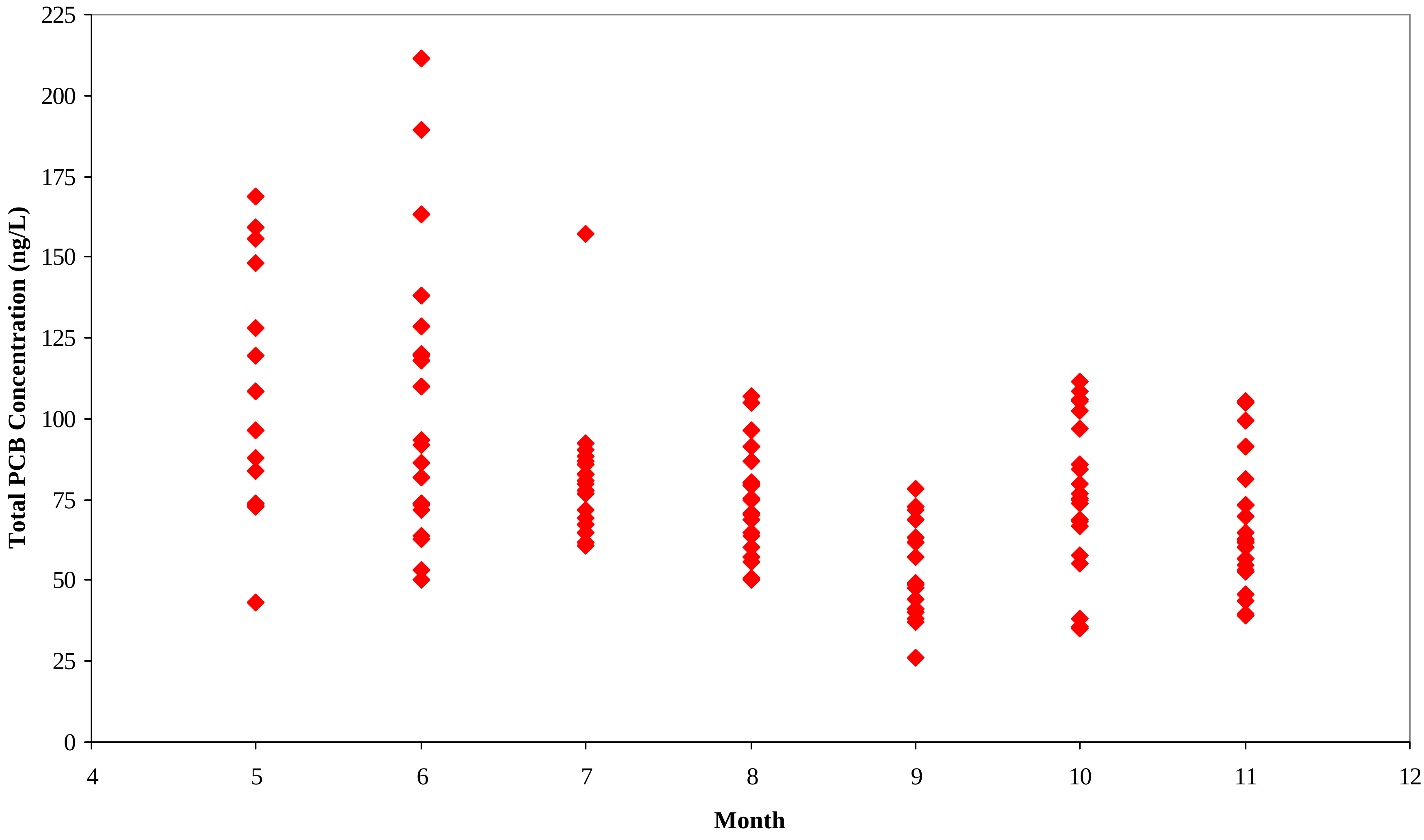
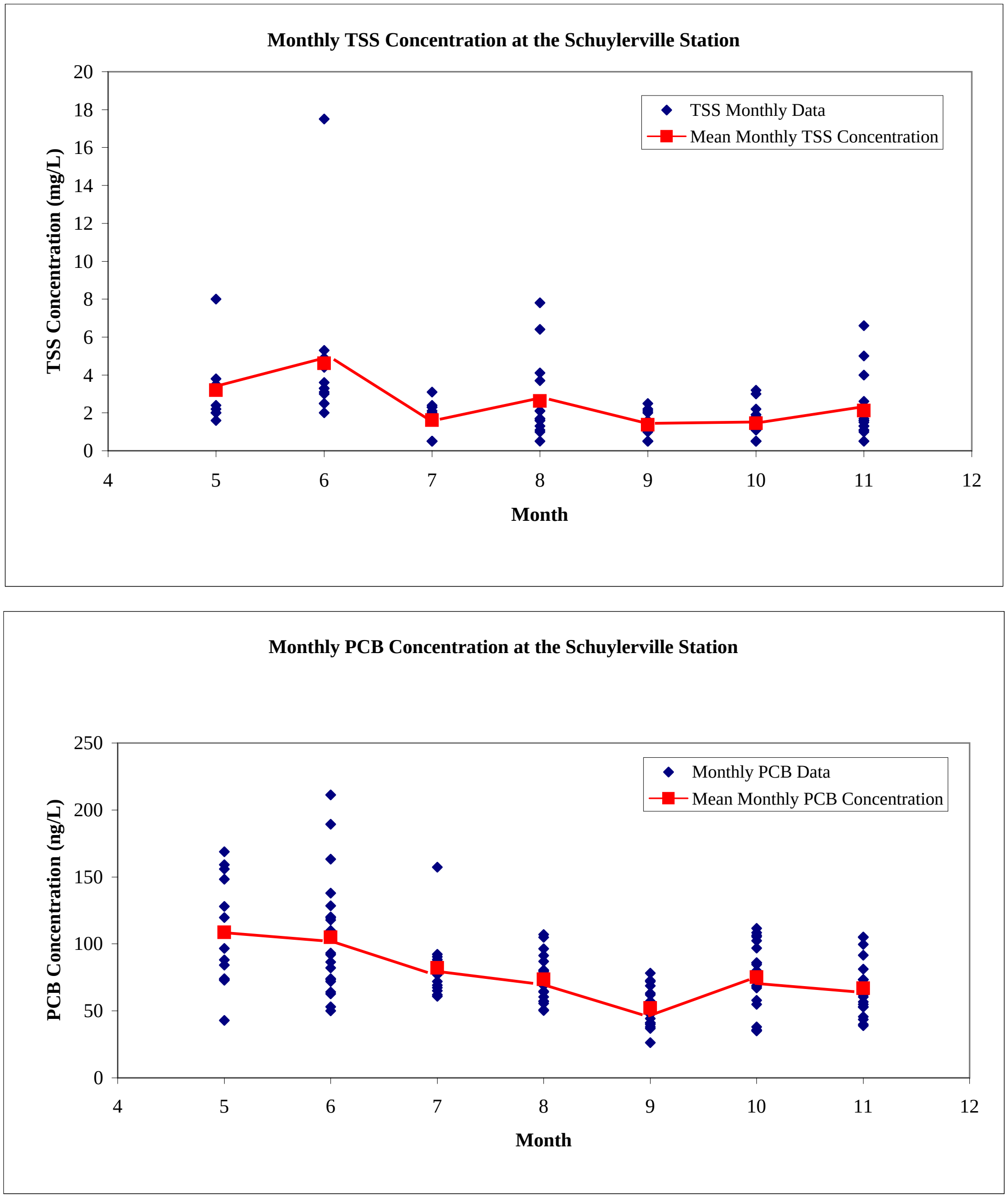


Figure 10. Schuylerville Station Monthly Total PCB Concentration Variation



Monthly TSS Concentration at the Schuylerville Station

Monthly PCB Concentration at the Schuylerville Station

Figure 11. Schuylerville Monitoring Station Monthly TSS and PCB Concentrations Plotted Against the Monthly Mean

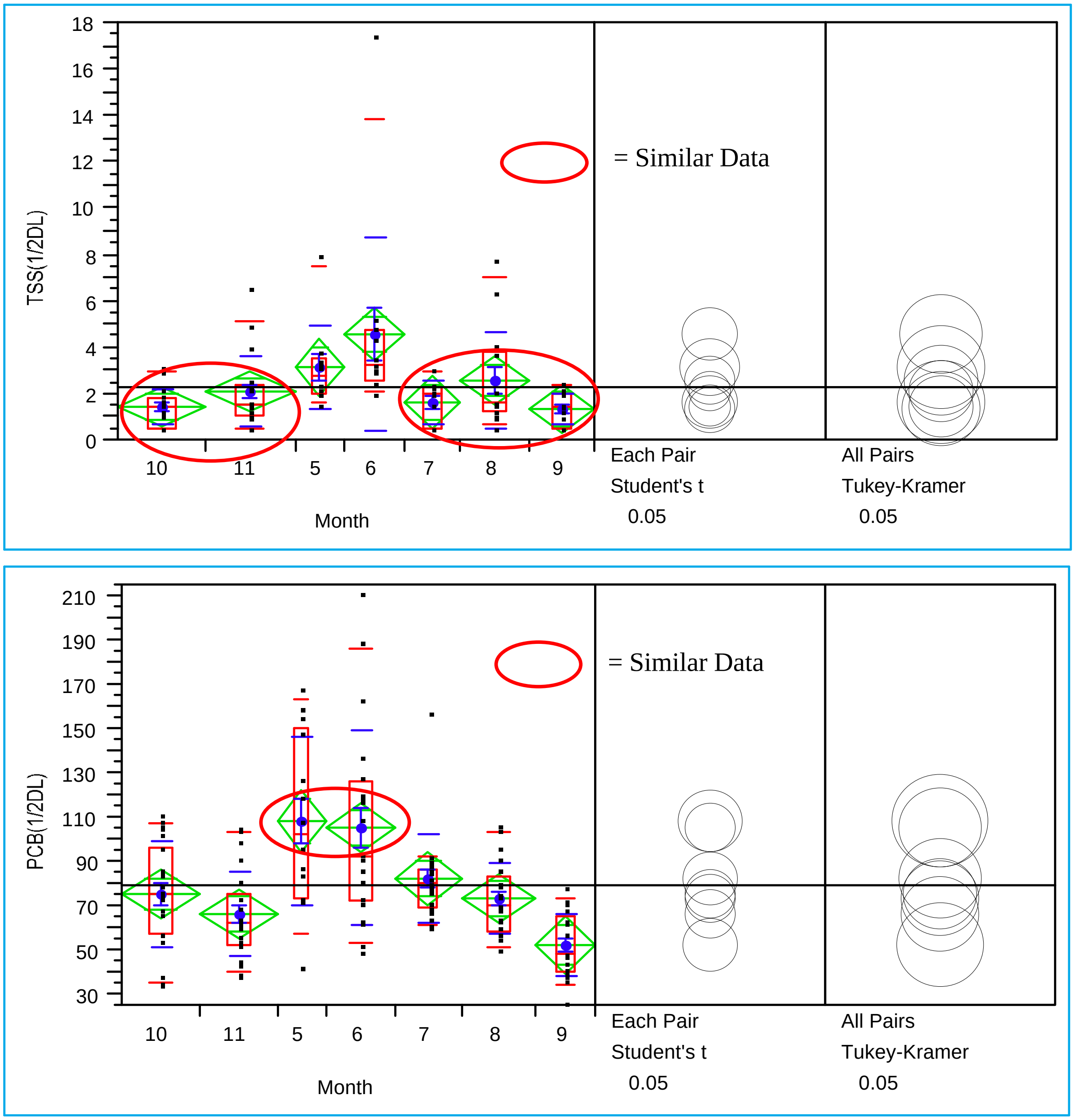


Figure 12. Schuylerville Station Box Plots
TSS Concentration vs. Month (Top Diagram)
Total PCB Concentration vs. Month (Bottom Diagram)

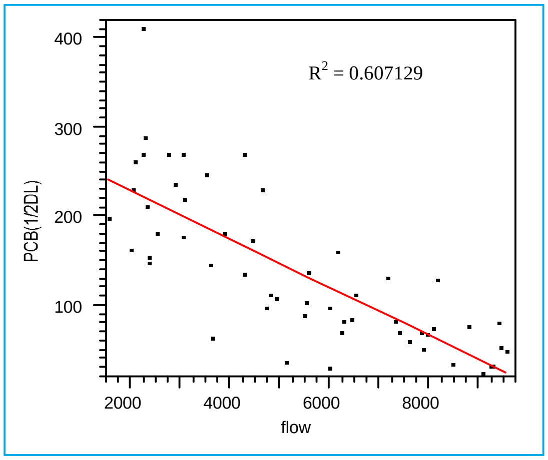


Figure 13: TID-West Monitoring Station
Flow verus Total PCB Concentration
Months of May and June

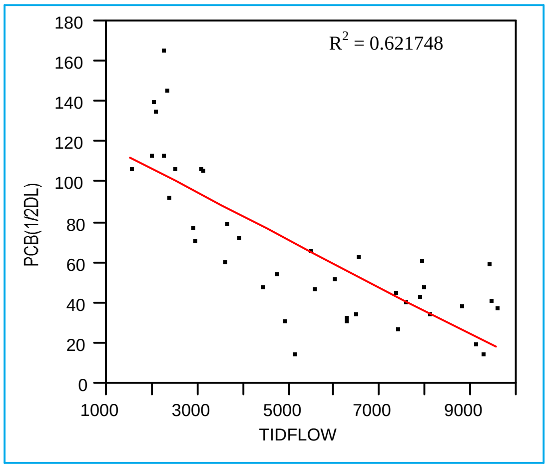


Figure 14: TID-PRW Monitoring Station
Flow versus Total PCB Concentration
Months of May and June

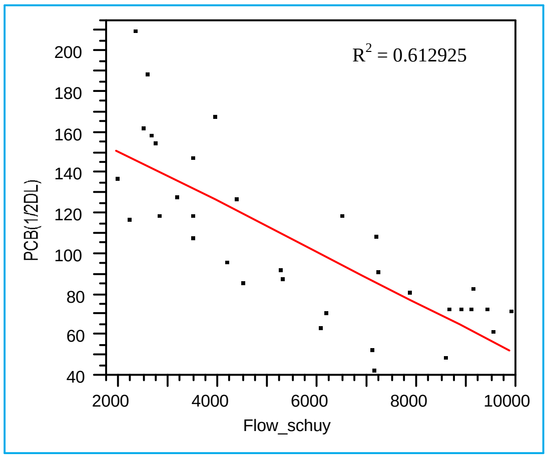


Figure 15. Schuylerville Monitoring Station
Flow versus Total PCB Concentration
Months of May and June

Units: Flow-cfs, PCB-ng.L

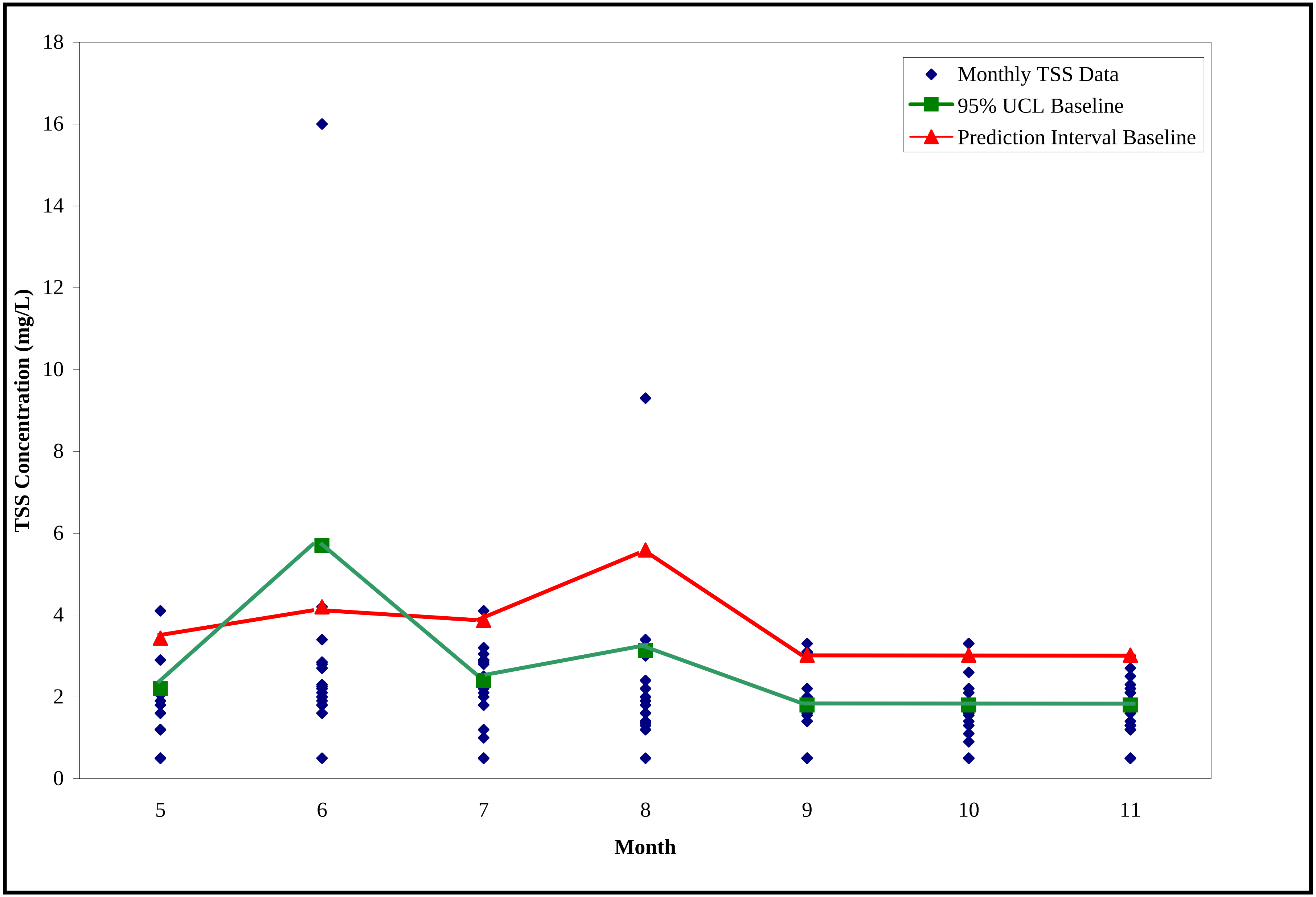


Figure 16. Fort Edward Monitoring Station Monthly TSS Data versus Estimated TSS Baselines

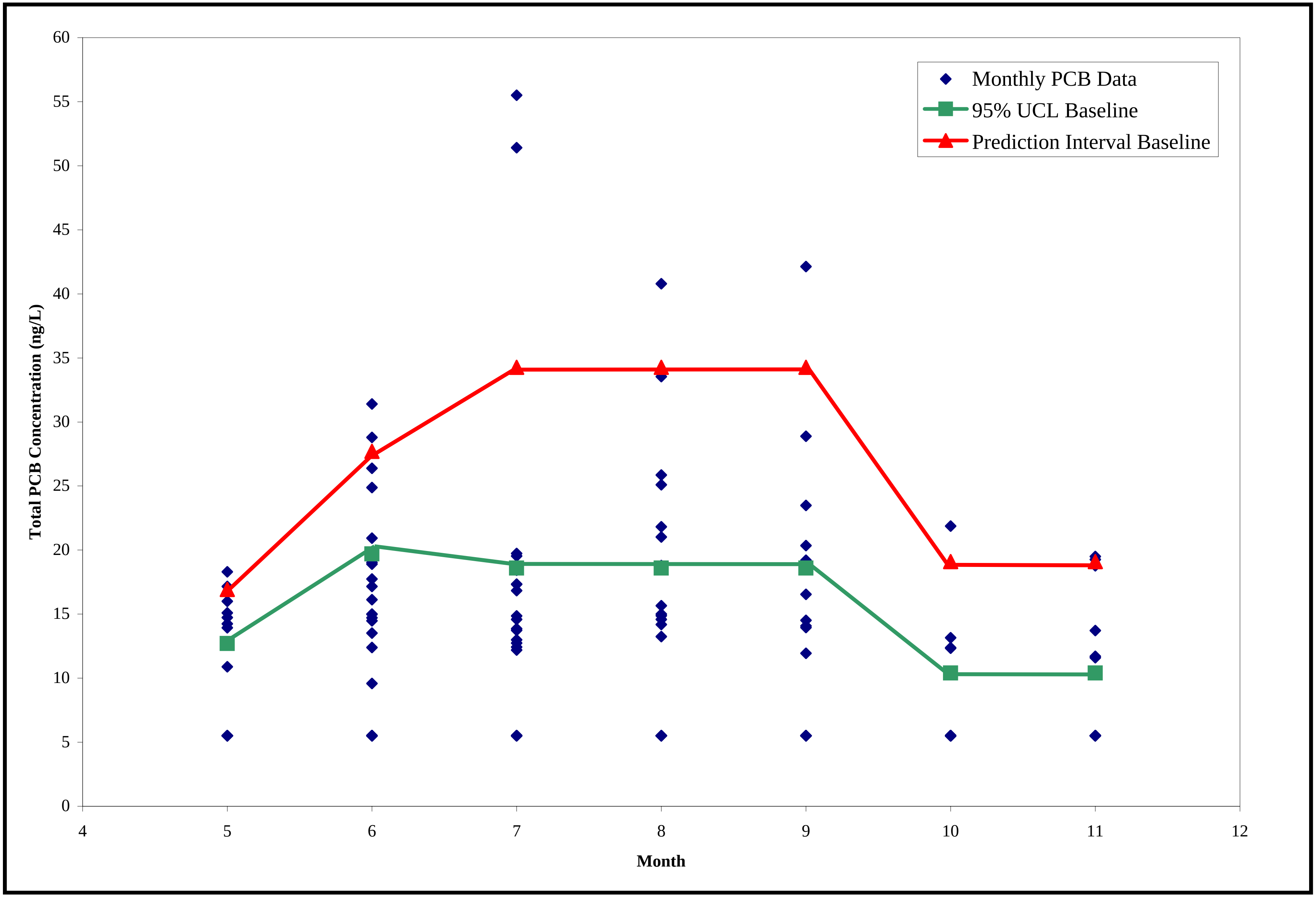


Figure 17. Fort Edward Monitoring Station Monthly Total PCB Data versus Estimated Total PCB Baselines

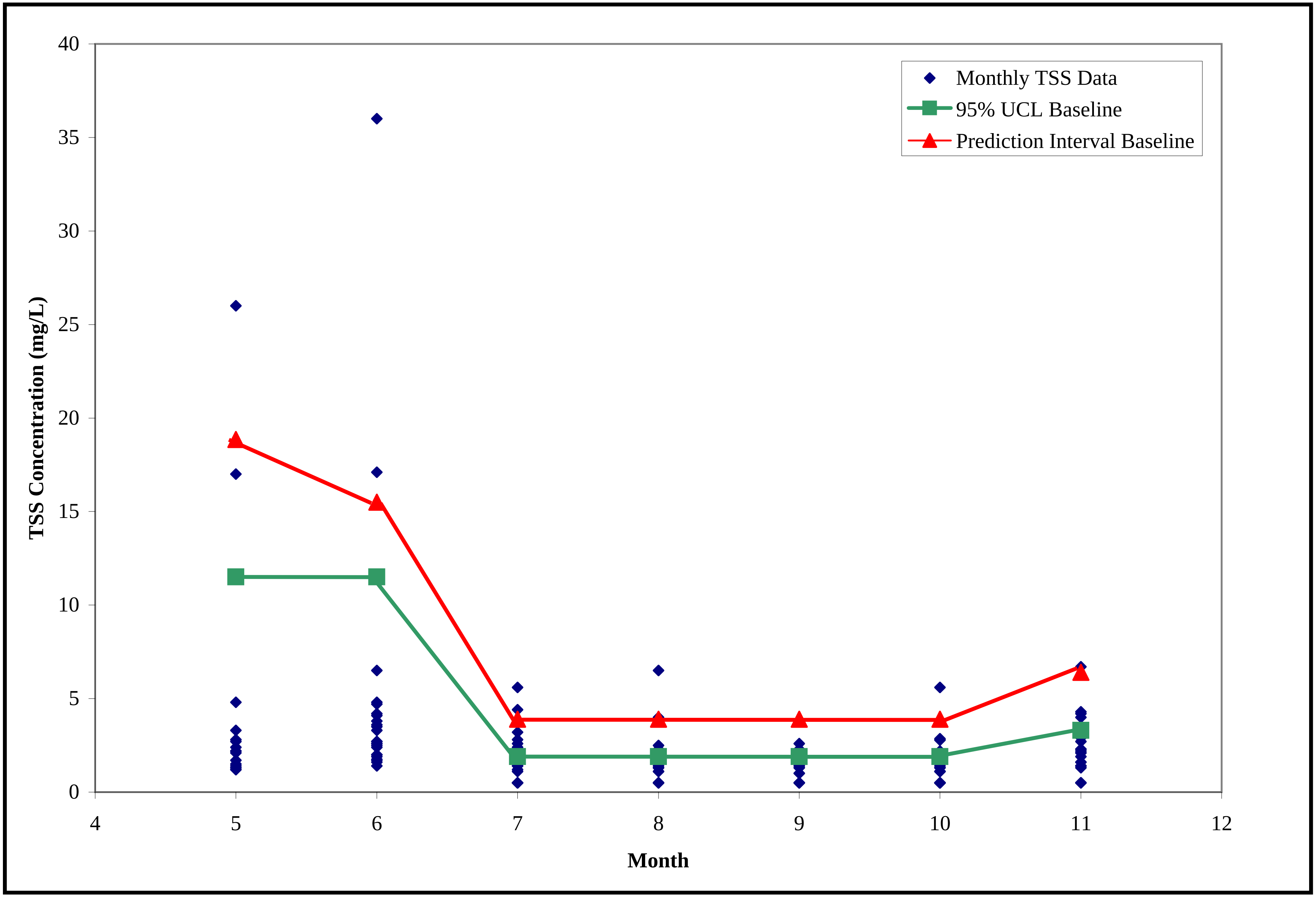


Figure 18. TID-West Monitoring Station Monthly TSS Data versus Estimated TSS Baselines

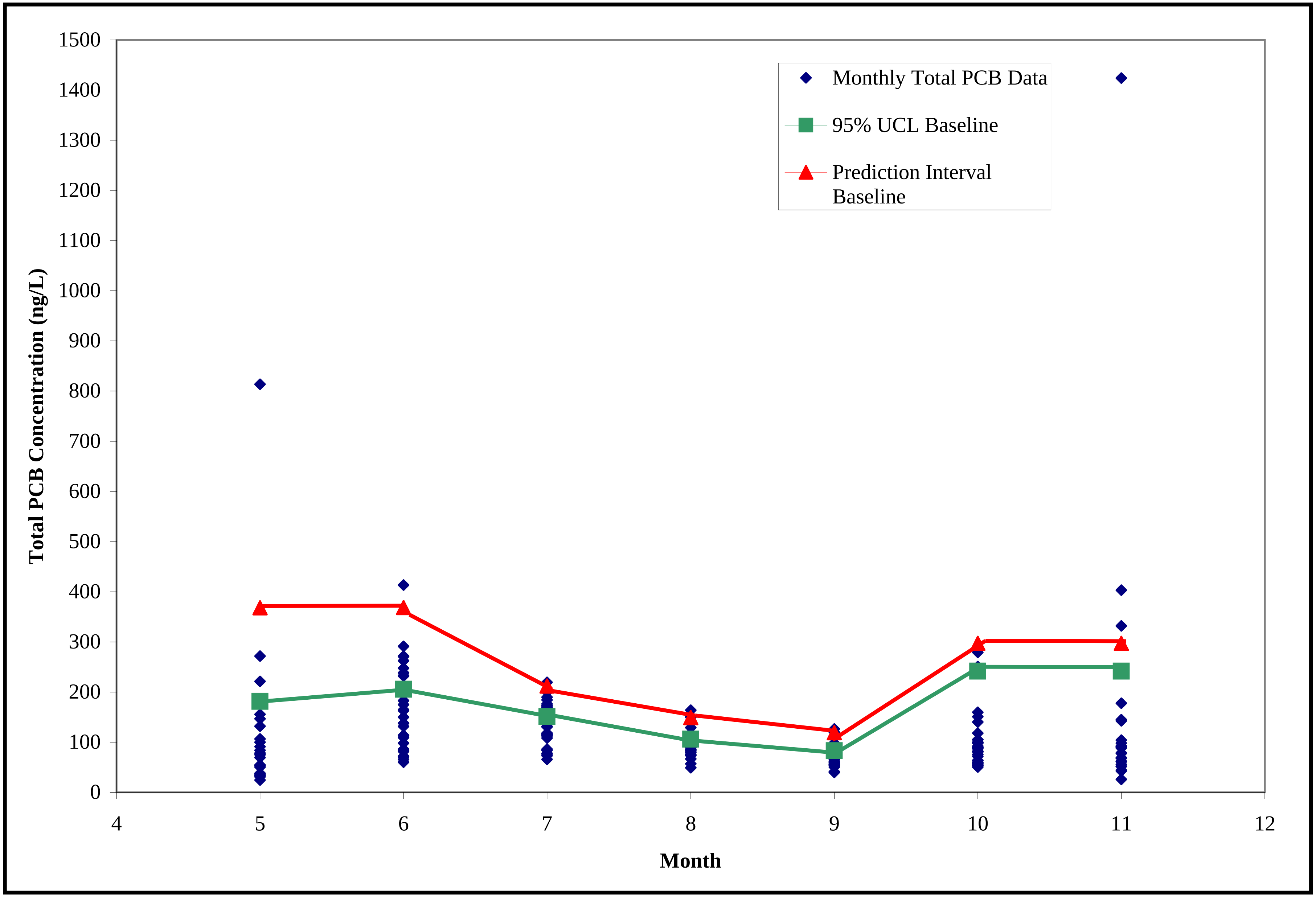


Figure 19. TID-West Monitoring Station Monthly Total PCB Data versus Estimated Total PCB Baselines

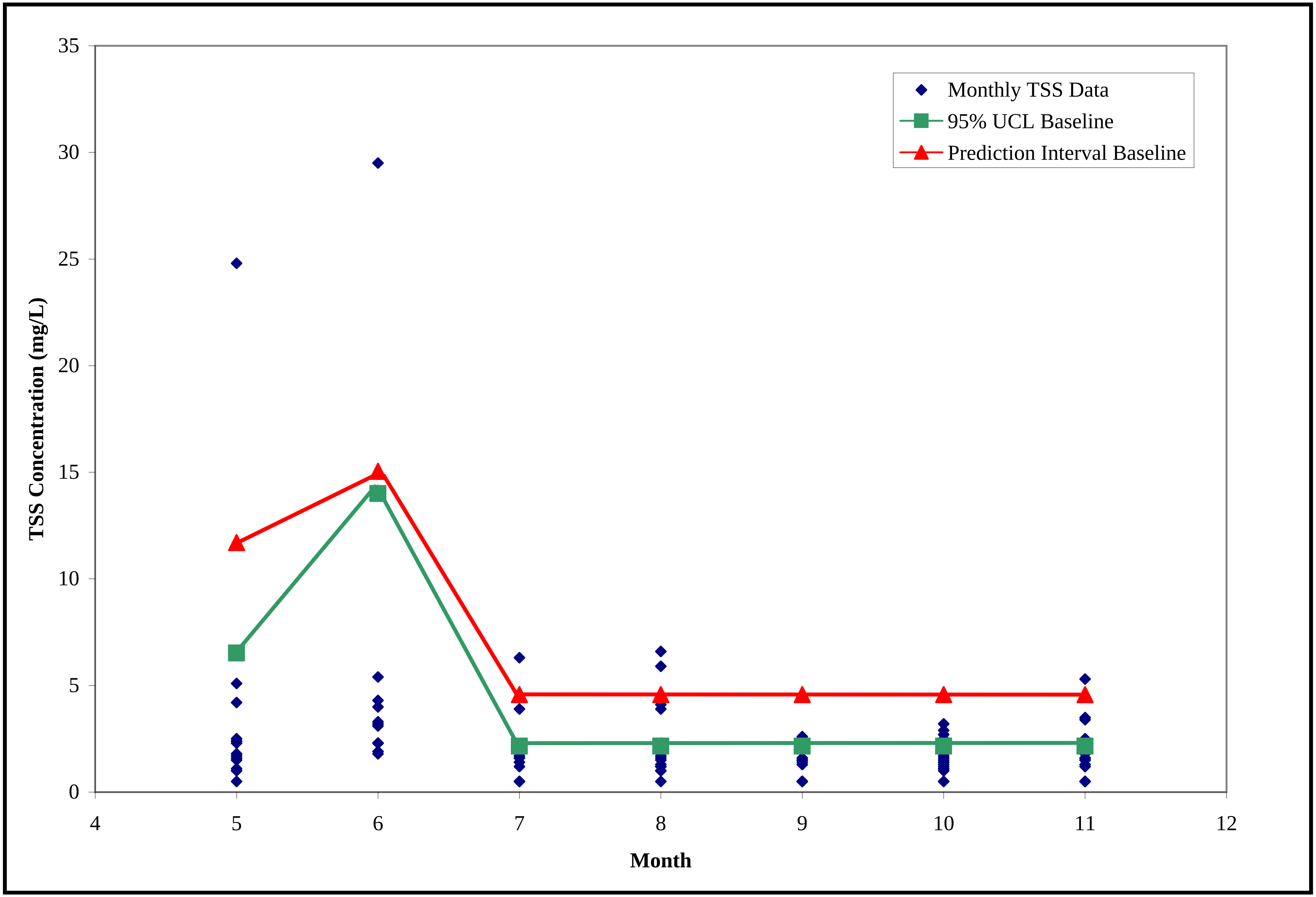


Figure 20. TID-PRW Monitoring Station Monthly TSS Data versus Estimated TSS Baselines

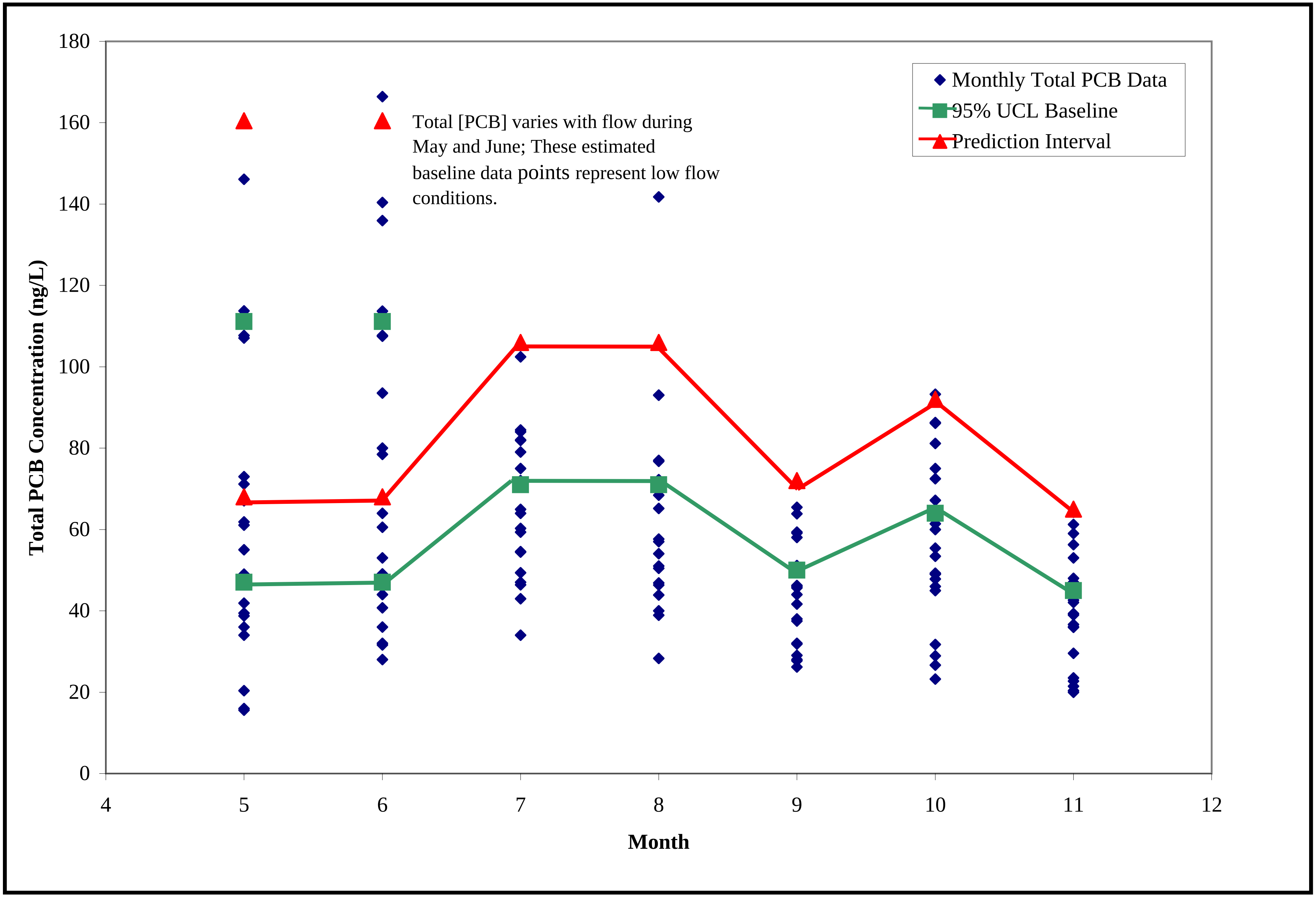


Figure 21. TID-PRW Monitoring Station Monthly Total PCB Data versus Estimated Total PCB Baselines

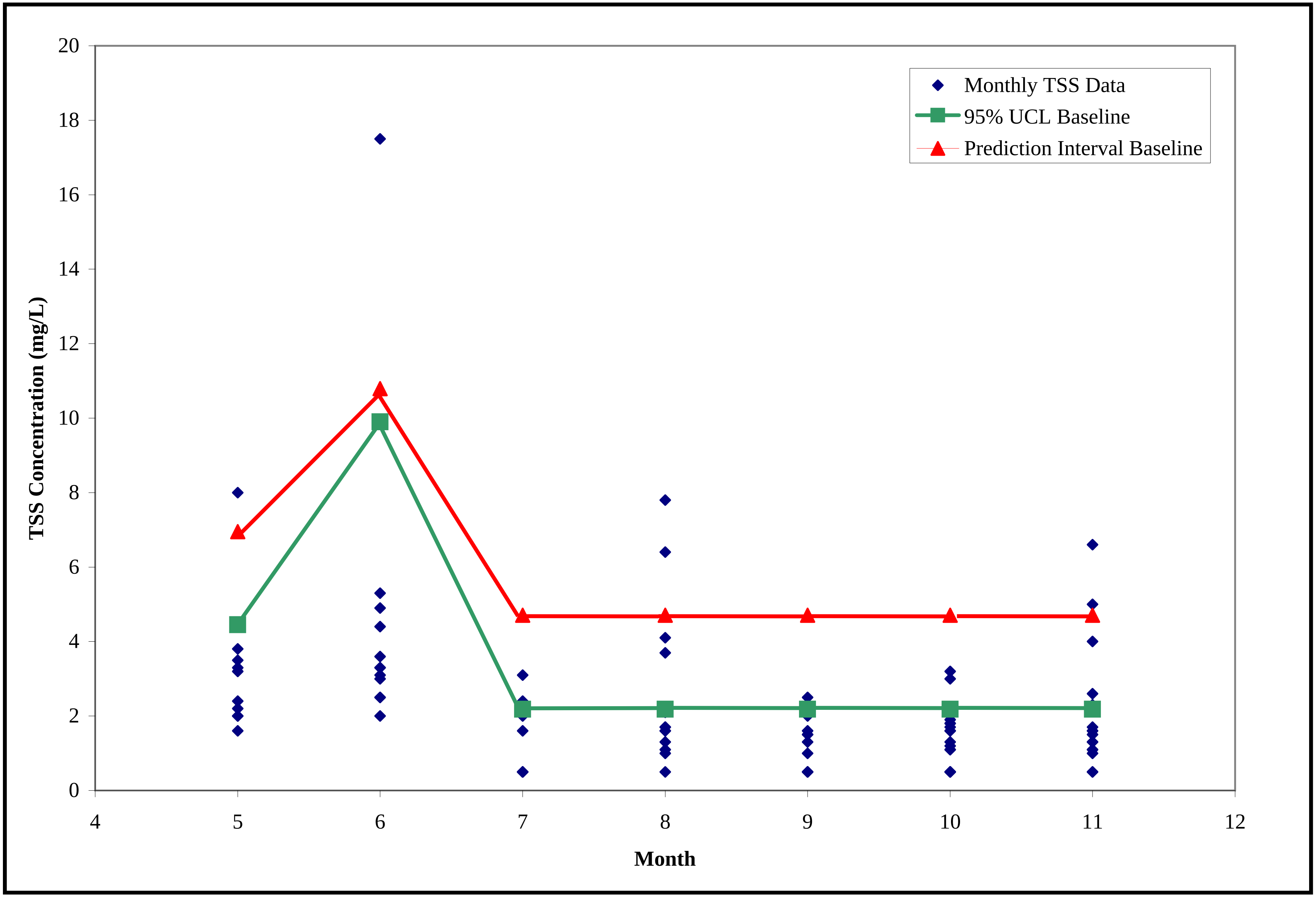


Figure 22. Schuylerville Monitoring Station Monthly TSS Data versus Estimated TSS Baselines

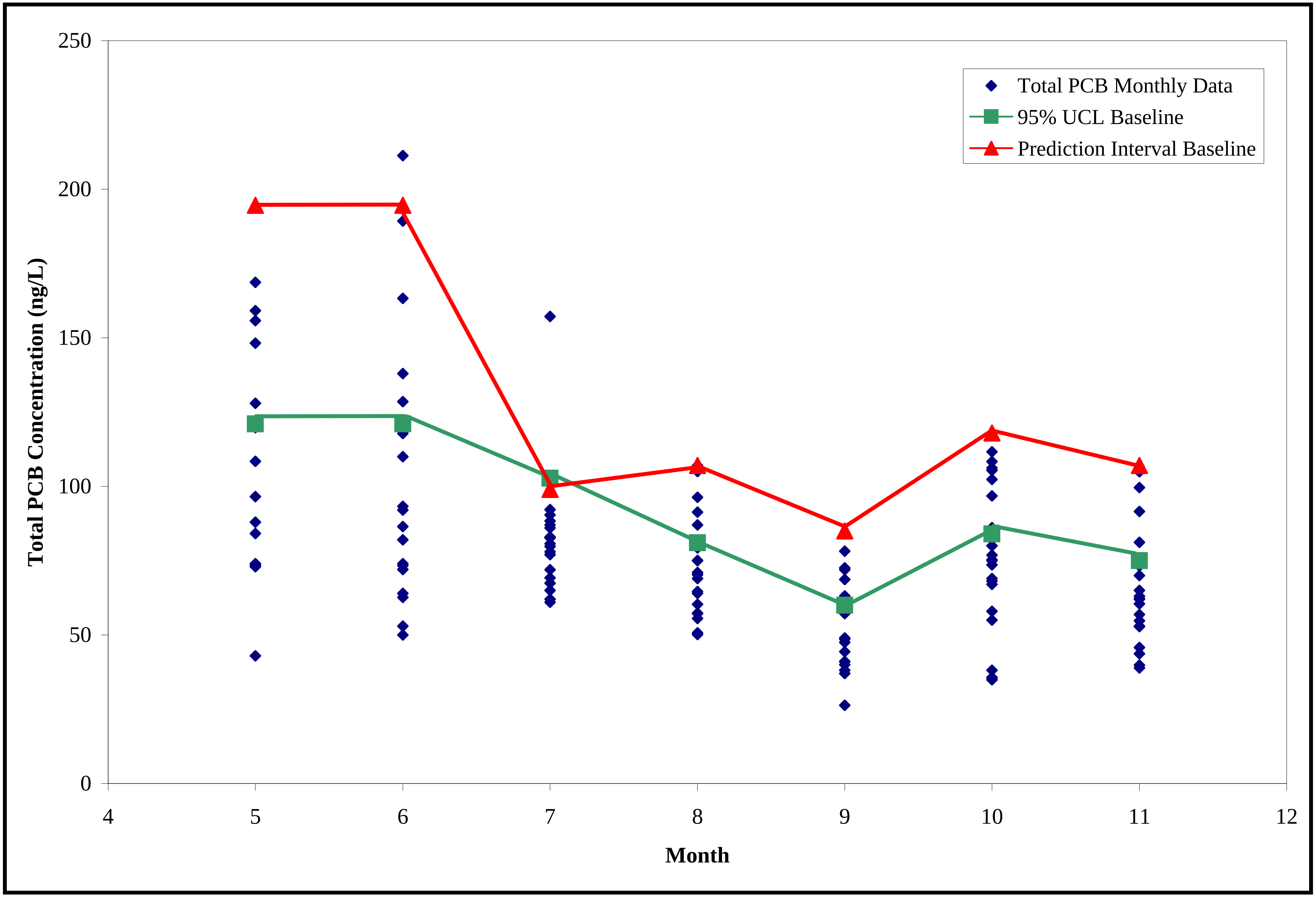


Figure 23. Schuylerville Monitoring Station Monthly Total PCB Data versus Estimated Total PCB Baselines

Attachment B

Resuspension Sensitivity

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Resuspension Sensitivity

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Attachment B

Resuspension Sensitivity

1.0 Objective

Baseline levels of PCBs in the water column fluctuate due to seasonal variables and heterogeneous sources. Therefore it is essential determine the dredging-related PCB releases as a function of time and flow that are detectable above the baseline variations. Furthermore, if data from water samples collected during dredge operations indicate that the PCB concentration transported downstream is within the baseline variation, then it is unlikely that the downstream concentrations will be noticeably impacted from dredging. Furthermore, the resuspension criteria must be set above the baseline variation in order to avoid false exceedances and unnecessary encumbrances to the dredging operations. This monitoring analysis involves the statistical range of baseline variations in total PCB water column concentrations (formulated in Attachment A) and the ability to identify a "significant increase" in the running averages that would signal an unacceptable dredging-related release (*i.e.,* exceedance of resuspension criterion) and require engineering contingencies. Historic data from the Thompson Island Dam (TID) and Schuylerville were used in this analysis, however the baseline and sensitivity calculations should be revised based on the results of the Baseline Monitoring Program. The 95 percent UCL calculations were analyzed for the all the resuspension criteria since they are based on running averages. The prediction limits are also provided, however, the prediction limit analyses indicate the likelihood that any given sample may exceed the criteria and does not apply to running averages. Assuming operations continued at the various criteria, the overall increases in loads within a dredging season were also examined.

2.0 Methodology

During remediation, water column monitoring will be implemented at far-field stations down-gradient of the work areas. Since the river system has baseline PCB levels, it is necessary to confirm that exceedances of the resuspension criteria are recognizable above the inherent variations around the baseline. If exceedances of the criteria were not discernible from the baseline variations, then either PCB levels of concern would not be detected or false exceedances could occur. To this end, an analysis was performed over a wide range of river flow rates (2,000 through 10,000 cfs) and dredging-induced resuspension PCB release rates (300 and 600 g/day), taking into account the variations in the baseline water column concentration (discussed in Attachment A of this report).

The total PCB increases due to dredging activities are based on the volume of sediment removed during each dredging season, the percent solids loss to the water column due to dredging activities, and the river discharge rate. These components are described as follows:

$$\Delta \mathrm{SS} = \frac{V_{sed} \times r \times \mathrm{loss}}{Q \times t_d} \times 9.07 \times 10^8 \qquad (1)$$

where: ΔSS = SS increase in water column (mg/L)
V_{sed} = volume of sediment to be removed (cy)
r = density of the sediment (tons/cy)
loss = dredging-induced resuspension loss rate (%)
Q = flow rate (L/s)
t_d = length of dredging season (s)
9.07×10^8 = conversion factor from tons to mg

The estimated volume of sediment to be removed with overcut, as estimated in the Feasibility Study (USEPA, 2000), is 2.6×10^6 cy. The dredging season is scheduled to occur from May 1 through November 30. Table 1 summarizes the estimated volume of sediment removal for each dredging season and the density of the sediment for each river section.

The total PCB increase in the water column due to dredging was calculated as follows:

$$\Delta \mathrm{TPCB} = \frac{M_{TPCB} \times \mathrm{loss}}{Q \times t_d} \times 10^{12} \qquad (2)$$

where: ΔTPCB = TPCB increase in water column (ng/L)
M_{TPCB} = mass of total PCB remediated (kg)
10^{12} = factor to convert kilograms to nanograms
and other parameters are defined above.

The estimated mass of Tri+ and total PCBs to be remediated are summarized in Table 2. The total PCB concentrations calculated for velocities of 2,000 cfs and 8,000 cfs, assuming 300 g/day and 600 g/day release rates and the 95 percent UCL and prediction interval baseline conditions, are presented in this analysis. These flow rates were selected based on historical flow data recorded during months in which dredging is antivipaed to occur (*i.e*. the dredging season months). Thus, at these two flow rates, the range of SS and total PCB conditions that will exist in the Hudson River during dredging operations were estimated. It should be noted that dredging activities are not expected to occur at Fort Edward flow rates as high as 8,000 cfs.

3.0 Discussion

As shown in the relationships demonstrated by Equations 1 and 2, the estimated total PCB concentration increase in the water column is a function of two things: the river flow rate and the solids loss rate from dredging. The estimated SS and total PCB increases as a result of 0.5 percent and 1 percent solids releases are shown in Tables 3 and 4. The 0.5 and 1 percent solids releases are equivalent to loss rates of 0.21 and 0.42 kg/s of solids, and correspond to 300 and 600 g/day total PCB releases, respectively. Data indicate that the increase in SS and PCB concentrations for a given loss rate is greatest under low flow conditions.

In order to ensure that the resuspension criteria are discernible from the baseline variations, a sensitivity analysis was performed. The sensitivity analysis was performed for the following:

- The baseline total PCB concentrations were compared with the estimated increases from dredging for total PCB release rates of 300 and 600 g/day and varying flow rates.
- The estimated total PCB water column concentrations during dredging operations associated with these release rates were computed by adding the estimated concentration increases (shown in Table 4) to the 95 percent upper confidence limit (UCL) baseline concentrations and the 95th percentile prediction interval baseline concentrations.
- The dredging related releases were superimposed onto the 95th percent UCL baseline to provide a table of conditions (dependent on flow and season), which can be compared to the running averages in order to discern if an exceedance is due to dredging operations.

The 95 percent UCL baseline data approximates the baseline variability of the total PCBs, and can be compared with resuspension criteria based on running averages. The prediction interval baseline data approximates the upper bound baseline concentration for one sampling incident, and can be compared with total PCB data collected from a single sample or incident during dredging activities to allow for the detection of a sudden increase or a change in river conditions. This method is only applicable to criteria that do not involve multiple samples, so it is not directly relevant to the current resuspension criteria.

This analysis was completed for three far field monitoring stations (Thompson Island Dam-West (TID-West), TID-PRW2, and Schuylerville) over the proposed dredging period (May through November) using historic data. New data collected during the Baseline Monitoring Program will provide a better estimate of the baseline level at the far-field monitoring stations.

The total PCB release rate of 300 g/day represents the lowest significantly detectable PCB concentration increase when added to the monthly baseline conditions. An analysis (based on the GE dataset for 1996-2000) of the annual PCB loading and 600 g/day total PCB release rate in the water column indicated the following:

- That a 600 g/day total PCB release rate due to dredging corresponds to approximately two standard deviations of the annual PCB loading of the river.

- That a 600 g/day total PCB release rate due to dredging corresponds to a dredging-induced PCB loading of approximately 130 kg per year.

It was also determined that the standard deviation for the annual PCB loading, based on existing GE water column data for the period 1996 to 2000, is approximately 70 kg total PCBs per year. Thus, a total PCB release rate greater than 600 g/day is likely to exceed the river system's annual baseline PCB loading, supporting the use of the 600 g/day release rate as an upper bound for PCB loading.

As a result, it was recommended that engineering evaluations and solutions be implemented when dredging releases approach 300 g/day total PCBs and it is mandatory that engineering evaluations and solutions be implemented for instances when dredging releases are greater than the river's baseline variation (*i.e.* 600 g/day total PCB). Ultimately, PCB loading corresponding to 300 and 600 g/day, combined with the results of this sensitivity analysis (described herein) were utilized to design a tiered, resuspension monitoring plan comprised of different action levels and monitoring requirements. These levels of monitoring will be implemented based on measured PCB concentrations and corresponding PCB loading estimates.

Additional criteria are based on SS, but the goal of the SS-based criteria is determine net dredging contributions, rendering baseline sensitivity analyses unnecessary. The monitoring programs for SS are described in Chapter 3 and Attachment F of this report.

4.0 Results

The following sections present the results of the sensitivity analysis and a discussion of estimated total PCB concentrations. The results presented assume the following:

- Variable flow rates
- Estimated baseline concentrations
- Total PCB release rates of 300 and 600 g/day.

The baseline conditions are examined at three monitoring stations, two at the TID (TID-West and TID-PRW2) and one at Schuylerville.

4.1 TID Monitoring Locations

Both TID-West and TID-PRW2 are located at the TID. As explained in Attachment A of this report, both of these stations have limitations associated with their data. The total PCB concentrations for TID-West were examined in the *Responsiveness Summary for the Data Evaluation and Interpretation Report* (DEIR) (USEPA, 1998). This analysis concluded that samples collected at the TID-West station are influenced by nearby sediment during low flows. It was also noted in the DEIR that samples collected at TID-PRW2 tend to be limited to the warmer months due to inaccessibility in the winter. Thus, it is thought that the results presented herein may not represent actual water column background conditions, and that adjustments to the location of the sampling station and sample collection in the years prior to dredging will provide a new baseline that is more appropriate. The following data, therefore, are representative of the best data that exist to date, though limitations and concerns with the data are apparent.

4.2 Increases in Total PCBs Average Concentrations Due to Dredging

As stated above, the PCB increases from dredging were estimated for PCB release rates of 300 and 600 g/day for flow rates ranging from 2,000 to 10,000 cfs. The 95 percent UCL baseline results for a total PCB release rate of 300 g/day are shown in Tables 5 through 7, and the results for a release rate of 600 g/day in Tables 8 through 10. Data for both release rates at all three monitoring stations are included. The estimated PCB concentration increases at 2,000 cfs and 8,000 cfs were added to the 95 percent UCL baseline conditions and shown in Figures 1 to 3 for TID-West, TID-PRW2 and Schuylerville respectively.

As depicted in Figures 1 through 3, the PCB concentrations are generally highest during the months of May and June, except for TID-PRW2, which also has high concentrations in October and November. The increases from dredging are more difficult to discern from baseline levels at higher flows, since the concentration increases are less than those at lower flows. In general the concentrations for these release rates are sufficiently above baseline to be discernable (at 8,000 cfs a release rate of 300 g/day increases the baseline concentration by more than 20 ng/L). In particular, TID-PRW2 and Schuylerville have fairly consistent total PCB concentrations from these releases at any given flow. However concentrations associated with these total PCB loads will have large variations with flow, making accurate flow rate measurements a necessity.

Due to the dependence of the load criteria on flow rate measurements, a second criterion for total PCBs of 350 ng/L is applied to same action level as the 600 g/day (the Control level). For TID-PRW2 and Schuylerville, this concentration is slightly higher than the 600 g/day PCB release rate and 95 percent UCL baseline concentration estimates. For TID-West, the concentrations for the 600 g/day release rates in May, June, October, and November and the 300 g/day release rate for October and November are estimated to be above the 350 ng/L criteria, assuming the 95 percent UCL baseline. This indicates that at low flows during these months, dredging in areas with high concentrations may require additional precautions to prevent dredging-related PCB releases from causing exceedances of the 350 ng/L criterion.

None of the concentrations estimated using the 300 g/day or 600 g/day loads at the 95th percentile UCL baselines are greater than the Resuspension Standard of 500 ng/L. However, since an exceedance of the Resuspension Standard only requires a confirmed occurrence, it is useful to compare the standard to the 95th prediction limits for the baseline with the 300 g/day and 600 g/day total PCB loads superimposed.

4.3 Increases in Total PCBs Single Sample Concentrations Due to Dredging

In order to examine the sensitivity of a single sampling incident, the prediction interval baseline results were applied for total PCB release rates of 300 g/day (Tables 11 to 13) and 600 g/day (Tables 14 through 16) for TID-West, TID-PRW2 and Schuylerville respectively. The estimated PCB concentration increases at 2,000 cfs and 8,000 cfs were added to the prediction interval baseline conditions and shown in Figures 4 through 6 for TID-West, TID-PRW2 and Schuylerville, respectively.

The PCB increases and prediction level baseline conditions for the 600 g/day total PCB release rate at 2,000 cfs shown in Figures 5 and 6 are below the USEPA Safe Drinking Water Act Maximum Contaminant Level (MCL) of 500 ng/L for TID-PRW2 and Schuylerville. However, for the analysis at TID-West, this 600 g/day total PCB release rate at 2,000 cfs exceeds 500 ng/L when added to the prediction level baseline for May, June, October, and November. However, the final monitoring station at the TID is expected have baseline conditions that are similar to a combination of those at TID-West and TID-PRW2. Therefore, the results from TID-West station alone are not expected to be truly representative of the PCB concentrations at the TID. Furthermore, an exceedance of the Resuspension Standard threshold requires the collection of four additional samples (in one day) to be analyzed with expedited turn-around times. Therefore, the final decision to cease operations will be based on at least 5 samples. Since the prediction limit shown represents a 5 percent chance of having one sample exceed the 500 ng/L criterion, the likelihood of 5 samples exceeding the 500 ng/L criterion will be lower. However, these results imply that in order to be conservative, dredging operations during these months at low flows may require additional precautions to prevent dredging-related PCBs from causing exceedances of the Resuspension Standard.

5.0 Comparison of the Annual Dredging Induced PCB Load to the Baseline PCB Load

Further analyses were performed to compare the annual baseline total PCB loads with the average annual total PCB loads resulting from solids releases of 0.21 kg/s and 0.42 kg/s, which are associated with the resuspension release criteria of 300 g/day and 600 g/day. The analysis assumed that these solids releases were consistently maintained throughout the dredging period. In addition, the annual loads associated with the Resuspension Standard of 500 ng/L were also examined.

Results and Discussion

The annual load, assuming that dredging operations continued with a far-field concentration of 500 ng/L throughout the dredging season (though it should be noted operations would not continue at this level), was calculated using the United States Geological Survey (USGS) daily discharge rates averaged by month at Fort Edward. The estimated loads are shown in Table 17. For these loads, it was assumed that the work will occur six days per week and that the increase in concentration occurs only during the 14–hour-a-day working period. The 0.5 and 1 percent solids releases are equivalent to loss rates of 0.21 and 0.42 kg/s of solids, and correspond to the 300 and 600 g/day total PCB release rates, respectively. The annual total PCB loads associated with these release rates were calculated, taking into account the dredging schedule proposed in the FS (USEPA, 2000) and the average concentration in each river section. The estimated loads are shown in Table 18.

The annual total PCB loads for 1992 through 2000 were calculated using the GE water column monitoring data and the USGS daily discharge estimates. The TID total PCB concentrations were adjusted for the TID-West bias according to the method described in the Responsiveness Summary to the DEIR (USEPA, 1998). At each station the daily load was calculated and the values were averaged within their respective months to get a monthly average. This average, along with the number of days within the each month, provided the monthly load. The monthly loads were then summed to determine the annual loads at each station. The average annual total PCB loads from 1992 to 2000 are shown in Table 19.

The annual loads from 1992-2000 from above Rogers Island, the TI Pool, and the stretch of river between the TID and the Schuylerville station are presented in Figure 7. The high concentrations detected in 1992 (which gradually declined) were the result of the Allen Mills failure. Controls put in place by the end of 1996 have reduced the seepage of dense non-aqueous phase liquid (DNAPL) into the Hudson River at the GE Hudson River Falls site. The DNAPL leakage is shown as the load at Fort Edward. The load for the Thompson Island (TI) Pool (Rogers Island to the TID) also decreased from the levels detected in 1992 – 1994, with the loads varying year to year between 1995 and 2000. The loads at Schuylerville are substantially less than the upstream loads, though data were available only for the years spanning 1998 – 2000.

Calculations presented in Attachment D of this Report, indicate that the best engineering estimate of the TSS fraction released from dredging would not exceed 0.13 percent. This loss rate represents approximately 110 kg of Total PCBs released throughout the entire dredging project. Assuming the same schedule presented in the FS, this amounts to an average of approximately 105 g/day (ranging from 78 to 209 g/day for the various river sections). This loss rate is less than half of that estimated using the lower resuspension criteria of 300 g/day total PCBs (*i.e.* the 300 g/day total PCB loss rate is over twice what is anticipated under normal dredging conditions), allowing for additional resuspension and mass loss resulting from the other components of the remediation, such as vehicle traffic, without exceeding the criteria. A well-controlled remediation of the Hudson River should not result in a mass loss in excess of the lower resuspension PCB load criteria; specifically, that less than 65 kg per year will be released to the river as a result of the remediation. The 65 kg/year of total PCBs is a small fraction of the baseline load to the river in most years, as shown in Table 19. A loss of 65 kg/yr represents less that 20 percent of the annual load for six of the nine years with load estimates.

A continued solids release of 0.42 kg/s would represent a release of approximately 130 kg/year total PCBs to the river. This rate of loss is approximately two standard deviations of the baseline annual loads from 1996-2000. A total PCB load of 130 kg/year within a dredging season with full production is similar to a load of 65 kg/year within a dredging season with half production (e.g., the Phase 1 resuspension criteria). Since this annual load represents continual releases that are considerably greater than the best engineer estimate resuspension rates in the FS, the dredging operations should not exceed these criteria unless excess resuspension is occurring. Continued operation at the 500 ng/L MCL would result in 500 kg/year of total PCBs being released to the river, a load similar to those found in the early 1990s. This loss is above the current baseline conditions and therefore operations cannot be maintained at this level and will be temporarily halted.

The baseline annual loads are highly variable and unpredictable. In earlier years, the annual loading was dominated by DNAPL releases from the GE Hudson Falls Plants. Since the controls have been installed, DNAPL releases have been greatly reduced and the annual loads are dominated by the release of PCBs from the sediments of the TI Pool. The annual loadings remain highly variable and significant. These calculations show that if the remediation is controlled such that the rate of mass loss is below the action levels, the increase in the annual loading will not be detectable.

6.0 References

USEPA. 1998. Hudson River PCBs Reassessment RI/FS; Responsiveness Summary for Volume 2A: Database Report; Volume 2B: Preliminary Model Calibration Report; Volume 2C: Data Evaluation and Interpretation Report. Prepared for USEPA Region 2 and USACE, Kansas City District by TAMS Consultants, Limno-Tech, Inc, Menzie-Cura & Associates, Inc., and TetraTech, Inc. December 1998.

USEPA, 2000. Hudson River PCBs Reassessment RI/FS; Feasibility Study. Prepared for USEPA Region 2 and USACE, Kansas City District by TAMS Consultants, Inc. December 2000.

USEPA, 2002. Hudson River Reassessment Record of Decision (ROD). Prepared for USEPA Region 2 and USACE, Kansas City District by TAMS Consultants, Inc. January 2002.

Tables

Table 1
Volume of Sediment Removed by Dredging Season

Sediment Removal Season, t_d	Dredging Location	Dredging speed	Volume of sediment removed [1], V_{sed}, (cy)	Sediment density, ρ, (tons/cy)
May 1 - Nov. 30, 2006	Sec. 1	half	260,000	0.94 [2]
May 1 - Nov. 30, 2007	Sec. 1	full	520,000	0.94 [2]
May 1 - Nov. 30, 2008	Sec. 1	full	520,000	0.94 [2]
May 1 - Aug. 15, 2009	Sec. 1 &	full	260,000	0.94 [2]
Aug. 16 - Nov. 30, 2009	Sec. 2	full	290,000	0.74 [3]
May 1 - Aug. 15, 2010	Sec. 2 &	full	290,000	0.74 [3]
Aug. 16 - Nov. 30, 2010	Sec. 3	full	255,000	0.71 [4]
May 1 - Aug. 15, 2011	Sec. 3	full	255,000	0.71 [4]

Notes:

1. Calculations of volume sediment removed were presented in the FS, Table 8-9.
2. Based on the calculations in the FS, sediment removed consists of 50% cohesive (ρ = 0.71 tons/cy) and 50% non-cohesive (ρ = 1.16 tons/cy).
3. Based on the calculations in the FS, sediment removed consists of 93% cohesive (ρ = 0.71 tons/cy) and 7% non-cohesive (ρ = 1.16 tons/cy).
4. Based on the calculations in the FS, sediment removed consists of cohesive sediment only (ρ = 0.71 tons/cy).

Table 2
Estimated Tri+ and Total PCB Mass to be Remediated

River Section	Length of time for remediation, t_d, (year)	Mass of Tri+ PCB remediated[2], M_{Tri+}, (kg)	Mass of TPCB remediated[2], M_{TPCB}, (kg)
River Section 1 (> 3 g/m^2)	3.5	11,100	36,000
River Section 2 (> 10 g/m^2)	1	7,100	24,300
River Section 3 (Select)	1	3,500	9,500
Total	5.5 [1]	21,700	69,800

Notes:

1. Dredging is scheduled to finish half way through the sixth year.
2. Mass of Tri+ and TPCB removed were calculated in the *Responsiveness Summary, Sediment PCB Inventory Estimates White Paper* (USEPA, 2002).

Table 3
Suspended Solids Estimated Increase to the Water Column

Sediment Removal Season	SS Increase @ 2,000 cfs (mg/L)	SS Increase @ 5,000 cfs (mg/L)	SS Increase @ 8,000 cfs (mg/L)
Assuming a 0.21 kg/s Solids Loss Rate from Dredging			
May 1 - Nov. 30, 2006	1.8	0.7	0.5
May 1 - Nov. 30, 2007	3.7	1.5	0.9
May 1 - Nov. 30, 2008	3.7	1.5	0.9
May 1 - Aug. 15, 2009	3.7	1.5	0.9
Aug. 16 - Nov. 30, 2009	3.2	1.3	0.8
May 1 - Aug. 15, 2010	3.2	1.3	0.8
Aug. 16 - Nov. 30, 2010	2.8	1.1	0.7
May 1 - Aug. 15, 2011	2.8	1.1	0.7
Assuming a 0.42 kg/s Solids Loss Rate from Dredging			
May 1 - Nov. 30, 2006	3.7	1.5	0.9
May 1 - Nov. 30, 2007	7.3	2.9	1.8
May 1 - Nov. 30, 2008	7.3	2.9	1.8
May 1 - Aug. 15, 2009	7.3	2.9	1.8
Aug. 16 - Nov. 30, 2009	6.5	2.6	1.6
May 1 - Aug. 15, 2010	6.5	2.6	1.6
Aug. 16 - Nov. 30, 2010	5.6	2.2	1.4
May 1 - Aug. 15, 2011	5.6	2.2	1.4

Table 4
Total PCBs Estimated Increase to the Water Column

Sediment Removal Season	Total PCB Increase @ 2,000 cfs (mg/L)	Total PCB Increase @ 5,000 cfs (mg/L)	Total PCB Increase @ 8,000 cfs (mg/L)
Assuming a 300 g/day total PCB Loss Rate from Dredging			
May 1 - Nov. 30, 2006	49	20	12
May 1 - Nov. 30, 2007	101	41	25
May 1 - Nov. 30, 2008	101	41	25
May 1 - Aug. 15, 2009	101	41	25
Aug. 16 - Nov. 30, 2009	202	81	51
May 1 - Aug. 15, 2010	202	81	51
Aug. 16 - Nov. 30, 2010	80	32	20
May 1 - Aug. 15, 2011	80	32	20
Assuming a 600 g/day total PCB Loss Rate from Dredging			
May 1 - Nov. 30, 2006	101	41	25
May 1 - Nov. 30, 2007	198	80	50
May 1 - Nov. 30, 2008	198	80	50
May 1 - Aug. 15, 2009	198	80	50
Aug. 16 - Nov. 30, 2009	418	168	105
May 1 - Aug. 15, 2010	418	168	105
Aug. 16 - Nov. 30, 2010	157	63	39
May 1 - Aug. 15, 2011	157	63	39

Table 5
Estimated Total PCB Concentrations Compared to the 95 Percent UCL Baseline Data at the TID-West Monitoring Station Assuming a 300 g/day Total PCB Release Rate

Total PCB Release Rate of 300 g/day			Total PCB – TID-West Station					
Flow (cfs)	Flow (m^3/s)	TPCB increase (ng/L)	May	June	July	August	Sept.	Oct. & Nov.
95% UCL Baseline TPCB Concentration			**181**	**205**	**151**	**106**	**83**	**241**
2,000	57	105	286	310	256	211	188	346
2,500	71	84	265	289	235	190	167	325
3,000	85	70	251	275	221	176	153	311
3,500	99	60	241	265	211	166	143	301
4,000	113	53	234	258	203	158	136	294
4,500	127	47	228	252	198	153	130	288
5,000	142	42	223	247	193	148	125	283
5,500	156	38	220	244	189	144	121	280
6,000	170	35	216	240	186	141	118	276
6,500	184	32	214	238	183	138	115	274
7,000	198	30	211	235	181	136	113	271
7,500	212	28	209	233	179	134	111	269
8,000	227	26	208	232	177	132	109	268
8,500	241	25	206	230	176	131	108	266
9,000	255	23	205	229	174	129	106	265
9,500	269	22	203	227	173	128	105	264
10,000	283	21	202	226	172	127	104	262

Table 6
Estimated Total PCB Concentrations Compared to the 95 Percent UCL Baseline Data at the TID-PRW2 Monitoring Station Assuming a 300 g/day Total PCB Release Rate

Total PCB Release Rate of 300 g/day			Total PCB - TID-PRW2 Station				
Flow (cfs)	Flow (m^3/s)	TPCB increase (ng/L)	May & June (1)	July and August	Sept.	Oct.	Nov.
95% UCL Baseline TPCB Concentration (Data representative of flow Rates>5,000 cfs)			**47**	**71**	**50**	**64**	**45**
2,000	57	105	216	176	155	169	150
2,500	71	84	195	155	134	148	129
3,000	85	70	181	141	120	134	115
3,500	99	60	171	131	110	124	105
4,000	113	53	164	123	103	117	98
4,500	127	47	158	118	97	111	92
5,000	142	42	153	113	92	106	87
5,500	156	38	85	109	88	102	84
6,000	170	35	82	106	85	99	80
6,500	184	32	79	103	82	97	78
7,000	198	30	77	101	80	94	75
7,500	212	28	75	99	78	92	73
8,000	227	26	73	97	76	91	72
8,500	241	25	72	96	75	89	70
9,000	255	23	70	94	73	88	69
9,500	269	22	69	93	72	86	68
10,000	283	21	68	92	71	85	66

Notes: (1) The 95% UCL baseline varies as a function of flow rate for the months of May and June. It was estimated that the 95% UCL baseline concentration is approximately 111 ng/L for flow rates less than 5,000 cfs. This value was applied when estimating the total PCB concentration shown in the above table for all flow rates less than 5,000 cfs.

Table 7
Estimated Total PCB Concentrations Compared to the 95 Percent UCL Baseline Data at the Schuylerville Monitoring Station Assuming a 300 g/day Total PCB Release Rate

Total PCB Release Rate of 300g/day			Total PCB (ng/L)- Schuylerville Station					
Flow (cfs)	Flow (m^3/s)	TPCB increase (ng/L)	May & June	July	August	Sept.	Oct.	Nov.
95% UCL Baseline Total PCB Concentration			**121**	**103**	**81**	**60**	**84**	**75**
2,000	57	105	226	207	185	165	189	180
2,500	71	84	205	186	164	144	168	159
3,000	85	70	191	172	150	130	154	145
3,500	99	60	181	162	140	120	144	135
4,000	113	53	174	155	133	113	136	128
4,500	127	47	168	149	127	107	131	122
5,000	142	42	163	144	122	102	126	117
5,500	156	38	160	140	118	98	122	113
6,000	170	35	156	137	115	95	119	110
6,500	184	32	154	134	112	92	116	107
7,000	198	30	151	132	110	90	114	105
7,500	212	28	149	130	108	88	112	103
8,000	227	26	148	128	106	86	110	101
8,500	241	25	146	127	105	85	109	100
9,000	255	23	145	125	103	83	107	98
9,500	269	22	143	124	102	82	106	97
10,000	283	21	142	123	101	81	105	96

Table 8
Estimated Total PCB Concentrations Compared to the 95 Percent UCL Baseline Data at the TID-West Monitoring Station Assuming a 600 g/day Total PCB Release Rate

Total PCB Release Rate of 600 g/day			Total PCB – TID-West Station					
Flow (cfs)	Flow (m^3/s)	TPCB increase (ng/L)	May	June	July	August	Sept.	Oct. & Nov.
95% UCL Baseline TPCB Concentration			**181**	**205**	**151**	**106**	**83**	**241**
2,000	57	210	391	415	361	316	293	452
2,500	71	168	349	373	319	274	251	410
3,000	85	140	321	345	291	246	223	382
3,500	99	120	301	325	271	226	203	361
4,000	113	105	286	310	256	211	188	346
4,500	127	93	275	299	244	199	176	335
5,000	142	84	265	289	235	190	167	325
5,500	156	76	258	282	227	182	159	318
6,000	170	70	251	275	221	176	153	311
6,500	184	65	246	270	216	170	148	306
7,000	198	60	241	265	211	166	143	301
7,500	212	56	237	261	207	162	139	297
8,000	227	53	234	258	203	158	136	294
8,500	241	49	231	255	200	155	133	291
9,000	255	47	228	252	198	153	130	288
9,500	269	44	226	250	195	150	127	286
10,000	283	42	223	247	193	148	125	283

Table 9
Estimated Total PCB Concentrations Compared to the 95 Percent UCL Baseline Data at the TID-PRW2 Monitoring Station Assuming a 600 g/day Total PCB Release Rate

Total PCB Release Rate of 600 g/day			Total PCB - TID-PRW2 Station				
Flow (cfs)	Flow (m^3/s)	TPCB increase (ng/L)	May & June (1)	July and August	Sept.	Oct.	Nov.
95% UCL Baseline TPCB Concentration (Data representative of flow Rates>5,000 cfs)			**47**	**71**	**50**	**64**	**45**
2,000	57	210	321	281	260	274	256
2,500	71	168	279	239	218	232	214
3,000	85	140	251	211	190	204	186
3,500	99	120	231	191	170	184	165
4,000	113	105	216	176	155	169	150
4,500	127	93	204	164	143	158	139
5,000	142	84	195	155	134	148	129
5,500	156	76	124	147	126	141	122
6,000	170	70	117	141	120	134	115
6,500	184	65	112	136	115	129	110
7,000	198	60	107	131	110	124	105
7,500	212	56	103	127	106	120	101
8,000	227	53	100	123	103	117	98
8,500	241	49	97	120	100	114	95
9,000	255	47	94	118	97	111	92
9,500	269	44	91	115	94	108	90
10,000	283	42	89	113	92	106	87

Notes: (1) The 95% UCL baseline varies as a function of flow rate for the months of May and June. It was estimated that the 95% UCL baseline concentration is approximately 111 ng/L for flow rates less than 5,000 cfs. This value was applied when estimating the total PCB concentration shown in the above table for all flow rates less than 5,000 cfs.

Table 10
Estimated Total PCB Concentrations Compared to the 95 Percent UCL Baseline Data at the Schuylerville Monitoring Station Assuming 600 g/day Total PCB Release Rate

Total PCB Release Rate of 600 g/day			Total PCB (ng/L)- Schuylerville Station					
Flow (cfs)	Flow (m^3/s)	TPCB increase (ng/L)	May & June	July	August	Sept.	Oct.	Nov.
95% UCL Baseline Total PCB Concentration			**121**	**103**	**81**	**60**	**84**	**75**
2,000	57	210	331	313	291	270	294	285
2,500	71	168	289	271	249	228	252	243
3,000	85	140	261	243	221	200	224	215
3,500	99	120	241	223	201	180	204	195
4,000	113	105	226	208	186	165	189	180
4,500	127	93	215	196	174	154	177	169
5,000	142	84	205	187	165	144	168	159
5,500	156	76	198	179	157	137	160	152
6,000	170	70	191	173	151	130	154	145
6,500	184	65	186	167	145	125	149	140
7,000	198	60	181	163	141	120	144	135
7,500	212	56	177	159	137	116	140	131
8,000	227	53	174	155	133	113	136	128
8,500	241	49	171	152	130	110	133	125
9,000	255	47	168	149	127	107	131	122
9,500	269	44	166	147	125	104	128	119
10,000	283	42	163	145	123	102	126	117

Table 11
Estimated Total PCB Concentrations Compared to the Prediction Interval Baseline Data at the TID-West Monitoring Station Assuming 300 g/day Total PCB Release Rate

Total PCB Release Rate of 300 g/day			Total PCB- TID-West Station					
Prediction Interval Baseline Total PCB Concentrations			May	June	July	August	Sept.	Oct. & Nov.
Flow (cfs)	Flow (m^3/s)	TPCB increase (ng/L)	**368**	**368**	**212**	**149**	**119**	**297**
2,000	57	105	473	473	317	254	224	402
2,500	71	84	452	452	296	233	203	381
3,000	85	70	438	438	282	219	189	367
3,500	99	60	428	428	272	209	179	357
4,000	113	53	420	421	264	201	172	350
4,500	127	47	415	415	258	195	166	344
5,000	142	42	410	410	254	191	161	339
5,500	156	38	406	406	250	187	157	336
6,000	170	35	403	403	247	184	154	332
6,500	184	32	400	401	244	181	151	330
7,000	198	30	398	398	242	179	149	327
7,500	212	28	396	396	240	177	147	325
8,000	227	26	394	395	238	175	145	324
8,500	241	25	393	393	236	173	144	322
9,000	255	23	391	392	235	172	143	321
9,500	269	22	390	390	234	171	141	319
10,000	283	21	389	389	233	170	140	318

Table 12
Estimated Total PCB Concentrations Compared to the Prediction Interval Baseline Data at the TID-PRW2 Monitoring Station Assuming a 300 g/day Total PCB Release Rate

Total PCB Release Rate of 300 g/day			Total PCB- TID-PRW2 Station				
Flow (cfs)	Flow (m^3/s)	TPCB increase (ng/L)	May & June (1)	July and August	Sept.	Oct.	Nov.
Prediction Limit Baseline TPCB Concentration (Data representative of flow Rates>5,000 cfs)			**68**	**106**	**72**	**92**	**65**
2,000	57	105	266	211	177	197	170
2,500	71	84	245	190	156	176	149
3,000	85	70	231	176	142	162	135
3,500	99	60	221	166	132	152	125
4,000	113	53	213	159	124	144	118
4,500	127	47	207	153	118	138	112
5,000	142	42	203	148	114	134	107
5,500	156	38	106	145	110	130	103
6,000	170	35	103	141	107	127	100
6,500	184	32	100	139	104	124	97
7,000	198	30	98	136	102	122	95
7,500	212	28	96	134	100	120	93
8,000	227	26	94	133	98	118	91
8,500	241	25	92	131	97	116	90
9,000	255	23	91	130	95	115	88
9,500	269	22	90	128	94	114	87
10,000	283	21	89	127	93	113	86

Notes: (1) The 95percent UCL baseline varies as a function of flow rate for the months of May and June. It was estimated that prediction interval baseline concentration is approximately 160 ng/L for flow rates less than 5,000 cfs. This value was applied when estimating the total PCB concentration shown in the above table for all flow rates less than 5,000 cfs.

Table 13
Estimated Total PCB Concentrations Compared to the Prediction Interval Baseline Data at the Schuylerville Monitoring Station Assuming a 300 g/day Total PCB Release Rate

Total PCB Release Rate of 300 g/day			Total PCB (ng/L) - Schuylerville Station					
Flow (cfs)	Flow (m^3/s)	TPCB increase (ng/L)	May & June	July	August	Sept.	Oct.	Nov.
Prediction Interval Baseline Total PCB Concentrations			**195**	**99**	**107**	**85**	**118**	**107**
2,000	57	105	300	204	212	191	223	212
2,500	71	84	279	183	191	170	202	191
3,000	85	70	265	169	177	156	188	177
3,500	99	60	255	159	167	146	178	167
4,000	113	53	247	151	159	138	170	160
4,500	127	47	241	145	153	132	164	154
5,000	142	42	237	141	149	127	160	149
5,500	156	38	233	137	145	124	156	145
6,000	170	35	230	134	142	120	153	142
6,500	184	32	227	131	139	118	150	139
7,000	198	30	225	129	137	115	148	137
7,500	212	28	223	127	135	113	146	135
8,000	227	26	221	125	133	112	144	133
8,500	241	25	219	123	131	110	142	132
9,000	255	23	218	122	130	109	141	131
9,500	269	22	217	121	129	108	140	129
10,000	283	21	216	120	128	106	139	128

Table 14
Estimated Total PCB Concentrations Compared to the Prediction Interval Baseline Data at the TID-West Monitoring Station Assuming 600 g/day Total PCB Release Rate

Total PCB Release Rate of 600 g/day			Total PCB- TID-West Station					
Prediction Interval Baseline Total PCB Concentrations			May	June	July	August	Sept.	Oct. & Nov.
Flow (cfs)	Flow (m^3/s)	TPCB increase (ng/L)	**368**	**368**	**212**	**149**	**119**	**297**
2,000	57	210	578	578	422	359	329	508
2,500	71	168	536	536	380	317	287	466
3,000	85	140	508	508	352	289	259	437
3,500	99	120	488	488	332	269	239	417
4,000	113	105	473	473	317	254	224	402
4,500	127	93	461	462	305	242	213	391
5,000	142	84	452	452	296	233	203	381
5,500	156	76	444	445	288	225	196	374
6,000	170	70	438	438	282	219	189	367
6,500	184	65	432	433	276	213	184	362
7,000	198	60	428	428	272	209	179	357
7,500	212	56	424	424	268	205	175	353
8,000	227	53	420	421	264	201	172	350
8,500	241	49	417	418	261	198	169	347
9,000	255	47	415	415	258	195	166	344
9,500	269	44	412	413	256	193	163	342
10,000	283	42	410	410	254	191	161	339

Table 15

Estimated Total PCB Concentrations Compared to the Prediction Interval Baseline Data at the TID-PRW2 Monitoring Station Assuming a 600 g/day Total PCB Release Rate

Total PCB Release Rate of 600 g/day			Total PCB- TID-PRW2 Station				
Flow (cfs)	Flow (m^3/s)	TPCB increase (ng/L)	May & June (1)	July and August	Sept.	Oct.	Nov.
Prediction Limit Baseline TPCB Concentration (Data representative of flow Rates>5,000 cfs)			**68**	**106**	**72**	**92**	**65**
2,000	57	210	371	317	282	302	275
2,500	71	168	329	275	240	260	233
3,000	85	140	301	246	212	232	205
3,500	99	120	281	226	192	212	185
4,000	113	105	266	211	177	197	170
4,500	127	93	254	200	165	185	158
5,000	142	84	245	190	156	176	149
5,500	156	76	144	183	148	168	141
6,000	170	70	138	176	142	162	135
6,500	184	65	132	171	136	156	130
7,000	198	60	128	166	132	152	125
7,500	212	56	124	162	128	148	121
8,000	227	53	120	159	124	144	118
8,500	241	49	117	156	121	141	114
9,000	255	47	114	153	118	138	112
9,500	269	44	112	151	116	136	109
10,000	283	42	110	148	114	134	107

Notes: (1) The 95percent UCL baseline varies as a function of flow rate for the months of May and June. It was estimated that prediction interval baseline concentration is approximately 160 ng/L for flow rates less than 5,000 cfs. This value was applied when estimating the total PCB concentration shown in the above table for all flow rates less than 5,000 cfs.

Table 16
Estimated Total PCB Concentrations Compared to the Prediction Interval Baseline Data at the Schuylerville Monitoring Station Assuming a 600 g/day Total PCB Release Rate

Total PCB Release Rate of 600 g/day			Total PCB (ng/L) - Schuylerville Station					
Flow (cfs)	Flow (m^3/s)	TPCB increase (ng/L)	May & June	July	August	Sept.	Oct.	Nov.
Prediction Interval Baseline Total PCB Concentrations			**195**	**99**	**107**	**85**	**118**	**107**
2,000	57	210	405	309	317	296	328	317
2,500	71	168	363	267	275	254	286	275
3,000	85	140	335	239	247	226	258	247
3,500	99	120	315	219	227	206	238	227
4,000	113	105	300	204	212	191	223	212
4,500	127	93	288	192	200	179	211	201
5,000	142	84	279	183	191	170	202	191
5,500	156	76	271	175	183	162	194	184
6,000	170	70	265	169	177	156	188	177
6,500	184	65	259	163	171	150	182	172
7,000	198	60	255	159	167	146	178	167
7,500	212	56	251	155	163	142	174	163
8,000	227	53	247	151	159	138	170	160
8,500	241	49	244	148	156	135	167	157
9,000	255	47	241	145	153	132	164	154
9,500	269	44	239	143	151	130	162	151
10,000	283	42	237	141	149	127	160	149

Table 17
Calculation of the Annual Dredging Induced PCB Load for the Fully Exhausted Standard (500 ng/L)

Month	Average Fort Edward Flow from 1976-1999	No. of Work Days/Mo.	Mass Loss @ 500 ng/L	
			Daily Mass Loss (kg)	Monthly Mass Loss (kg)
5	7,300	26	5	135
6	3,800	26	3	71
7	2,800	26	2	52
8	2,800	27	2	54
9	3,100	26	2	58
10	4,300	26	3	80
11	5,600	26	4	104

Table 18
Calculation of the Annual Dredging Induced PCB Load for the 300 and 600 g/day Total PCB Mass Loss Control Limits

0.5% loss rate (Average of 300 g/day Total PCB Mass Loss)								
Sediment Removal Season	Dredging Location	speed	Cubic yards of sediment removed	Total PCB conc. on solids (mg/kg)	Total PCB flux (g/day)	Total PCB flux (kg/day)	Total PCB flux (kg/wk)	Total PCB flux (kg/year)
May 1 - Nov. 30, 2004	Sec. 1	half	260,000	27	140	0.14	0.84	25
May 1 - Nov. 30, 2005	Sec. 1	full	520,000	27	290	0.29	1.74	52
May 1 - Nov. 30, 2006	Sec. 1	full	520,000	27	290	0.29	1.74	52
May 1 - Aug. 15, 2007	Sec. 1 &	full	260,000	27	290	0.29	1.74	26
Aug. 16 - Nov. 30, 2007	Sec. 2	full	290,000	62	580	0.58	3.48	52
May 1 - Aug. 15, 2008	Sec. 2 &	full	290,000	62	580	0.58	3.48	52
Aug. 16 - Nov. 30, 2008	Sec. 3	full	255,000	28	230	0.23	1.38	21
May 1 - Aug. 15, 2009	Sec. 3	full	255,000	28	230	0.23	1.38	21
Total PCB flux (kg/project)								**302**
1% loss rate (Average of 600 g/day Total PCB Mass Loss)								
Sediment Removal Season	Dredging Location	speed	Cubic yards of sediment removed	Total PCB conc. on solids (mg/kg)	Total PCB flux (g/day)	Total PCB flux (kg/day)	Total PCB flux (kg/wk)	Total PCB flux (kg/year)
May 1 - Nov. 30, 2004	Sec. 1	half	260,000	27	290	0.29	1.74	52
May 1 - Nov. 30, 2005	Sec. 1	full	520,000	27	600	0.57	3.42	103
May 1 - Nov. 30, 2006	Sec. 1	full	520,000	27	600	0.57	3.42	103
May 1 - Aug. 15, 2007	Sec. 1 &	full	260,000	27	600	0.57	3.42	51
Aug. 16 - Nov. 30, 2007	Sec. 2	full	290,000	62	1200	1.2	7.2	108
May 1 - Aug. 15, 2008	Sec. 2 &	full	290,000	62	1200	1.2	7.2	108
Aug. 16 - Nov. 30, 2008	Sec. 3	full	255,000	28	450	0.45	2.7	41
May 1 - Aug. 15, 2009	Sec. 3	full	255,000	28	450	0.45	2.7	41
Total PCB flux (kg/project)								**606**

Table 19
Dredging Induced Loss - Percent of the Baseline Annual Load

Year	Annual Load to the Water Column	300 g/day Loss (65 kg)	600 g/day Loss (130 kg)	Fully Exhausted Standard (500 kg)
1992	1,017	6%	13%	49%
1993	610	11%	21%	82%
1994	499	13%	26%	100%
1995	302	22%	43%	166%
1996	391	17%	33%	128%
1997	258	25%	50%	194%
1998	410	16%	32%	122%
1999	293	22%	44%	171%
2000	384	17%	34%	130%
Standard Deviation	70 kg/yr for the years 1996-2000 220 kg/yr for the years 1992-2000			

Figures

Figure 1

TID-West Monitoring Station - 95% UCL - Total PCB

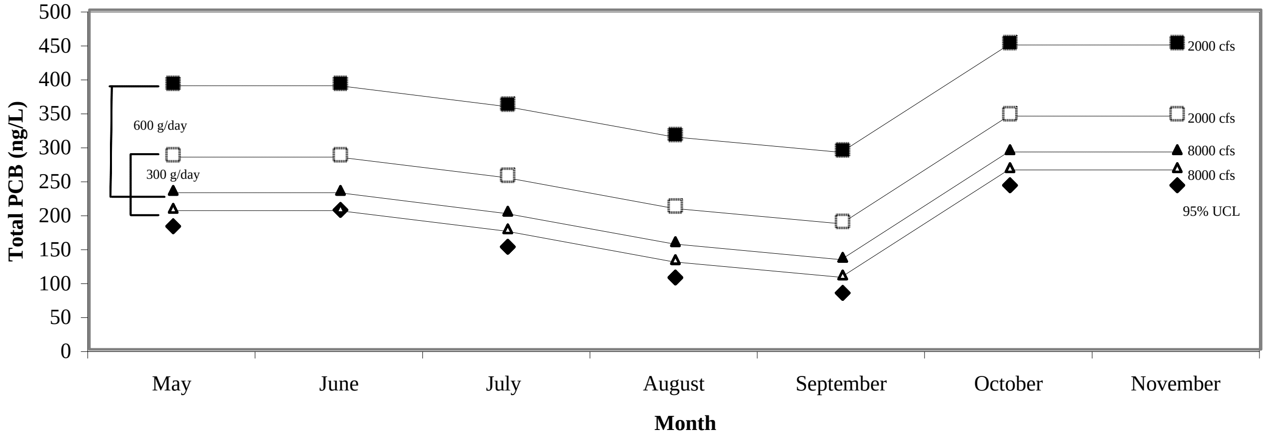


Figure 2

TID-PRW2 Monitoring Station - 95% UCL - Total PCB

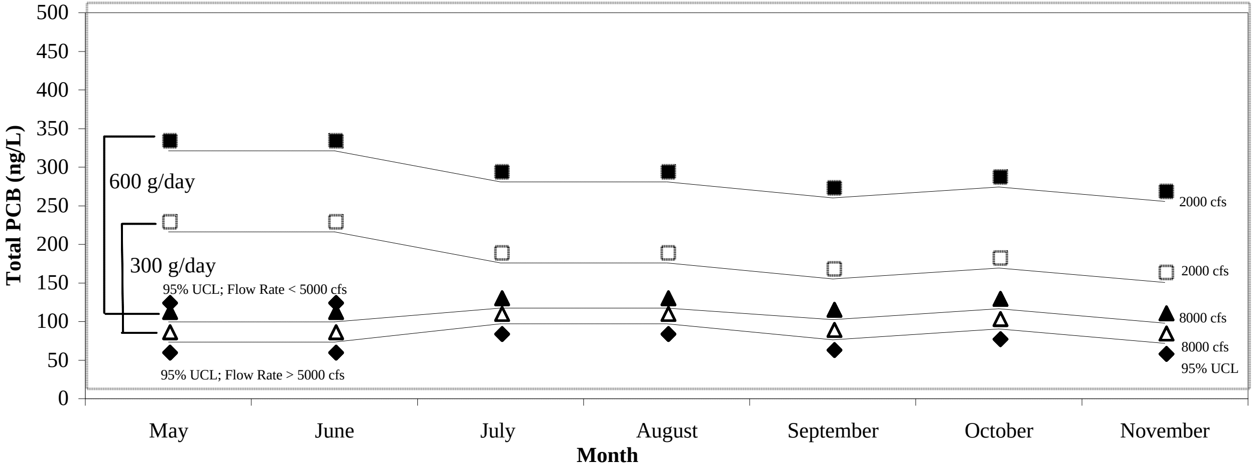


Figure 3

Schuylerville Monitoring Station - 95% UCL - Total PCB

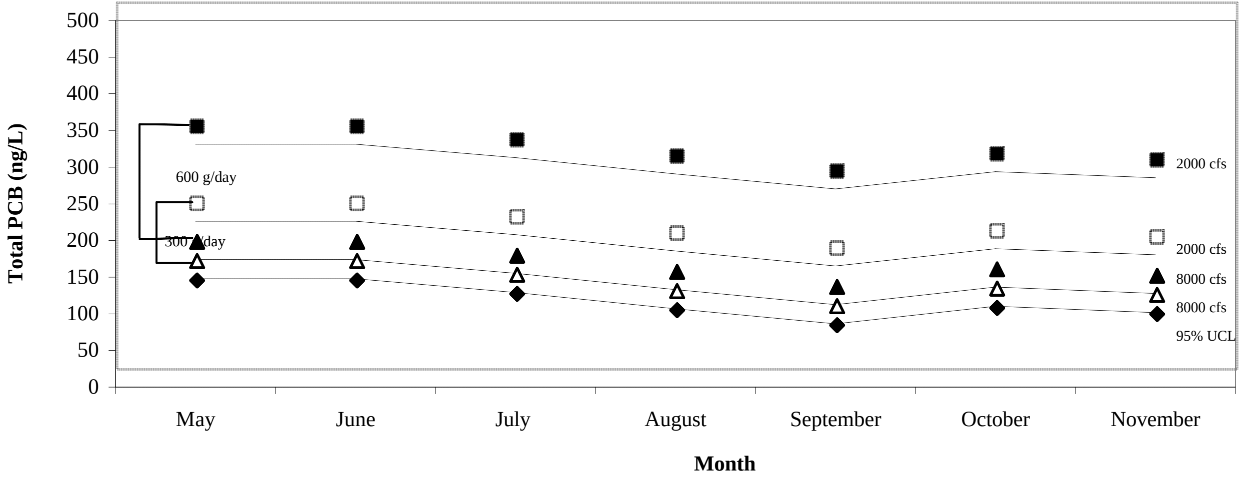


Figure 4

TID-West Monitoring Station - Single Incident - Total PCB

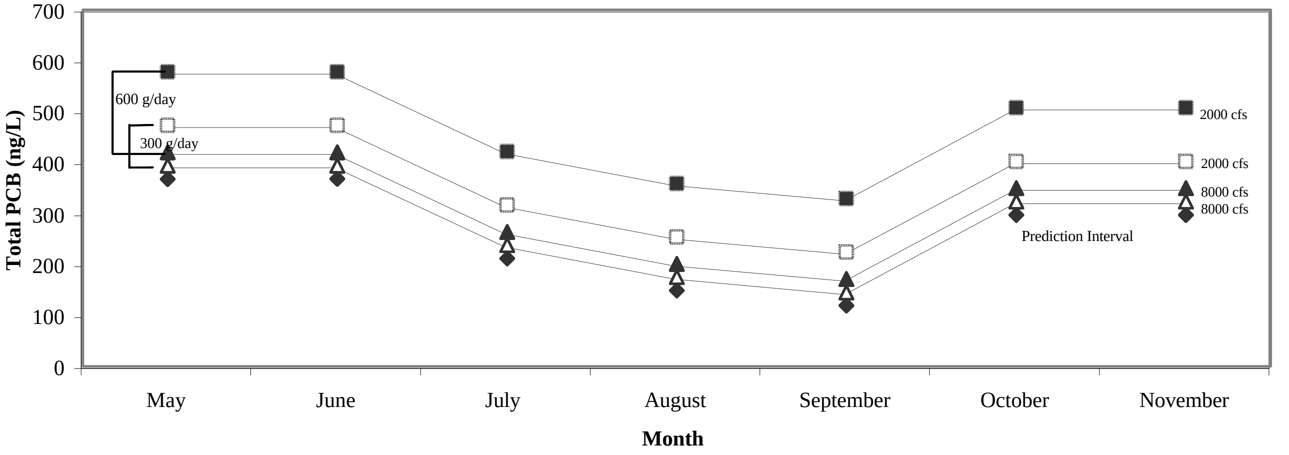


Figure 5

TID-PRW2 Monitoring Station - Single Incident - Total PCB

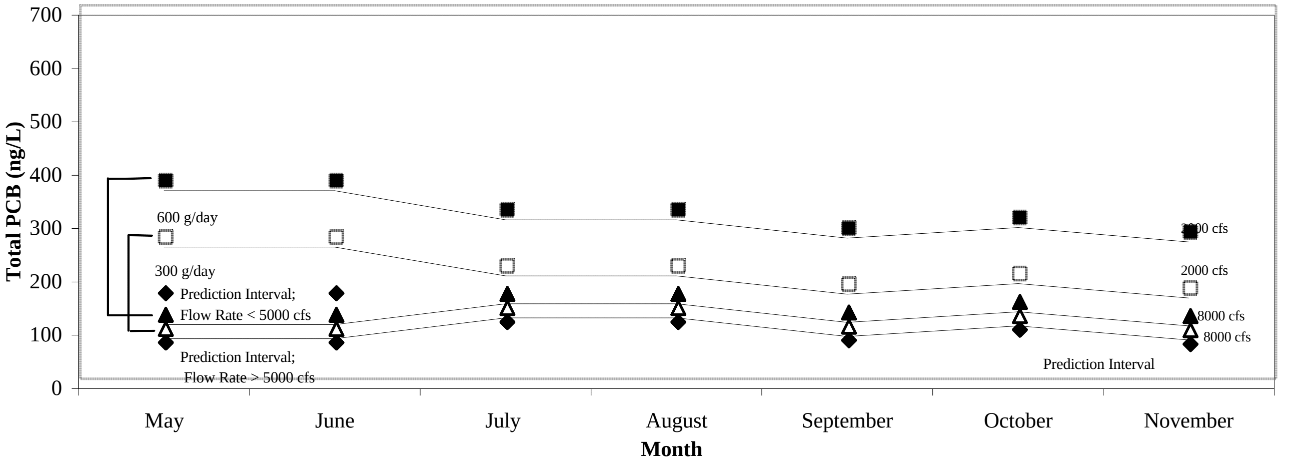
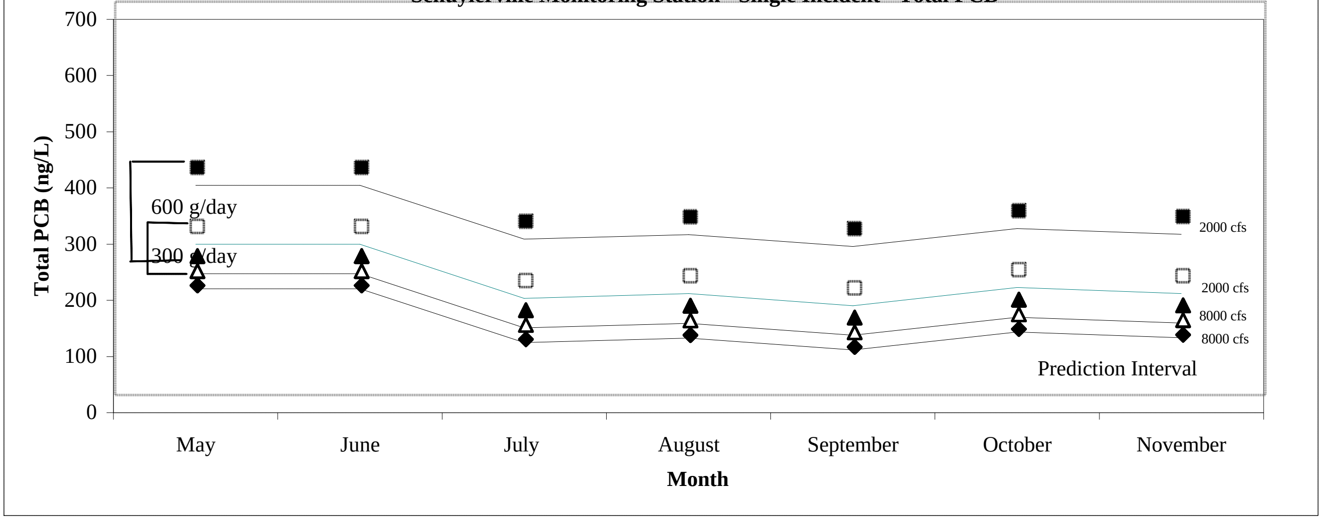


Figure 6

Schuylerville Monitoring Station - Single Incident - Total PCB



Attachment C

Examination of Mechanisms For High Dissolved Phase PCB Concentrations

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Attachment C

Examination of Mechanisms for High Dissolved Phase PCB Concentrations

1.0 Introduction

A United States Geological Survey (USGS) study of the Fox River SMU 56/57 demonstration projects (USGS, 2000) concluded that a large dissolved phase release of PCBs had occurred in the absence of any apparent increase in the water column load of suspended solids. Although there are some aspects of this study that suggest the conclusions regarding dissolved phase release may be incorrect, the United States Environmental Protection Agency (USEPA) has conducted several theoretical assessments of possible mechanisms to determine if, in fact, such a release is a realistic possibility. In order to address the issue of dissolved phase release, the proposed monitoring program specifies the collection of whole water PCB data under normal operating conditions (where water column concentrations are below a control limit that varies by month and flow rate outlined in Attachment B). If the water column concentrations are above a control limit, separate dissolved and particulate phase PCB concentration analyses will be required. Other indicators of the total PCB concentration in the water column will be measured, including total suspended solids, dissolved organic carbon, and a qualitative measurement of dissolved phase PCB concentrations using semipermeable membrane devices (SPMDs).

The Fox River dredging demonstration studies were examined in the *White Paper – Resuspension of PCBs During Dredging* (USEPA, 2002). However, several significant concerns were raised regarding the occurrence of a dissolved phase release during the review of this study. To summarize the white paper: although a substantial amount of data were collected from the Fox River dredging demonstration projects, the sampling approach and compositing strategy mask the results. A close review shows that the study results can only be considered inconclusive and should not be used as the basis for estimating resuspension from any future dredging operations. The limitations in the Fox River studies were discussed at length in the white paper, and are repeated here for the convenience of the reader:

- The load-gain estimate is based on a cross-section that is located too close to the dredging area. The cross-section is also located in an area that is a likely backwater (it is in a turning basin, with a nearby coal boat canal). It should be noted that sampling activities during boat activity showed higher PCB concentrations and were included in estimates of releases. Thus, flows through the cross-section are unlikely to be consistent and the estimation of load from concentration using these flows is suspect. The proximity of the cross-section to the dredging area also increases the likelihood that the sampling will not be representative of the total load, since the input from dredging will be poorly mixed.

- The sample compositing strategy, designed to reduce the number and cost of PCB analyses, was not appropriate to support the mass flux analysis that was attempted. The equal volume composites do not allow consideration of flow variation across the cross-section. USGS (2000) states that stagnant areas and even reversed flows were observed during sampling operations, confirming the errors associated with the composite PCB samples. The TSS sample composites induce less error and provide a more accurate estimate of downstream TSS flux, yet they showed an unexplained decrease in suspended sediment across the dredging operation. The decrease is almost certainly an artifact associated with compositing equal volume samples from 20 percent and 80 percent depth. Even though it has long been established that velocity measurements from these depths represent the average velocity in an open channel, there is no justification for suggesting that a composite sample from these depths represents the average concentration along the profile. This is particularly true in deeper water where the two samples represent 25 feet or more of water depth.

- The method of PCB collection was not documented, but it appears that the method represents the dissolved and suspended matter fractions inaccurately, based on the lack of change in PCB pattern across the dredging area. The load gain is attributed to a large gain in dissolved PCBs, but this is inconsistent with the PCB congener pattern. A large dissolved phase PCB contribution from the sediments, either by porewater displacement or sediment-water exchange, should yield a gain whose pattern is similar to the filter supernatant (see Figure 336740-6 in the Responsiveness Summary to the ROD [USEPA, 2002]). The fact that the congener pattern is unchanged across the study area would suggest a direct sediment addition, yet the suspended solids data document no increase in suspended sediments.

- Similarly, the total PCB concentration of the suspended matter doubles, yet there is no change in the suspended matter loading. Given the proximity of the downstream sampling cross-section to the source area, it is unlikely that the majority of the TSS in the river could be directly affected by dredging induced resuspension.

- A review of the PCB loading over the dredging period shows that PCB loads were relatively low for the first 2.5 months of operation, when dredging took place at the more upstream end of the targeted area. During this period, the estimated release was only 3 kg, or about 1.2 kg/month. This changed dramatically during the last month of operation, when the loading rate increased to about 13.5 kg/month. During this latter period, the dredging took place at the downstream end of the targeted area, very close (the closest station less than 80 feet) to the sampling cross-section, near areas with higher PCB concentrations. As discussed in the USGS paper, another significant factor that may have caused elevated PCB concentrations in the downstream profile was increased water flow velocities. Proximity of dredging operations to the deposit or water flow could have been significant contributing factors to the increased PCB concentrations observed in the downstream profile. To conclude that observed increases are only related to dredging fails to consider these and other potential influences. Additionally, a lack of comparable transect data for PCB water column concentrations pre-dredging (i.e., baseline) and during dredging also contributes to the uncertainty in evaluating dredging surface water contributions.

- The fact that significant loss of PCBs only occurred when the dredging area was close to the sampling cross-section suggests that the settling of any resuspended matter occurs within a short distance of the dredging operation. Only when the monitoring location was close to the dredging could this signal be found. This suggests that the loads obtained by this study do not represent PCBs released for long-distance transport. Rather, the PCBs appear to be quickly removed from the water column a short distance downstream. As such, it is inappropriate to use these results to estimate downstream transport from a dredging site.

There is much debate over the possibility of a dissolved phase PCB release during dredging. In the following discussion, theoretical arguments are presented as to mechanisms of release and a quantitative analysis of the magnitude of these releases. The results of the New Bedford Harbor Pre-Design Test, where both dissolved and particulate phase PCB concentrations were measured during dredging, are examined and compared to the results of the theoretical analyses. A literature review of this issue is appended to this Attachment (Attachment C-1).

2.0 Possible Release Mechanisms

In order to monitor PCBs correctly and minimize the impacts of dredging activities on water quality, the nature of PCB releases due to dredging must be understood. Specifically, the possibility that dredging will release dissolved phase PCBs must be considered. There are two basic pathways through which dredging activities may cause significant releases of dissolved phase PCBs:

- The first mechanism requires a direct release of water containing dissolved phase PCBs. Such water would most likely originate as porewater, since porewater is in direct contact with the contaminated sediments and typically contains high dissolved organic carbon concentrations, which can enhance the apparent dissolved phase PCB concentration. The possibility of such a release mechanism and the required water volumes are examined extensively from a theoretical approach in Section 2.1. The analysis presented suggests that this pathway is highly unlikely to result in significant releases.

- The second mechanism of dissolved phase releases into the water column from dredging is by desorption of PCBs from resuspended sediments. If the suspended solids added are of sufficient mass and contamination level, the dissolved phase concentration could rise markedly. It is worthy to note that the process of equilibration will not be undone by adsorption if, as a result of downstream transport, a large fraction of the suspended sediments are lost to settling. Since equilibrium between solid and dissolved phase is concentration-driven and not mass-driven, if a large mass of sediments is added to the water column, allowed to equilibrate, and lost via settling, the water column will be left with a large dissolved phase burden. This scenario is addressed in Section 2.2.

Although dissolved phase releases have historically been noted (USEPA, 1997; 2000) under baseline conditions in the TI Pool, these releases occurred during summer low flow periods without any significant resuspension of sediments. The conditions of these releases suggest that a significant portion of the dissolved phase flux may be biologically mediated. Due to the nature of dredging, it is unlikely that the same mechanism underlying these releases will cause dredging-related dissolved phase releases.

2.1 Estimates of the Effects of Dredging on the Dissolved phase PCB Concentration Using a Three-Phase Partitioning Model

2.1.1 Theoretical Estimation of the Mass of PCBs Available in the Dissolved Phase

During the Fox River PCB dredging project demonstration studies, the Water Resources Institute of the University of Wisconsin reported that 25 percent of the PCB load released from the Deposit N dredging demonstration project was in the dissolved phase (FRRAT, 2000). The United States Geological Survey (USGS) concluded in the paper *A mass-balance approach for assessing PCB movement during remediation of a PCB-contaminated deposit on the Fox River, Wisconsin*, "if chemical transport is to be quantified during a PCB remediation, then monitoring of TSS and turbidity alone is not adequate" (USGS, 2000). The study appeared to indicate that approximately 35 percent of the PCB load from dredging Sediment Management Unit 56/57 was in the dissolved phase (USGS, 2000). Due to this seemly high dissolved phase release it was concluded that a concentration-based approach to assessing remediation could be misleading unless the concentrations are converted into masses. Based on this, the PCB load into the water column mass represented less than 2.5 percent of what was dredged from the deposit. Since 35 percent of the PCB water column concentration increase was in the dissolved phase, the fraction of total mass lost as dissolved phase PCBs during dredging was 0.9 percent (2.5 percent total loss x 35 percent as dissolved) or nearly one percent of the total mass removed. Three phase partitioning models were used to estimate the volume of Hudson River porewater required for a 1 percent release of dissolved phase PCBs into the water column.

To evaluate the plausibility of the dissolved phase-based release mechanism, the estimation of dissolved and DOC-bound PCB concentrations using a three-phase equilibrium partitioning model was explored. Partitioning of organic chemicals between sediment and porewater can be approached on either a mass concentration basis (*i.e.*, mass of contaminant per dry weight of sediment), or a volumetric concentration basis (*i.e.*, mass of contaminant per volume of sediment). In this discussion, partitioning in the sediments will be analyzed on a volumetric basis. The equilibrium partitioning model assumes that the contaminant reaches equilibration among the different phases. On a volumetric basis, one volume of sediment contains PCBs sorbed to the particulate phase (solids) fraction, PCBs in the dissolved phase, and PCBs sorbed to the dissolved organic carbon. The derivation of the following equations is based on the *Data Evaluation and Interpretation Report* (DEIR) and Karickhoff (USEPA, 1997; Karickhoff, 1981). The mass of PCBs in particulate phase is described as:

$$M_P = C_{solid} \times M_{solid} \times 10^{-6} \qquad \text{(EQ 1)}$$

where:
M_P = mass of PCBs in particulate phase (mg)
C_{solid} = concentration of PCBs on the suspended matter (mg/kg)
M_{solid} = mass of sediments contained in the example volume (mg)
10^{-6} = factor to convert milligrams to kilograms

The mass of PCBs in the truly dissolved phase is described as:

$$M_d = \frac{C_{solid}}{K_{OC} \cdot foc} \times \frac{M_w}{r_w} \times 10^{-6} \quad \text{(EQ 2)}$$

where:
M_d = mass of PCBs in the truly dissolved phase (mg)
C_{solid} = concentration of PCBs on the suspended matter (mg/kg)

K_{OC} = partition coefficient between water and organic carbon (L/kg)
foc = fraction of organic carbon in the solid phase (unitless)
M_w = mass of water in example volume (mg)
ρ_w = density of water (g/cc)
10^{-6} = factor to convert liters to cubic centimeters and grams to milligrams

The mass of PCBs in the DOC-bound phase is described as:

$$M_{dc} = \frac{C_{solid}}{K_{OC} \cdot foc} \times K_{DOC} \times M_{DOC} \times 10^{-6} \qquad \text{(EQ 3)}$$

where:
M_{dc} = mass of PCBs in DOC-bound phase (mg)
K_{DOC} = partition coefficient between water and dissolved organic carbon (L/kg)
10^{-6} = factor to convert kilograms to milligrams
M_{DOC} = Mass of dissolved organic carbon (mg), defined as $DOC \times V_{water}$, where:
V_{water} = Volume of water in example (L)
DOC = Dissolved organic carbon concentration (mg/L)

and other parameters are defined above.

The total concentration in the sample is given as the total mass of PCBs over the total sample mass:

$$C_T = \frac{C_{solid} M_{solid} + \frac{C_{solid}}{K_{OC} \cdot foc} \times M_w + \frac{C_{solid}}{K_{OC} \cdot foc} \times K_{DOC} \times M_{DOC}}{M_{solid} + M_w + M_{DOC}} \qquad \text{(EQ 4)}$$

where: C_T = *total concentration of PCBs*

and other parameters are defined above.

The United States Army Corp of Engineers (USACE) Waterways Experiment Station (WES) studied the partitioning of PCBs to organic carbon for differing degrees of aromaticity (USACE, 1997). WES reported studies showing that the partitioning of nonpolar organic compounds is strongly related to the octanol-water partitioning coefficient of the compound (Karickhoff, 1981). The K_{OC} values for a particular compound have been reported to vary widely between sediments (Schrap and Opperhuizen, 1989; Brannon et al., 1993, 1995a). Similarly, wide variations in K_{DOC} for sediment porewater from different sediments have been observed (Chin and Gschwend, 1992, Brannon et al., 1995b). During their study, WES found that the measured values of

K_{DOC} were consistently lower than the estimated K_{DOC} calculated using the method of DiToro and others (1991) or Karickhoff (1981).

The USEPA estimated PCB partitioning coefficients using water column transect data and the two-phase and three-phase sediment-water partition models during the Phase 2 reassessment. The results are summarized in the DEIR, Table 3-10a (USEPA, 1997). For the purpose of evaluating the DOC-bound PCB fraction for the Hudson River, BZ#4 was used to represent the mono- and di-chlorinated homologues fraction and BZ#28 and BZ#31 to represent Tri+ PCBs. The partitioning coefficient for these congeners can be found in Table 1.

The estimate of porewater DOC was obtained from the sediment sampling program conducted by the General Electric Company (GE) in 1991 (O'Brien and Gere, 1993). The median of composited porewater DOC was 37 mg/L (range of 10 to 212 mg/L), (USEPA, 1997).

The concentration of PCBs sorbed to solids in the sediment, C_{solid}, was obtained from the length-weighted average PCB concentrations reported in the *White Paper – Sediment PCB Inventory Estimates*. The average PCB concentration for River Section 1 was calculated using data from the 1984 New York State Department of Environmental Conservation (NYSDEC) survey, while concentrations in River Sections 2 and 3 were computed using the 1994 low resolution coring data. Table 2 presents the *in situ* remediated, non-remediated, and reach-wide length-weighted averages of Tri+ and Total PCBs (without any overcut). In the calculations, the average concentration of 50 mg/kg for the remediated sediment of Tri+ PCBs was used in the three-phase equilibrium calculations. This average concentration serves as an upper bound value since the remediated sediment average Tri+ concentrations for all three river sections are less than 50 mg/kg (Table 2).

To simplify the calculation, the entire Tri+ mass was assumed to act as BZ#28, which is among the more soluble of the Tri+ congeners and thereby provides an upper bound on the mass of Tri+ dissolved. Using this concentration, the mass of BZ#28 in the particulate phase was 5×10^{-2} mg, while the mass of BZ#28 in the truly dissolved and DOC-bound dissolved phases was estimated at 8.2×10^{-7} and 4.4×10^{-7} mg, respectively. The calculation was repeated for BZ#31, another common constituent of the Tri+ congeners. The BZ#31 partitioning coefficients resulted in slightly higher truly dissolved and DOC-bound phases; the values were 9.0×10^{-7} and 8.4×10^{-7} mg for the truly dissolved and DOC-bound dissolved phases, respectively. Table 3 summarizes the results of the three-phase equilibrium partitioning for BZ#4, BZ#28, and BZ#31.

To simulate the mono- and di-homologue fraction, BZ#4, the principal di-homologue found in the sediment was used in the calculation. The concentration on the solid phase for this calculation was obtained from River Section 2 (see Table 2). The Total PCB average concentration of *in situ* sediment (without any overcut) targeted for remediation in the FS for River Section 2 was 147 mg/kg, while the Tri+ average concentration for this section of the river was only 44 mg/kg. This indicates that the mono- and di-chlorinated homologues represent the majority of PCB mass in the sediments that may be selected for remediated in River Section 2. Based on this information, an average concentration of approximately 100 mg/kg was selected for the combined mono- and di-chlorinated homologue concentration. Using BZ#4 as a surrogate for this group, the mass of BZ#4 in the particulate phase is 1.0×10^{-1} mg and the mass of BZ#4 in the truly dissolved and DOC-bound dissolved phases is 3.5×10^{-7} and 3.5×10^{-6} mg, respectively.

Assuming equilibrium conditions, it is clear that the sediment porewater contains very little of the *in situ* sediment PCB mass. For the Tri+ fraction, the ratio of combined dissolved and DOC-sorbed phases to the sediment-bound PCB fraction is given by:

$$\frac{(8.2\times10^{-7} + 4.4\times10^{-7})}{5.2\times10^{-2}} = 2.4\times10^{-5}$$

$$or\, 0.002\, percent$$

Similarly for the mono- and di-homologue fractions:

$$\frac{(3.5\times10^{-7} + 3.5\times10^{-6})}{1\times10^{-1}} = 3.9\times10^{-5}$$

$$or\ 0.004\ percent$$

A simple calculation can be used to estimate the number of porewater volumes that would have to be displaced to achieve the roughly 1 percent of mass reportedly lost for the Fox River study. This calculation assumes that each porewater volume would be mixed with the sediments and brought to equilibrium before being released to the river. Thus, to remove 1 percent of the mass via a dissolved phase displacement (without resuspension), the proportion of water to sediment volume is given by the ratio of the desired mass to be lost (1 percent) over the mass available in a single porewater volume (0.0024 for Tri+ and 0.004 for mono- and di-homologues). Using the higher fraction to yield the minimum number of volumes gives:

$$\frac{1}{0.004} = 250$$

or 250 porewater volumes. Since the sediments are roughly half water by volume, to achieve the 1 percent loss without resuspension would require that each cubic yard of sediment be washed with 250 porewater volumes, or about 125 cubic yards of water. For the Tri+ fraction, with a lower percentage in the dissolved phase, this proportion would nearly double to 420 volumes, or 210 cubic yards of water. It is important to note that this mixing volume would have to be achieved for each yard of sediment removed and not for the much smaller fraction of sediment that is lost or spilled.

In conclusion, assuming an equilibrium-based porewater concentration, a direct loss of dissolved phase PCBs to the water column from porewater is highly unlikely. The required mixing volumes of sediment to water are unlikely to be attained under any reasonably well-operated dredging program. In fact, the mixing ratios suggested are much more akin to a resuspension flux where the volume of water to the mass of solids can easily achieve this, or even a much higher[1], proportion. Thus, if a large mass of dissolved PCBs is present in the water column downstream of the dredging operation, it is more likely to be the result of the resuspension of sediment accompanied by PCB equilibration between dissolved and suspended matter.

2.2 Analysis of Dissolved Phase PCB Increase as a Result of Solids Resuspension Using a Two-Phase Partitioning Model

Section 2.1 demonstrates that it is highly unlikely that the increases in dissolved phase concentration reported for the Fox River resulted from a direct release of dissolved or “apparently dissolved” DOC-bound PCBs from the sediments. An alternative explanation for the increase in reported dissolved concentrations is that it is due to desorption from temporarily resuspended contaminated sediments. This section examines the mechanisms for dissolved phase increase as a result of solids resuspension. The analysis also examines the related question of whether the dissolved fraction of PCBs present in the water column can be used as an indicator of dredging-related PCB releases.

A primary objective of the resuspension monitoring is to distinguish the dredging-related contribution of PCB contamination to the water column from the baseline flux of PCBs from the contaminated sediments. To meet this objective, it is important to determine whether or not measurement of the whole-water PCB concentration is sufficient to characterize an increase in the water column PCB concentration resulting from dredging, or if the measurement of the dissolved phase PCB concentration is also necessary.

One way to distinguish a dredging-related PCB release from the baseline PCB concentration is to compare the concentration of PCBs in the dissolved phase to the total concentration of PCBs in the water column due to dredging activities. The next step would be to compare these values to those of the baseline PCB concentrations in the TI Pool. If the ratio of the concentrations detected during dredging operations differs from the baseline ratio, then it is possible to distinguish dredging-induced inputs from the baseline.

As evidenced by the GE float survey, USEPA Phase 2 inventory assessment, and GE water column monitoring program data, Hudson River sediments continue to release PCBs to the water column throughout the year. The data analyzed during the Phase 2 reassessment and subsequent data collected by GE show that PCBs are released to the water column during low flow periods without resuspension of sediment, particularly from May through November. During low flow periods, the observed suspended phase concentration in the water column was low.

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[1] The addition of solids to achieve a concentration of 10 mg/L (a nominal value from Section 3 of this attachment) represents a liquid to solids ratio of roughly a million to one.

Recognizing the fact that there is PCB release to the water column without any corresponding increase in total suspended solids (TSS), a scenario where dredging operations cause the TSS levels to increase temporarily is considered. The affect of the TSS increase to the water column is examined using a two-phase partitioning model. This model provides a preliminary evaluation as to whether the effects of dredging activities could be distinguished from baseline river conditions by examining the relative magnitude of dissolved phase to total PCB releases to the water column.

As in the sediments, PCBs in the water column behave as a three-phase system, with components of a dissolved phase, a phase sorbed to sediment, and a phase sorbed to DOC. However, as discussed in the DEIR, the DOC-sorbed phase is of relatively minor importance in the water column of the Hudson River. In addition, because DOC concentrations are relatively constant, the system can be analyzed as an equivalent two-phase system consisting of a sediment-sorbed fraction and an “apparent” (or unfilterable) dissolved fraction that consists of truly dissolved and DOC-sorbed PCBs. Therefore, the analysis that follows is presented in terms of a two-phase partitioning model.

The two-phase partitioning model assumes that the water column and the sediments are in equilibrium. In a two-phase system, the PCB concentration in the water column is equal to the sum of the dissolved phase fraction and the suspended solids fraction, such that:

$$C_{Total} = C_{dissolved} + C_{suspended} = C_{dissolved} + \mathrm{TSS} \times C_{dissolved} \times K_D \times 10^{-6} \tag{EQ 5}$$

where:

C_{Total} = total water column PCB concentration (ng/L)

$C_{dissolved}$ = PCB concentration of apparent (non-filterable) dissolved fraction (ng/L)

$C_{suspended}$ = PCB concentration of suspended solids fraction (ng/L)

K_d = soil-water partition coefficient (L/kg)

TSS = total suspended solids concentration (ng/L)

The whole water background concentration of the water column in the northern portion of the TI Pool is nominally 50 ng/L. The background TSS value of 1 mg/L is assumed. The concentration of the PCBs on the suspended matter, obtained from the instantaneous total PCB water column loading for Transect 6 (USEPA, 1999), is approximately 5 mg/kg. Using these values and the equation above, the suspended solids concentration of PCBs is estimated as:

$$C_{PCB\ -susp} \times C_{TSS} = C_{PCB\ as\ susp} \qquad \text{(EQ 6)}$$

$$(5\ ng/mg) \times (1\ mg/L) = 5\ ng/L$$

where:

$C_{PCB-susp}$ = concentration of PCBs on the suspended solids in ng/mg (same as mg/kg)

C_{TSS} = concentration of suspended solids in the water (mg/L)

$C_{PCB\ as\ susp}$ = concentration of PCBs on suspended solids per unit volume of water (ng/L)

and the dissolved phase concentrations is estimated at:

$$(50\ ng/L) – (5\ ng/L) = 45\ ng/L$$

The sediment-water partition coefficient for this example can be checked against the values determined in the DEIR (nominally 10^5) by dividing the concentration in the sediment by the concentration in the dissolved phase. The estimated K_d value is:

$$(5\ mg/kg) / (45\times10^{-6}\ mg/L) = 1.1\times10^5$$

which agrees well with the more rigorous calculation done in the DEIR. For this calculation, the dredging operation is assumed to take place midway through the TI Pool. For dredging scenarios with 1 percent loss rate at full production and flow between 2000 to 5000 cfs (57 to 142 m^3/s), the additional TSS value to the water column due to dredging is approximately 7 to 3 mg/L. Assuming the sediment concentration of 50 mg/kg (which is an upper bound for remediated sediment average concentrations for all three river sections, USEPA, 2002), and the median TSS concentration (5 mg/L), the additional PCB concentration associated with the suspended solids becomes:

$$(50\ ng/mg) \times (5\ mg/L) = 250\ ng/L$$

Therefore, the total concentration of PCBs in the water column accounting for the additional TSS releases from dredging becomes:

$$(250\ ng/L) + (45\ ng/L) + (5\ ng/L) = 300\ ng/L$$

The dissolved phase fraction of PCBs added due to the TSS increase in the water column can be calculated using equation 5 as:

$$(300\ ng/L) = C_{dissolved} + [(5\ mg/L + 1\ mg/L) \times C_{dissolved} \times 1.1\times10^5\ L/kg \times 10^{-6}\ kg/mg],$$

which gives: $C_{dissolved}$ = 180 ng/L.

The sediment concentration (C_{sed}) becomes:

$$C_{sed} = C_{dissolved} \times K_D \times 10^{-6} \qquad \text{(EQ 7)}$$

$$C_{sed} = (180\ \text{ng/L}) \times (1.1\times10^{5}\ \text{L/kg}) \times (1\ \text{kg}/10^{6}\ \text{mg}) = 20\ \text{ng/mg}$$
or 20 mg/kg.

Assuming, at the subsequent monitoring station, that all the dredging-related TSS has resettled and equilibrium is achieved before the sediment settles, the TSS inventory goes from:

$$(6\ \text{mg/L}) \times (20\ \text{mg/kg}) = 120\ \text{ng/L}$$

to

$$(1\ \text{mg/L}) \times (20\ \text{mg/kg}) = 20\ \text{ng/L}.$$

The loss in the inventory is approximately 100 ng/L, which means the total water column concentration decreases from 300 ng/L to 200 ng/L during transport from the dredging location to the downstream monitoring station.

The fraction of the dissolved phase to the total concentration of PCBs in the water column due to dredging is:

$$(180\ \text{ng/L})/(200\ \text{ng/L}) = 0.9.$$

Thus, resuspension of contaminated sediment and re-equilibration in the water column provides a plausible explanation for the observation of an increased dissolved phase concentration downstream of a dredging site.

As shown in the DEIR and FS, the sediments in the TI Pool continue to release PCBs to the water column. Additionally, the seasonal variability of the last three to four years of monitoring data collected by GE is strongly indicative of the absence of flow dependence in the TI Pool's PCB loads. The absence of flow dependence would suggest that resuspension resulting from flow is unlikely to be the cause of the PCB loading from the TI Pool.

PCB loadings in the TI Pool were extensively quantified during the Phase 2 reassessment. The Phase 2 water column monitoring program presents estimates of water column fluxes for the period January to September 1993 (USEPA, 1997). Based on both instantaneous and 15-day mean measurements, the TI Pool sediment was shown to be the dominant source of PCBs to the water column in eight out of nine months of monitoring. This source released less chlorinated PCB congeners that were predominantly found in the dissolved phase in the water column (USEPA, 1997). In addition, GE and USGS water column monitoring data support the findings based on Phase 2 data. In particular, the GE data show the importance of the TI Pool sediment source for the period of 1991 to 1995.

These observations can be seen in Transects 5 and 6 during low flow conditions (Figure C-3 and Figure 3-47 [corrected] of Appendix C of the *Low Resolution Coring [LRC] Responsiveness Summary*, respectively [USEPA, 1999]). The values of whole (total) water column, dissolved phase, and suspended solids concentrations at TI Dam and Schuylerville are summarized in Table 4. These data showed that the baseline flux of PCBs to the water column have a relative magnitude of dissolved phase to total concentration on the order of 0.9.

Since the fraction of the dissolved phase to the total water column PCB concentration for both background and after dredging is similar (on the order of 0.9), it is not possible to distinguish the effect of dredging by examining the fraction of the dissolved phase increase in the water column.

3.0 Estimate of the Rate of PCB Desorption

3.1 Literature Review

The theoretical assessments presented above are based on the three-phase and two-phase partitioning models. Both theoretical arguments assume that the solid and dissolved phase PCBs reach equilibrium. Recent studies have demonstrated that desorption of hydrophobic chemicals from sediments can be quite slow, and that chemical equilibrium may not be a good approximation in many real situations. In a dredging scenario, the residence time (contact time) of the resuspended sediment in the water column is relatively short, on the order of hours. It is unlikely that PCBs reach equilibrium in this period of time. Desorption rates and the relative fractional amounts of hydrophobic organic chemicals, including PCBs, released from sediment have been studied (Carroll *et al*., 1994, Borglin *et al*., 1996; Cornelissen *et al*., 1997; ten Hulscher *et al*., 1999, 2002; and Ghosh *et al*., 2000). Such kinetic rates could be used as an alternative to provide estimates of the dissolved phase PCBs resulting from dredging activities. Literature on the desorption rates of PCBs was reviewed to obtain desorption equilibrium and kinetics rates for PCBs.

Many researchers showed evidence that desorption of contaminants takes place in at least two steps: a fast and slow step. The desorption of PCBs from Hudson River sediments was studied by Brown (1981) and Carroll and associates (Carroll *et al*., 1994). Brown developed and tested a method for the analysis of rates of PCB desorption from sediment suspended by dredging activities. The data used were taken from dredging operations in the Hudson River at the town of Fort Edward in 1977. The monitoring stations were placed in the east channel of Rogers Island. Brown used the Freundlich isotherms model to obtain the sinking and sorption-desorption rate constants of Aroclor 1016. In the report, the author used the term “sinking” to refer to the rate constant for the first order settling coefficient. The sinking and sorption-desorption rates were chosen using trial and error methodology to fit the measured concentration of Aroclor 1016 under low and high flow conditions. For low flow conditions, it was found that a sinking rate of –0.08 hr^{-1} and desorption rate constants ranging from 0.025 hr^{-1} to 0.05 hr^{-1} fit the measured data well. Under high flow conditions, a reasonable fit was obtained using a sinking rate of –0.4 hr^{-1} and desorption rate constants on the order of 1.0 hr^{-1}. Brown concluded that the rate of PCB desorption from solids is proportional to the difference between the PCB burden of the suspended sediments and the burden that would be in equilibrium with the existing soluble concentration.

Carroll and associates studied the desorption of PCBs from Hudson River sediment using XAD-4 resin as a PCB adsorbent. They used sediments contaminated with high, medium, and low levels of PCBs from the Hudson River near Moreau, New York. The three Hudson River sediments used in their study contained 25, 64, and 205 mg/kg (dry weight) PCBs with total organic carbon contents of 0.96, 3.43, and 4.59 percent, respectively. They reported that the PCBs present in the sediments consisted primarily of mono- and di-chlorinated biphenyls (60-70 percent of total). Both a rapidly desorbing labile component and a more slowly desorbing resistant component were observed. Rate constants for the labile (fast) and resistant (slow) fractions were obtained using a model developed by Berens and Huvard (1981). For the purpose of this study, the desorption rate constant of the untreated moderately (64 mg/kg dry weight PCB) PCB-contaminated Hudson River sediment is considered. The desorption rate constant obtained from the Carroll and associates study was approximately 0.018 hr^{-1} (Table 5).

Borglin and associates studied parameters affecting the desorption of hydrophobic organic chemicals from suspended sediments (Borglin *et al.*, 1996). In their paper, Borglin and associates presented the results from long-term experiments performed for three hydrophobic organic chemicals (hexachlorobenzenes and two polychlorinated biphenyls). They concluded that the desorption times are on the order of a month to several years, and observed that the desorption rates are dependent on the:

- Particle/floc size and density distributions.
- Type of water.
- Amount of organic carbon in the sediments.
- Time of adsorption before desorption.
- Chemical partition coefficient.

Borglin and associates presented results describing the amount of PCBs (monochlorobiphenyl and hexachlorobiphenyl) desorbed over time. The rate constants calculated are on the order of 0.0049 hr^{-1} and 0.00042 hr^{-1} for monochlorobiphenyl and hexachlorobiphenyl, respectively.

Cornelissen and associates studied desorption kinetics for chlorobenzenes, PAH, and PCBs for different contact times and solute hydrophobicity (Cornelissen *et al.*, 1997). They used a technique employing Tenax TA® beads as a “sink” for desorbed solute to measure the kinetics of desorption of the compounds mentioned above. For PCBs, they studied PCB-65 (2,3,5,6-tetrachlorobiphenyl) and PCB-118 (2,3’,4,4’,5-pentachlorobiphenyl). The sediment used was taken from Lake Oostvaardersplassen, located in the Netherlands. They observed two stages of desorption rates: the rapid release of the “labile” sorbed fraction, and slow release of the “non-labile” fraction. Two different contact times were considered in this study: 2 days and 34 days. The desorption rate constants were varied for the different contact times for both the rapid and slow release. The values are summarized in Table 5.

In 1999, ten Hulscher and associates studied desorption kinetics and partitioning of chlorobenzenes, PCBs, and PAHs in long-term field contaminated sediment cores and top layer sediment (ten Hulscher *et al.*, 1999). They concluded that the desorption from sediment was triphasic: fast, slow, and very slow. In this study, they used the sediment from Lake Ketelmeer, located in The Netherlands. Only core results were presented for PCB-28. They reported desorption rate constants with values of 0.21×10^{-3} hr^{-1} and 0.19×10^{-3} hr^{-1} for a very slow fraction.

Ghosh and associates studied the relationship between PCB desorption equilibrium, kinetics, and availability during land biotreatment (Ghosh *et al*., 2000). For this purpose, they conducted a study of the equilibrium partitioning and desorption kinetics using industrial lagoon sediments containing 0.91 percent oil and grease as a function of biotreatment duration. A two compartment model was used to model the desorption of PCBs from sediment. Desorption rate constants were reported for tri-, tetra-, penta-, and hexa-chlorobiphenyls. Values for the untreated sediment are summarized in Table 5.

Recently, ten Hulschler and associates studied the desorption kinetics of *in-situ* chlorobenzenes and 2,4,4'-trichlorobiphenyl (PCB-28) from River Rhine suspended matter in Lobith, located in The Netherlands (ten Huschler *et al*., 2002). They observed fast, slow, and very slow desorption rates for PCB-28. Rate constants observed were on an average of 0.2 hr^{-1} for fast, 0.0004 hr^{-1} for slow, and 0.00022 hr^{-1} for very slow desorption rates.

Table 5 summarizes the PCB desorption rate constants from different literature. From this table it can be seen that there is a high degree of variation in the magnitude of PCB desorption rate constants.

3.2 Dissolved Phase, Suspended Solids, and Whole Water PCB Concentration Estimates using Desorption Rate Constants

Most of the reported values of desorption rate constants for PCBs are homologue-based, except for Carroll, *et al*. who used an untreated PCB consisting of 60-70 percent mono- and di-chlorinated biphenyls. The desorption rate constants from literature vary from 4.2×10^{-4} to 0.2 hr^{-1} (Table 6). The highest desorption rate constant reported is within the range of those reported by Brown in 1981 for the Hudson River sediment (0.025 to 1.0 hr^{-1}). The reported rate constants correspond to a half-life range of approximately 3 to 1,700 hours and equilibrium range of 26 hours to 980 days (Table 6).

Given the length of time required for PCBs to reach equilibrium for desorption, it is unlikely that there will be large release of dissolved phase PCBs as a result of dredging activities. To demonstrate this hypothesis, the amount of dissolved phase PCBs within one hour of dredging was estimated using the two-phase partitioning model, as was described in Section 2 of this attachment. The desorption rate constants were used to estimate what level of equilibrium was achieved in one hour. Due to lack of knowledge on the amount of "labile" (fast) and "non-labile" (slow) fractions in the dredged material, only fast desorption rate constants (ranging from 4.2×10^{-4} to 0.2 hr^{-1}) are considered in this study in order to be conservative. Since the reported desorption rate constants were homologue-based, the ratios of the homologue to total PCBs are needed. The ratio of the homologue to total PCBs for the sediment was taken from the low resolution coring data (USEPA, 1998), while the ratio for the suspended solids and dissolved phase were taken from Transect 6 water column PCB homologue composition for the TI Pool reported in the DEIR (USEPA, 1997).

The background and additional concentrations and TSS values used in this analysis were the same as the values used in Section 2 of this attachment. The whole water background concentration is 50 ng/L and the corresponding TSS value is 1 mg/L (Table 7). The additional TSS value is 5 mg/L and sediment concentration is 50 mg/kg (Table 7). Assuming a residence time of 1 hour, the dissolved phase PCB released due to dredging ranges from 7.6×10^{-5} ng/L to 3.23 ng/L (Table 8). The percentage of the dissolved phase to the total concentration of PCB in the water column due to dredging ranges from 0.042 to 11 percent. From this analysis, it appears that the amount of dissolved phase in the water column as a result of dredging is relatively small.

4.0 Results from Field Studies with Dissolved and Suspended Phase PCB Measurements

4.1 New Bedford Harbor

The analyses presented in Sections 2 and 3 of this attachment conclude that a significant release of dissolved phase PCBs is unlikely to occur as a result of dredging activities. It is possible to assess these results using case study field measurements of dissolved and suspended PCB concentrations data in the water column during dredging. Measurements of dissolved and particulate phase PCBs were collected during the pre-design field test conducted at the New Bedford Harbor during August 2000.

A hybrid environmental mechanical/hydraulic excavator dredge was delivered and demonstrated by Bean Environmental LLC. The system included a portable, shallow draft barge platform, a horizontal profiling grab bucket (HPG), a crane monitoring system (CM), the Bean-patented slurry processing unit (SPU), and a water recirculation system. The average production rate for the dredge was 80 cubic yards per hour. An estimated optimal rate for the system is 95 cubic yards per hour.

A summary of field samples and analytical data is presented in Table 9. TSS and turbidity were measured along with dissolved and suspended phase PCBs. 18 National Oceanic and Atmospheric Administration (NOAA) congeners were measured and an equation developed during a previous study was used to calculate the total PCB concentration. The following information was available:

- Two pre-dredging measurements
- Data from upstream and downstream monitoring points during dredging activities
- Two measurements at the point of dredging.

The pre-dredging samples were collected 1000 feet to the north and south of the dredging location. The harbor is tidal, so the upstream/downstream locations reverse periodically. That is, the stations are located either north or south of the dredge, depending on the tide. Sampling locations were placed as follows:

Location	Initially	Adjusted in Field
Upstream	1000’	1000’
Downstream	50’	50’
Downstream	100’	300’
Downstream	500’	700’
Downstream	NA	1000’

Graphs of PCBs, TSS, and turbidity vs. distance from the dredge are shown in Figure 1. The results for the pre-dredging samples are shown at +/–1500 feet on Figure 1 for comparison. The particulate PCB and TSS measurement give similar patterns of concentrations as would be expected. At the point of dredging, the particulate PCB concentrations are elevated about ten times over the upstream conditions, but 1000 feet downstream the concentrations are just above the highest measured upstream concentration. Turbidity measurements drop off quickly with distance to a level similar to the upstream monitoring point conditions.

The dissolved phase PCB concentrations at the dredge are about ten times larger than the upstream concentrations, but these concentrations drop off quickly into the range of the upstream samples. Looking at the fraction of dissolved phase PCBs in the water column, the upstream PCBs are about 60 percent dissolved. At the dredge, this percentage drops to below 20 percent. Downstream of the dredge, the percent of dissolved phase is more variable but still less than the 60 percent fraction detected at the upstream location. This variability in the downstream samples is mirrored in the particulate PCB and TSS measurements.

These results are consistent with a mechanism of PCB release through the suspension of contaminated solids, not a significant dissolved phase release mechanism. This conclusion is more convincing in light of the high concentrations at this location (857 ppm on average in the top 0- to 1-foot segment) relative to the Hudson River (approximately 50 ppm on average in the TI Pool) and the nearly full production rate.

4.2 PCB Load Calculation

Dissolved and particulate phase PCB loads can be calculated using PCB concentrations and estimates of the flow rate. Linear velocity was measured at one location 1500 feet downstream of the dredging area. The estimate is quite crude because the volumetric flow rate is not known, but can only be calculated by using a rough estimate of the cross-sectional area at the point of the linear velocity measurement and by making the assumption that the linear velocity measurement represents the entire cross-section. This calculation further assumes that the PCB concentrations are a measure of concentration in the entire cross-section, not a portion of the harbor that has been influenced by the plume.

The linear velocity was measured at a reference station 1500 feet south of the dredge area. This section of the harbor is approximately 800 feet wide and varies from 7 to 10.5 feet in depth, depending on the tide. The velocity was measured every 10 minutes. The northern velocities peaked at 14 cm/s. A velocity 10 cm/s will be used as an average flow rate for the calculation. A limited southern component of flow was detected, indicating a stratified system.

Several measurements of the PCB concentrations were made at locations from 50 to 1000 feet downstream from the dredge area. For this estimate of load, the maximum concentration detected at the 100- to 1000-foot stations was selected to represent the mass that would remain in the water column outside of the influence of the dredge. Both the maximum dissolved and particulate concentrations were measured on the same day at

700’ from the dredge. A maximum dissolved phase PCB concentration of 0.95 ug/L was detected. A maximum particulate phase PCB concentration of 2.6 ug/L was detected. Two background measurements were made. The dissolved and particulate phase background concentrations will be subtracted. The duration of the dredging operation in hours was estimated from the time of the turbidity measurements.

Using these measurements of flow, concentration, and dredging operation duration, the maximum likely PCB loads are 1.8 kg in the dissolved phase and 7.0 kg in the particulate phase. The calculation is shown in Table 10. Twenty percent of the load is in the dissolved phase, and 80 percent in the particulate phase. It was estimated that 1,495 kg of PCBs were removed from the evaluation area. The dissolved phase load translates into 0.1 percent of the total mass removed, and the particulate phase load translates into 0.5 percent of the total mass removed.

5.0 Conclusions

The release of a significant amount of dissolved phase PCBs as a result of dredging but independent of the process of sediment resuspension would appear highly unlikely in light of the discussion presented above. There is not a sufficient reservoir of dissolved phase PCBs available to be the sole cause of a large increase in water column concentrations. That noted, the process of suspended sediment-water contact could result in a large inventory of dissolved phase PCBs if sufficient time is available to permit exchange between suspended sediments and water. It is this latter process that may be of concern during the Hudson River remediation.

Two important issues arise from this process, however. If the equilibration of dissolved and suspended matter PCBs occurred sufficiently fast, the original nature of the source (*i.e.,* the suspended solids-borne PCBs) could be masked by the changes that occur. For this reason, whole water PCB concentrations will be the main measure of PCB transport, capturing all forms of PCBs present. Measurement of suspended matter PCBs alone may under-represent the total level of PCB release.

The second issue relates to the usefulness of suspended solids as a surrogate and real-time monitoring parameter. Near-field monitoring of suspended solids can probably be relied upon to provide a useful indication of the amount of resuspension, although it will not be quantitative for several reasons, including the issue discussed above. The monitoring of suspended solids at the main downstream stations will be less sensitive to resuspension inputs, but will still provide a useful measure of conditions in general. Given the typically low suspended solids load of the Hudson during the dredging season, it is likely that major suspended solids releases will still be discernable at these stations. To account for this, whole water PCB samples will suffice when both suspended solids and PCB concentrations fall below the lowest control limit. In the event that concentrations of either parameter exceed this control limit, a second level of sampling will be required, with more frequent sampling and separate analysis of both dissolved phase and suspended matter PCBs. In addition, SPMDs will be deployed on a continuous basis to give an indication of the dissolved phase concentrations between the water column sampling events.

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Attachment C-1

Literature Review

Attachment C-1
Literature Reviews

1.0 Literature Search For the Impact of Dissolved Phase Contaminants During Sediment Removal Operations

Evidence has been reported that suggests that a significant dissolved phase release of PCBs is possible without any apparent increase in the suspended solids load in the water column. Because of this, several theoretical assessments of the possible mechanisms behind such an increase have been performed by the USEPA.

Two basic pathways exist that can result in high dissolved phase PCB concentrations due to dredging. The first is the direct release of water with a high dissolved phase PCB concentration. This water would most likely originate as contaminated porewater within the sediment. Porewater can be highly contaminated for two primary reasons: it is in direct contact with contaminated sediments, and it typically contains a high concentration of dissolved organic carbon, a medium that can enhance the apparent dissolved phase concentration. In addition to porewater, water that comes in contact with the sediments during the dredging process may also contain relatively high concentrations.

The second mechanism with the potential to create a high dissolved phase concentration is an event that suspends a large mass of contaminated sediments in the water column. PCBs will tend to equilibrate between solid and dissolved phases, effectively removing PCBs from the suspended sediments to the water column. If the suspended solids added are of sufficient mass and contamination level, the dissolved phase concentration can rise markedly. It can be noted that the process of equilibration will not be undone if a large fraction of the suspended sediments is lost to settling as the plume is transported downstream. Because the equilibrium between the solid and dissolved phases is concentration-driven and not mass-driven, the water column will be left with a large dissolved phase burden if a significant mass of sediments is added to the water column, allowed to equilibrate, and lost via settling.

To try to predict the changes in the water column dissolved PCB concentration during an intrusive activity like dredging, it is important to have a basic understanding of the possible mechanisms that could result in the dissolution of sorbed PCBs. The scientific papers below were reviewed towards that end.

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1. Rapidly Desorbing Fractions of PAHs in Contaminated Sediments as a Predictor of the Extent of Bioremediation (Cornelissen et al., 1998)

Desorption kinetics of PAHs from contaminated sediments before and after bioremediation are discussed in this study. The rapid desorption rate constant was approximately 100-3000 times larger than the slow desorption rate constant. It is concluded that the rapidly desorbing PAHs are primarily degraded during bioremediation and the slowly desorbing amounts remain unchanged.

Reference:
Cornelissen, G.; Rigterink, H.; Ferdinandy, M. M. A.; Van Noort, P. C. M. "Rapidly Desorbing Fractions of PAHs in Contaminated Sediments as a Predictor of the Extent of Bioremediation," *Environmental Science and. Technology,* Vol. 32, pp. 966-970, 1998.

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2. A Simple Tenax Extraction Method to Determine the Availability of Sediment-Sorbed Organic Compounds (Cornelissen et al., 2001)

Fractions of PAHs, PCBs and chlorobenzenes that can be removed from contaminated sediments by means of a single Tenax extraction are evaluated in this study. Two extraction times (6 and 30 hours) in six different contaminated sediments collected from various locations in The Netherlands were used to determine the fractions of PAHs, PCBs, and chlorobenzenes that could be removed using the Tenax Extraction Method.

Results of the experiment indicated that extraction by Tenax for 30 hours completely removed the rapidly desorbing fractions, plus some part of the slowly desorbing fraction, whereas the fraction extracted by Tenax for 6 hours removed about half of the rapidly desorbing fraction for chlorobenzenes, PCBs, and PAHs.

This study concluded that the concentration in sediment of rapidly desorbing, linearly sorbed fractions can be determined by the amount desorbed to Tenax. For PCBs, the amount linearly sorbed is about two times the amount desorbed to Tenax after a six-hour contact time.

Reference:
Cornelissen, G.; Rigterink, H.; Ten Hulscher, D. E. M.; Vrind, B. A.; Van Noort, P. C. M. "A Simple Tenax Extraction Method to Determine the Availability of Sediment-Sorbed Organic Compounds;" *Environmental Toxicology and Chemistry,* Vol. 4, pp. 706-711, 2001.

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3. Fate and Transport of PCBs at the New Bedford Harbor Superfund Site (Garton, et al., 1996)

This study presents a modeling approach, combining the theoretical, deterministic, and empirical elements that were used to predict the fate and transport of PCBs at the estuarine New Bedford Harbor Superfund Site. The theoretical approach was used to characterize volatilization and sorption. Sediment processes including settling, flocculation, resuspension, advection, and dispersion were characterized empirically and sediment settling velocity deterministically from experimental data. The following observations were reported from the model:

- Sorption to sediments was reported to be the preferred state of PCBs in water environments, with sorption coefficients ranging from 10^{-23} to $10^{-0.4}$ m^3/g for Aroclor 1242 and Aroclor 1260. Affinity to sediments reportedly increased with an increase in the percent chlorine.

- Sediments in the harbor were undergoing continuous resuspension to the water column and corresponding deposition. Resuspension and deposition were driven by the change in the suspended solids concentration and tides. Deposition was found to be greater during flood, while resuspension was greater during ebb.

- Fluid shear was the most significant flocculation mass removal mechanism contributing to the settling velocity calculation. It was observed by means of visual observation that differential settling accounted for 30 percent of the mass removal and fluid shear for 90 percent of the mass removal. Both these mechanisms accounted for 100 percent mass removal and particle removal via fluid shear occurred before differential settling.

It was concluded that the PCBs at the New Bedford Harbor are not very soluble and that they volatilize or sorb to sediment rather than staying in solution. This allows PCB transport from the harbor, either sorbed to sediments, transferred to mobile sediments during resuspension activity, or by volatilization, thus leading to PCB contamination of the water column, downstream areas, or atmosphere.

Reference:
Garton, L.S.; Bonner, J. S.; Ernest, A.N.; Autenrieth, R. L. "Fate and Transport of PCBs at the New Bedford Harbor Superfund Site," *Environmental Toxicology and Chemistry,* Vol. 15, pp. 736-745, 1996.

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4. PCB Availability Assessment of River Dredging Using Caged Clams and Fish (Rice et al., 1987)

The effects of dredging to remove PCB-contaminated sediments in the South Branch of the Shiawassee River in south-central Michigan are presented in this study. The bioavailability of PCBs was monitored using caged fingernail clams and fathead minnows. Changes in water column concentrations of PCBs before dredging, during dredging, and up to six months after dredging was completed were monitored and compared to PCB bioavailabity data.

Monitoring of water, clams, and fish during dredging indicated that significant amounts of PCBs were released from the sediments during dredging, which declined quickly farther downstream. There were increases in the availability of PCBs for at least six months at all locations downstream and in the area of dredging. However, there was no noticeable change in the total PCB concentration in the water column after dredging. Post-dredge uptake was also higher downstream. Overall, clams showed less uptake than fish. It was concluded that dredging worsened the problem of bioavailability, at least over the short term.

The researchers noted several important site-specific features of the south branch of the Shiawassee River:

- Large PCB deposits were found to occur along with fine, erodable, and distinctly organic silt.
- The sediment of the river was essentially lacking in clay.

The researchers stated that these factors might tend to make PCBs more available than would be the case in the well mixed, sand-silt-clay type typically found on larger rivers.

Overall, it was concluded that among water, clams, and fish, there was no one ideal monitor for the true bioavailability of PCBs in the South Branch of the Shiawassee River. The fish were sensitive indicators of changes in PCB availability more than six miles downstream of the dredging site. Uptake by fingernail clams appeared to reflect local conditions at the sediment-water interface, but was not a sensitive indicator more than one mile downstream.

Reference:
Rice, C. P.; White, D. S. "PCB Availability Assessment of River Dredging Using Caged Clams and Fish," *Environmental Toxicology and Chemistry,* Vol. 6, pp. 259-274, 1987.

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5. PCB Removal from the Duwamish River Estuary: Implications to the Management Alternative for the Hudson River PCB Cleanup (Pavlou et al., 1979)

This study presents the cleanup of the Duwamish River, Washington, and uses it as a test case to compare it to the Hudson River problem. A transformer handling accident resulted in a spill of transformer fluid, containing PCBs, into the river.

The initial cleanup was staged by divers using a hand dredge to recover submerged pools of the liquid. This dredging ended within 20 days of the spill occurrence. The second, more extensive cleanup that took place approximately 17 months later used a hydraulic dredge and lasted approximately 24 days. Suspended particulate matter (SPM) and water column concentrations were monitored during this second cleanup phase. The results of monitoring reportedly revealed the following:

- No change in the SPM concentration was observed throughout the dredging operation.

- Water column PCB concentrations were observed to be constant throughout the dredging operation.

- Greater than 90 percent of PCBs were recovered in 44 days of dredging.

This study concluded that the dredging operations did not significantly alter the PCB characteristics of the river.

Using the performance results of dredging in the Duwamish River as the basis, four management alternatives for cleanup of the Hudson River were proposed. The management alternatives included:

- No Management Action Further Study
- Stabilization and / or Removal of Remnant Deposits
- Removal of Remnant Deposits and Sediments > 50 ppm
- Removal of all River Sediments > 1 ppm.

The researchers stated that the best alternative for cleanup of the Hudson River would be "Removal of Remnant Deposits and Sediments > 50 ppm," as this alternative was similar to what was done in the Duwamish River, where no changes in the PCB levels of SPM and water were observed. The paper also concluded that this alternative would also remove 90 percent of the toxicant load, as was done in the Duwamish River, within reasonable economic limits.

Reference:
Pavlou, S.P; Hom, W. "PCB Removal from the Duwamish River Estuary: Implications to the Management Alternative for the Hudson River PCB Cleanup," ANNALS N.Y. ACAD. SCI., Vol. 320, pp. 651-672, 1979.

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6. Predicting Effluent PCBs from Superfund Site Dredged Material (Thackston et al., 1992)

This paper discusses a feasibility study of dredge use to remove PCBs from sediments in New Bedford Harbor, Massachusetts. Part of the study evaluated the usage of an onshore confined disposal facility (CDF) to contain dredged material. A CDF is commonly used in the disposal of dredged material that contains a wide range of contaminants.

The researchers also evaluate the validity of results generated by the modified elutriate test to determine dissolved contaminant concentration and the concentrations associated with suspended solids in the effluent generated from a CDF.

The modified elutriate test simulates the expected chemical and physical conditions present in the CDF, and is based on both the dissolved and total concentrations of each contaminant in the elutriate. The test is used to predict the contaminant concentrations in the dissolved phase and also the concentrations associated with suspended solids present in the elutriate.

The paper concludes that the elutriate test is a useful, accurate, and conservative predictor of the concentrations of contaminants in the effluent from a CDF receiving highly contaminated sediments.

Reference:
Thackston, Edward L; Palermo, Michael R. “Predicting Effluent PCBs from Superfund Site Dredged Material,” *Journal of Environmental Engineering*, Vol. 118, no. 5, 657-665, 1992.

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7. Predicting Release of PCBs at Point of Dredging (DiGiano et al., 1993)

A dredging elutriate test (DRET) was used to predict the concentration of contaminants (dissolved and suspended PCBs) as a function of initial concentration of sediment, aeration time, and settling time in the water column at the point of dredging. Results from the DRET were compared to field data from a pilot dredging operation at New Bedford Harbor, Massachusetts.

The total PCB concentrations were proportional to the final TSS, while the soluble PCB concentrations are nearly independent of the final TSS. The DRET tests also found that aeration time had little effect on final TSS concentration. Settling times greater than six hours produced little further removal of TSS, regardless of the initial TSS concentrations or aeration time.

This study found that while small particles dominate the particle distribution with increasing settling time, the PCB concentration per unit mass is not any greater than for larger particles, thus the fraction of organic carbon, which determines the extent of partitioning in the sediment, is not a function of particle size.

The New Bedford Harbor Field Data used three different dredge heads (cutter head, horizontal auger, and matchbox), and samples taken directly from the ports of the dredge head and from within 30m of the dredging area (plume samples). Sorbed and dissolved PCB concentrations for the field plume samples were similar to the DRET data. The data indicate that the horizontal auger causes the largest concentration of PCBs in the water column of the three methods used.

All results suggest TSS is the most important factor in determining the PCB released into the water at the point of dredging. The relationship between aqueous TSS concentration and aqueous Total PCB concentration is directly proportional. The researchers proved that the DRET could describe partitioning. The flocculent nature of particle settling implies that far less efficient settling and thus higher total PCB concentrations may be expected in freshwater dredging operations where destabilization of particles is less effective.

Reference:
DiGiano, F. A.; Miller, C. T.; Yoon, J. "Predicting Release of PCBs at Point of Dredging," *Journal of Environmental Engineering*, Vol. 119, No. 1, pp. 72-89, January/February, 1993

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8. The Effect of Sediment Dredging on the Distribution of Organochlorine Residues in a Lake Ecosystem (Sodergren et al., 1984)

Redistribution and deeper penetration of remaining residues of DDT compounds and PCBs were observed in a Swedish lake after dredging. Water, sediment, and fish samples were analyzed. Dredging was carried out in the summers of 1970 and 1971, and removed 300,000m^3 of contaminated sediment.

Ten years after dredging, the level of PCBs in the upper 5 cm of sediment was about twice as high as it had been immediately after the operations. The researchers believe that the dredging operations apparently caused mixing and internal circulation of sediment particles.

Levels of PCBs in sediment from an area of the lake that were not dredged were about ten times higher than those in the central part of the lake before dredging.. Relatively high PCB concentrations in this undredged area may be due to the historic contamination of the area as an industrial dump for drainage water.

Reference:
Sodergren, Anders. "The Effect of Sediment Dredging on the Distribution of Organochlorine Residues in a Lake Ecosystem," Ambio. Stockholm [AMBIO.], Vol. 13, no.3, pp. 206-210, 1984.

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9. Slowly Reversible Sorption of Aliphatic Halocarbons in Soils I. Formation of Residual Fractions (Pignatello et al., 1990)

This study describes the formation (thermodynamics and kinetics) of slowly reversible sorbed fractions of various halogenated aliphatic hydrocarbons (HHCs) (halogenated solvents CT, TCA, TCE, TeCE, and soil fumigants 1,3-D, 1,2-DCP, EDB, and DBCP) in two surface soils (Cheshire fine sandy loam, and an Agawam fine sandy loam). Soils were allowed to sorb the compounds under two conditions: unsaturated soil (10 percent moisture by weight), and soil suspended in an aqueous solution of HHC.

Desorption experiments using batch extraction of the HHCs from the soils with water showed that the apparent soil-water distribution coefficients increased progressively to as much as 200 times greater than equilibrium sorption coefficients K_d, obtained separately from sorption isotherms. In each desorption case, the apparent distribution coefficient ($K_{d,app}$) increased with each extraction from a value after the first extraction that was comparable to K_d, to a value after the 16th extraction that was 1 to 2 orders of magnitude greater than K_d. Thus, after repeated extraction, the soil retained significant quantities of HHC, releasing it only slowly to the aqueous phase. Desorption experiments of HHCs on soil using a continuous removal of Tenax CC polymeric absorbent beads yielded slowly reversible residual fractions in the soil.

Desorption experiments using Tenax in an aqueous suspension showed that desorption from the soil was rate-limiting. The researchers note that it is possible that uptake by Tenax actually occurred from the vapor phase, although distribution of the HHCs from the aqueous phase into Tenax is highly favorable; because Tenax is poorly wetted by water and is known from extensive use in GC applications to be an efficient absorbent of organic vapors.

The results of these experiments show that even compounds normally regarded as labile in the environment by their volatility and weak equilibrium sorption tendencies can generate kinetically slow sorbed residues.

Reference:
Pignatello, J.J. "Slowly Reversible Sorption of Aliphatic Halocarbons in Soils. I. Formation of Residual Fractions," *Environmental Toxicology and Chemistry,* Vol. 9, pp. 1107-1115, 1990.

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10. Why biota still accumulate high levels of PCB after removal of PCB ontaminated sediments in a Norwegian fjord (Voie et al., 2002)

This study focused on a marine fjord located outside of Haakonsvern, a naval base in Norway. Sediments contained in the fjord were found to be highly contaminated with PCBs, and were removed via dredging in 1998. The objective of this study was to determine which of the following hypotheses best corresponds to the reality of bioavailability:

- That contaminated food is the most important source accumulation due to the low concentration of PCBs in water (estimated using the octanol-water partition coefficient).
- That the PCBs in the dissolved phase are the most important source of exposure.

Accumulation of low chlorinated PCB congeners with a low K_{ow} in blue mussels and SPMDs was higher than for the highly chlorinated congeners with a high K_{ow}. Bioaccumulation concentrations of PCBs before, during, and after dredging did not change. Suspended matter/solids concentrations were not addressed. Water column concentrations were not reported.

Related experiments indicated that PCBs are accumulated from the water column, and that bioaccumulation in blue mussels and SPMDs occurs mostly from PCBs dissolved in the water column. After dredging, more coarse materials were exposed to the seabed. The coarse material has less ability to bind PCBs. Also, fine contaminated particles might settle after dredging, leaving a thin contaminated layer of material.

Lower chlorinated PCBs are transported a longer distance than the higher chlorinated congeners, thus accumulation of low chlorinated PCBs was higher in less contaminated areas (4 km away).

If PCBs accumulate in blue mussel and SPMDs due to presence in the water column, the bioaccumulation amounts in the biota may not have varied as significantly, as the water concentrations of PCBs remained unchanged after dredging due to the low solubility of PCBs.

Reference:
Voie, O. A.; Johnsen, A.; Rossland, H. K. "Why biota still accumulate high levels of PCB after removal of PCB contaminated sediments in a Norwegian fjord," *Chemosphere,* Vol. 46, pp. 1367-1372, 2002.

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11. Desorption Kinetics of Chlorobenzenes, Polycyclic Aromatic Hydrocarbons, and Polychlorinated Biphenyls: Sediment Extraction with Tenax® and Effects of Contact time and Solute Hydrophobicity (Cornelissen et al., 1997)

The kinetics of desorption of chlorobenzenes, polychlorinated biphenyls, and polyaromatic hydrocarbons using Tenax beads from contaminated sediment (Lake Oostvaardersplassen, Netherlands) was studied.

The sediment was dried to remove remaining organic contaminants as well as a number of non-identified components that disturb chromatographic analyses. Contaminated lake sediments and contaminated water spiked with concentrations ranging from 1 to 100 μg/l were allowed to equilibrate for 2 days and 34 days. After the equilibration time, sediment and supernatant were separated by centrifugation, extracted with hexane, and analyzed for contaminants and dissolved organic carbon.
Kinetics of desorption were determined by the Tenax extraction method. Rates of extraction from the aqueous phase were also measured separately without any sediment. The added amount of Tenax in this experiment was rendered insufficient due to the amount of organic carbon present in the samples.

DOC data indicate that DOC is slowly released from the sediment during equilibration. The fractions of contaminant present in the slowly desorbing sediment compartment, F_{slow}, are observed to increase with increasing test compound hydrophobicity. The rate constants of slow desorption, k_{slow}, are observed to decrease with increasing equilibration time, while F_{slow} slightly increased with equilibration time. This phenomenon can be explained by proceeding diffusion into the slowly exchanging sediment part (higher F_{slow}) and by the presence of the solute at more remote locations from which desorption is slower (lower k_{slow}).

First order rate constants of rapid desorption were in the order of 10^{-1}/h. First order rate constants of slow desorption were in the order of 10^{-3}/h. These correlate well with the molecular volumes of the compounds used and decrease between 2 and 34 days of equilibration. Slowly desorbing fractions increase with both increasing solute hydrophobicity and increasing equilibration time.

Reference:
Cornelissen, G.; Van Noort, P. C. M.; Govers, H. "Desorption Kinetics of Chlorobenzenes, Polycyclic Aromatic Hydrocarbons, and Polychlorinated Biphenyls: Sediment Extraction with Tenax® and Effects of Contact time and Solute Hydrophobicity," *Environmental Toxicology and Chemistry,* Vol. 16, No. 7, pp. 1351-1357, 1997.

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12. Comparing Polychlorinated Biphenyl Concentrations and Patterns in the Saginaw River Using Sediment, Caged Fish, and Semipermeable Membrane Devices (Echols et al., 2000)

This experiment compared three possible techniques to assess the amount of bioavailable polychlorinated biphenyls (PCBs) in the Saginaw River, Michigan:

- Measurement of PCB concentrations in sediments.
- Measurement of PCB concentrations in caged channel catfish.
- Measurement of PCB concentrations in SPMDs.

The caged fish and SPMDs were placed in the river for 28 days at five sites where sediments were sampled. Rates of PCB accumulation by SPMDs that have been reported previously were used to estimate the aqueous concentrations from the PCB concentrations found in the SPMDs, sediment-water partition coefficients were used to estimate the dissolved PCB concentration from the sediment, and steady-state bioaccumulation factors and depuration rate constants were used to estimate the aqueous PCB concentration from the caged fish. The relative PCB patterns from the three techniques were compared using principal components analysis.

The study found that SPMD and sediment results were complementary; the sediment concentrations represent long-term accumulation and weathered components, while the SPMDs show accumulations only from the sampling period. The lower chlorinated PCBs predominate in the SPMDs as compared with the distribution in the fish and the sediments, likely due to the higher solubilities of the lower chlorinated PCBs. The distribution differences between the fish and the SPMDs are likely the result of metabolism and depuration of certain congeners by the fish.

Results from the water pattern modeling did not cluster on the principal component analysis plot, co-varying positively and negatively on different axes. The sediment and SPMD modeled data had similar patterns in the principal component analysis, but the water concentrations derived from the sediment model were three to nine times higher than those calculated from the SPMD model. The fish model results were closer to those obtained from the SPMD model, but the patterns were different, likely due to the use of alternate fish constraints (due to the lack of species-specific constraints available on then model) or congener metabolism and depuration.

Reference:
Echols, K. R.; Gale, R.W.; Schwartz, T. R.; Huckins, J. N.; Williams, L. L.; Meadows, J. C.; Morse, D.; Petty, J. D.; Orazio, C. E.; Tillitt, D. E. "Comparing Polychlorinated Biphenyl Concentrations and Patterns in the Saginaw River Using Sediment, Caged Fish, and Semipermeable Membrane Devices," *Environmental Science and Technology,* Vol. 34, pp. 4095-4102, 2000.

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13. Mobilization of PAHs and PCBs from In-Place Contaminated Marine Sediments During Simulated Resuspension Events (Latimer et al., 1999)

This study used a particle entrainment simulator (PES) to investigate the resuspension transport of hydrophobic organic compounds, specifically PCBs and polycyclic aromatic hydrocarbons (PAHs), to the overlying water column through the experimental production of representative estuarine resuspension events. During the experiment, the contaminants were evaluated in bulk sediments, size-fractioned sediments, resuspended particulate material, and, in some cases, dissolved phases. Two types of sediment, dredged material and bedded estuarine sediment, were used in this study, and they represented gradients in contaminant loadings and textual characteristics. The sediments were collected from Black Rock Harbor, Connecticut, and Narragansett Bay, Rhode Island. The objectives of the study were to evaluate the chemistry and dynamics of the contaminants as a function of the magnitude of resuspension.

Several conclusions regarding the resuspension chemistry and dynamics of hydrophobic organic compounds were drawn:

- The size of the particles entrained from the bedded sediments changed as the resuspension magnitude increased. This can be attributed to the non-uniform characteristics of the sediment with depth in the resuspension zone (up to 1 mm). In a case of more highly contaminated sediments, the mean particle size was relatively constant under varying conditions of resuspension. The mean particle size was also similar to that of the bulk sediment characteristics. In contrast, for the less contaminated bedded sediment, the particle sizes decreased over the same applied shear range. Also, the particle size distribution exhibited by the bedded sediments during resuspension was more skewed toward smaller particles than the bulk sediments.

- On the basis of mass loading and an organic carbon loading weight, the amount of PCBs and PAHs with a log $K_{ow} < 6$ in the entrained particulate material was somewhat depleted as the applied shear increased and the amount of material resuspended in the water column was increased. Alternately, some higher molecular weight PAH (log $K_{ow} < 6$) showed slightly enriched loadings under the same conditions. On a volume-weighted basis, the concentration of organic contaminants increased in the water column as more material was resuspended.

- In the case of the bedded sediments, accurate predictions of the entrained PAH and PCB loadings on resuspended material were made using the resuspended particle sizes and the concentration of the PAHs and PCBs in the particle size pools of the bulk sediment. This prediction could not be made for the dredged material, possibly due to contributions from the colloidal particles not specifically measured in the study.

- During the resuspension events, the distribution of PAHs between the dissolved and particulate phases (K_ds) showed relatively minor decreases with increased applied shear and TSS levels. It was possible to calculate within a factor of 2 the fraction with which the PAHs were associated based on the amount of organic carbon in each of the resuspended samples. In order to obtain more accurate predictions, however, kinetic factors and the role of other unmeasured substrates would need to be taken into consideration.

The research suggests that resuspension, while periodic in nature, is likely an important process affecting the fate and effects of contaminants in the coastal and marine environment. Further study is needed to address the roles played by different sized particles in this contamination contribution to shallower water systems and the conditions under which theses contributions occur.

Reference:
Latimer, J.S.; Davis, W.R.; Keith, D.J. “Mobilization of PAHs and PCBs from In-Place Contaminated Marine Sediments During Simulated Resuspension Events.” *Estuarine, Coastal, and Shelf Science*, Vol. 49, pp. 577-595, 1999.

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14. Distribution of Organic Carbon and Organic Xenobiotics Among Different Particle-Sized Fractions in Sediments (Kukkonen et al., 1996)

The distributions of benzo[a]pyrene, hexachlorobiphenyl, and total organic carbon in sediment samples taken from Lake Michigan and Florissant, Missouri, were determined and compared to the known bioavailability of the compounds. The goals of the study were to demonstrate that the settling velocity method can be used for measuring the xenobiotic distribution among sediment particles; to measure the effect of water quality (lake water vs. distilled water) on the distribution of particles, organic carbon, and xenobiotics in two different sediments; and to examine the sorption behavior of two different xenobiotics (one PAH and one PCB) of similar hydrophobicity to try to account for previously observed differences in bioavailability.

The distribution of the organic compounds among particles < 63 μm in diameter differed from that of the total organic carbon;, however, the organic matter remained the major sorbent for most of these compounds. Altering the fractionation conditions by performing the procedure in distilled water rather than natural lake water changed the particle distributions for both the organic carbon and the xenobiotics.

In addition, the contaminant distribution relative to the organic carbon content differed between particle-size fractions and between contaminants of different compound classes, e.g., PAHs and PCBs. The different distributions of the contaminants in the particle fractions likely contributed to the observed differences in the bioavailability of the organic contaminants to benthic organisms and may be exacerbated by selective feeding.

Reference:
Kukkonen, J.; Landrum, P.F.; "Distribution of Organic Carbon Xenobiotics Among Different Particle-Size Fractions in Sediments," *Chemospehere,* Vol. 32, no. 6, pp.1063-1076, 1996.

2.0 Literature Review for PCB Desorption Rates

Resistant Sorption of *In Situ* Chlorobenzenes and a Polychlorinated Biphenyl in River Rhine Suspended Matter

In this study, desorption kinetics of *in situ* chlorobenzenes (dichlorobenzenes, pentachlorobenzene and hexachlorobenzene) and 2,4,4'-trichlorobiphenyl (PCB-28) were measured for River Rhine suspended matter in Lobith, The Netherlands. The desorption behavior of these pollutants (chlorobenzenes and PCB-28) in the suspended matter was compared to their desorption behavior in the top layer (5-10 cm) of sediment in Lake Ketelmeer, as this suspended matter was reported to be the main source of sediment accumulation in Lake Ketelmeer.

Results of this study showed similarity of desorption profiles between River Rhine suspended matter and the top layer of sediment from Lake Ketelmeer. Rate constants observed were on an average 0.2 h^{-1} for fast desorption, 0.004 h^{-1} for slow desorption and 0.00022 h^{-1} for very slow desorption, which were in agreement to the values reported in the literature. Fast desorbing fractions were not detected for any of the compounds other than PCB-28 (1.6 percent of fast desorbing fractions were detected). The results of this study concluded the following:

- Slow and very slow desorbing fractions were already present in the material forming the top layer of Lake Ketelmeer and were not formed after deposition of this material in the lake.

- The absence of recent pollution of the suspended matter could have caused the absence of detectable fast fractions for most compounds in the suspended matter.

- Rapid disappearance of compounds from the fast fraction could also be due to a combination of a high affinity of very slow sites for these compounds and their relatively high volatility.

- The presumed differences in desorption patterns between a sediment top layer (5-10 cm) and the deepest layers (> 10 cm) did not always exist.

Reference:
ten Hulscher, T. E. M.; Vrind, B. A.; van Noort, P. C. M.; Govers, H. A. J. "Resistant Sorption of In Situ Chlorobenzenes and a Polychlorinated Biphenyl in River Rhine Suspended Matter," *Chemosphere,* Vol. 49, pp. 1231-1238, 2002.

Desorption Rates of Two PCB Congeners from Suspended Sediments – I. Experimental Results

Desorption of 2,5,2’, 5’-tetrachlorobiphenyl (PCB-52) and 2,4,5,2’, 4’, 5’-hexachlorobiphenyl (PCB-153) from suspended particles in a gas stripping reactor were studied in this paper and experimental results reported. The objectives of the research were to study the effects of particle size, congener properties, and equilibration time on PCB desorption rates during resuspension events, and to develop a kinetic model to simulate such a desorption process.

The experimental results indicated that PCB desorption was characterized by a two-stage behavior - an initial rapid desorption followed by a prolonged slower desorption. PCB desorption was found to be dependent on octanol-water partition coefficient (K_{oc}), independent of particle size during the initial rapid desorption stage and dependent on particle size during the second desorption stage. Inverse relationship (decrease in overall desorption as the equilibration time increased from 20 days to 3 years) between desorption rate and equilibration time (aging effect) was observed and was reported to be consistent with previous results reported in the literature.

The aging effect observed reportedly suggested that the release rates of PCBs in natural systems were likely much lower than those observed in short-term laboratory experiments, indicating that not only a kinetic model should be used in many aquatic system models, but also that kinetic constants obtained in short-term laboratory experiments may not be directly applicable to the desorption process in natural systems.

Reference:
Gong, Y.; Depinto, J. V.; Rhee, G. Y.; Liu, X. “Desorption Rates of Two PCB Congeners from Suspended Sediments – I. Experimental Results,” *Water Resources,* Vol. 32, No. 8, pp. 2507-2517, 1998.

Desorption Rates of Two PCB Congeners from Suspended Sediments – II. Model Simulation

Development of a two-compartment diffusion model and its application to simulate the desorption kinetics of two PCB congeners 2,5,2’, 5’-tetrachlorobiphenyl (PCB-52) and 2,4,5,2’, 4’, 5’-hexachlorobiphenyl (PCB-153) from suspended aquatic sediments are discussed in this paper. The primary objectives of this paper were:

- To explore other potential mechanisms (in addition to the retarded pore diffusion) that may contribute to the two-distinct-rate behavior of PCB desorption.

- To develop a sorption kinetics submodel that was consistent with the majority of mechanistic models and was practicable for system-level modeling of PCB transport and fate.

- To apply the developed model to simulate the experimental results presented in the preceding paper (Paper 2 above).

The simulation results of this model concluded the following:

- Both non-equilibrium sorption and non-uniform particle size distribution of the natural sediments may contribute to the two-distinct-rate desorption behavior of the PCBs that has been observed.

- Compared to the single retarded pore diffusion model, the two-compartment diffusion model, which assumed that one fraction of PCBs in solid phase reached an instantaneous equilibrium with the surrounding aqueous phase while the other fraction followed intra-particle diffusion, fit the data far better than the single retarded pore diffusion model.

- Increased adsorption time (aging) would in general decrease the instantaneous equilibrium fraction and the effective pore diffusion coefficient.

Reference:
Gong, Y.; Depinto, J. V. "Desorption Rates of Two PCB Congeners from Suspended Sediments – II. Model Simulation," *Water Resources,* Vol. 32, No. 8, pp. 2518-2532, 1998.

Polychlorinated Biphenyl Desorption from Low Organic Carbon Soils: Measurement of Rates in Soil-Water Suspensions

Desorption-release rates of 13 individual PCB congeners from four contaminated soils suspended in water were investigated using the gas purge technique. The soil samples used for this investigation were obtained from PCB spill sites and had been in contact with Aroclor 1242/1254 mixtures for 3 or more years, therefore it was assumed that sorption equilibrium was obtained in these soil samples. Soils analyzed were "engineered" ground cover materials used at utility industry substations and consisted of fine rock chips and sand-silt-clay fractions with organic carbon < 0.2 percent. The PCB congeners in the soils contained three to five chlorine atoms. Proper functioning of the gas purge technique for measurement of congener release rates was confirmed by measuring the Henry's law constants for ^{14}C-labeled congeners 24', 22'55' and 22'44'55' and comparing the results obtained with the values reported in the literature.

For all 13 congeners and all soil samples analyzed the following results were reported:

- The labile fraction was found to be 80 to 90 percent of the total congener concentration.

- Majority of the labile fraction was desorbed or released within 48 hours of contact with water.

- Release of the remaining non-labile fraction persisted for over six months with complete release estimated to be one to two years.

- Release rate constants, Kd were found to decrease with increase in the number of chlorines. The typical Kd values for labile and non-labile fractions were found to range from 1.4 to 0.5 d^{-1} and 0.008 to 0.0006 d^{-1}, respectively.

Reference:
Girvin, D. C.; Sklarew, D. S.; Scott, A. J; Zipperer, J. P. "Polychlorinated Biphenyl Desorption from Low Organic Carbon Soils: Measurement of Rates in Soil-Water Suspensions," *Chemosphere*, Vol. 35, No. 9, pp. 1987-2005, 1997.

A Simple Tenax Extraction Method to Determine the Availability of Sediment-Sorbed Organic Compounds

Fractions of PAHs, PCBs and chlorobenzenes that can be removed from contaminated sediments by means of a single Tenax extraction are evaluated in this study. Two extraction times (6 and 30 hours) in six different contaminated sediments from various locations in the Netherlands were used to determine the fractions of PAHs, PCBs, and chlorobenzenes that could be removed using the Tenax Extraction Method. Results of the experiment indicated that extraction by Tenax for 30 hours completely removed the rapidly desorbing fractions plus some part of the slowly desorbing fraction, whereas the fraction extracted by Tenax after 6 hours was about 0.5 times the rapidly desorbing fraction for chlorobenzenes, PCBs an PAHs.

Reference:
Cornelissen, G.; Rigterink, H.; Ten Hulscher, D. E. M.; Vrind, B. A.; Van Noort, P. C. M. "A Simple Tenax Extraction Method to Determine the Availability of Sediment-Sorbed Organic Compounds;" *Environmental Toxicology and Chemistry*, Vol. 4, pp. 706-711, 2001.

PCB in the Upper Hudson River: Sediment Distributions, Water Interactions, and Dredging

This paper is a summary of a number of studies performed by the DEC and various consultants dealing with the PCB sediment distribution, water interaction, and dredging for the Upper Hudson River. The studies were grouped by type and presented together. The following conclusions were reached in the area of sediment distributions:

- Over the course of mapping the sediment distributions in the Upper Hudson, it was found that sampling on transects across the river and obtaining precise locations for those samples was essential. The variation of PCB concentrations across the river was extreme, while the concentration variation was more gradual down the river.

- The distribution of PCBs in the sediments can be classified as lognormal.

- The PCB concentration was generally highest in silty sediments, next highest in coarse sands containing wood chips, and lowest in the sands and gravels that do not contain any woodchips or organics. The same trend held in sieved samples composed of sand, wood chips, and silt.

- PCB hot spots that contained concentrations above 50 μg/g were typically found in low velocity and near bank areas. In the Upper Hudson, about 68 percent of the total mass of PCBs is contained in hot spots that cover only 8 percent of the river area.

- PCB concentration was positively correlated with Cs-137, specific heavy metals, and volatile solids. PCB concentration was negatively correlated with total solids.

- Sediment cores indicated that the maximum PCB concentrations were normally found 8-30 cm below the top of the core. Dating using Cs-137 techniques placed the peak discharge of PCBs in the 1960s. PCB contamination was rarely found below 90 cm in the first 10 km from the contamination source, and rarely below 60 cm for the rest of the Upper Hudson.

The following conclusions were drawn from the water interaction studies:

- The bulk of PCBs were adsorbed on solids in a concentrated sediment-water mixture. When moving from a 10/1 elutriate test to a more dilute river system, the sediment-water coefficient increased, and a higher percentage of the PCBs in the mixture became soluble in the water. Given that Aroclor 1221 has a lower sediment-water partition coefficient than Aroclor 1254, this finding is significant to groundwater attenuation, river transport, and dredging systems.

- Cationic polymers and chitosan were helpful in rapidly removing the suspended solids in a sediment-water mixtures and reducing the concentration of PCBs in the water.

- High PCB concentrations occurred at low flow in the river, a phenomenon possibly explained by desorption of PCBs from bottom sediments. The highest concentrations of PCBs occurred during very high flows that eroded and suspended bed material. The water PCB concentrations were lowest under intermediate flow conditions.

- The projected loss of PCBs to the Lower Hudson river over 20 years averaged 3,630 kg/yr, and modeled results indicated that this would occur for decades if no action was taken.

- The rate of PCB volatilization from the Upper Hudson varies with temperature, wind speed, and turbulence conditions. The volatilization rate is projected to be 0.45-4.5 kg/day. This is in the range of the total river water transport of PCBs under low flow conditions of 3-5 kg/day.

The examination of dredging projects yielded the following conclusions:

- 20 mg/l of cationic polymer was found to be effective in boosting PCB and suspended solids removals in spoils lagoons for three full-scale hydraulic dredging projects on the Hudson. The best results were achieved when the polymer was fed at an intermediate box between the two lagoons.

- A minimum of one-hour retention time is recommended in the spoils lagoon system for a hydraulic dredging project in the Hudson.

- Scum removal in the hydraulic spoils lagoons and in the river downstream of a dragline dredge was found to be essential in the Hudson due to the high concentration of PCBs in the scum.

- Hydraulic and mechanical dredging losses to the water column for the hot spot dredging were projected to be about 2 percent of the PCB and 1 percent of the solids, based on the monitoring data. The contaminated solids not picked up by the dredge were projected to be 5 percent or greater. If the dredge operation is not precisely controlled, the loss could potentially be greater than 5 percent.

- Over 60 percent of the total mass of 200,000 kg of PCBs in the upper river is expected to be removed via dredging of the hot spots and routine maintenance dredging in 8 percent of the Upper Hudson.

Reference:

Toffelmire, T. J.; Hetling, L. J., Quinn, S.O. "PCB in the Upper Hudson River: Sediment Distributions, Water Interactions, and Dredging," *DEC Technical Paper No. 55,* January 1979.

Volatilization of PCB from Sediment and Water: Experimental and Field Data

Studies done on the Hudson River PCB issue have suggested that the loss of PCBs through the process of volatilization is substantial despite the fact that the contaminant has a low vapor pressure. This report summarizes initial data and studies done to examine PCB loss from the Hudson River through volatilization at the water-air and solid-air interfaces.

Experimental data suggested that the volatilization of PCBs can be an important source of air pollution under certain environmental conditions. The results of field monitoring have shown that that PCB concentrations are fairly high in the ambient air and in vegetation growing near PCB dump sites or certain contaminated dredge sites.

PCBs volatilized from contaminated water and sediment at substantial rates. For a number of open PCB disposal and dredge spoil sites along the Upper Hudson River it was observed that volatilization of PCBs was a worse problem than groundwater contamination, although traditional control programs have been aimed at preventing groundwater pollution.

Improved methods to prevent and control losses due to volatilization are needed, and their long-term costs and consequences need to be considered. The comparison of some exposure routes for PCBs indicate that intake from air exposure is greater than intake from drinking water.

Reference:
Toffelmire, T. J.; Shen, T. T.; Buckley, E. H. "Volatilization of PCB from Sediment and Water: Experimental and Field Data." *Technical Paper # 63, December* 1981.

Parameters Affecting Desorption of Hydrophobic Organic Chemicals from Suspended Sediments

This study used long-term batch experiments to address the issue of chemical equilibrium and its applicability as an approximation of the adsorption and desorption of hydrophobic organic chemicals to soils and sediments. The experiments examined the behavior of three hydrophobic organics: hexachlorobenzene, a monochlorobiphenyl, and a hexachlorobiphenyl in Detroit River sediments suspended in pure water and/or filtered tap water.

The experiments performed using hexachlorobenzene were extensive and demonstrated the dependence of desorption rates on the particle/floc size and density distributions, the type of water, and the organic content of the sediments. It was also demonstrated that desorption was more rapid for sediments that were only partially equilibrated with the chemical after a short-term adsorption period.

The studies done on HCB also indicated that the rate of desorption was greatest initially and decreased as the compound was desorbed, suggesting that the rates are also dependent on the sediment concentration.

The experiments performed using PCBs demonstrated that desorption rates were also dependent on the equilibrium coefficient partition coefficient of the chemical. For example, the larger the partition coefficient, the slower desorption occurred. For more highly chlorinated PCBs and other hydrophobic chemicals with high partition coefficients, the desorption process is relatively slow, with desorption times on the order of years. For areas where the effective particle sizes are or can potentially be much larger (for example, bottom sediments and soils), the desorption times would be proportionately greater.

It was also demonstrated that a chemical diffusion model with a diffusion coefficient that is dependent on the porosity of the particle/floc, the organic content of the sediments, the chemical partition coefficient, and also the distribution of the particle/floc size and density distributions, was sufficient to explain the experimental results.

Reference:
Borglin, S.; Wilke, A.; Jepsen, R.; Lick, W. "Parameters Affecting the Desorption of Hydrophobic Organic Chemicals from Suspended Sediments," *Environmental Toxicology and Chemistry,* Vol. 15, No. 10, pp. 2254-2262, 1996.

PCB Desorption from River Sediments Suspended During Dredging: An Analytical Framework

The purpose of this paper was to develop and test a method to analyze the rates of PCB desorption from sediment that has been suspended by dredging activity. The data used were taken from the monitoring of a dredging operation in the Hudson River at Fort Edward in 1977. The monitoring activities took place in the east channel of Roger's Island.

A system of PCB sorption-desorption kinetics that was developed to describe food chain sorbents was used in the framework of a one-dimensional advective transport model and solved at steady state conditions. The partition coefficient for Aroclor 1016 was chosen for use in the model due to the prevalence of that particular PCB in the system. Due to this, only Aroclor 1016 data will be included in the study. The sinking rate coefficient was calculated using data from one of the monitoring stations, and the boundary conditions were estimated using the partition coefficient and the total water column PCB concentration.

The application of a sinking rate of $-0.08\ ^{hr-1}$ and sorption-desorption rate constants ranging from $0.025\ ^{hr-1}$ to $0.05\ ^{hr-1}$ fitted the low flow average water column concentration of Aroclor 1016 (C_T) reasonably well. However, applying a significantly slower rate indicates that if no PCBs moved from the sorbed phase to the dissolved phase, the model results would not differ significantly from what was observed. A mechanistic fit of the data using a higher sinking rate requires the utilization of a higher desorption rate constant.

In the natural system, the results indicate that if the sinking rates are very large compared to the rate of desorption, then a very low concentration of PCBs would be lost during suspension. Conversely, if the desorption rates were high relative to the sinking rates, then a substantially higher concentration of PCBs would be lost during suspension.

The best fits during model runs attempting to simulate high flow average monitoring results for suspended solids were produced sinking rates between –0.4 and –0.5 $^{\text{hr-1}}$ and desorption rate constants on the order of 1.0 $^{\text{hr-1}}$. Rate constants that produced reasonable fits for either high or low flow data ranged from 0.025 to 1.0 $^{\text{hr-1}}$.

Reference:

Brown, M. “PCB Desorption from River Sediments Suspended During Dredging: An Analytical Framework,” *DEC Technical Paper No. 65,* April 1981.

Tables

Table 1
Three-Phase Partition Coefficient Estimates for PCBs in Sediments of the Freshwater Portion of the Hudson River

PCB Congener (BZ#)	Water Column Partition Coefficient Estimates[a]	
	log K_{OC}	log K_{DOC}
4	5.19	5.43
28	5.84	4.16
31	5.80	4.40

Note:

a. Averages by homologue reported by Burgess et al. (1996) for the 4-8 cm depth layer

Source: DEIR, Table 3-10a (USEPA, 1997)

Table 2

Mean Length Weighted Average Concentration Estimate using 1984 Thiessen Polygons, 1994 LRC and GE 1991 Composite Samples (from Table 363334-2 of White Paper - Sediment PCB Inventory Estimates)

Total PCB	Remediated			Not Remediated			Reach Wide		
Contaminant (PCB) Average Concentration	Fine	Coarse	All	Fine	Coarse	All	Fine	Coarse	All
River Section 1 (> 3 g/m^2) (2)	164.5	35.2	92.1 (3)	39.4	23.8	25.4 (3)	145.3	28.9	63.0 (3)
River Section 2 (> 10 g/m^2) (2)	146.5	-	146.5 (4)	-	14.8	14.8 (5)	59.3	12.1	40.4 (7)
River Section 3 (Select) (2)	-	-	31.7 (4)	-	-	9.6 (6)	-	-	9.8 (7)

Tri+	Remediated			Not Remediated			Reach Wide		
Contaminant (PCB) Average Concentration	Fine	Coarse	All	Fine	Coarse	All	Fine	Coarse	All
River Section 1 (> 3 g/m^2) (2)	46.2	12.4	27.2 (8)	12.7	8.9	9.3 (8)	41.1	10.4	19.4 (8)
River Section 2 (> 10 g/m^2) (2)	43.1	-	43.1 (9)	-	7	6.9 (5)	-	-	17.3 (7)
River Section 3 (Select) (2)	-	-	11.7 (10)	-	-	5.1 (6)	-	-	5.4 (7)

Notes

1. Average concentrations were constructed using Thiessen polygons and Length Weighted Average values for the individual sampling locations. Note that the Total PCB values for section 1 represent the Sum of Aroclors 1242, 1254, and 1260.
2. Includes channel area to be dredged.
3. LWA concentration estimate based on 1984 Thiessen Polygons. (Concentrations based on the Sum of Aroclors 1242, 1254, and 1260).
4. Mean MVUE values estimated from 1994 coring data from Hot Spots 25, 28, 31, 34, 35 for Section 2 and from Hot Spots 37 and 39 for Section 3 (Table 4-7 Low Resolution Coring Report).
5. LWA concentration estimate based on GE 1991 Composite samples falling outside the remediation boundaries (exclusion for Rocky Areas). (Estimated from a single composite sample)
6. LWA concentration estimate based on GE 1991 composite samples falling outside the remediation boundaries (no exclusion for Rocky Areas). (Estimated from 45 composite samples)
7. LWA concentration estimate based on all GE 1991 Composite samples in the section.
8. LWA concentration estimate based on 1984 Thiessen Polygons. A factor of 0.944 is applied to the sum of Aroclors values to obtain estimates of Tri+ PCB values.
9. Tri+ values based on Total PCB estimates from 1994 coring data. A divider of 3.4 is applied to the Total PCB value.
10. Tri+ values based on Total PCB estimates from 1994 coring data. A divider of 2.7 is applied to the Total PCB value.

Table 3
Three-Phase Equilibrium Partitioning Model Results

PCB Congener (BZ#)	Mass in particulate phase, M_P (mg)	Log K_{OC}	Mass in truly dissolved phase, M_d (mg)	Log K_{DOC}	Mass in DOC-bound phase, M_{dc} (mg)	Total Mass (mg)	Dissolved Mass (mg)	Percent of dissolved mass (%)
4	1.0E-01	5.19	3.5E-07	5.43	3.5E-06	1.0E-01	3.9E-06	0.0038%
28	5.0E-02	5.84	8.2E-07	4.40	4.4E-07	5.0E-02	1.3E-06	0.0025%
31	5.0E-02	5.80	9.0E-07	4.16	8.4E-07	5.0E-02	1.7E-06	0.0035%

Table 4
Water-Column Instantaneous PCB Loading at TI Dam

TI Dam	Flow (m^3/s)	Whole (total) water PCBs (ng/L)	Dissolved phase PCB (ng/L)	Suspended solids PCBs (ng/L)	Ratio of dissolved to total concentration
TI DAM					
Transect 5	76	192	184	11.2	0.96
Transect 6	69	92	88	2.9	0.96
Schuylerville					
Transect 5	85	160	150	15	0.94
Transect 6	74	89	84	4.8	0.94

Table 5
Desorption Rate Constants from Literature

Compounds	Rate Constants (k)										
	Borglin *et al*., 1996	ten Hulscher *et al*., 1999; 2002			Cornelissen *et al*., 1997				Ghosh *et al*., 2000		Carrol *et al*., 1994
		Lobith susp. Matter		Ketelmeer	k_{rapid} (hr^{-1})		k_{slow} (hr^{-1})		k_{fast} (day^{-1})	k_{slow} (day^{-1})	k (hr^{-1})
	day^{-1}	k_{fast} (hr^{-1})	k_{vslow} (hr^{-1})	k_{vslow} (hr^{-1})	2 day	34 day	2 day	34 day			
Monochlorobiphenyls	0.1174										
Trichlorobiphenyls									0.83	0.011	
PCB-28 (trichloro)		0.2	2.25E-04	2.00E-04							
PCB 65 (tetra)					0.058	0.117	2.54E-03	1.74E-03			
Tetrachlorobiphenyls									0.38	0.011	
PCB 118 (penta)					0.045	0.112	2.01E-03	9.80E-04			
Pentachlorobiphenyls									0.15	0.004	
Hexachlorobiphenyl	0.0101								0.07	0.005	
Moderately PCB contaminated Hudson River Sediment[a]											0.018

Note:

[a] As reported by Carrol *et al*., 1994. Moderately PCB contaminated sediment contained 64 mg/kg (dry weight) PCBs, with total organic carbon of 3.43%. The PCB presents in the sediments consisted of primarily mono- and di-chlorinated biphenyls (60-70% or total).

Table 6
PCBs Desorption Rate Constants and Partitioning Coefficients

Compound	Rate constant (k) hr^{-1}	hr^{-1}	Half-life hr	hr	Estimated equilibrium time		Log Koc [h]	Log Kd [i]
PCB in equilibrium								5.05
Monochlorobiphenyls	0.0049 [a]		142 [a]		84 days [a]		5.65	4.38
Trichlorobiphenyls	0.035 [b]		20 [b]		9 days [b]		5.84	4.57
PCB-28 (trichloro)	0.2 [c]		3 [c]		26 hr [c]		5.84	4.57
PCB 65 (tetra)	0.058 [d,e]	0.117 [d,f]	12 [d,e]	6 [d,f]	5.5 days [d,e]	2.7 days [d,f]	6.27	5.00
Tetrachlorobiphenyls	0.016 [b]		44 [b]		14 days [b]		6.27	5.00
PCB 118 (penta)	0.045 [d,e]	0.112 [d,f]	15 [d,e]	6 [d,f]	7 days [d,e]	2.8 days [d,f]	6.41	5.14
Pentachlorobiphenyls	0.0063 [b]		111 [b]		50.7 days [b]		6.41	5.14
Hexachlorobiphenyl	0.00042 [a]	0.0029 [b]	1664 [a]	238 [b]	980 days [a]	108 days [b]	6.55	5.28
Moderately PCB contaminated[g]	0.0181 [g]		38 [g]		422 days [g]			5.05

Notes:

[a] Borglin *et al*. (1996)

[b] Ghosh *et al*. (2000)

[c] ten Hulscher *et al*. (1999; 2002)

[d] Cornelissen *et al*. (1997)

[e] k is for 2 day contact time

[f] k is for 34 day contact time

[g] Carroll $^{\text{et al}}$. (1994).Moderately PCB contaminated sediment contained 64 mg/kg (dry weight) PCBs, with total organic carbon of 3.43%. The PCB presents in the sediments consisted of primarily mono- and di-chlorinated biphenyls (60-70% or total).

[h] Partitioning coefficients were taken from DEIR Table 3-8 (USEPA, 1997)

[i] foc of sediment is 5.38%

Table 7

Background and Dredging Induced PCB Concentrations

Compound	Ratio to Total PCB (sediment)[a]	Ratio to Total PCB (suspended phase)[b]	Ratio to Total PCB (dissolved phase)[b]	Background Concentrations					Dredging Induced			
				Csed_b mg/kg	TSS_b mg/L	Ctotal_b ng/L	Csusp_b ng/L	Cdiss_b ng/L	Csed_d mg/kg	TSS_d mg/L	Csusp_d ng/L	Ctotal_b+d ng/L
PCB in equilibrium	1	1	1	5	1	50	5	45	50	5	250	300
Monochlorobiphenyls	0.14	0.0013	0.16	0.70	0.00131	8	9.11E-04	8.2	7	0.0065	0.0455	8
Trichlorobiphenyls	0.30	0.0103	0.27	1.51	0.01034	13	0.02	13.2	15	0.0517	0.78	14
PCB-28 (trichloro)	0.30	0.0103	0.27	1.51	0.01034	13	0.02	13.2	15	0.0517	0.78	14
PCB 65 (tetra)	0.13	0.0072	0.13	0.63	0.00722	7	0.005	6.51	6.3	0.0361	0.23	6.7
Tetrachlorobiphenyls	0.13	0.0072	0.13	0.63	0.00722	7	0.005	6.51	6.3	0.0361	0.23	6.7
PCB 118 (penta)	0.044	0.0032	0.026	0.22	0.00317	1	0.0007	1.28	2.2	0.0158	0.035	1.3
Pentachlorobiphenyls	0.044	0.0032	0.026	0.22	0.00317	1	0.0007	1.28	2.2	0.0158	0.035	1.3
Hexachlorobiphenyl	0.016	0.0021	0.0035	0.08	0.00208	0.17	0.00016	0.17	0.79	0.0104	0.0082	0.18
Moderately PCB contaminated[g]	1	1	1	5	1	50	5	45	50	5	250	300

Notes:

[a] Ratio of homologue to Total PCB in the sediment was taken from the low resolution coring data (USEPA, 1998)

[b] Ratio of homologue to Total PCB were taken from transect 6 water column data reported in DEIR (USEPA, 1997)

Table 8
Dissolved Phase PCB Concentration Estimates

Compound	Time (hour)	In 1 hour					
		% equilibrium		Cdiss due to dredge ng/L		Cdiss/Ctotal %	
PCB in equilibrium	equil	100%		180[h]		60.0%[h]	
Monochlorobiphenyls	1	0.49%[a]		4.03E-02		0.5%	
Trichlorobiphenyls	1	3.4%[b]		4.76E-01		3.4%	
PCB-28 (trichloro)	1	18%[c]		2.54		18.1%	
PCB 65 (tetra)	1	5.6%[d,e]	11%[d,f]	3.78E-01	7.42E-01	5.6%	11.0%
Tetrachlorobiphenyls	1	1.6%[b]		1.06E-01		1.6%	
PCB 118 (penta)	1	4.4%[d,e]	11%[d,f]	5.79E-02	1.39E-01	4.4%	10.6%
Pentachlorobiphenyls	1	0.6%[b]		8.20E-03		0.6%	
Hexachlorobiphenyl	1	0.042%[a]	0.29%[b]	7.60E-05	5.31E-04	0.0%	0.29%
Moderately PCB contaminated[g]	1	1.8%[g]		3.23		1.1%	

Note:

[a] Borglin *et al*. (1996)

[b] Ghosh *et al*. (2000)

[c] ten Hulscher *et al*. (1999; 2002)

[d] Cornelissen *et al*. (1997)

[e] k is for 2 day contact time

[f] k is for 34 day contact time

[g] Carroll et al. (1994).Moderately PCB contaminated sediment contained 64 mg/kg (dry weight) PCBs, with total organic carbon of 3.43%. The PCB presents in the sediments consisted of primarily mono- and di-chlorinated biphenyls (60-70% or total).

[h] Assumed equilibrium was achieved

Table 9

Summary of Field Samples and Analytical Data
from the Pre-Design Field Test - Dredge Technology Evaluation Report (8/6/2001)

							Turbidity (NTU)				Total PCBs (ug/L) 18 Congeners				
Date	Type	Northing	Easting	Hour	Min		Max	Min	Avg	TSS (mg/L)	Particulate	Dissolved	Particulate+ Dissolved	Fraction Particulate	Fraction Dissolved
8/7/00	Grab	2704955	815354	16	26	Background Value - Acushnet Estuary 1000ft N				10	0.89	0.52	1.41	0.63	0.37
8/7/00	Grab	2703124	815820	16	36	Background Value - Acushnet Estuary 1000ft S				4	0.25	0.18	0.43	0.58	0.42
8/15/00	Grab	2704040	815356	17	52	Turbidity/TSS - Acushnet Estuary	26	26	26	53					
8/15/00	Grab			18	5	Turbidity/TSS - Acushnet Estuary	12	12	12	22					
8/15/00	Grab			18	8	Turbidity/TSS - Acushnet Estuary	3	5	4	5					
8/16/00	Grab	2703129	815608	9	20	Up-Current reference sample	3	6	4.5	6	0.11	0.21	0.32	0.34	0.66
8/16/00	EBB			11	56	Sampling HR1 - Station 1 (50ft)	7	10	8.5	20					
8/16/00	EBB	2703959	815530	12	2	Sampling HR1 - Station 2 (100ft)	16	21	18.5	24					
8/16/00	EBB	2703621	815717	12	11	Sampling HR1 - Station 3 (500ft)	5	12	8.5	17					
8/16/00	EBB	2704948	815379	12	22	Sampling HR1 - REF (1000ft up-current)	3	12	7.5	9					
8/16/00	EBB			13	16	Sampling HR2 - Station 1 (50ft)				11					
8/16/00	EBB	2703833	815506	14	6	Sampling HR2 - Station 2 (100ft)				43					
8/16/00	EBB	2703647	815675	14	15	Sampling HR2 - Station 3 (500ft)				11					
8/16/00	EBB	2704948	815379	14	22	Sampling HR2 - REF (1000ft up-current)				12					
8/16/00	Composite					Composite Station 1				16	1.3	0.77	2.07	0.63	0.37
8/16/00	Composite					Composite Station 2				27	2.1	0.79	2.89	0.73	0.27
8/16/00	Composite					Composite Station 3	23	27	25	12	0.85	0.75	1.6	0.53	0.47
8/16/00	Composite					Composite -REF	10	17	13.5	9	0.89	0.9	1.79	0.50	0.50
8/16/00	FLOOD	2703995	815351	16	59	Sampling HR1 - Station 1 (50ft)				20					
8/16/00	FLOOD	2704110	815393	17	17	Sampling HR1 - Station 2 (100ft)	20	20	20	17					
8/16/00	FLOOD	2704375	815410	17	23	Sampling HR1 - Station 3 (500ft)	40	40	40	25					
8/16/00	FLOOD	2702780	815578	17	44	Sampling HR1 - REF (1000ft up-current)	6	15	10.5	6					
8/16/00	FLOOD	2704028	815329	17	56	Sampling HR2 - Station 1 (50ft)	21	27	24	12					
8/16/00	Grab			17	56	Surface oil slick observed at HR1 - Station 1 (50ft)									
8/16/00	FLOOD	2704140	815363	17	58	Sampling HR2 - Station 2 (100ft)	10	15	12.5	13		1.5			
8/16/00	FLOOD	2704375	815410	18	19	Sampling HR2 - Station 3 (500ft)	39	42	40.5	9					
8/16/00	FLOOD	2702780	815578	18	40	Sampling HR2 - REF (1000ft up-current)	38	42	40	7					
8/16/00	Composite					Composite Station 1				27	2.6	0.66	3.26	0.80	0.20
8/16/00	Composite					Composite Station 2				10	0.99	0.58	1.57	0.63	0.37
8/16/00	Composite					Composite Station 3				16	1.1	0.52	1.62	0.68	0.32
8/16/00	Composite					Composite -REF				5	0.25	0.36	0.61	0.41	0.59
8/17/00	EBB			10	58	Sampling - Up-Current reference sample	23	27	25	5	0.29	0.46	0.75	0.39	0.61

Table 10
Dissolved and Particulate Percent PCB Mass Loss

Dissolved Phase Maximum						
Max >=100', no flood	0.95	ug/L				
minus background	0.52	ug/L				
	0.43	ug/L				
Maximum Flow Rate	10	cm/s	3.9	in/s	0.3	ft/s
wide	800	ft				
deep	8.75	ft				
Maximum Flow Rate	2297	cfs	2.8E-02	m^3/cf	65.0	m^3/s
	65	m3/s	1000	L/m3	65032	L/s
	65032	L/s				
x	0.43	ug/L				
	27964	ug/s				
Mass loss/second	2.8E-05	kg/s				
time worked	17.5	hrs	3600	s/hr	63000	s
	2.8E-05	kg/s				
x	63000	s				
PCB mass loss	1.8	kg				
PCBs removed	1495	kg				
Dissolved Phase Percentage	0.1%					
Particulate Phase Maximum						
Max >=100', no flood	2.6	ug/L				
minus background	0.89	ug/L				
	1.71	ug/L				
Maximum Flow Rate	10	cm/s	3.9	in/s	0.3	ft/s
wide	800	ft				
deep	8.75	ft				
Maximum Flow Rate	2297	cfs	2.83E-02	m^3/cf	65.0	m^3/s
	65	m3/s	1000	L/m3	65032	L/s
	65032	L/s				
x	1.71	ug/L				
	111205	ug/s				
Mass loss/second	1.1E-04	kg/s				
time worked	17.5	hrs	3600	s/hr	63000	s
	1.1E-04	kg/s				
x	63000	s				
PCB mass loss	7.0	kg				
PCBs removed	1495	kg				
Particulate Phase Percentage	0.5%					
Percent Dissolved	20%					
Percent Particulate	80%					

Table 9 Cont'd

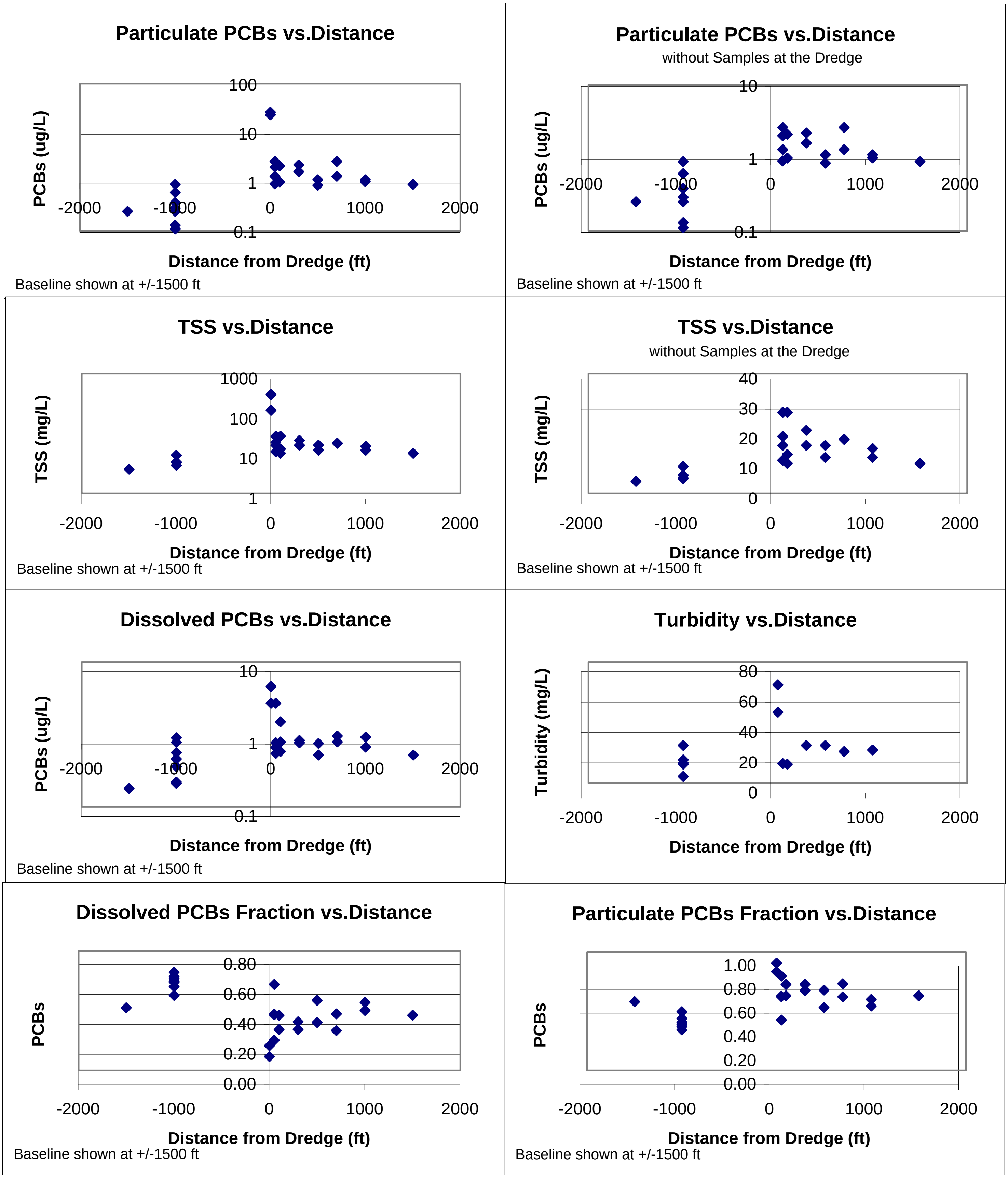
							Turbidity (NTU)				Total PCBs (ug/L) 18 Congeners				
Date	Type	Northing	Easting	Hour	Min		Max	Min	Avg	TSS (mg/L)	Particulate	Dissolved	Particulate+ Dissolved	Fraction Particulate	Fraction Dissolved
8/17/00	EBB	2703878	815379	11	7	Sampling HR1 - Station 1 (50ft)	11	18	14.5	6					
8/17/00	EBB	2702964	815758	11	42	Sampling HR1 - Station 4 (1000ft)	10	17	13.5	12					
8/17/00	EBB	2703218	815599	11	46	Sampling HR1 - Station 3 (700ft)	10	17	13.5	17					
8/17/00	EBB	2703625	815534	11	50	Sampling HR1 - Station 2 (300ft)	11	18	14.5	12					
8/17/00	EBB	2704948	815379	11	59	Sampling HR1 - REF (1000ft up-current)	9	18	13.5	9					
8/17/00	EBB	2702964	815758	12	32	Sampling HR2 - Station 4 (1000ft)	6	10	8	8					
8/17/00	EBB	2703218	815599	12	38	Sampling HR2 - Station 3 (700ft)	12	17	14.5	11					
8/17/00	EBB	2703625	815534	12	45	Sampling HR2 - Station 2 (300ft)	11	17	14	15					
8/17/00	EBB	2703878	815379	12	52	Sampling HR2 - Station 1 (50ft)	9	15	12	11					
8/17/00	EBB	2704948	815379	13	1	Sampling HR2 - REF (1000ft up-current)	5	12	8.5	7					
8/17/00	Grab			13	45	MIAMI II Plume (peak field turbidity)	60	70	65	300	26	2.7	28.7	0.91	0.09
8/17/00	EBB	2703878	815379	13	48	Sampling HR3 - Station 1 (50ft)	28	34	31	62					
8/17/00	EBB	2703625	815534	13	58	Sampling HR3 - Station 2 (300ft)	19	23	21	29					
8/17/00	EBB	2703218	815599	14	3	Sampling HR3 - Station 3 (700ft)	13	18	15.5	18					
8/17/00	EBB	2702964	815758	14	8	Sampling HR3 - Station 4 (1000ft)	13	21	17	21					
8/17/00	EBB	2704948	815379	14	38	Sampling HR3 - REF (1000ft up-current)	9	12	10.5	10					
8/17/00	EBB	2703878	815379	14	47	Sampling HR4 - Station 1 (50ft)	26	29	27.5	39					
8/17/00	EBB	2703625	815534	14	53	Sampling HR4 - Station 2 (300ft)	19	26	22.5	31					
8/17/00	EBB	2703218	815599	14	57	Sampling HR4 - Station 3 (700ft)	27	29	28	37					
8/17/00	EBB	2702964	815758	15	3	Sampling HR4 - Station 4 (1000ft)	13	18	15.5	22					
8/17/00	Composite					Composite Station 1	10	16	13	19	2	2.7	4.7	0.43	0.57
8/17/00	Composite					Composite Station 2	21	29	25	21	2.2	0.83	3.03	0.73	0.27
8/17/00	Composite					Composite Station 3	18	24	21	18	1.3	0.79	2.09	0.62	0.38
8/17/00	Composite					Composite Station 4	20	24	22	15	1	0.67	1.67	0.60	0.40
8/17/00	Composite					Composite -REF	13	18	15.5	9	0.61	0.78	1.39	0.44	0.56
8/17/00	FLOOD	2704000	815324	16	49	Sampling HR1 - Station 1 (50ft)	13	16	14.5	17					
8/17/00	FLOOD	2704266	815441	17	6	Sampling HR1 - Station 2 (300ft)	14	19	16.5	20					
8/17/00	FLOOD	2704727	815455	17	12	Sampling HR1 - Station 3 (700ft)	60	70	65	210					
8/17/00	FLOOD	2705097	815357	17	18	Sampling HR1 - Station 4 (1000ft)	10	13	11.5	10					
8/17/00	FLOOD	2702805	815548	17	33	Sampling HR1 - Station 5 (1000ft up-current)	6	13	9.5	9					
8/17/00	FLOOD	2704000	815321	18	0	Sampling HR2 - Station 1 (50ft)	6	13	9.5	8					
8/17/00	FLOOD	2704266	815441	18	6	Sampling HR2 - Station 2 (300ft)	15	18	16.5	15					
8/17/00	FLOOD	2704727	815455	18	12	Sampling HR2 - Station 3 (700ft)	11	19	15	16					
8/17/00	FLOOD	2705097	815357	18	15	Sampling HR2 - Station 4 (1000ft)	12	17	14.5	14					
8/17/00	FLOOD	2702805	815548	18	30	Sampling HR2 - REF (1000ft up-current)	11	13	12	6					

Table 9 Cont'd

							Turbidity (NTU)				Total PCBs (ug/L) 18 Congeners				
Date	Type	Northing	Easting	Hour	Min		Max	Min	Avg	TSS (mg/L)	Particulate	Dissolved	Particulate+ Dissolved	Fraction Particulate	Fraction Dissolved
8/17/00	FLOOD	2704000	815321	19	4	Sampling HR3 - Station 1 (50ft)	12	15	13.5	13					
8/17/00	FLOOD	2704266	815441	19	8	Sampling HR3 - Station 2 (300ft)	11	16	13.5	20					
8/17/00	FLOOD	2704727	815455	19	12	Sampling HR3 - Station 3 (700ft)	8	13	10.5	11					
8/17/00	FLOOD	2705097	815357	19	16	Sampling HR3 - Station 4 (1000ft)	12	19	15.5	19					
8/17/00	FLOOD	2072805	815548	19	33	Sampling HR3 - REF (1000ft up-current)	4	9	6.5	3					
8/17/00	Composite					Composite Station 1				11	0.91	0.55	1.46	0.62	0.38
8/17/00	Composite					Composite Station 2				16	1.6	0.77	2.37	0.68	0.32
8/17/00	Composite					Composite Station 3				18	2.6	0.95	3.55	0.73	0.27
8/17/00	Composite					Composite Station 4				12	1.1	0.92	2.02	0.54	0.46
8/17/00	Composite					Composite -REF				6	0.38	0.56	0.94	0.40	0.60
8/18/00	Grab			10	48	Sample Up-current-reference (Event scrubbed)	10	15	12.5	6	0.13	0.22	0.35	0.37	0.63
8/18/00	Grab			17	44	Sample inside moonpool during active dredging	44	50	47	120	23	4.6	27.6	0.83	0.17

Figures

Figure 1
PCB, TSS and Turbidity vs. Distance from the Dredge



Attachment D

Modeling Analysis

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Attachment D

Modeling Analysis

1.0 Introduction

Modeling of conditions expected during dredging operations was undertaken to evaluate the short and long-term effects of remedial activities. Far-field models - consisting of fate, transport and bioaccumulation models - were utilized to measure the long-term effects of dredging and to determine the percent PCB mass loss that will result in unacceptable river recovery and adverse impacts to downstream water supply intakes. In addition to far-field modeling, near-field modeling was conducted to simulate dredging and resulting river conditions near the dredge bucket/head and up to a mile downstream. One near-field model (TSS-Chem) was used to estimate PCB water column conditions in a lateral direction from the dredge (across the width of the river) up to one mile downstream. The modeling results were used to aid in the determination of the best location for monitoring points, the water column concentration near sensitive locations, settling effects and rates of PCB flux for use in the long-term models. A second near-field model (CSTR-Chem) was developed assuming that the conditions near the dredge are similar to a continuous stirred tank reactor (CSTR). The model provided a basis for assumptions regarding the dissolved phase PCB concentrations in the immediate vicinity of the dredge.

2.0 Objectives

2.1 Near-Field Modeling

Near-field modeling was completed to simulate water column suspended solids and total PCB concentrations in the vicinity of the dredge. The downstream models were applied to determine the following:

- Estimate monitoring locations for suspended solids and turbidity;
- Estimate plume geometry of the resuspended sediment (sediment transport and flux in close proximity to the dredge);
- Estimate depositional patterns of the settled resuspended sediment, thickness of the deposited material, and its impact on surficial sediments that are deposited downstream;
- Evaluate the potential PCB dissolved phase release downstream of the dredge.

2.2 Far-Field Modeling

Far-field modeling was completed to simulate water column, sediment and fish total PCB concentrations in the Upper and Lower Hudson River as a result of the dredging operation. The far-field model was applied to determine the following:

- Estimate the impact of contaminant mass loss from resuspension during remediation and its effect on water column concentrations at public water intakes;
- Determine the acceptable mass loss for protection on downstream water resources and public water intakes;
- Evaluate the impact of accidental release scenario on resulting water column concentrations at public water intakes and on the recovery of the river.

3.0 Selection of the Transport Models

Dredging operations are expected to release suspended sediment and PCBs into the water column. As a result, modeling was needed to estimate the duration and intensity of these impacts at sensitive downstream locations. Sensitive locations include the immediate dredging area and downstream water supply intakes. Modeling at multiple scales was conducted to estimate these impacts at all locations in the river system.

A far-field model was necessary to predict PCB concentrations over the extent of the remediated area and downstream into the Lower Hudson River. The far-field model was capable of estimating PCB concentrations during the years of dredging activities as well as several years following the completion of dredging. In contrast, a near-field model capable of estimating PCB water column concentrations over a short period of time (weeks or months) was required to simulate river conditions in the vicinity of the dredge.

During preparation of the Hudson River Feasibility Study (FS) report (USEPA, 2000a) and the Hudson River Responsiveness Summary (RS) report (USEPA, 2002), the USEPA water quality model, HUDTOX, was developed to project current river conditions into the future for comparison against model runs where active remediation such as capping and dredging were simulated. This model forecasts future water column and sediment PCB concentrations for various scenarios so the benefit of active remediation versus monitored natural attenuation (MNA) could be compared and evaluated. The results of the HUDTOX model were then utilized as input for the FISHRAND model to evaluate fish bioaccumulation PCB levels as a result of the various scenarios. This model, HUDTOX, was used to estimate far-field river and sediment concentrations for various scenarios to allow for the development of a protective resuspension performance standard.

An evaluation was conducted to determine if HUDTOX could be applied to simulate dredging conditions near the dredge (near-field modeling) since HUDTOX already reflects the conditions of the Hudson River. However, HUDTOX could not be readily modified to obtain adequate resolution for estimating near-field river conditions, therefore other models have been developed specifically for the near-field modeling.

A USACE model, SED2D, was evaluated for use as the near-field model since it has been proven to simulate near-field dredging conditions with similar accuracy as the HUDTOX model only in a much shorter time frame. SED2D is part of the TABS-MD (multi-dimensional) modeling system that was used in the development of HUDTOX. It is a two-dimensional model that can be used for depth-averaged transport of cohesive or a representative grain size of non-cohesive sediments and the deposition, erosion, and formation of bed deposits. Until 1995, this model was distributed under the name of STUDH. Sediment loading and bed elevation changes can be calculated when supplied with a hydrodynamic solution computed by the model RMA2. RMA2 is a hydrodynamic model that supports sub-critical flow analysis. The SED2D and STUDH models were not selected for use, because of the limitations of the model, including modeling a single type of solids. RMA2 was used to estimate the linear water velocities and depths at various flowrates.

The near-field model used previously in the FS and ROD was DREDGE. DREDGE is a module of the Automated Dredging and Disposal Alternatives Modeling System (ADDAMS) distributed by the USACE through the Environmental Laboratory, USAE Research and Development Center Waterways Experiment Station. DREDGE estimates the rate at which bottom sediments become suspended into the water column as the result of dredging operations and the resulting suspended sediment concentrations. TSS-Chem was developed to model the downstream transport of solids and PCBs through the near-field in the Hudson River. TSS-Chem is similar to the DREDGE model described in Appendix E of the FS. It applies the same Gaussian plume for solids transport as DREDGE but is able to model both coarse and fine solids and includes two phase partitioning of PCBs from the solids into the dissolved phase. However, unlike the DREDGE model, TSS-Chem is only applicable for dredging activities with 4-cy dredge buckets. The TSS-Chem model provides estimates of PCB and solids concentrations and fluxes across the river width from 10 meters downstream to approximately one mile downstream.

Since TSS-Chem is unable to estimate conditions directly around the dredge bucket, a second near-field model was necessary. CSTR-Chem models the area directly around the dredge bucket as a continuous stirred tank reactor. The conditions in this area are essential to the loading of TSS-Chem. By estimating the surroundings of the dredge bucket, a basis for assumptions regarding the solids source of TSS-Chem was obtained.

3.1 Interaction Among the Transport Models

The main goal of the modeling effort is to study the long-term impacts of dredging operations in the Upper and Lower Hudson River. As part of this, fish tissue recovery can provide a threshold or limit to define an unacceptable impact due to dredging releases and thereby a limit on the export rate is needed. The modeling efforts were focused on examining the impact of running the dredging operation at the specified action levels in the Resuspension Standard. The resuspension scenarios for the Resuspension Standards are specified as the PCB export rate at the far-field monitoring stations. The HUDTOX/FISHRAND model cannot be used for this purpose strictly since HUDTOX is not designed to simulate the process of dredging releases. Due to the nature of the HUDTOX model structure, PCB loads cannot be readily specified at far-field locations (i.e., specifying the resuspension export rate). Rather, the input of PCBs is specified as an input load at a location within the river, equivalent to a resuspension release rate. In order to create a correctly loaded HUDTOX run, it is first necessary to estimate the local resuspension release rate from the dredging operation; that is, the rate of Tri+ PCB, Total PCB and solids transport at the downstream end of the dredge plume. At this location most of the solids that are going to settle out, will have settled out and the suspended solids will more closely resemble those simulated by HUDTOX. To estimate the input loading term for HUDTOX, the two models designed to address the dredging release process and near-field transport, CSTR-Chem and TSS-Chem, were used.

The three models were used to represent and link the three different scales of resuspension. The immediate vicinity of the dredge (10 m radius) is simulated by the CSTR-Chem. The region from the dredge to a distance of one mile (10 to 1610 m) is represented by TSS-Chem with its solids transport and geochemical model. Finally, the region beyond one mile is represented by HUDTOX. The choice of the TSS-Chem model to represent a one-mile interval is related to the size of the individual HUDTOX cell, which is approximately 2/3 of a mile long. Figure 1 shows the links among the transport models and the different scales of resuspension they represent.

4.0 Near-Field Modeling

The near-field models are useful in determining the appropriate locations for monitoring stations and provide a practical basis for defining criteria by estimating resuspension rates that correspond to various action level scenarios. The resuspension rates were compared to production rates and the ability to realistically resuspend solids at such rates from dredge bucket operations were examined.

4.1 Parameters

The parameters required for HUDTOX and other long-term models are not directly applicable to the near-field models. Many of the HUDTOX parameters were developed empirically for long-term conditions. The near-field models only apply to periods of dredge activities. Therefore, the parameters applied for use in the near-field models were chosen based on extensive literature research, consideration of the unique conditions found in the Upper Hudson River and a tendency towards conservative (greater release) estimates.

For the near-field model simulations, the concentration of PCBs on the suspended particles was estimated as the average sediment concentrations of the removed material for each river section including the overcut. While in the water column the PCBs undergo two-phase partitioning from the suspended to dissolved phase. The partitioning of the PCBs between the two phases is based on the partition coefficient which dictates the equilibrium fractions of the phases and the desorption rate which will determine how quickly equilibrium is approached. The selection of the partition coefficient and the desorption rate is discussed in Attachment C since they are not exclusively used for these models.

With a given partition coefficient and desorption rate the time available for partitioning will control the amount of desorption that occurs. The time that the particles remain suspended is primarily a function of the sediment type. Generally the silt particles will remain suspended longer than the coarse particles. In the model, the rate at which particles fall through the water column is determined by the particle settling velocity. The model includes different settling velocities for fine and coarse particles. In addition to the time constraint, the concentration of suspended PCBs within the plume will also affect the equilibrium conditions. In the TSS-Chem model dispersion of the solids within the plume and thereby the concentration is dictated by the lateral dispersion coefficient. The selection of both the settling velocities and lateral dispersion coefficient is discussed below.

4.1.1 Settling Velocities

To accurately represent the solids concentrations and the time available for partitioning in the CSTR-CHEM and TSS-CHEM models, settling velocities for both fine and coarse resuspended sediments were researched. Eight references were examined and considered in the selection of the settling velocities for the two models. The selection process took into account the applicability of the studies to the Hudson River sediments and the inclusion of significant dynamic aspects of settling solids (*i.e.*, flocculation) in the studies. Previous data analyses have been completed to define and characterize the Hudson River sediments and the typical properties of the sediments are summarized in Table 1.

4.1.1.1 Literature Search

As part of a literature search the following references that reported or used settling velocities were examined:

(1) ***Estimating the Size-Dependent Settling Velocity of Suspended Particles Using the LISST-ST.*** (Sequoia Scientific, Inc.)
The LISST-ST is a particle counter manufactured by Sequoia Scientific, which is employed in the water column of rivers and used to count particle sizes and measure the time it takes for the particle to settle out in the chamber of the instrument. This data is then used to estimate the particle settling velocity. Data generated from field studies is indicative of:

- For particle of size 50 microns, $V_s = 0.01$ cm/s
- For a particle of size 100 microns, $V_s = 0.10$ cm/s
- For a particle of size 400 microns, $V_s = 0.005$ cm/s

(2) ***Transport and Transformation of Contaminants Near the Sediment-Water Interface.*** (DePinto *et al*., 1994)
This reference examined both freshwater and saltwater sediment particles for slightly flocculent New Bedford Harbor sediment and highly flocculent Passaic Valley Sewage Sludge. Data generated from this study indicated:

- New Bedford Harbor Freshwater sediment with a particle size of 21 μm: $V_s = 0.0124$ cm/s
- Passaic Valley Freshwater sewage sludge with a particle size of 22 μm: $V_s = 0.0057$ cm/s

(3) ***Filtration and Separation.com***.
This web site has an interactive program that allows the user to enter in a sediment particle size and density and then use the properties of water (density and viscosity) to compute the particle settling rate. This program computes the settling velocity using Stokes' Law, the Heywood Tables (valid for Reynolds Numbers up to 100,000) and Archimedes correlation, which bases the estimated

settling velocity on the Reynolds number computed for the specific information in the program. All results are provided as output with a recommendation of which value is most applicable.

(4) ***Measurement Suspended Sediment Characteristics in an Embanked Flood Plain Environment of the River Rhine.*** (Thonon and Van Der Perk, 2002)
This paper describes the study conducted on the River Rhine located in The Netherlands. The study was conducted to help quantify the amount of sediment-transported pollution that is occurring in the flood plains of the River Rhine. This data is being used to calibrate flood plain sedimentation models and to assist in the assessment of the fate and transport of sediment-associated pollutants in riverine environments. Field studies were completed by deploying a LISST-ST Type C portable particle counter manufactured by Sequoia Scientific at the main distributary of the Rhine River.

Generally, this instrument measures particle sizes and settling velocities for particles ranging from 2.5 to 500 um using laser diffraction principles. At the beginning of each study, the settling tube is opened for four seconds and allowed to fill with river water and suspended matter. It is then closed and the test is run for a duration of 12 hours. The suspended matter size is then measured in the tube 71 times over the 12-hour period. Finally, the settling velocity is computed from the decrease of the volume of concentration of the different particle fractions over time. Results of this study were as follows:

- For a particle of size 10 microns: V_s = 0.001 cm/s
- For a particle of size 50 microns: V_s = 0.005 cm/s
- For a particle of size 100 microns: V_s = 0.01 cm/s
- For a particle of size 400 microns: V_s = 0.01 to 0.001 cm/s

(5) ***Model for Turbidity Plume Induced by Bucket Dredge*** (Kuo and Hayes, 1991)
This study employed a model to evaluate the plume created in a river by a mechanically operated dredge. This study was completed for three river systems. Sediment characteristics were provided for each of these river systems and the settling velocity was computed using Stokes' Law.

- St. John's River: Particle size of 39.6 microns (98% of sediment finer than 62 microns) and sediment density of 2.40 g/cc; Vs = 0.12 cm/s
- Black River Harbor: Particle size of 36.3 microns and sediment density of 2.39 g/cc; V_s = 0.10 cm/s
- Thames River: Particle size of 150 microns and sediment density of 2.50 g/cc; V_s = 1.84 cm/s
- Thames River: Particle size of 160 microns and sediment density of 2.50 g/cc; V_s = 2.10 cm/s

(6) ***Dredge Induced Turbidity Plume Model***. (Kuo *et al*, 1985)

This paper examined a model to help describe the turbidity plume resulting from dredging in a ship channel with a hydraulic dredge. The model was developed to predict the sediment concentration within the plume and the resulting sedimentation alongside the dredged channel. Results of the model are compared with actual field measurements. It was concluded that the model calibrated parameters agreed with field observations and measurements. The settling velocity was computed for model input using the following equation:

$$\mathbf{Vs = w = 1/18v * ((r_{sp} / r w) - 1)) * g * a\hat{}2}$$

Where:

v = viscosity of water = 1.08 X 10^{-5} ft/s = 0.01 cc/s
ρ_{sp} = density of particle (g/cc)
ρ_w = density of water = 1 g/cc
g = acceleration due to gravity = 32.2 ft/s = 980 cm/s^2
a = particle size (cm)
In the referenced paper, a = 20 microns = 20 X 10^{-4} cm and ρ_{sp} = 2.65 g/cc and V_s = 0.0359 cm/s

Applying this equation to the Hudson River Sediment Characteristics:

- Silt assuming a particle size of 20 microns and range of particle densities from 2.2 –2.6 g/cc: V_S = 0.026 –0.035 cm/s
- Fine Sand assuming a particle size of 100 microns and range of particle densities from 2.2 –2.6 g/cc: V_S = 0.653 –0. 871 cm/s
- Medium-Coarse sand assuming a particle size of 400 microns and a range of particle densities from 2.2 – 2.6 g/cc: V_S = 4.0 – 8.5 cm/s

(7) ***New Bedford Harbor Water Quality Monitoring Pre-Design Field Test Dredge Technology Evaluation Report, Appendix K.*** (USACE, 2001)
An estimate of V_s using Stokes' Law and particle size for silts and clay was provided as follows:

- Silt with particle size of 0.02 mm; V_s = 3.21 X 10^{-6} cm/s
- Clay with particle size of 0.002 mm; V_s = 3.21 X 10^{-8} cm/s

(8) ***1999. PCBs in the Upper Hudson River Volume 2. A Model of PCB Fate, Transport, and Bioaccumulation.*** (QEA, 1999)
For application of a model to predict PCB concentrations in the Hudson River, a fate and transport model was applied. One of the parameters required for input into this model was the specific Hudson River sediment characteristics including the particle size, particle density, and the particle settling velocity. Settling velocities for cohesive and non-cohesive sediments were estimated using different

methods. The settling velocity for cohesive sediment was computed utilizing the following formula:

$$V_s = 3.3 * (C_1G)^{\wedge}0.12 \qquad \text{(EQ 1)}$$

Where:
C_1 = particle concentration (mg/l)
G = water column bottom shear stress = $C_f * q^{\wedge}2$ (dynes/cm^2)

This formula was developed for the fine particles when flocculation occurs among particles during the settling procedure. Therefore, settling velocities may be applied to silt particles since coarse/sand particles will not aggregate. Measured settling velocities were plotted as a function of C_1G and have a range from 4 to 9 m/day while the value of C_1G ranges from 10 to 2000 (mg/L*dynes/cm^2). However, the study did not show a trend with particle density (within the silt range used). In this study the non-cohesive settling velocity was estimated based on particles size and particle density using Stokes' Law.

4.1.1.2 Selection of Settling Velocity

A summary of the settling velocities from the studies above is provided in Table 2. For most of studies Stokes' Law is the theoretical basis for estimating the settling velocity of sand particles. This approach is appropriate for discrete particles that do not aggregate. For the fine sand sediments of the Hudson River, the settling velocity would be 0.6 – 0.8 cm/s assuming that the range of particle density is 2.2 to 2.6 g/cc and the particle size of fine sand is 100 microns. Using the same range of particle density, the settling velocity of medium-coarse sand in Hudson River sediments is 4.0 to 8.5 cm/s assuming that the typical particle size is 400 microns. For the CSTR-Chem and TSS-Chem models 6 cm/s was used as a conservative estimate of the typical settling velocity for the sand fraction of Hudson River sediments.

Stokes' Law only applies to discrete particles settling and does not account for the flocculation during settling. Flocculation increases the rate at which silts settle from the water column, but the rate of flocculation depends on site specific conditions and sediment properties. The silt settling velocities presented in QEA's report (1999) for Hudson River sediments were used in the near-field models since these values were directly applicable to Hudson River sediments and included the effects of flocculation. Even though the settling velocity was presented as a function of C_1*G (particle concentration * shear stress), the settling velocity varied in a very narrow range (4-9 m/day) while the value of C_1*G varied in 3 orders of magnitude (from single digit number to a couple thousands). Therefore, 7 m/day, equivalent to 8.1×10^{-3} cm/sec, was chosen as the typical settling velocity for Hudson River silt/clay. The range of 4 m/day and 9 m/day were applied to the sensitivity analyses of the models. It should be noted that 8.1×10^{-3} cm/sec is one order of magnitude less than the velocity estimated by Stokes'

Law (0.026 – 0.035 cm/s) when assuming that the particle size is 20 microns and the density is 2.2-2.6 g/cc.

Concern has been raised that a probability factor of settling should be applied to account for the effects of near-bed turbulence on particle deposition. However, sediment particles in the near-bed zone have effectively been removed from the water column. They are not available for downstream transport within the water column and no longer contribute significantly to water column exposure. Thus, the water quality models applied here do not attempt to deal with complex near-bottom sediment erosion and deposition. It would be reasonable to develop and apply models capable of considering a wider range of processes, e.g. near-bed erosion and deposition, during the design phase when more detailed analyses of the fate and transport of sediments and associated constituents are appropriate.

4.1.2 Lateral Dispersion Coefficient

The lateral dispersion coefficient impacts the width of the solids plume and therefore the concentration within the plume, as the solids are transported downstream. In order to use TSS-Chem to model the movement of the solids plume downstream, a lateral dispersion coefficient must be specified. Since the coefficient is dependent on the velocity of the river water, more than one lateral dispersion coefficient value was required.

A time-of-travel study conducted by USGS in Upper Hudson River (USGS, 1969) examined dye concentrations vs. time at both center and side channel stations located near Schuylerville. The peak concentration at the center channel station occurred 0.5 to 1 hour earlier than the peak concentration at the side channel station, demonstrating the lateral dispersion of the dye. Theoretically, the lateral dispersion coefficient can be estimated based on the conservation of dye mass, but the locations of the center and side channel stations and the raw data for the dye concentrations are not provided in the report. Due to the limitation of available data and the difficulty of finding data from an old report, the numerical solution was not pursued based on this report. Due to the limitation of available data and the complexity of natural river systems, the results presented below are considered to provide an order of magnitude estimate of the lateral dispersion coefficient.

Fischer (1979) provides the practical rule that the lateral dispersion in a bounded channel can be approximated as:

$$e_t = 0.6du^* \qquad \text{(EQ 2)}$$

Where:

e_t = lateral dispersion coefficient (m^2/s)

d = average depth of flow (m)

u^* = shear velocity (m/s), $\sqrt{gdS}$

g = gravitational acceleration, 9.81 m/s^2

S = slope of the channel (unit less)

Since surface water elevation is the energy grade indicator of the river, surface water elevation slope can also be used to calculate the shear velocity. USGS monitors the daily water elevation at gauged stations throughout the year. Gauge 119 is located near Lock 7 and gauge 118 is located near TI Pool. The distance between these two gauges is about 6 miles. The surface water elevation slope between these two gauges represents the energy slope within the TI Pool. The average water elevation difference was calculated on a monthly basis for several years of data. Negative water elevation differences were observed and treated as 0 in the averaging, which does not significantly change the monthly average values. As summarized in Table 3, the maximum monthly average elevation difference occurred in March due to high flows during spring run-off. For the dredging season (May through November), the monthly elevation difference is relatively consistent. Using these months a dredging-period slope of 8×10^{-6} was obtained.

The hydrodynamic model RMA2 (described below in Section 4.2) was used to obtain applicable depths and linear velocities for various river flowrates (2000-8000 cfs) and locations (RM 190 and 193) along the Upper Hudson River. Equation 2 was used with the applicable depths, velocities and average dredge-season slope to calculate the lateral dispersion coefficients under different conditions. The results are presented in Table 4. Dispersion coefficients calculated for the eastern segment at RM 190 were used as the typical condition. The dispersion coefficients for the other conditions were investigated in the sensitivity analysis.

4.2 RMA2

RMA2 is a hydrodynamic model created by the USACE that can be used to simulate ambient water conditions such as velocity magnitude and direction at potential dredging sites. Initially, LTI used the RMA2 model to simulate the flow patterns in the Thompson Island Pool to develop the hydrodynamic portion of the HUDTOX model. These results were presented in the Revised Baseline Model Report (USEPA, 2000b). The focus of the LTI study was to derive the spatial distribution of the shear stresses, which in turn was used to determine the depth of scouring and aggregate amount of re-suspension. The amount of re-suspension was then partitioned to PCB loads and incorporated into a long-term transport model (*i.e.*, HUDTOX).

The LTI RMA2 model considered a wide range of flows, from an average flow of about 4,000 cfs to the 100-year flow of about 47,000 cfs. While the low to moderate flows were confined within the Hudson River banks, the higher flows required the inclusion of the Hudson River flood plains into the model. Therefore, the computational domain had to be extended to include the flood plains even under low flow conditions.

Since the dredging activities are more likely to take place during normal summer flow conditions, it is logical to reconfigure the computational model and allocate all available computing resources, *(i.e.*, memory, speed, and total number of elements) to normal flow conditions only (excluding the flood plains). As a result, the narrowed flow range allows the model to incorporate a refined resolution in the river and near the dredging sites. The refined grid can also be used to incorporate more detailed bathymetric variations and to reproduce higher accuracy flow patterns.

4.2.1 Methodology

The new computation grid for RMA2 reflected the following considerations:

(1) It essentially confined to the deep channel of the river and focused on the wet boundary at low flow conditions;
(2) It uses highly refined spatial resolution (a typical resolution is about 15 feet in the transverse direction of the flow);
(3) It represents the river bathymetry more realistically by incorporating the 1990 bathymetric survey data on the refined grids. Additionally, the new grid has adopted quadratic elements to reduce numerical dispersion and enhance numerical convergence at internal wet-dry boundaries.

The new configuration of the RMA2 model to depict dredging conditions was validated by comparison to the LTI RMA2 model. To maintain continuity and consistency between the two studies for comparison, the refined model and the previous model were both set up to simulate the flow patterns and surface profiles with the same boundary conditions and physical parameters. Comparable results from both models would indicate that the refined model has inherited the characteristics of the previous model, and more importantly the credentials that the previous model has built from a thorough calibration process.

The is cross-model validation process was conducted for two flow conditions:

(1) The 100-year flow condition which was presented in the Revised Baseline Modeling Report (USEPA, 2000b);
(2) A 4,000 cfs flow condition which approximates the average flow conditions.

For the previous LTI RMA2 model, the geometry file and boundary condition file were obtained from LTI. The geometry file included both mesh and bathymetry information, and the boundary condition files included physical and model control parameters. For the refined model the boundary conditions and physical parameters were kept the same as the previous model.

The refined model and the LTI RMA2 model were compared for flow patterns for 100-year flow condition. The upstream flow is 47,330 cfs, and the downstream elevation is at 126 feet. Two Manning's n values were used in the previous model, 0.20 in the channel and 0.60 in the flood plain. The refined model is mostly confined to the river channel, therefore the Manning's n was kept at 0.20. Turbulent dispersion coefficient was 100 lb-sec/ft^2 and homogenous for both models. The previous and the refine models show similar flow patterns and velocity magnitudes. The notable differences can be attributed to the omission of flood plain in the refined model. Due to the relatively higher flow depth, the more accurate representation of the bathymetry in the refined model does not seem to contribute significantly to changes in flow pattern or the velocity magnitude.

In addition, the two models were compared for the flow patterns for 4,000 cfs. At this flow rate, the downstream water surface elevation is at 119.2 feet. Because the flows are confined mainly to the river channel, the omission of the flood plain is immaterial. However, at this lower elevation, the effects of the more detailed representation of bathymetry on the flow depth and velocities with the refined model became noticeable.

4.2.2 Results of RMA2

Once the model was validated with the previous model, it was used to simulate the flow patterns at the normal summer flow range. Three representative flows were selected based on the actual flow records - 2,000, 5,000 and 8,000 cfs. In all of these runs the Manning's n value was kept at 0.2 and the turbulent dispersion coefficients was at 100 lb-sec/ft^2. The downstream elevations were at 118.6, 119.2 and the 120.6 feet respectively. It can be seen that the magnitude of the velocity increases with flow and results an increased water surface elevation upstream.

In addition to providing more detailed velocity magnitude and direction at potential dredging sites, the RMA2 simulation results would provide a more accurate shear stress representation and scouring analysis. Potentially the simulated flow field can be used directly in contaminant and sediment transport models such as RMA4 and SED2D. As dredging operations progress, the bathymetry in the model can be easily updated to reflect the post-dredging bathymetry. The flow patterns can then be revised with the updated geometry. The impact of the post-dredging bathymetry can become particularly important when the dredged depth is comparable to the water depth and when the dredging area is relatively large.

4.3 CSTR-Chem

4.3.1 Methodology

The objective of this analysis is to estimate the net contribution of solids, and dissolved and suspended phase PCB to the water column in the immediate vicinity of the dredging operations. This analysis describes the approximation of water quality impacts in the immediate vicinity of a dredging operation using a mathematical model based upon the CSTR concept. It assumes that the waters are completely mixed by ambient and induced currents.

Ideal reactor configurations are used to simplify mathematical modeling of constituent concentrations in surface waters. Two primary ideal reactor configurations are used – continuous flow stirred tank reactors (CSTRs) and plug-flow reactors (PFRs). CSTRs assume that a constant concentration and flow influent is instantaneously mixed as it enters a confined, well-mixed tank. Physical and chemical reactions occur while the water is within the ideal tank and the tank effluent is at the same flow as the influent and at the uniform concentration within the tank. PFRs assume that constituent laden waters travel downstream in a perfectly uniform pattern without lateral and vertical mixing; physical and chemical reactions occur during downstream movement.

Real surface water systems do not have mixed flow conditions; *i.e.*, the waters are never completely mixed or travel downstream without lateral or vertical mixing. However, representing sections of water bodies as one of these ideal reactors can provide useful approximate results, often within errors associated with data available to support the models. The CSTR concept is most appropriate to the analysis of dredging operations because turbulence in the area of the dredge, coupled with ambient flows, may be assumed to produce mixed conditions.

Water Column Mass Balance for Suspended Sediments[1]

Suspended sediment concentrations in the well-mixed water volume that can be approximated as a CSTR can be approximated by:

.... $V_{nf}\frac{dm}{dt} = qm_{in} - qm - v_s A_h m + \dot{M}_R$ (EQ 3)

where:

V_{nf} = volume of the near-field area (m^3)

m = Suspended solids concentration in the near-field volume approximated as a CSTR (mg/L)

t = elapsed time (sec)

q = flow through the near-field volume (m^3/sec)

m_{in} = Suspended solids concentration of flow entering the near-field volume (mg/L)

?$_s$ = settling velocity of suspended particles in near-field volume (m/sec)

A_h = cross sectional area perpendicular to the height (m^2), and

$\dot{M}_R$ = rate of mass resuspension into the near-field area due to dredging (g/sec).

Steady-state Conditions

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[1] This analysis consists of a mass balance for suspended sediments in the water column only.

If q, $\dot{M}_R$, and v_s are constant for a relatively long period of time, steady-state conditions will be reached, *i.e.*, dm/dt = 0. Steady state suspended solids concentration can then be estimated as:

$$m = \frac{m_{in} q + \dot{M}_R}{l_m V_{nf}} \tag{EQ 4}$$

and

$$l_m = \frac{1}{q_{nf}} + \frac{v_s}{H} \tag{EQ 5}$$

where:

V_{nf} = volume of the near-field area (m^3)
T = hydraulic retention time within CSTR (sec)
H = water depth (m).

If the near-field area is assumed to be a square box over a water depth H, than the volume can be expressed as:

$$V_{nf} = w^2 H$$

where:

w = width of the near-field area (m)

Hydraulic retention time is the volume divided by the flow rate

$$q_{nf} = \frac{V_{nf}}{Q_{nf}} \tag{EQ 6}$$

It should be noted that the hydraulic retention time is only a function of the width and linear velocity of the near-field. This is illustrated in the following equation.

$$q_{nf} = \frac{w^2 H}{uHw} = \frac{w}{u} \tag{EQ 7}$$

where:

u = linear velocity of water (m/s)

The solids concentration inside the CSTR before settling can be expressed as:

$$m_{added} = m_{in} + \frac{\dot{M}_R}{q} \tag{EQ 8}$$

and the solids concentration lost to settling is:

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; m_{settled} = m_{added} - m_{out} \tag{EQ 9}$$

Note that the concentration exiting the CSTR (m_{out}) is equivalent to that in the CSTR (m). In cases where the sediment type (*i.e.*, silt, sand) is of importance, the suspended solids mass balance can be applied to each sediment component, using the respective settling velocities.

Toxic Constituents[2]

The transport, fate and impact of toxicants are intimately connected with how they partition or associate with solid matter in or below the water body. This implies that the two forms of the toxicant - the dissolved and suspended forms must be distinguished in any analysis. This distinction has an impact on transport and fate because certain mechanisms differently impact the two forms. In the analysis that follows, volatilization and transformation of the contaminant are assumed to be negligible.

Recent studies have demonstrated that desorption of hydrophobic chemicals from sediments can be quite slow and that chemical equilibrium may not be a good approximation in many real situations. To be consistent with the literature on PCB desorption, transient partitioning is assumed in the model, and the rate of PCB desorption from solids is proportional to the difference between the PCB concentration of the suspended sediments and the concentration that would be in equilibrium with the existing soluble concentration. Therefore, a complete formulation of a mass balance under the transient partitioning first requires the concentrations of PCB under equilibrium conditions.

Contaminant Equilibrium Partitioning

It is assumed that equilibrium conditions exist in the near-field CSTR. A mass balance for the concentration of total PCB under this condition can be expressed as:

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; V_{nf}\,\frac{dc_{Total}}{dt} = qc_{Total,in} - qc_{Total} - v_s A_h F_{s,eq} c_{Total} + \dot{M}_R c_{sed} \tag{EQ 10}$$

where:

V_{nf} = volume of the near-field area (m^3)

C_{Total} = total concentration of the contaminant (ng/L), which is the sum of the dissolved and suspended concentrations in the near-field volume

$c_{d,eq}$ = equilibrium contaminant concentration in dissolved form in the near-field volume approximated as a CSTR (ng/L)

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[2] Porewater contributions are assumed to be negligible and are not considered in this analysis.

$c_{s,eq}$ = equilibrium contaminant concentration in suspended form in the near-field volume approximated as a CSTR (ng/L)
t = elapsed time (sec)
q = flow through the near-field volume (m^3/sec)
$c_{Total,in}$ = total concentration of the contaminant in the flow entering the near-field volume (ng/L)
$?_s$ = settling velocity of suspended particles in near-field volume (m/sec)
A_h = cross sectional area perpendicular to the height (m^2)
$\dot{M}_R$ = rate of mass resuspension into the near-field area due to dredging (g/sec)
c_{sed} = contaminant concentration on bottom sediments (mg/kg).
$F_{s,eq}$ = fraction of contaminant mass in suspended form in equilibrium (unitless)

This fraction of contaminant in suspended form under equilibrium partitioning can be estimated:

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots F_{s,eq} = \frac{K_d m \times 10^{-6}}{1 + K_d \times m \times 10^{-6}} \qquad \text{(EQ 11)}$$

where:
K_d = two-phase contaminant partition coefficient (L/kg)
m = suspended solids concentration in the near-field

Under steady state conditions:

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots c_{Total} = \frac{q c_{Total,in} + \dot{M}_R c_{sed}}{q + n_s A_h F_{p,eq}} \qquad \text{(EQ 12)}$$

The equilibrium concentrations in the dissolved phase and suspended phase along with the concentration on the particles can then be computed as:

$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots c_{d,eq} = \frac{c_{Total}}{1 + K_d \times m \times 10^{-6}} \qquad \text{(EQ 13)}$$

$$C_{p,eq} = C_{d,eq} \times K_d \times 10^{-6} \quad \text{and} \quad C_{s,eq} = C_{p,eq} \times m \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(EQ 14)}$$

where:
$C_{p,eq}$ = contaminant equilibrium concentration on the particles (mg/kg)

If the background concentration is assumed to be in equilibrium and the suspended solids and fraction of dissolved PCB are known then K_d may be computed as:

$$K_d = \frac{1 - F_{d,in}}{F_{d,in} \times m_{in} \times 10^{-6}} \quad \text{..(EQ 15)}$$

where:

$F_{d,in}$ = fraction of contaminant mass in dissolved form in the background (unitless).

For lipophilic contaminants such as PCBs, three-phase partitioning (adding partitioning to dissolved organic carbon) may be important in determining the phase distribution of contaminants. The equations presented above, however, remain valid if $c_{d,eq}$ is interpreted as the “apparent” dissolved concentration or the non-filterable portion that may include both truly dissolved and DOC-sorbed PCBs.

Transient C*ontaminant Partitioning*

Assuming that desorption from the suspended particles to the waster column occurs during the residence time in the CSTR, mass balance expressions for both the dissolved and suspended phases are:

$$V_{nf}\frac{dc_d}{dt} = qc_{d,in} - qc_d + kV_{nf}\left(c_{d,eq} - c_d\right) \quad \text{..(EQ 16)}$$

$$V_{nf}\frac{dc_s}{dt} = qc_{s,in} - qc_s - kV_{nf}\left(c_{s,eq} - c_s\right) - v_s A_h c_s + \dot{M}_R c_{sed} \quad \text{......................................(EQ 17)}$$

where:

c_d = contaminant concentration in dissolved form in the near-field volume approximated as a CSTR (ng/L)

c_s = contaminant concentration in suspended form in the near-field volume approximated as a CSTR (ng/L)

$c_{d,eq}$ = equilibrium contaminant concentration in dissolved form in the near-field volume approximated as a CSTR (ng/L). Obtained from equation 13.

$c_{s,eq}$ = equilibrium contaminant concentration in suspended form in the near-field volume approximated as a CSTR (ng/L). Obtained from equation 14

$c_{d,in}$ = dissolved contaminant concentration of flow entering the near-field volume (ng/L)

$c_{s,in}$ = suspended contaminant concentration of flow entering the near-field volume (ng/L)

k = rate of desorption of contaminant concentration from suspended form, also defined as the rate at which equilibrium is reached (1/sec).

If steady-state conditions exist in the near-field area, the dissolved and suspended concentrations along with the concentration on the particles, under transient partitioning can be estimated from equations 16 and 17 as follows:

$$c_d = \frac{qc_{d,in} + kV_{nf}c_{d,eq}}{q + kV_{nf}} \quad \text{.......(EQ 18)}$$

$$c_s = \frac{qc_{s,in} + \dot{M}_R c_{sed} + kV_{nf}c_{p,eq}}{q + kV_{nf} + n_s A_h} \quad \text{.......(EQ 19)}$$

$$c_p = \frac{c_s}{m} \quad \text{.......(EQ 20)}$$

The net contribution of dredging activities can be calculated as:

$$c_{Total,net} = \left(c_d + c_s\right) - \left(c_{d,in} + c_{s,in}\right) \quad \text{.......(EQ 21)}$$

$$c_{d,net} = c_d - F_{d,in}c_{Total,in} \quad \text{.......(EQ 22)}$$

and

$$c_{s,net} = c_s - (1 - F_{d,in})c_{Total,in} \quad \text{.......(EQ 23)}$$

4.3.2 Results

The analysis below describes the results of CSTR-Chem model application to three different sections of the Hudson River. The following describes the model parameterization:

- Applicability of the CSTR model depends upon the presence of near-field conditions that can reasonably be represented as well-mixed. In this context, well-mixed means suspended solids and toxic constituent concentrations are identical throughout the reactor. Mixing induced by the vertical movement of a bucket dredge suggests that well-mixed conditions will exist in the immediate vicinity of the dredging position. The size of the well-mixed zone depends upon the size of the bucket, both open and closed, and the speed at which it is raised and lowered.

Mixing is less obvious with a hydraulic dredge, but should be a reasonable assumption in relatively shallow water.

- The diameter of the cylindrical area approximated as a CSTR should reflect the extent to which well-mixed conditions exist. For the purposes of this analysis, a CSTR width of 10 meters is used. Buckets expected to be used in the Hudson River project are generally 2 to 3 m in diameter closed and somewhat more open. It is reasonable to assume that velocities induced by bucket movement could extend across most of a 10 m width used in this analysis.

- The FS assumed that a 4-cy environmental bucket would be used to dredge the Hudson River with a two-minute cycle time. Appendix E-6 estimated a sediment resuspension rate of about 1 kg/sec.

- This application also considered two sediment types – silt and coarse materials. Appendix E of the FS contains information cohesive and non-cohesive fraction of sediments, as well as the silt and coarse fraction. Tables 1 and 5 summarize this information for the three sections of the river considered.

- Newly suspended bed sediments are the primary source of new toxic constituents to the water column during a dredging operation. Based upon the research of Warren, Bopp, and Simpson (1997) equilibrium is reached at a rate of 0.20/hr or less; a conservative estimate of 0.2/hr is used as the rate of PCB desorption in this analysis. The selection of the desorption rate is discussed in more detail in Attachment C.

- The partitioning coefficients used for each river section were obtained by assuming that background concentrations of dissolved and suspended PCB are in equilibrium.

- It is assumed that the inflow to the near-field consists only of silt particles. The appropriate settling velocities for silt and sand particle were obtained from review of literature on particle settling in similar systems. Sediments resuspended due to dredging operation are assumed to have uniform particulate PCB content, regardless of type.

- Transient partitioning is assumed for desorption from resuspended sediments. All other partitioning behavior is assumed to be adequately described by equilibrium assumptions.

Table 6 presents the model inputs for the three sections along with model simulation results. The results suggest that under transient partitioning conditions, which are expected within the CSTR, over 98% of the resuspended PCBs are simulated to remain in particle form.

4.3.3 Sensitivity Analysis

The CSTR-Chem model was used to simulate the net suspended solids, net fraction dissolved PCB and net total PCB flux in the near-field as a result of dredging operations. Because models typically contain parameters, the simulation results can be highly sensitive to small changes in the parameter values. Therefore, a sensitivity analysis was performed to quantify the sensitivity of model outputs of greatest interest in the CSTR-Chem model to uncertainty and variability in input parameters. This analysis is important for checking the quality of the CSTR-Chem model, as well as the robustness and reliability of CSTR-Chem modeling analysis.

The CSTR-Chem model parameters on which the sensitivity analysis was performed include:

- River Volumetric flow (thereby linear flow and depth),
- Resuspension rate,
- Silt fraction in the sediment,
- PCB sediment concentration,
- Near-field width,
- Background conditions (suspended solids and PCB concentrations, and dissolved PCB fraction),
- Partition coefficient
- Desorption rate
- Silt and Coarse Settling Velocity

Four model output values were selected to assess the sensitivity of the above parameters. These outputs of concern were:

- The net fraction of dissolved PCBs from dredging, which is estimated as fraction of the net total PCB that is dissolved. The net total PCB is the output total PCB less the background total PCB.
- Net fraction of silts, which is the fraction of net suspended solids (output suspended solids less background suspended solids) that is silt.
- Net total PCB flux exiting the near-field.
- Net suspended solids flux exiting the near-field.

A deterministic approach, which assesses sensitivity of a model output to the range of variation of a parameter, was used in this sensitivity analysis. This method involves calculating the output for a few values of an input parameter. This analysis evaluates the effect on model outputs exerted by individually varying only one of the model input parameters across its entire range of plausible values, while holding all other inputs at their nominal or base case values.

Results and Discussion

The results of the sensitivity analysis were presented using two techniques as follows:

- A dimensionless sensitivity coefficient $S_{Parameter,output}$ for each parameter was calculated as follows:

$$S_{Paramater,output} = \frac{\Delta Output / Output}{\Delta Parameter / Parameter}$$

where,

Parameter = parameter value for the base case, which is the model default value.
? *Parameter* = the absolute change in input parameter value.
Output = model simulated output for the base case input value.
? *Output* = the absolute change in model simulated output

The average of the $S_{Parameter,Output}$ values was calculated for each output of concern and the results are presented in Table 7. The higher the sensitivity coefficient for a particular input parameter, the more sensitive the model output is to perturbation of that parameter.

- A graphical method, which gave a visual indication of how each output is affected by variations in inputs, was also used to represent the results (Figures 2 through 15). These graphical representations depict the linearity or non-linearity of the relationships between parameter values and model-simulated outputs.

The results of the parameter sensitivity analysis can be summarized as follows:

- There were no significant differences between the River Sectons in the sensitivity to most of the parameters (e.g. River wide flow and sediment PCB concentration). Therefore, the sensitivity analysis is mainly focused on River Section 1.

- The net fraction dissolved is most sensitive to changes in the width of the near-field CSTR. The CSTR width directly affects the contaminant residence in the near-field, and the residence time is important to the kinetics of particulate PCB desorption. The net fraction dissolved is relatively less sensitive to changes in width at lower CSTR widths (Figure 6). However the width becomes highly sensitive at higher values, as indicated by the slope of the graph between the net fraction dissolved and the CSTR width.

- The net fraction of dissolved PCB is also sensitive to changes in the PCB partitioning coefficient and the rate of PCB desorption. The partitioning coefficient controls the equilibrium concentrations of dissolved and suspended phases, while the rate of desorption control the PCB desorption kinetics. Both parameters had no effect on the other outputs simulated.

- The net total PCB concentration is only sensitive to changes in the concentration of PCB in sediment, and rate of resuspension. Note that the net fraction dissolved is sensitive to changes in resuspension rates and sediment PCB concentrations under conditions of very low resuspension rates (Figure 7) and very low sediment PCB concentrations (Figure 9), respectively.

- The settling velocities of suspended particles were not sensitive parameters especially for silt particles. However, all the outputs of concern are moderately sensitive to the specification of the sediment silt fraction.

The sensitivity analysis suggests that the CSTR width, the PCB partitioning coefficient and the PCB desorption rate are the three most important parameters controlling the release of suspended PCB to the dissolve phase. The width of the CSTR depends on the dimensions of the dredge bucket, and a conservative input of 10 m is used as the base value in the model. The Hudson river FS presented detailed values of the partitioning coefficient of PCB for several congeners suggesting that values of this parameter are well constrained. Therefore, the rate of the PCB desorption is the only parameter that can significantly affect the reliability of the CSTR-Chem model simulations.

Recent studies have demonstrated that desorption of hydrophobic chemicals from sediments can be quite slow and that chemical equilibrium may not be a good approximation in many real situations. In the CSTR-Chem model the rate of PCB desorption from solids is proportional to the difference between the PCB concentration of the suspended sediments and the concentration that would be in equilibrium with the existing soluble concentration. Several studies (Carroll *et al*., 1994, Borglin *et al*., 1996; Cornelissen *et al*., 1997; ten Hulscher *et al*., 1999, 2002; and Ghosh *et al*., 2000) have characterized the kinetics of PCB desorption as a two stage process: 1) the desorption of a fast desorbing labile fraction and 2) a slow desorption of a non-labile fraction. A representative value for desorption rate of the fast fraction of PCB from these studies is 0.2 hr^{-1}. The rate of desorption of the slow fraction is over an order of magnitude lower that that given for the fast fraction. In order to be conservative, the CSTR-Chem model simulation for the base case were performed using a constant desorption rate of 0.2 hr^{-1}.

Conclusions

The sensitivity analysis indicates that model simulations using conservative values of PCB desorption and CSTR width should not affect the reliability of model conclusions. Given the small residence time within the CSTR, most of the silt particles are expected to exit the CSTR. However, no significant release dissolved phase release of PCBs is expected.

4.4 TSS-Chem

4.4.1 Methodology

TSS-Chem is intended to provide a model of the downstream transport of solids and PCBs through the near-field (approximately 1 mile). TSS-Chem contains both a solids component and a PCB component. The solids considered are from the silt and coarse resuspended sediments and PCB concentrations modeled are both suspended and dissolved.

TSS-Chem uses the solids source strength of dredging activities to model downstream transport of suspended solids. The source strength differs from the resuspension rate since resuspended sediments settle around the dredgehead, and only a fraction of the suspended solids will be available for downstream transport. As was shown in the CSTR model, the solids that settle within this area are primarily coarse material. Due to the high settling velocity of coarse solids, they do not supply a significant amount of solids or PCB transport. In order to show that the coarse material will not supply a significant amount of solids or PCBs, the solids downstream transport model in Appendix E and Resuspension White Paper of the RS, was modified in TSS-Chem to include the contribution of coarse solids as well as fine solids.

During the downstream transport PCBs adsorbed to the solids will partition into the water-column. In this model two-phase partitioning from the suspended phase into the dissolved phase is estimated. As shown in the CSTR the initial dissolved phase available for downstream transport is not significant and the initial PCB concentration on the solids available for transport downstream (known as the source strength) is not significantly different from the sediment concentration.

Suspended Solids – Kuo and Hayes Model (General Equation)

The current suspended solids plume model utilizes the Kuo and Hayes (1991) Gaussian equation (Equation 24) for modeling the downstream transport of resuspended sediments with clamshell bucket dredges. This equation assumes no lateral or downstream barriers, uniform and unidirectional flow, and constant water depth.

$$c(x,y) = \frac{g}{uh\sqrt{4pk_Y x/u}}\, e^{-\left[\frac{uy^2}{4k_Y x} + \frac{wx}{hu}\right]} \qquad \text{(EQ 24)}$$

Where:

x = distance downstream of source (m)
y = distance across stream from the source (m)
g = sediment loss rate (kg/s)
u = ambient linear velocity in the x- direction (m/s)
h = depth (m)

k_y = lateral (y-direction) dispersion coefficient
w = settling velocity

The model presented in Equation 24 is a continuous mathematical function/model that models transport in the x-direction by advection only. Dispersion in the x direction is not considered a significant factor. It computes a concentration for a given x, y location. That value is valid at that x,y point only. However, it is not unreasonable to assume that concentration represents an approximate average of the concentration between some x-distance before the point and a similar x-distance beyond the point. Simple averaging in the lateral direction yields a less correct answer. In fact, over the centerline, it can yield an extremely incorrect answer. Equation 26 computes concentrations out to infinity, as discussed below, a cut-off concentration is necessary to limit the width of the plume to within the river. However, with a cut-off concentration the mass outside the designated plume width will not be accounted for and the model will not conserve mass. Therefore to conserve mass the integration of this function should be used obtain an average concentration of a transect (x=constant).

Suspended solids – Kuo and Hayes Model (Integrated Equation)

In order to conserve mass the average concentration along a transect is calculated using the integrated version of Equation 24. The following known integral (*CRC Handbook of Chemistry and Physics*) can be applied to Equation 24 to obtain the product of the average concentration and width of the plume with total reflection of solids along the shorelines (no mass lost past the shorelines).

$$\int_0^\infty e^{a^2 y^2}\,dy = \frac{\sqrt{p}}{2a} \qquad \text{(EQ 25)}$$

Applying Equation (25) to Equation (24) and multiplying by two for both sides of the plume yields:

$$c_{avg}\, y_{plume} = 2 * \frac{g}{uh\sqrt{4pk_Y x/u}} e^{-\frac{wx}{hu}} * \frac{\sqrt{p}}{2\sqrt{u/(4pk_Y x)}} = \frac{g}{uh} e^{-\frac{wx}{hu}} \qquad \text{(EQ 26)}$$

Where: y_{plume} = width of the plume (lateral extent of the plume) (m)

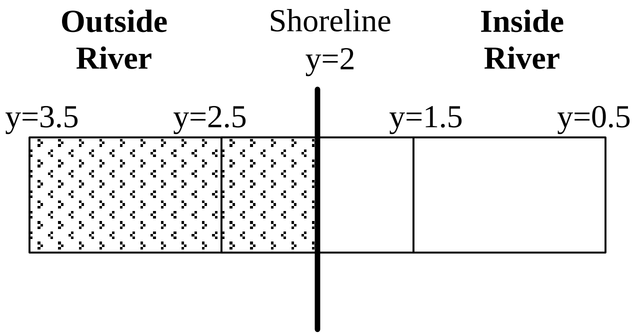
Suspended solids – Kuo and Hayes Model – Determining y_{plume} (General Equation)

To determine the width of the plume Equation 24 can be modified. The width can then be bound by a cut-off concentration or a percentage of the concentration at x=0. Equation 24 may be used to calculate the suspended concentrations for various locations along a river transect (x=constant). If the width of the river is given than a y-increment can be chosen to estimate the average concentration along the transect. The width is separated into discreet boxes each with a width equal to the y-increment, except for the outer two boxes.

For instance, if the source is located 2 meters from the shoreline and a y-increment of 1 is chosen the boxes are:

y = 2 to 1.5 (represented by y=2, width=0.5),
y = 1.5 to 0.5 (represented by y=1, width=1),
y = 0.5 to -0.5 (represented by y=0, width=1),
y = -0.5 to -1.5 (represented by y=-1, width=1), etc.

Since the model will be used to calculate the solid concentrations for a source close to one shoreline Equation 24 must be modified to include shoreline reflection. In this model it was assumed that there is total reflection. Therefore the solids that would be 1 meter outside the shoreline were added to the solids 1 meter within the shoreline. For instance in the example above:



y = 2 to 1.5 would also include the solid concentration from y=2.5 to 2,
y = 1.5 to 0.5 would also include the solid concentration from y=3.5 to 2.5, etc.

Equation 24 then becomes:

$$c(x,y) = \frac{g}{uh\sqrt{4pk_Y x/u}} e^{-\left[\frac{uy^2}{4k_Y x} + \frac{wx}{hu}\right]} + \frac{g}{uh\sqrt{4pk_Y x/u}} e^{-\left[\frac{uy_{out}{}^2}{4k_Y x} + \frac{wx}{hu}\right]}$$

or

$$c(x,y) = \frac{g}{uh\sqrt{4pk_Y x/u}} e^{-\left[\frac{wx}{hu}\right]} \left(e^{-\left[\frac{uy^2}{4k_Y x}\right]} + e^{-\left[\frac{uy_{out}{}^2}{4k_Y x}\right]} \right)$$

(EQ 27)

Where:

y_{out} = the lateral distance the reflected solids would have traveled without reflection (m)

The y_{out} can be expressed in terms of y as:

$$y_{out} = \left(y_{shore} - y\right)\times 2 + y \tag{EQ 28}$$

Where:

y_{shore} = the distance to the shoreline from the source (m)

When the cut-off to determine the width of the plume (y_{plume}) is expressed as a percentage of the solids concentration at x=0, y_{plume} is calculated as the sum of the box widths that contain solid concentrations above the cut-off or:

$$y_{plume} = \sum_{-n}^{n} width_{(box,y=i)} \tag{EQ 29}$$

Where:

n and $-n$ = furthest y distance that has a concentration greater than the cutoff

$width_{box,y=I}$ = width of the box represented by solids concentration at y=i (m)

For this model the plume was confined to solid concentrations greater or equal to 1% of the concentration at x = 0.

Suspended solids – Kuo and Hayes Model (Two Settling Velocities)

If the source is assumed to contain both silts and coarse grain materials Equations 24 and 26 need to be modified to include a second settling term. It the two sediment types are assumed to have the same lateral dispersion coefficient than Equation 24 may be modified to:

$$c(x,y) = \frac{g_{silt}}{uh\sqrt{4\pi k_Y x/u}} e^{-\left[\frac{uy^2}{4k_Y x} + \frac{w_{silt}x}{hu}\right]} + \frac{g_{coarse}}{uh\sqrt{4\pi k_Y x/u}} e^{-\left[\frac{uy^2}{4k_Y x} + \frac{w_{coarse}x}{hu}\right]}$$

or

$$c(x,y) = \frac{g_{total}}{uh\sqrt{4\pi k_Y x/u}} e^{-\left[\frac{uy^2}{4k_Y x}\right]} \left(f_{silt} e^{-\left[\frac{w_{silt}x}{hu}\right]} + (1 - f_{silt}) e^{-\left[\frac{w_{coarse}x}{hu}\right]} \right) \tag{EQ 30}$$

and

$$f_{silt} = \frac{g_{silt}}{g_{total}} = 1 - \frac{g_{coarse}}{g_{total}}$$

Where:

f_{silt} = fraction of silt in released sediment (unitless)

g_{total} = total sediment loss rate (kg/s)

To account for both reflection from one shoreline and two settling velocities Equation 24 becomes:

$$c(x,y) = \frac{g_{silt}}{uh\sqrt{4pk_Y x/u}} e^{-\left[\frac{uy^2}{4k_Y x} + \frac{w_{silt}x}{hu}\right]} + \frac{g_{silt}}{uh\sqrt{4pk_Y x/u}} e^{-\left[\frac{uy_{out}{}^2}{4k_Y x} + \frac{w_{silt}x}{hu}\right]} +$$

$$\frac{g_{coarse}}{uh\sqrt{4pk_Y x/u}} e^{-\left[\frac{uy^2}{4k_Y x} + \frac{w_{coarse}x}{hu}\right]} + \frac{g_{coarse}}{uh\sqrt{4pk_Y x/u}} e^{-\left[\frac{uy_{out}{}^2}{4k_Y x} + \frac{w_{coarse}x}{hu}\right]}$$

or

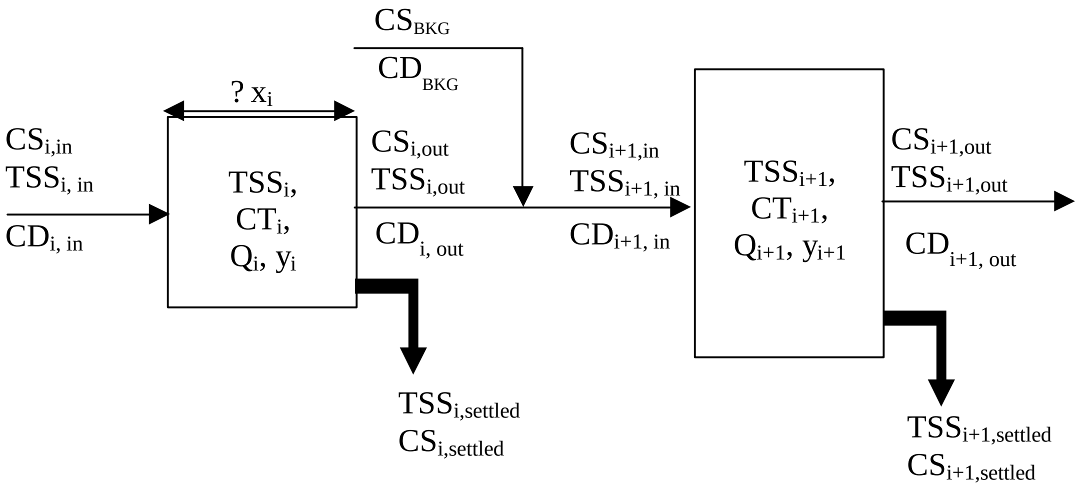
$$c(x,y) = \frac{g_{total}}{uh\sqrt{4pk_Y x/u}} \left(f_{silt} e^{-\left[\frac{w_{silt}x}{hu}\right]} + (1 - f_{silt}) e^{-\left[\frac{w_{coarse}x}{hu}\right]} \right) \left(e^{-\left[\frac{uy^2}{4k_Y x}\right]} + e^{-\left[\frac{uy_{out}{}^2}{4k_Y x}\right]} \right) \qquad \text{(EQ 31)}$$

The integral already accounts for total reflection therefore Equation 26 only needs to be modified to account for two settling velocities. Equation 26 is modified as:

$$c_{avg} y_{plume} = \frac{g_{silt}}{uh} e^{-\frac{w_{silt}x}{hu}} + \frac{g_{coarse}}{uh} e^{-\frac{w_{\cos rse}x}{hu}} = \frac{g_{total}}{uh} \left(f_{silt} e^{-\left[\frac{w_{silt}x}{hu}\right]} + (1 - f_{silt}) e^{-\left[\frac{w_{coarse}x}{hu}\right]} \right) \qquad \text{(EQ 32)}$$

Two-Phase Partition Model for PCBs

The two-phase partition model is used to estimate PCB concentrations in the water column based on the sediment releases from dredging, the PCB concentrations of the suspended sediments and the background conditions. Both the dissolved and suspended (particulate) PCB concentrations are modeled using equilibrium partitioning. As shown from the CSTR model runs, the initial fraction of the dissolved PCBs is not significant and may be assumed to be zero. For the initial conditions of the two-phase partitioning model, partitioning between dissolved and suspended has not reached equilibrium and PCBs will continue to be transferred from the particles to the dissolved phase as they are carried downstream. To estimate the progression towards equilibrium the two-phase partitioning model factors in the residence time of the sediment in the water column (time available to reach equilibrium). A conceptual depiction of the model is shown below.



Where:

TSS_i = Concentrations of TSS (mg/l)
CS_i = PCB concentration on the suspended particles (mg/kg)
CD_i = Dissolved PCB concentration in the water column (ng/l)
CT_i = Total PCB concentration in the water column (ng/l)
Q_i = Volumetric flowrate of box *i* (m^3/s)
x = Distance traveled by the water and solids within each box (m)
y_i = width of the plume (m)

in, out and *BKG* apply to the entering, exiting and background conditions respectively

The path of PCBs being transported downstream of the dredge head is divided into segments. Each segment is addressed as a box. The width of the box equals to the width of the suspended solids plume at the location of the box (its distance downstream of the dredge head). It is assumed that the width of the plume does not change within a box and therefore the volume and flowrate of the box remains constant. The incremental distances downstream (x-increments) used in the model determine the residence time of suspended solids within the boxes, since the residence time is equal to the length of the box divided by the linear velocity. The suspended solids concentration entering each box is assumed to be the average concentration inside the plume. The following assumptions are made in the calculations:

(1) The solids entering the box remain suspended. Settling only occurs after the particles exit. Therefore the PCB concentration on the settled solids equals the PCB concentration on the particles exiting the box.
(2) The change in plume width occurs between boxes. Therefore both the dissolved phase and the suspended PCBs are diluted before entering a subsequent larger box. Additional background PCBs would be included at this point since the larger plume width spreads into areas with a baseline concentration.
(3) Besides the partitioning between dissolved phase and suspended solids and loss through settling, no other mechanism or reaction exists to affect the fate of PCB

in the water column (*i.e.* volatilization, transformation, and reactions are not being considered in this model).

The equations for the two-phase partitioning model based on the conceptual model and assumptions above are listed below.

Equations for Entering Conditions

The volumetric flowrate (Q) must be calculated for each box (since it is dependent on the width of the plume). The volumetric flowrate is calculated using:

$$Q_i = u * h * y_i \qquad \text{(EQ 33)}$$

Where:

u = ambient water velocity (m/s)
h = water depth (m)

The concentration of suspended solids within the plume must also be calculated for each box. The suspended solids concentration given by the Kuo and Hayes Model above is without background; therefore, the background concentration must be added for each segment.

$$TSS_{i,in} = TSS_{KuoHayes,i} + TSS_{BKG} \qquad \text{(EQ 34)}$$

The flux into the first segment

The total PCB concentration and the dissolved fraction for the background are known. In addition, the dissolved fraction of PCBs from dredging activities is given either by the CSTR model or by assuming it is zero. The concentration of PCBs from dredging activities may also be given from the CSTR model or calculated by using:

$$CT_{Dredging} = \frac{g * CS_{SED} * 10^3}{Q_1} \qquad \text{(EQ 35)}$$

Where:

g = sediment loss rate (kg/s)
CS_{SED} = concentration of the suspended sediment (mg/kg)

The total, dissolved and suspended PCB fluxes into the first segment are:

$$\begin{aligned} F_{CT,BKG,1} &= Q_1 CT_{BKG} \\ F_{CT,Dredge,1} &= Q_1 CT_{Dredging} \\ F_{CT,1,in} &= F_{CT,Dredge,1} + F_{CT,BKG,1} \end{aligned}$$

(EQ 36)

$$\begin{aligned} F_{CD,BKG,1} &= f_{BKG} F_{CT,BKG,1} \\ F_{CD,Dredge,1} &= f_{Dredge,1} F_{CT,Dredge,1} \\ F_{CD,1,in} &= F_{CD,Dredge,1} + F_{CD,BKG,1} \end{aligned}$$

(EQ 37)

$$\begin{aligned} F_{CS,BKG,1} &= (1 - f_{BKG}) F_{CT,BKG,1} \\ F_{CS,Dredge,1} &= (1 - f_{Dredge,1}) F_{CT,Dredge,1} \\ F_{CS,1,in} &= F_{CS,Dredge,1} + F_{CS,BKG,1} \end{aligned}$$

(EQ 38)

Where:

F = Flux (g/s)
f = PCB fraction dissolved (unitless)

Subsequent segments:

For subsequent segments an additional flux from background will be added if the plume width has increased. The additional background contribution and total flux into box *i+1* may be calculated as follows:

$$F_{CT,BKG,i+1} = (Q_{i+1} - Q_i)CT_{BKG} * 10^{-6} \quad \text{(EQ 39)}$$

$$F_{CT,i+1,in} = F_{CT,i,out} + F_{CT,BKG,i+1} \quad \text{(EQ 40)}$$

$$F_{CD,i+1,in} = F_{CD,i,out} + f_{BKG}F_{CT,BKG,i+1} \quad \text{(EQ 41)}$$

$$F_{CS,i+1,in} = F_{CS,i,out} + (1 - f_{BKG})F_{CT,BKG,i+1} \quad \text{(EQ 42)}$$

The average total and dissolved concentrations in the plume are calculated by dividing the flux by the volumetric flowrate as:

$$CT_{i,in} = \frac{F_{CT,i,in}}{Q_i} * 10^6 \qquad CD_{i,in} = \frac{F_{CD,i,in}}{Q_i} * 10^6 \quad \text{(EQ 43, 44)}$$

The average concentration on the particles is calculated by dividing the flux by the volumetric flowrate and suspended solids concentration.

$$CS_{i,in} = \frac{F_{CS,i,in}}{Q_i * TSS_{i,in}} * 10^6 \quad \text{(EQ 45)}$$

Equations for Inside Conditions (Approaching Equilibrium)

Inside the box Q, suspended solids, and the fluxes remain the same as the entering conditions. The concentrations change as the PCBs begin to partition off of the particles and into the dissolved phase. The retention time within the box is determined by:

$$q_i = \frac{\Delta x_i * y_i * h_i}{Q_i} * 3600 \quad \text{(EQ 46)}$$

Where:

$?_i$ = retention time/suspended solids contact time (hr)

If the retention time were long enough equilibrium would be achieved and the dissolved and suspended concentrations would be:

$$CD_{eq_i} = \frac{CT_i}{\left(1 + K_d \times TSS_i \times 10^{-6}\right)} \qquad CS_{eq_i} = CD_{eq_i} \times K_d \times 10^{-6} \qquad \text{(EQ 47, 48)}$$

Where:

K_d = partitioning coefficient (L/Kg)

Before equilibrium is reached the dissolved and suspended concentrations must be calculated using the following equations for net desorption:

$$CD_i = CD_{i,in} + (CD_{eq_i} - CD_{i,in}) \times (1 - e^{-l t_i}) \qquad \text{(EQ 49)}$$

$$CS_i = CS_{i,in} - \left(CS_{i,in} - CS_{eq_1}\right) \times (1 - e^{-l t_i}) \qquad \text{(EQ 50)}$$

Where:

? = desorption rate constant (hr^{-1})

Equations for Exiting Conditions

The exiting dissolved and suspended (concentration on the particles mg/kg) are equal to the concentrations inside the box or:

$$CD_{i,out} = CD_i \qquad \text{and} \qquad CS_{i,out} = CS_i \qquad \text{(EQ 51, 52)}$$

To calculate the total concentration, the suspended solids lost to settling must be calculated. The suspended solids loss must be calculated using the suspended solids flux since the plume volume increases in the next segment and the suspended solids concentration is being diluted, therefore the suspended solids concentration in the *i+1* box will not equal the suspended solids out of *i*. Suspended solids loss to settling can be calculated as:

$$TSS_{Settled,i} = \frac{(TSS_i * Q_i - TSS_{i+1} * Q_{i+1})}{Q_i} \qquad \text{(EQ 53)}$$

and

$$TSS_{i,out} = TSS_i - TSS_{Settled,i} \qquad \text{(EQ 54)}$$

The total PCB concentration may be calculated as:

$$CT_{i,out} = CD_{i,out} + CS_{i,out} * TSS_{i,out} \qquad \text{(EQ 55)}$$

The total, dissolved, and suspended fluxes are:

$$F_{CT,i,out} = CT_{i,out} * Q_i * 10^{-6} \tag{EQ 56}$$

$$F_{CD,i,out} = CD_{i,out} * Q_i * 10^{-6} \tag{EQ 57}$$

$$F_{CS,i,out} = CS_{i,out} * Q_i * TSS_{i,out} * 10^{-6} \tag{EQ 58}$$

Equations for Net Conditions

To get the effects from dredging alone, the contributions from background must be subtracted. The equations for the concentrations are as follows:

$$CT(net)_{i,out} = CT_{i,out} - CT_{BKG} \tag{EQ 59}$$

$$CD(net)_{i,out} = CD_{i,out} - CD_{BKG} \tag{EQ 60}$$

$$CS(net)_{i,out} = \frac{CS_{i,out} * TSS_{i,out} - CS_{BKG} * TSS_{BKG}}{TSS_{i,out} - TSS_{BKG}} \tag{EQ 61}$$

Equation for the K_d value

From previous studies the background conditions are well defined. It is assumed that the conditions of the background represent equilibrium. When the fraction of dissolved and suspended concentrations is given and a background suspended solids value the K_d value can be calculated by:

$$\frac{CD_{BKG}}{CT_{BKG}} = f_{BKG} = \frac{1}{\left(1 + K_d \times TSS_{BKG} \times 10^{-6}\right)} \tag{EQ 62}$$

4.4.2 Relationship between CSTR-Chem and TSS-Chem

The objective of the models was to determine the relationship between suspended solids and PCB (dissolved and particulate) fluxes downstream and resuspension rates. TSS-Chem is useful for the near-field downstream transport of solids and PCBs but is inadequate for modeling the resuspension from dredging activities. Therefore the CSTR-Chem model must be used to translate the resuspension rate, and sediment characteristics to the source strength and suspended solid characteristics used in the TSS-Chem model. The source strength and suspended solid characteristics will in turn determine the suspended solids and PCB fluxes downstream. The resuspension rate of sediments (input to CSTR-Chem) and source strength of suspended solids (output of CSTR-Chem, input to TSS-Chem) are not directly related since the CSTR-Chem model will provide a source strength which has a width dependent on the dredge used and the TSS-Chem models a point source. However, the CSTR-Chem can provide estimations of the initial conditions of the TSS-Chem, specifically the silt and coarse fractions within the sediment and source strength and the initial dissolved fraction of PCBs in the source strength.

Dissolved PCBs from Dredging Activities

The results of the CSTR-Chem model showed that the suspension time of the solids around the dredge head was not long enough to achieve equilibrium conditions. Though some partitioning occurred between the PCBs on the resuspended sediments and the water column, the results indicated that the amount of partitioning was negligible and the dissolved PCB fraction exiting was insignificant. However, it was necessary to determine the impact of an initial dissolved PCB source (other than background) on the PCB and suspended solids fluxes downstream. Therefore, the TSS-Chem model was run for the 350 ng/l far-field criteria scenario in River Sections 1 (2007) and 2 (2009) with and without the dredging dissolved PCB concentrations obtained from the corresponding CSTR-Chem runs. The results are shown in Table 8. The source strengths for the scenario runs did not require adjustments since the PCB flux at one mile experienced a negligible change. The suspended solids flux did not change given that it is not dependent on the dissolved PCB concentration and the source strength was not adjusted. Therefore the dissolved concentration directly around the dredgehead from the partitioning of resuspended material has a negligible effect on the downstream PCB concentration and could be assumed to be zero for the TSS-Chem model runs.

Silt and Coarse Fractions

When the fractions of silt and coarse material in the sediments were applied to the CSTR-Chem model the residence time of the solids within the model was long enough to allow a significant amount of coarse material to settle. For instance, the silt fraction in River Section 1 sediments is approximately 0.37. When the resuspension of this material is modeled using CSTR-Chem, the solids exiting the area around the dredge have a silt fraction of 0.66. To determine the impact of the silt and coarse fractions on the source strengths and fluxes, the TSS-Chem model was run for the 350 ng/l far-field criteria scenarios in sections 1 (2007) and 2 (2009) with and without coarse solids. The results for these runs are shown in Table 9. As the table shows the effect of adding coarse solids does not significantly affect the suspended solids or PCB flux. The total source strength without coarse materials, however, must change to equal the silt source strength when coarse solids are present. This illustrates that while the coarse materials will not have a significant contribution on the relationship between PCB and suspended solids fluxes downstream, they will affect the resuspension rates required to obtain those fluxes. Therefore in calculating the different resuspension rate requirements it is necessary to consider the coarse material.

4.4.3 Results

The results of the TSS-Chem analysis indicated that a significant amount of PCBs released would partition off of the solids and become dissolved by a distance of one mile.

The dissolved fraction at one mile is greater when the source strength is decreased. The majority of the PCB load at one mile was contributed by the silt fraction, since the coarse material generally fell to less than 0.1 percent of the total solids within the plume within 30 meters downstream. The results for the average source strength analyses and near-field suspended solids criteria are discussed below.

4.4.3.1 Average Source Strength Estimations

The resuspension rate is the rate at which sediments directly around the dredge will be suspended into the water column. Before the sediments are available for transport downstream resettling in the dredge area occurs. The resettled material is predominately coarse sediment. The particles that do not resettle around the dredge move downstream. The rate at which the particles are transported downstream out of the immediate dredge area is the source strength.

As outlined in Appendix E.6 of the FS and White Paper: Resuspension of PCBs During Dredging (336740) of the RS, the average resuspension rate is based on a combination of field data from other sites and a resuspension model. The downstream transport rates (source strengths) only apply to silts and finer particles (65 percent of cohesive and 20 percent of non-cohesive sediments for the Hudson River) within the sediment. The use of only silts does not significantly affect the PCB flux estimates since the silt resuspension rate (which is essentially equal to the silt source strength) is the driving source term for the PCB flux downstream. This aspect of the models is discussed in Section 4.4.2 of this attachment.

The average source strength in the FS was originally based on the cohesive sediments. An estimate of 0.3 percent of cohesive sediments was expected to be available for transport downstream. Since this only applies to silt, the percentage can be normalized to the silt fraction in cohesive sediments as 0.003)0.65 to yield 0.5 percent of silts and finer particles. The contribution to the average source strength from non-cohesive sediments must also be added to the average source strength since they are 20 percent silts. The overall fraction of non-cohesive sediments is 0.005×0.2 or 0.1 percent of cohesive sediments. Since silt fractions can be estimated for each section based on the percentages of silts in cohesive and non-cohesive sediments (given above) the source strengths can be calculated as 0.5 percent of the production rates of silty sediments.

The production rates were based on a total of five dredging seasons (two half and four full seasons). Given the amount of sediment removal necessary and the time limitations involved, the average production rates for each river section were calculated. The silt fractions in each river section were applied to yield an average source strength. Each source strength was run through TSS-Chem to estimate the resulting flux and concentration increases at one mile. The production rates, source strengths, and results are shown in Table 10.

Model Revisions from FS Appendix E.6 and RS White Paper Semi-Quantitative Estimates

As part of the FS and RS semi-quantitative assessments of water quality impacts associated with dredging activities were performed. The assessments utilized the DREDGE model (discussed in section 3.0 of this attachment) which is similar to TSS-Chem, however the assessments were not as extensive as those performed for the resuspension performance standard modeling. The semi-quantitative assessments had several assumptions that were modified by the new models. In the analysis of the FS and RS, a model similar to the TSS-Chem model was used to estimate the solids plume within 10 meters of the source term. The estimates of the plume in this model and the TSS-Chem model use the same modeling equations for solids but differ in the modeling of PCB concentrations. The modeling of solids for the TSS-Chem calculations does not use the same parameters as the solids modeling in Appendix E.6. The parameters were revised as part of an extensive literature search since the publication of the FS. The various parameters (*i.e.* dispersion coefficient and settling velocity) and the rationale for their current values are discussed in Section 4.4.1 of this attachment. The differences between the analyses and the individual effects of the differences (overall effects will vary) are discussed below.

The three differences that had the greatest effects on the estimates were:

- Mass was conserved – The suspended solids plume equations will predict concentrations to infinity. In the previous analyses the solids concentration was cut-off at 1 mg/L (or 0.5 mg/L if no values were greater than 1). Therefore the mass outside the cut-off concentration was not accounted for in the suspended solids or PCB flux. In order to preserve mass the TSS-Chem model uses the integrated form of the suspended solids plume equation. The new method increases the suspended solids and PCB concentration and flux estimates for any given resuspension rate. Even if all the other parameters had remained the same the suspended solids Flux estimates at 10 meters with mass conserved in River Section 1 increases from 11.5 to 40 g/sec and in River Sections 2 and 3 from 30.1 to 52 g/sec.

- PCB phase partitioning was included – The TSS-Chem model estimates the phase partitioning of PCBs from suspended to dissolved phases. When partitioning is taken into account the PCB flux and water column concentrations increase relative to the approach used in the FS and RS since the particles settling have a lower concentration and more PCBs remain in the water column. For the average source strengths, the TSS-Chem model estimates net PCB fluxes that contain more than one third dissolved PCBs.

- Settling velocity of silts was decreased – A decrease in the settling velocity of the silts, causes an increase in PCB concentration and flux estimates. After an extensive literature search the settling velocity was estimated to be an order of magnitude lower than was previously predicted. The revised settling velocity greatly increased the amount of solids and PCBs lost to downstream transport.

Other differences that affected the solids and PCB estimates are:

- Plume width concentration was decreased – The former models defined the plume width as described above (greater than 1 mg/L or greater than 0.5 mg/L if no values were above 1 mg/L). TSS-Chem defines the width of the plume by concentrations greater than 1% of the center concentration. The plume width is greater using the current method, however, the volumetric flow rate of the plume varies accordingly and width will not directly affect flux. The concentration in the plume is dependent on the width (concentration will decrease with increasing width), however due to the difference in plume concentration estimated (see "mass was conserved" above) the new method did not decrease the plume concentrations. This increase in the plume width is a model constraint and is not directly related to the change in the lateral dispersion coefficient discussed below.

- Dispersion coefficient was decreased – A decrease in dispersion coefficient increases the PCB concentration within the plume by decreasing the width, but does not change the average river-wide concentration or the flux.

- Linear velocity was increased – An increase in velocity results in an increase in the PCB concentration and flux estimates.

- Depth was decreased – A decrease in depth results in a decrease in the PCB concentration and flux estimates.

- River-wide volumetric flow was increased – The flow examined was changed from 3,000 cfs to 4,000 cfs, since 4,000 cfs is approximately the average flow of the summer months across the three river sections. An increase in flow decreases the PCB concentration but increases the PCB flux.

- Distance downstream was increased – The suspended solids plume concentrations in Appendix E.6 were taken for a distance downstream of 10 meters from the source term. No further removal by settling was permitted. For the revised PCB flux, the TSS-Chem model was extended to one mile downstream allowing for further settling between 10 meters and one mile. An increase in distance, and thereby in settling, will decrease estimates of PCB concentration and flux.

- PCB basis changed from Tri+ to Total – The Tri+ PCB concentrations were used in the former analysis while the new estimates are based on Total PCB concentrations. This would not change the Total PCB flux unless the PCB sediment concentrations and Tri+ to Total PCB ratio were revised. Both the sediment concentrations and the Tri+ to Total PCB ratios were revised from the FS values as part of the RS. The values from the RS were used in this analysis.

4.4.3.2 Particle Settling Results

Some fraction of the sediment resuspended from the dredge will settle downstream. If the material is contaminated, this will add to the PCB mass and concentration in the surrounding downstream areas. Using the modeled suspended solids concentrations in the water column downstream of the dredge with the associated PCB concentration on the suspended solids, it is possible to estimate the increase in PCB mass in these areas. The increase in mass per unit area and the length-weighted average concentration of the top six inch bioavailable layer will be used to measure the effect of the settled material.

The amount of settled material is estimated by calculating the mass of suspended solids in the water column at each modeled location. The mass at each cross section is summed. The difference in mass between each cross section is the amount of solids that has settled downstream. The loss for each section is distributed in the cross section in the same proportion as the amount of mass in the water column along the cross section. The rate of deposition is calculated considering the flow rate. Using the PCB concentration estimated for the suspended sediment, the rate of PCB deposition is estimated at each modeled location.

The spatial distribution of the settled contamination will vary according to the shape of the target area and the rate of dredging. For this estimate, the target area is assumed to be 5 acres, 200 ft across and approximately 1,100 ft long, because the areas of contamination are typically located in the shoals of the river and are narrow. From the FS, a time needed to dredge a 5-acre area with 1 m depth of contamination would take 15 days operating 14 hours per day. It is assumed that the dredge will move in 50 ft increments across and down the target area. With this assumption, the dredge will relocate approximately every two hours. To simulate the deposition of settled material, the amount of PCB mass per unit area, the mass of the settled material and the thickness of the settled material that is deposited in two hours downstream at each modeled location is added on a grid as the dredge moves across and down the area.

The TSS-Chem results for each river section and action levels were used to estimate the additional mass per unit area and length weighted average concentration in the target area, 100 feet to the side of the target area and approximately 2 acres downstream. The remediation could operate continuously at Evaluation Level of 300 g/day or the Control Level of 600 g/day but not Control Level of 350 ng/L. The results are shown in Table 11.

The increase in mass per unit area can be compared to the mass per unit areas values used to select the target areas in River Sections 1 and 2. Areas in River Section 3 are not selected on the basis of a single mass per unit area value. The Tri+ PCB mass per unit area values for River Sections 1 and 2 are 3 g/m^2 and 10 g/m^2. Using the conversion factors for Tri+ PCBs to total PCBs (USEPA, 2002), the total PCB mass per unit area for River Sections 1 and 2 are 6.6 g/m^2 and 34 g/m^2. It is estimated that only a small amount of PCBs will be deposited in the area to the side of the target area with the greatest increase in mass per unit area being only 0.004 g/m^2 in River Section 3.

In the target area, the increase in mass per unit area is more substantial. The mass per unit area increases by 1.8 g/m^2 in River Section 1 for the Control Level of 600g/day, which is nearly a third of the value used to select the areas. In River Section 2, the increase in mass per unit area is nearly the same as in River Section 1, but this increase is only 4 percent of the value used to select the areas. For Control Level of 350 ng/L, the increase in mass per unit area is 3.9 g/m^2 in River Section 1 (65 percent of the value used to select the areas), 4.7 g/m^2 in River Section 2 and 5.6 g/m^2 in River Section 3.

In the area immediately downstream of the target area, in River Sections 1, 2 and 3 for Evaluation Level, the increase in mass per unit area is 0.2, 0.1 and 0.2 g/m^2, respectively. The mass per unit area increases another 2 to 3 times for the 600 g/day Total PCB scenario over the Evaluation Level and increases another two to four times between the 600 g/day and 350 ng/L Total PCB scenarios. These increases in mass per unit area are only significant for Control Level Total PCB criterion of 350 ng/L in River Section 1, which is 17 percent of the value used to select the areas.

The length weighted area concentrations were calculated assuming that the PCB concentration in the sediment underlying the settled material is 1 mg/kg. The ROD defines 1 mg/kg as the acceptable residual concentration. In the area to the side of the target area, no increase in concentration was found. In the target area, the concentrations range from 5 to 29 mg/kg. In the 2 acres below the target area, the concentrations range from 2 to 9 mg/kg. These increases suggest that dredging should proceed from upstream to downstream if no silt barriers are in place so that settled material can be captured by the dredge. Also, silt barriers may be needed to prevent the spread of contamination to areas downstream of the target areas have already been dredged or are not selected for remediation. This settled material is likely to be unconsolidated and easily resuspended under higher flow conditions.

4.4.3.3 Suspended Solids Near-field Criteria and Monitoring Locations

Introduction

PCB criteria for resuspension are set in terms of concentration or load at the far-field monitoring stations. Achieving these criteria requires controlling the PCB concentration and flux from the dredging operation. Paired with the far-field PCB monitoring, suspended solids will be measured at the near-field locations in order to provide the real-time or near real-time monitoring for the potential contaminant flux from the dredging operation. High levels of suspended solids in the near-field may result in exceedances of the PCB criteria at the far-field stations, and therefore should trigger some level of concern. The near-field suspended solids criteria have been developed corresponding to the far-field PCB action levels. HUDTOX and TSS-Chem models were utilized to simulate the connection between the far-field PCB concentrations and loads and the near-field suspended solids concentrations.

Approach

The HUDTOX model was used to predict the PCB levels at the far-field stations. Therefore, for the Control Level, the regulated PCB load of 600 g/day is the output flux simulated by HUDTOX. Similarly for the total PCB concentration criterion of this action level, (350 ng/L), the PCB loads were calculated (at different flows) and were the output fluxes of the HUDTOX model (H_{out}).

HUDTOX simulates an effective rate of PCB loss during transport, due to volatilization and settling. The percentage reduction (1 – output flux/input flux) during transit through a river section varies by section and by year of operation. The percentage reduction obtained from previous HUDTOX runs was used to estimate the input of HUDTOX runs (H_{in}) which will result in the PCB level at the far-field stations corresponding to the action levels. When performing the near-field and far-field model simulation, it is assumed that PCB flux 1 mile downstream of the dredge head estimated by the TSS-CHEM model (T_{1mile}) is the input flux for the HUDTOX model (H_{in}). The input flux for TSS-Chem (T_{in}) was determined by trial and error, until the simulated plume at one mile (T_{1mile}) matched the targeted input to the HUDTOX model. The resulting suspended solids concentrations in these simulations was used as the basis to develop the near-field criteria.

Since some of the TSS-Chem input parameters, such as lateral dispersion coefficient and flow velocity, are flow-dependent, the resulting suspended solids and PCB concentrations and loads are also flow-dependent. As mentioned above, when the output concentration is set as the target value at the far-field stations, the associated load will be calculated and used as the controlling value in the whole process of estimation. Load varies with flow when the concentration is constant. Therefore, it is expected that different flows will generate different plumes at the near-field locations, which means that at the same location, the estimated suspended solids concentration can be significantly different when the flow varies. Suspended solids concentrations at different flows were fully investigated and the most reasonable value, which provides the best representation of the near-field conditions, was chosen as the basis to develop the near-field suspended solids standard.

Since the model simulation determines the values and no actual data is available, other uncertainty factors were taken into account while finalizing the criteria. Criteria were only formulated for the Evaluation Level and Control Level to avoid unnecessary shutdowns.

Results

Multiple TSS-Chem runs were used to simulate the suspended solids plume in the near-field using the one mile downstream PCB flux as the controlling factor. The estimated suspended solids concentrations downstream of the dredge head for River Section 1 at 4,000 cfs and a far-field PCB concentration of 500 ng/L is shown in Figure 16. The profile shown in Figure 16 is a good representation of the estimated suspended solids plumes under all scenarios. The suspended solids concentration decreases and the width of plume increases as the solids area transported downstream. The suspended solids concentration at 300 m downstream is about ¼ to 1/3 of the concentration at 50 m downstream. Assuming that the boundary of the plume is the location where the suspended solids concentration is 5 mg/L higher than the background level (2.3 mg/L in River Sections1 and 2, 1.7 mg/L in River Section3), the width of the plume at 50 m, 100 m, 300 m and 600 m downstream is 21 m, 29 m, 47 m and 61 m, respectively, for the scenario shown in Figure 16. The plume widths at these locations for other scenarios are within the same scale. Since the plume is wider further downstream there is more assurance that a sample collected at 300 m is within the plume than a sample collected a 50 m. At 50 m downstream, due to the narrow width, it is possible to miss the plume when collecting a sample. This could potentially cause a large exceedance at the far-field stations without any indication in the near-field. In addition, the curved shape of the river channel at some points will make it more difficult to predict the direction and the location of the center of the plume when going further downstream. However, further downstream the plume is more diluted and less visible. Therefore it is possible to miss the plume when collecting a sample. In order to counter balance the requirements, ease of sampling within the plume and ease of identifying the plume, two near-field locations are necessary. From the results of this analysis 100 m and 300 m were chosen as the near-field monitoring locations downstream of the dredge.

As mentioned in the approach section, flow will change the current velocity and the lateral dispersion coefficient, which result in different suspended solids concentrations corresponding to the same PCB level at the far-field station. Figure 17 presents the suspended solids concentration at 300 m downstream when only flow varies. Consistent with intuition considering the dilution caused by the flow, a 2,000 cfs flow results in the highest concentration and the lowest concentration occurs with the 8,000 cfs flow. But the difference in concentration is not directly proportional to the flow mainly due to the changes in the lateral dispersion coefficient. Since the flow will vary during dredging a conservative criteria was selected. Therefore the criteria were based on the lowest suspended solids level at 8,000 cfs flow.

Estimated suspended solids concentrations within the plume are used to set the criteria. As mentioned above, the boundary of the plume is determined by the location where the suspended solids concentration is 5 mg/L above the background level. The average flow during the dredging period is assumed to be 4,000 cfs. To provide a common basis for comparing the concentration at different flows, the width of the plume determined by the 4,000 cfs flow is applied to other flow conditions. That is, if the width of plume at 300 m downstream is 47 m when the flow is 4,000 cfs, the widths of plume at the same location under other flows are 47 m as well. As noted above, suspended solids concentration under the high flow is lower than the suspended solids under the low flow. Since the width of the plume is determined by the concentration at the 4,000 cfs flow and the plume at 8,000 cfs is actually not as wide, the average concentration calculated at 8,000 cfs is underestimated. This results in lower values and thereby conservative criteria.

Mean suspended solids concentrations within the plume at 300 m downstream at 8,000 cfs are summarized in Table 12 for each section, corresponding to each far-field action level. The suspended solids levels are similar in River Sections 1 and 3, while the concentrations in River Section 2 are approximately half of the values for River Sections 1 and 3. This is due to the higher average PCB sediment concentration in River Section 2. The average PCB concentration on the dredged sediment is 27, 62 and 29 ppm for Section 1, 2 and 3 respectively. Since the PCB far-field criteria are the same for all three river sections, and dredging in River Section 2 is expected to suspended solids with higher PCB concentrations, section specific SS criteria are necessary. The same criteria may be applied to River Sections 1 and 3 since the average PCB sediment concentrations in these sections are similar.

Suspended solids concentrations reported for the water column monitoring samples collected during the dredging operations in the Lower Fox River SMU 56/57 and New Bedford Harbor pre-design field test were reviewed and compared to the numbers simulated by the models. During the SMU 56/57 work, the downstream suspended solids samples were collected at fixed locations within 800 ft downstream of the dredge head. Most suspended solids numbers fall between 20 and 40 mg/L, with one greater than 100 mg/L and two around 80 mg/L. During New Bedford Harbor pre-design field test, suspended solids samples were collected at different locations within 1000 ft down current of the dredge head. These data were in the range of 10 –30 mg/L. Assuming that the suspended solids concentrations in the Hudson River during dredging are similar to these two projects, the action level corresponding to the 600 g/day of total PCBs at the far-field stations exceed too frequently and possibly cause unnecessary contingencies. Therefore, the SS action level criteria are not based on the numbers determined by 600 g/day of total PCBs, but are based on the numbers corresponding to 350 ng/L at the far-field stations

The near-field suspended solids standard assuming hourly samples is finalized and summarized below.

River Sections 1 and 3 (100 mg/L) and River Section 2 (60 mg/L)

Evaluation Level	6 hrs continuously or 9 hrs in a 24 hour period
Control Level	daily dredging period or 24 hour period

Monitoring of suspended solids at near-field stations is intended to provide timely feedback and allow prompt adjustments to be implemented in order to avoid any significant impact on the far-field stations. Decisions to shutdown operations will be made based on the PCB levels at the far-field station.

The concentration limits (100 mg/L and 60 mg/L) are based on model predictions of a total PCB concentration of 350 ng/L at the far-field station as listed in Table 12. Evaluation Level and Control Level use the same concentration limit but different durations. The duration is chosen based on engineering judgment with an emphasis on the cumulative impact of resuspension on the water quality due to dredging. The impact of a long period with a relatively low concentration is more significant than one sample with a high concentration. It should be noted that the suspended solids concentration regulated herein is the net suspended solids concentration increase, which is the suspended solids concentration 300 m downstream of the dredge head minus the suspended solids concentration upstream of the dredge head, in order to control the suspended solids increase from resuspension and thereby maintain consistent correlation between the PCB concentrations and loads and sediment concentrations.

According to the monitoring plan, the near-field suspended solids sample will be collected at 5 stations, one upstream, one close to the side channel, and three downstream. The upstream sample will provide the background suspended solids level necessary to calculate the net suspended solids increase caused by dredging. The sample for the side channel is intended to provide information on the suspended solids caused by river traffic. For the three samples collected downstream, one will be located at 100 m downstream of the dredge operation and two will be located at 300 m downstream. Even though the criteria are based on the suspended solids level at 300 m downstream, a sample collected 100 m downstream will provide information on how the suspended solids are being transported downstream, and may be useful for Phase 2 work if modifications based on Phase 1 results are necessary. The higher concentration between the two samples collected 300 m downstream will be used for determining compliance with performance standards.

In addition to the performance standards above, a second Evaluation Level criteria is set at 700 mg/L for over three hours at 100 m downstream. This concentration limit is estimated based on the maximum concentration within the plume at 100 m downstream corresponding to a total PCB concentration of 500 ng/L at the far-field station and a flow of 8000 cfs. Collection of PCB samples at the nearest far-field station should be designed to sample the suspended solids release of concern based on the travel of time and any necessary engineering contingencies will be based on the PCB results.

In the formulation of the criteria above no assumptions were made for solid control measures. At any location where a solid control measure such as a silt curtain is used, as described in the monitoring section, the near-field downstream location should be 150 m downstream of the most exterior silt control barrier. Under these conditions the single-level concentration standard (700 mg/L) is not applicable.

4.4.4 Sensitivity Analyses

Two sensitivity analyses were performed. The first analysis examines the distribution of PCBs on the fine and coarse-grained sediments, to determine if they should be modeled with different concentrations. The second sensitivity analysis varies all the inputs one at a time to determine which parameters have the greatest impact on the model outputs.

4.4.4.1 Fine and Coarse-grained PCB Distributions

The analysis presented below uses published data from River Section 1 sediment to examine the
relationships between grain size, organic content and Total PCB concentration. The limited data set was used to provide a ratio of Total PCBs for the fine and coarse-grained sediments. Using these ratios dredging-related PCB resuspension (assuming the average source strength) was modeled for different fine-grained Total PCB sediment concentrations.

The original analysis of the source strength, modeled at 4000 cfs with an average Total PCB sediment concentration of 27 mg/kg, yielded a Total PCB flux of 78 g/day. Published grain-size, organic content and PCB data indicated that the Total PCB concentration on the fine-grained sediments may range from 30 to 36 Total PCB mg/kg. The TSS-Chem transport model indicated that these concentrations on the fine-grained sediments for flows ranging from 2000 to 5000 cfs have PCB fluxes at one mile of 44 to 115 g (Total PCB) /day. Therefore, the model indicated that the Total PCB concentrations investigated do not represent a significant change in the flux or the water column concentration increase, particularly when the uncertainties in sediment homogeneity and river-wide flowrates are considered.

Although the results suggest that the original estimate may not be as conservative as possible, there are many other conservative assumptions in the model. Due to limitations of modeling, the resuspension criteria and action levels were based on the MCL and fish body burdens in the Lower Hudson. The modeling was used as an aid in estimating the resuspension rates each of the criteria may represent. During Phase 1 the model will be reevaluated and possibly modified.

Discussion

While USEPA recognizes that PCB concentrations are generally higher in fine-grained sediments relative to coarse-grained sediments when classified as a whole sample, it is not clear that the organic carbon content within a sample can approximate this relationship. That is, it is not clear that within a given sample, the PCB content of each grain-size fraction is well approximated by the organic carbon content for the sample.

The lack of a direct correlation between organic carbon content and PCB concentration can be seen in Figure 3-21 of the Low Resolution Sediment Coring Report (USEPA, 1998), included in this attachment as Figure 18. This figure shows that PCB concentration does not increase linearly with TOC and that significant variation can be found at any organic carbon concentration. The USEPA agrees that there may be some enhancement of PCB concentration with smaller particles but it is not clear that the response is linear.

According to a study of contaminated Hudson River sediments conducted by General Electric Corporate Research and Development and MIT published in Environmental

Science and Technology (Carroll et al, 1994) the Hudson River sediments greater than 0.069 µm (sand) had % TOC values from 3.2 to 7.3 while the sediments less than 0.069 µm (silt/clay) had a %TOC value of 3.9, indicating little if any difference. These data suggest that the organic carbon content is relatively homogeneous in fine-grained sediments. The data set presented in the paper represents a limited number of samples so it is unclear how far this data can be extrapolated. Nonetheless, it indicates that organic carbon content may not vary with grain size fraction in fine-grained sediments. Furthermore the PCB concentrations for these sediment fractions did not substantively differ. The sand fraction PCB concentrations ranged from 203-284 ppm and the silt/clay concentration was 338 ppm. The data are shown in Figure 19. If the ratio of these samples (which were all taken from Moreau NY, and therefore only represent River Section 1) were assumed to be applicable to the average sediment concentration in River Section 1 (27 ppm), the silt Total PCB concentration would range from 30 to 36 ppm. The equations used to estimate this range are shown below (River Section 1 has an estimated silt fraction of 37%).

$$C_{silt} f_{silt} + C_{coarse} f_{coarse} = C_{Total}$$

$$C_{silt} f_{silt} + Ratio_{coarse-to-silt} C_{silt} f_{coarse} = C_{Total}$$

or,

$$C_{silt} = \frac{C_{Total}}{f_{silt} + Ratio_{coarse-to-silt}(1 - f_{silt})} \quad \text{(EQ 63)}$$

Where:

C= PCB concentration (mg/kg)

f = fraction (kg sediment type/kg total)

$Ratio_{coarse-to-silt}$ = Ratio of PCB concentrations on coarse-grained and silty sediments

Further TSS-Chem model runs were performed using River Section 1 Total PCB silt concentrations of 27, 30 and 36 mg/kg and river-wide flows of 2000, 4000, and 5000 cfs. The results are shown in Table 13.

Results

The PCB flux using the values from the previous source strength modeling (27 Total PCB mg/kg and 4000 cfs) was 78 g (Total PCB) /day at one mile. With the different concentrations and flows the PCB fluxes ranged from 44 to 115 g (Total PCB) /day. The Total PCB water-column concentration modeled in the original analysis was 14 ng/L at one mile. With the different flows and sediment concentrations the water-column concentration was modeled to range from 13-19 ng/L. Given the dependency of Total PCB flux on flow, the uncertainty introduced by using the average sediment concentrations instead of the silt concentrations (exhibited by the data from Carroll et al, 1994) is not significant.

Conclusions

Although these results suggest that the estimates originally presented may not be as conservative as possible, they are still quite conservative based on other assumptions made in the development of the standard. In particular, the model transport mechanisms themselves are quite conservative. For example, the source strength term is derived from an upper-bound estimate of the releases due to dredging. Secondly, the transport mechanisms have been idealized and further settling of particles is expected relative to the model predictions.

4.4.4.2 TSS-Chem Model Sensitivity Analysis

The sensitivity of four modeled outputs were examined for the TSS-Chem model. The four output values selected to assess the sensitivity of the above parameters are defined as:

- The net fraction of dissolved PCBs from dredging is equal to the dissolved PCB concentration minus the dissolved background concentration, divided by the total PCB concentration minus the background PCB concentration.
- The distance downstream from the dredge at which the coarse material is less than 0.1 percent of the net suspended solids from dredging.
- The net total PCB flux at one mile, which is the flux at one mile minus the contribution from background.
- The net suspended solids flux at one mile, which is estimated as the flux at one mile minus the contribution from background.

Two of the outputs, the net suspended solids and PCB fluxes, are inputs in HUDTOX. The other two outputs examined are the net dissolved PCB fraction and the distance downstream at which the coarse material is less than 0.1 percent of the net suspended solids. To test the sensitivity of these outputs, each input parameter was varied within reasonable ranges while the others were held constant and the effect on each output was examined. The ranges used for each input parameter are shown in Table 14.

The model parameters on which the sensitivity analysis was performed include:

- Volumetric flow (thereby linear flow, depth, and lateral dispersion),
- Source strength,
- Silt fraction of the entering solids (from dredging),
- PCB sediment concentration,
- Background conditions (suspended solids and PCB concentrations, and dissolved PCB fraction),
- Partition coefficient,
- Desorption rate,

- Lateral dispersion coefficient, and
- Settling velocities of silt and coarse solids being transported downstream

Along with the general effects on modeled outputs, the relative change caused by varying each input was examined. The relative change of an input parameter on the output (X) was calculated by the sensitivity of the parameter $S_{\text{Parameter,X}}$ as defined by Gbondo-Tugbawa *et al.*, 2001:

$$S_{Paramater,Output} = \frac{(Output_i - Output_{default}) / Output_{default}}{(Paramter_i - Parameter_{default}) / Parameter_{default}} \qquad \text{(EQ 64)}$$

The higher the value of the average $S_{Parameter,Output}$, the more sensitive the model output is to that parameter. The relative sensitivities of the parameters were ranked by the magnitude of their average $S_{Parameter,Output}$. If the parameter was among the top 30 percent in the ranking the relative sensitivity was labeled as "high", within 60 percent was "moderate" and below that was "low". If the output was not sensitive to the parameter it was labeled as "none".

Results

The input ranges are presented in Table 14. Direct and indirect relationships between the various inputs and outputs are indicated in Table 15. The relative sensitivities are qualitatively given in Table 13. The average of the absolute $S_{Parameter,Output}$ values are presented in Table 16.

Flow

The first parameter examined was the river-wide volumetric flow since this is an environmental parameter and is likely to vary continuously. The river-wide volumetric flow was varied from 2000 to 8000 cfs which is consistent with the natural variation between low and high flow in the Hudson River. However, it should be noted that dredging activities are not expected to occur at such high flow rates (8000 cfs). The default value is 4000 cfs since this is the average flow for the summer months. By changing the river-wide volumetric flows, three model parameters (linear velocity, depth and lateral dispersion) were varied. Using the RMA2 model (at RM 190 and RM 193) the linear velocities and depths for these river flows were acquired as input for the TSS-Chem model. River-wide flows have specific linear velocity-depth pairs, however since the width of the river is not constant there is more than one depth-velocity pair for each river-wide flow. In addition, the lateral dispersion is a function of linear velocity since it is dependent on the shear forces. The results for various river-wide flows are shown in Figure 20. Due to the variations in the other input parameters there is no consistent effect of varying the river-wide flow. In order to provide a clear representation of the effects each input parameter (velocity, depth and dispersion coefficient) was examined separately.

Velocity

The velocity was varied separately in the range of linear velocities that apply to the river-wide flow rates discussed above. The results of varying the velocity are shown in Figure 21. By varying the velocity, the solids will reach one mile downstream in less time. Therefore, the PCBs on the solids will have less time to partition into the water column and the net dissolved PCB fraction will decrease. Likewise, the solids will have less time to settle and the distance at which the coarse solids are less than 0.1 percent of the net solids and the net suspended solids flux will increase. The net PCB flux increases as well since a large fraction of the PCBs are associated with the solids flux. As shown in Figure 21 the net suspended solids flux and net PCB flux are closely correlated to each other.

Depth

The depth was varied separately using the depths that apply to the river-wide flow rates discussed above. The results are shown in Figure 22. For this model the depth affects the amount of settling that will take place and the volumetric flow inside the plume. With increasing depth the amount of solids lost to settling decreases therefore the solids remain suspended in the water column for a longer period of time and have more time to partition, increasing the dissolved fraction. The decrease in settling also increases the fluxes and the distance at which coarse materials are less than 0.1 percent of the net solids. As shown in Figure 22 there is still a strong correlation between PCBs and suspended solids with varying depths.

Source Strength

The source strength was varied from 0.01 kg/s to 40 kg/s. This upper limit was chosen since the production rates in the various river sections are expected be around 40 kg solids/s. It should be noted that this upper bound is unrealistic as a source strength since at this rate the dredge would be resuspending all of the material it is collecting, furthermore the reduction of suspended solids in the near-field due to settling (as exhibited by the CSTR-Chem model) is not being taken into account. For the TSS-Chem runs used to obtain HUDTOX inputs this parameter is set by the standard being examined. For instance if the HUDTOX output of 600 g/day was being examined the source term in the TSS-Chem model was increased until the PCB flux out of HUDTOX equaled 600 g/day. Therefore there is no clear default value and 1 kg/s was chosen.

The results of varying the source strength are shown in Figure 23. As the source strength is increased the net dissolved concentration increases. The net dissolved fraction however decreases since the system is being overwhelmed by solids and the PCBs associated with them. The distance that the coarse material becomes less than 0.1 percent of the net solids remains constant since it is only a function of the flow, settling rates and initial silt fraction. Both the net total PCB flux and the net suspended solids flux have a direct linear relationship to the source strength.

Silt Fraction Entering

The silt fraction entering was varied from 0 to 1. It is anticipated that the fraction will be closer to unity since the coarse materials are less prone to resuspension and have a greater settling velocity. However due to the heterogeneous nature of sediments within a river the full range including all coarse material was applied. The default value of 0.66 was obtained by entering the fractions of silt and coarse in the sediments of Section 1 into the CSTR-Chem model with the same parameter values used in the TSS-Chem model runs. The net silt fraction exiting the CSTR-Chem model (0.66) was then used as the input of the TSS-Chem model.

The results with varying silt fractions are shown in Figure 24. Since silt has a lower settling rate than coarse solids, an increase in the silt fraction entering the system will cause more solids to remain in the water column longer. With increasing silt fractions, the solids are available for partitioning longer and the dissolved PCB concentration increases. However by increasing the initial silt fraction, the suspended PCB fraction at one mile also increases. The overall effect tends to drive the dissolved PCB fraction down, as is shown in Figure 24.

The distance to 0.1 percent coarse material decreases as less coarse material is added into the system. The relationship is not linear and the distance is noticeably less sensitive between initial silt fractions of 0.1 to 0.9 in which the distance only changes by 18 meters.

As shown in Figure 24, both the net PCB flux and the net suspended solids flux linearly increase with increasing silt fraction entering. As was discussed above the increases are due to the lower settling velocity (less settling) and the greater time period available for partitioning.

PCB Sediment Concentration

Due to the heterogeneous nature of the sediments the PCB concentration may have large variations and therefore the range used for the sensitivity analysis is also large (1 to 1000 mg/kg). The default value of 27 mg/kg is the average concentration of the sediments that will be removed in River Section 1. The results for the varying sediment concentrations are shown in Figure 25.

Neither the distance at which the coarse material is less than 0.1 percent of the net solids nor the net TSS flux are dependent on PCB sediment concentrations. The net dissolved fraction increases with increasing sediment concentration, however the sensitivity of the parameter is greatest between 1 and 20 mg/kg. As shown in Figure 25, above 20 mg/kg the fraction begins to plateau. The reason this occurs can be shown by examining the calculations for the net dissolved fraction. Equation 65 below is the equation for the net dissolved fraction (for a small ? x):

$$\frac{CD_{out}-CD_{BKG}}{CT_{out}-CT_{BKG}}=\frac{CD_{in}+\left(\frac{CT_{in}}{\left(1+K_d\times TSS_{in}\times 10^{-6}\right)}-CD_{in}\right)\times(1-e^{-l\,t})-CD_{BKG}}{CT_{in}-CT_{settled}-CT_{BKG}} \qquad \text{(EQ 65)}$$

Where:

TSS = Concentrations of suspended solids (mg/l)
CD = Dissolved PCB concentration in the water column (ng/l)
CT = Total PCB concentration in the water column (ng/l)
x = Distance downstream (m)
K_d = partitioning coefficient (L/Kg)
? = desorption rate constant (hr^{-1})
BKG = Background, and

In, *out* and *settled* apply to the concentrations in, out and settling for *?x*.

The equation can be simplified by grouping some of the parameters that are not dependent on the sediment concentration such as K_d, TSS_{in}, $e^{-?t}$.

$$f_{net,dissolved}=\frac{CD_{in}+\left(\frac{CT_{in}}{K}-CD_{in}\right)\times E-CD_{BKG}}{CT_{in}-CT_{settled}-CT_{BKG}} \qquad \text{(EQ 66)}$$

As the sediment concentration increases $CT_{in} >> CD_{in} > CD_{BKG}$, and $CT_{in} >> CT_{settled}$ and the fraction begins to approach CT_{in}/CT_{in}*constants.

The net PCB flux is highly sensitive to the PCB sediment concentration as is exhibited in Figure 25. Since the relationship is a linear one and deviations from the average value are equally likely in either direction (though lower values will probably be more common due to over cutting), the fluctuations within a day would most likely balance out the daily loads to those anticipated with the average sediment concentration.

Dissolved PCB Fraction in the Background

The dissolved PCB fraction in the background, the background suspended solids concentration and the partition coefficient are interrelated by the following equation:

$$\frac{CD_{BKG}}{CT_{BKG}}=f_{BKG}=\frac{1}{\left(1+K_d\times TSS_{BKG}\times 10^{-6}\right)} \qquad \text{(EQ 67)}$$

Therefore in order to vary the dissolved fraction in the background the partition coefficient was held constant at the literature value of 5,500 L/kg and the suspended solids concentration in the background was varied from 0.5 to 40 mg/L. These values determined background PCB dissolved fraction between 0.31 and 0.97.

The results for the various PCB dissolved fractions are shown in Figure 26. Neither of the net solid outputs (distance to 0.1 percent net coarse and net suspended solids flux) are dependent on the background PCB dissolved fraction or the suspended solids concentration. The net dissolved fraction increases with an increasing background fraction since a higher background fraction will limit the partitioning and therefore the particles that settle will have a higher concentration. By the time the solids have reached one mile so many solids with higher concentrations have settled out of the water column that the conditions have moved further away from equilibrium. Therefore the dissolved concentration and net dissolved fraction at one mile increases with an increasing dissolved background fraction. However, by removing more concentrated solids through settling, the overall PCB concentration (and thereby the flux) decreases.

Partition Coefficient

As noted above, the partition coefficient, dissolved PCB fraction in the background and the background suspended solids concentration are interrelated. In order to test the model sensitivity to the partition coefficient, the coefficient was varied from 5×10^3 to 5×10^5 and the suspended solids background concentration was held constant (therefore the dissolved PCB fraction in the background varied from 0.99 to 0.47). This range was used since it is not uncommon to find partition coefficients given as log values, and therefore likely to vary by an order of magnitude. The default value is given by the measured dissolved PCB fractions and suspended solids concentrations in the background.

As is shown in Figure 27 neither the distance at which the coarse material becomes less than 0.1% of the net, nor the net suspended solids flux is effected by the varying partition coefficient (and background PCB dissolved fraction). It should be noted that a log scale is used in Figure 27 for the partition coefficient. The net dissolved fraction is highly sensitive to the partition coefficient since it indicates the equilibrium fractions. However, the net PCB flux is not highly sensitive to the magnitude changes in the partition coefficient, since most of the total PCB concentration is dominated by the suspended concentration and the suspended solids concentration is not being affected. Given that most of the criteria are determined by the total PCB value and the confidence in the default partition coefficient is fairly high, variations in the partition coefficient are not expected to limit the usefulness of the TSS-Chem model.

Desorption Rate

The range of desorption rates was obtained through a literature search which is described in attachment C in this attachment. The default value was set at the maximum of the range since this is a conservative assumption and will allow the partitioning to approach equilibrium conditions more quickly. The results for the various desorption rates are shown in Figure 28. As with many of the other parameters there is no effect on the two solids outputs.

The net dissolved fraction increases with increasing desorption rate since the system approaches equilibrium conditions more quickly. The net PCB flux increases with increasing desorption rate since both the dissolved concentration is increasing and the concentration on the settled solids is decreasing.

Lateral Dispersion

The range and default value of the lateral dispersion coefficient was obtained through a literature search, which is described Section 4.4.1 in this attachment. The results for the various coefficients are shown in Figure 29. It should be noted that a log scale is used in Figure 29.

With an increase in lateral dispersion the net dissolved fraction increases since the ratio of the volume of water to the solids becomes larger. The slope of the increase in the net dissolved fraction decreases as the solids begin to disperse so quickly that the width of the plume becomes the width of the river well before it is a mile downstream. The net PCB flux increases due to the increase in dissolved PCBs and decrease in the PCB content of settled solids. As is shown in Figure 29, the net PCB flux is less sensitive than the net dissolved fraction to changes in the lateral dispersion coefficient, due to the significance of the suspended PCB concentrations.

PCB Background Concentration

The range of background PCB water column concentrations is based on the variations experienced throughout the years. The default value is based on the average background value for June to November. The results for the various PCB Background concentrations are shown in Figure 30.

The PCB background concentration has a linearly indirect effect on both the net dissolved fraction and the net PCB flux. The high PCB background values introduce more dissolved PCBs into the system and limit the partitioning of the solids in the water column. Therefore there is a decrease in the net dissolved PCBs and the net fraction decreases. Similarly, the net total PCB flux decreases due to low dissolved concentrations, and high PCB concentrations on settled particles.

Settling Velocity of Silts

The range and default value of the settling velocity of silts was obtained through a literature search, which is described in Section 4.4.1 in this attachment. The results for the various coefficients are shown in Figure 31.

The settling velocity of the silt determines the residence time of silty solids in the water column, thereby affecting the time available for partitioning. As the silt settling velocity increases, the net dissolved concentration will decrease. However, the suspended PCB concentration is also decreasing as particles settle more quickly with higher concentrations. As shown in Figure 31, the decrease in the net dissolved concentration is smaller than the decrease in the net total PCB concentration and the net fraction thereby increases. The decrease in the total PCB concentration and flux is a result of less partitioning and therefore lower dissolved PCB concentrations and greater PCB concentrations on settled particles.

The settling velocity of the silt also affects the two solid outputs, by determining how long the silty solids will remain in the water column. Since the silt settling velocity is much greater than the coarse settling velocity and the distance at which the coarse fraction becomes 0.1 percent is limited by the incremental nature of the model (the value is only given to the nearest meter), the effect of increasing the silt settling velocity is negligible and not exhibited in Figure 31. The net suspended solids flux decreases with increasing settling velocities since the silt particles are settling from the water column at a faster rate.

Settling Velocity of Coarse Particles (Sand)

The range and default value of the settling velocity of sand was obtained through a literature search, which is described in Section 4.4.1 in this attachment. The results for the various coefficients at one mile are shown in Figure 32.

The distance at which the coarse material is less than 0.1 percent decreases as the coarse particles settle more quickly. The settling velocity of the coarse particles does not have a significant effect on the net dissolved PCB fraction, net PCB flux, or net suspended solids flux at one mile, since the coarse material settles out of the water column within 60 meters. Therefore the contributions of the coarse materials at one mile, to both PCB partitioning and solids presence are minimal.

5.0 Far-Field Modeling

5.1 HUDTOX and FISRAND: Fate, Transport, and Bioaccumulation Modeling to Simulate the Effect of the Remedial Alternative

HUDTOX models suspended sediment and PCB transport from Fort Edward through the Thompson Island Pool and downstream to the Federal Dam at Troy, New York. HUDTOX consists of a 2-dimensional vertically-averaged hydrodynamic mathematical model (the USACE RMA-2V model) and a 2-dimensional water quality model with sediment resuspension and scour submodels.

The RMA-2V half of the model simulates water movement by applying conservation of mass and momentum to a finite element mesh overlaying the water surface. It computes water depth and the depth-averaged velocity, both magnitude and direction, in each cell under a specific set of conditions. The finite element mesh used for the Thompson Island Pool consisted of about 6,000 cells connected at approximately 3,000 nodes. Nodes were spaced about 92 m apart in the downstream direction and 15 m apart laterally (see Figure 3-2 from Revised Baseline Modeling Report (BMR) (USEPA, 2000b). RMA-V2 was calibrated by adjusting Manning's n (flow resistance) values to match available water level and velocity data for steady flow conditions at 30,000 cfs. This flow represents the highest values associated with both the upstream and downstream rating curves. The model was validated using data from a 29,800 cfs event that occurred in April 1993.

HUDTOX's submodel is used to estimate sediment deposition and erosion based upon the results of the hydrodynamic model. Variations in bottom velocities within Thompson Island Pool and bottom sediment characteristics - both laterally and vertically - dictated careful consideration of sediment dynamics to accurately estimate changes in water column concentrations due to bottom sediments scour or suspended sediment deposition. PCB concentrations in some areas of the river are higher at depth than at the surface. Thus the exposure of these buried deposits is of particular concern. The Depth of Scour Model (DOSM) with a 2 cm vertical discretization was used to assess bottom sediment dynamics and changes in bottom sediment PCB concentrations due to river flows.

Fate and transport modeling within HUDTOX is based upon EPA's WASP4/TOXI4 models. One-dimensional, transient water quality models considering advection, diffusion, external loadings (e.g., sediment releases) and transformation (e.g., settling) were applied to both suspended solids and PCBs assuming vertical (z-domain) and lateral (y-domain) homogeneity. A finite difference solution was used to predict average water column concentrations in adjoining segments over time. The finite-difference derivation of the general WASP mass balance equations and the specific solution technique implemented to solve these equations are described in Ambrose *et al*. (1993).

Details on all components of the HUDTOX model along with calibration and validation procedures can be found in the Revised Baseline Modeling Report (USEPA, 2000b).

To examine the PCB transport and fish body burdens of PCB, fate, transport, and bioaccumulation models were used. The FISHRAND model requires surface sediment and dissolved water Tri+ PCB concentrations corresponding to the three river sections as described in the FS. FISHRAND is a time-varying mechanistic model based on the modeling approach presented in Gobas (1993 and 1995). The model relies on solutions of differential equations to describe the uptake of PCBs over time, and incorporates both sediment and water sources to predict the uptake of PCBs based on prey consumption and food web dynamics.

5.1.1 HUDTOX Input Values

The resuspension performance standard consists of a Resuspension Standard threshold and action levels. This action level covers operations in the immediate vicinity of dredging operations (near-field) and at the main fixed monitoring locations (far-field) so that water quality responses to the dredge operation, site conditions, engineering controls and other management efforts can be quickly identified. The action levels include both mass and concentration criteria, and apply to suspended solids and Total PCBs. The action levels for Total PCBs are:

Load Criterion of Evaluation Level	The net increase in Total PCB mass transport due to dredging-related activities at any downstream far-field monitoring station exceeds 300 g/day.
Load Criterion of Control Level	The net increase in Total PCB mass transport due to dredging-related activities at any downstream far-field monitoring station exceeds 600 g/day.
Concentration Criterion of Control Level	The total PCB concentration at any downstream far-field monitoring station exceeds 350 ng/L.

Because of the different scale of resuspension (near-field vs. far-field), the following terms have been defined in the preliminary draft of the resuspension performance standard:

- *Resuspension production rate.* Dredging-related disturbances suspend PCB-bearing sediments in the water column. The rate at which this occurs is the *resuspension production rate.*

- *Resuspension release rate.* Since most of the sediments to be remediated in the Upper Hudson are fine sands, a significant fraction and often the majority of this material will settle in the immediate vicinity of the dredge. Materials that remain in the water column are then transported away by river currents. The rate of sediment transport from the immediate vicinity of the dredge is defined as the *resuspension release rate.*

- *Resuspension export rate.* Beyond roughly 1,000 yards, further PCB removal from the water column by particle settling becomes small and most of the PCB in the water column is likely to travel long distances before it is removed or captured by natural geochemical processes. The rate at which PCBs are transported beyond 1,000 yards is defined as the *resuspension export rate.*

The Evaluation Level and the load criterion of the Control Level specify the Total PCB load at the far-field monitoring stations and the concentration criterion of the Control Level specifies the Total PCB concentration at the far-field monitoring stations. These resuspension criteria are the targeted export rates. During dredging operations, it is necessary to specify the load to the water column in the near-field that yields the targeted export rate at the far-field stations. However, there is no prior knowledge of the relationship among the resuspension production, release and export rates. For this reason, computer models will be utilized to estimate the relationship between the far-field and the near-field dredging-induced PCB transport and loss. These computer models are CSTR-Chem, a Gaussian plume model with its associated geochemical component (TSS-Chem), and HUDTOX. The three models will be used to represent and link the three different scales of resuspension. The resuspension production rate in the immediate vicinity of the dredge (30 m) is simulated by the CSTR-Chem. The resuspension release rate in the region from the dredge to a distance of one mile (30 to 1600 m) is represented by TSS-Chem model. Finally, the resuspension export rate in the region beyond one mile is represented by HUDTOX. The choice of the TSS-Chem model to represent a one-mile interval is related to the size of the individual HUDTOX cell, which is approximately 2/3 of a mile long. In addition to the fate and transport models, a series of model simulations is also needed to assess the impacts of dredging to the fish tissue concentrations in the Upper and Lower River. For this purpose, FISHRAND will be used to predict the fish trajectory in the Upper and Lower River and the Farley model will be used to predict the water column and sediment concentrations in the Lower River.

This series of computer models was used to simulate all action levels at the far-field monitoring stations. For the purpose of the modeling effort, all the far-field monitoring for River Section 1 will be done at Thompson Island Dam (TID) and all monitoring for River Sections 2 and 3 will be done at Schuylerville and Waterford, respectively. The one-mile exclusion for the monitoring purposes as stated in the performance standard is not considered in the model runs.

Since the Total PCB action levels are specified as the export rate, HUDTOX is expected to simulate the upper river dredging conditions that caused the conditions at the far-field monitoring stations as specified in the action levels (*i.e.*, 300 g/day, 600 g/day and 350 ng/L). Due to the inherent nature of the HUDTOX model structures, PCB loads cannot be readily specified at far-field locations. Rather, the input of PCBs is specified as an input load at a location within the river, equivalent to a resuspension release rate. For the initial supporting model runs completed for the performance standard, the resuspension release rate was set equal to the desired export rate, recognizing that this yields export rates less than the desired test value. In order to create a correctly loaded HUDTOX run, it is first necessary to estimate the resuspension release rate from the dredging operation, that is, the rate of PCB and solids transport at the downstream end of the dredge plume. At this location most of the solids that are going to settle out, will have settled out and the suspended solids will more closely resemble those simulated by HUDTOX. Therefore, to estimate the input loading term for HUDTOX, the CSTR-Chem and TSS-Chem models were used.

From the initial model runs, it was observed that the HUDTOX model yields an approximately 25 percent reduction (75 percent throughput) of the resuspension release rate to the export rate at the far-field monitoring stations. Therefore, based on these initial runs, the input loading of the HUDTOX model was corrected.

The model formulations for each action level will be discussed in the next sections. The Control Level Total PCB criterion of 350 ng/L will be discussed first since in the preliminary draft of the performance standard at this level, engineering solutions were mandatory and they were only suggested for the other two levels.

Control Level - 350 ng/L at the Far-Field Monitoring Stations

The Control Level of the performance standard specifies that the Total PCB concentration at any downstream far-field monitoring station (compliance point) should not exceed 350 ng/L. The 350 ng/L action level will include both mass flux and concentration criteria, and apply to total suspended solids (suspended solids) and Total PCBs.

To calculate the total flux based on the maximum concentration of 350 ng/L, the following formula is used:

$$F_T = 350\ \frac{ng}{L} \times q \times \frac{1000\ L}{m^3} \times \frac{10^{-9}\ g}{ng}$$

where:

F_T = total Total PCB flux (g/sec)
350 ng/L = Maximum Total PCB concentration (ng/L)
q = flow rate (m^3/sec)
1000 L/m^3 = conversion factor from m^3 to L
10^{-9} g/ng = conversion factor from ng to g

The 350 ng/L resuspension criterion includes ambient PCB loads as well as loads from all sources upstream of the monitoring location. To obtain the load as a result of dredging only, the ambient Total PCB loads (mean baseline loads) should be subtracted from the total flux of Total PCB. Mean baseline load is calculated as follows:

$$F_{MB} = CS_{MB} \times q \times \frac{1000\ L}{m^3} \times \frac{10^{-9}\ g}{ng}$$

where:

F_{MB} = Mean baseline Total PCB flux (g/sec)
CS_{MB} = Mean baseline Total PCB concentration (ng/L)

and other parameters as described above.

The mean baseline Total PCB concentrations were analyzed for TID and Schuylerville based on the water column samplings collected by GE in their on-going weekly sampling program. The methodology and results of the baseline concentrations analysis can be found in Attachment A of the Resuspension Performance Standard. The mean baseline Total PCB concentration for TID and Schuylerville stations can be found in Tables 17 and 18, respectively. Due to limited data available for Waterford, the mean baseline concentrations at this station were estimated by applying a dilution factor of 0.75 to the Schuylerville data. The dilution factor was based on the drainage area ratio of Schuylerville (3440 ft^2) to that of the Waterford (4611 ft^2). The drainage areas for Schuylerville and Waterford were obtained from USGS. The mean baseline Total PCB concentration for Waterford can be found in Table 19.

The net dredging export flux at the monitoring station is then:

$$F_{ND} = F_T - F_{MB}$$

where:

F_{ND} = Net dredging Total PCB flux (g/sec)
and other parameters as described above

The net dredging flux in a day depends on the length of the production or the working hours and is described as follows:

$$F_{NDdaily} = F_{ND} \times t_w \times 3600\ \frac{\sec}{hr}$$

where:

$F_{NDdaily}$ = Daily net dredging Total PCB flux (g/day)
t_w = production/working hours in one day (hr/day)
3600 sec/hr = conversion factor from seconds to hour

The daily net dredging Total PCB flux was calculated for all river sections using the above equations for both 14-hour and 24-hour workdays. Table 20 summarizes the daily net dredging flux for River Sections 1, 2, and 3. For the modeling purposes, a 14-hour workday was used to be consistent with the productivity standard.

Dredging operations are scheduled from 2006 to 2011 with a dredging season from May 1 to November 30 each year, except for the last year of dredging which ends on August

15, 2011. For the purpose of the modeling effort, May conditions are excluded in the daily average of the net dredging Total PCB flux since flow conditions in May are not representative of the remainder of the dredging season (*i.e.*, May has high flow rates compared to other months). The average is only from June to November. In the model simulation, using this average Total PCB flux will also be protective for May conditions.

As mentioned above, the resuspension criterion of 350 ng/L is specified at the far-field monitoring stations. This means the export rate at the monitoring stations should not exceed 350 ng/L. In order to simulate the 350 ng/L Total PCB concentration at the far-field monitoring stations, the Total PCB flux at the near-field location or station that causes the 350 ng/L at the far-field monitoring station is needed. Once the Total PCB flux that represents the 350 ng/L at the far-field monitoring station was obtained using the above equations, the value was increased based on the fraction remaining of the HUDTOX input to the Total PCB flux at the monitoring stations. For the first attempt, a 75 percent fraction remaining at the monitoring station was used based on the previous HUDTOX model runs (Table 21). The input to HUDTOX is calculated by applying the average daily flux for the specific river section for the whole dredging period (May to November) divided by the fraction remaining at the monitoring stations and is described as follows:

$$F_{NDinput} = \frac{F_{NDave}}{\gamma}$$

where

$F_{NDinput}$ = Daily net dredging Total PCB flux input to HUDTOX (g/day)
F_{NDave} = June to November average of daily net dredging Total PCB flux (g/day)
γ = fraction remaining at the far-field monitoring station (%)

Table 21 summarizes the Total PCB flux input to the HUDTOX segments. For the first year of dredging, the resuspension release is applied to June 1 to September 15, 2006 only to account for the half-speed production during that period.

In order to conduct forecast simulations with the HUDTOX model, it was necessary to specify suspended solids and Tri+ PCB flux instead of Total PCB flux. To obtain the Tri+ PCB flux, the Total PCB values were divided by the sediment Total to Tri+ PCB ratio estimated in the Responsiveness Summary to the Record of Decision (USEPA, 2002). The ratio of Total to Tri+ PCB in the sediment for River Section 1 is 3.2, River Section 2 is 3.4 and River Section 3 is 2.7 (USEPA, 2002).

There is no existing data on how to load the suspended solids flux associated with the Total PCB flux for the HUDTOX input. One way to obtain the suspended solids flux is to assume instantaneous equilibrium for PCBs in the water column and use the sediment PCB concentrations in each section of the river to come up with the suspended solids flux (Table 22). However, in dredging scenario, the residence time (contact time) of the sediment in the water column is relatively short, on the order of hours. For this period of time, it is unlikely that PCB reaches equilibrium. Therefore, the suspended solids flux was estimated using TSS-Chem model that accounts for the non-equilibrium partitioning for the desorption of the Total PCBs. The suspended solids flux one mile downstream of the dredge-head was first chosen based on the size of the HUDTOX cells. The suspended solids flux at one mile downstream of the dredge-head was about 3 to 6 percent lower than that of the full equilibrium scenario, depending on the river section (Table 22).

From the Total PCB concentrations downstream of dredge-head plot, it was shown that at three miles downstream, both particulate and dissolved Total PCBs are closer to the equilibrium conditions (Figure 33). Since the HUDTOX far-field model assumes equilibrium partitioning of PCBs, the second attempt of simulating the 350 ng/L resuspension criterion is to take the suspended solids flux from TSS-Chem at three miles downstream of the dredge-head. The suspended solids flux values are slightly smaller than those at the one-mile downstream location (Table 22). To bound the model estimate, a scenario of 350 ng/L without suspended solids flux added to the model was also simulated.

Based on initial HUDTOX runs, the fraction of PCBs remaining at the monitoring station differs by reach of the river, and the fraction remaining is higher closer to the monitoring stations (Table 23). Discussions on the HUDTOX results for the first attempt of 350 ng/L can be found in the Section 5.1.4 of this attachment. Based on the first attempt results, the fraction remaining at the monitoring station was adjusted accordingly (Table 23). The final 350 ng/L scenario was simulated based on the corrected fraction remaining of total PCBs at the monitoring stations and the suspended solids flux at one mile downstream of the dredge-head. The input to the HUDTOX model for the 350 ng/L can be found in Table 23.

Evaluation Level – 300 g/day Total PCB Flux Export Rate

In Evaluation Level, the Total PCB flux at the downstream monitoring stations should not exceed 300 g/day. To examine the effect of running the dredging operation at this action level for the entire dredging period, the Total PCB flux at the downstream monitoring stations was set to be 300 g/day. The input loading for the HUDTOX model was then calculated using the corrected fraction remaining at the monitoring stations. The suspended solids flux associated with the Total PCB flux was calculated using the TSS-Chem model at one mile downstream of the dredge-head. The schedule and the input functions of the 300 g/day resuspension criterion can be found in Table 24.

Control Level – 600g/day Total PCB Flux Export Rate.

Similar to Evaluation Level , the load criterion of the Control Level specified that the Total PCB flux at the downstream monitoring stations should not exceed 600 g/day. Therefore, to study the effect of running the dredging operation at 600 g/day for the entire dredging period, the Total PCB flux at the downstream monitoring stations was set at 600 g/day. Just like the Evaluation Level scenario, the 600 g/day scenario was based on the corrected fraction remaining at the monitoring stations with suspended solids flux at 1 mile downstream of the dredge-head obtained from TSS-Chem. Table 25 summarizes the schedule and input functions of the 600 g/day resuspension criterion.

Accidental Release Scenario

HUDTOX was used to model an accidental release scenario. The purpose of modeling this scenario is to demonstrate the short-term and long-term impact to the public water intakes. The following accidental release scenarios were proposed:

1. A hopper barge containing 870 tons of silty sand (barge capacity is 1000 tons, with 87 percent sediment and 13 percent water) from River Section 2 is damaged and releases the entire load in the area just above Lock 1. The contents fall in a mound and no effort is made to remove or contain the material. Over a period of one week, the entire load is swept downstream. The sediment had been removed by mechanical dredging. The background concentrations are at the 600 g/day Total PCB flux at the River Section 3 monitoring location. For this scenario, there will be additional release of 113,000 kg/day suspended solids, with a baseline condition of 20,000 kg/day for a one week period from July 1 through 7, 2011.

2. A hydraulic pipe bursts. The dimension is 3-mile long and 16 inch diameter. The pipe consists of 20 percent solids (USEPA, 2002; Herbich and Brahme, 1991). For this scenario, the additional suspended solids flux will be approximately 125,000 kg/day for a one-day period.

Case 1 is more severe than case 2. In addition, the case 1 scenario is quite conservative in that the average concentration from River Section 2 is higher than in the TI Pool because areas with mass per unit area greater than 10 g/m^2 are targeted whereas, in the TI Pool, areas greater than 3 g/m^2 are targeted. The hopper barge was used because it has a larger capacity than the deck barge (200 tons), which was also proposed in the FS. The location of the accident is just above the public water intakes at Halfmoon and Waterford, minimizing any reductions that may occur in the water column concentration resulting from settling and dilution. Because the sediment was removed by a mechanical dredge, the entire weight is attributed to sediment with no dilution with water. The already elevated water column concentrations result in water column concentrations at the public water intakes greater than the MCL.

5.1.2 Methodology

The resuspension criteria are defined as Resuspension Standard threshold and action levels. The standard threshold is the maximum total PCB concentration of 500 ng/L at the far-field monitoring stations and represents the acute component of the criteria. The secondary action levels represent a chronic component (*i.e.*, control of long-term impacts to fish and related receptors). For the chronic component, a modeling effort was performed to define a basis for a Total PCB flux standard in terms of Total PCB mass export per year as well as a total mass exported due to dredging for the entire remedial period.

Long term impacts of dredging focus largely on annual rates of PCB transport and changes in fish body burdens of PCBs. For an unacceptable rate of release of resuspended sediments the model would forecast impacts that deviate from the selected alternative. That is, fish at downstream locations exhibit a slower recovery as a result of PCB resuspension losses relative to the original no-resuspension scenario.

To study the long-term impacts of dredging, far-field modeling was completed to simulate water column, sediment and fish Tri+ PCB concentrations in the Upper and Lower Hudson River. The modeling efforts were focused on examining the impact of running the dredging operation at the specified action levels in the resuspension performance standard. The water column, sediment and fish total PCB concentrations were forecast using USEPA's coupled, quantitative models for PCB fate, transport and bioaccumulation in the Upper Hudson River, called HUDTOX and FISHRAND, which were developed for the Reassessment RI/FS. HUDTOX was developed to simulate PCB transport and fate for 40 miles of the Upper Hudson River from Fort Edward to Troy, New York. HUDTOX is a fate and transport model, which is based on the principle of conservation of mass. The fate and transport model simulates PCBs in the water column and sediment bed, but not in fish. For the prediction of the future fish PCB body burdens, the FISHRAND model will be used. FISHRAND is a mechanistic time-varying model incorporating probability distributions and based on a Gobas approach and it predicts probability distributions of expected concentrations in fish based on mechanistic mass-balance principles, an understanding of PCB uptake and elimination, and information on the feeding preferences of the fish species of interest. Detailed descriptions of HUDTOX and FISHRAND models can be found in the Revised Baseline Modeling Report (USEPA, 2000b).

For the Lower Hudson River, the Farley *et al*. (1999) fate and transport model was used. The water and sediment concentrations from the Farley fate and transport model are used as input for FISHRAND to generate the PCB body burdens for fish species examined in the Lower Hudson.

5.1.3 HUDTOX Input Study and Relationship Between Resuspension Release and Export Rates

HUDTOX Total PCB and Suspended Solids Flux Input Study

As part of the long term impacts study, a measure of fish tissue recovery that can provide a threshold or limit to define an unacceptable impact due to dredging releases and thereby a limit on the export rate needs to be determined. The lower bound will be the ideal conditions of dredging, where there is no sediments being spilled (no resuspension) and the upper bound will be the MNA scenario. The HUDTOX/FISHRAND model runs that exist cannot be used for this purpose strictly since HUDTOX is not designed to simulate the process of dredging releases. From the previous HUDTOX model runs for the RI/FS and the Responsiveness Summary of the FS, the model runs appear to be correctly executed but it is clear from the HUDTOX's handling of the solids that the application of the model is not entirely correct. Essentially HUDTOX is exporting too many suspended solids from dredging operation. This happens because the boundary conditions formulations were not done properly. Therefore, the specification of dredging releases to HUDTOX needs to be refined.

During dredging operations, it is necessary to specify the load to the water column in the near-field that yields the targeted export rate at the far-field stations. However, there is no prior knowledge of the relationship between the near-field load and export rates at the far-field stations. Due to the inherent nature of the HUDTOX model structure, PCB loads cannot be readily specified at far-field locations (*i.e.*, specifying the resuspension export rate). Rather, the input of PCBs is specified as an input load at a location within the river, equivalent to a resuspension release rate. In order to create a correctly loaded HUDTOX run, it is first necessary to estimate the local export rate from the dredging operation, that is, the rate of Total PCB and solids transport at the downstream end of the dredge plume. At this location most of the solids that are going to settle out, will have settled out and the suspended solids will more closely resemble those simulated by HUDTOX. Unfortunately, there is no prior knowledge on the relationship between the resuspension release and export rates. In addition to the lack of knowledge on the relationship between the resuspension release and export rates, there is no existing data on how to load the suspended solids flux associated with the Total PCB flux for the HUDTOX input. To estimate the suspended solids flux input loading term for HUDTOX, the TSS-Chem model was used. The total PCB input loading term for HUDTOX (the resuspension release rate) was derived iteratively. The resuspension release rate was obtained by checking the resuspension export rate (output from HUDTOX) until the model output gives the desired total PCB export rate. Once the resuspension release rate that creates the desired resuspension export rate was obtained, the corresponding suspended solids flux associated with the total PCB release rate is estimated using TSS-Chem model. These iterations also took into account the different river sections, with their corresponding target sediment properties (*i.e.*, silt fraction), PCB concentrations and hydrodynamics. The simulations also accounted for the changes in dredging location as the remediation progresses.

To study the effect of different formulations of suspended solids flux input to the HUDTOX model, the Control Level (350 ng/L at the far-field monitoring stations) was modeled and examined in detail. The following scenarios were considered for the 350 ng/L export rate HUDTOX input:

- Suspended solids and Total PCB flux at one mile downstream of the dredge-head from TSS-Chem model (HUDTOX run number d006). The choice of the TSS-Chem model to represent a one-mile interval is related to the size of the individual HUDTOX cell, which is approximately 2/3 of a mile long.

- Suspended solids and Total PCB flux at three miles downstream of the dredge-head from TSS-Chem model (HUDTOX run number d007). This scenario was chosen based on TSS-Chem model results where the Total PCB concentrations (both particulate and dissolved phase) at 3 miles downstream of dredge-head are closer to the equilibrium conditions (Figure 33). Since the HUDTOX model assumes equilibrium partitioning of PCBs, the second attempt of simulating the 350 ng/L resuspension criterion is to take the suspended solids flux from TSS-Chem at 3 miles downstream of the dredge-head. The suspended solids flux values for the 3-mile scenario are slightly lower than those of the 1-mile location (Table 10).

- No suspended solids associated with Total PCB flux (HUDTOX run number sr03). This scenario is essentially the pure dissolved phase Total PCB release during dredging and was chosen to serve as an upper bound for the 350 ng/L simulation. The model simulation for this scenario is carried out to the year 2020 only.

- Suspended solids and Total PCB flux at one mile downstream of the dredge-head from TSS-Chem model with a corrected of the fraction remaining at the far-field monitoring stations (HUDTOX run number sr04). This scenario was simulated based on the first three runs of the 350 ng/L (d006, d007, and sr03).

From the previous HUDTOX runs, it was estimated that there is an approximately 25 percent reduction (75 percent throughput) of the resuspension release rate to the export rate. For the first attempt of simulating the export rate represented by the 350 ng/L, the input to HUDTOX model was obtained by taking the suspended solids and Total PCB flux at 1 mile downstream of the dredge-head from TSS-Chem model (d006). The suspended solids and PCB flux input to the HUDTOX model segments can be found in Table 20. The Tri+ PCB input flux was calculated based on the maximum Total PCB concentration of 350 ng/L at the monitoring locations. Detailed calculations can be found in the Sections 5.1.1 and 5.1.2 of this attachment.

The HUDTOX results are in the form of Tri+ PCB at the monitoring stations and they are:

- Tri+ PCB daily flux.
- Integrated daily flow.
- Suspended solids daily flux.

- Dissolved phase Tri+ PCB daily flux.

The Tri+ PCB HUDTOX output includes both the ambient Tri+ PCB loads, as well as loads from all sources upstream of the monitoring location, and the load resulted from dredging operations. The baseline (background) Tri+ PCB flux can be obtained from the no-resuspension scenario (d004) model run. Since the output of HUDTOX model is in Tri+ PCB, conversions are needed to get the Total PCB concentrations. Baseline Tri+ PCB concentrations are on a 24-hour basis. The Total PCB baseline concentrations can be calculated as follows:

$$\text{Baseline Tri+ PCB} = \frac{F_{\text{Tri+}}\ \text{no-resusp}}{q} \times \frac{1\ \text{hour}}{3600\ \text{sec}} \times \frac{1\ \text{day}}{24\ \text{hour}} \times \frac{1\ \text{ft}^3}{0.02832\ \text{m}^3} \times \frac{1\ \text{m}^3}{1000\ \text{L}} \times \frac{10^{12}\ \text{ng}}{1\ \text{kg}}$$

where

Baseline Tri+ PCB = Tri+ PCB concentration in the water column (ng/L)
$F_{\text{Tri+}}$ no - resusp = HUDTOX Tri+ PCB flux output for no-resuspension scenario (kg/day)
q = Flow rate (ft^3/sec)
1 hour/3600 sec = Conversion factor from seconds to hours
1 day/24 hour = Conversion factor from hours to days
1 ft^3/0.02832 m^3 = Conversion factor from ft^3 to m^3
1 m^3/1000 L = Conversion factor from m^3 to Liters
10^{12} ng/1 kg = Conversion factor from kg to ng

To estimate the Total PCB baseline concentrations, the ratios of Total PCB to Tri+ PCB in the water column are used. The Total PCB to Tri+ PCB ratios in the water column are presented in the Responsiveness Summary (RS) to the FS, Table 424694-1 (USEPA, 2002). Using the water column Total PCB to Tri+ PCB ratios, the Total PCB baseline concentrations can be calculated as follows:

$$\text{Baseline Total PCB} = \text{Baseline Tri+ PCB} \times \text{water column ratio}$$

Where:

Baseline total PCB = Total PCB concentration in the water column (ng/L)
water column ratio = Water column ratio of Total PCB to Tri+ PCB.
The value is
2 for River Sections 1 and 2;
1.4 for River Section 3

and other parameters as defined above.

The net addition of Tri+ PCB concentration due to dredging is based on the 14-hour work period since the dredging operations are assumed to be 14 hours in one day, and it is estimated as follows:

$$\text{Net Tri}+\text{PCB}=\frac{(\Delta F_{Tri+})}{q}\times\frac{1\text{ hour}}{3600\text{ sec}}\times\frac{1\text{ day}}{14\text{ hour}}\times\frac{1\text{ ft}^3}{0.02832\text{ m}^3}\times\frac{1\text{ m}^3}{1000\text{ L}}\times\frac{10^{12}\text{ ng}}{1\text{ kg}}$$

where:

Net Tri+ PCB = Net additional Tri+ PCB concentration from the model run output (ng/L)
$\Delta F_{\text{Tri+}}$ = F_{Tri+}dredge scenario – F_{Tri+}no resuspension = Net Tri+ PCB flux output from dredging scenario (kg/day)
q = Flow rate (ft^3/sec)
1 hour/3600 sec = Conversion factor from hours to seconds
1 day/14 hour = Conversion factor from hours to days, taking into account 14-hour work period.
1 ft^3/0.02832 m^3 = Conversion factor from ft^3 to m^3
1 m^3/1000 L = Conversion factor from m^3 to Liter
10^{12} ng/1 kg = Conversion factor from ng to kg

To calculate the net additional Total PCB in the water column due to dredging, the sediment ratios of Total PCB to Tri+ PCB are used. The net addition of Total PCB due to dredging is calculated using the following formulas:

Net Total PCB = Net Tri+ PCB × sediment ratio

Where:

Net total PC = Net additional Total PCB concentration in the water column (ng/L)
sediment ratio = Sediment ratio of Total PCB to Tri+ PCB.
The value is
3.2 for River Section 1;
3.4 for River Section 2;
2.7 for River Section 3;
and other parameters as defined above

The whole water Total PCB concentration is then:

Total PCB concentration = Baseline Total PCB + Net total PCB

Where:

Total PCB concentration = Whole water Total PCB concentration (ng/L)

and all other parameters as defined above.

From the first attempt of the 350 ng/L scenario (d006), it was found that the fraction remaining at the monitoring station was different for different section of the river. The fraction remaining is higher closer to the monitoring stations (Table 25). This happens because in the model simulations, the monitoring station for all River Section 1 dredging was assumed to be at Thompson Island (TID). And all the monitoring for River Sections 2 and 3 dredging were assumed to be at Schuylerville and Waterford, respectively. The one-mile monitoring exclusion from the dredging operations location was not considered in the modeling effort. Therefore, as the dredging operations moved downstream (closer to the monitoring location), the amount of Total PCB flux transported downstream were getting higher. In other words, there is less settling taking place due to the distance from the dredge-head to the monitoring station.

The model results showed that the HUDTOX model is not sensitive to the suspended solids flux input. Three different suspended solids flux inputs were modeled (Table 26). The suspended solids flux input for the 350 ng/L for the 3-mile downstream of the dredge-head scenario is about 6 to 23 percent lower than that of the 1-mile scenario. However, HUDTOX predicted that the Total PCB flux and concentrations at the far-field monitoring stations are almost the same. Figure 34 shows the Total PCB concentration in the water column for TID, Schuylerville, and Waterford, respectively for different 350 ng/L Total PCB concentration scenarios. The scenario with the suspended solids flux at three miles downstream of the dredge-head resulted in a slightly lower Total PCB flux at the monitoring stations than that of the 1-mile scenario. However, the difference is less than 2 percent (Table 26). The upper bound estimate is the model scenario with pure dissolved phase total PCB release (sr03). The model estimated a higher Total PCB flux for this scenario. However, the difference is less than 15 percent.

The effect of different suspended solids flux input to the model can also be seen from the predicted annual Tri+ PCB loads. The predicted annual Tri+ PCB loads over the TID, Schuylerville, and Waterford for each of the HUDTOX forecast scenarios are shown in Tables 28through 30. The annual loads for the 1- and 3-mile scenarios (d006 and d007) are practically the same. The predicted Tri+ PCB cumulative loads for the no suspended solids flux scenario (sr03) are higher compared to the 1- and 3-mile scenarios. However, the predicted increase in loads is less than 3 percent. Figure 35 shows the predicted Tri+ PCB cumulative loads over the TID, Northumberland Dam, and Waterford, respectively.

Due to the model's insensitivity to the amount of suspended solids flux input and to be consistent with the scale of the HUDTOX and TSS-Chem models, the 350 ng/L (sr04) scenario was simulated based on the suspended solids flux at 1 mile of the dredge-head and the fraction remaining at the far-field monitoring stations was adjusted based on the 1-mile (d006) model run results.

Similarly, the Total PCB load criterion for the Evaluation Level and Contorl Level were simulated based on the 1-mile suspended solids flux and the fraction remaining at the far-field monitoring stations was based on d006 run.

Relationship Among the Resuspension Production, Release, and Export Rates

As mentioned before, there is no prior knowledge of the relationship on the amount of sediment being suspended to the water column to the suspended solids and PCB fluxes downstream of the dredge-head. For this reason, computer models were utilized to estimate the relationship between the far-field and the near-field dredging-induced PCB transport and loss. The TSS-Chem and HUDTOX models were used to represent and link the resuspension production (at the dredge-head), release, and export rates. The resuspension production rate is represented by the source strength of the TSS-Chem model. The resuspension release rate in the region from the dredge to a distance of one mile is represented by TSS-Chem model and the resuspension export rate in the region beyond one mile is represented by HUDTOX.

The TSS-Chem and HUDTOX models were used to examine the amount of sediment being suspended to the water colum at the dredge-head, the suspended solids and Total PCB flux at one mile downstream of the dredge-head and the Total PCB flux at the far-field monitoring stations for all three action levels. Table 31shows the resuspension production, release, and export rates for the simulated action levels. Because HUDTOX predicted that the fraction remaining at the monitoring station was different for different reach of the river, the TSS-Chem model was run to simulate the Total PCB flux at 1 mile for each year of dredging. From the results it was predicted that to create an export rate of 300 g/day of Total PCB at the TID, the amount of sediments need to be suspended is approximately 1 to 1.3 kg/s depending on the location of the dredge-head to the monitoring stations. The farther away the dredge-head from the monitoring location, the larger the amount of solids may be suspended to the water column (Table 31). In order to get the same result, the resupension production rates that create an export rate of 300 g/day are on the order of 2 to 3 percent of the solids production rate, which is 42 kg/s. In River Section 2, the solids production rate is lower than that of the River Section 1, with a value of approximately 37 kg/s. For this river section, the amount of solids suspended to the water column to create the 300 g/day Total PCB flux is approximately 0.3 kg/s, which is on the order of one percent of the solids production rate. River Section 3 has the lowest solids production rate, with a value approximately 31 kg/s. The resuspension production rate that creates the 300 g/day of Total PCB flux is approximately 0.9 kg/s when the dredge-head is farther away from the monitoring location and it is around 0.7 kg/s when the dredge-head moves downstream closer to the monitoring station.

For the Control Level load criterion (600 g/day Total PCB flux), the required amount of solids suspended into the water column in River Section 1 ranges from 2 to 2.7 kg/s (on the order 5 to 6 percent of the solids production rate). In River Section 2, to obtain an export rate of 600 g/day, approximately 0.6 to 0.7 kg/s of solids need to be suspended to the water column (approximately 2 percent of the solids production rate). For River Section 3, approximately 1.4 to 1.9 kg/s of solids need to be suspended to the water column to create an export rate of 600 g/day Total PCB flux (on the order of 2 percent).

Finally, the Control Level criterion of 350 ng/L Total PCBs was also simulated. The Total PCB flux at the TID, Schuylerville, and Waterford that represents the 350 ng/L is 1200, 2000, and 2300 g/day, respectively. The resuspension production rates correspond to the 350 ng/L Total PCB concentration at TID are approximately 4 to 5.6 kg/s, which is approximately 10 to 13 percent of the solids production rate. For River Section 2, the resuspension production rates are approximately 0.6 to 0.75 kg/s (approximately 6 to 7 percent of the solids production rate). In River Section 3, approximately 6 to 7.5 kg/s of solids need to be suspended to the water column to create an export rate of 350 ng/L Total PCB concentrations. These resuspension production rates are approximately 19 to 24 percent of the solids production rate.

As for the resuspension release rates, under the 300 g/day (sr02) and 600 g/day (sr01) scenarios, HUDTOX predicted that the values are approximately 1 to 1.3 times the resuspension export rate (Table 31). For example, during the second year of dredging in River Section 1 (2007), a 400 g/day Total PCB flux resuspension release creates an export rate of 300 g/day. For the 350 ng/L scenario, HUDTOX predicted that the resuspension release rates are approximately 1 to 1.4 times the resuspension export rates.

Example of CSTR-Chem, TSS-Chem and HUDTOX Application

As an example of the use of CSTR-Chem, TSS-Chem and HUDTOX to simulate the fate and transport of PCBs during dredging operations, the development of the 350 ng/L (i.e., the Control Level) dredging scenario is discussed in this section. To simulate the Control Level, the water column at the far-field monitoring stations was specified to be 350 ng/L. The models were used in a backward sense, first determining the desired conditions to be simulated (in this case 350 ng/L at the far-field stations) and then iterating through the use of the models to determine the fluxes and dredging resuspension terms that would yield the desired condition. The far-field monitoring stations for River Sections 1, 2, and 3 were assumed to be the Thompson Island Dam (TID), Schuylerville, and Waterford, respectively. The PCB fate and transport model analysis was done in the following sequence:

1. The expected Total PCB fluxes based on the 350 ng/L scenario at these three monitoring stations are 1,200 g/day, 2,000 g/day, and 2,300 g/day, respectively based on mean flow at these stations and the desired water column concentration (Table 31)[3]. These are the resuspension export rates to be produced by HUDTOX model when driven by input conditions derived from the near-field models. HUDTOX input is the suspended solids and Total PCB flux at the upstream of the far-field monitoring stations plus the resuspension loading terms derived from TSS-Chem.
2. For HUDTOX to give the most reliable results, the Total PCB flux and the corresponding suspended solids to the water column in the near-field need to be determined. The Total PCB flux input was estimated based on previous HUDOX runs. The near-field suspended solids load derived from the TSS-Chem model run at the desired Total PCB output flux. Based on the previous HUDTOX runs, the Total PCB flux at the near-field (i.e., the resuspension release rate) is approximately 5 to 30 percent higher than the flux at the far-field monitoring stations (i.e., the resuspension export rate), depending on the river section and the dredging season (Table 31). For example, in River Section 1 during May 1 to November 30, 2007 dredging season, the input Total PCB flux was predicted to

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[3] Note that the target loads and concentrations for HUDTOX were estimated for mean flow conditions and the desired concentrations. The model was not run attempting to attain exactly 350 ng/L on each day of the period of simulation. This approach is consistent with the long-term framework of HUDTOX, *i.e.,* the model was designed to address annual scales and longer.

be approximately 27 percent higher than the output (Table 31). Therefore, for an expected Total PCB flux of 1,200 g/day, the input Total PCB flux (i.e., the resuspension release rate) has to be approximately 1,600 g/day. The 1,600 g/day Total PCB flux is the value to be attained as the output of the TSS-Chem model. The TSS-Chem output of 1,600 g/day was taken at approximately 1 mile downstream of the dredge-head to be consistent with the size of the HUDTOX model grid size. As mentioned above, the corresponding suspended solids load for the 1,600 g/day Total PCB flux was obtained from TSS-Chem model.

3. Since the target for the TSS-Chem model is to produce as output the Total PCB flux needed as input to HUDTOX, the TSS-Chem model was run iteratively to determine the corresponding suspended solids and Total PCB input to TSS-Chem. Once the suspended solids input rate to TSS-Chem yielded the desired Total PCB flux (i.e., approximating the resuspension release rate), the flux of suspended solids at 1 mile downstream of the dredge-head was taken as the suspended solids load input to HUDTOX model. For example, in River Section 1 during the May 1 to November 30, 2007 dredging season, the corresponding suspended solids input flux to TSS-Chem that creates the 1,600 g/day Total PCB output flux was approximately 60,000 kg/day.
4. To determine the resuspension production rate at the dredge-head, the CSTR-Chem model was used. The suspended solids input flux to the CSTR-Chem model the resuspension production rate. The TSS-Chem suspended solids input flux is the output of the CSTR-Chem model. Knowing the desired suspended solids output flux for CSTR-Chem, the input to the CSTR-Chem was obtained iteratively. For example, in River Section 1 during the May 1 to November 30, 2007 dredging season, the suspended solids input flux to the CSTR-Chem model that creates a 60,000 kg/day suspended solids flux was approximately 280,000 kg/day.

5.1.4 HUDTOX Results

HUDTOX was used to simulate the following scenarios:

- Control Level – 350 ng/L Total PCB concentrations at the monitoring stations (HUDTOX run number sr04).
- Contorl Level – 600 g/day Total PCB flux at the monitoring stations (HUDTOX run number sr01).
- Evaluation Level 1 – 300 g/day Total PCB flux at the monitoring stations (HUDTOX run number sr02).
- Accidental release (HUDTOX run number srA1).

The following sections summarize the results from the HUDTOX model simulations.

Control Level – 350 ng/L HUDTOX Simulation Results

The Total PCB concentration criterion of the Control Level specificies that the Total PCB concentration at any downstream far-field monitoring station (compliance point) should not exceed 350 ng/L. The suspended solids and PCB flux input to the model can be found in Sections 5.1.1 and 5.1.2 of this attachment . The 350 ng/L (sr04) scenario simulation showed that the predicted Total PCB flux at the far-field monitoring stations is within 5 percent of the expected values (Table 20). The Tri+ PCB loads for this scenario are lower than the previous two 350 ng/L model runs (d006 and d007). The HUDTOX model predicted that the Tri+ PCB loads over the TID for the 350 ng/L scenario is lower than the monitored natural attenuation (MNA) scenario by 2034 (Table 2827). The loads are higher during dredging period (2006 to 2011) and 20 years beyond the completion of dredging (Figure 35). However, by approximately 2033, the Tri+ PCB loads are the same. Similarly, the amount of Tri+ PCB loads over the Schuylerville station is higher than that of the MNA until approximately 2034 (Figure 35), where they become lower than the MNA beyond that year. The Tri+ PCB loads over the Waterford (transported to the Lower River) are predicted to be slightly higher than that of the MNA (Figure 35). However, the predicted increase is minimal, less than 4 percent.

In terms of total PCB, the loads in the water column for the 350 ng/L scenario (sr04) are predicted to be much higher than that of the MNA for all the monitoring stations (TID, Schuylerville, and Waterford). The Total PCB loads over TID, Schuylerville, and Waterford can be found in Figure 36. The Total PCB loads are higher because in order to obtain the Total PCB loads for the MNA scenario, the multiplier is the water column ratio of Total to Tri+ PCB while the multiplier for the 350 ng/L scenario is the ratio of the Total to Tri+ PCB ratio for the sediment. The ratio or Total to Tri+ PCB for the sediment is much higher than that of the water column ratio. Even though the Total PCB loads are much higher, the impact to the fish tissue is expected to be minimal. Only Tri+ PCBs include the PCB congeners that bioaccumulate in fish and hence are key to the risk assessment (USEPA, 2000b).

Figure 37 shows the whole water, particulate, and dissolved Total PCB concentrations at TID for the 350 ng/L (sr04) scenario during the dredging period (2006 through 2011). The HUDTOX model predicted that the average whole water Total PCB concentrations during dredging period in the first three years of River Section 1 is less than 350 ng/L. By the end of the River Section 1 dredging, the whole water column Total PCB concentrations are very low (Figure 37). The amount of dissolved phase Total PCB in the water column is about 40 to 50 percent of the whole water total PCB. The amount of particulate phase Total PCB increase in the reach closer to the monitoring stations (Figure 37).

During River Section 2 dredging, the predicted Total PCB concentrations in the water column are high. This is because the flow during that dredging period (August 16 to November 30, 2009), on average is about 15 percent lower than the historical flow based on the USGS data. Therefore, the high concentrations are expected. However, the average concentrations during the whole dredging period for River Section 2 (August 16 to November 30, 2009 and May 1 to August 15, 2010) is around 380 ng/L (Figure 37). HUDTOX predicted that the amount of dissolved phase Total PCB during the first period of River Section 2 dredging is about the same as the particulate phase (approximately 50 percent). During the next period of dredging (May 1 to August 15, 2010) the model predicted a slightly higher dissolved phase than the particulate phase Total PCB (Figure 37). This is probably due to the model prediction of flows that is low for that particular year and section of the river.

In River Section 3, there are some high whole water Total PCB concentrations during the last year of the dredging period. However, the average Total PCB concentration in the water column during the whole dredging period is less than 350 ng/L (Figure 37). Again, the amount of dissolved phase Total PCB is about the same as the particulate phase in the dredging period of August 16 to November 30, 2010. The next period of the dredging operations, the dissolved phase is less than the particulate because the location of the dredging operations is closer to the monitoring station (Waterford) and hence there is less settling.

Control Level – 600 g/day HUDTOX Simulation Results

The PCB load criterion of the Control Level, specifies that the Total PCB flux at any downstream monitoring station should not exceed 600 g/day. To examine the effect of running the dredging operation at this action level for the entire dredging period, the Total PCB flux at the downstream monitoring stations was set to be 600 g/day. Based on the first attempt of the 350 ng/L scenario and to be consistent with the scale of HUDTOX and TSS-Chem models, the suspended solids flux for this model simulation was based on the 1-mile TSS-Chem model results. The input suspended solids and PCB flux can be found in Sections 5.1.1 and 5.1.2 of this attachment.

The HUDTOX model predicted that the Total PCB flux at the far-field monitoring stations are within 10 percent of the expected Total PCB flux values (Table 33). The whole water Total PCB concentrations at TID during the dredging period (2006 to 2011) are predicted to be less than 250 ng/L except for few days in June 2008 (Figure 38). The whole water Total PCB concentrations at the Schuylerville and Waterford monitoring stations are predicted to be lower than 200 and 150 ng/L, respectively (Figure 38). For this scenario, HUDTOX predicted a higher fraction of dissolved phase Total PCB in the water column compared to the particulate phase total PCB. At TID, the amount of dissolved phase is slightly higher than the particulate phase Total PCB during the first and second year dredging period (May 1 to November 30, 2006 and May 1 to November 30, 2007). As the dredging operations moved downstream in the subsequent years (May 1 to November 30, 2008 and May 1 to August 15, 2009), the particulate phase Total PCB increases and the amount of dissolved and particulate phase Total PCB are almost the same (Figure 38). The fraction of dissolved phase in the water column is even higher in River Section 2 (Schuylerville monitoring station). The amount of dissolved phase in the water column is about 70 percent of the whole water Total PCB concentrations (Figure 38). The dissolved phase Total PCB in the water column at Waterford is approximately 50 percent of the whole water Total PCB concentrations (Figure 38).

The predicted annual Tri+ PCB loads over the TID, Schuylerville, and Waterford monitoring stations for the 600 g/day (sr01) scenario are shown in Figure 39. The predicted Tri+ PCB cumulative loads over TID and Schuylerville for 600 g/day scenario are below the MNA by the year 2014 (Figure 39). The predicted Tri+ PCB cumulative load over Waterford is slightly above the MNA for another year, to approximately 2015. Tables 28 through 30 summarize the predicted annual Tri+ PCB loads over TID, Schuylerville, and Waterford. In terms of total PCB, the annual loads for the 600 g/day (sr01) scenario stays higher than that of the MNA for a longer period of time (Figure 39). Similar to the 350 ng/L scenario, this is due to the sediment ratios used in converting the Tri+ PCB to total PCB.

The Total PCB Load criterion of the Control Level requires that the net increase in Total PCB mass transport due to dredging-related activities at any downstream far-field monitoring station cannot exceed 600 g/day. Look-up tables of PCB concentrations that correspond to the 600 g/day Total PCB flux as a function of river flow and month are provided in the resuspension performance standard. The concentrations that correspond to the 600 g/day Total PCB flux in these look-up tables were calculated based on the GE water column samples data at TID and Schuylerville. Since the concentrations were calculated based on the historical data, the reduction of the baseline concentrations at the subsequent section of the river due to the completion of the previous section of the river was not accounted. The HUDTOX simulation for the 600 g/day takes into account the reduction of the baseline concentrations in River Section 2 after dredging River Section 1. After completion of River Section 1 dredging, the baseline water column Total PCB concentrations in River Section 2 are lower since the source upstream at the Thompson Island Pool (TI Pool) has been removed. Control Level 1 as it is currently written assumed the baseline of whole water Total PCB concentrations at Schuylerville as if the TI Pool has not been dredged. In other words, the action level as specified in the resuspension performance standard is too high. The mean baseline Total PCB concentrations were analyzed for TID and Schuylerville based on the water column samples collected by GE in their on-going weekly sampling program. The methodology and results of the baseline concentrations analysis can be found in Attachment A of the Resuspension Performance Standard.

To examine the additional loading that might be added due to this discrepancy, the HUDTOX results for the 600 g/day are adjusted as follows. Assuming the baseline water column monitoring will be performed from 2003 through 2005, the average monthly Total PCB concentrations were estimated based on the MNA scenario results.

The difference of the average monthly Total PCB concentrations between the MNA and the 600g/day (sr01) scenarios are calculated using the following formula:

$$\Delta TPCB_i = MNA_{base_i} - sr01_{base_i}$$

where:

$\Delta TPCB_i$ = Average difference in Total PCB concentrations in month *i* (ng/L).

MNA_{base_i} = Average baseline Total PCB concentration from MNA scenario for month *i* (ng/L).

$sr01_{base_i}$ = average baseline Total PCB concentration from 600 g/day (sr01) scenario for month *i* (ng/L)

For River Section 2, the difference in Total PCB concentrations was calculated for September through November 2009 and May through August 2010. Once the average monthly difference in Total PCB was obtained, the Total PCB flux was calculated using the following formula:

$$\Delta\text{TPCBflux}_i = \Delta\text{TPCB}_i \times q_{\text{ave}_i} \times 0.02832\ \text{ft}^3/\text{m}^3 \times 3600\ \text{sec/hour} \times 14\ \text{hour/day} \times 1000\ \text{m}^3/\text{L} \times 10^{-9}\ \text{g/ng}$$

where:

$\Delta\text{TPCBflux}_i$ = Average difference in Total PCB flux for month *i* (g/day).
q_{ave_i} = Average flow rate for month *i* (ft3/sec).
$0.02832\ \text{ft}^3/\text{m}^3$ = Conversion factor from ft^3 to m^3.
3600 sec/hour = Conversion factor from second to hour
14 hour/day = Conversion factor from hour to day
$1000\ \text{m}^3/\text{L}$ = Conversion factor from m^3 to liter
10^{-9} g/ng = Conversion factor from gram to nanogram

From the average Total PCB flux difference, the average Total PCB flux difference for the whole dredging period (August 16 – November 30, 2009 and May 1 – August 15, 2010) in River Section 2 was calculated. May conditions are excluded in the average of the difference in Total PCB flux since flow conditions in May are not representative of the remainder of the dredging period. From the calculations above, the average difference in Total PCB flux for River Section 2 is approximately 200 g/day. The 200 g/day Total PCB flux was then added to the Total PCB flux of River Section 2 from HUDTOX results (sr01).

Similarly, to account for the reduction in the baseline whole water column Total PCB concentrations at Schuylerville during dredging River Section 3, the difference in Total PCB flux was calculated using the above formulas. For River Section 3, the Total PCB concentrations difference was calculated for September through November 2010 and May through August 2011. The estimated Total PCB flux that needs to be added to the Waterford Total PCB loads is approximately 300 g/day. During River Section 2 dredging, the sediments from Schuylerville are being transported downstream to River Section 3. HUDTOX predicted that 45 percent of the sediment from Schuylerville is transported to River Section 3. Therefore, during River Section 2 dredging period, 45 percent of the additional flux to the Schuylerville (95 g/day) will be transported to River Section 3. Overall, the adjustment for Total PCB loads at Waterford is an additional 95 g/day Total PCB flux from September through November 2009 and May through August 2010 and an additional of 300 g/day Total PCB flux from September through November 2010 and May through August 2011.

By adding this difference, the Total PCB loads over Schuylerville and Waterford stations are predicted to increase by approximately 2 and 3 percent, respectively. However, the 70-year forecast Total PCB loads for this scenario are still lower than that of the MNA

(Figure 39). The adjusted Tri+ PCB loads over Schuylerville and Waterford are also plotted.

Evaluation Level – 300 g/day HUDTOX Simulation Results

Similar to the Control Level, the Evaluation Level specified that the Total PCB flux at the downstream monitoring stations should not exceed 300 g/day. Therefore, to study the effect of running the dredging operation at 300 g/day for the entire dredging period, the Total PCB flux at the downstream monitoring stations was set at 300 g/day. The suspended solids flux for this model simulation was based on the 1-mile TSS-Chem model results. The input suspended solids and PCB flux can be found in Sections 5.1.1 and 5.1.2 of this attachment.

The HUDTOX model predicted that the Total PCB flux at the far-field monitoring stations is within 13 percent of the expected Total PCB flux values of 300 g/day (Table 34). Figure 40 shows the whole water Total PCB concentrations in the water column at TID, Schuylerville, and Waterford. The HUDTOX model predicted that by running the dredging operations at the load criterion of the Control Level (total PCB flux of 300 g/day), the whole water column Total PCB concentrations at TID are less than 160 ng/L. At Schuylerville and Waterford, the HUDTOX model predicted that the whole water column concentrations are less than 120 and 80 ng/L, respectively (Figure 40). The model predicted that the fraction of dissolved phase in the water column is approximately 60 to 70 percent depending on the location of the dredging operations relative to the monitoring stations for River Sections 1 and 2 (Figure 40). At Waterford, the fraction of dissolved phase Total PCB in the water column is estimated to be approximately 50 percent of the whole water column Total PCB (Figure 40).

Tables 28 through 30 summarize the predicted annual Tri+ PCB loads over the TID, Schuylerville, and Waterford stations. HUDTOX predicted that the 300 g/day (sr02) scenario has the lowest annual Tri+ PCB loads for all stations (Figure 41). Similar to the 600 g/day (sr01) scenario, the annual Total PCB loads for the 300 g/day (sr02) scenario remain higher than that of the MNA for a longer period (Figure 41). Again, this is due to the ratios of Tri+ PCB to Total PCB used in converting the Total PCB loads.

Similar to the Control Level, the 300 g/day Total PCB flux is the net increase in Total PCB mass transport due to dredging-related activities. To be consistent with the performance standard, in which it does not take into account the reduction of the mean baseline Total PCB concentrations after completion of River Sections 1 and 2 dredging operations, the Tri+ PCB and Total PCB loads for the 300 g/day Total PCB flux results from HUDTOX need to be adjusted. Based on the 600 g/day Total PCB flux (sr01) scenario results, the adjustment is expected to be small (on the order of 2 to 3 percent).

Comparison of the Water Column PCB Concentrations for Different Resuspension Criteria

Figure 41 presents comparisons over 70-year forecast period of predicted HUDTOX Tri+ PCB concentrations in the water column at various locations throughout the Upper Hudson River for the MNA, no resuspension and three action levels scenarios.

The effect of running the dredging operations at the Total PCB load criteria of the Evaluation Level and Control Level on predicted water column Tri+ PCB concentrations is largely confined to the six-year active dredging period (2006 through 2011). Outside of the period of scheduled dredging, impacts on water column Tri+ PCB concentrations are minimal. However, running the dredging operations at the PCB concentration criterion of the Control Level results in significantly higher water-column concentrations during the dredging period and slightly elevated water-column concentrations for approximately 10 years in River Section 3 (Figure 43).

The fraction of dissolved phase Total PCB in the water column is higher for dredging scenario with lower suspended solids flux introduced to the water column (compare Figures 37, 38, and 40). For example, the dissolved phase Total PCB for the 600 g/day (sr01) scenario is higher than that of the 350 ng/L (sr04) dredging scenario. This is because the amount of suspended solids flux to the water column for the 600 g/day scenario is relatively lower than that of the 350 ng/L scenario. Compared to the 600 g/day and 350 ng/L dredging scenarios Total PCB flux, the predicted Total PCB flux for the 300 g/day scenario is higher because the amount of solids introduced to the water column is less than both 600 g/day and 350 ng/L scenarios. The smaller the amount of solids introduced to the water column due to dredging, the higher the fraction of dissolved phase Total PCB in the water column.

HUDTOX Results for Accidental Release Scenario

An accidental release scenario was simulated based on a hopper barge running aground just above Lock 1 during dredging Section 3 of the river. The barge carried dredged sediment from River Section 2. The accidental release scenario was assumed to happen when dredging operations were operated under the Control Level criterion of 600 g/day Total PCB flux. The Tri+ PCB loads over TID and Schuylerville remain the same as the 600 g/day (sr01) scenario (Figure 39). The Tri+ PCB load over Waterford was predicted to increase due to the accidental release. The Tri+ PCB load increase is minimal, less than 1 percent. Due to this small increase, the impact to the fish body burdens is expected to be minimal and FISHRAND was not used to model the long-term impact of this release to the fish concentrations.

HUDTOX provided the whole water, particulate bound, and dissolved phase PCB concentrations in the water column. The model predicted that the accidental release scenario results in a short-term increase of the whole water Total PCB above the MCL in the water column at Waterford (Figure 42). However, the highest dissolved phase Total PCB concentration was less than 350 ng/L (Figure 42). These concentrations can be examined against minimal treatment such as filtration and activated carbon to give an indication if the public water supply will be adversely affected, even in the short term. The impact of the elevated solids in the water column during the one-week period can be examined versus the capacity of the Waterford treatment plant to cope with solids.

5.1.5 FISHRAND Results for the Upper and Lower River

FISHRAND model was used to simulate the dredging operations at the Control Level only. FISHRAND modeling results for the Upper River show, similar to the HUDTOX modeling, that the impact of running the dredging operations at load based criterion of the Control Level to the fish tissue concentrations are largely confined to the dredging period in River Sections 1 and 2 (Figure 43). In River Section 3, the impact to the fish tissue concentrations lasts about three years beyond the dredging period to approximately 2014. Table 35 shows the years where FISHRAND model forecasted that the fish tissue concentrations difference to the no resuspension dredging scenario is approximately 0.5 mg/kg. By 2009, the predicted fish tissue concentrations in River Section 1 are within 0.5 mg/kg of the no-resuspension scenario fish tissue concentrations. For River Section 2, the fish tissue concentrations are within less than 0.5 mg/kg of the no-resuspension scenario in 2008. The fish tissue concentrations difference in River Section 3 are predicted to be always less than 0.5 mg/kg. The 0.5 mg/kg difference in fish tissue concentrations was used because this number is within the measurement variability.

The impact of dredging operations at the Control Level criterion of 350 ng/L Total PCBs is larger than running the dredging operations at the 600 g/day scenario (Figure 43). Predicted fish tissue concentrations for the 350 ng/L scenario are within less than 0. 5 mg/kg to the no-resuspension scenario by approximately 2010 in River Section 1 (Table 37). The impact of the 350 ng/L scenario is slightly longer lasting in River Section 2 compared to that for River Section 1. The predicted fish tissue concentrations in River Section 2 are greater than 0. 5 mg/kg of the no-resuspension scenario until approximately 2010. However, in River Section 3, the predicted fish tissue concentration under the 350 ng/L scenario is within 0.05 mg/kg of the no-resuspension scenario in approximately 2011.

The Evaluation Level was not simulated since the Tri+ PCB loads to the Lower River are lower than the load and concentration based criteria of the Control Level (Figure 32 and Table 30). The results for the load based criterion of the Control Level show that the fish tissue concentrations are only slightly impacted and there is only about four years delay for the fish tissue concentrations to be the same as the no-resuspension scenario. In addition, the annual average Tri+ PCB concentrations in the water column for the Evaluation Level scenario are almost the same as that of the no-resuspension scenario by the end of dredging period. Therefore, the Evaluation Level was not simulated and the impact of running the dredging operations at this level is expected to have no adverse impact.

For the Lower Hudson River, the FISHRAND model predicted that the fish recovery is slightly longer further downstream (Figure 44). Note that the fish tissue concentrations in the Lower River are lower than those of the Upper River. The predicted fish tissue concentrations for the 600 g/day (Control Level) scenario are within less than 0.05 mg/kg relative to the no-resuspension scenario between 2013 and 2014 for all river miles (Figure 44 and Table 36). As for the 350 ng/L (Control Level) scenario, the fish tissue concentrations are within less than 0.05 mg/kg relative to the no-resuspension scenario between 2016 and 2017 at RMs 152 and 113. Further downstream, at RMs 90 and 50, the predicted fish tissue concentrations are within 0.05 mg/kg of the no-resuspension scenario in 2018 (Table 36).

5.2 Relative Reduction In Human Health And Ecological Risks In The Upper And Lower Hudson River

Human health hazards and risks and ecological risks in the Upper and Lower Hudson River were calculated for the no resuspension, 350 ng/L Total PCB, 600 g/day Total PCB, and monitored natural attenuation (MNA) scenarios. All active remediation scenarios showed reductions in human and ecological risks, as compared to the MNA scenario, with minimal differences generally seen between most active remediation scenarios.

5.2.1 Introduction

PCB body burdens in fish under various resuspension scenarios were used to calculate long term long-term risks (i.e., after completion of dredging) to anglers and ecological receptors (as represented by the river otter [Lutra canadensis]). The following four scenarios and their run designations (e.g., d004) were modeled:

- ? No resuspension (d004).
- ? 350 ng/L Total PCB (sr04).
- ? 600 g/day Total PCB (sr01).
- ? Monitored natural attenuation.

Risks were calculated with the same exposure durations used as those used the for the Hudson River PCBs Reassessment RI/FS reports (e.g., 40 years for evaluating cancer risks to the reasonably maximally exposed [RME] adult angler, 7 years for evaluating non-cancer health hazards to the RME adult angler). Start years for calculating risks were set to begin one year after the year in which dredging will be completed in the each section of the river and the average of the upper river. All other risk assumptions, locations, toxicity values, receptors, and fate, transport, and bioaccumulation models (i.e., HUDTOX, FISHRAND, and Farley) used to evaluate risks under various resuspension scenarios are the same as those used for baseline conditions in the Revised Human Health

Risk Assessment, the Revised Baseline Ecological Risk Assessment, the Feasibility Study, and the Responsiveness Summary for the Record of Decision, except where noted.

5.2.2 Human Health Risk Reduction

5.2.2.1 Upper Hudson River

Table 37 presents annual species-weighted fish fillet PCB concentrations in the Upper Hudson River, as compared to the risk-based remediation goal (RG) for the protection of human health of 0.05 mg/kg PCBs in fish fillet. The RG is based on non-cancer hazard indices for the RME adult fish consumption rate of one half-pound meal per week, but this level is protective of cancer risks as well. Other target concentrations are 0.2 mg/kg PCBs in fish fillet, which is protective of human health at a fish consumption rate of one half-pound meal per month and 0.4 mg/kg PCBs in fish fillet, which is protective of the CT or average angler, who consumes one half-pound meal every two months.

FISHRAND, the model used to calculate fish body burdens, models fish tissue PCBs on a Tri+ basis. PCB contamination in fish tissue has been shown to contain almost exclusively Tri + PCB homologues (USEPA, 2002). Therefore EPA's fish forecasts and modeling analyses, based on Tri+ PCB, require no revision for comparison to total PCB toxicity values.

The time to reach human health fish target concentrations of 0.2 mg/kg Tri+ PCB and 0.4 mg/kg Tri+ PCB in the Upper Hudson River was shorter for all resuspension scenarios as compared to monitored natural attenuation in the upper river as a whole, and in each individual river section (Table 38). The remediation goal of 0.05 mg/kg Tri+ PCB was only reached in Section 3. The greatest differences seen in the time to achieve fish target concentrations between the active remediation scenarios and MNA were seen in River Sections 1 and 2, where the MNA scenarios took up to 17 years longer to achieve some target concentrations. Smaller differences were seen between scenarios in River Section 3.

Using fish fillet concentrations based upon the three resuspension scenarios (i.e., no resuspension, 350 ng/L, and 600 g/day) human health fish consumption cancer risks and noncancer hazards show at least a 50 percent reduction in the upper river as a whole, Section 1 (River Mile 189), and Section 2 (River Mile 184) compared to monitored natural attenuation for both RME and average exposures (Tables 39 and 40). Risk reductions in Section 3 were seen for the no resuspension and 600 g/day scenarios as compared to monitored natural attenuation, but not for the 350 ng/L Total PCB scenario.

5.2.2.2 Mid-Hudson River

Based on site-specific angler surveys, the Human Health Risk Assessment determined that Mid-Hudson River anglers have a different diet than anglers in the upper river, consisting of 53 percent brown bullhead, 15 percent largemouth bass, 1.4 percent yellow perch, 7.6 percent white perch, and 23 percent striped bass (USEPA, 2000). Striped bass concentrations were modeled using the Farley model for the Hudson River RI/FS reports. However, the Farley model was not run for fish tissue concentrations for resuspension scenarios and therefore precise estimated of human health cancer risks and noncancer hazards for Mid-Hudson River anglers could not be calculated.

To provide an estimate of relative risks amongst the resuspension scenarios, angler intake was calculated using fish concentrations from the FISHRAND model. Striped bass intake was proportionally divided between the remaining fish species (i.e., 69 percent brown bullhead, 19 percent largemouth bass, 2.0 percent yellow perch, and 10 percent white perch) and white perch concentrations from the FISHRAND model were used in the absence of Farley model data. Calculated fish exposure concentrations were used only for comparison between alternatives and do not represent predicted intake concentrations based on mid-river angler consumption patterns. As expected, fewer differences were seen between the resuspension scenarios in the lower river than in the upper river, with long-term cancer risks and non-cancer hazards differing by a maximum of 32 percent. The no resuspension and 600 g/day Total PCB scenarios showed the greatest risk reductions as compared to monitored natural attenuation scenario. The 350 ng/L Total PCB showed lower and sometimes no reductions in risk, owing to elevated concentrations of PCBs predicted in fish tissues for several years following dredging operations under the 350 ng/L scenario (Table 41).

5.2.3 Ecological Risk Reduction

5.2.3.1 Upper Hudson River

Risks to ecological receptors, as represented by the river otter, were evaluated by examining largemouth bass whole fish PCB concentrations and comparing them to toxicity reference value (TRV) based target levels using lowest-observed-adverse-effect-level (LOAEL) and no- observed-adverse-effect-level (NOAEL) concentrations. In the Upper Hudson River the LOAEL target levels were reached within the modeling timeframe for the upper river as a whole and in Section 3 for all scenarios (Table 42). All resuspension scenarios, reached the LOAEL target level of 0.3 PCBs mg/kg 17 years prior to the MNA scenario for the upper river as a whole (Table 43). Ecological target levels were not reached within the modeling timeframe for Sections 1 and 2 of the river. In Section 3, all scenarios reached the LOAEL target level within five years of one another.

5.2.3.2 Lower Hudson River

Largemouth bass PCB concentrations in the Lower Hudson River were lower under all resuspension scenarios than under the MNA scenario (Table 44). The LOAEL PCB target concentration in largemouth bass was reached 4 to 11 years sooner under the various resuspension scenarios than under MNA (Table 45).

5.2.4 Conclusions

Resuspension may temporarily increase PCB concentrations locally, resulting in slight increases in fish PCB concentrations. However, human health noncancer hazards and cancer risks and ecological risks under active remediation scenario were calculated to be well below those under the monitored natural attenuation scenario. Minor differences were seen between the various resuspension scenarios indicating the human health and environmental impacts from dredging are predicted to be minimal, particularly since levels of resuspension approaching the performance criteria are expected to occur on an intermittent, rather than continuing basis. In general, human health and ecological target concentrations are achieved within similar time frames under active remediation. Non-cancer hazards, cancer risks, and ecological toxicity quotients showed minimal differences between scenarios. Increased resuspension results in a maximum delay of five years to achieve human health target concentrations under active remediation, as compared to up to 17 year delays under monitored natural attenuation.

5.3 Suspended solids Far-Field Criteria

The far-field suspended solids criteria are based on the PCB far-field criteria. The suspended solids concentration was calculated based on the PCB increase of the criteria, assuming the solids concentrations were equal to the dredged material. For a total concentration of 500 ng/L, and a background concentration of 100 ng/L, the net increase would be 400 ng/L. As stated in the FS, the average PCB concentration on the dredged sediment across all three River Sections is approximately 34 ppm. Therefore, the suspended solids concentration for 500 ng/L was calculated to be about 12 mg/L. Considering the uncertainty associated with some of the calculation assumptions, the TSS criterion for Control Level was set at twice the estimated concentration or 24 mg/L, and the TSS criterion for the Evaluation Level was set at 12 mg/L. Two-tiered far-field suspended solids criteria, applicable to all the far-field stations, are established and summarized below. It should be noted that the concentration of PCBs at the far-field station with a suspended solids concentration of 12 mg/L is modeled by TSS-Chem to be greater than 500 ng/L Total PCBs since the PCB dissolved phase would also contribute to the concentration. The far-field suspended solids criteria are specified in Chapter 2 of Volume 1.

No standard was formulated for Resuspension Standard to avoid unnecessary shutdown of operations. Exceedance of the far-field suspended solids criteria will not cause any engineering contingency except for additional monitoring of PCBs.

6.0 Modeling Studies Used

6.1 New Bedford Harbor Pre-Design Field Test Dredge Technology Evaluation Report

A numerical model of Upper New Bedford Harbor was used to predict concentrations of suspended sediments in the water column resulting from dredging activities. The model was based on previous hydrodynamic modeling of New Bedford Harbor performed by the US Army Corps of Engineers (USACE 1998; USACE 2001). The computer models RMA2 and SED2D were used to simulate hydrodynamics and sediment transport, respectively.

Methods

Hydrodynamic Model (RMA2)

RMA2 is a two-dimensional depth averaged finite element model that simulates free surface flow. The mesh size for this model ranged from 30 meters (98 feet) over most of the domain (from Cogeshall Bridge at the south to Wood Bridge at the north) to 5 meters (16 feet) in the vicinity of the dredging area (refer to Appendix K of the Pre-Design Field Test Report, Figure K-3). This model, used at the New Bedford Harbor in 1988, was calibrated to two sets of conditions: a spring high tide (March 1986), and a tide between mean high tide and mean spring tide (April 1986). The model was rerun in 2000 to study the potential impact of confined disposal facility construction on the hydrodynamics of New Bedford Harbor. The predicted water surface elevation at the Cogeshall Bridge was used to drive the new Upper New Bedford Harbor hydrodynamic model at the southern boundary, while the same freshwater inflow used in the initial model was used at the northern boundary.

Sediment Transport Model (SED2D)

The SED2D model was used to simulate sediment transport resulting from dredging activities. The model calculates suspended sediment concentration and change in bed elevation. For the application of the model to dredging it was assumed that the only sediment source was due to dredging operations, and the bed surface was assumed to be non-erodible due to waves, tidal currents, precipitation run-off etc.

Sediment source was defined as a constant input mass rate of sediment released in the water column at four mesh elements. The resolution of the model mesh in the dredging area is roughly 5 m (16 feet) square. The source was assumed to cover an area of four mesh elements at any time, an area approximately equal to that of the dredge moon pool (10 meters × 10 meters or 33 feet × 33 feet). The source strength was estimated from the expected production rate of 69 m^3/hr (90 yd^3/hr), and the fraction of sediment lost to the water column by the environmental bucket used (estimated 1 percent). Combining the production rate and the percent lost, the total sediment release rate to the water column was calculated to be about 482 kg/hr (1063 lb/hr).

The sediments were assumed to be composed of three main sediment fractions which were assumed to be non-cohesive with fall velocities calculated using Stokes' Equation, as shown in Table 466. Since the SED2D model can only simulate one sediment type at a time, each fraction was run independently, and the results were combined to obtain the total suspended solids concentration.

Model Parameters and Variables

In the absence of field measurements to calibrate the present model, a series of simulations were performed with dispersion coefficient values of 0.1, 1.0, 10 and 100 m^2/s (1, 11, 108, 1076 ft^2/s). It was confirmed that the dispersion coefficient had a major impact on the extent of the suspended sediment plume and predicted concentrations.

Results

The model was run with a constant sediment source at the point of dredging for two tide cycles, and the results for each sediment fraction were combined to predict the total suspended sediment concentration throughout Upper New Bedford Harbor at half-hour intervals. Modeled suspended sediment concentrations for flood tide and ebb tide are shown in the Pre-Design Field Test Report, Figures K-4 and K-5, respectively. Figure K-6 of the Pre-Design Field Test Report presents a time series of predicted suspended sediment concentration at specified distances north and south of the dredge, along with water surface elevations at the Cogeshall Street Bridge.

Numerous scenarios were considered with different combinations of dredge location within the test area, mass release rate, and dispersion coefficients. Predicted local suspended solids concentrations were greatest when the dredge was in the shallower waters (at the eastern end of the dredge area). However, far-field suspended solids levels were similar to those levels predicted to be present when dredging in deep waters. The peak concentration predicted (immediately adjacent to the sediment release/dredge location) decreased with increasing dispersion coefficients and varied from a maximum of about 390 mg/L for dispersion coefficient of 0.1 m^2/s (1 ft^2/s), to less than 5 mg/L for a coefficient of 100 m^2/s (1076 ft^2/s). The later value was within the variability of background measurements; therefore it was difficult to detect above ambient conditions. Table 47 presents the peak suspended sediment concentration predicted for different dispersion coefficient values. In all cases, the results predicted no re-suspended sediment transport under the Cogeshall Street Bridge to the Lower Harbor while the dredged operation within the designated Pre-Design Field Test area.

Comparison of Predictive Modeling and Field Measurements

The predictive transport of suspended solids using a dispersion coefficient of 10 m^2/s (108 ft^2/s) provided a reasonable match with the results of field monitoring. The model predicted a maximum elevation of suspended solids over background of 13 mg/L, and an elevation of 5 mg/L extending approximately 400 feet (122 m) down current. The suspended solids levels measured in the samples collected during the field test displayed some elevations above background that were slightly higher and extended further downstream than the predictions. In addition, the turbidity measurements and suspended solids data revealed much greater variability in the distribution of elevations than the model predictions of suspended solids. These differences between predictions and measured values are understandable given the following:

- Dredging source term differences – The model assumed a constant, steady source of sediment introduced to the water column while actual dredging proceeds at a highly variable pace. The model also assumes release of the sediment over the entire water column of the designated source cells. The actual release of material during the dredging process can be much more focused at a particular location (both x-y space in the depth).

- Additional source terms – The model did not include additional source terms from support activities in the area. In particular, the operation and grounding of the support vessel (shallow draft tender tug) Miami II during the monitoring period are thought to have contributed to some of the elevations noted in the suspended solids data.

Comparison of the model predictions with field measurements provided two additional insights that are important in planning additional modeling and monitoring efforts in the Upper Harbor:

- Three-dimensional flow field – Despite the shallowness of the Upper Harbor *(i.e.,* generally 1 to 4 feet), the field measurements revealed distinct variations in the flow field over depth. Although a two-dimensional simulation provides a reasonable approximation for overall circulation, consideration must be given to the vertical variation in flow when addressing transport issues.

- Environmental factors – Even the moderate winds that occurred during the field test had a measurable impact on the current regime. This highlights the importance of the use of field measurements to assess model predictions and sample collection locations on a daily basis.

6.2 Manistique River and Harbor, Michigan

The USACE RECOVERY model is employed to predict the temporal responses of surface water to contaminated sediment. This model is generally employed to simulate natural recovery of the river system. Input data to the RECOVERY model consists of sediment contaminant concentration data from the sediment mixed-layer and corresponding surface water concentrations. Output data consist of contaminant and water concentration concentrations over a projected period of time. For the Manistique River system, A second USACE model employed is the TGU (turbidity generating unit) model. This model projects the amount of suspended mass per unit volume that will result from dredging operations (*i.e.* resuspension). Typically, values of TGU range from 2 to 50 kg/m3 based various dredges and a variety of sediment bed types. This model assumes that the dredge operates within a volume of water (m3) and using a solid mass balance once can estimate the solids concentration in the water column surrounding the dredge assuming the use of permeable vertical barriers both upstream and downstream of the dredge. This set-up bases its analysis on the theory that the turbidity barriers will retain all solids while allowing water to pass through the area. This assumes that the solids must eventually settle out onto the stream body when the system reaches a steady state.

Once output is generated from the TGU model, the Equilibrium Model (EQUIL) is utilized. EQUIL is a chemical release model that determines chemical equilibrium between the particle bound solid and within the water column or aqueous phase. An end result of this model is an estimate of the soluble fraction partitioning from the resuspended solid and the constituent concentration in the dredged suspended sediment on the river bottom.

The combination of these three models was used to simulate the dredging operation at Manistique harbor. The RECOVERY model was used to simulate natural recovery following dredging (the pre-dredge condition) and the TGU/EQUIL models were used to predict the water concentration increase and the dredge suspended sediment deposit increase (*i.e.* residual from dredging). Lastly, the results from the TGU/EQUIL models were set as the starting or boundary condition into the RECOVERY model to simulate the post-dredge sediment and water quality conditions projected into the future or for a set period following the completion of dredging.

Results of the TGU/EQUIL model predicted a PCB water concentration during dredging of 460ng/L. In comparison, actual water quality samples collected during dredging in 1997 resulted in an average PCB concentration in the water column of 230ng/L and 81ng/L in 1998 or an overall average for these two dredge seasons of 170ng/L. With regard to sediment concentrations within the sediment mixed-layer following dredging, the model predicted sediment PCB concentrations would increase to 30 ppm immediately following dredging but assuming a natural depositional rate of 1 inch per year, the PCB concentration in the sediment reduced to 10 ppm in the year 2000 (two years after dredging), and to 0.012 ppm by the year 2020 (22 years after dredging). As indicated previously, the average PCB concentrations measured in the sediment following dredging in 1997 was 18.1 ppm while the average sediment PCB concentrations measured in the year 2000 by the FIELDS team following the completion of all dredging activities was 7.06 ppm. Thus, it can be concluded that the TGU/EQUIL model overestimated dredging resuspension and sediment residual concentrations following dredging activities.

7.0 Response to GE's Comments on Hudson River FS

7.1 Summary of GE's Conceptual Model and Results

In Appendix A (Assessment of Sediment Resuspension and PCB Release During Dredging Activities) of GE's comments on the FS (GE, 2001) Section 3.1, GE's consultants presented a conceptual model of the near-field dredging area. Their analysis assumed the following:

- The near-field area can be approximated as a CSTR
- Steady state condition exist in the near-field area
- Equilibrium partitioning between the suspended phase and dissolved phase PCB.

Using these assumptions GE concluded that significant losses of resuspended PCBs are expected. While the first two assumptions are reasonable, the third assumption does not accurately represent the PCB desorption kinetics of this system.

7.2 Kinetics of PCB Desorption: Literature Review

Recent studies have demonstrated that desorption of hydrophobic chemicals from sediments can be quite slow and that chemical equilibrium may not be a good approximation in many real situations. In a dredging scenario, the residence time (contact time) of the resuspended sediment in the water column is relatively short, on the order of hours. For this period of time, it is unlikely that PCB reaches equilibrium.

Many researchers showed evidence that desorption of contaminants takes place in at least two steps, a fast step and a slow step as discussed in Attachment C of this document. The desorption of PCBs from Hudson River sediments was studied by Brown (1981) and Carroll and co-workers (Carroll *et al.*, 1994). Brown developed and tested a method for the analysis of rates of PCB desorption from sediment suspended by dredging activities. The data used were taken from dredging operations in the Hudson River at the town of Fort Edward during 1977. The monitoring stations were placed in the east channel of Rogers Island. Brown used the Freundlich isotherms model to obtain the sinking and sorption-desorption rate constants of Aroclor 1016. In the report, the author used a term sinking rate constant for the first order decay settling coefficient. In this study, the sinking and sorption-desorption rates were chosen by trial and error method to fit the measured concentration of Aroclor 1016 during the low and high flow conditions. For low flow conditions, it was found that a sinking rate of –0.08 hr^{-1} and desorption rate constants ranging from 0.025 hr^{-1} to 0.05 hr^{-1} fitted the measured data well. Under the high flow conditions, a reasonable fit was obtained using a sinking rate of –0.4 hr^{-1} and desorption rate constants on the order of 1.0 hr^{-1}. Brown concluded that in the model, the rate of PCB desorption from solids is proportional to the difference between the PCB burden of the suspended sediments and the burden that would be in equilibrium with the existing soluble concentration.

Carroll and co-workers studied desorption of PCBs from Hudson River sediment using XAD-4 resin as a PCB adsorbent. They used sediments contaminated with high, medium, and low levels of PCBs from the Hudson River near Moreau, NY. The three Hudson River sediment used in their study contained 25, 64, and 205 mg/kg (dry weight) PCBs with total organic carbon contents of 0.96, 3.43, and 4.59 percent, respectively. They reported that the PCBs present in the sediments consisted primarily mono- and di-chlorinated biphenyls (60-70 percent of total). Both a rapidly desorbing labile component and a more slowly desorbing resistant component were observed. Rate constants for the labile (fast) and resistant (slow) fractions were obtained using a model developed by Berens and Huvard (1981). For the purpose of our study, the desorption rate constant of the untreated moderately (64 mg/kg dry weight PCB) PCB-contaminated Hudson River sediment is considered. The desorption rate constant obtained from Carrol and co-workers study was approximately 0.018 hr^{-1} (refer to Table 5 in Attachment C).

Borglin and co-workers studied parameters affecting the desorption of hydrophobic organic chemicals from suspended sediments (Borglin *et al*., 1996). In their paper, Borglin and co-workers presented the results from the long-term experiments performed for three hydrophobic organic chemicals (hexachlorobenzene and two polychlorinated biphenyls). They concluded that the desorption times are on the order of a month to several years and they observed that the desorption rates are dependent on the particle/floc size and density distributions, the type of water, the amount of organic carbon in the sediments, the time of adsorption before desorption, and the chemical partition coefficient. Borglin and co-workers presented the results of the amount of PCBs (monochlorobiphenyl and hexachlorobiphenyl) desorbed over time. From these results, the rate constants obtain are on the order of 0.0049 hr^{-1} and 0.00042 hr^{-1} for monochlorobiphenyl and hexachlorobiphenyl, respectively.

Cornelissen and co-workers studied the desorption kinetics of chlorobenzenes, PAH, and PCBs for different contact times and solute hydrophobicity (Cornelissen *et al*., 1997). They used a technique employing Tenax TA® beads as "sink" for desorbed solute to measure the kinetics of desorption of the compounds mentioned above. For PCBs, they studied PCB-65 (2,3,5,6-tetrachlorobiphenyl) and PCB-118 (2,3',4,4',5-pentachlorobiphenyl). The sediment used was taken from Lake Oostvaardersplassen, The Netherlands. They observed two stages of desorption rates, the rapid release of the "labile" sorbed fraction and slow release of the "nonlabile" fraction. Two different contact times were considered in this study, 2 and 34 days. The desorption rate constants were varied for the different contact times for both the rapid and slow release. The values are summarized in Attachment C.

In 1999, ten Hulscher and co-workers studied desorption kinetics and partitioning of chlorobenzenes, PCBs, and PAHs in long term field contaminated sediment cores and top layer sediment (ten Hulscher *et al*., 1999). They concluded that the desorption from sediment was triphasic: fast, slow, and very slow. In this study, they used the sediment from Lake Ketelmeer, The Netherlands. Only core results were presented for PCB-28.

They reported the desorption rate constant for very slow fraction with values of 0.21×10^{-3} hr^{-1} and 0.19×10^{-3} hr^{-1}.

Ghosh and co-workers studied the relationship between PCB desorption equilibrium, kinetics, and availability during land biotreatment (Ghosh *et al*., 2000). For this purpose, they conducted a study of the equilibrium partitioning and desorption kinetics using industrial lagoon sediments containing 0.91 percent oil and grease as a function of biotreatment duration. A two compartment model was used to model the desorption of PCBs from sediment. Tri-, tetra-, penta-, and hexa-chlorobiphenyls desorption rate constants were reported. The values for the untreated sediment are summarized in Attachment C.

Recently, ten Hulschler and co-workers studied desorption kinetics of in-situ chlorobenzenes and 2,4,4'-trichlorobiphenyl (PCB-28) from River Rhine suspended matter in Lobith, The Netherlands (ten Huschler *et al*., 2002). They observed fast, slow and very slow desorption rates for PCB-28. Rate constants observed were on an average of 0.2 hr^{-1} for fast, 0.0004 hr^{-1} for slow, and 0.00022 hr^{-1} for very slow desorption rates.

7.3 CSTR-Chem Model

A near-field CSTR model (CSTR-Chem) was developed to understand the net effect of dredging on solids, fraction of dissolved PCB and total PCB flux. The model description, its application and sensitivity are presented in section 4.3 of this attachment. CSTR-Chem used a conservative rate of desorption of 0.2 hr^{-1}. This desorption rate was applied to the difference between the PCB concentration of the suspended sediments and the concentration that would be in equilibrium with the existing soluble PCB concentration. This formulation is consistent with the theory presented above.

Model simulations using CSTR-Chem suggest that the net fraction of dissolved PCB from dredging operations under river flows of 4,000 cfs, is approximately 0.03 percent. This net fraction of dissolved PCB of 0.03 percent was consistent for all near-field velocity and river depth values simulated in the sensitivity analysis. Therefore, negligible losses of PCBs are expected in the near-field dredging area.

8.0 Case Studies – Dissolve Phase Releases and Export Rates

Every Superfund site represents a unique setting, with different hydrologic and geological conditions, different discharge histories, and different contaminants. However, a study of other dredging sites can provide information on the conditions that may be encountered during this dredging project. In particular these other sites provide a basis to determine what distances are reasonable for monitoring, what export rates are achievable and what type of releases will occur. As the Hudson River PCBs Site is one of the largest Superfund sites, identical or near-identical conditions would not be expected at other sites. However, taken together, data from these other sites demonstrate the feasibility of achieving the individual components of the Hudson River remedy.

The previous examination of the export rates for the case studies in the Responsiveness Summary to the ROD (RS, USEPA, 2002) indicated:

- The range of resuspension rates modeled as the average source strengths (best engineering estimates) was reasonable. Furthermore, the data from the case studies indicated that the export rates estimated are likely to overestimate the anticipated export rate under routine conditions in the Hudson River.
- The releases observed at other sites have been predominately associated with the solids. As the solids are transported downstream dissolution will occur. The magnitude of the dissolution is dependent on the sediments concentrations, distance downstream and flow. The case studies with reliable split phase concentrations support the conclusion that dredging-related PCB releases are predominately solids.

Given the limitations of these case studies they are not used directly to infer the conditions that will occur during dredging in the Hudson River. Therefore, the Remedial Design should provide contingencies and dredging techniques to deal with site-specific factors.

8.1 Introduction

None of the case studies examined provide specific estimates for the conditions in the Hudson River. Rather, the studies presented evidence for:

- The range of export rates achieved and how the export rates can be accurately determined;
- The type of releases (i.e. solid or dissolved phase) that generally occur.

In the case studies reviewed, the monitoring plans, sediment concentrations/classifications, the nominal flows and weather conditions were different than those anticipated in the Hudson River. It is acknowledged that the case studies do not provide perfect templates, and therefore they were not used as such.

The three case studies examined in depth were New Bedford Harbor, Fox River, and Hudson Falls. Since these sites were examined previously for the Feasibility Study (USEPA, 2000a) and RS (USEPA, 2002), only new analyses or further clarification for each of these three sites is provided below. Other case studies were also examined, but either there was not enough information concerning resuspension or the conditions were too dissimilar to be relevant to the Hudson River PCBs Site; these are discussed briefly.

8.2 New Bedford Harbor, Massachusetts

The New Bedford Harbor Pre-Design Field Test dissolved phase releases were also discussed in Attachment C. The discussion provided here is specific to the modeling results presented in this attachment. The New Bedford Harbor Superfund Site is located in Bedford, Massachusetts, about 55 miles south of Boston. The site is contaminated with PCBs, heavy metals, and other organic chemicals from industrial discharges. Removal of PCB-contaminated sediments in hot spots located on the west side of the Acushnet River estuary was completed between April 1994 and September 1995. Dredging of the hot spots was performed using a hydraulic dredge, and the slurry was subsequently pumped into a confined disposal facility (CDF). Following the hot spot dredging, a pre-design field test using mechanical dredging equipment was performed in August 2000 and documented in the Pre-Design Field Test Final Report (USACE, 2001). During the Pre-Design Field Test the area directly around the dredge was referred to as the moonpool. At times oily sheens and oily slick releases were noticed. The report contains detailed information regarding the dredging operation, water quality monitoring for turbidity, particulate PCBs, dissolved PCBs, threshold water column levels, and contingency plans to be put in effect in the event that the action level was detected at one of the monitoring stations. Since the hot spot removal has been previously discussed in depth in the RS (USEPA, 2002), only the pre-design study is considered in this analysis.

Export Rate
A rough estimate of the PCB loading was provided in Attachment C. However due the lack of flow data, the results are not discussed any further in this attachment.

Dissolved Phase Release
In the Pre-design Field Report it was noted that New Bedford Harbor contains free oil phase PCBs as well as sediment-bound PCBs. For this analysis (and the analysis in the Performance Standard Report), the data from the oil releases and moonpool were not included since these samples represent a multiphase system, and multi-phase systems are not applicable to the lower PCB concentrations typical of the Hudson. Essentially, samples labeled as “oily sheen” or “oil slick” do not apply to the sediment resuspension processes anticipated for the Hudson. Exclusion of these oil-bearing samples provides a more consistent picture of the PCB release process at New Bedford Harbor.

In Figure 45, the total, suspended, and dissolved phase PCB concentrations are presented as a function of distance upstream and downstream of the dredging operations. For each

PCB form (total, suspended and dissolved), two plots are presented – one showing all data, and a second showing an expanded scale. In each case, samples within the "moonpool" around the dredging operation (0 distance from the dredge) show very high levels relative to baseline (i.e., upstream) conditions. These samples represent conditions in the immediate vicinity of the dredge. Examining the expanded scale graphs allows a comparison of the upstream and downstream conditions. In this comparison, it is clear that all three forms of PCB (total, dissolved, and suspended) increased downstream of the dredge, indicative of resuspension release. These conditions represent the near-field conditions referred to in the standard. However, it is also clear that the suspended matter concentration has increased substantially more than the dissolved phase, indicating that the primary form of the net PCB increase took place in suspended matter form, consistent with the analysis provided in the standard. The suspended matter concentration increased by more than 100 percent from approximately 500 ng/L to 1000-1500 ng/L. The dissolved phase increased form about 500 ng/L to about 750 ng/L or about 50 percent. The impact of the dredging related release can also be seen in Figure 46, which presents the fraction of the dissolved phase as a function of total PCB concentration and distance from the dredge. In the diagram comparing dissolved fraction to total PCB, there is a clear trend toward lower dissolved fractions as the total PCB concentration increases [i.e., the fraction of the Total PCB load in the dissolved fraction decreases as the Total PCB load (sum of dissolved and suspended) increases]. This trend correlates with the decrease in dissolved fraction PCB that occurs from upstream to downstream, as also shown in the figure. These data all support the assertion that PCB releases due to dredging occur primarily as a suspended matter release and thus can be tracked in the near field by suspended matter or possibly turbidity measurements. This also shows that PCBs enter the water column as suspended matter, a process that is independent of the baseline dissolved phase PCB concentration.

Subsequent to the resuspension, greater dissolution of PCBs takes place but the elevated PCB suspended matter fraction remains, indicating that it is possible to track PCB releases by suspended matter or turbidity. Additionally, as shown in Figure 45, the total PCB concentrations increased by roughly 1,000 ng/L or about 100 percent. Of the 1000 ng/L increase, roughly 750 ng/L is particle-borne and 250 ng/L is dissolved phase-borne. This corresponds to an increase in TSS of roughly 100 percent, consistent with the PCB gain. This TSS signal would be readily detected by the monitoring scheme required for the standard. Notably, the dissolved baseline PCB concentrations, while elevated at 500 ng/L, are not so far above those typically found in the Hudson during peak summer time conditions (150 to 200 ng/L). Thus, similar behavior of PCBs is expected in the Hudson with respect to the downstream distribution on dissolved and suspended matter fractions.

Results

As noted, the Pre-Design Field Test was not used to estimate the magnitude of dredging related PCB releases. Only the nature of the releases was examined. Nonetheless the data clearly show elevated mean concentrations of PCBs downstream of the dredge, regardless of the downstream distance. Additionally, the data show increased mean PCB concentrations on the suspended matter, as well as an increase in suspended solids at all points downstream (see Figure 47). The examination of these data shows that the suspended solids would be clear indicators of the PCB releases and that the dredging-related PCB releases are predominately from solids.

8.3 Fox River SMU 56/57 1999 And 2000 Dredging Projects, Wisconsin

The Fox River sediment management unit (SMU) 56/57 is located along the Fox River adjacent to the Fort James Plant. This river system is part of the Great Lakes Area of Concern. Approximately 80,000 cy of PCB-contaminated sediment were targeted for removal using a hydraulic cutter head dredge. After one week of dredging activities, the dredge was switched to an IMS 5012 Versi dredge in attempt to increase the solids content of the dredge slurry. The dredge was upgraded two more times during the first month of dredging in an attempt to meet an optimum production rate of 200 cy/hr. The Fox River SMU 56/57 was divided into 100 x 100 foot subunits. Dredging was conducted from August 1999 to December 1999. It was determined at the end of Phase I (December 1999) that unacceptably high residuals were left in the area dredged due to mounds of sediment left behind between dredge passes. As a result, the dredging equipment was switched to a horizontal auger dredge for Phase II, which was carried out from late August 2000 to the end of November 2000. Phase I subunits were re-dredged to meet a 1 ppm PCB residual concentration. The activities were documented in the Final Summary Report for Sediment Management Unit 56/57 (September 2000) and the Environmental Monitoring Report (July 2000). The reports contain information regarding water quality monitoring, PCB water column levels and loading, turbidity measurements, and post-dredge sampling. Since, the export rate was estimated in the Responsiveness Summary (RS, USEPA 2002) the discussion below only discusses why the export estimation is likely an overestimate of the conditions anticipated during dredging in the Hudson.

Export Rate
The export rate determined for the Fox River site is not directly applicable to the export rates anticipated in the Hudson due to difference in the monitoring locations, dredge type used, and sampling technique. However, the Fox River export estimate obtained is within the range considered in the performance standard criteria.

As noted in the Resuspension White Paper in the RS (USEPA, 2002), the Fox River studies were complicated by the location of the monitoring stations. The fact that significant loss of PCBs only occurred when the dredging area was close to the sampling cross-section suggests that settling of any resuspended matter occurs within a short distance of the dredging operation. Only when the monitoring location was close to the dredging could this signal be detected. This suggests that the loads obtained by this study do not represent PCB released for long-distance transport. Rather, the PCBs appear to be quickly removed from (settle out of) the water column a short distance downstream. As such, it is inappropriate to use these results to estimate downstream transport from a dredging site.

Furthermore, as discussed in the white paper, the higher resuspension rates may also be a result of the dredge used in these operations. In fact, the New Bedford pilot study compared the sediment resuspension characteristics of a horizontal auger dredge (used in Fox River) with a conventional hydraulic cutterhead suction dredge and found a disparity similar to that observed between the Fox River and average source strength estimates.

The sample compositing may not have been performed in such a manner as to account for flow. As noted it the Resuspension White Paper in the RS:

The sample compositing strategy [of the Fox River Studies], designed to reduce the number and cost of PCB analyses, was contrary to the mass flux analysis attempted. The equal volume composites do not allow consideration of flow variation across the cross-section. USGS (2000) states that stagnant areas and even reversed flows were observed during sampling operations, confirming the errors associated with the composite PCB samples. The TSS sample composites induce less error and provide a more accurate estimate of downstream TSS flux, yet they showed an unexplained decrease in suspended sediment across the dredging operation. The decrease is almost certainly an artifact associated with compositing equal volume samples from 20 percent and 80 percent depth. Even though it has long been established that velocity measurements from these depths represent the average velocity in an open channel, there is no justification for suggesting that a composite sample from these depths represents the average concentration along the profile. This is particularly true in deeper water where the two samples represent 25 feet or more of water depth. (USEPA, 2002)

As discussed previously in the Responsiveness Summary for the ROD (USEPA, 2002), Attachment C, there were several reasons why the field estimates for Fox River were considered overestimations. The most significant of these is that the proximity of the monitoring locations to the dredging operations did not allow for export to be reliably calculated. The sampling locations were located too close to the operations, and therefore export estimates from these samples did not account for settling. In addition, the samples taken in the cross-sections were not composited in a manner representative of the entire load. Despite these reservations, a rate of loss equivalent to 2.2 percent was obtained from the previous analysis. It should be noted that a short-term (days to weeks) export rate of 2.2 percent would not cause exceedances of the Resuspension Standard (i.e., 500 ng/L) in any of the river sections. Furthermore, the models indicate that a release of 2.2 percent would only represent a concern for the 350 ng/L Total PCB criterion in River Section 2 due to the higher sediment concentrations. However, according to the modeling this resuspension rate would represent loads greater than 600 g/day Total PCB, thus prompting additional sampling and possibly additional engineering controls if these levels are sustained. Ultimately, the Resuspension Standard has been designed to allow for occasional large loads without prompting immediate cessation of the operation.

Dissolved Phase Release

It is unclear how much time elapsed between sample collection and separation of the sample into dissolved and particulate fractions, confounding conclusions with regard to dissolved and suspended loads. The data provide evidence of this lag in separations. As noted in the RS, the data are not consistent with a large dissolved phase release based on the lack of change in PCB congener pattern across the dredging area. A large dissolved-phase PCB contribution from the sediments, either by porewater displacement or sediment-water exchange, should yield a gain whose PCB congener pattern is similar to that of the filter supernatant. The fact that the congener pattern is unchanged across the study area suggests a direct sediment addition. Yet the TSS data do not document an increase in suspended sediment concentrations. Please refer to the Resuspension White Paper in the RS (USEPA, 2002) for further details.

Results
The measurements provided in the Fox River report are not applicable or appropriate for use directly in the Resuspension Performance Standard for a variety of reasons. As noted in the Resuspension White Paper in the RS, the Fox River study was complicated by the location of the monitoring stations. In this case study there was a paper mill close by that significantly affected the monitoring results. Furthermore,

The fact that significant loss of PCBs only occurred when the dredging area was close to the sampling cross-section suggests that settling of any resuspended matter occurs within a short distance of the dredging operation. Only when the monitoring location was close to the dredging could this signal be found. This suggests that the loads obtained by this study do not represent PCB released for long-distance transport. Rather, the PCBs appear to be quickly removed from the water column a short distance downstream. As such, it is inappropriate to use these results to estimate downstream transport from a dredging site. (USEPA, 2002)

The data are not particularly useful for analysis of the PCB release mechanisms during dredging either, since the times lag prior to phase separation of the split samples may have allowed for further dissolution between the phases. Despite the analysis performed in the Resuspension Standard Report as well as previous reports suggesting no significant dissolved release will exist at the dredge, the resuspension criteria do not rely on this (i.e., assuming that the dissolved phase releases are small relative to the suspended phase). The criteria downstream are for total PCBs, both dissolved and particulate, and therefore releases in either phase (dissolved or suspended) will be detected.

8.4 Hudson Falls

Hudson River sediments were removed from the vicinity of the GE pump house near Hudson Falls. Sediments in this area contained high levels of PCBs, as well as pure PCB oil. Dredging was accomplished by diver-directed suction hoses over a total period of about seven months (October through December, 1977, and August through November, 1998). During this period, GE conducted its regular monitoring at Bakers Falls and Rogers Island, which can be used to estimate the effects of dredging to the downstream. Since the original analysis of the export rate was provided in the previous analysis (USEPA, 2002), the following discussion is only provided to further clarify the conservative assumptions incorporated in that analysis.

Export Rate
In the Hudson Falls dredging project, PCBs were present in the non-aqueous phase liquid (NAPL) form as well as on sediments. The presence of this NAPL PCB has the potential to escape on its own or to supersaturate the water column. As a result, the anticipated release and export rates should be higher than that expected from sediment resuspension alone. The mass of sediment removed from Hudson Falls was provided by the NYSDEC and the average PCB concentrations were taken from cores in the dredged area. Even if the calculations of the mass were off by a factor of two, the export rate would still be less than 1 percent. PCB export at this rate would not exceed the Resuspension Standard in any river section, based on the modeling analysis Furthermore the export rates estimated for the Hudson Falls site represent upper bounds on the losses due to dredging because of the historical sources between Bakers Falls and Rogers Island, (i.e., the Hudson Falls and Fort Edward facilities). While the baseline is considered relatively well constrained as a result of controls implemented by GE at Hudson Falls, the addition of PCBs by the GE facilities was still occurring at the time, thus potentially adding to the total load and yielding an overestimate of the export from the Hudson Falls site. Overall, the conditions noted for the Hudson Falls dredging project suggest that the conditions experienced were likely to have been much worse than those to be anticipated for this dredging project. The means of estimating loads represents a conservative approach and thus provides a useful upper bound on the actual PCB export. For these reasons it was a useful site for inclusion in the analysis for the resuspension standard.

Dissolved Phase Release
Split phase data were not available for this site.

Results
Since the export rate estimations for the Hudson Falls dredging operations were based on conservative assumptions, it is likely that the export rate has been overestimated.

8.5 Other Sites

Data from Fox River Area N and Manistique Harbor were not used for comparison to the modeled dissolved phase release and export rates based on the project size as well as the application of a dredging technology that was deemed inappropriate for the Hudson and unlikely to be used (based on its apparent loss rate). For the Fox River Area N study only slightly more than 100 lbs of PCBs were removed, suggesting that operations were too small to become routine. Much of the loss may have been associated with start-up. It is likely that the larger project on the Fox River (Areas 56/57 with nearly 1,500 lbs of PCBs removed) is more reflective of the dredging related losses even though these are probably overestimated as well. The data for Manistique are not available, however it is known that dredging at Manistique was primarily accomplished with a cable arm bucket dredge (although other dredges were used as well). In the dredged locations, extensive areas of dense, coarse sediments and debris inhibited the effectiveness of the dredge bucket. The cable arm bucket is designed to dredge soft sediments and does not perform as well where either consolidated materials or debris are present. Thereby, the Remedial Design will have to consider the type of dredge as well as the other engineering contingencies, particularly in areas identified as likely to resuspend.

8.6 Conclusions

The export rates obtained from the case studies are not directly applicable for comparison to the resuspension criteria since these represent daily averages and the criteria pertain to running averages. The long-term effects on the river will be dependent on the export rates downstream. The case studies exhibit that the monitoring stations should be sufficiently downstream to correctly measure the release rate (i.e., the load to the Lower Hudson River). As the near-field transport model of the Performance Standard Report and the Fox River case study indicated much of the TSS settle close to the dredging operations. It is likely that these solids will be removed as the dredge moves downstream.

Ultimately, these studies are not expected to be comprehensive templates for dredging on the Hudson since the conditions of dredging (operations, engineering contingencies, etc.) may have been different from those to be used on the Hudson River PCBs Site. The case studies are used to show that dredging operations at other sites (even in the Hudson) have had success with minimizing export through various techniques and engineering contingencies.

When taken together, these sites demonstrate a consistent level of site clean-up and resuspension release when viewed on a relative basis. The Resuspension Standard as developed for the Hudson River PCBs Site does not require greater degree of control for resuspension than that achieved by other remedial efforts at other sites.

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Tables

Table 1
Properties of Hudson River Sediments

	Non-cohesive sediments	**Cohesive sediments**
Typical location	Deeper areas and channel	Shallower areas
Fine sand or coarser (%)	80	35
Silt or finer (%)	20	65
Solids (%)	76	58
In-situ Density (gm/cc)	1.74	1.45
Organic content (%)	1 to 2	3 to 4
Average Particle Size	62 µm – 250 µm	< 1 µm to 62 µm
Particle Density	2.2- 2.6	2.2 –2.6

Table 2
Summary of Settling Velocities

Reference	Particle Density	Particle Size	V_s or w (cm/s)
Sequoia Scientific, Inc	Not Indicated	50 microns	0.01
		100 microns	0.1
		400 microns	0.005
DePinto *et al*, 1994	DePinto et al, 1994	20.7 microns	0.0124
	Passaic Valley Freshwater Sewage Sludge	22 microns	0.0022
Filtration & Separation.com, 2003	2.2 g/cc	100 microns	0.603
	2.6 g/cc	100 microns	0.789
	2.2 g/cc	400 microns	4.7
	2.6 g/cc	400 microns	5.8
Thonon and Van Der Perk, 2002	Not Indicated	10 microns	0.001
		50 microns	0.005
		100 microns	0.01
		400 microns	0.001-0.1
Kuo and Hayes, 1991	St. John's River 2.40 g/cc	39.6 microns	0.12
	Black Rock Harbor 2.39 g/cc	36.3 microns	0.1
	Thames River 2.50 g/cc	150 microns	1.84
		160 microns	2.1
Kuo *et al*, 1985	From paper: 2.65 g/cc	20 microns	3.59×10^{-2}
	HR: 2.2 g/cc	20 microns	0.026
	HR: 2.6 g/cc	20 microns	0.035
	HR: 2.2	100 microns	0.653
	HR: 2.6 g/cc	100 microns	0.871
	HR: 2.2 g/cc	400 microns	10.453
	HR: 2.6 g/cc	400 microns	13.938
USACE, 2001	Silt	20 microns	3.21×10^{-6}
	Clay	2 microns	3.21×10^{-8}
QEA, 1999	Silt	Based on cohesive Hudson River	0.005 to 0.01 (4-9m/day)

Table 3
Surface Water Elevation Slope in TI Pool based on USGS Gauge Data

Month	Monthly Average Elevation Difference (ft) including negative values	Monthly Average Elevation Difference (ft) negative values treated as 0	Slope (6 mile distance)
3	1.05	1.05	3.00E-05
4	0.676	0.694	2.00E-05
5	0.416	0.436	1.00E-05
6	0.223	0.244	8.00E-06
7	0.151	0.169	5.00E-06
8	0.147	0.168	5.00E-06
9	0.166	0.185	6.00E-06
10	0.234	0.254	8.00E-06
11	0.336	0.349	1.00E-05
12	0.577	0.582	2.00E-05
Dredging period Average	0.239	0.258	8.00E-06

Table 4
Estimated Shear Velocity and Lateral Dispersion Coefficient for Upper Hudson River

RM	Flow (cfs)	Location	Depth (m)	Based on Water Elevation Slope Slope	Shear Velocity (m/s)	Lateral Dispersion Coefficient (cm^2/s)
RM 193	2000	overall	2.4	8.00E-06	0.01	190
		west	0.9	8.00E-06	0.01	40
		center	3.5	8.00E-06	0.02	350
		east	2.4	8.00E-06	0.01	190
	4000	overall	2.6	8.00E-06	0.01	200
		west	1.1	8.00E-06	0.01	100
		center	3.7	8.00E-06	0.02	400
		east	2.6	8.00E-06	0.01	200
	5000	overall	2.7	8.00E-06	0.01	240
		west	1.2	8.00E-06	0.01	70
		center	3.9	8.00E-06	0.02	410
		east	2.7	8.00E-06	0.01	240
	8000	overall	3	8.00E-06	0.02	280
		west	1.6	8.00E-06	0.01	110
		center	4.2	8.00E-06	0.02	460
		east	3.1	8.00E-06	0.02	280
RM 190	2000	overall	2.9	8.00E-06	0.02	260
		west	3	8.00E-06	0.02	280
		center	4	8.00E-06	0.02	420
		east	1.7	8.00E-06	0.01	120
	4000	overall	3.1	8.00E-06	0.02	290
		west	3.2	8.00E-06	0.02	310
		center	4.2	8.00E-06	0.02	450
		east	1.9	8.00E-06	0.01	140
	5000	overall	3.2	8.00E-06	0.02	300
		west	3.3	8.00E-06	0.02	320
		center	4.3	8.00E-06	0.02	470
		east	2	8.00E-06	0.01	150
	8000	overall	3.5	8.00E-06	0.02	350
		west	3.6	8.00E-06	0.02	370
		center	4.6	8.00E-06	0.02	520
		east	2.3	8.00E-06	0.01	190

Table 5
Silt Fractions in Hudson River Sections

Section	Cohesive Sediment Fraction[1]	Non-Cohesive Sediment Fraction[1]	Silt Fraction[2]
1	0.37	0.63	0.37
2	0.62	0.38	0.48
3	0.62	0.38	0.48

Note:

1. Sediment in each river section is consisted of cohesive sediment and non-cohesive sediment.
   The sum of cohesive sediment fraction and non-cohesive sediment fraction is equal to 1.
2. It is assumed that the percentage of silt is 65% in the cohesive sediment and 20% in the non-cohesive sediment.
   Therefore, the silt fraction in Section 1 is 0.37*0.65+0.63*0.2 = 0.37 and in Section 2 and 3 is 0.65*0.62+0.2*0.38 = 0.48.

Table 6
Summary of CSTR-Chem Model simulation results for dredging operations in Section 1-3 of the Hudson River

		River Sections		
		Section 1	Section 2	Section 3
Ambient River Characteristics				
m_{in}	Ambient TSS - Silt (mg/L)	2.3	2.3	1.7
$c_{Total,in}$	Ambient PCB (ng/L)	122	76	57
$F_{d,in}$	Fraction Dissolved in BKG	0.9	0.9	0.92
Q	River flow (cfs)	4000	4000	4000
H	Water Depth (m)	1.88	1.88	1.88
u	Upstream velocity (m/s)	0.131	0.131	0.131
Dredging and Sediment Characteristics				
ν_1	Settling Velocity Silt (m/s)	0.00008	0.00008	0.00008
ν_2	Settling Velocity Sand (m/s)	0.06	0.06	0.06
F_{silt}	Fraction Sediment Silt	0.3665	0.479	0.479
c_{sed}	Sediment PCB (mg/Kg)	27	62	29
M dot R	Resuspension rate (kg/sec)	1	1	1
CSTR Conditions				
w_{nf}	width of the near field (m)	10	10	10
q_{nf}	CSTR flow (m^3/s)	2.4623	2.4623	2.4623
A_{nf}	Horizontal Area (m^2)	100	100	100
V_{nf}	CSTR Volume (m^3)	188.4	188.4	188.4
θ_{nf}	Retention time (s)	77	77	77
PCB Geochemistry				
K_d	Partition Coefficient (L/kg)	48309	48309	51151
k	Desorption Rate (1/hr)	0.2	0.2	0.2
Model Simulation Results				
Total TSS (Combined silt and coarse materials)				
m(dredge)	TSS from dredge	406	406	406
m(loss)	TSS lost to settling (mg/L)	183	151	151
m(out)	TSSout (mg/L)	226	258	257
Sediment Type 1 - Silt				
m(dredge)	TSS from dredge	149	195	195
m(loss)	TSS lost to settling (mg/L)	0	1	1
m(out)	TSSout (mg/L)	151	196	196

Table 6
Summary of CSTR-Chem Model simulation results for dredging operations in Section 1-3 of the Hudson River

Model Simulation Results (cont.)				
Sediment Type 2 – Coarse materials				
m(dredge)	TSS from dredge	257	212	212
m(loss)	TSS lost to settling (mg/L)	182	150	150
m(out)	TSSout (mg/L)	75	62	62
Equilibrium Conditions				
$C_{d,eq}$	Equilibrium Dissolved Conc (ng/L)	535	1218	541
$C_{s,eq}$	Equilibrium Suspended Conc (ng/L)	10552	24037	11293
$C_{p,eq}$	Equilibrium Particle conc (mg/kg)	25.8	58.9	27.7
$F_{d,eq}$	Equilibrium Dissolved Fraction	0.048	0.048	0.046
$F_{s,eq}$	Equilibrium Particulate Fraction	0.952	0.952	0.954
Transient Partitioning Conditions				
C_{Total}	Exiting Total Conc (ng/L)	6172	15966	7483
C_d	Exiting Dissolved Conc (ng/L)	111.6	73.3	54.5
C_s	Exiting Suspended Conc (ng/L)	6060	15893	7428
C_p	Exiting Particle Conc (mg/kg)	26.9	61.7	28.9
F_d	Exiting Fraction Dissolved	0.01808	0.00459	0.00729
F_p	Exiting Fraction Particulate	0.982	0.995	0.993
NET DREDGING Contribution				
$C_{Total,net}$	Net Total Conc (ng/L)	6050	15890	7426
$C_{d,net}$	Net Dissolved Conc (ng/L)	1.8	4.88	2.07
$C_{s,net}$	Net Suspended Conc (ng/L)	6048	15885	7424
$C_{p,net}$	Net Particle Conc (mg/kg)	27.1	62.2	29.1
TSS_{net}	Net TSS Conc (mg/L)	223	255	255
$F_{d,net}$	Net Fraction Dissolved	2.98E-04	3.07E-04	2.79E-04
$F_{p,net}$	Net Fraction Particulate	0.9997	0.9997	0.9997
$F_{silt,net}$	Net Fraction Silt Exiting	0.66	0.76	0.76

Table 7
Summary of Sensitivity of Model Outputs to Model Parameter Inputs

			Sensitivity Coefficient (S)			
Input Parameter	Range of Values	Model Default Value	Net Fraction Dissolved PCBs	Net Fraction Silt	Net PCB Flux	Net TSS Flux
River-wide Volumetric Flow (Velocity & Depth)	2000 - 8000 cfs	4000 cfs	0.14	0.16	0.16	0.16
			0.11	0.11	0.11	0.11
			0.1	0.11	0.11	0.11
Velocity (alone)	0.08 - 0.25 m/s	0.131 m/s	0.27	0.22	0.23	0.23
Depth (alone)	0.9 - 2.3 m	1.88 m	0.73	0.26	0.25	0.25
Near-Field Width	1 - 100 meters	10 meters	5.34	0.15	0.17	0.17
Resuspension Rate	0.5 - 40 kg/s	1 kg/s	0.25	<0.01	1	1
Sediment Silt Fraction	0 - 1	0.37 (Section 1)	0.46	0.52	0.47	0.47
		0.48 (Sections 2 & 3)				
Sediment PCB Concentration	1 - 1000 mg/kg	27 mg/kg (Section 1)	0.62	<0.01	1	<0.01
		62 mg/kg (Section 2)	0.33	<0.01	1	<0.01
		29 mg/kg (Section 3)	0.28	<0.01	1	<0.01
Dissolved Fraction in Background (& TSS Concentration in Background)[1]	0.15 - 1	0.9 (Sections 1 & 2)	0.16	<0.01	0.11	<0.01
		0.92 (Section 3)				
Partition Coefficient (& PCB Dissolved Fraction in Background)[2]	5E3 - 5E5 L/kg	4.8E4 (Sections 1 & 2)	2.95	<0.01	<0.01	<0.01
		5.1E4 (Section 3)				
Desorption Rate	1.6E-4 - 0.2 hr^{-1}	0.2 hr^{-1}	1	<0.01	<0.01	<0.01
Total PCB Concentration in Background	0 - 500 ng/L	122 ng/L (Section 1)	0.24	<0.01	<0.01	<0.01
		76 ng/L (Section 2)				
		57 ng/L (Section 3)				
Silt Settling Velocity	4.1 - 9 m/day	6.9 m/day (8E-5 m/s)	0	<0.01	<0.01	<0.01
Coarse Settling Velocity	0.03 - 0.08 m/s	0.06 m/s	0.25	0.26	0.27	0.27

Table 8
TSS-Chem Model Runs for the PCB 350 ng/L far-field Criterion with and without Dissolved PCBs from Dredging as Modeled by CSTR-Chem

River Section	Year	Dissolved PCBs from dredging (ng/L)	g (source strength) (kg/s)	SS Flux (1 mile) (kg/day)	TPCB Flux (1 mile) (g/day)	Fraction Dissolved (unitless)
Section 1	2007	0	3.052	60,593	1,684	0.09
Section 1	2007	1.89	3.052	60,593	1,684	0.09
Section 2	2009	0	1.669	37,841	2,466	0.14
Section 2	2009	5.06	1.669	37,841	2,466	0.14

Table 9
TSS-Chem Model Runs for the PCB 350 ng/L far-field Criterion with and without Coarse solids from Dredging as Modeled by CSTR-Chem

River Sectio	Year	Sediment Silt Fraction (unitless)	CSTR-Chem Resuspension Rate (kg/s)	Silt Fraction from dredging (unitless)	TSS-Chem source strength (kg/s)	Silt source strength (kg/s)	SS Flux (1 mile) (kg/day)	TPCB Flux (1 mile) (g/day)	Fraction Dissolved (unitless)
Section 1	2007	0.37	5.6	0.66	3.1	2.0	60,593	1,684	0.09
Section 1	2007	1	2.0	1	2.0	2.0	60,609	1,684	0.09
Section 2	2009	0.48	2.7	0.76	1.7	1.3	37,841	2,466	0.14
Section 2	2009	1	1.3	1	1.3	1.3	37,847	2,466	0.14

Table 10
Results for Average Source Strength Estimated Fluxes

	INPUT				TSS-Chem RESULTS				PERCENT LOSS	
	PCB Production rate kg PCB/day	Sediment production rate kg solids/day	Silt Fraction	SS Silt Source Strength (1,2) (kg/s)	Net TSS Flux at 1 mile (2) (kg/day)	Net Total PCB Flux at 1 mile (2) (g/day)	Net Fraction Dissolved PCBs at 1 mile unitless	Concentration increase at 1 mile (ng/l)	SS Loss at 1 mile %	PCB Loss at 1 mile %
River Section										
Section 1	57	2,099,921	0.37	0.077	2,303	78	0.35	14	0.11	0.14
Section 2	116	1,857,493	0.48	0.088	2,642	209	0.39	37	0.14	0.18
Section 3	45	1,563,927	0.48	0.074	2,225	81	0.40	14	0.14	0.18

Notes:

1. Source strengths apply to silt and finer particles only
2. Production rates are based on 7 days/week, 14 hours per day, 630 days in Section 1 and 210 days each in River Sections 2 & 3.
3. Values are based on river-wide volumetric flow of 4000 cfs.

Table 11
Increase in PCB Mass from Settled Material Estimated Using the TSS-Chem Model Results

Management Level	Condition at Far Field Station	River Section	Increase in PCB Mass from Settled Material (g/sq. m) Target Area	Increase in PCB Mass from Settled Material (g/sq. m) Sides of Target Area	Increase in PCB Mass from Settled Material (g/sq. m) 2-Acres Below the Target Area	Length Weighted Average Concentration (ppm) Target Area	Length Weighted Average Concentration (ppm) Sides of Target Area	Length Weighted Average Concentration (ppm) 2-Acres Below the Target Area
Evaluation	300 g/day PCB Mass Loss	1	0.9	6E-04	0.2	7.0	1.0	2.6
Control	600 g/day PCB Mass Loss	1	1.8	1E-03	0.5	12	1.0	4.2
Control	350 ng/L	1	3.9	3E-03	1.0	14	1.0	6.6
Evaluation	300 g/day PCB Mass Loss	2	0.6	4E-04	0.1	5.0	1.0	2.0
Control	600 g/day PCB Mass Loss	2	1.2	8E-04	0.3	10	1.0	3.3
Control	350 ng/L	2	4.7	3E-03	1.2	29	1.0	9.1
Evaluation	300 g/day PCB Mass Loss	3	0.6	4E-04	0.2	5.5	1.0	2.2
Control	600 g/day PCB Mass Loss	3	1.4	9E-04	0.4	10	1.0	3.5
Control	350 ng/L	3	5.6	4E-03	1.5	15	1.0	8.6

1. Mass/Area used to define the lateral extent of dredging in River Sections 1 and 2 is approximately 6.6 g/sq. m and 34 g/sq. m, respectively. In River Section 3, a mass/area was not used to select the areas in this way.

2. The length weighted average concentration was calculated assuming the concentration below the deposited PCBs is 1 ppm.

Table 12
TSS Average Concentration within the Plume at 300 m Downstream and under 8000 cfs Flow

Management Levels	River Section 1	River Section 2	River Section 3
350 ng/L	94	54	110
600 g/day	23	11	22

Table 13
Average Source Strength Estimated Fluxes and Concentrations for River Section 1 with Various Flows and Total PCB Sediment Concentrations

INPUT			TSS-Chem RESULTS				PERCENT LOSS	
Silt Sediment PCB Concentration (mg/kg)	Silt Fraction unitless	TSS Silt Source Strength (1,2) (kg/s)	Net TSS Flux at 1 mile (2) (kg/day)	Net Total PCB Flux at 1 mile (2) (g/day)	Net Fraction Dissolved PCBs at 1 mile unitless	Concentration increase at 1 mile (ng/l)	TSS Loss at 1 mile %	PCB Loss at 1 mile %
4000 cfs								
27	0.37	0.077	2,303	78	0.35	14	0.11	0.14
30	0.37	0.077	2,303	87	0.36	15	0.11	0.15
36	0.37	0.077	2,303	105	0.37	18	0.11	0.18
2000 cfs								
27	0.37	0.077	671	39	0.55	14	0.03	0.07
30	0.37	0.077	671	44	0.56	15	0.03	0.08
36	0.37	0.077	671	53	0.57	19	0.03	0.09
5000 cfs								
27	0.37	0.077	2,721	86	0.27	12	0.13	0.15
30	0.37	0.077	2,721	95	0.28	13	0.13	0.17
36	0.37	0.077	2,721	115	0.28	16	0.13	0.20

Table 14
Range of Values and Relative Sensitivities of Each Parameter

				Relative Model Sensitivity			
Input parameter		Range of Values	Default Value	Net Fraction Dissolved PCBs at 1 mile	Distance where coarse < 0.1%	Net PCB Flux at 1 mile	Net TSS Flux at 1 mile
River-wide Volumetric Flow (Velocity & Depth)	Q	2000-8000 cfs	4000 cfs	moderate	low	moderate	low
Velocity (alone)	u	0.08-0.25 m/s	0.131 m/s	moderate	moderate	moderate	low
Depth (alone)	h	0.9-2.3 m	1.88 m	low	moderate	moderate	moderate
Source Strength	g	0.01-40 kg/s	1 kg/s	moderate (high at low values of source strength)	none	high	high
Silt Fraction Entering	fsilt,sed	0-1	0.66 (Section 1)	moderate	low	high	high
Sediment PCB Concentration	Csed	1-1000 mg/kg	27 mg/kg (Section 1)	high (low at high concentrations)	none	high	none
Dissolved Fraction in Background (& TSS Concentration in Background)[1]	fd,bkg	0.31-0.97	0.9 (Sections 1)	low	none	low	none
Partition Coefficient (& PCB Dissolved Fraction in Background)[2]	Kd	5E3-5E5 L/kg	4.8E4 (Sections 1)	high	none	low	none
Desorption Rate	λ	1.6E-4 to 0.2 hr^{-1}	0.2 hr^{-1}	high	none	low	none
Lateral Dispersion (alone)	k(y)	1E-4 to 1E2	0.014 m^2/s	low (high at low coefficients)	none	low	low
Total PCB Concentration in Background	PCB(bkg)	0-500 ng/L	122 ng/L (Section 1)	low	none	low	none
Silt Settling Velocity	w(silt)	4.1-9 m/day	6.9 m/day (8E-5 m/s)	low	none	moderate	moderate
Coarse Settling Velocity	w(coarse)	0.03-0.08 m/s	0.06 m/s	low	high	low	none

Notes:

1. The dissolved PCB fraction in the background and the TSS concentration were varied, with Kd held constant at 5,500 L/kg.
2. The partition coefficient (Kd) and PCB dissolved fraction in the background was varied with TSS background concentration held constant at 2.3 mg/L.

Table 15
Effect on Model Output Values from Increase in Input Paramters

Input parameter		Effect on Net Fraction Dissolved PCBs at 1 mile	Effect on distance where coarse < 0.1%	Effect on Net PCB Flux at 1 mile	Effect on Net TSS Flux at 1 mile
River-wide Volumetric Flow (Velocity, Depth and Lateral Dispersion)	Q	Varies	Varies	Varies	Varies
Velocity (alone)	u	Decrease	Increase (linear)	Increase	Increase
Depth (alone)	h	Increase	Increase (linear)	Increase	Increase
Source Strength	g	Decrease	No Effect	Increase (linear)	Increase (linear)
Silt Fraction Entering	fsilt,sed	Decrease	Decrease	Increase (linear)	Increase (linear)
Sediment PCB Concentration	Csed	Increase	No Effect	Increase (linear)	No Effect
Dissolved Fraction in Background (& TSS Concentration in Background)[1]	fd,bkg	Increase	No Effect	Decrease	No Effect
Partition Coefficient (& PCB Dissolved Fraction in Background)[2]	Kd	Decrease	No Effect	Decrease	No Effect
Desorption Rate	λ	Increase	No Effect	Increase	No Effect
Lateral Dispersion (alone)	k(y)	Increase	No Effect	Increase	No Effect
Total PCB Concentration in Background	PCB(bkg)	Decrease (linear)	No Effect	Decrease (linear)	No Effect
Silt Settling Velocity	w(silt)	Increase (linear)	Increase	Decrease	Decrease
Coarse Settling Velocity	w(coarse)	No Effect	Decrease	No Effect	No Effect

Notes:

1. The dissolved PCB fraction in the background and the TSS concentration were varied, with Kd held constant at 5,500 L/kg.
2. The partiton coefficient (Kd) and PCB dissolved fraction in the background was varied with TSS background concentration held constant a
3. Due to the stepwise characteristic of the model (particularly with the distance to 0.1% coarse material), linearity was defined as an r-square greater than 99%.

Table 16
Average Sensitivity Values and Individual magnitudes

		Average $S_{parameter,output}$			
Input parameter		Net Fraction Dissolved PCBs at 1 mile	Distance where coarse < 0.1%	Net PCB Flux at 1 mile	Net TSS Flux at 1 mile
River-wide Volumetric Flow (Velocity & Depth)	Q	-0.51 (-)	0.69 (+/-)	0.32 (+/-)	0.37 (+/-)
Velocity (alone)	u	-0.71 (-)	0.97 (+)	0.43 (+)	0.52 (+)
Depth (alone)	h	0.17 (+)	1.07 (+)	0.57 (+)	0.61 (+)
Source Strength	g	-0.49 (-)	0	0.96 (+)	1 (+)
Silt Fraction Entering	fsilt,sed	-0.71 (-)	-0.72 (-)	0.96 (+)	1 (+)
Sediment PCB Concentration	Csed	0.9 (+)	0	1.02 (+)	0
Dissolved Fraction in Background (& TSS Concentration in Background)[1]	fd,bkg	0.27 (+)	0	-0.09 (+/-)	0
Partition Coefficient (& PCB Dissolved Fraction in Background)[2]	Kd	-0.93 (-)	0	-0.05 (-)	0
Desorption Rate	λ	0.87 (+)	0	0.03 (+)	0
Lateral Dispersion (alone)	k(y)	0.2 (+)	0	0.02 (+)	-5.44E-17 (+/-)
Total PCB Concentration in Background	PCB(bkg)	-0.23 (-)	0	-0.02 (-)	0
Silt Settling Velocity	w(silt)	0.33 (+)	0	-0.45 (-)	-0.53 (-)
Coarse Settling Velocity	w(coarse)	-0.0002 (-)	-1.25 (-)	-0.0009 (-)	0

Notes:

1. The dissolved PCB fraction in the background and the TSS concentration were varied, with Kd held constant at 5,500 L/kg.
2. The partition coefficient (Kd) and PCB dissolved fraction in the background was varied with TSS background concentration held constant at 2.3 mg/L.
3. The sign (+/-) indicates that the individual Sensitivity values were both positive and negative.

Table 17
Average Baseline Conditions at Thompson Island Dam

Month	Mean flow, q[1] (cfs)	Mean baseline concentrations[2] TSS (mg/L)	TPCB (ng/L)	Mean baseline Load (g/sec)
May	7,800	4	128	0.028
June	4,200	5	169	0.020
July	3,000	2	138	0.012
August	3,000	2	96	0.008
September	3,100	2	75	0.007
October	4,300	2	127	0.015
November	5,500	2	127	0.020
June - Nov Average[3]	3,900	2.3	122	0.014

Notes:

[1] Mean flow was estimated based on USGS flow data from 1977 to 2002 at Thompson Island Dam.

[2] TSS and TPCB values are arithmetic means obtained from the baseline analysis study. See Attachment A for detail analysis.

[3] Only June to November mean baseline concentrations were used. May was excluded since flow is not typical.

Table 18
Average Baseline Conditions at Schuylerville

Month	Mean flow, q[1] (cfs)	Mean baseline concentrations[2] TSS (mg/L)	TPCB (ng/L)	Mean baseline load (g/sec)
May	8,800	3	106	0.026
June	4,900	5	106	0.015
July	3,400	2	82	0.008
August	3,400	2	74	0.007
September	3,600	2	52	0.005
October	4,800	2	75	0.010
November	6,200	2	67	0.012
June - Nov Average[3]	4,400	2.3	76	0.009

Notes:

[1] Mean flow was estimated based on USGS flow data from 1977 to 2002 at Schuylerville

[2] TSS and TPCB values are arithmetic means obtained from the baseline analysis study. See Attachment A for detail analysis.

[3] Only June to November mean baseline concentrations were used. May was excluded since flow is not typical.

Table 19
Average Baseline Conditions at Waterford

Month	Mean flow, q[1] (cfs)	Mean baseline concentrations[2] TSS (mg/L)	TPCB (ng/L)	Mean baseline load (g/sec)
May	11,300	2	79	0.025
June	6,400	3	79	0.014
July	4,200	1	61	0.007
August	4,000	1	55	0.006
September	4,200	1	39	0.005
October	6,500	1	56	0.010
November	8,300	1	50	0.012
June - Nov Average[3]	5,600	1.7	57	0.009

Notes:

[1] Mean flow was estimated based on USGS flow data from 1977 to 2002 at Waterford

[2] TSS and TPCB values were obtained by multiplying a dilution factor based on drainage area ratio. Drainage areas were obtained from USGS data. Drainage area for Schuylerville and Waterford is 4611 and 3440 ft ^{2}, respectively.

[3] Only June to November mean baseline concentrations were used. May was excluded since flow is not typical.

Table 20
Daily Net Dredging Total PCB Flux for River Sections 1, 2, and 3 at the Monitoring Stations

Month	River Section 1 (TID)		River Section 2 (Schuylerville)		River Section 3 (Waterford)	
	Net Dredge TPCB Flux (14-hr basis) g/day	Net Dredge TPCB Flux (24-hr basis) g/day	Net Dredge TPCB Flux (14-hr basis) g/day	Net Dredge TPCB Flux (24-hr basis) g/day	Net Dredge TPCB Flux (14-hr basis) g/day	Net Dredge TPCB Flux (24-hr basis) g/day
May	2,500	4,200	3,000	5,200	4,400	7,500
June	1,100	1,900	1,700	2,900	2,500	4,200
July	900	1,600	1,300	2,300	1,700	3,000
August	1,100	1,800	1,300	2,300	1,700	2,900
September	1,200	2,100	1,500	2,600	1,900	3,200
October	1,400	2,300	1,900	3,200	2,700	4,700
November	1,700	3,000	2,500	4,300	3,600	6,100
June - Nov Average	***1,200***	2,100	***1,700***	2,900	***2,300***	4,000

Note:

Numbers are rounded to 2 significant digits

Bold italic numbers - values were used as the TPCB flux representing the 350 ng/L at the monitoring stations.

Table 21
HUDTOX Input for 350 ng/L with TSS Flux at 1 Mile Downstream of the Dredge-Head

Sediment removal season	Dredging Location	speed	Cubic yards of sediment removed[1]	Monitoring Location (Compliance Point)[2]	Sediment Total PCB concentration[3] (mg/kg)	Expected Total PCB export rate at compliance point[4] (g/day)	Percent remaining at the monitoring location[5]	TPCB input flux to HUDTOX (g/day)	Ratio of Total to Tri+ PCB[6]	Tri+ PCB Flux input to HUDTOX[7] (g/day)	TSS Flux input to HUDTOX[8] (kg/day)	HUDTOX Segment(s)
Jun. 1 - Sep. 15, 2006[9]	Sec. 1	half	260,000	TID	27	1,237	75%	1,649	3.2	520	58,800	5 & 7
May 1 - Nov. 30, 2007	Sec. 1	full	520,000	TID	27	1,237	75%	1,649	3.2	520	58,800	11 & 13
May 1 - Nov. 30, 2008	Sec. 1	full	520,000	TID	27	1,237	75%	1,649	3.2	520	58,800	20 & 22
May 1 - Aug. 15, 2009	Sec. 1 &	full	260,000	TID	27	1,237	75%	1,649	3.2	520	58,800	26 & 28
Aug. 16 - Nov. 30, 200	Sec. 2		290,000	Schuylerville	62	2,034	75%	2,712	3.4	670	34,300	30
May 1 - Aug. 15, 2010	Sec. 2 &	full	290,000	Schuylerville	62	2,034	75%	2,712	3.4	670	34,300	31
Aug. 16 - Nov. 30, 201	Sec. 3		255,000	Waterford	29	2,334	75%	3,112	2.7	1,150	104,500	38
May 1 - Aug. 15, 2011	Sec. 3	full	255,000	Waterford	29	2,334	75%	3,112	2.7	1,150	104,500	45

Notes:

[1] Volume of sediment removed is taken from Table 8-9 of the Feasibility Study.

[2] All TIP monitoring is done at TID, all River Section 2 monitoring is done at Schuylerville, and all River Section 3 monitoring is done at Waterford. 1 mile exclusion is not considered.

[3] Total PCB concentration in the sediment is for the dredge material and was taken from Table 363334-6 of the Sediment Inventory White Paper of the Resp. Summ.

[4] Total PCB Flux is the average net flux for June to Nov at the compliance point (TID, Schuylerville, & Waterford). PCB flux in May was excluded since flow is not typical.

[5] Percent reduction at the monitoring location was obtained from the initial HUDTOX runs performed for the preliminary draft of the resuspension performance standard

[6] Ratio of Total to Tri+ PCB is based on the amount of Total PCB and Tri+ PCB removed for each river section (USEPA 2002).

[7] Tri+ PCB flux is calculated based on the Total PCB flux 1 mile downstream of the dredgehead divided by the ratio of Total to Tri+ PCB for each section.

[8] TSS flux from TSS-Chem model, 1 mile downstream of the dredge-head

[9] Actual dredging period is from May 1 - Nov. 30, 2006. The PCB and TSS flux is loaded only from June 1 to Sep. 15, 2006 to account for half speed operation.

Table 22
TSS Flux Comparisons for Different Scenarios

Sediment removal season	Dredging Location	speed	Cubic yards of sediment removed	Monitoring Location (Compliance Point)[1]	Full TSS Flux[2] (kg/day)	TSS Flux[3] @ 1 mile (kg/day)	TSS Flux[3] @ 3 mile (kg/day)	TSS Flux[4] @ 1 mile with corrected percent reduction (kg/day)
Jun. 1 - Sep. 15, 2006[5]	Sec. 1	half	260,000	TID	60,602	58,800	51,200	61,030
May 1 - Nov. 30, 2007	Sec. 1	full	520,000	TID	60,602	58,800	51,200	60,575
May 1 - Nov. 30, 2008	Sec. 1	full	520,000	TID	60,602	58,800	51,200	53,423
May 1 - Aug. 15, 2009	Sec. 1 &	full	260,000	TID	60,602	58,800	51,200	45,599
Aug. 16 - Nov. 30, 2009	Sec. 2		290,000	Schuylerville	36,595	34,300	26,500	37,814
May 1 - Aug. 15, 2010	Sec. 2 &	full	290,000	Schuylerville	36,595	34,300	26,500	32,242
Aug. 16 - Nov. 30, 2010	Sec. 3		255,000	Waterford	107,575	104,500	98,400	106,675
May 1 - Aug. 15, 2011	Sec. 3	full	255,000	Waterford	107,575	104,500	98,400	82,308

Notes:

[1] All TIP monitoring is done at TID, all River Section 2 monitoring is done at Schuylerville, and all River Section 3 monitoring is done at Waterford. 1 mile exclusion is not considered.

[2] TSS flux using the concentrations of the dredged sediment in each section of the river

[3] TSS flux is obtained from TSS-Chem model output.

[4] TSS flux is obtained from TSS-Chem model output at 1 mile with corrected percent reduction at the monitoring stations.

[5] Actual dredging period is from May 1 - Nov. 30, 2006. The PCB and TSS flux is loaded only from June 1 to Sep. 15, 2006 to account for half speed operation.

Table 23
HUDTOX Input for 350 ng/L with TSS Flux at 1 Mile Downstream of the Dredge-Head and Corrected Percent Reduction at the Monitoring Stations

Sediment removal season	Dredging Location	speed	Cubic yards of sediment removed[1]	Monitoring Location (Compliance Point)[2]	Sediment Total PCB concentration[3] (mg/kg)	Expected Total PCB export rate at compliance point[4] (g/day)	Percent remaining at the monitoring location[5]	TPCB input flux to HUDTOX (g/day)	Ratio of Total to Tri+ PCB[6]	Tri+ PCB Flux input to HUDTOX[7] (g/day)	TSS Flux input to HUDTOX[8] (kg/day)	HUDTOX Segment(s)
Jun. 1 - Sep. 15, 2006[9]	Sec. 1	half	260,000	TID	27	1,237	73%	1,697	3.2	530	61,030	5 & 7
May 1 - Nov. 30, 2007	Sec. 1	full	520,000	TID	27	1,237	73%	1,684	3.2	526	60,575	11 & 13
May 1 - Nov. 30, 2008	Sec. 1	full	520,000	TID	27	1,237	83%	1,490	3.2	466	53,423	20 & 22
May 1 - Aug. 15, 2009	Sec. 1 &	full	260,000	TID	27	1,237	97%	1,278	3.2	399	45,599	26 & 28
Aug. 16 - Nov. 30, 200	Sec. 2		290,000	Schuylerville	62	2,034	82%	2,466	3.4	725	37,814	30
May 1 - Aug. 15, 2010	Sec. 2 &	full	290,000	Schuylerville	62	2,034	96%	2,117	3.4	623	32,242	31
Aug. 16 - Nov. 30, 201	Sec. 3		255,000	Waterford	29	2,334	74%	3,150	2.7	1,167	106,675	38
May 1 - Aug. 15, 2011	Sec. 3	full	255,000	Waterford	29	2,334	96%	2,441	2.7	904	82,308	45

Notes:

[1] Volume of sediment removed is taken from Table 8-9 of the Feasibility Study.

[2] All TIP monitoring is done at TID, all River Section 2 monitoring is done at Schuylerville, and all River Section 3 monitoring is done at Waterford. 1 mile exclusion is not considered.

[3] Total PCB concentration in the sediment is for the dredge material and was taken from Table 363334-6 of the Sediment Inventory White Paper of the Resp. Summ.

[4] Total PCB Flux is the average net flux for June to Nov at the compliance point (TID, Schuylerville, & Waterford). PCB flux in May was excluded since flow is not typical.

[5] Percent remaining at the monitoring location was obtained from the initial HUDTOX runs performed for the preliminary draft of the resuspension performance standard

[6] Ratio of Total to Tri+ PCB is based on the amount of Total PCB and Tri+ PCB removed for each river section (USEPA 2002).

[7] Tri+ PCB flux is calculated based on the Total PCB flux 1 mile downstream of the dredgehead divided by the ratio of Total to Tri+ PCB for each section.

[8] TSS flux from TSS-Chem model, 1 mile downstream of the dredge-head

[9] Actual dredging period is from May 1 - Nov. 30, 2006. The PCB and TSS flux is loaded only from June 1 to Sep. 15, 2006 to account for half speed operation.

Table 24
HUDTOX Schedule and Input Loading for 300 g/day Export Rate Scenario

River Section	Dredging Season	Monitoring Station	Tri+ PCB Flux input to HUDTOX[1] (g/day)	TSS Flux input to HUDTOX[2] (kg/day)	TPCB input flux to HUDTOX[3] (g/day)	Percent remaining at the monitoring location[4]	Expected Total PCB at monitoring station[5] (g/day)
Section 1 dredging	May 1-Nov 30, 2006	TID	129	13,948	411	73%	300
	May 1-Nov 30, 2007	TID	128	13,828	408	73%	300
	May 1-Nov 30, 2008	TID	113	12,130	361	83%	300
	May 1-Aug 15, 2009	TID	97	10,311	310	97%	300
Section 2 dredging	Aug 16 - Nov 30, 2009	Schuylerville	107	4,873	364	82%	300
	May 1 - Aug 15, 2010	Schuylerville	92	4,118	312	96%	300
Section 3 dredging	Aug 16 - Nov 30, 2010[3]	Waterford	150	12,725	405	74%	300
	May 1 - Aug 15, 2011	Waterford	116	9,702	314	96%	300

Notes:

[1] Tri+ PCB flux is calculated by dividing the TPCB flux with the Total to Tri+ PCB ratio estimated in the RS. The ratio is 3.2 for Section 1, 3.4 for Section 2, and 2.7 for Section 3

[2] TSS flux from TSS-Chem model, 1 mile downstream of the dredge-head

[3] Total PCB input is based on the expected flux at monitoring locations divide by the percent reduction. Same as Gaussian plume output at 1 mile.

[4] Percent remaining at the monitoring location was obtained from the initial HUDTOX runs performed for the preliminary draft of the resuspension performance standard

[5] Expected net export rate of TPCB flux at monitoring station (300 g/day).

Table 25
HUDTOX Schedule and Input Loading for 600 g/day Export Rate Scenario

River Section	Dredging Season	Monitoring Station	Tri+ PCB Flux input to HUDTOX[1] (g/day)	TSS Flux input to HUDTOX[2] (kg/day)	TPCB input flux to HUDTOX[3] (g/day)	Percent reduction at the monitoring location[4]	Expected Total PCB at monitoring station[5] (g/day)
Section 1 dredging	May 1-Nov 30, 2006	TID	257	28,975	823	73%	600
	May 1-Nov 30, 2007	TID	255	28,676	817	73%	600
	May 1-Nov 30, 2008	TID	226	25,179	723	83%	600
	May 1-Aug 15, 2009	TID	194	21,582	620	97%	600
Section 2 dredging	Aug 16 - Nov 30, 2009	Schuylerville	214	10,379	728	82%	600
	May 1 - Aug 15, 2010	Schuylerville	184	8,799	625	96%	600
Section 3 dredging	Aug 16 - Nov 30, 2010	Waterford	300	26,398	810	74%	600
	May 1 - Aug 15, 2011	Waterford	232	20,193	627	96%	600

Notes:

[1] Tri+ PCB flux is calculated by dividing the TPCB flux with the Total to Tri+ PCB ratio estimated in the RS. The ratio is 3.2 for Section 1, 3.4 for Section 2, and 2.7 for Section 3

[2] TSS flux from TSS-Chem model, 1 mile downstream of the dredge-head

[3] Total PCB input is based on the expected flux at monitoring locations divide by the percent reduction. Same as Gaussian plume output at 1 mile.

[4] Percent reduction at the monitoring location was obtained from the initial HUDTOX runs performed for the preliminary draft of the resuspension performance standard

[5] Expected net export rate of TPCB flux at monitoring station (600 g/day).

Table 26
Percent Reduction at the Monitoring Locations Comparison for the 350 ng/L Scenario

River Section	Dredging Season	Monitoring Station[1]	d006 percent remaining[2]	d007 percent remaining[3]	sr03 percent remaining[4]	sr04 percent remaining[5]
Section 1 dredging	May 1-Nov 30, 2006	TID	73%	74%	82%	73%
	May 1-Nov 30, 2007	TID	73%	74%	85%	73%
	May 1-Nov 30, 2008	TID	83%	83%	91%	83%
	May 1-Aug 15, 2009	TID	97%	97%	99%	97%
Section 2 dredging	Aug 16 - Nov 30, 2009	Schuylerville	82%	84%	92%	83%
	May 1 - Aug 15, 2010	Schuylerville	96%	97%	99%	96%
Section 3 dredging	Aug 16 - Nov 30, 2010	Waterford	74%	75%	85%	71%
	May 1 - Aug 15, 2011	Waterford	96%	96%	99%	95%

Notes:

[1] All TIP monitoring is done at TID, all River Section 2 monitoring is done at Schuylerville, and all River Section 3 monitoring is done at Waterford. 1 mile exclusion is not considered.

[2] d006 is the 350 ng/L model run with TSS and TPCB flux at 1 mile downstream of the dredge-head obtained from TSS-Chem.

[3] d007 is the 350 ng/L model run with TSS and TPCB flux at 3 mile downstream of the dredge-head obtained from TSS-Chem.

[4] sr03 is the 350 ng/L model run without any TSS flux associated with the TPCB flux.

[5] sr04 is the 350 ng/L model with TSS and TPCB flux at 1 mile downstream of the dredge-head and corrected percent reduction.

Table 27
Expected versus Model Prediction of PCB Flux for Control Level 3 - 350 ng/L Scenario

River Section	Dredging Season	Monitoring Station	Total PCB @ monitoring station				
			Expected (g/day)[2]	d006 - model estimate[3] (g/day)	d007 - model estimate[4] (g/day)	sr03 - model estimate[5] (g/day)	sr04 - model estimate[6] (g/day)
Section 1 dredging	May 1-Nov 30, 2006	TID	1237	1213	1224	1360	1234
	May 1-Nov 30, 2007	TID	1237	1222	1233	1410	1244
	May 1-Nov 30, 2008	TID	1237	1381	1389	1519	1252
	May 1-Aug 15, 2009	TID	1237	1611	1615	1653	1245
Section 2 dredging	Aug 16 - Nov 30, 2009	Schuylerville	2034	1879	1909	2097	2049
	May 1 - Aug 15, 2010	Schuylerville	2034	2189	2200	2261	2029
Section 3 dredging	Aug 16 - Nov 30, 2010	Waterford	2334	2276	2290	2619	2223
	May 1 - Aug 15, 2011	Waterford	2334	2969	2974	3083	2302

Notes:

[1] Output loading from HUDTOX d006 run at the assigned monitoring station.

[2] Total PCB flux at the monitoring station based on max concentration of 350 ng/L minus baseline concentrations.

[3] d006 is the 350 ng/L model run with TSS and TPCB flux at 1 mile downstream of the dredge-head obtained from TSS-Chem.

[4] d007 is the 350 ng/L model run with TSS and TPCB flux at 3 mile downstream of the dredge-head obtained from TSS-Chem.

[5] sr03 is the 350 ng/L model run without any TSS flux associated with the TPCB flux.

[6] sr04 is the 350 ng/L model with TSS and TPCB flux at 1 mile downstream of the dredge-head and corrected percent reduction.

Table 28
Annual Tri+ PCB Load Over TID

Year	MNA (p3nas2)	No Resuspension (d004)	Total PCB 350 ng/L @ 1 mile (d006)	Total PCB 350 ng/L @ 3 mile (d007)	Total PCB 350 ng/L fraction remaining adjusted (sr04)	Total PCB 350 ng/L with no Solids (sr03)	Total PCB 600g/day (sr01)	Total PCB 300 g/day (sr02)	Accidental Release (srA1)
	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load
2005	0	0	0	0	0	0	0	0	0
2006	57	56	97	97	98	102	77	67	77
2007	114	106	228	230	231	246	169	138	169
2008	152	133	348	349	341	374	237	185	237
2009	190	154	423	425	405	452	279	217	279
2010	241	180	450	452	431	478	305	244	305
2011	284	203	474	475	455	501	328	266	328
2012	325	224	495	497	477	523	350	288	350
2013	365	246	517	519	498	545	371	309	371
2014	398	264	536	538	517	564	390	328	390
2015	429	282	554	556	535	582	408	346	408
2016	454	297	569	571	550	597	423	361	423
2017	476	311	583	586	564	612	437	375	437
2018	503	327	599	601	580	627	453	391	453
2019	524	340	612	614	593	641	466	404	466
2020	546	354	626	629	607	655	480	418	480
2021	567	368	640	642	621		494		494
2022	584	380	652	655	633		506		506
2023	601	392	664	666	644		518		518
2024	622	405	677	680	658		531		531
2025	639	417	689	692	670		543		543
2026	656	429	701	704	682		555		555
2027	671	440	712	715	693		566		566
2028	686	452	724	727	705		578		578
2029	702	463	735	738	716		589		589
2030	716	475	747	750	728		601		601
2031	732	486	758	761	739		612		
2032	747	497	769	772	750		623		
2033	760	508	780	783	761		634		
2034	774	519	791	794	771		645		
2035	787	529	801	804	782		656		
2036	801	540	812	815	793		666		
2037	814	551	823	826	803		677		
2038	826	561	832	836	813		687		
2039	841	571	843	846	824		698		
2040	852	581	853	856	834		707		

Table 28
Annual Tri+ PCB Load Over TID

Year	MNA (p3nas2) Cumulative Load	No Resuspension (d004) Cumulative Load	Total PCB 350 ng/L @ 1 mile (d006) Cumulative Load	Total PCB 350 ng/L @ 3 mile (d007) Cumulative Load	Total PCB 350 ng/L fraction remaining adjusted (sr04) Cumulative Load	Total PCB 350 ng/L with no Solids (sr03) Cumulative Load	Total PCB 600g/day (sr01) Cumulative Load	Total PCB 300 g/day (sr02) Cumulative Load	Accidental Release (srA1) Cumulative Load
2041	864	591	863	866	844		717		
2042	874	600	872	875	853		726		
2043	887	611	882	886	863		737		
2044	899	621	893	896	873		747		
2045	911	631	902	906	883		757		
2046	921	640	912	915	893		766		
2047	932	649	921	924	902		776		
2048	944	659	930	934	911		785		
2049	955	668	939	943	920		794		
2050	967	677	949	952	930		804		
2051	979	687	959	962	940		813		
2052	989	696	968	971	949		822		
2053	999	705	976	980	957		831		
2054	1009	714	985	988	966		840		
2055	1019	723	995	998	975		849		
2056	1028	731	1003	1006	984		858		
2057	1038	740	1012	1015	993		867		
2058	1047	749	1021	1024	1002		876		
2059	1057	758	1030	1033	1010		884		
2060	1067	767	1039	1042	1020		894		
2061	1078	777	1049	1052	1030		904		
2062	1087	786	1057	1061	1038		912		
2063	1096	794	1066	1069	1047		921		
2064	1105	803	1075	1078	1056		930		
2065	1114	812	1084	1087	1065		939		
2066	1123	821	1092	1096	1073		947		
2067	1132	829	1101	1104	1081		956		

Table 29
Tri+ PCB Load Over Schuylerville

Year	MNA (p3nas2)	No Resuspension (d004)	Total PCB 350 ng/L @ 1 mile (d006)	Total PCB 350 ng/L @ 3 mile (d007)	Total PCB 350 ng/L fraction remaining adjusted (sr04)	Total PCB 350 ng/L with no Solids (sr03)	Total PCB 600g/day (sr01)	Total PCB 300 g/day (sr02)	Accidental Release (srA1)	Total PCB 600 g/day corrected to MNA (sr01)
	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load
2005	0	0	0	0	0	0	0	0	0	0
2006	78	77	110	111	111	117	94	86	94	94
2007	162	155	256	258	258	280	208	183	208	208
2008	207	190	362	365	357	404	276	234	276	276
2009	253	221	496	501	488	551	344	285	344	359
2010	327	263	610	615	596	667	405	337	405	442
2011	390	291	640	645	626	697	434	365	434	471
2012	444	316	668	673	654	723	460	390	460	496
2013	499	341	695	701	681	750	485	416	485	522
2014	540	361	717	723	703	772	507	437	507	543
2015	578	381	738	744	723	793	527	457	527	564
2016	607	397	755	761	740	809	543	473	543	580
2017	632	412	770	776	755	825	558	488	558	595
2018	666	429	788	794	773	843	575	505	575	612
2019	690	443	802	808	787	857	589	519	589	626
2020	717	458	818	824	803	873	604	534	604	641
2021	742	472	832	839	817		619		619	655
2022	761	485	845	851	830		631		631	668
2023	779	496	857	863	842		643		643	679
2024	804	511	872	878	857		658		658	694
2025	824	523	884	891	869		670		670	707
2026	843	536	897	904	882		682		682	719
2027	859	547	908	915	893		693		693	730
2028	877	559	920	927	905		705		705	742
2029	894	570	932	938	917		717		717	754
2030	910	582	943	950	928		728		728	765
2031	929	594	955	962	940		741			777
2032	945	605	967	974	952		752			789
2033	959	616	977	984	962		762			799
2034	974	627	988	995	973		773			810
2035	988	638	999	1006	984		784			821
2036	1003	649	1010	1017	995		795			832
2037	1018	659	1021	1028	1006		806			843
2038	1030	669	1031	1038	1016		816			853
2039	1046	680	1042	1049	1027		827			864
2040	1058	690	1052	1059	1037		837			873
2041	1070	700	1062	1069	1047		846			883
2042	1079	708	1070	1077	1055		855			891
2043	1093	719	1081	1088	1066		866			902
2044	1106	730	1091	1099	1076		876			913
2045	1119	739	1101	1108	1086		886			923

Table 29

Tri+ PCB Load Over Schuylerville

Year	MNA (p3nas2)	No Resuspension (d004)	Total PCB 350 ng/L @ 1 mile (d006)	Total PCB 350 ng/L @ 3 mile (d007)	Total PCB 350 ng/L fraction remaining adjusted (sr04)	Total PCB 350 ng/L with no Solids (sr03)	Total PCB 600g/day (sr01)	Total PCB 300 g/day (sr02)	Accidental Release (srA1)	Total PCB 600 g/day corrected to MNA (sr01)
	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load
2046	1130	749	1111	1118	1096		896			932
2047	1140	758	1120	1127	1105		905			942
2048	1152	767	1129	1136	1114		914			951
2049	1163	776	1138	1145	1123		923			960
2050	1175	786	1147	1155	1132		932			969
2051	1188	795	1157	1164	1142		942			979
2052	1198	804	1166	1173	1151		951			988
2053	1208	812	1174	1181	1159		959			996
2054	1217	821	1183	1190	1168		968			1005
2055	1228	830	1192	1199	1177		978			1014
2056	1237	838	1200	1207	1185		985			1022
2057	1247	847	1209	1216	1194		994			1031
2058	1256	855	1217	1224	1202		1003			1039
2059	1265	864	1226	1233	1211		1011			1048
2060	1275	873	1235	1242	1220		1021			1057
2061	1286	883	1245	1252	1230		1031			1067
2062	1295	892	1253	1261	1238		1039			1076
2063	1304	900	1262	1269	1247		1047			1084
2064	1313	908	1270	1277	1255		1056			1092
2065	1322	917	1279	1286	1264		1064			1101
2066	1331	925	1287	1294	1272		1073			1109
2067	1339	933	1295	1302	1280		1081			1117

Table 30
Tri+ PCB Load Over Waterford

Year	MNA (p3nas2)	No Resuspension (d004)	Total PCB 350 ng/L @ 1 mile (d006)	Total PCB 350 ng/L @ 3 mile (d007)	Total PCB 350 ng/L fraction remaining adjusted (sr04)	Total PCB 350 ng/L with no Solids (sr03)	Total PCB 600g/day (sr01)	Total PCB 300 g/day (sr02)	Accidental Release (srA1)	Total PCB 600 g/day corrected to MNA (sr01)
	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load
2005	0	0	0	0	0	0	0	0	0	0
2006	102	102	116	117	117	122	110	106	110	110
2007	205	201	250	251	251	266	227	214	227	227
2008	254	245	325	327	324	352	287	267	287	287
2009	301	285	404	408	401	445	342	315	342	349
2010	393	353	607	612	601	664	451	404	451	484
2011	464	397	782	788	754	843	524	463	535	580
2012	528	437	848	854	818	908	572	508	584	628
2013	595	478	906	912	875	967	618	551	631	674
2014	643	508	949	955	917	1010	652	583	665	708
2015	687	536	987	993	954	1047	683	612	696	738
2016	714	553	1010	1017	977	1069	702	631	715	757
2017	738	569	1032	1038	998	1090	719	648	733	775
2018	771	588	1055	1061	1021	1113	739	667	753	795
2019	793	602	1072	1079	1039	1130	754	681	768	810
2020	821	620	1094	1100	1059	1151	772	699	786	828
2021	847	636	1112	1119	1078		789		803	845
2022	865	648	1127	1133	1092		802		816	858
2023	882	659	1140	1146	1105		813		827	869
2024	911	677	1160	1166	1125		832		846	888
2025	930	689	1174	1180	1139		845		859	901
2026	949	702	1188	1194	1153		858		872	913
2027	964	712	1199	1205	1164		868		882	924
2028	982	724	1211	1218	1177		880		894	936
2029	999	736	1224	1230	1189		892		906	948
2030	1015	747	1236	1242	1201		903		917	959
2031	1033	759	1248	1255	1213		916			972
2032	1048	769	1259	1266	1224		926			982
2033	1061	779	1269	1276	1234		936			992
2034	1077	790	1281	1287	1246		947			1003
2035	1100	809	1292	1298	1257		958			1014
2036	1134	839	1303	1310	1268		970			1026
2037	1164	864	1316	1324	1281		1001			1057
2038	1185	882	1341	1349	1307		1023			1079
2039	1212	905	1372	1380	1338		1050			1106
2040	1228	919	1391	1399	1357		1067			1123
2041	1243	932	1408	1416	1374		1082			1138
2042	1253	941	1420	1428	1385		1093			1149
2043	1272	958	1440	1447	1405		1111			1166
2044	1292	974	1457	1465	1423		1128			1184
2045	1308	987	1471	1479	1437		1141			1197

Table 30
Tri+ PCB Load Over Waterford

Year	MNA (p3nas2)	No Resuspension (d004)	Total PCB 350 ng/L @ 1 mile (d006)	Total PCB 350 ng/L @ 3 mile (d007)	Total PCB 350 ng/L fraction remaining adjusted (sr04)	Total PCB 350 ng/L with no Solids (sr03)	Total PCB 600g/day (sr01)	Total PCB 300 g/day (sr02)	Accidental Release (srA1)	Total PCB 600 g/day corrected to MNA (sr01)
	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load	Cumulative Load
2046	1322	1000	1484	1492	1450		1154			1210
2047	1334	1010	1496	1503	1461		1165			1221
2048	1346	1020	1507	1514	1472		1176			1232
2049	1356	1028	1516	1523	1481		1185			1241
2050	1369	1039	1527	1535	1492		1195			1251
2051	1382	1049	1539	1546	1504		1207			1262
2052	1392	1057	1547	1555	1513		1215			1271
2053	1400	1065	1555	1562	1520		1222			1278
2054	1409	1072	1563	1570	1528		1230			1286
2055	1419	1081	1572	1579	1537		1239			1295
2056	1426	1087	1579	1586	1544		1245			1301
2057	1435	1095	1587	1594	1552		1254			1310
2058	1443	1103	1595	1602	1560		1261			1317
2059	1451	1110	1602	1609	1567		1269			1325
2060	1462	1120	1612	1619	1577		1278			1334
2061	1473	1130	1622	1629	1587		1289			1345
2062	1481	1137	1629	1636	1594		1296			1352
2063	1488	1144	1636	1643	1601		1303			1359
2064	1495	1151	1643	1650	1608		1310			1366
2065	1503	1158	1650	1658	1616		1317			1373
2066	1510	1165	1658	1665	1623		1324			1380
2067	1517	1172	1664	1671	1629		1331			1387

Table 31
Resuspension Production, Release, and Export Rates from TSS-Chem and HUDTOX Models

Scenario	Sediment Removal Period	Dredging Location and Monitoring Station	Resuspension Production Rate of Sediment[1] (kg/s)	Resuspension Production Rate of Total PCB[2] (g/day)	Net TSS Flux at 1 mile from TSS-Chem (kg/s)	TPCB flux at 1 mile[3] (Resuspension Release Rate) (g/day)	TPCB Flux at Monitoring Stations from HUDTOX[4] (Resuspension Export Rate) (g/day)	TPCB Production Rate[6] (g/day)	Solids Production Rate[7] (kg/s)	Source Strength as Percentage of TPCB Removed[8] (%)	Resuspension Export Rate as Percentage of TPCB Removed[9] (%)
Evaluation Level - 300 g/day TPCB Flux at Monitoring Stations	May 1 - November 30, 2006	Section 1, TID	1.3	1,700	0.28	410	320	5.7.E+04	42	3%	0.56%
	May 1 - November 30, 2007	Section 1, TID	1.3	1,700	0.27	410	320	5.7.E+04	42	3%	0.56%
	May 1 - November 30, 2008	Section 1, TID	1.1	1,500	0.24	360	300	5.7.E+04	42	3%	0.53%
	May 1 - August 15, 2009	Section 1, TID	0.9	1,300	0.20	310	310	5.7.E+04	42	2%	0.54%
	August 16 - November 30, 2009	Section 2, Schuylerville	0.3	1,100	0.10	360	330	1.2.E+05	37	1%	0.29%
	May 1 - August 15, 2010	Section 2, Schuylerville	0.3	900	0.08	310	300	1.2.E+05	37	1%	0.26%
	August 16 - November 30, 2010	Section 3, Waterford	0.9	1,300	0.25	400	340	4.5.E+04	31	3%	0.75%
	May 1 - August 15, 2011	Section 3, Waterford	0.7	1,000	0.19	310	340	4.5.E+04	31	2%	0.75%
Control Level - 600 g/day TPCB Flux at Monitoring Stations	May 1 - November 30, 2006	Section 1, TID	2.6	3,600	0.57	820	620	5.7.E+04	42	6%	1.1%
	May 1 - November 30, 2007	Section 1, TID	2.6	3,600	0.57	820	630	5.7.E+04	42	6%	1.1%
	May 1 - November 30, 2008	Section 1, TID	2.3	3,100	0.50	720	620	5.7.E+04	42	6%	1.1%
	May 1 - August 15, 2009	Section 1, TID	2.0	2,700	0.43	620	590	5.7.E+04	42	5%	1.0%
	August 16 - November 30, 2009	Section 2, Schuylerville	0.7	2,300	0.21	730	620	1.2.E+05	37	2%	0.5%
	May 1 - August 15, 2010	Section 2, Schuylerville	0.6	1,900	0.17	630	590	1.2.E+05	37	2%	0.5%
	August 16 - November 30, 2010	Section 3, Waterford	1.9	2,700	0.52	810	660	4.5.E+04	31	6%	1.5%
	May 1 - August 15, 2011	Section 3, Waterford	1.4	2,100	0.40	630	650	4.5.E+04	31	5%	1.4%
Control Level - 350 ng/L TPCB Concentrations at Monitoring Stations	May 1 - November 30, 2006	Section 1, TID	5.6	7,600	1.2	1,700	1,200	5.7.E+04	42	13%	2.1%
	May 1 - November 30, 2007	Section 1, TID	5.6	7,600	1.2	1,700	1,200	5.7.E+04	42	13%	2.1%
	May 1 - November 30, 2008	Section 1, TID	4.9	6,700	1.1	1,500	1,300	5.7.E+04	42	12%	2.3%
	May 1 - August 15, 2009	Section 1, TID	4.2	5,700	0.91	1,300	1,200	5.7.E+04	42	10%	2.1%
	August 16 - November 30, 2009	Section 2, Schuylerville	2.7	8,300	0.75	2,500	2,000	1.2.E+05	37	7%	1.7%
	May 1 - August 15, 2010	Section 2, Schuylerville	2.3	7,100	0.64	2,100	2,000	1.2.E+05	37	6%	1.7%
	August 16 - November 30, 2010	Section 3, Waterford	7.5	10,900	2.1	3,100	2,200	4.5.E+04	31	24%	4.9%
	May 1 - August 15, 2011	Section 3, Waterford	5.8	8,400	1.6	2,400	2,300	4.5.E+04	31	19%	5.1%

Table 31
Resuspension Production, Release, and Export Rates from TSS-Chem and HUDTOX Models

Scenario	Sediment Removal Period	Dredging Location and Monitoring Station	Resuspension Production Rate of Sediment[1] (kg/s)	Resuspension Production Rate of Total PCB[2] (g/day)	Net TSS Flux at 1 mile from TSS-Chem (kg/s)	TPCB flux at 1 mile[3] (Resuspension Release Rate) (g/day)	TPCB Flux at Monitoring Stations[10] (Resuspension Export Rate) (g/day)	TPCB Production Rate[6] (g/day)	Solids Production Rate[7] (kg/s)	Source Strength as Percentage of TPCB Removed[8] (%)	Resuspension Export Rate as Percentage of TPCB Removed[9] (%)
Resuspension Standard - 500 ng/L TPCB Concentrations at Monitoring Stations	May 1 - November 30, 2006	Section 1, TID	9.4	12,800	2.0	2,800	2,100	5.7.E+04	42	23%	3.7%
	May 1 - November 30, 2007	Section 1, TID	9.3	12,700	2.0	2,800	2,100	5.7.E+04	42	22%	3.7%
	May 1 - November 30, 2008	Section 1, TID	8.2	11,200	1.8	2,500	2,100	5.7.E+04	42	20%	3.7%
	May 1 - August 15, 2009	Section 1, TID	7.1	9,600	1.53	2,100	2,100	5.7.E+04	42	17%	3.7%
	August 16 - November 30, 2009	Section 2, Schuylerville	3.5	10,900	0.99	3,200	2,700	1.2.E+05	37	9%	2.3%
	May 1 - August 15, 2010	Section 2, Schuylerville	3.0	9,300	0.84	2,800	2,700	1.2.E+05	37	8%	2.3%
	August 16 - November 30, 2010	Section 3, Waterford	11	16,600	3.2	4,800	3,500	4.5.E+04	31	37%	7.7%
	May 1 - August 15, 2011	Section 3, Waterford	8.8	12,800	2.5	3,700	3,500	4.5.E+04	31	28%	7.7%

Notes:

Numbers are rounded to 2 significant digits.

[1] Source strength represents the amount of solids being suspended to the water column at the dredge-head in kg/s. The value is obtained from the TSS-Chem model.

[2] TPCB flux for source strength is obtained by multiplying the solids source strength with the TPCB concentration in the sediment. The TPCB concentration for River Sections 1, 2, and 3 is 27, 62, and 29 mg/kg, respectively.

[3] Net TSS flux is the TSS-Chem model result at a distance 1 mile downstream of the dredge-head.This number is also the TSS flux input to the HUDTOX model.

[4] Values represent the amount of TPCB flux at the monitoring stations as predicted by HUDTOX.

[5] TPCB flux is obtained from TSS-Chem model. It is the TPCB flux at 1 mile downstream of the dredge-head. This is also the input TPCB flux to the HUDTOX model.

[6] TPCB production rate based on the total TPCB being removed in each river section (36,000 kg, 24,300 kg, and 9,500 kg of TPCB for River Sections 1, 2, and 3, respectively);
assuming 7days/week, 14 hours/day, 630 days in River Section 1 and 210 days each in River Sections 2 and 3.

[7] Solids production rate based on the total sediment being removed including overcut (1.5x10^6 cy, 5.8x10^5 cy, and 5.1x10^5 cy of solids in River Sections 1, 2, and 3, respectively);
assuming 7days/week and 14 hours/day, 630 days in River Section 1 and 210 days each in River Sections 2 and 3.

[8] Percentage is calculated as TPCB source strength divide by the TPCB production rate.

[9] Percentage is calculated as TPCB flux at the monitoring station divide by the TPCB production rate.

[10] TPCB flux is calculated based on the 500 ng/L at the far-field monitoring stations minus the mean baseline TPCB concentrations based on the GE water column samples data.

Table 32
Example of CSTR-Chem, TSS-Chem, and HUDTOX Application

Sediment removal season	Dredging Location	speed	Cubic yards of sediment removed[1]	Monitoring Location (Compliance Point)[2]	Expected Total PCB export rate at compliance point[3] (g/day)	Percent remaining at the monitoring location[4]	Total PCB input flux to HUDTOX (g/day)	TSS-Chem Output at 1 Mile of Dredge-head[5] (kg/day)	CSTR-Chem Input[6] (kg/day)
Jun. 1 - Sep. 15, 2006[7]	Sec. 1	half	260,000	TID	1,237	73%	1,697	61,030	281,965
May 1 - Nov. 30, 2007	Sec. 1	full	520,000	TID	1,237	73%	1,684	60,575	279,856
May 1 - Nov. 30, 2008	Sec. 1	full	520,000	TID	1,237	83%	1,490	53,423	246,754
May 1 - Aug. 15, 2009	Sec. 1 &	full	260,000	TID	1,237	97%	1,278	45,599	210,718
Aug. 16 - Nov. 30, 200	Sec. 2		290,000	Schuylerville	2,034	82%	2,466	37,814	133,724
May 1 - Aug. 15, 2010	Sec. 2 &	full	290,000	Schuylerville	2,034	96%	2,117	32,242	114,014
Aug. 16 - Nov. 30, 201	Sec. 3		255,000	Waterford	2,334	74%	3,150	106,675	377,052
May 1 - Aug. 15, 2011	Sec. 3	full	255,000	Waterford	2,334	96%	2,441	82,308	290,921

Notes:

[1] Volume of sediment removed is taken from Table 8-9 of the Feasibility Study.

[2] All TIP monitoring is done at TID, all River Section 2 monitoring is done at Schuylerville, and all River Section 3 monitoring is done at Waterford. 1 mile exclusion is not considered.

[3] Total PCB Flux is the average net flux for June to Nov at the compliance point (TID, Schuylerville, & Waterford). PCB flux in May was excluded since flow is not typical.

[4] Percent remaining at the monitoring location was obtained from the initial HUDTOX runs performed for the preliminary draft of the resuspension performance standard

[5] Input to HUDTOX

[6] CSTR-Chem suspended solids flux is the resuspension production rate.

[7] Actual dredging period is from May 1 - Nov. 30, 2006. The PCB and TSS flux is loaded only from June 1 to Sep. 15, 2006 to account for half speed operation.

Table 33
Expected versus Model Prediction of PCB Flux for Control Level - 600 g/day Scenario

River Section	Dredging Season	Loading period		Monitoring Station	Tri+ PCB Input		Tri+ PCB Output		Total PCB @ monitoring station	
		From	To		(g/day)	(g/period)	(g/day)	(g/period)[1]	Expected (g/day)[2]	Model estimate (g/day)
Section 1 dredging	May 1-Nov 30, 2006	1-Jun-06	15-Sep-06	TID	260	27,820	195	20,853	600	624
	May 1-Nov 30, 2007	1-May-07	30-Nov-07	TID	260	55,640	197	42,114	600	630
	May 1-Nov 30, 2008	1-May-08	30-Nov-08	TID	230	49,220	195	41,740	600	624
	May 1-Aug 15, 2009	1-May-09	15-Aug-09	TID	190	20,330	186	19,865	600	594
Section 2 dredging	Aug 16 - Nov 30, 2009	16-Aug-09	30-Nov-09	Schuylerville	210	22,470	183	19,573	600	622
	May 1 - Aug 15, 2010	1-May-10	15-Aug-10	Schuylerville	180	19,260	174	18,609	600	591
Section 3 dredging	Aug 16 - Nov 30, 2010[3]	16-Aug-10	30-Nov-10	Waterford	300	27,300	243	22,373	600	657
	May 1 - Aug 15, 2011	1-May-11	15-Aug-11	Waterford	230	24,610	240	25,680	600	648

Notes:

[1] Output loading from HUDTOX

[2] Total PCB flux at the monitoring station based on 1% export rate at the monitoring stations

[3] September output from HUDTOX appears to have incorrect loading, 15 days instead of 30 days. Input loading was adjusted to reflect this.

Table 34
Expected versus Model Prediction of PCB Flux for Evaluation Level - 300 g/day Scenario

River Section	Dredging Season	Loading period		Monitoring Station	Tri+ PCB Input		Tri+ PCB Output		Total PCB @ monitoring station	
		From	To		(g/day)	(g/period)	(g/day)	(g/period)[1]	Expected (g/day)[2]	Model estimate (g/day)
Section 1 dredging	May 1-Nov 30, 2006	1-Jun-06	15-Sep-06	TID	130	13,910	100	10,664	300	319
	May 1-Nov 30, 2007	1-May-07	30-Nov-07	TID	130	27,820	101	21,667	300	324
	May 1-Nov 30, 2008	1-May-08	30-Nov-08	TID	110	23,540	95	20,287	300	303
	May 1-Aug 15, 2009	1-May-09	15-Aug-09	TID	100	10,700	98	10,492	300	314
Section 2 dredging	Aug 16 - Nov 30, 2009	16-Aug-09	30-Nov-09	Schuylerville	110	11,770	98	10,456	300	332
	May 1 - Aug 15, 2010	1-May-10	15-Aug-10	Schuylerville	90	9,630	89	9,565	300	304
Section 3 dredging	Aug 16 - Nov 30, 2010[3]	16-Aug-10	30-Nov-10	Waterford	150	13,650	125	11,464	300	336
	May 1 - Aug 15, 2011	1-May-11	15-Aug-11	Waterford	120	12,840	125	13,421	300	339

Notes:

[1] Output loading from HUDTOX

[2] Total PCB flux at the monitoring station based on 0.5% export rate at the monitoring stations

[3] September output from HUDTOX appears to have incorrect loading, 15 days instead of 30 days. Input loading was adjusted to reflect this.

Table 35

FISHRAND Forecast for Year to Reach Fish Tissue Concentration Difference of 0.5 mg/kg Relative to the No Resuspension - Upper River

River Section	Total PCB 600 g/day (sr01)	Total PCB 350 ng/L (sr04)
Section 1 (RM 189)	2008-2009	2009-2010
Section 2 (RM 184)	2008	2010
Section 3 (RM 154)	Always < 0.5 mg/kg	2011

Table 36

FISHRAND Forecast for Year to Reach Fish Tissue Concentration Difference of 0.05 mg/kg Relative to the No Resuspension - Lower River

River Section	Total PCB 600 g/day (sr01)	Total PCB 350 ng/L (sr04)
RM 152	2013-2014	2016-2017
RM 113	2014	2016-2017
RM 90	2014	2018
RM 50	Always < 0.05 mg/kg	2018

Table 37
Upper Hudson Species-Weighted Fish Fillet Average PCB Concentration (in mg/kg)

Year	No Resuspension (d004)				350 ng/L (sr04)			
	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)
1998	3.317	6.813	9.271	1.537	3.316	6.807	9.276	1.537
1999	3.328	6.908	9.406	1.510	3.328	6.909	9.410	1.509
2000	2.866	5.747	8.346	1.300	2.865	5.751	8.338	1.300
2001	2.582	5.098	7.588	1.177	2.583	5.104	7.585	1.177
2002	2.370	4.841	6.925	1.053	2.372	4.848	6.924	1.054
2003	2.182	4.340	6.471	0.978	2.182	4.338	6.474	0.978
2004	2.290	5.285	6.356	0.946	2.290	5.286	6.354	0.946
2005	1.905	3.912	5.712	0.816	1.911	3.910	5.740	0.821
2006	1.617	2.996	5.119	0.716	1.703	3.111	5.350	0.770
2007	1.487	2.838	4.669	0.647	1.709	3.461	5.141	0.739
2008	1.297	2.318	4.226	0.571	1.673	3.762	4.743	0.694
2009	0.964	1.573	2.949	0.489	1.323	2.317	3.769	0.687
2010	0.595	0.899	1.355	***0.398***	0.928	1.012	1.835	0.753
2011	0.447	0.661	0.847	0.332	0.817	0.736	1.122	0.781
2012	0.404	0.723	0.786	0.269	0.631	0.774	0.999	0.537
2013	***0.342***	0.568	0.717	0.229	0.515	0.600	0.883	0.433
2014	0.318	0.593	0.669	***0.199***	0.453	0.602	0.803	***0.361***
2015	0.289	0.520	0.638	0.178	***0.400***	0.524	0.751	0.312
2016	0.294	0.586	0.651	0.170	0.391	0.589	0.750	0.287
2017	0.296	0.671	0.612	0.161	0.379	0.672	0.704	0.260
2018	0.272	0.606	0.574	0.149	0.344	0.605	0.665	0.233
2019	0.281	0.710	0.567	0.140	0.341	0.702	0.656	0.210
2020	0.243	0.584	0.502	0.125	0.292	0.579	0.584	***0.180***
2021	0.217	0.471	0.482	0.117	0.260	0.468	0.557	0.164
2022	0.215	0.476	0.477	0.114	0.253	0.473	0.548	0.155
2023	0.216	0.529	0.454	0.108	0.247	0.524	0.514	0.142
2024	***0.195***	0.484	0.417	0.094	0.219	0.480	0.463	0.122
2025	0.176	0.415	***0.391***	0.088	***0.196***	0.413	0.426	0.110
2026	0.163	***0.357***	0.377	0.084	0.180	0.355	0.405	0.103
2027	0.183	0.490	0.380	0.083	0.197	0.488	0.403	0.100
2028	0.177	0.509	0.353	0.076	0.189	0.508	***0.371***	0.090
2029	0.158	0.414	0.337	0.072	0.168	0.412	0.351	0.084
2030	0.143	0.326	0.326	0.072	0.152	***0.325***	0.342	0.082
2031	0.151	0.422	0.303	0.067	0.159	0.421	0.320	0.075
2032	0.138	0.362	0.288	0.064	0.145	0.362	0.305	0.071
2033	0.133	0.349	0.277	0.061	0.138	0.349	0.295	0.066
2034	0.132	0.368	0.259	0.060	0.134	0.368	0.276	0.060
2035	0.123	0.279	0.249	0.068	0.116	0.279	0.266	0.056
2036	0.148	0.356	0.242	0.087	0.124	0.356	0.258	0.051
2037	0.137	0.297	0.234	0.086	0.115	0.298	0.250	0.053
2038	0.140	0.337	0.221	0.083	0.130	0.337	0.235	0.068
2039	0.128	0.270	0.214	0.083	0.132	0.271	0.227	0.087
2040	0.124	0.262	0.214	0.079	0.132	0.262	0.225	0.087
2041	0.140	0.359	0.219	0.079	0.150	0.360	0.228	0.091
2042	0.143	0.400	0.223	0.074	0.153	0.401	0.229	0.087
2043	0.123	0.318	0.202	0.068	0.132	0.318	0.206	0.080
2044	0.108	0.245	***0.191***	0.064	0.114	0.246	***0.193***	0.073
2045	0.112	0.282	0.190	0.063	0.118	0.283	0.191	0.070

BOLD-ITALICIZED - First occurrence of species-weighted fish fillet average PCB concentration below risk-based remediation goal of 0.05 mg/kg. Target concentrations of 0.2 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/month) and 0.4 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/ 2 months) are also italicized.

Upper Hudson River average is weighted by river section length:

River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 37
Upper Hudson Species-Weighted Fish Fillet Average PCB Concentration (in mg/kg)

Year	No Resuspension (d004)				350 ng/L (sr04)			
	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)
2046	0.105	0.258	0.184	0.058	0.109	0.256	0.184	0.064
2047	0.109	0.284	0.187	0.058	0.112	0.271	0.187	0.065
2048	0.115	0.329	0.188	0.057	0.118	0.318	0.187	0.064
2049	0.116	0.339	0.190	0.055	0.120	0.340	0.189	0.062
2050	0.105	0.289	0.183	0.052	0.109	0.290	0.182	0.057
2051	0.101	0.286	0.180	***0.047***	0.104	0.287	0.178	0.052
2052	0.094	0.244	0.181	0.047	0.097	0.246	0.180	0.051
2053	0.113	0.359	0.187	0.048	0.116	0.359	0.185	0.052
2054	0.105	0.311	0.185	0.047	0.107	0.311	0.184	0.050
2055	0.098	0.274	0.182	0.045	0.100	0.274	0.180	***0.048***
2056	0.105	0.307	0.195	0.046	0.106	0.307	0.193	0.048
2057	0.105	0.323	0.185	0.045	0.107	0.324	0.183	0.047
2058	0.095	0.253	0.188	0.045	0.096	0.253	0.186	0.047
2059	0.109	0.356	0.181	0.043	0.110	0.356	0.181	0.045
2060	0.091	0.256	0.175	0.040	0.092	0.256	0.175	0.042
2061	0.086	0.234	0.169	0.040	0.087	0.233	0.169	0.042
2062	0.091	0.261	0.171	0.040	0.091	0.261	0.170	0.042
2063	0.091	0.261	0.172	0.041	0.091	0.260	0.171	0.041
2064	0.093	0.268	0.175	0.041	0.093	0.268	0.174	0.042
2065	0.092	0.255	0.178	0.043	0.093	0.255	0.177	0.043
2066	0.105	0.353	0.172	0.041	0.105	0.353	0.171	0.041
2067	0.095	0.275	0.180	0.042	0.095	0.275	0.179	0.042

BOLD-ITALICIZED - First occurrence of species-weighted fish fillet average PCB concentration below risk-based remediation goal of 0.05 mg/kg. Target concentrations of 0.2 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/month) and 0.4 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/ 2 months) are also italicized.

Upper Hudson River average is weighted by river section length:

River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 37
Upper Hudson Species-Weighted Fish Fillet Average PCB Concentration (in mg/kg)

Year	600 g/day (sr01)				Monitored Natural Attenuation			
	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)
1998	3.316	6.807	9.276	1.537	3.353	6.774	9.659	1.529
1999	3.328	6.909	9.410	1.509	3.212	6.621	8.877	1.501
2000	2.865	5.751	8.338	1.300	2.791	5.563	8.028	1.292
2001	2.583	5.104	7.585	1.177	2.504	4.924	7.210	1.171
2002	2.372	4.848	6.924	1.054	2.301	4.705	6.571	1.047
2003	2.182	4.338	6.474	0.978	2.129	4.290	6.090	0.980
2004	2.290	5.286	6.354	0.946	2.204	5.084	5.934	0.942
2005	1.908	3.909	5.726	0.819	1.852	3.739	5.523	0.812
2006	1.666	3.076	5.237	0.746	1.574	2.890	4.904	0.716
2007	1.614	3.225	4.920	0.697	1.474	2.862	4.489	0.654
2008	1.525	3.216	4.582	0.634	1.371	2.774	4.168	0.586
2009	1.106	1.907	3.140	0.583	1.262	2.616	3.877	0.519
2010	0.707	0.943	1.411	0.535	1.116	2.321	3.533	0.440
2011	0.568	0.697	0.901	0.483	0.971	1.921	3.164	***0.388***
2012	0.469	0.747	0.818	***0.350***	0.878	1.851	2.879	0.324
2013	***0.389***	0.572	0.734	0.291	0.791	1.682	2.601	0.287
2014	0.353	0.582	0.675	0.248	0.742	1.666	2.396	0.258
2015	0.316	0.506	0.638	0.219	0.686	1.535	2.229	0.237
2016	0.317	0.573	0.648	0.205	0.680	1.610	2.126	0.231
2017	0.315	0.660	0.610	***0.190***	0.649	1.573	1.978	0.221
2018	0.289	0.595	0.577	0.173	0.593	1.437	1.765	0.210
2019	0.295	0.694	0.572	0.161	0.577	1.497	1.619	***0.200***
2020	0.253	0.571	0.507	0.142	0.512	1.270	1.480	0.182
2021	0.226	0.459	0.486	0.131	0.460	1.080	1.365	0.171
2022	0.222	0.464	0.482	0.126	0.450	1.093	1.296	0.166
2023	0.222	0.517	0.461	0.118	0.435	1.088	1.225	0.158
2024	***0.200***	0.474	0.427	0.102	***0.385***	0.939	1.123	0.139
2025	0.181	0.406	0.402	0.094	0.350	0.842	1.019	0.129
2026	0.166	***0.347***	***0.388***	0.089	0.325	0.757	0.952	0.124
2027	0.186	0.483	0.387	0.088	0.339	0.888	0.920	0.121
2028	0.179	0.504	0.353	0.080	0.322	0.863	0.875	0.111
2029	0.159	0.407	0.332	0.076	0.287	0.720	0.801	0.105
2030	0.143	0.320	0.322	0.075	0.261	0.620	0.735	0.103
2031	0.152	0.418	0.302	0.069	0.257	0.679	0.675	0.095
2032	0.139	0.357	0.289	0.066	0.234	0.602	0.610	0.091
2033	0.133	0.343	0.279	0.063	0.219	0.560	0.564	0.086
2034	0.132	0.366	0.261	0.059	0.208	0.545	0.521	0.082
2035	0.114	0.275	0.251	0.055	***0.191***	0.443	0.475	0.089
2036	0.125	0.352	0.244	0.055	0.209	0.504	0.446	0.104
2037	0.125	0.295	0.237	0.070	0.190	0.427	0.410	0.101
2038	0.140	0.335	0.224	0.083	0.189	0.456	***0.386***	0.098
2039	0.131	0.268	0.218	0.087	0.173	0.382	0.363	0.096
2040	0.128	0.260	0.217	0.085	0.164	0.352	0.346	0.092
2041	0.146	0.358	0.222	0.087	0.180	0.461	0.347	0.092
2042	0.148	0.399	0.225	0.081	0.178	0.486	0.337	0.084
2043	0.129	0.320	0.205	0.075	0.155	***0.386***	0.316	0.078
2044	0.114	0.256	***0.195***	0.069	0.136	0.301	0.289	0.074
2045	0.118	0.301	0.194	0.066	0.137	0.329	0.278	0.071

BOLD-ITALICIZED - First occurrence of species-weighted fish fillet average PCB concentration below risk-based remediation goal of 0.05 mg/kg. Target concentrations of 0.2 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/month) and 0.4 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/ 2 months) are also italicized.

Upper Hudson River average is weighted by river section length:

River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 37
Upper Hudson Species-Weighted Fish Fillet Average PCB Concentration (in mg/kg)

	600 g/day (sr01)				Monitored Natural Attenuation			
Year	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)	Upper River Average	River Section 1 (RM 189)	River Section 2 (RM 184)	River Section 3 (RM 154)
2046	0.110	0.273	0.187	0.062	0.131	0.319	0.269	0.067
2047	0.112	0.285	0.190	0.062	0.153	0.474	0.261	0.066
2048	0.116	0.316	0.190	0.061	0.175	0.612	0.263	0.066
2049	0.117	0.328	0.192	0.059	0.166	0.574	0.259	0.063
2050	0.106	0.283	0.185	0.055	0.151	0.498	0.251	0.060
2051	0.104	0.294	0.182	***0.050***	0.140	0.457	0.242	0.055
2052	0.099	0.263	0.184	0.049	0.130	0.402	0.236	0.054
2053	0.118	0.379	0.189	0.050	0.146	0.494	0.244	0.055
2054	0.109	0.327	0.187	0.049	0.134	0.430	0.235	0.053
2055	0.101	0.287	0.183	0.047	0.125	0.383	0.231	0.052
2056	0.108	0.322	0.195	0.047	0.129	0.407	0.233	0.051
2057	0.108	0.337	0.186	0.046	0.126	0.397	0.231	0.050
2058	0.097	0.264	0.188	0.046	0.116	0.337	0.226	0.050
2059	0.111	0.366	0.182	0.044	0.127	0.422	0.228	***0.047***
2060	0.093	0.266	0.175	0.041	0.106	0.316	0.209	0.044
2061	0.087	0.241	0.169	0.041	0.100	0.286	***0.200***	0.043
2062	0.092	0.268	0.170	0.041	0.102	0.297	0.197	0.043
2063	0.092	0.266	0.171	0.041	0.101	0.296	0.196	0.043
2064	0.094	0.273	0.175	0.042	0.103	0.306	0.196	0.044
2065	0.093	0.260	0.177	0.043	0.100	0.283	0.195	0.045
2066	0.106	0.358	0.171	0.041	0.113	0.377	0.195	0.043
2067	0.096	0.279	0.179	0.043	0.101	0.301	0.183	0.044

BOLD-ITALICIZED - First occurrence of species-weighted fish fillet average PCB concentration below risk-based remediation goal of 0.05 mg/kg. Target concentrations of 0.2 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/month) and 0.4 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/ 2 months) are also italicized.

Upper Hudson River average is weighted by river section length:

River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 38

Upper Hudson River Modeled Times (Years) of Compliance with Human Health Risk-Based Concentrations Resuspension Scenarios

	No Resuspension (d004)	350 ng/L (sr04)	600 g/day (sr01)	MNA
Upper River Average				
Human Health risk-based RG 0.05 mg/kg	>2067	>2067	>2067	>2067
Fish Target Concentration 0.2 mg/kg	2024	2025	2024	2035
Fish Target Concentration 0.4 mg/kg	2013	2015	2013	2024
River Section 1- RM 189				
Human Health risk-based RG 0.05 mg/kg	>2067	>2067	>2067	>2067
Fish Target Concentration 0.2 mg/kg	>2067	>2067	>2067	>2067
Fish Target Concentration 0.4 mg/kg	2026	2030	2026	2043
River Section 2- RM 184				
Human Health risk-based RG 0.05 mg/kg	>2067	>2067	>2067	>2067
Fish Target Concentration 0.2 mg/kg	2044	2044	2044	2061
Fish Target Concentration 0.4 mg/kg	2025	2028	2026	2038
River Section 3- RM 154				
Human Health RG 0.05 mg/kg	2051	2055	2051	2059
Fish Target Concentration 0.2 mg/kg	2014	2020	2017	2019
Fish Target Concentration 0.4 mg/kg	2010	2014	2012	2011

Note: RG = risk-based remediation goal
Upper Hudson River average is weighted by river section length. River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 39
Resuspension Scenarios - Long-Term Fish Ingestion
Reasonable Maximum Exposure and Central Tendency PCB Non-Cancer Hazard Indices
Upper Hudson River Fish - Adult Angler

Remedial Alternative	PCB Conc. in Fish (mg/kg ww)	Intake (Non-Cancer) (mg/kg-day)	Reference Dose (mg/kg-day)	Hazard Index
Reasonable Maximum Exposure				
Upper Hudson Average				
No Resuspension d004	0.30	1.4E-04	2.0E-05	6.9
350 ng/L sr04	0.58	2.6E-04	2.0E-05	13
600 g/day sr01	0.50	2.3E-04	2.0E-05	11
MNA	1.4	6.4E-04	2.0E-05	32
River Section 1 (RM 189)				
No Resuspension d004	0.62	2.8E-04	2.0E-05	14
350 ng/L sr04	0.64	2.9E-04	2.0E-05	15
600 g/day sr01	0.62	2.8E-04	2.0E-05	14
MNA	1.7	7.7E-04	2.0E-05	39
River Section 2 (RM 184)				
No Resuspension d004	0.66	3.0E-04	2.0E-05	15
350 ng/L sr04	0.79	3.6E-04	2.0E-05	18
600 g/day sr01	0.67	3.1E-04	2.0E-05	15
MNA	2.3	1.0E-03	2.0E-05	52
River Section 3 (RM 154)				
No Resuspension d004	0.18	8.0E-05	2.0E-05	4.0
350 ng/L sr04	0.30	1.4E-04	2.0E-05	6.8
600 g/day sr01	0.21	9.7E-05	2.0E-05	4.8
MNA	0.23	1.1E-04	2.0E-05	5.4
Central Tendency				
Upper Hudson Average				
No Resuspension d004	0.27	1.2E-05	2.0E-05	0.6
350 ng/L sr04	0.52	2.4E-05	2.0E-05	1.2
600 g/day sr01	0.46	2.1E-05	2.0E-05	1.0
MNA	1.2	5.5E-05	2.0E-05	2.8
River Section 1 (RM 189)				
No Resuspension d004	0.60	2.7E-05	2.0E-05	1.4
350 ng/L sr04	0.61	2.8E-05	2.0E-05	1.4
600 g/day sr01	0.59	2.7E-05	2.0E-05	1.4
MNA	1.50	6.9E-05	2.0E-05	3.5
River Section 2 (RM 184)				
No Resuspension d004	0.59	2.7E-05	2.0E-05	1.4
350 ng/L sr04	0.70	3.2E-05	2.0E-05	1.6
600 g/day sr01	0.60	2.7E-05	2.0E-05	1.4
MNA	1.9	8.7E-05	2.0E-05	4.4
River Section 3 (RM 154)				
No Resuspension d004	0.15	6.8E-06	2.0E-05	0.3
350 ng/L sr04	0.24	1.1E-05	2.0E-05	0.5
600 g/day sr01	0.18	8.0E-06	2.0E-05	0.4
MNA	0.21	9.4E-06	2.0E-05	0.5

Notes: The RME non-cancer exposure time frame is seven years, while the CT time frame is 12 years.
Upper Hudson River average is weighted by river section length. River Section 1: 6.3 miles = 15.4%;
River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 40
Resuspension Standard Scenarios - Long-Term Fish Ingestion
Reasonable Maximum Exposure and Central Tendency Cancer Risks
Upper Hudson River Fish - Adult Angler

Remedial Alternative	PCB Conc. in Fish (mg/kg ww)	Intake (Cancer) (mg/kg-day)	Cancer Slope Factor (mg/kg-day)	Cancer Risk
Reasonable Maximum Exposure				
Upper Hudson Average				
No Resuspension d004	0.18	4.6E-05	2	9.3E-05
350 ng/L sr04	0.32	8.3E-05	2	1.7E-04
600 g/day sr01	0.30	7.7E-05	2	1.5E-04
MNA	0.60	1.7E-04	2	3.3E-04
River Section 1 (RM 189)				
No Resuspension d004	0.43	1.1E-04	2	2.2E-04
350 ng/L sr04	0.43	1.1E-04	2	2.2E-04
600 g/day sr01	0.42	1.1E-04	2	2.2E-04
MNA	0.86	2.2E-04	2	4.5E-04
River Section 2 (RM 184)				
No Resuspension d004	0.36	9.3E-05	2	1.9E-04
350 ng/L sr04	0.40	1.0E-04	2	2.1E-04
600 g/day sr01	0.36	9.4E-05	2	1.9E-04
MNA	0.90	2.4E-04	2	4.9E-04
River Section 3 (RM 154)				
No Resuspension d004	0.09	2.4E-05	2	4.8E-05
350 ng/L sr04	0.12	3.2E-05	2	6.4E-05
600 g/day sr01	0.10	2.7E-05	2	5.3E-05
MNA	0.12	3.2E-05	2	6.4E-05
Central Tendency				
Upper Hudson Average				
No Resuspension d004	0.27	2.1E-06	1	2.1E-06
350 ng/L sr04	0.52	4.0E-06	1	4.0E-06
600 g/day sr01	0.46	3.6E-06	1	3.6E-06
MNA	1.2	9.5E-06	1	9.5E-06
River Section 1 (RM 189)				
No Resuspension d004	0.60	4.7E-06	1	4.7E-06
350 ng/L sr04	0.61	4.8E-06	1	4.8E-06
600 g/day sr01	0.59	4.7E-06	1	4.7E-06
MNA	1.5	1.2E-05	1	1.2E-05
River Section 2 (RM 184)				
No Resuspension d004	0.59	4.7E-06	1	4.7E-06
350 ng/L sr04	0.70	5.5E-06	1	5.5E-06
600 g/day sr01	0.60	4.7E-06	1	4.7E-06
MNA	1.9	1.5E-05	1	1.5E-05
River Section 3 (RM 154)				
No Resuspension d004	0.15	1.2E-06	1	1.2E-06
350 ng/L sr04	0.24	1.9E-06	1	1.9E-06
600 g/day sr01	0.18	1.4E-06	1	1.4E-06
MNA	0.21	1.6E-06	1	1.6E-06

Notes: The RME cancer exposure time frame is 40 years, while the CT time frame is 12 years.
Upper Hudson River average is weighted by river section length. River Section 1: 6.3 miles = 15.4%;
River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 41
Mid-Hudson River
Species-Weighted Fish Fillet Average PCB Concentration (in mg/kg)

	No Resuspension (d004)			350 ng/L (sr04)		
Year	River Section 1 (RM 152)	River Section 2 (RM 113)	River Section 3 (RM 90)	River Section 1 (RM 152)	River Section 2 (RM 113)	River Section 3 (RM 90)
1999	1.150	0.963	0.792	1.150	0.963	0.792
2000	1.080	0.851	0.712	1.080	0.851	0.712
2001	1.154	0.821	0.656	1.154	0.821	0.656
2002	0.972	0.745	0.611	0.972	0.745	0.611
2003	0.837	0.658	0.553	0.837	0.658	0.553
2004	0.622	0.537	0.485	0.622	0.537	0.485
2005	0.592	0.462	0.420	0.598	0.463	0.420
2006	0.605	0.435	***0.373***	0.661	0.453	***0.375***
2007	0.522	***0.398***	0.337	0.641	0.441	0.349
2008	***0.386***	0.335	0.301	0.560	0.407	0.326
2009	0.316	0.278	0.263	0.537	0.370	0.296
2010	0.308	0.250	0.231	0.734	0.420	0.294
2011	0.307	0.234	0.208	1.119	0.558	0.325
2012	0.247	0.205	***0.187***	0.570	0.464	0.329
2013	0.253	***0.192***	0.170	0.443	***0.381***	0.308
2014	0.217	0.172	0.155	***0.330***	0.305	0.274
2015	***0.181***	0.152	0.140	0.259	0.245	0.238
2016	0.136	0.127	0.125	***0.186***	***0.190***	0.201
2017	0.118	0.110	0.111	0.138	0.149	***0.168***
2018	0.110	0.098	0.099	0.118	0.123	0.139
2019	0.093	0.086	0.088	0.095	0.099	0.115
2020	0.108	0.084	0.080	0.109	0.090	0.098
2021	0.101	0.081	0.075	0.101	0.084	0.086
2022	0.087	0.075	0.071	0.087	0.077	0.078
2023	0.080	0.070	0.066	0.080	0.071	0.071
2024	0.085	0.069	0.064	0.085	0.070	0.066
2025	0.088	0.070	0.063	0.088	0.071	0.064
2026	0.083	0.068	0.061	0.083	0.068	0.062
2027	0.069	0.063	0.059	0.069	0.063	0.060
2028	0.068	0.060	0.056	0.068	0.060	0.057
2029	0.076	0.060	0.055	0.076	0.060	0.055
2030	0.074	0.060	0.054	0.074	0.060	0.054
2031	0.068	0.058	0.054	0.068	0.058	0.054
2032	0.067	0.058	0.053	0.067	0.058	0.053
2033	0.063	0.056	0.052	0.063	0.056	0.052
2034	0.064	0.055	0.051	0.064	0.055	0.051
2035	0.095	0.063	0.052	0.095	0.063	0.052
2036	0.126	0.078	0.056	0.126	0.078	0.056
2037	0.141	0.091	0.063	0.141	0.091	0.063
2038	0.138	0.093	0.068	0.138	0.094	0.068
2039	0.122	0.091	0.070	0.122	0.091	0.070
2040	0.106	0.086	0.070	0.106	0.086	0.070
2041	0.081	0.075	0.067	0.081	0.075	0.067
2042	0.069	0.066	0.063	0.069	0.066	0.063
2043	0.079	0.064	0.059	0.079	0.064	0.059
2044	0.091	0.067	0.058	0.091	0.067	0.058
2045	0.085	0.067	0.057	0.085	0.067	0.057
2046	0.076	0.063	0.056	0.076	0.063	0.056

BOLD-ITALICIZED - First occurrence of species-weighted fish fillet average PCB concentration below risk-based remediation goal of 0.05 mg/kg. Target concentrations of 0.2 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/month) and 0.4 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/ 2 months) are also italicized.

Note: Fish concentrations were not available for all species used to model Mid-Hudson River angler consumption. Therefore, the concentrations here provide only an estimate of fish concentrations.

Table 41
Mid-Hudson River
Species-Weighted Fish Fillet Average PCB Concentration (in mg/kg)

	600 g/day (sr01)			Monitored Natural Attenuation		
Year	River Section 1 (RM 152)	River Section 2 (RM 113)	River Section 3 (RM 90)	River Section 1 (RM 152)	River Section 2 (RM 113)	River Section 3 (RM 90)
1999	1.150	0.963	0.792	1.126	0.952	0.788
2000	1.080	0.851	0.712	1.093	0.848	0.708
2001	1.154	0.821	0.656	1.138	0.822	0.654
2002	0.972	0.745	0.611	0.959	0.742	0.607
2003	0.837	0.658	0.553	0.826	0.655	0.549
2004	0.622	0.537	0.485	0.611	0.532	0.482
2005	0.595	0.463	0.420	0.580	0.459	0.417
2006	0.633	0.444	***0.374***	0.598	0.432	***0.370***
2007	0.589	0.420	0.343	0.500	***0.394***	0.334
2008	0.478	***0.374***	0.314	***0.388***	0.333	0.299
2009	0.420	0.321	0.280	0.333	0.279	0.261
2010	0.467	0.316	0.259	0.367	0.272	0.236
2011	0.549	0.335	0.251	0.391	0.276	0.222
2012	***0.343***	0.284	0.235	0.338	0.256	0.210
2013	0.313	0.252	0.215	0.352	0.252	***0.199***
2014	0.253	0.216	***0.193***	0.303	0.230	0.188
2015	0.205	***0.182***	0.171	0.246	0.202	0.173
2016	***0.152***	0.147	0.149	***0.185***	***0.167***	0.155
2017	0.130	0.124	0.130	0.171	0.145	0.138
2018	0.120	0.109	0.113	0.165	0.136	0.125
2019	0.100	0.094	0.098	0.143	0.120	0.112
2020	0.115	0.090	0.088	0.168	0.120	0.104
2021	0.106	0.085	0.081	0.153	0.115	0.098
2022	0.091	0.079	0.075	0.127	0.106	0.093
2023	0.084	0.073	0.070	0.119	0.097	0.087
2024	0.088	0.072	0.066	0.127	0.097	0.084
2025	0.091	0.073	0.065	0.131	0.100	0.083
2026	0.085	0.070	0.063	0.119	0.095	0.081
2027	0.070	0.065	0.061	0.098	0.087	0.078
2028	0.070	0.061	0.058	0.098	0.081	0.073
2029	0.078	0.061	0.056	0.106	0.081	0.070
2030	0.075	0.061	0.055	0.102	0.079	0.068
2031	0.069	0.059	0.054	0.094	0.077	0.067
2032	0.068	0.058	0.054	0.092	0.077	0.068
2033	0.064	0.056	0.052	0.084	0.073	0.066
2034	0.062	0.055	0.051	0.086	0.071	0.063
2035	0.069	0.056	0.050	0.118	0.079	0.064
2036	0.068	0.055	***0.050***	0.145	0.093	0.067
2037	0.111	0.070	0.053	0.166	0.107	0.074
2038	0.152	0.088	0.060	0.156	0.107	0.079
2039	0.141	0.094	0.066	0.139	0.105	0.080
2040	0.123	0.093	0.070	0.120	0.098	0.080
2041	0.094	0.083	0.069	0.092	0.085	0.076
2042	0.078	0.072	0.066	0.078	0.073	0.070
2043	0.088	0.071	0.063	0.093	0.073	0.066
2044	0.097	0.073	0.062	0.107	0.077	0.064
2045	0.087	0.070	0.060	0.098	0.076	0.064
2046	0.078	0.066	0.058	0.086	0.072	0.062

BOLD-ITALICIZED - First occurrence of species-weighted fish fillet average PCB concentration below risk-based remediation goal of 0.05 mg/kg. Target concentrations of 0.2 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/month) and 0.4 mg/kg PCBs (protective at a fish consumption rate of 0.5 lbs/ 2 months) are also italicized.

Note: Fish concentrations were not available for all species used to model Mid-Hudson River angler consumption. Therefore, the concentrations here provide only an estimate of fish concentrations.

Table 42
Upper Hudson River Average Largemouth Bass (Whole Fish) PCB Concentration (in mg/kg)

Year	No Resuspension (d004)				Total PCB 350 ng/L (sr04)			
	Upper River Average	**Section 1 (RM 189)**	**Section 2 (RM 184)**	**Section 3 (RM 154)**	**Upper River Average**	**Section 1 (RM 189)**	**Section 2 (RM 184)**	**Section 3 (RM 154)**
1998	7.13	16.73	17.22	3.33	7.13	16.70	17.24	3.33
1999	7.04	17.11	16.80	3.20	7.04	17.12	16.83	3.20
2000	5.84	13.71	14.51	2.66	5.84	13.74	14.47	2.66
2001	5.29	12.01	13.33	2.47	5.30	12.04	13.32	2.47
2002	4.91	11.63	12.30	2.20	4.92	11.66	12.29	2.20
2003	4.43	10.12	11.39	2.01	4.43	10.11	11.40	2.01
2004	5.12	14.37	11.49	2.04	5.12	14.38	11.48	2.04
2005	3.94	9.68	9.91	1.67	3.95	9.67	9.97	1.68
2006	3.14	6.44	8.80	1.45	3.38	6.61	9.48	1.63
2007	2.96	6.45	8.04	1.33	3.63	8.59	9.25	1.59
2008	2.59	5.37	7.38	1.17	3.88	11.02	8.77	1.51
2009	2.00	4.08	5.15	1.02	3.06	6.90	7.31	1.50
2010	1.35	2.88	2.56	0.81	2.14	3.17	3.68	1.66
2011	1.00	2.02	1.57	0.68	1.94	2.18	2.05	1.86
2012	0.94	2.35	1.48	0.55	1.38	2.45	1.85	1.07
2013	0.76	1.69	1.30	0.47	1.08	1.75	1.59	0.85
2014	0.72	1.80	1.22	0.41	0.97	1.81	1.44	0.71
2015	0.64	1.52	1.16	0.37	0.85	1.53	1.35	0.62
2016	0.68	1.72	1.26	0.36	0.87	1.72	1.43	0.59
2017	0.73	2.17	1.18	0.35	0.89	2.16	1.34	0.54
2018	0.66	1.93	1.09	0.32	0.79	1.91	1.24	0.48
2019	0.72	2.34	1.13	***0.30***	0.83	2.32	1.28	0.43
2020	0.59	1.89	0.92	0.26	0.68	1.86	1.06	0.36
2021	0.51	1.44	0.90	0.25	0.59	1.43	1.03	0.33
2022	0.51	1.43	0.92	0.24	0.58	1.43	1.04	0.33
2023	0.54	1.69	0.88	0.24	0.60	1.67	0.98	0.30
2024	0.49	1.58	0.79	0.20	0.53	1.57	0.87	***0.25***
2025	0.43	1.29	0.74	0.19	0.46	1.29	0.80	0.23
2026	0.38	1.08	0.71	0.18	0.41	1.07	0.75	0.21
2027	0.47	1.60	0.74	0.18	0.50	1.59	0.78	0.21
2028	0.46	1.69	0.65	0.16	0.48	1.69	0.68	0.18
2029	0.39	1.34	0.63	0.15	0.41	1.33	0.65	0.17
2030	0.35	0.99	0.63	0.16	0.36	0.98	0.65	0.18
2031	0.40	1.42	0.58	0.15	0.41	1.41	0.61	0.16
2032	0.35	1.18	0.55	0.14	0.36	1.18	0.58	0.15
2033	0.34	1.14	0.53	0.13	0.35	1.13	0.56	0.14
2034	0.34	1.23	0.49	0.13	0.35	1.23	0.52	0.13
2035	***0.29***	0.88	0.47	0.14	***0.28***	0.87	0.50	0.12
2036	0.40	1.21	0.48	0.22	0.33	1.21	0.50	0.11
2037	0.36	0.98	0.46	0.21	0.29	0.98	0.49	0.11
2038	0.36	1.13	0.43	0.19	0.33	1.13	0.45	0.14
2039	0.33	0.89	0.42	0.19	0.34	0.89	0.44	0.21
2040	0.31	0.86	0.42	0.17	0.33	0.86	0.44	0.20

Notes:
1. Fish fillets multiplied by 2.5 to obtain whole fish concentrations.
2. All whole fish PCB concentrations are above target fish concentration of 0.3 mg/kg and/or 0.03 mg/kg based on the river otter lowest-observed-adverse-effects-level (LOAEL) and no-observed-adverse-effects-level (NOAEL), respectively.

Upper Hudson River average is weighted by river section length:
River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 42
Upper Hudson River Average Largemouth Bass (Whole Fish) PCB Concentration (in mg/kg)

Year	No Resuspension (d004)				Total PCB 350 ng/L (sr04)			
	Upper River Average	Section 1 (RM 189)	Section 2 (RM 184)	Section 3 (RM 154)	Upper River Average	Section 1 (RM 189)	Section 2 (RM 184)	Section 3 (RM 154)
2041	0.37	1.23	0.44	0.18	0.40	1.23	0.45	0.22
2042	0.39	1.40	0.46	0.16	0.42	1.40	0.47	0.20
2043	0.33	1.10	0.39	0.15	0.35	1.10	0.40	0.18
2044	0.28	0.82	0.37	0.14	0.29	0.82	0.37	0.16
2045	0.30	0.97	0.38	0.14	0.31	0.97	0.38	0.16
2046	0.27	0.86	0.36	0.13	0.28	0.86	0.36	0.14
2047	0.28	0.93	0.37	0.13	0.29	0.91	0.37	0.14
2048	0.30	1.08	0.37	0.13	0.31	1.07	0.37	0.14
2049	0.31	1.14	0.39	0.12	0.33	1.15	0.39	0.14
2050	0.28	0.96	0.36	0.12	0.29	0.96	0.36	0.13
2051	0.27	0.96	0.36	0.10	0.28	0.96	0.36	0.11
2052	0.24	0.80	0.36	0.10	0.25	0.80	0.36	0.11
2053	0.32	1.26	0.38	0.11	0.32	1.26	0.38	0.12
2054	0.29	1.08	0.38	0.11	0.29	1.08	0.38	0.11
2055	0.26	0.93	0.36	0.10	0.26	0.93	0.36	0.11
2056	0.28	1.03	0.41	0.10	0.29	1.02	0.40	0.11
2057	0.29	1.14	0.37	0.10	0.30	1.14	0.37	0.10
2058	0.25	0.85	0.37	0.10	0.25	0.85	0.37	0.10
2059	0.31	1.27	0.36	0.10	0.31	1.26	0.36	0.10
2060	0.24	0.88	0.35	0.09	0.25	0.87	0.35	0.09
2061	0.23	0.79	0.33	0.09	0.23	0.79	0.33	0.09
2062	0.25	0.89	0.34	0.09	0.25	0.89	0.34	0.09
2063	0.24	0.89	0.35	0.09	0.25	0.89	0.34	0.09
2064	0.25	0.92	0.36	0.09	0.25	0.92	0.36	0.09
2065	0.25	0.88	0.36	0.10	0.25	0.87	0.36	0.10
2066	0.30	1.25	0.34	0.09	0.30	1.25	0.34	0.09
2067	0.26	0.95	0.37	0.09	0.26	0.95	0.37	0.09

Notes:

1. Fish fillets multiplied by 2.5 to obtain whole fish concentrations.
2. All whole fish PCB concentrations are above target fish concentration of 0.3 mg/kg and/or 0.03 mg/kg based on the river otter lowest-observed-adverse-effects-level (LOAEL) and no-observed-adverse-effects-level (NOAEL), respectively.

Upper Hudson River average is weighted by river section length:
River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 42
Upper Hudson River Average Largemouth Bass (Whole Fish) PCB Concentration (in mg/kg)

	Total PCB 600 g/day (sr01)				**Monitored Natural Attenuation**			
Year	**Upper River Average**	**Section 1 (RM 189)**	**Section 2 (RM 184)**	**Section 3 (RM 154)**	**Upper River Average**	**Section 1 (RM 189)**	**Section 2 (RM 184)**	**Section 3 (RM 154)**
1998	7.13	16.70	17.24	3.33	7.19	16.61	18.04	3.29
1999	7.04	17.12	16.83	3.20	6.76	16.16	15.91	3.17
2000	5.84	13.74	14.47	2.66	5.74	13.09	14.57	2.64
2001	5.30	12.04	13.32	2.47	5.13	11.34	12.94	2.45
2002	4.92	11.66	12.29	2.20	4.76	11.11	11.84	2.18
2003	4.43	10.11	11.40	2.01	4.33	9.92	10.73	2.03
2004	5.12	14.38	11.48	2.04	4.88	13.63	10.57	2.02
2005	3.94	9.67	9.95	1.68	3.85	9.04	10.09	1.66
2006	3.28	6.57	9.17	1.55	3.06	5.97	8.70	1.46
2007	3.35	7.78	8.73	1.47	2.96	6.39	7.95	1.36
2008	3.40	9.02	8.30	1.36	2.78	6.45	7.30	1.21
2009	2.49	5.39	5.93	1.27	2.60	6.16	6.88	1.10
2010	1.65	3.00	2.76	1.17	2.31	5.51	6.40	0.92
2011	1.34	2.12	1.67	1.11	1.95	4.24	5.61	0.83
2012	1.07	2.41	1.54	0.70	1.78	4.21	5.16	0.68
2013	0.85	1.71	1.34	0.59	1.55	3.47	4.60	0.61
2014	0.79	1.80	1.23	0.50	1.46	3.49	4.23	0.55
2015	0.70	1.51	1.16	0.44	1.33	3.13	3.87	0.50
2016	0.73	1.71	1.26	0.43	1.36	3.53	3.65	0.50
2017	0.77	2.16	1.18	0.40	1.38	3.73	3.60	0.49
2018	0.70	1.92	1.10	0.37	1.24	3.29	3.21	0.46
2019	0.75	2.33	1.14	0.34	1.25	3.68	2.94	0.43
2020	0.61	1.87	0.93	***0.29***	1.08	3.02	2.71	0.38
2021	0.53	1.42	0.91	0.27	0.93	2.43	2.40	0.36
2022	0.53	1.42	0.93	0.27	0.93	2.51	2.26	0.36
2023	0.55	1.68	0.89	0.25	0.94	2.67	2.21	0.35
2024	0.50	1.57	0.81	0.21	0.82	2.26	2.05	***0.29***
2025	0.44	1.28	0.76	0.20	0.73	1.98	1.82	0.28
2026	0.39	1.06	0.72	0.19	0.66	1.69	1.68	0.26
2027	0.48	1.59	0.75	0.19	0.75	2.29	1.66	0.27
2028	0.46	1.69	0.66	0.17	0.73	2.33	1.61	0.23
2029	0.40	1.33	0.62	0.16	0.62	1.83	1.44	0.22
2030	0.35	0.98	0.62	0.17	0.55	1.45	1.33	0.23
2031	0.40	1.41	0.58	0.15	0.59	1.86	1.27	0.21
2032	0.35	1.18	0.55	0.14	0.53	1.59	1.13	0.20
2033	0.34	1.13	0.53	0.13	0.49	1.47	1.04	0.18
2034	0.34	1.23	0.49	0.13	0.48	1.50	0.98	0.17
2035	***0.28***	0.87	0.48	0.12	0.41	1.12	0.87	0.18
2036	0.33	1.20	0.48	0.12	0.51	1.43	0.85	0.26
2037	0.32	0.98	0.47	0.15	0.45	1.19	0.75	0.24
2038	0.37	1.13	0.43	0.20	0.45	1.32	0.72	0.22
2039	0.34	0.89	0.42	0.21	0.41	1.09	0.68	0.22
2040	0.32	0.86	0.42	0.19	0.38	0.98	0.63	0.20

Notes:

1. Fish fillets multiplied by 2.5 to obtain whole fish concentrations.
2. All whole fish PCB concentrations are above target fish concentration of 0.3 mg/kg and/or 0.03 mg/kg based on the river otter lowest-observed-adverse-effects-level (LOAEL) and no-observed-adverse-effects-level (NOAEL), respectively.

Upper Hudson River average is weighted by river section length:
River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 42
Upper Hudson River Average Largemouth Bass (Whole Fish) PCB Concentration (in mg/kg)

	Total PCB 600 g/day (sr01)				**Monitored Natural Attenuation**			
Year	**Upper River Average**	**Section 1 (RM 189)**	**Section 2 (RM 184)**	**Section 3 (RM 154)**	**Upper River Average**	**Section 1 (RM 189)**	**Section 2 (RM 184)**	**Section 3 (RM 154)**
2041	0.39	1.23	0.44	0.20	0.45	1.42	0.66	0.21
2042	0.41	1.40	0.46	0.18	0.46	1.56	0.65	0.19
2043	0.34	1.10	0.40	0.16	0.39	1.22	0.62	0.17
2044	0.28	0.83	0.37	0.15	0.32	0.88	0.55	0.16
2045	0.31	1.00	0.38	0.15	0.34	1.04	0.52	0.16
2046	0.28	0.88	0.36	0.14	0.32	0.95	0.51	0.15
2047	0.29	0.93	0.37	0.14	0.35	1.17	0.49	0.15
2048	0.31	1.07	0.37	0.13	0.39	1.42	0.50	0.15
2049	0.32	1.13	0.39	0.13	0.38	1.39	0.50	0.14
2050	0.28	0.95	0.37	0.12	0.34	1.21	0.49	0.13
2051	0.27	0.96	0.37	0.11	0.32	1.12	0.47	0.12
2052	0.25	0.82	0.36	0.11	***0.29***	0.98	0.44	0.12
2053	0.33	1.28	0.38	0.11	0.37	1.41	0.49	0.12
2054	0.30	1.10	0.38	0.11	0.32	1.18	0.46	0.12
2055	0.27	0.95	0.36	0.10	0.30	1.06	0.44	0.11
2056	0.29	1.04	0.41	0.10	0.32	1.16	0.45	0.11
2057	0.30	1.15	0.37	0.10	0.32	1.17	0.46	0.11
2058	0.25	0.87	0.38	0.10	0.27	0.91	0.43	0.11
2059	0.31	1.28	0.36	0.10	0.33	1.31	0.46	0.10
2060	0.25	0.89	0.35	0.09	0.26	0.93	0.40	0.10
2061	0.23	0.80	0.33	0.09	0.25	0.84	0.38	0.09
2062	0.25	0.90	0.34	0.09	0.26	0.91	0.38	0.10
2063	0.25	0.89	0.35	0.09	0.26	0.91	0.37	0.10
2064	0.25	0.92	0.36	0.09	0.27	0.97	0.38	0.10
2065	0.25	0.88	0.36	0.10	0.25	0.87	0.38	0.10
2066	0.30	1.25	0.34	0.09	0.31	1.26	0.40	0.09
2067	0.26	0.95	0.37	0.09	0.27	0.97	0.37	0.10

Notes:

1. Fish fillets multiplied by 2.5 to obtain whole fish concentrations.
2. All whole fish PCB concentrations are above target fish concentration of 0.3 mg/kg and/or 0.03 mg/kg based on the river otter lowest-observed-adverse-effects-level (LOAEL) and no-observed-adverse-effects-level (NOAEL), respectively.

Upper Hudson River average is weighted by river section length:
River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 43
Modeled Times of Compliance with River Otter Risk-Based Fish Concentrations Upper Hudson River

	River Otter - RI/FS TRVs (whole fish tissue)	
	LOAEL 0.3 PCBs mg/kg	NOAEL 0.03 PCBs mg/kg
Upper Hudson River Average		
No Resuspension (d004)	2035	> 2067
Total PCB 350 ng/L (sr04)	2035	> 2067
Total PCB 600 g/day (sr01)	2035	> 2067
Monitored Natural Attenuation	2052	> 2067
Upper Hudson River Section 1		
No Resuspension (d004)	> 2067	> 2067
Total PCB 350 ng/L (sr04)	> 2067	> 2067
Total PCB 600 g/day (sr01)	> 2067	> 2067
Monitored Natural Attenuation	> 2067	> 2067
Upper Hudson River Section 2		
No Resuspension (d004)	> 2067	> 2067
Total PCB 350 ng/L (sr04)	> 2067	> 2067
Total PCB 600 g/day (sr01)	> 2067	> 2067
Monitored Natural Attenuation	> 2067	> 2067
Upper Hudson River Section 3		
No Resuspension (d004)	2019	> 2067
Total PCB 350 ng/L (sr04)	2024	> 2067
Total PCB 600 g/day (sr01)	2020	> 2067
Monitored Natural Attenuation	2024	> 2067

Notes:
First year in which fish target concentrations are achieved are provided.
Upper Hudson River average is weighted by river section length. River Section 1: 6.3 miles = 15.4%; River Section 2: 5.1 miles = 12.5%; and River Section 3: 29.5 miles = 72.1%.

Table 44
Lower Hudson River Average Largemouth Bass (Whole Fish) PCB Concentration (in mg/kg)

	No Resuspension (d004)				**Total PCB 350 ng/L (sr04)**			
Year	River Mile 152	River Mile 113	River Mile 90	River Mile 50	River Mile 152	River Mile 113	River Mile 90	River Mile 50
1998	7.15	5.21	3.55	3.26	7.15	5.21	3.55	3.26
1999	4.53	4.12	3.30	3.01	4.53	4.12	3.30	3.01
2000	3.81	3.56	2.93	2.73	3.81	3.56	2.93	2.73
2001	4.50	3.54	2.66	2.49	4.50	3.54	2.66	2.49
2002	3.97	3.19	2.49	2.31	3.97	3.19	2.49	2.31
2003	3.42	2.82	2.26	2.10	3.42	2.82	2.26	2.10
2004	2.42	2.26	1.97	1.89	2.42	2.26	1.97	1.89
2005	2.27	1.95	1.69	1.67	2.27	1.95	1.69	1.67
2006	2.37	1.85	1.49	1.48	2.53	1.89	1.49	1.49
2007	1.93	1.71	1.35	1.34	2.37	1.86	1.40	1.36
2008	1.54	1.41	1.22	1.20	2.33	1.77	1.33	1.25
2009	1.21	1.15	1.06	1.05	2.03	1.53	1.18	1.12
2010	1.10	1.02	0.92	0.94	2.55	1.71	1.16	1.06
2011	1.25	1.01	0.84	0.86	5.16	2.57	1.35	1.10
2012	0.92	0.86	0.75	0.77	2.17	2.06	1.38	1.13
2013	1.02	0.82	0.68	0.71	1.78	1.63	1.28	1.11
2014	0.86	0.74	0.62	0.64	1.33	1.29	1.12	1.04
2015	0.72	0.65	0.56	0.59	1.04	1.04	0.96	0.94
2016	0.55	0.53	0.50	0.53	0.76	0.78	0.79	0.83
2017	0.46	0.45	0.44	0.48	0.54	0.60	0.65	0.73
2018	0.43	0.41	0.39	0.44	0.45	0.50	0.54	0.63
2019	0.34	0.35	0.35	0.40	0.35	0.39	0.44	0.54
2020	0.42	0.35	0.32	0.36	0.42	0.37	0.38	0.46
2021	0.41	0.34	***0.30***	0.34	0.41	0.36	0.34	0.41
2022	0.35	0.32	0.29	0.32	0.35	0.33	0.31	0.37
2023	0.30	***0.29***	0.27	***0.30***	0.30	***0.29***	***0.28***	0.33
2024	0.32	0.28	0.25	0.28	0.32	0.28	0.26	0.31
2025	0.35	0.30	0.25	0.27	0.35	0.30	0.26	***0.29***
2026	0.33	0.29	0.25	0.27	0.33	0.29	0.25	0.28
2027	***0.26***	0.26	0.24	0.26	***0.26***	0.26	0.24	0.27
2028	0.24	0.24	0.23	0.25	0.24	0.25	0.23	0.26
2029	0.29	0.25	0.22	0.24	0.29	0.25	0.22	0.25
2030	0.29	0.25	0.22	0.24	0.29	0.25	0.22	0.24
2031	0.25	0.24	0.21	0.23	0.25	0.24	0.21	0.23
2032	0.25	0.24	0.21	0.23	0.25	0.24	0.21	0.23
2033	0.23	0.23	0.21	0.23	0.23	0.23	0.21	0.23
2034	0.22	0.22	0.20	0.22	0.22	0.22	0.20	0.22
2035	0.35	0.25	0.21	0.22	0.35	0.25	0.21	0.22
2036	0.48	0.32	0.23	0.23	0.48	0.32	0.23	0.23
2037	0.57	0.39	0.26	0.24	0.57	0.39	0.26	0.24
2038	0.58	0.40	0.28	0.26	0.58	0.40	0.28	0.26
2039	0.48	0.39	0.29	0.27	0.48	0.39	0.29	0.27
2040	0.43	0.37	0.29	0.27	0.43	0.37	0.29	0.27
2041	0.30	0.32	0.28	0.27	0.30	0.32	0.28	0.27
2042	0.25	0.27	0.26	0.26	0.25	0.27	0.26	0.26
2043	0.29	0.26	0.24	0.25	0.29	0.26	0.24	0.25
2044	0.35	0.28	0.23	0.24	0.35	0.28	0.23	0.25
2045	0.33	0.28	0.23	0.24	0.33	0.28	0.23	0.24
2046	0.29	0.26	0.22	0.24	0.29	0.26	0.22	0.24

Notes:

Fish fillets multiplied by 2.5 to obtain whole fish concentrations.

All whole fish PCB concentrations are above target fish concentration of 0.3 mg/kg and/or 0.03 mg/kg based on the river otter lowest-observed-adverse-effects-level (LOAEL) and no-observed-adverse-effects-level (NOAEL), respectively.

Table 44
Lower Hudson River Average Largemouth Bass (Whole Fish) PCB Concentration (in mg/kg)

Year	**Total PCB 600 g/day (sr01)**				**Monitored Natural Attenuation**			
	River Mile 152	River Mile 113	River Mile 90	River Mile 50	River Mile 152	River Mile 113	River Mile 90	River Mile 50
1998	7.15	5.21	3.55	3.26	7.54	5.30	3.55	3.24
1999	4.53	4.12	3.30	3.01	4.37	4.06	3.28	2.99
2000	3.81	3.56	2.93	2.73	4.01	3.56	2.91	2.71
2001	4.50	3.54	2.66	2.49	4.51	3.54	2.65	2.47
2002	3.97	3.19	2.49	2.31	3.91	3.17	2.47	2.28
2003	3.42	2.82	2.26	2.10	3.39	2.82	2.25	2.08
2004	2.42	2.26	1.97	1.89	2.39	2.23	1.96	1.88
2005	2.27	1.95	1.69	1.67	2.25	1.94	1.68	1.66
2006	2.49	1.86	1.49	1.49	2.34	1.86	1.49	1.47
2007	2.20	1.79	1.38	1.34	1.89	1.70	1.35	1.32
2008	1.97	1.60	1.27	1.23	1.57	1.42	1.21	1.20
2009	1.62	1.34	1.12	1.08	1.27	1.16	1.06	1.05
2010	1.73	1.30	1.02	1.00	1.36	1.13	0.94	0.95
2011	2.43	1.49	1.01	0.96	1.63	1.22	0.91	0.89
2012	1.32	1.20	0.96	0.90	1.30	1.11	0.86	0.83
2013	1.27	1.08	0.88	0.84	1.48	1.13	0.83	0.79
2014	1.01	0.92	0.78	0.77	1.27	1.03	0.79	0.74
2015	0.82	0.78	0.69	0.70	1.00	0.90	0.73	0.70
2016	0.61	0.61	0.60	0.63	0.76	0.72	0.65	0.64
2017	0.51	0.51	0.51	0.56	0.68	0.62	0.57	0.59
2018	0.47	0.45	0.45	0.50	0.65	0.58	0.51	0.53
2019	0.37	0.38	0.39	0.45	0.52	0.50	0.46	0.49
2020	0.45	0.37	0.35	0.40	0.68	0.51	0.42	0.44
2021	0.44	0.36	0.32	0.36	0.63	0.49	0.40	0.41
2022	0.37	0.34	0.30	0.34	0.51	0.45	0.38	0.39
2023	0.32	0.30	***0.28***	0.32	0.46	0.41	0.35	0.37
2024	0.33	***0.29***	0.26	***0.30***	0.48	0.40	0.34	0.35
2025	0.37	0.31	0.26	0.29	0.53	0.43	0.34	0.34
2026	0.34	0.29	0.25	0.28	0.48	0.40	0.33	0.33
2027	***0.26***	0.27	0.24	0.27	0.37	0.36	0.32	0.32
2028	0.25	0.25	0.23	0.26	0.35	0.34	***0.30***	0.31
2029	0.30	0.25	0.22	0.25	0.42	0.34	0.28	***0.30***
2030	0.30	0.25	0.22	0.24	0.40	0.34	0.28	0.29
2031	0.25	0.24	0.22	0.24	0.34	0.32	0.27	0.28
2032	0.26	0.24	0.22	0.24	0.35	0.32	0.27	0.28
2033	0.23	0.23	0.21	0.23	0.31	0.30	0.26	0.28
2034	0.22	0.22	0.20	0.23	***0.29***	***0.29***	0.25	0.27
2035	0.27	0.23	0.20	0.22	0.42	0.33	0.25	0.26
2036	0.23	0.22	0.20	0.22	0.54	0.38	0.27	0.26
2037	0.40	0.28	0.21	0.22	0.69	0.46	0.30	0.28
2038	0.65	0.38	0.24	0.23	0.65	0.47	0.32	0.29
2039	0.56	0.41	0.27	0.25	0.55	0.44	0.33	0.30
2040	0.51	0.40	0.29	0.26	0.48	0.42	0.33	0.31
2041	0.35	0.35	0.28	0.27	0.35	0.36	0.31	0.30
2042	0.29	0.30	0.27	0.27	0.28	0.30	0.28	0.29
2043	0.33	0.29	0.25	0.26	0.35	0.30	0.26	0.28
2044	0.38	0.31	0.25	0.25	0.42	0.32	0.26	0.27
2045	0.34	0.30	0.24	0.25	0.38	0.32	0.26	0.26
2046	0.30	0.27	0.23	0.24	0.33	0.30	0.25	0.26

Notes:
Fish fillets multiplied by 2.5 to obtain whole fish concentrations.
All whole fish PCB concentrations are above target fish concentration of 0.3 mg/kg and/or 0.03 mg/kg based on the river otter lowest-observed-adverse-effects-level (LOAEL) and no-observed-adverse-effects-level (NOAEL), respectively.

Table 45
Modeled Times of Compliance with River Otter Risk-Based Fish Concentrations Lower Hudson River

	River Otter - RI/FS TRVs (whole fish tissue)	
	LOAEL 0.3 PCBs mg/kg	NOAEL 0.03 PCBs mg/kg
Lower Hudson River RM 152		
No Resuspension (d004)	2027	> 2067
Total PCB 350 ng/L (sr04)	2027	> 2067
Total PCB 600 g/day (sr01)	2027	> 2067
Monitored Natural Attenuation	2034	> 2067
Lower Hudson River RM 113		
No Resuspension (d004)	2023	> 2067
Total PCB 350 ng/L (sr04)	2023	> 2067
Total PCB 600 g/day (sr01)	2024	> 2067
Monitored Natural Attenuation	2034	> 2067
Lower Hudson River RM 90		
No Resuspension (d004)	2021	> 2067
Total PCB 350 ng/L (sr04)	2023	> 2067
Total PCB 600 g/day (sr01)	2023	> 2067
Monitored Natural Attenuation	2028	> 2067
Lower Hudson River RM 50		
No Resuspension (d004)	2023	> 2067
Total PCB 350 ng/L (sr04)	2025	> 2067
Total PCB 600 g/day (sr01)	2024	> 2067
Monitored Natural Attenuation	2029	> 2067

Notes:
First year in which fish target concentrations are achieved are provided.

Table 46
Sediment Characteristics

Fraction Name	Fraction by Weight (%)	Mass Release Rate (kg/hr)	Representative Grain Diameter (mm)	Fall velocity from Stokes equation[1] (m/s)	Comments
Sand	0.19	91.5	2	3.21	Middle of ASTM 1990 "fine sand"
Silt	0.53	255.2	0.02	3.21 x 10-4	Middle of ASTM 1990 "silt"
Clay	0.28	134.8	0.002	3.21 x 10-6	Middle of ASTM 1990 "clay"

1. Stokes equation: Fall velocity (w) = gd2/rs-r)/18m, where g is 9.81 m/s2, d is the diameter of a spherical grain (m), rs is the density of sediment particles (kg/m3), r is the water density (999 kg/m3), and m is the dynamic viscosity of water (1.12 x 10-3 N-s/m2 at 15.6oC). A dry density of 700 kg/m3 was assumed for all sediments.

Table 47
Impact of Dispersion Coefficient on Predicted Peak Concentration and Length of Suspended Sediment Plume

Dispersion Coefficient (m2/s)	Peak suspended sediment concentration in immediate vicinity of dredge (mg/L) – above ambient conditions	Approximate length of plume at 5 mg/L contour (m)
0.1	390	900
1	72	800
10	13	120
100	2	0

Figures

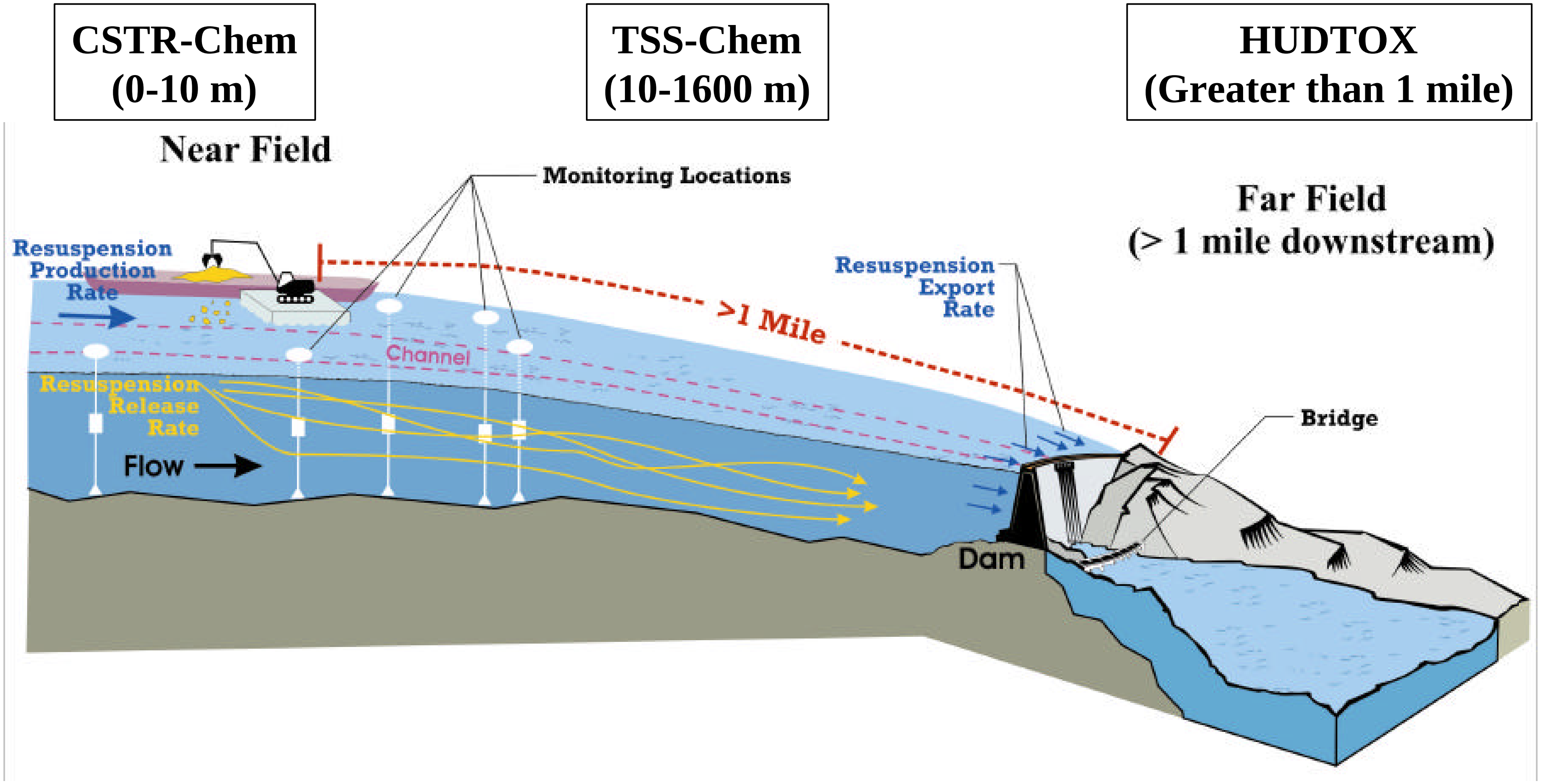
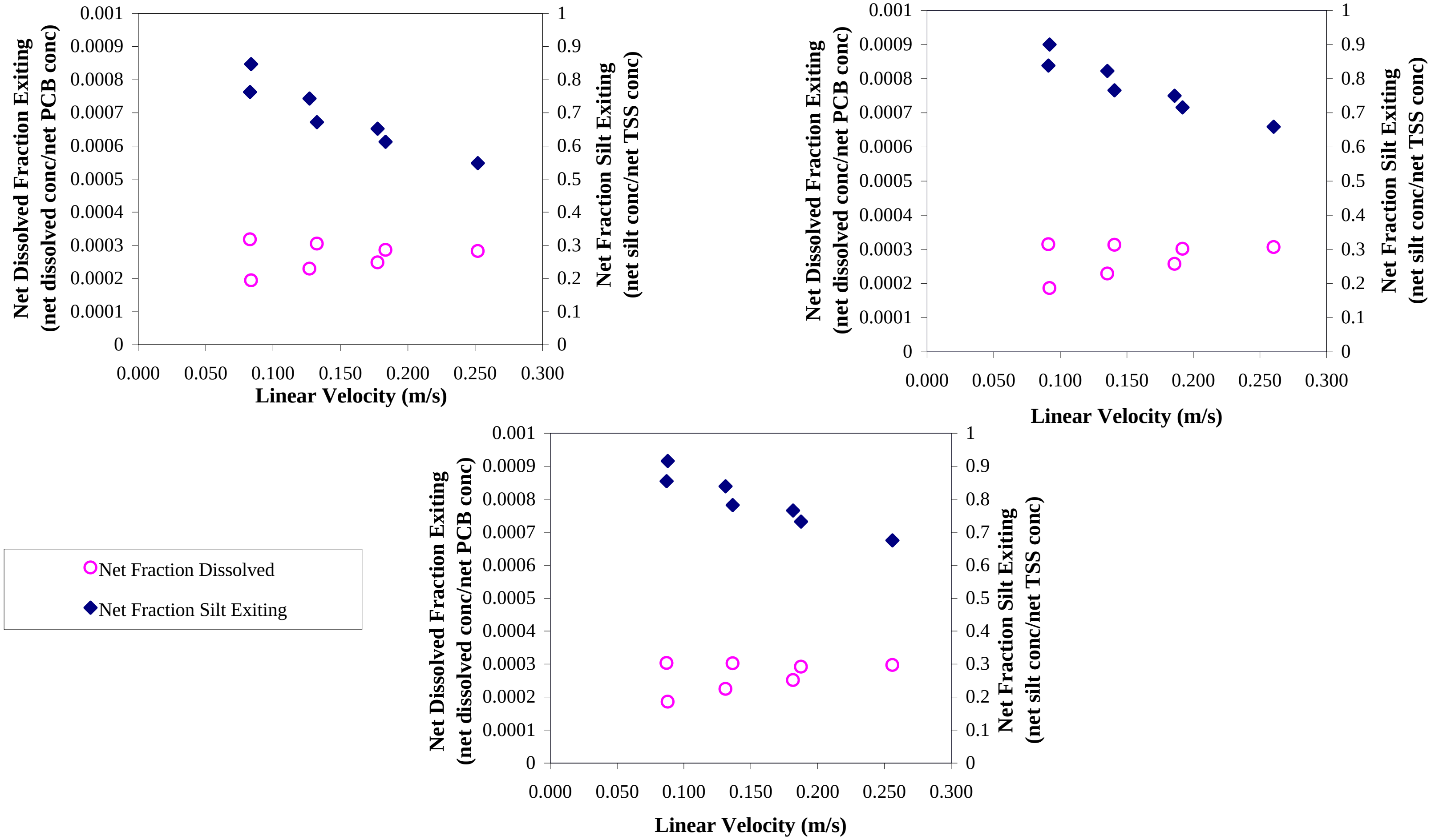


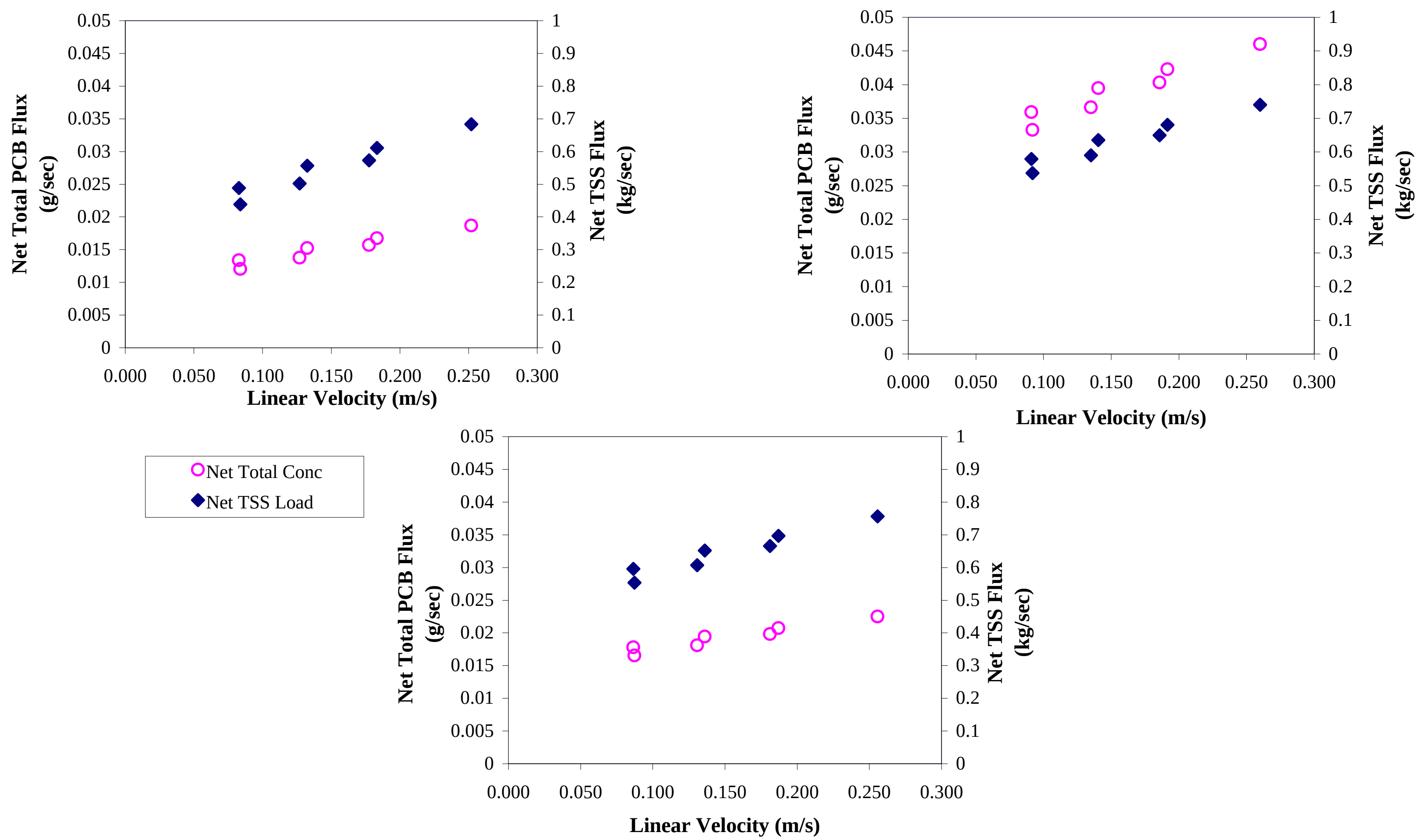
Figure 1. Interaction Among the Transport Models



Note: Net concentrations exclude background.

Figure 2

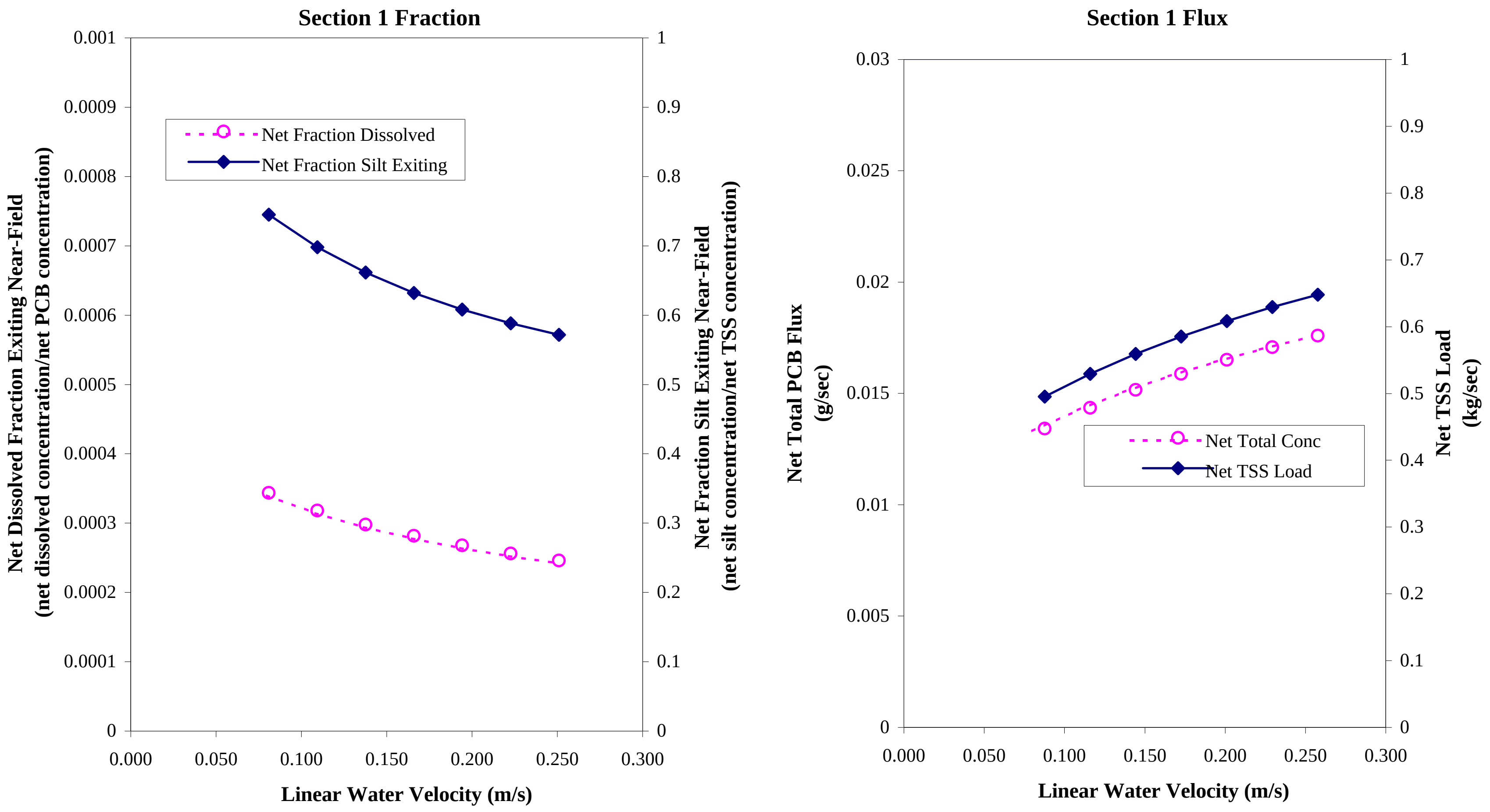
Sensitivity of Net Dissolved and Silt Fractions Exiting Near-Field with Variations in Linear Velocity and Depth for CSTR-Chem



Note: Net concentrations exclude background.

Figure 3

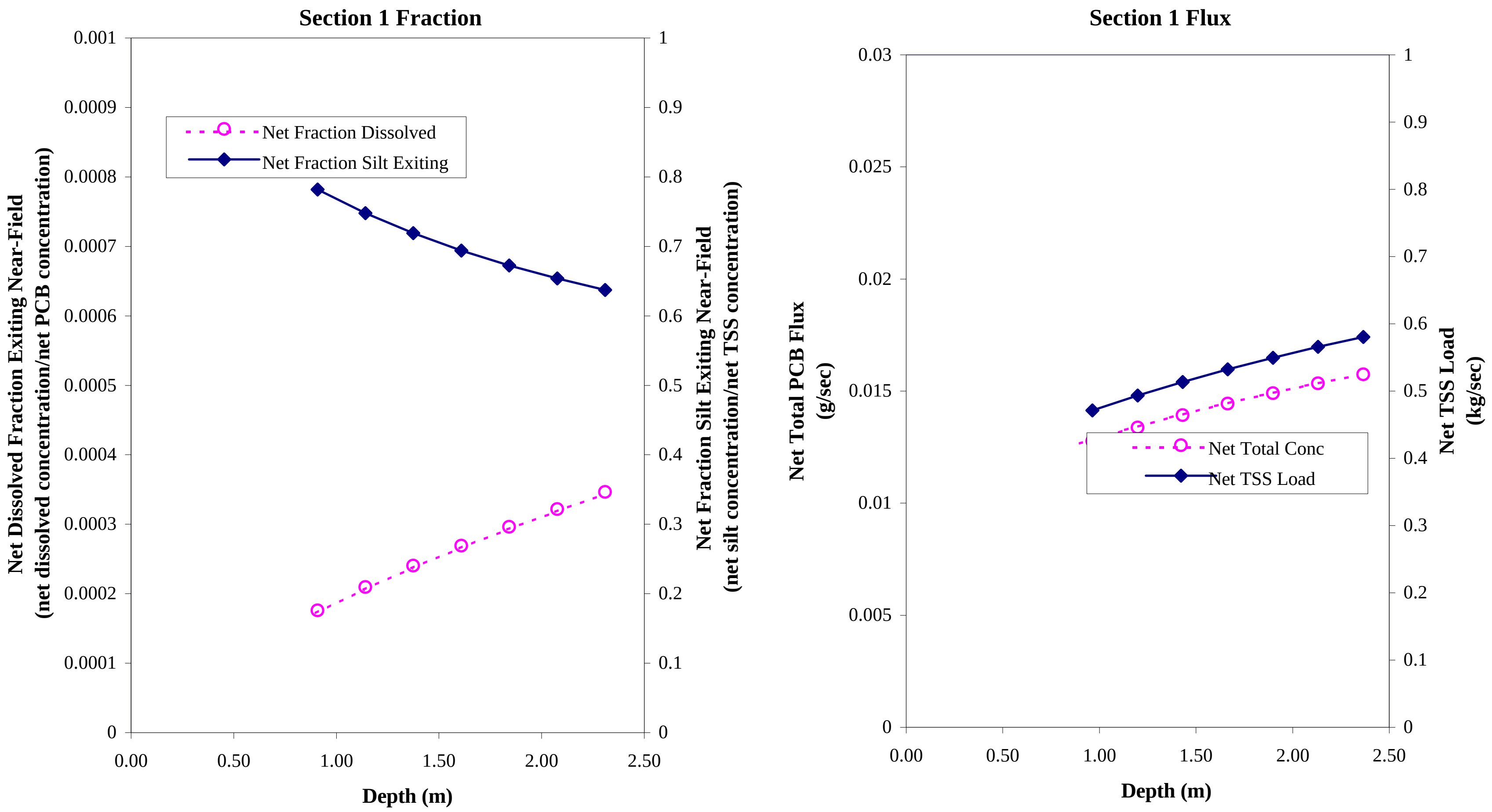
Sensitivity of Net Total PCB Flux and Net TSS Flux Exiting Near-Field with Variations in Linear Velocity and Depth for CSTR-Chem



Note: Net concentrations exclude background.

Figure 4

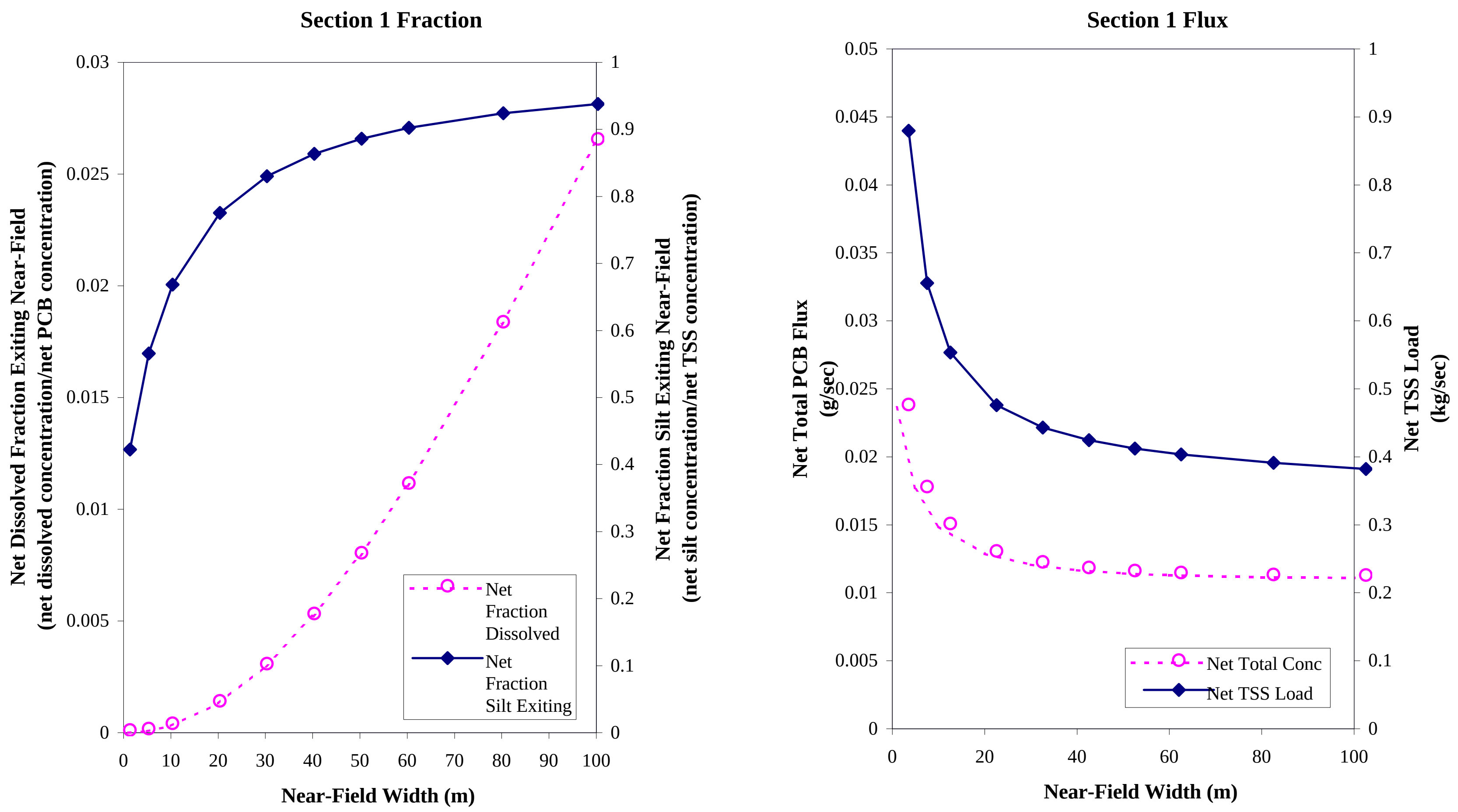
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Velocity for CSTR-Chem



Note: Net concentrations exclude background.

Figure 5

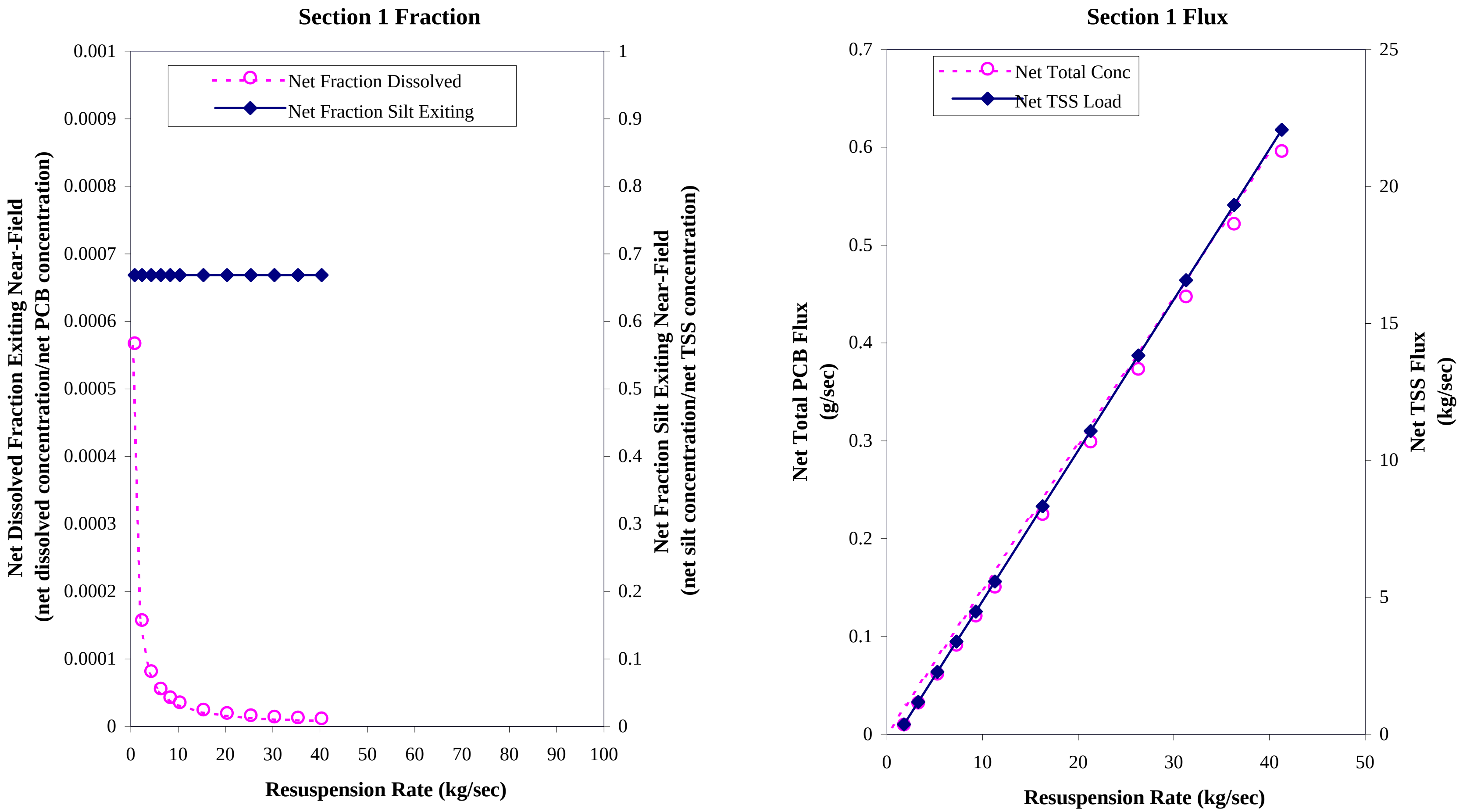
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Depth for CSTR-Chem



Note: Net concentrations exclude background.

Figure 6

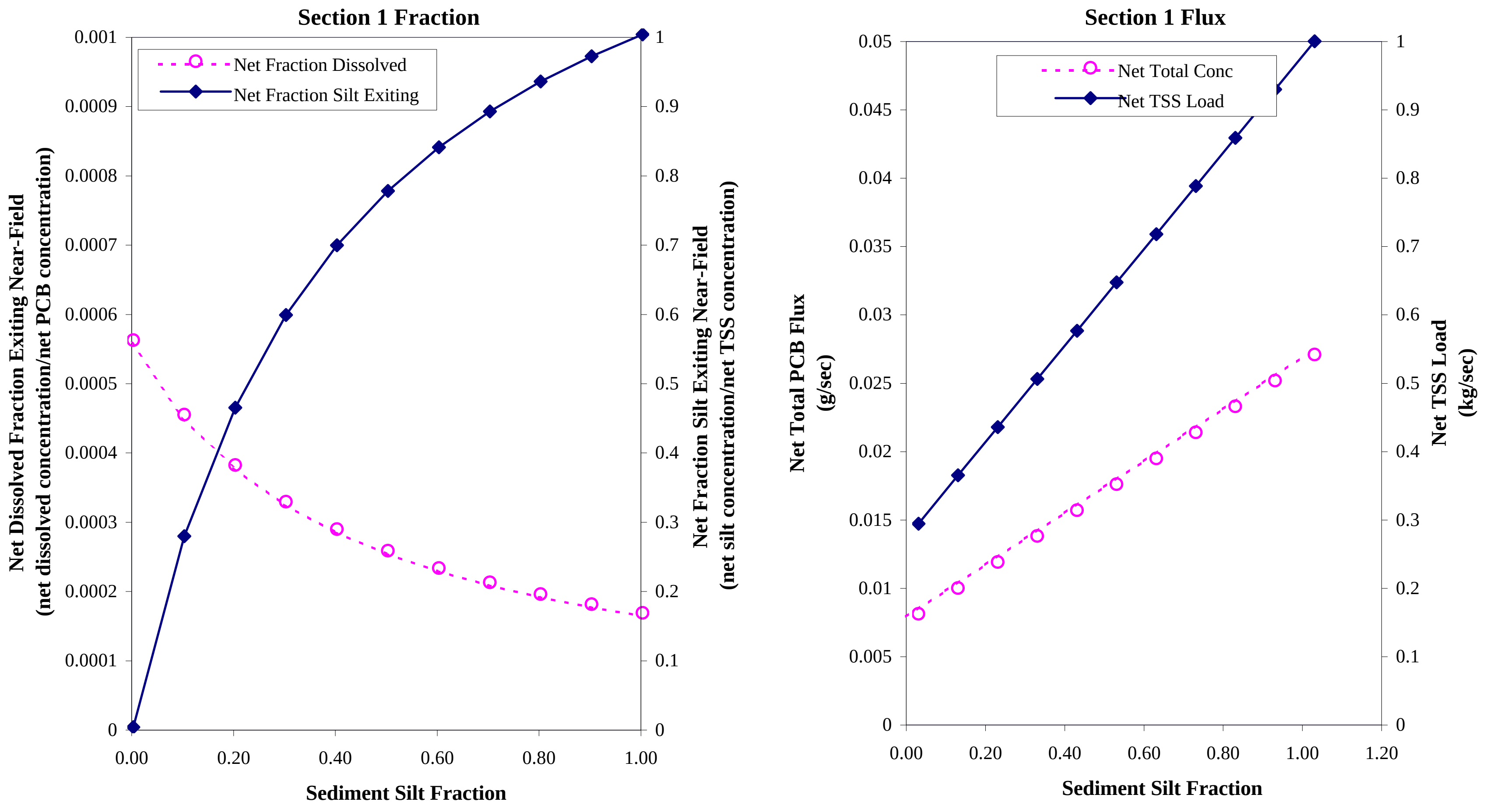
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Near-Field Width for CSTR-Chem



Note: Net concentrations exclude background.

Figure 7

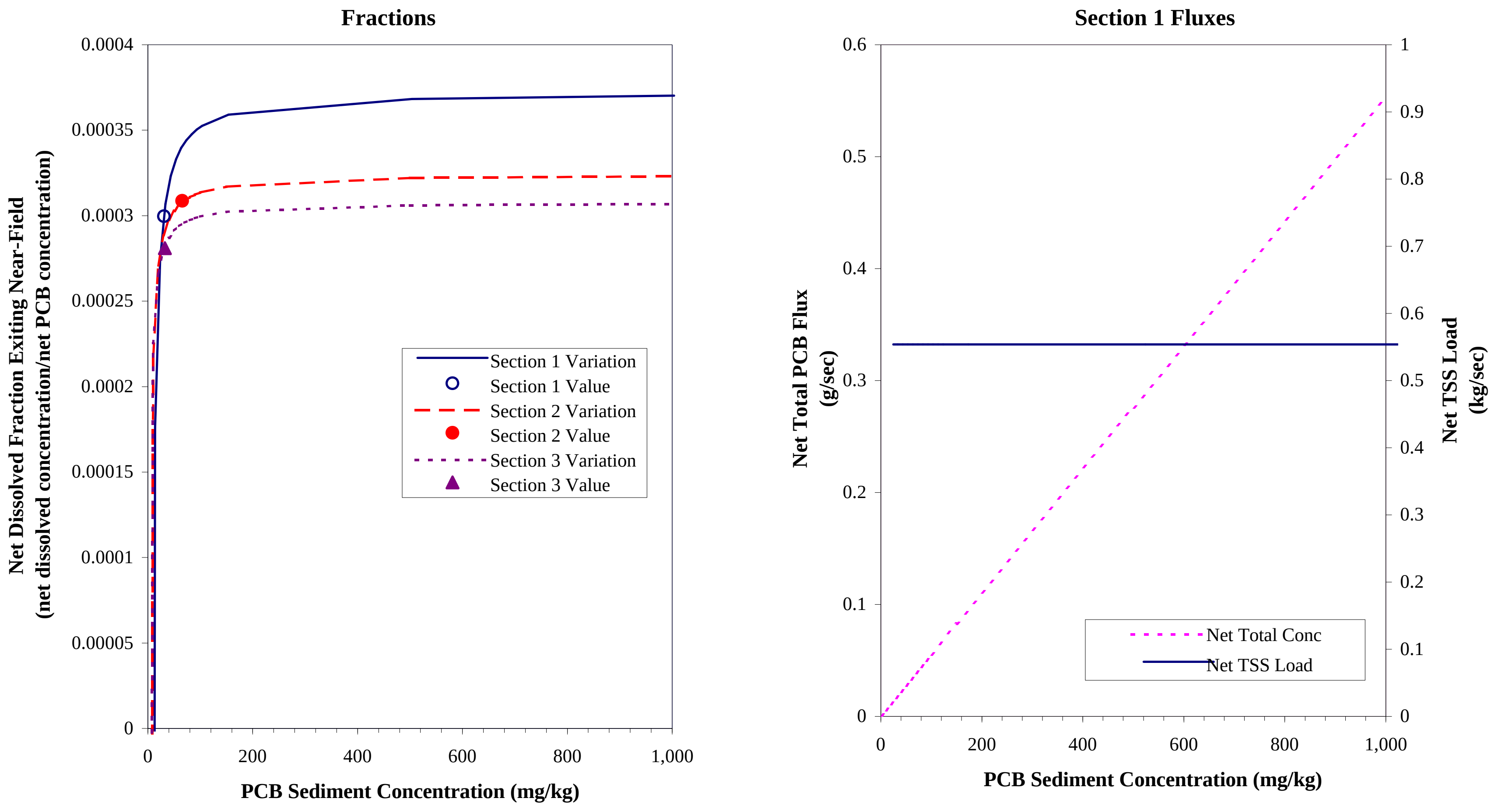
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Resuspension Rate for CSTR-Chem



Note: Net concentrations exclude background.

Figure 8

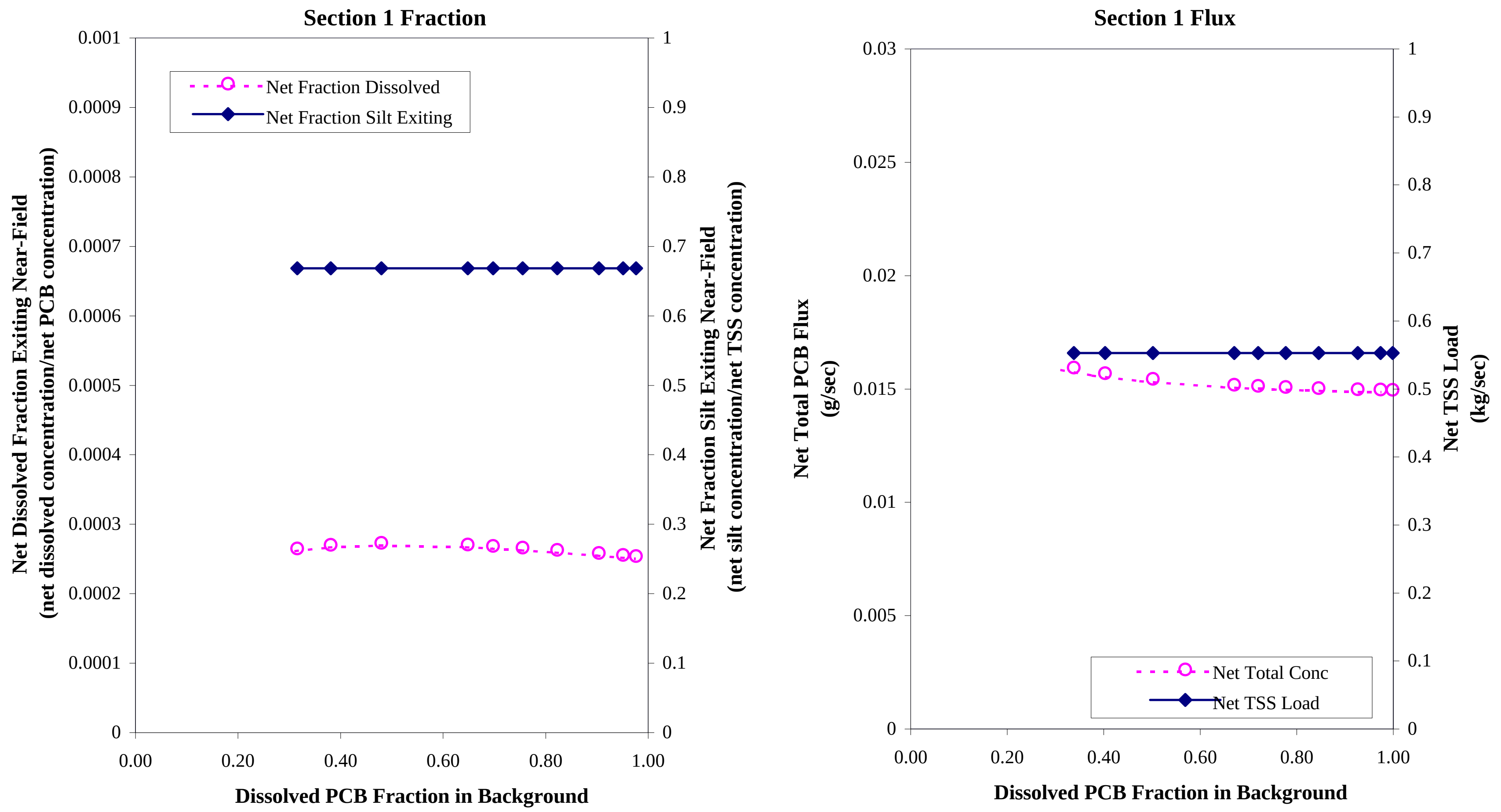
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Sediment Silt Fraction for CSTR-Chem



Note: Net concentrations exclude background.

Figure 9

Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of PCB Sediment Concentration for CSTR-Chem

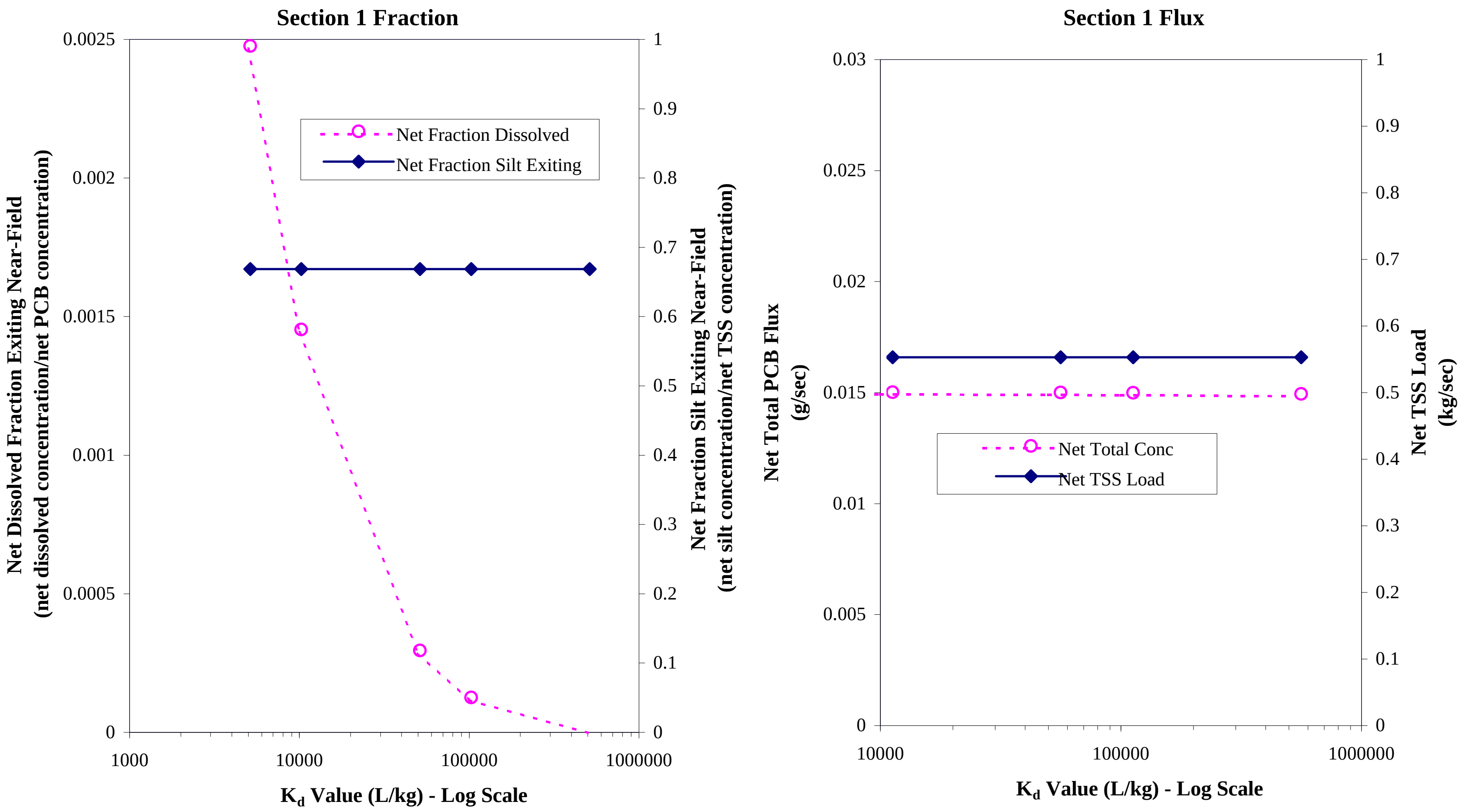


Note: Net concentrations exclude background.

Kd was held constant at 5,500 L/kg and Background TSS was varied from 0.5 to 40 mg/L.

Figure 10

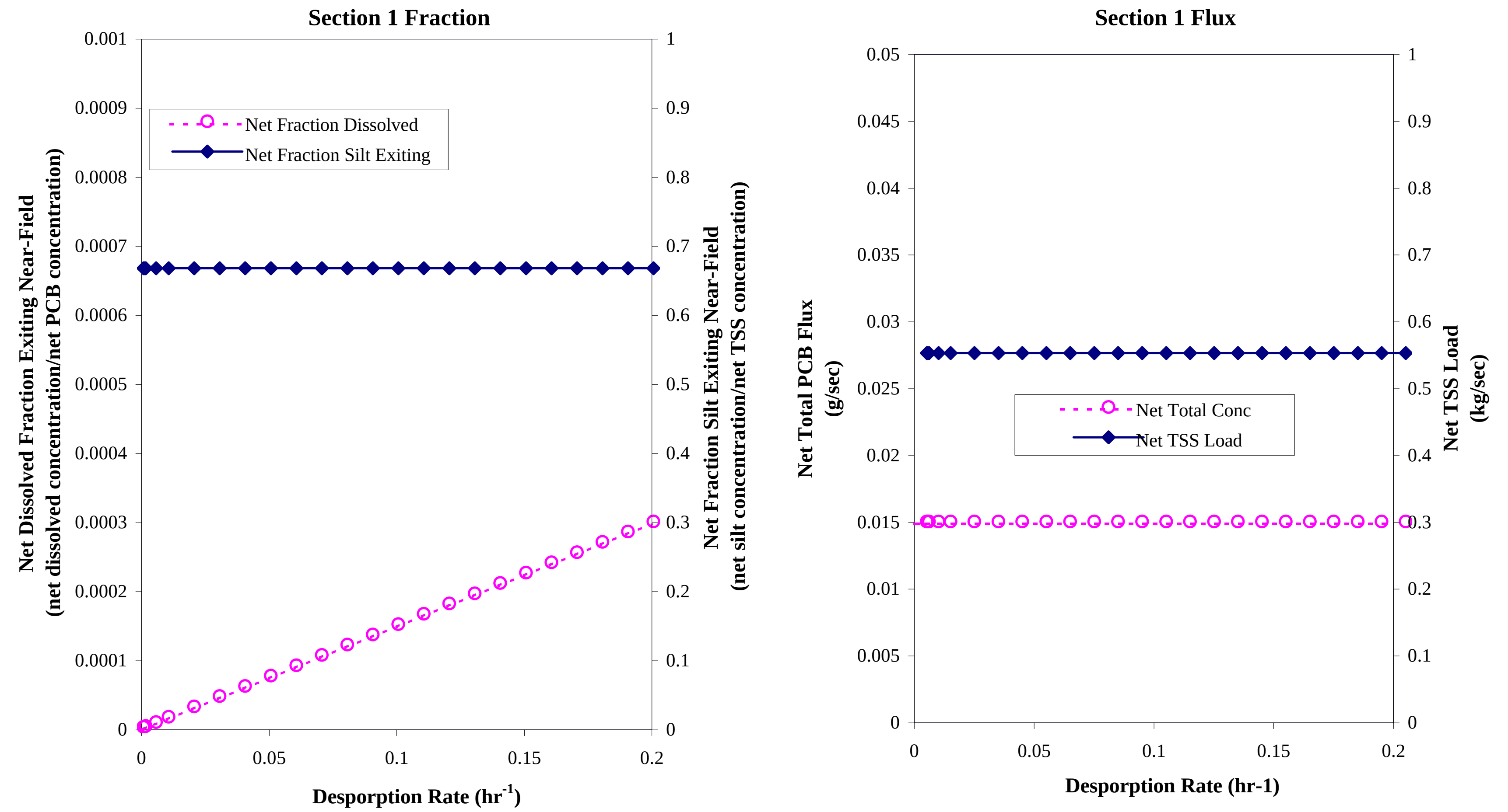
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Dissolved PCB Fraction in the Background and TSS Background Concentrations for CSTR-Chem



Note: Net concentrations exclude background.
Background TSS was held constant at 2.3 mg/L

Figure 11

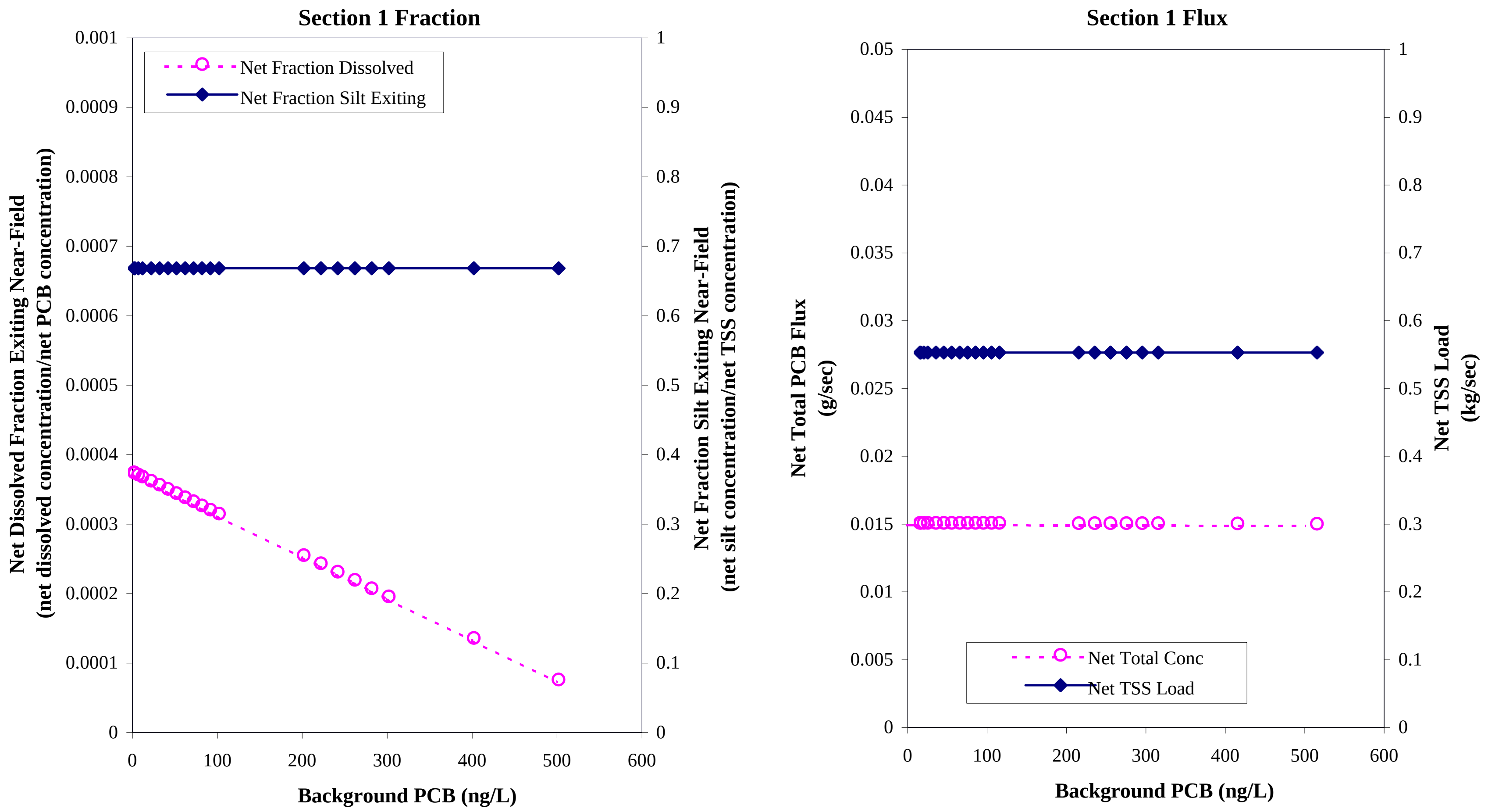
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Dissolved PCB Fraction in the Background and Kd Value for CSTR-Chem



Note: Net concentrations exclude background.

Figure 12

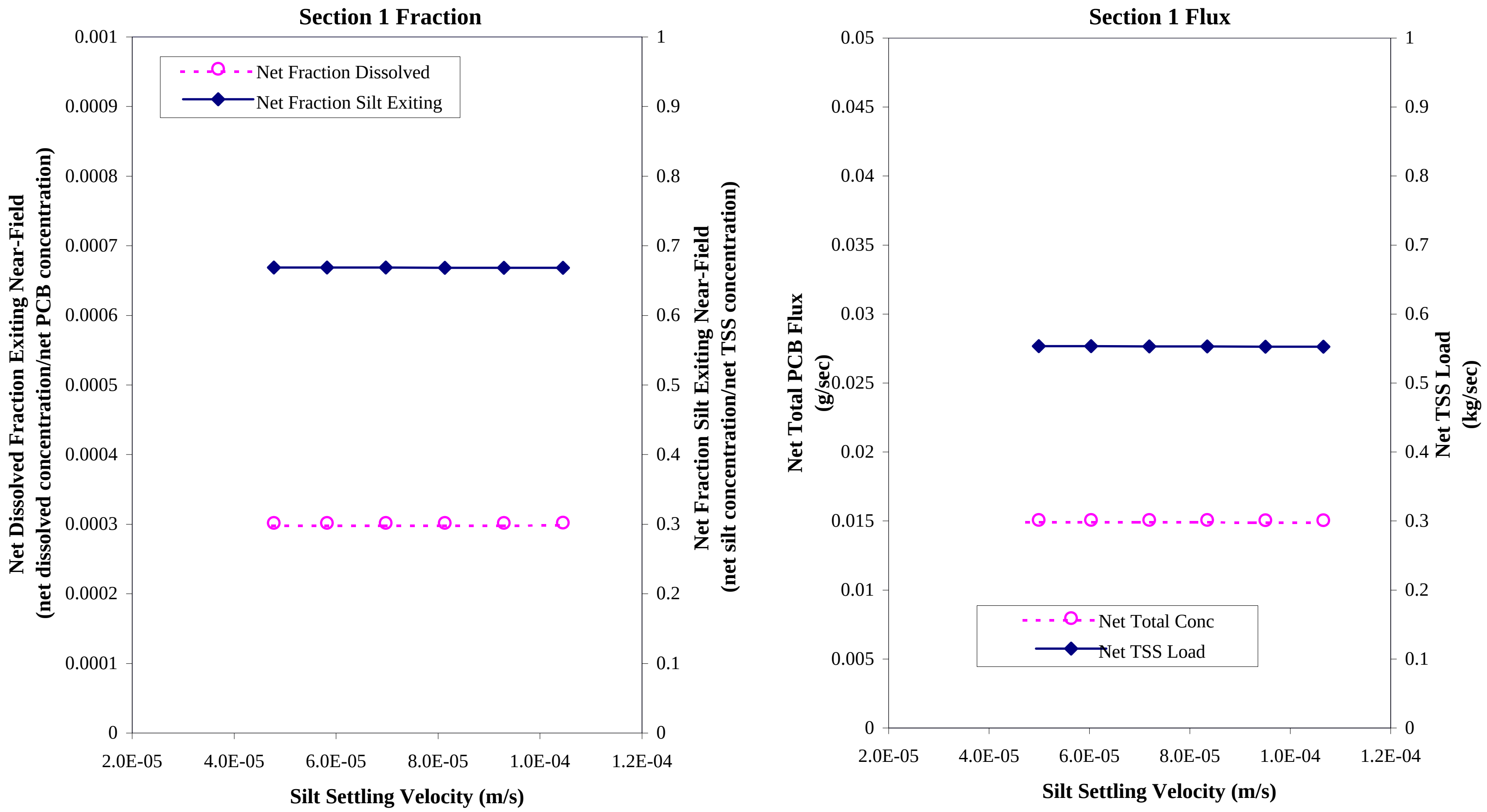
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Desorption Rate for CSTR-Chem



Note: Net concentrations exclude background.

Figure 13

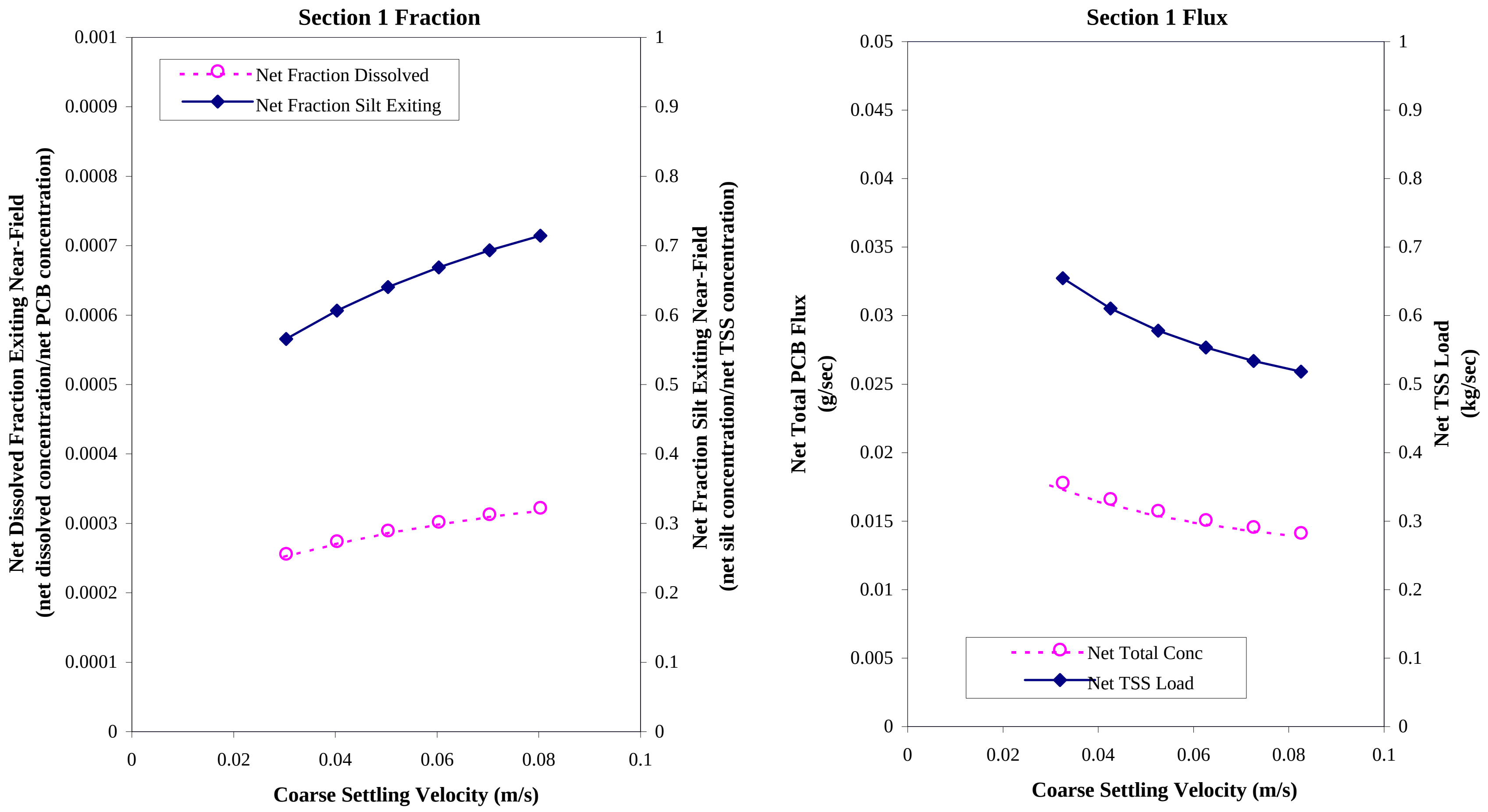
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Background PCB Concentration for CSTR-Chem



Note: Net concentrations exclude background.

Figure 14

Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Silt Settling Velocity for CSTR-Chem



Note: Net concentrations exclude background.

Figure 15

Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Coarse Settling Velocity for CSTR-Chem

Figure 16
Estimated TSS Concentration Downstream of the Dredge Head in Section 1 (Flow is 4000 cfs and PCB concentration is 500 ng/L at the far field station)

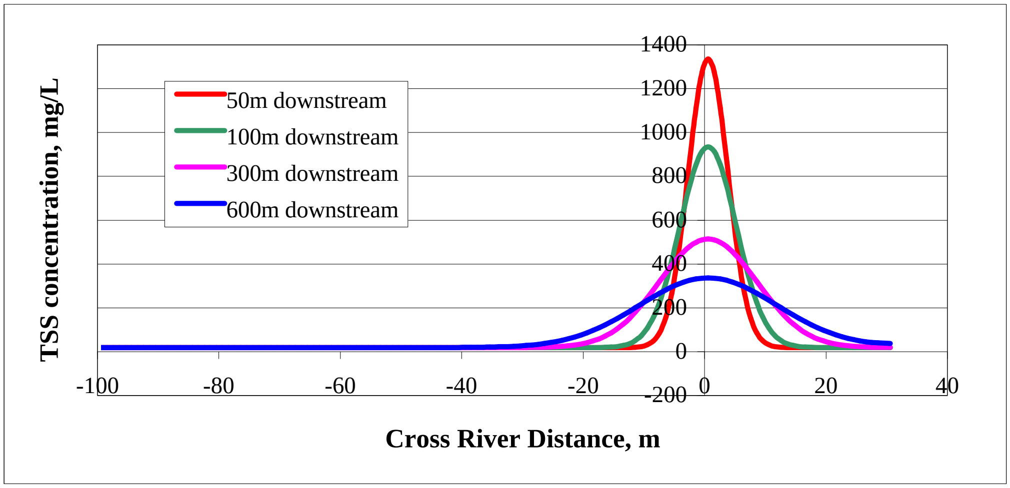
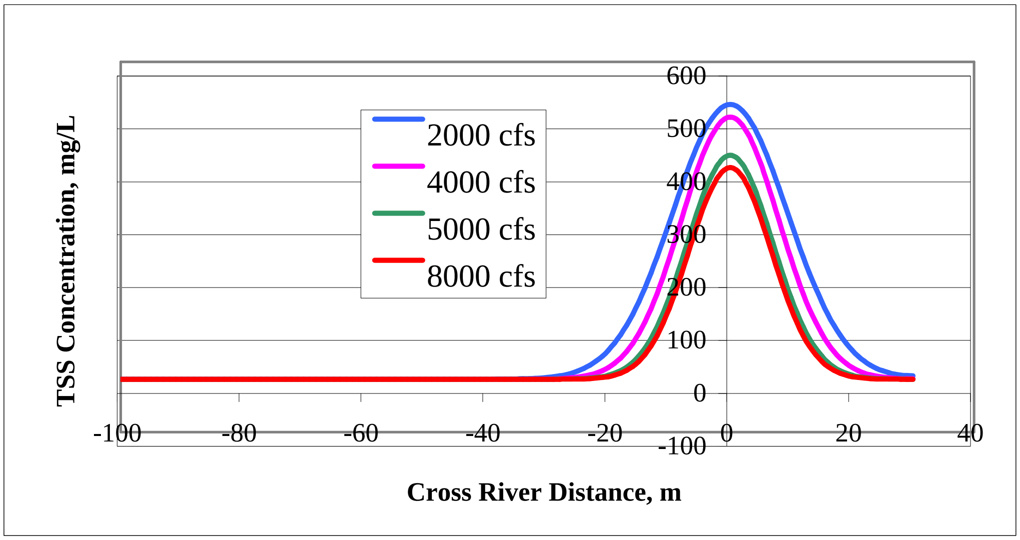
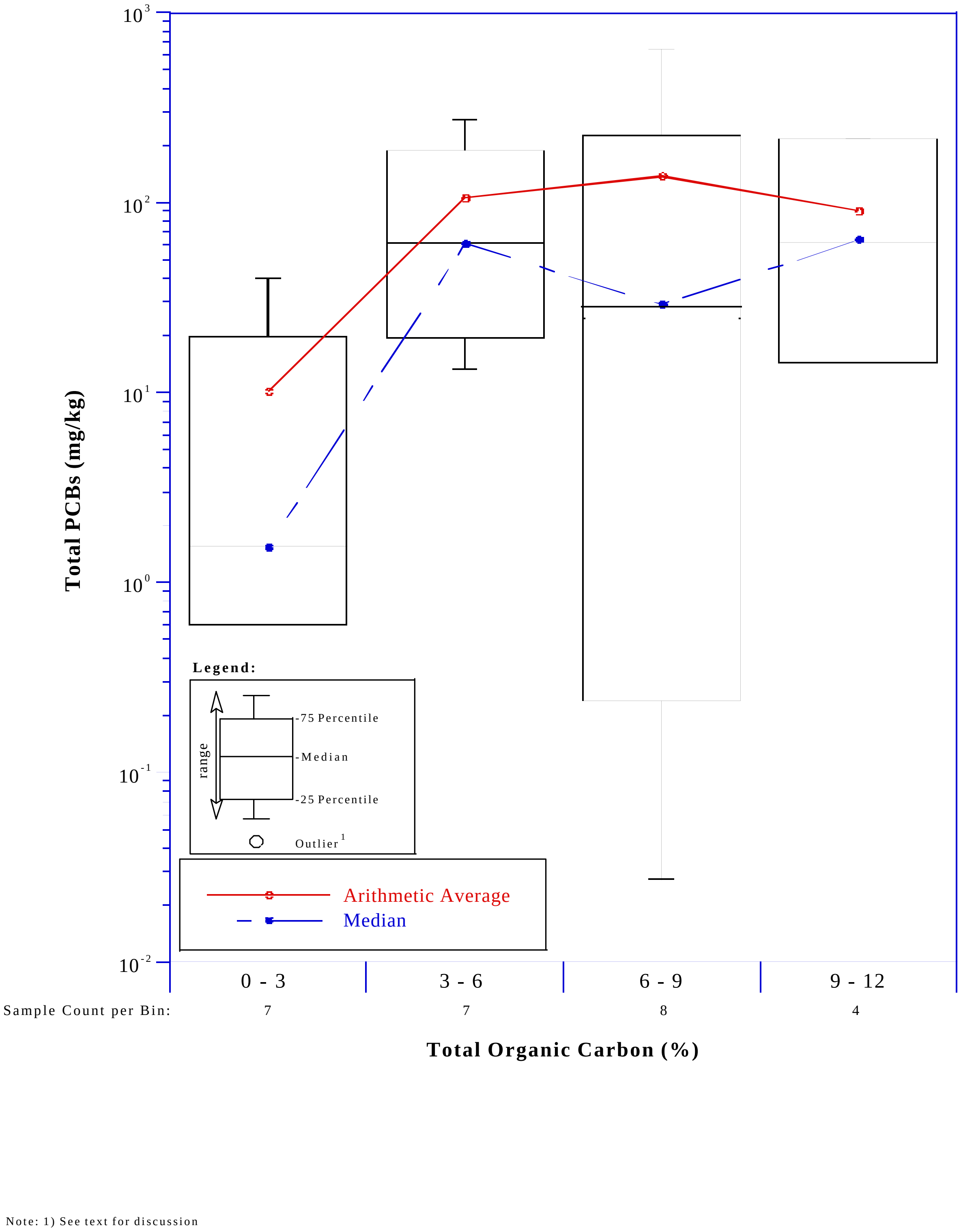


Figure 17
Estimated TSS Concentration at 300 m Downstream of the Dredge Head in Section 1 (PCB concentration at the far-field station is 500 ng/L)





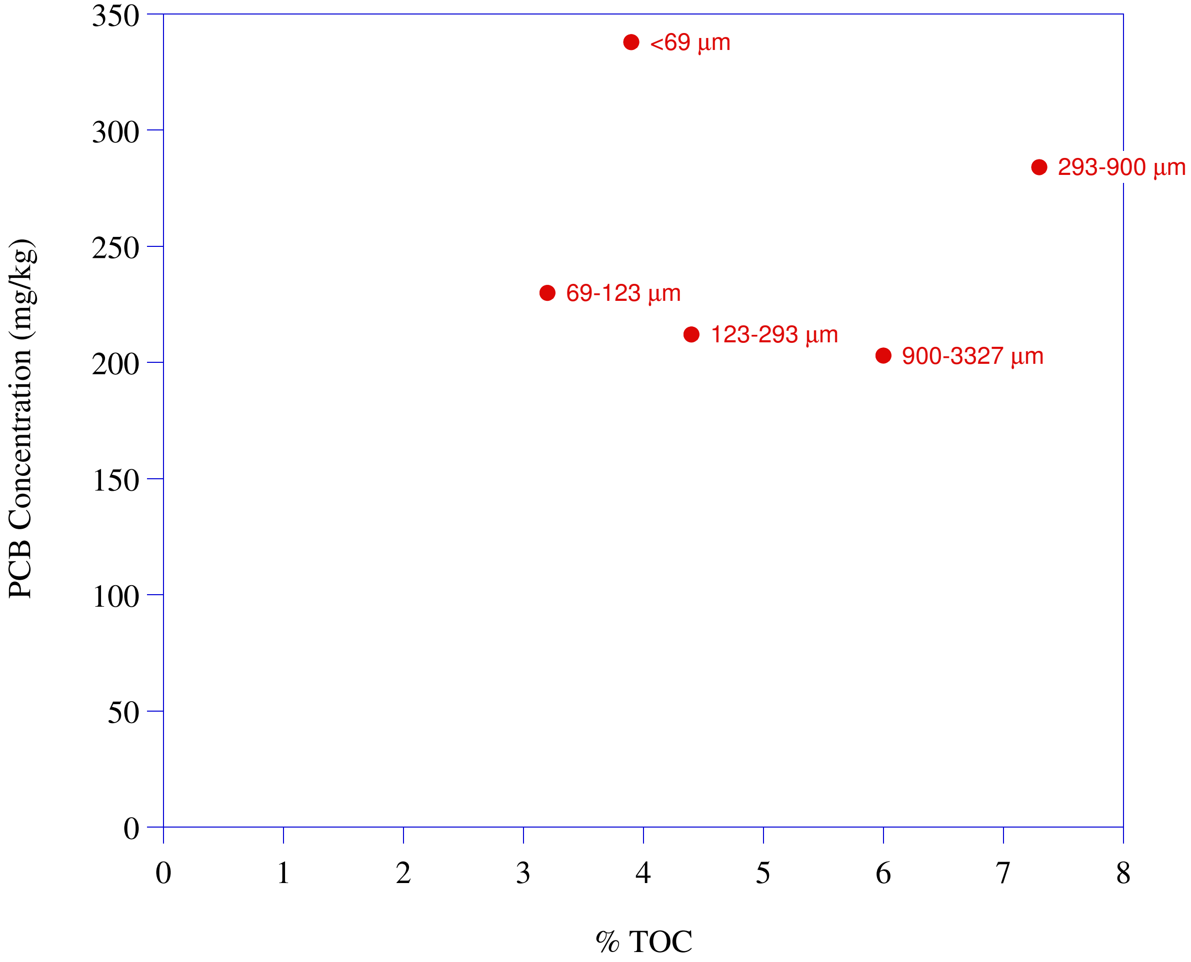
Note: 1) See text for discussion

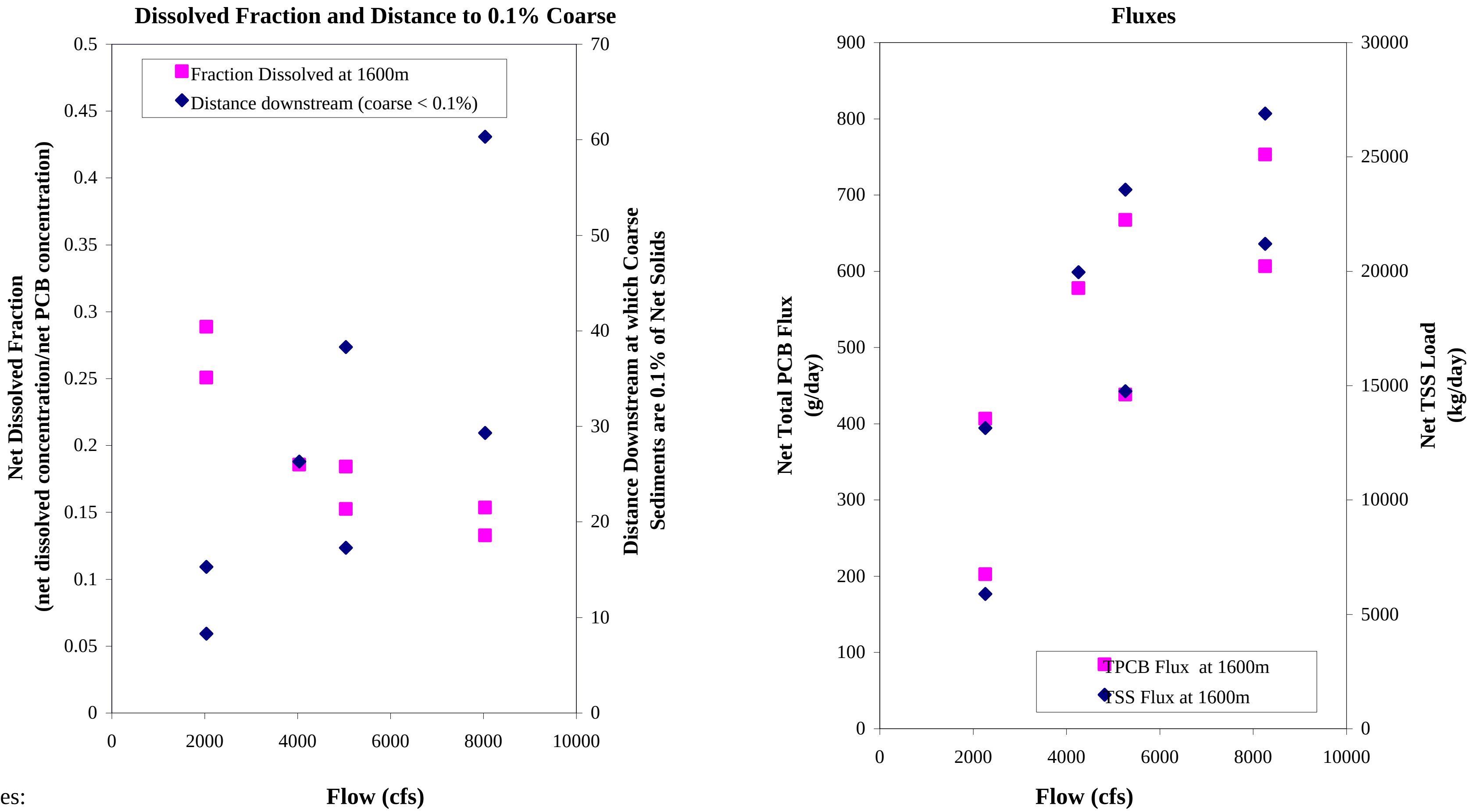
Source: TAMS/Gradient Database, Release 3.5

TAMS

Figure 18 (Figure 3-21 of LRC Report)
Total PCBs Grouped by Total Organic Carbon

Figure 19
Grain Size, Organic Content and PCB Concentrations in Hudson River Sediment collected near Moreau

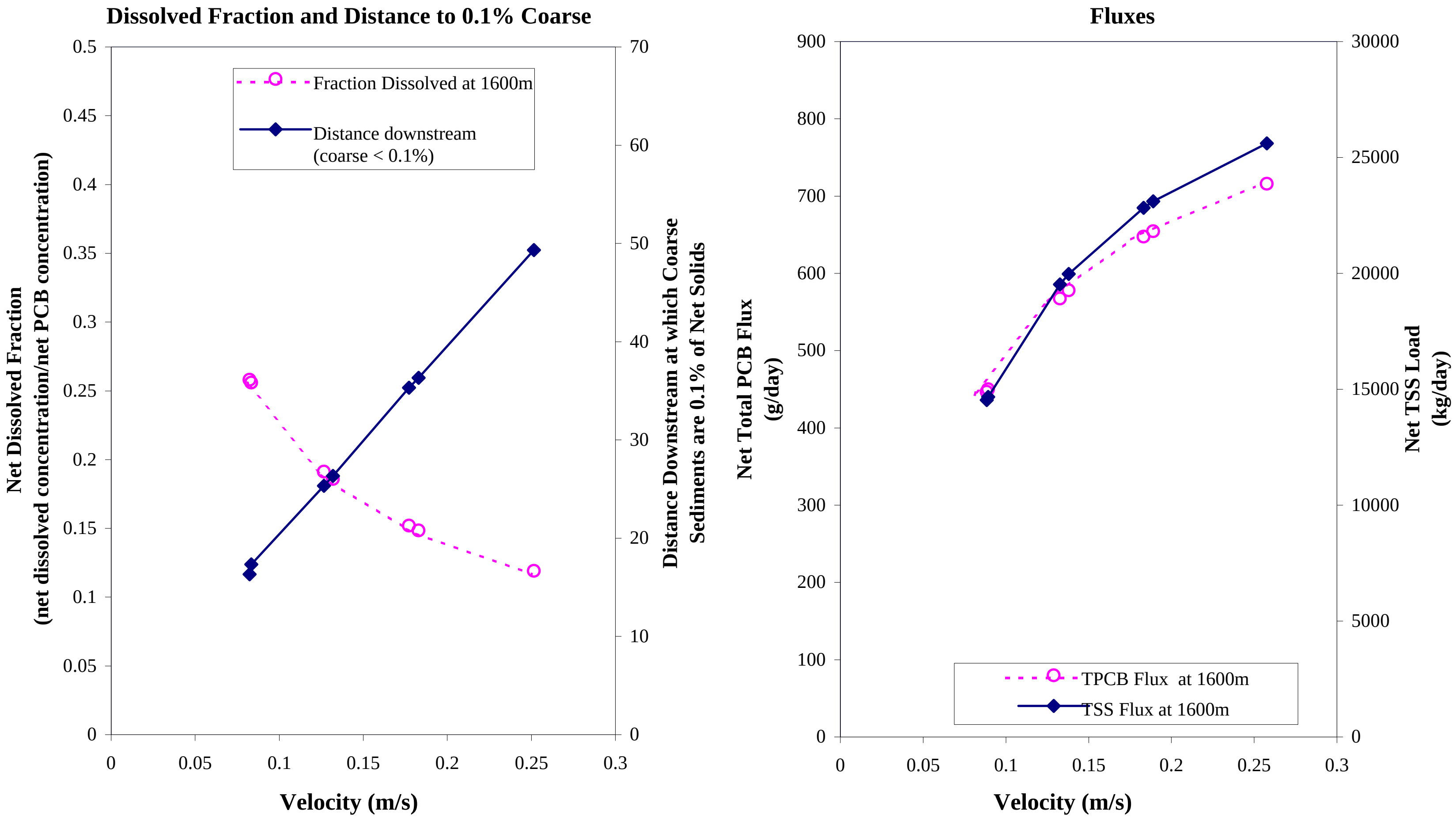




Notes:
1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 20

Net Dissolved PCB Fraction, Distance to Coarse < 0.1%, Net Total PCB Flux and Net TSS Flux at 1600 meters as Functions of Riverwide Volumetric Flow (Velocity-Depth Pairs) for the TSS-Chem

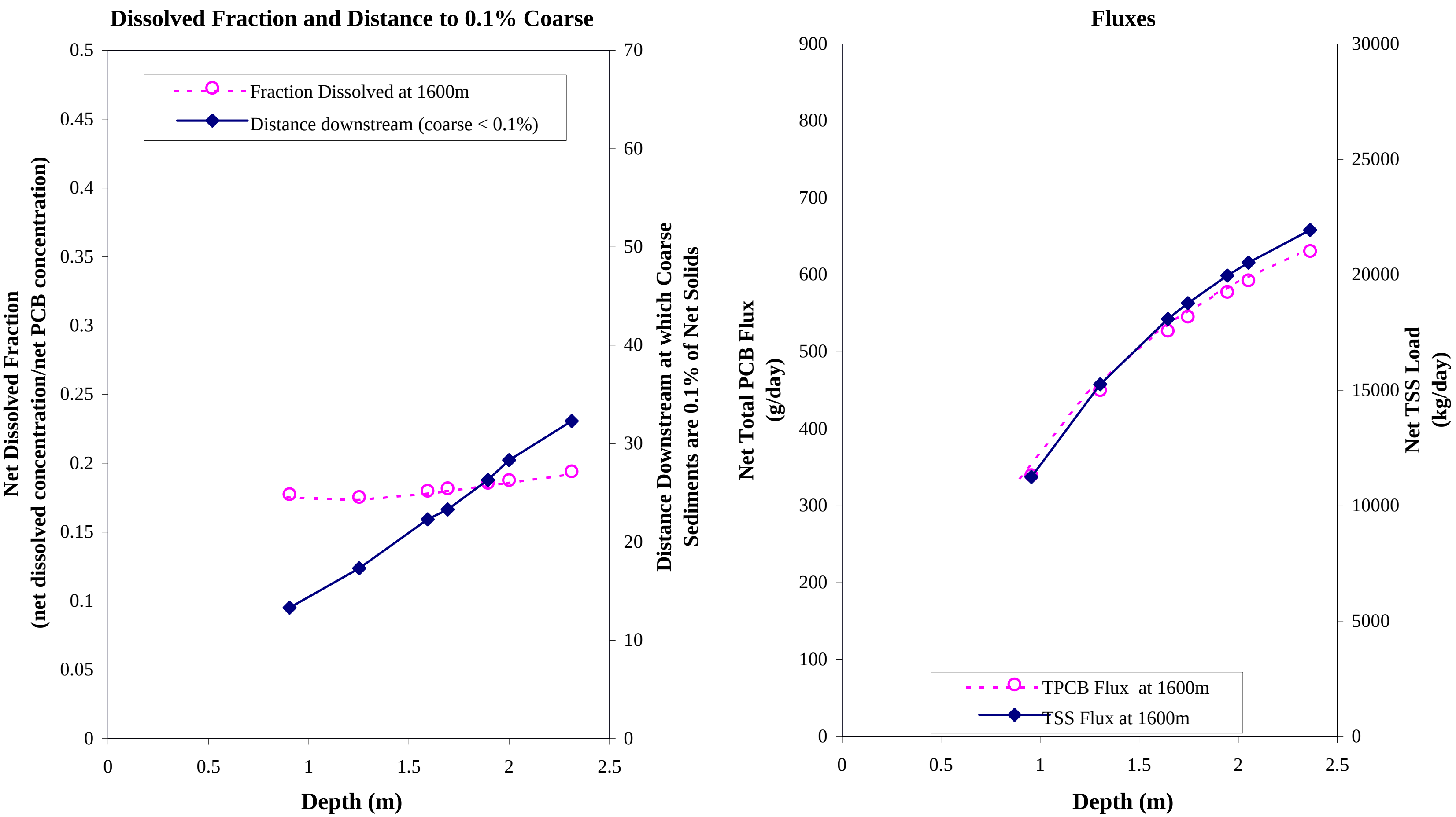


Notes:

1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 21

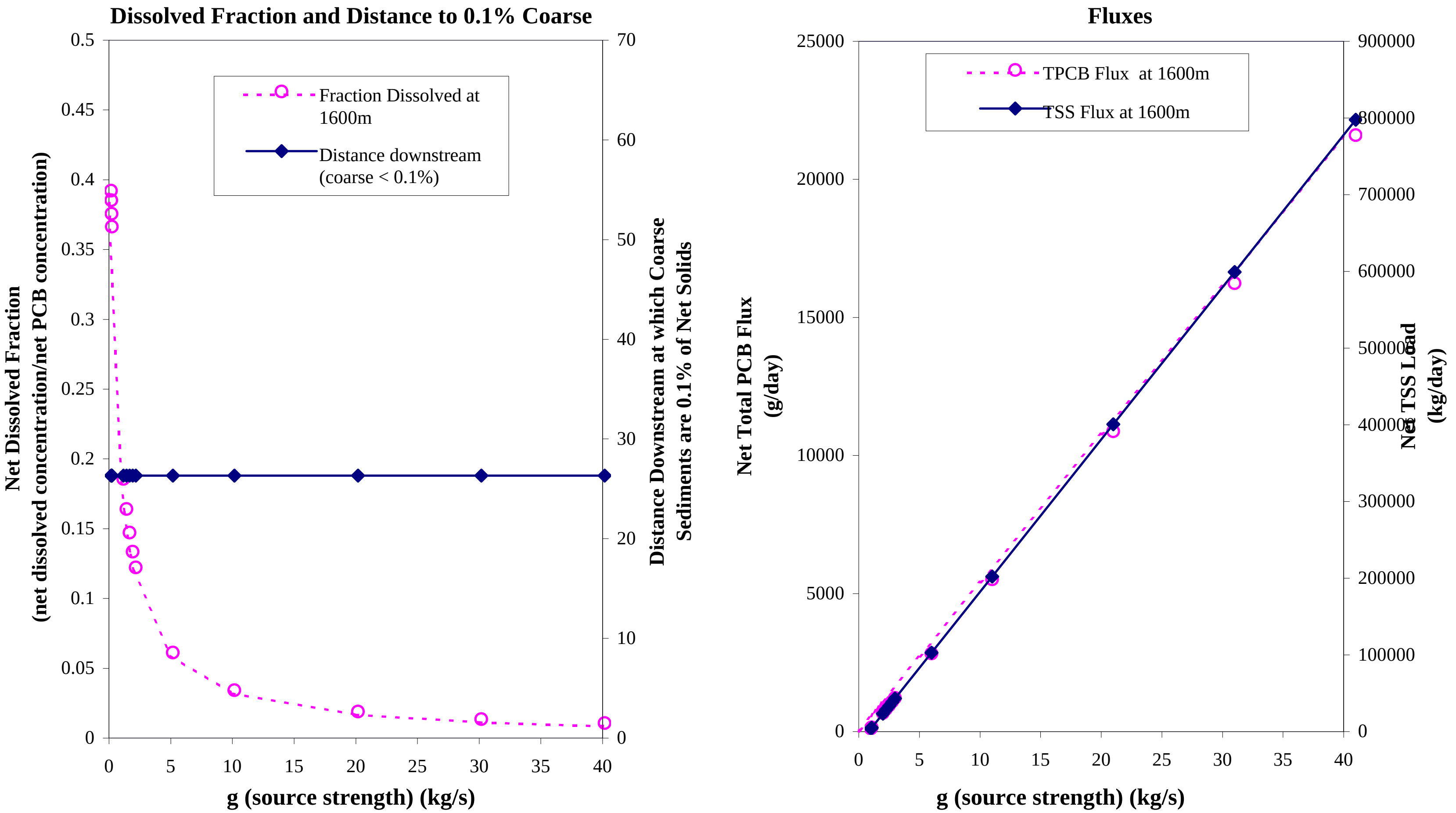
Net Dissolved PCB Fraction, Distance to Coarse < 0.1%, Net Total PCB Flux and Net TSS Flux at 1600 meters as Functions of Velocity for the TSS-Chem



Notes:
1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 22

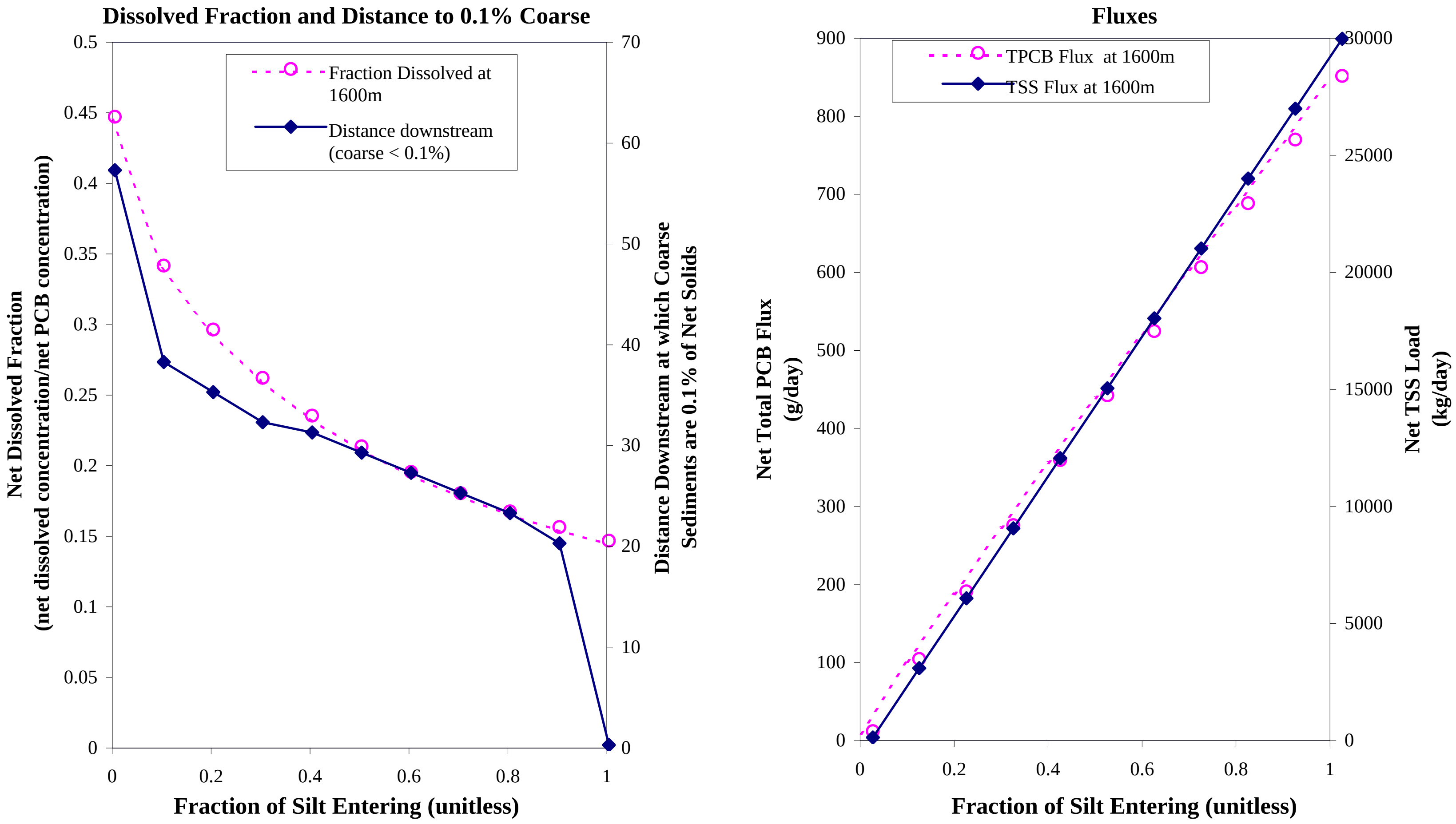
Net Dissolved PCB Fraction, Distance to Coarse < 0.1%, Net Total PCB Flux and Net TSS Flux at 1600 meters as Functions of Depth for the TSS-Chem



Notes:
1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 23

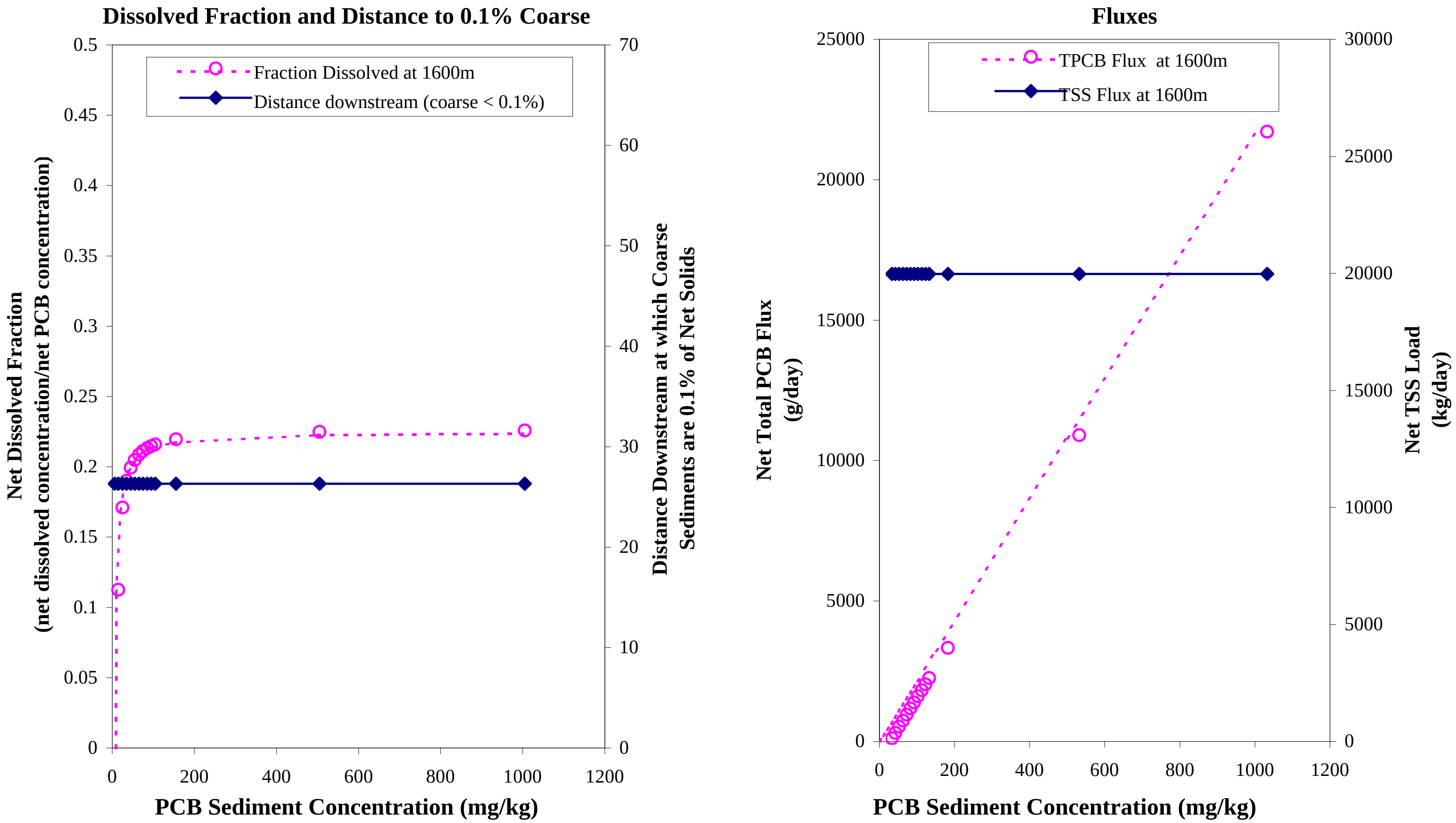
Net Dissolved PCB Fraction, Distance to Coarse < 0.1%, Net Total PCB Flux and Net TSS Flux at 1600 meters as Functions of Source Strength for the TSS-Chem



Notes:
1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 24

Net Dissolved PCB Fraction, Distance to Coarse < 0.1%, Net Total PCB Flux and Net TSS Flux at 1600 meters as Functions of Silt Fraction Entering for the TSS-Chem

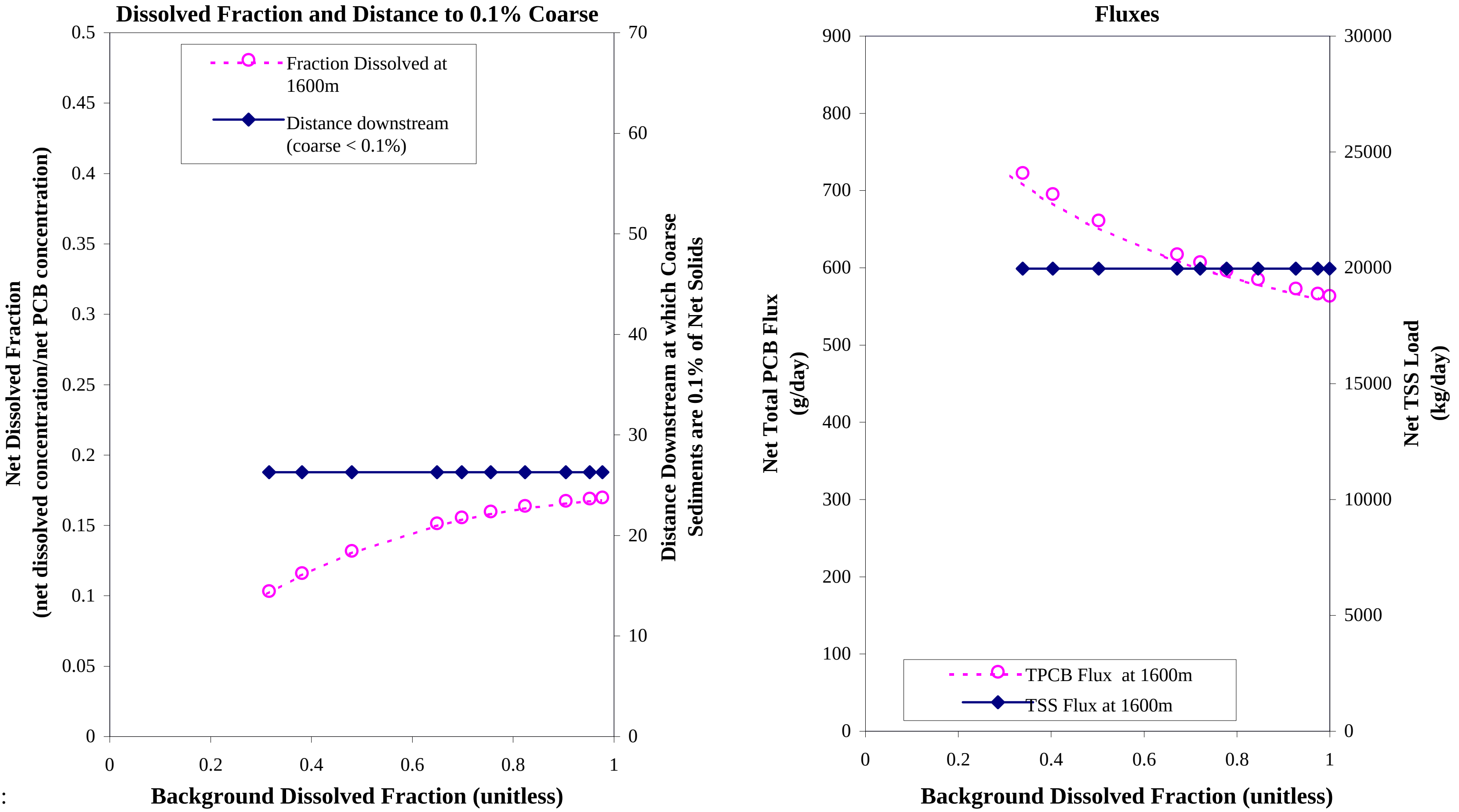


Notes:

1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 25

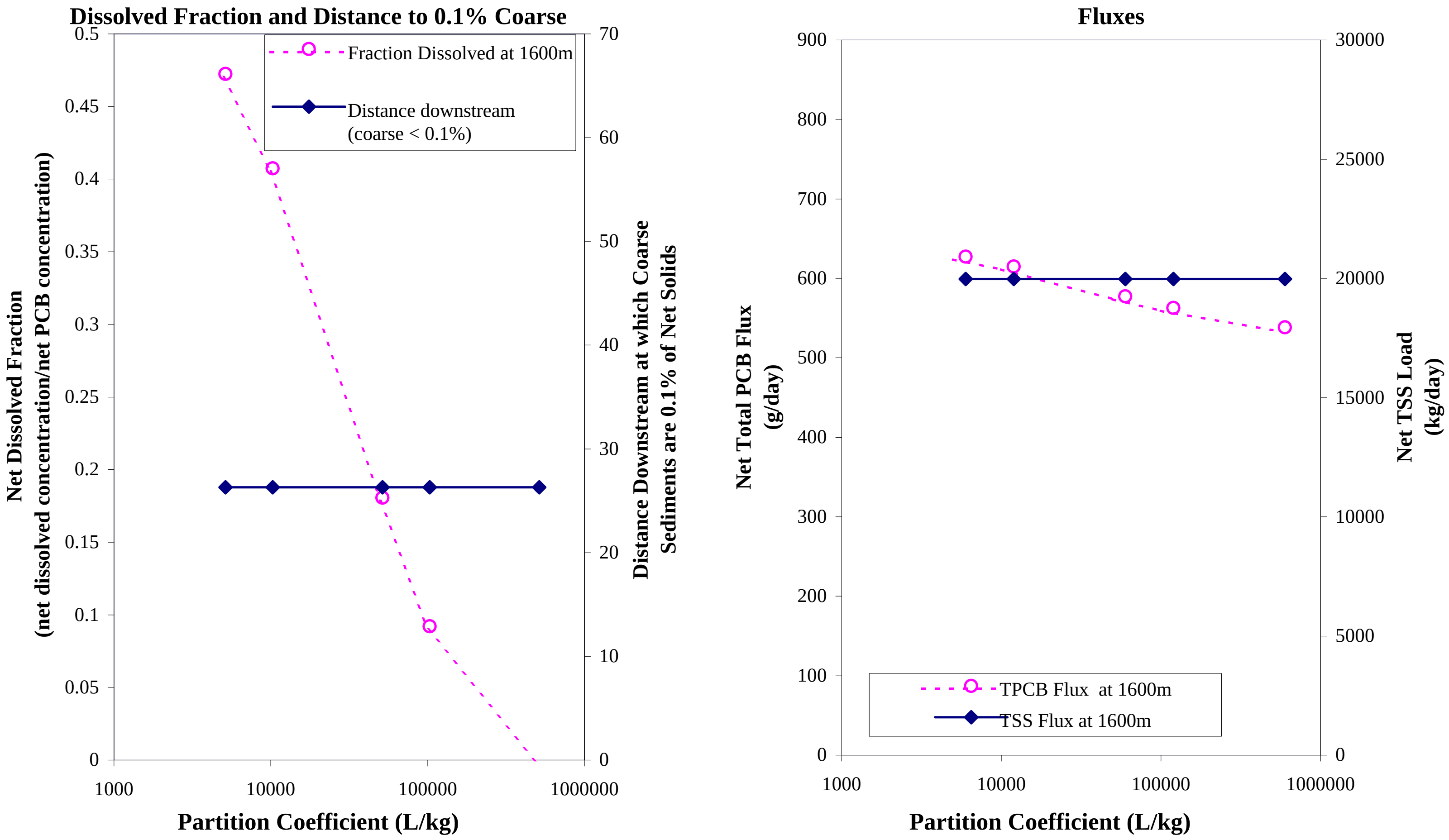
Net Dissolved PCB Fraction, Distance to Coarse < 0.1%, Net Total PCB Flux and Net TSS Flux at 1600 meters as Functions of Sediment PCB Concentration for the TSS-Chem



Notes:
1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 26

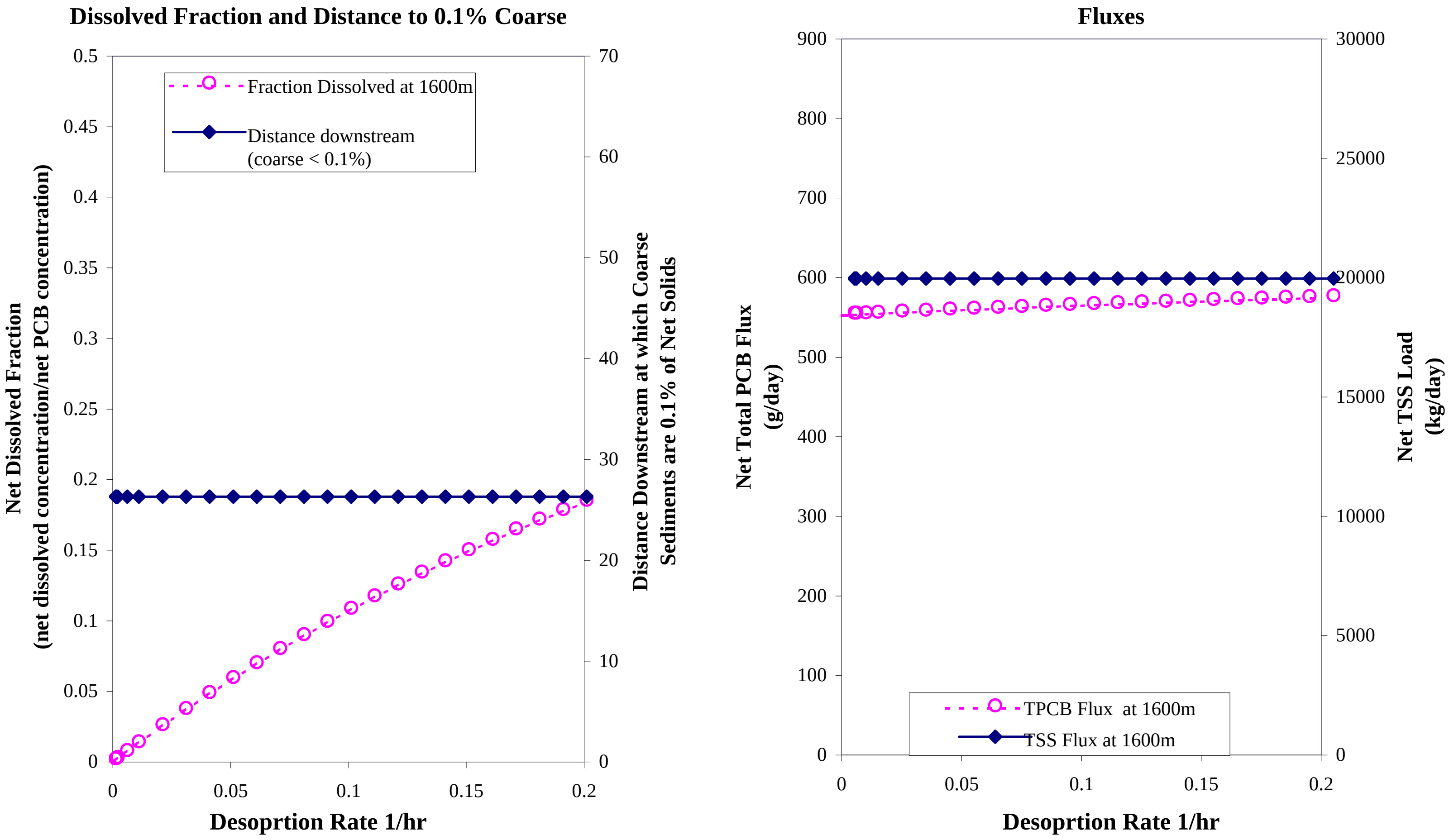
Net Dissolved PCB Fraction, Distance to Coarse < 0.1%, Net Total PCB Flux and Net TSS Flux at 1600 meters as Functions of TSS Background and PCB Dissolved Fraction (Kd = 55,000) for the TSS-Chem



Notes:
1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 27

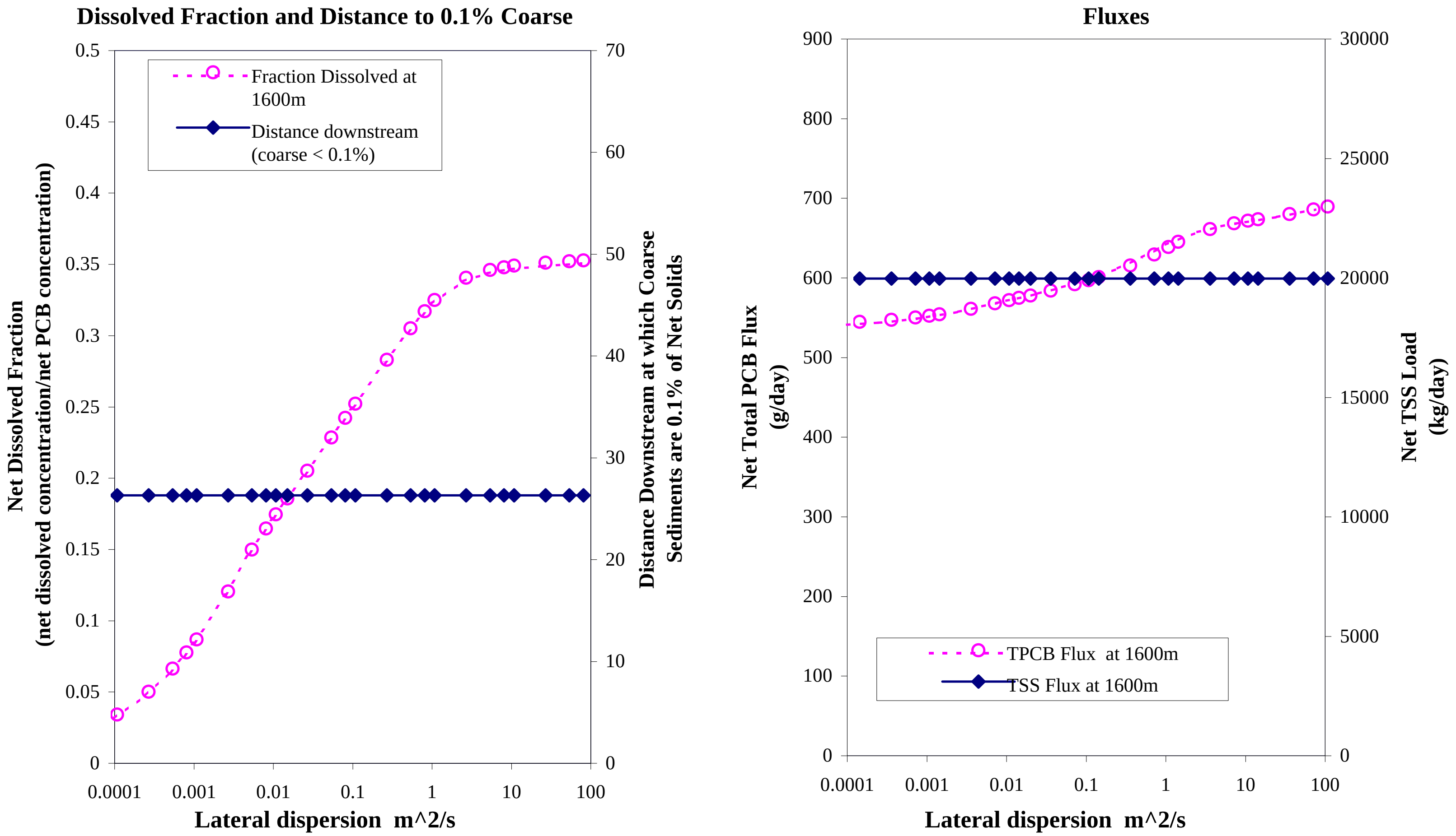
Net Dissolved PCB Fraction, Distance to Coarse < 0.1%, Net Total PCB Flux and Net TSS Flux at 1600 meters as Functions of Kd for the TSS-Chem



Notes:
1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 28

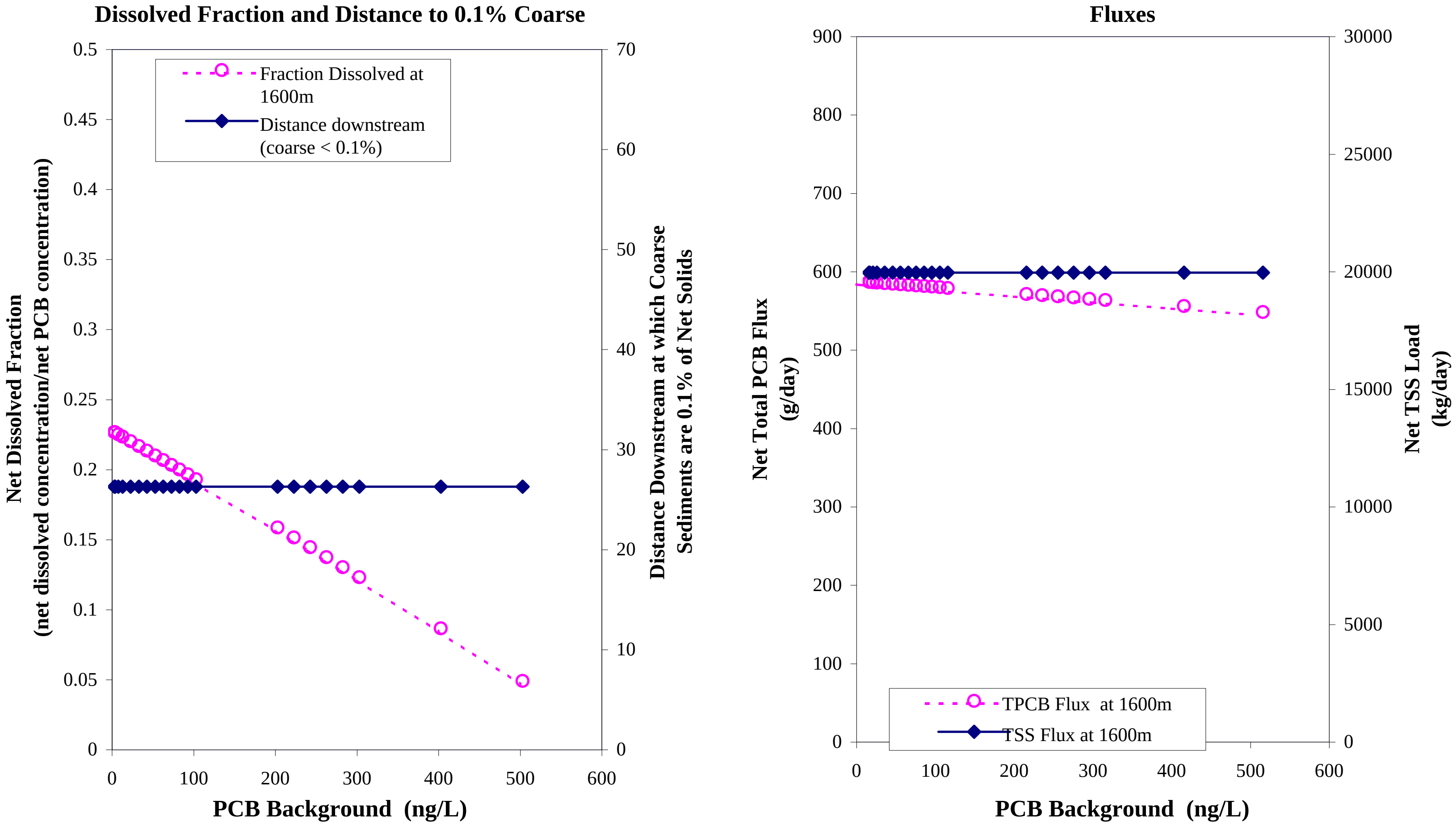
Net Dissolved PCB Fraction, Distance to Coarse < 0.1%, Net Total PCB Flux and Net TSS Flux at 1600 meters as Functions of Desorption Rate for the TSS-Chem



Notes:
1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 29

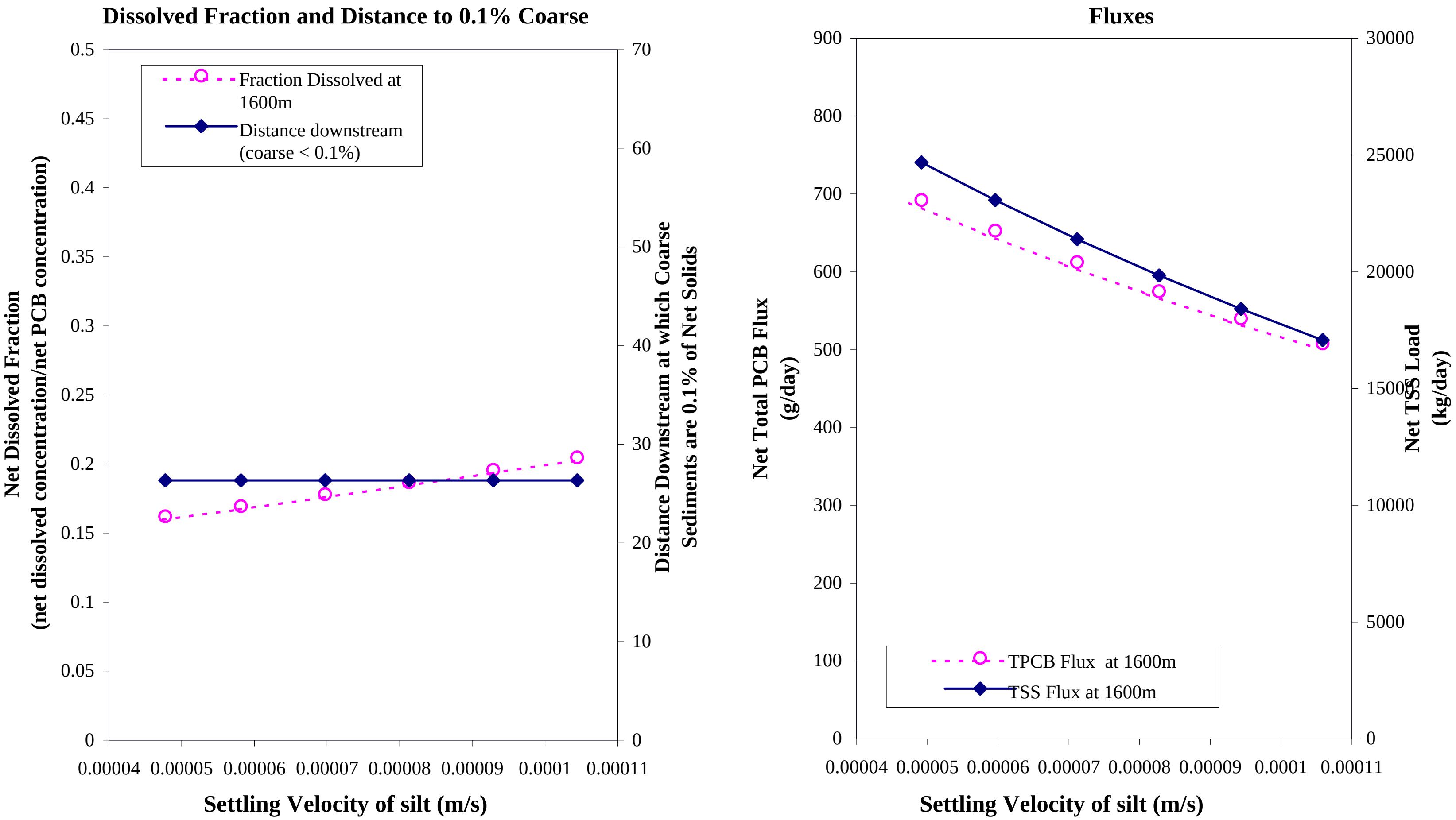
Net Dissolved PCB Fraction, Distance to Coarse < 0.1%, Net Total PCB Flux and Net TSS Flux at 1600 meters as Functions of Lateral Dispersion for the TSS-Chem



Notes:
1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 30

Net Dissolved PCB Fraction, Distance to Coarse < 0.1%, Net Total PCB Flux and Net TSS Flux at 1600 meters as Functions of PCB Background Concentration for the TSS-Chem

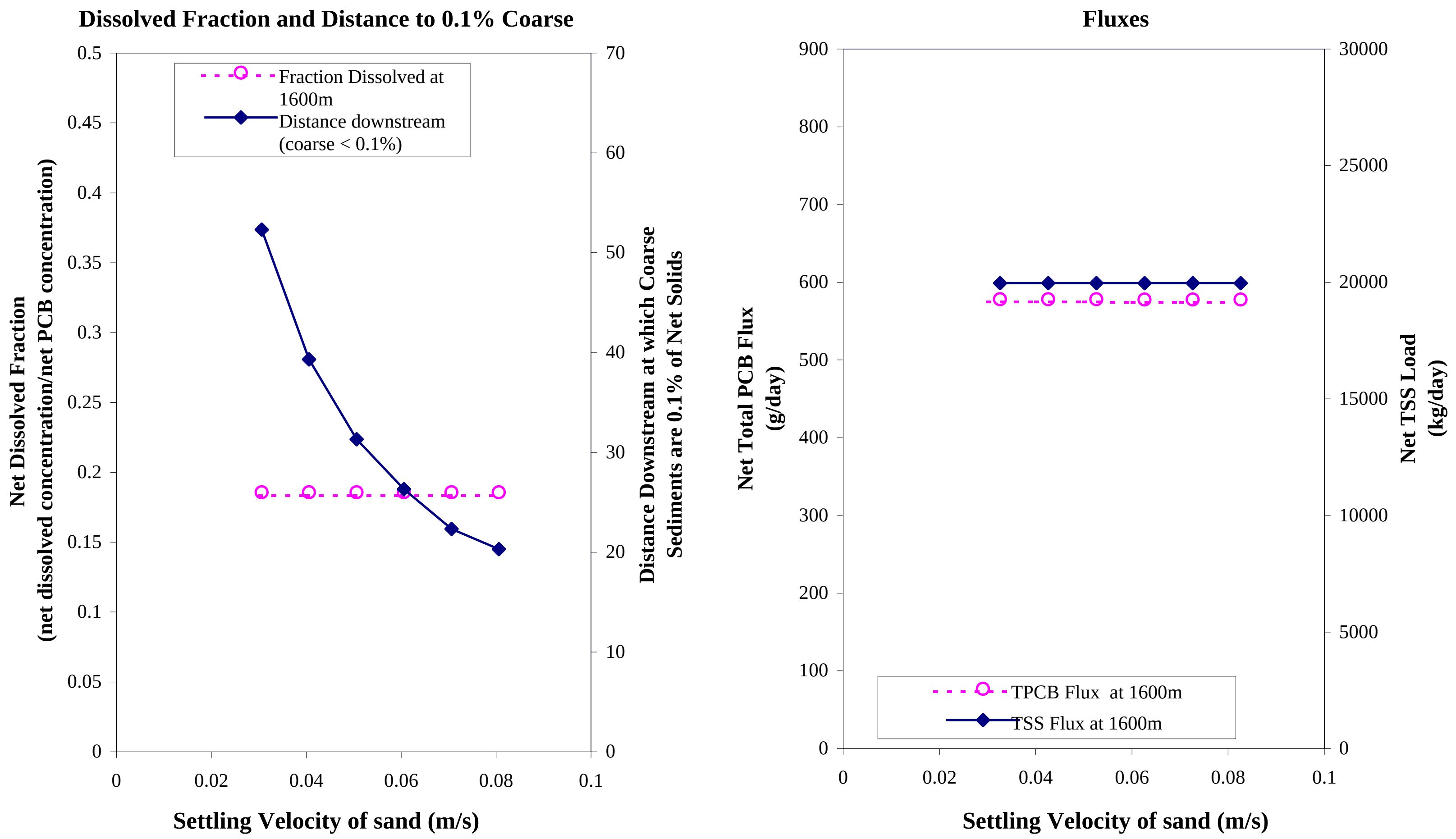


Notes:

1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 31

Net Dissolved PCB Fraction, Distance to Coarse < 0.1%, Net Total PCB Flux and Net TSS Flux at 1600 meters as Functions of Silt Settling Velocity for the TSS-Chem



Notes:
1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 32

Net Dissolved PCB Fraction, Distance to Coarse < 0.1%, Net Total PCB Flux and Net TSS Flux at 1600 meters as Functions of Sand Settling Velocity for the TSS-Chem

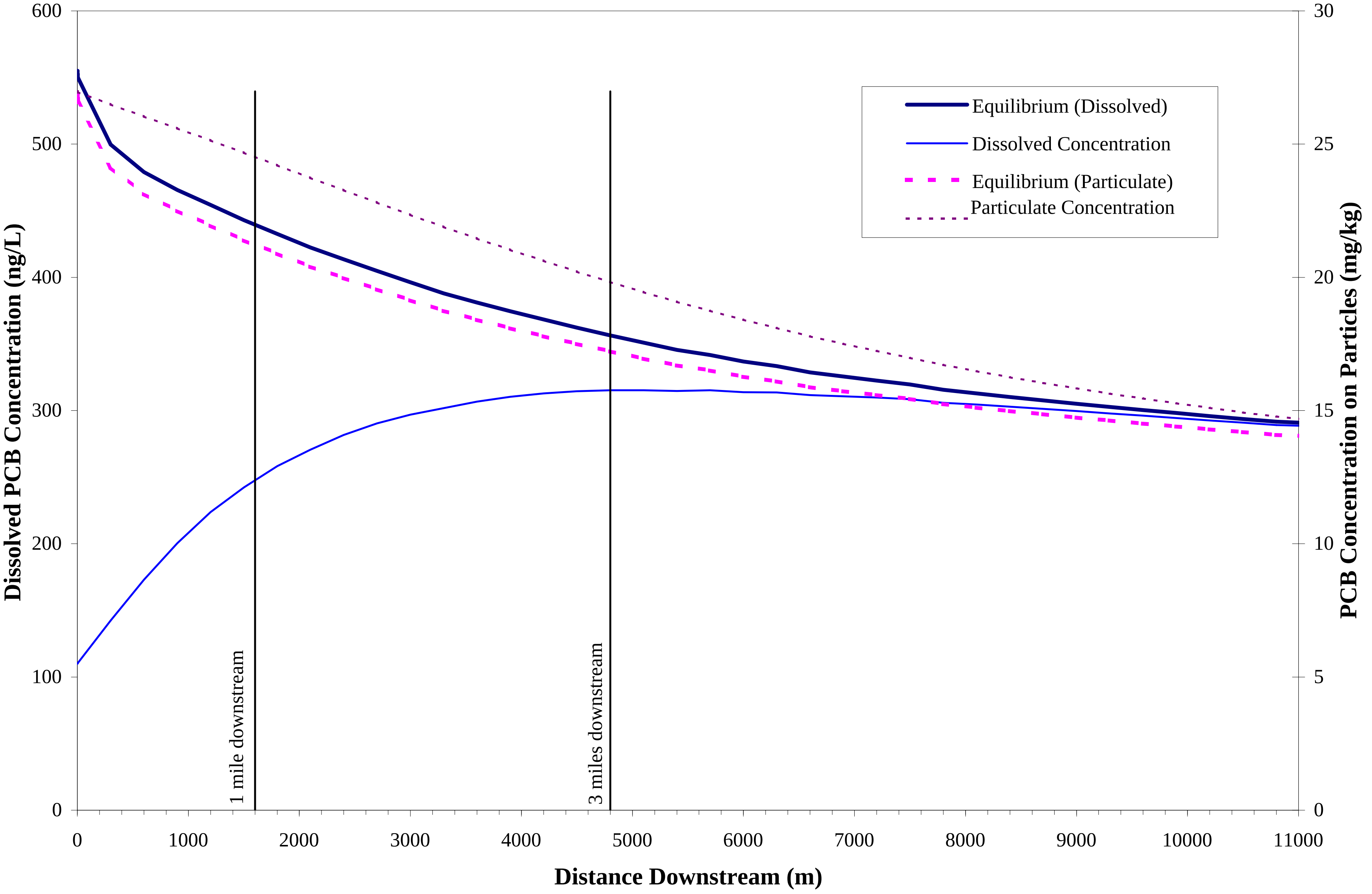


Figure 33
PCB Concentrations Downstream of Dredge for 350 ng/L scenario
Section 1 at 1 mile and 3 miles

Figure 34
Whole Water Total PCB Concentration for Different 350 ng/L Input Formulations

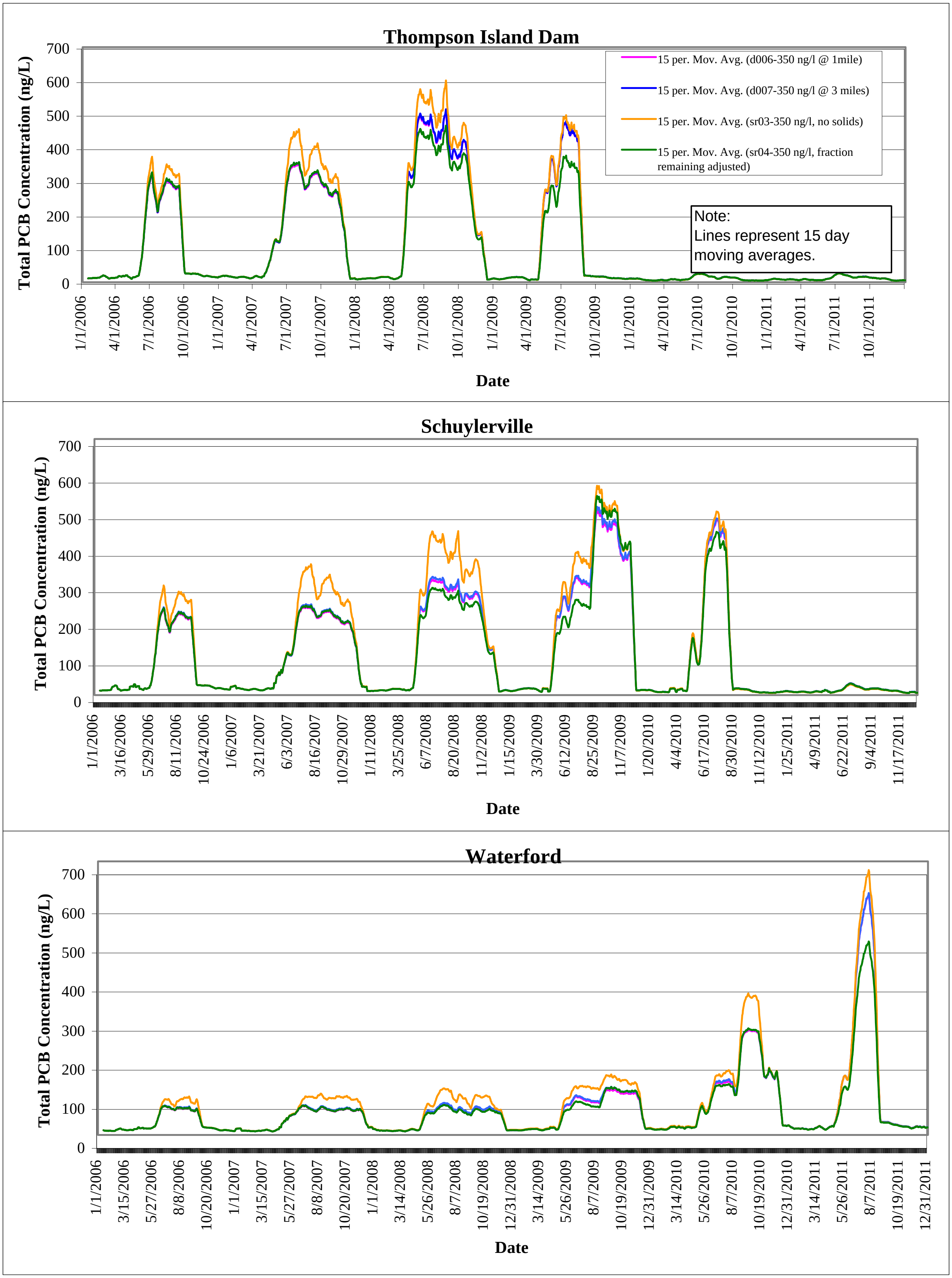


Figure 35
Tri+ PCB Cumulative Load for Different Dredging Scenarios

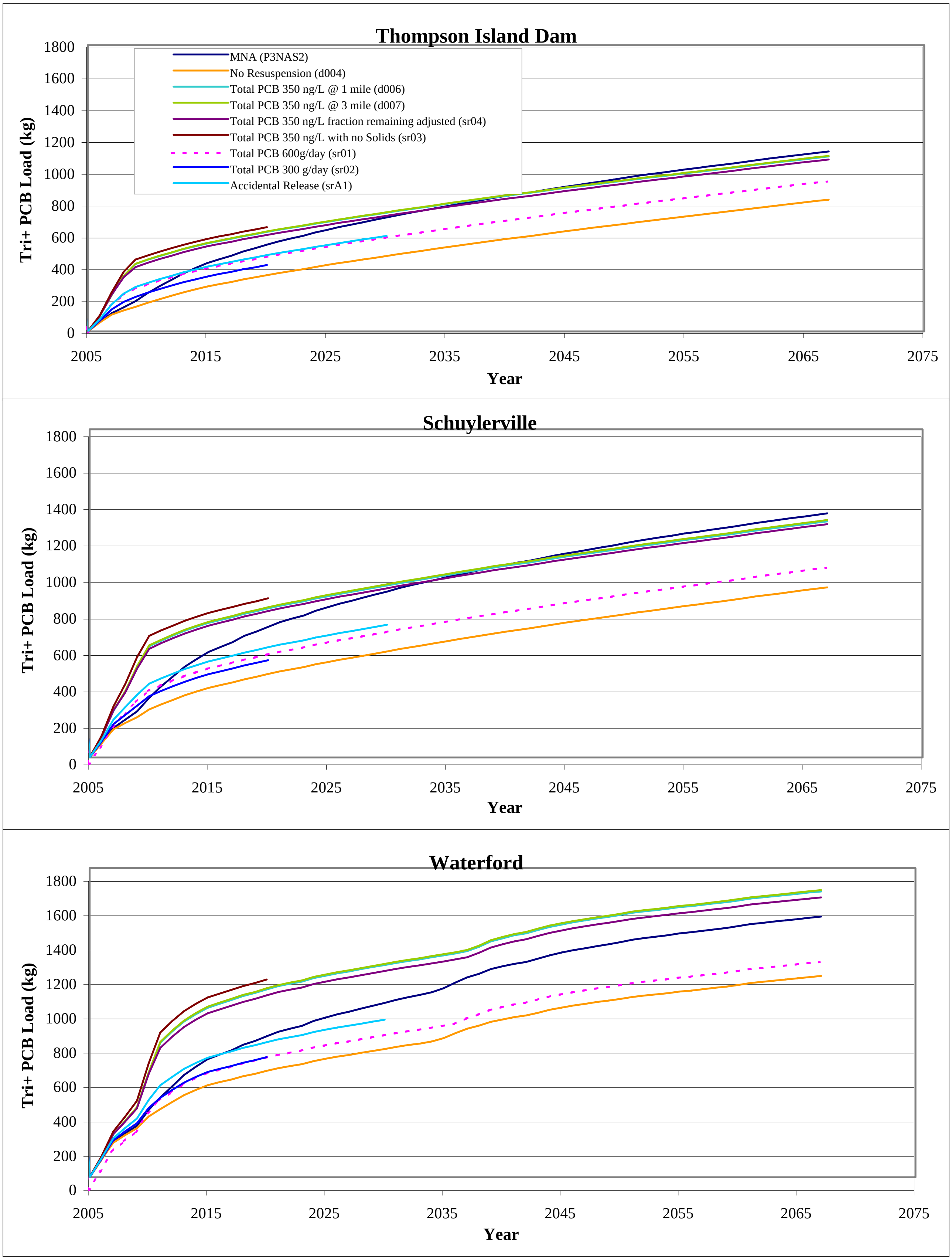


Figure 36

Total PCB Cumulative Load for Different Dredging Scenarios

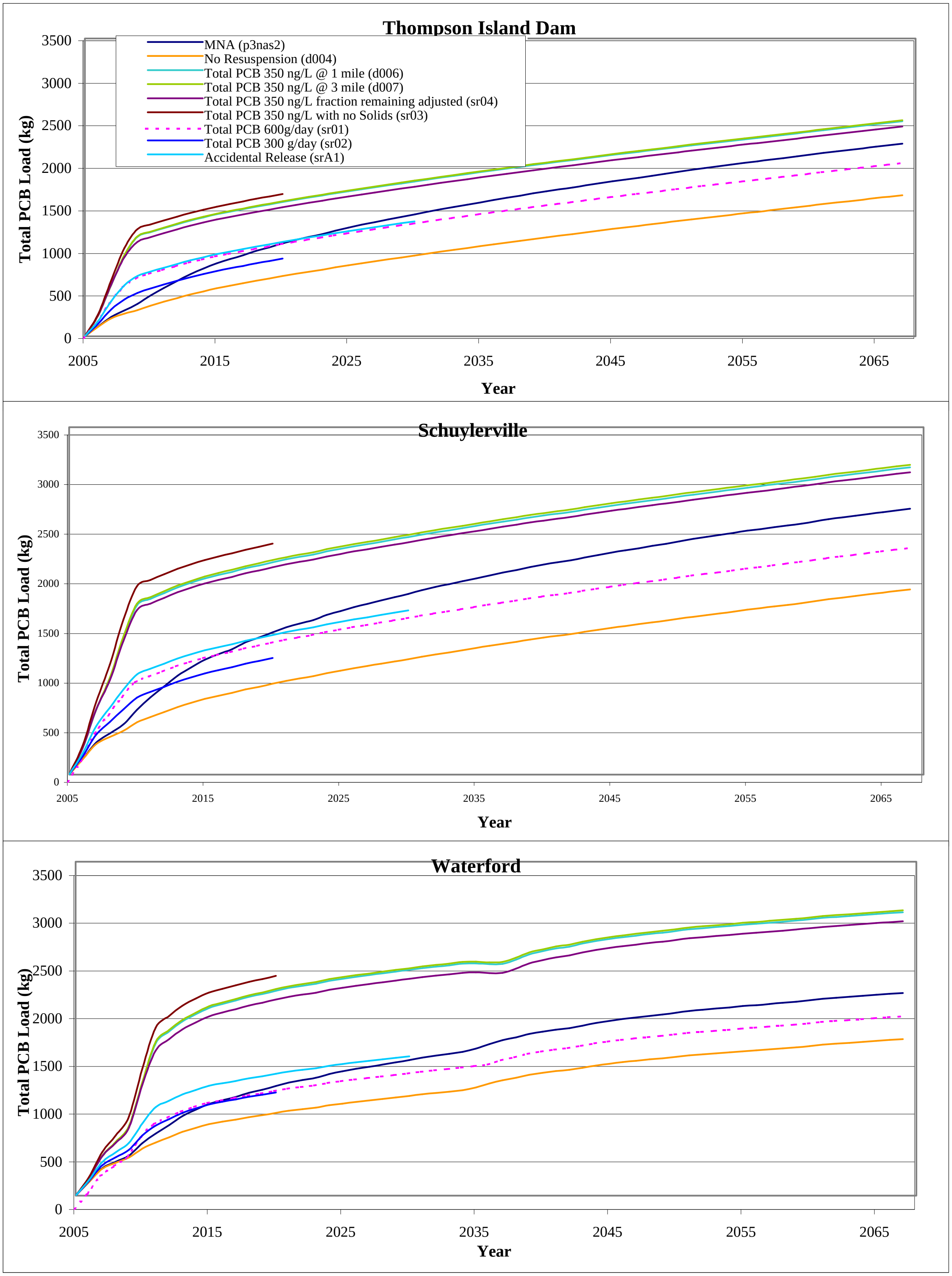


Figure 37
Whole Water, Particulate, and Dissolved Total PCB Concentrations for the 350 ng/L Dredging Scenario (sr04)

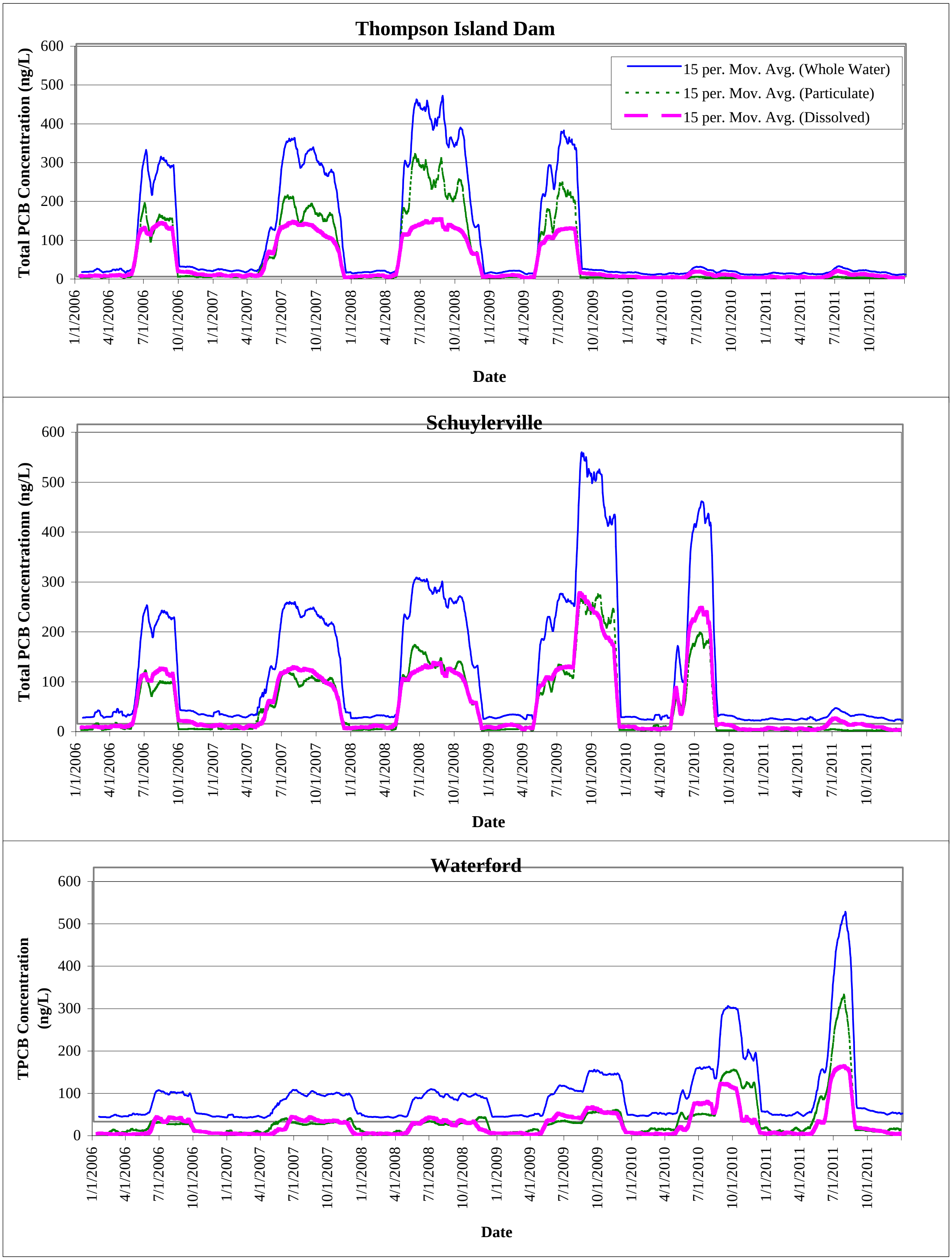


Figure 38
Whole Water, Particulate and Dissolved Total PCB Concentration for Control Level - 600 g/day Total PCB Flux Dredging Scenario (sr01)

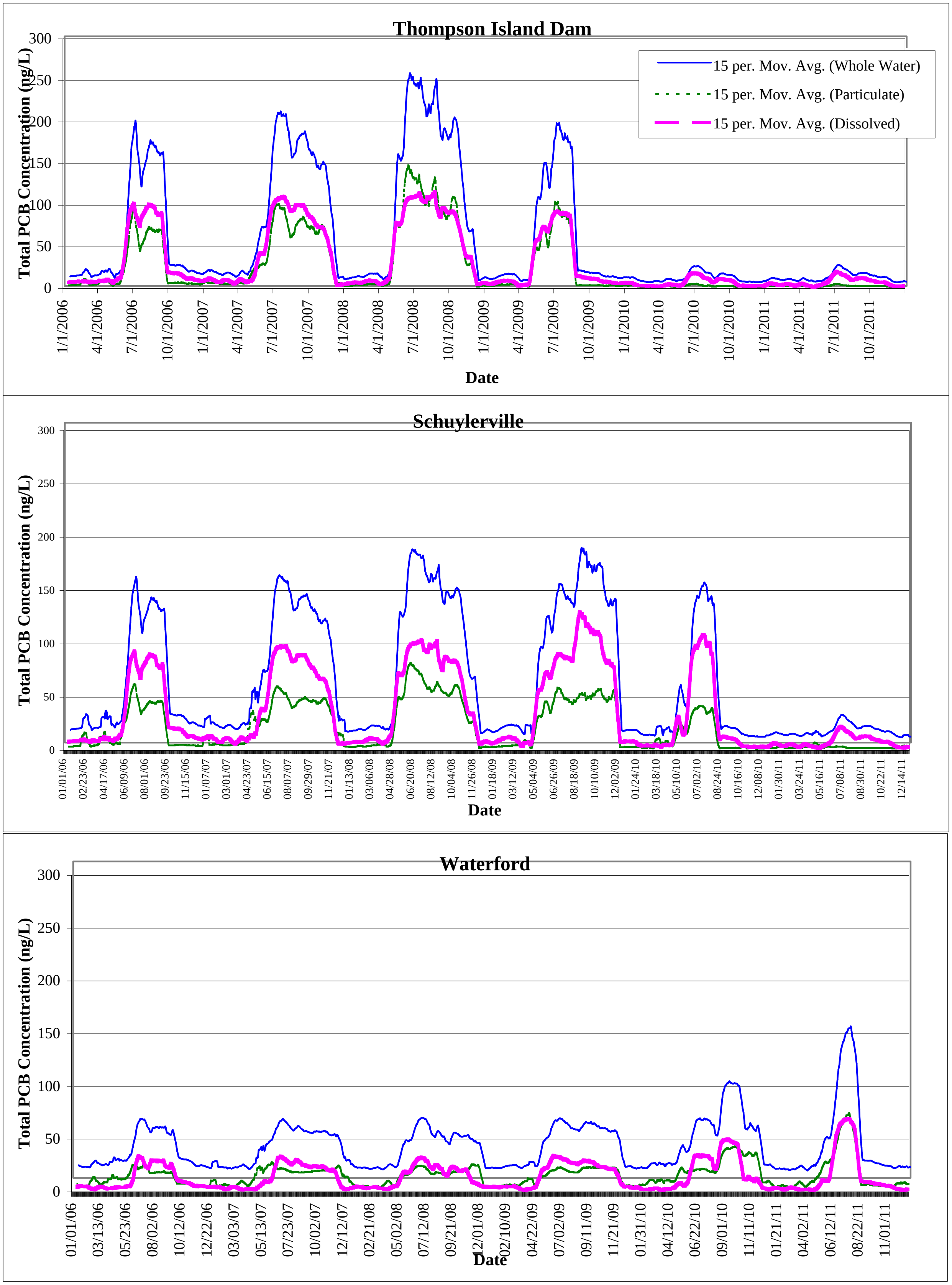
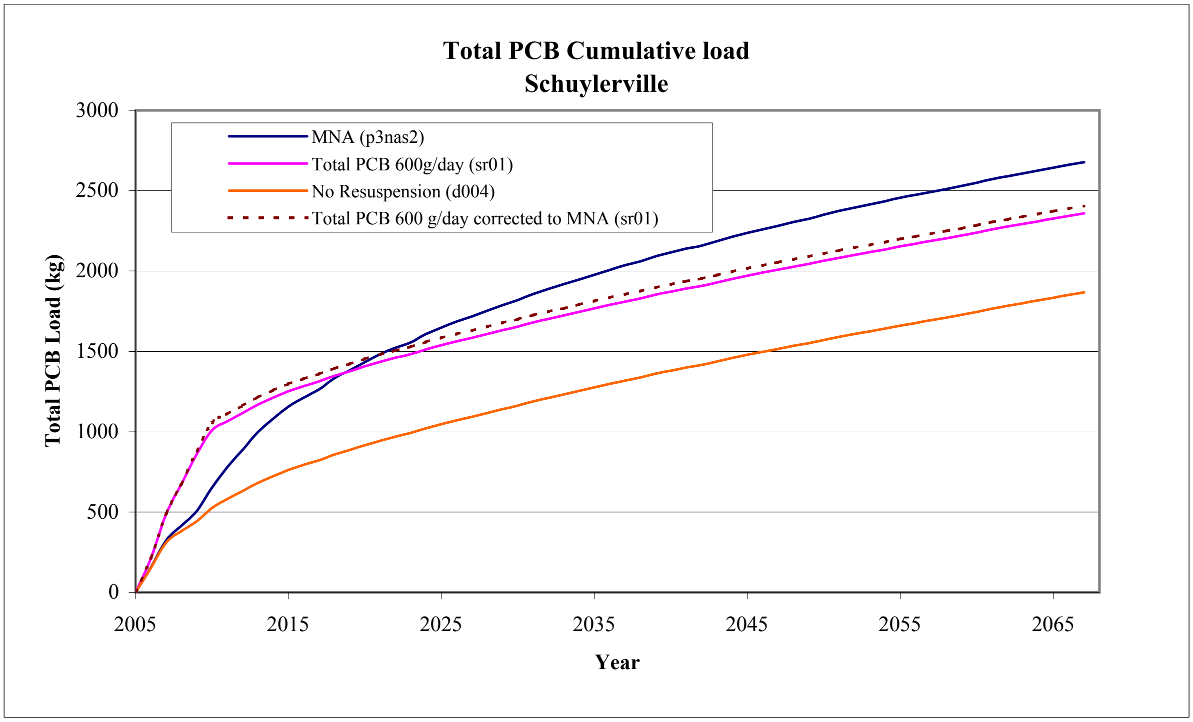


Figure 39. Tri+ PCB and Total PCB Cumulative Load for 600 g/day (sr01) Scenario



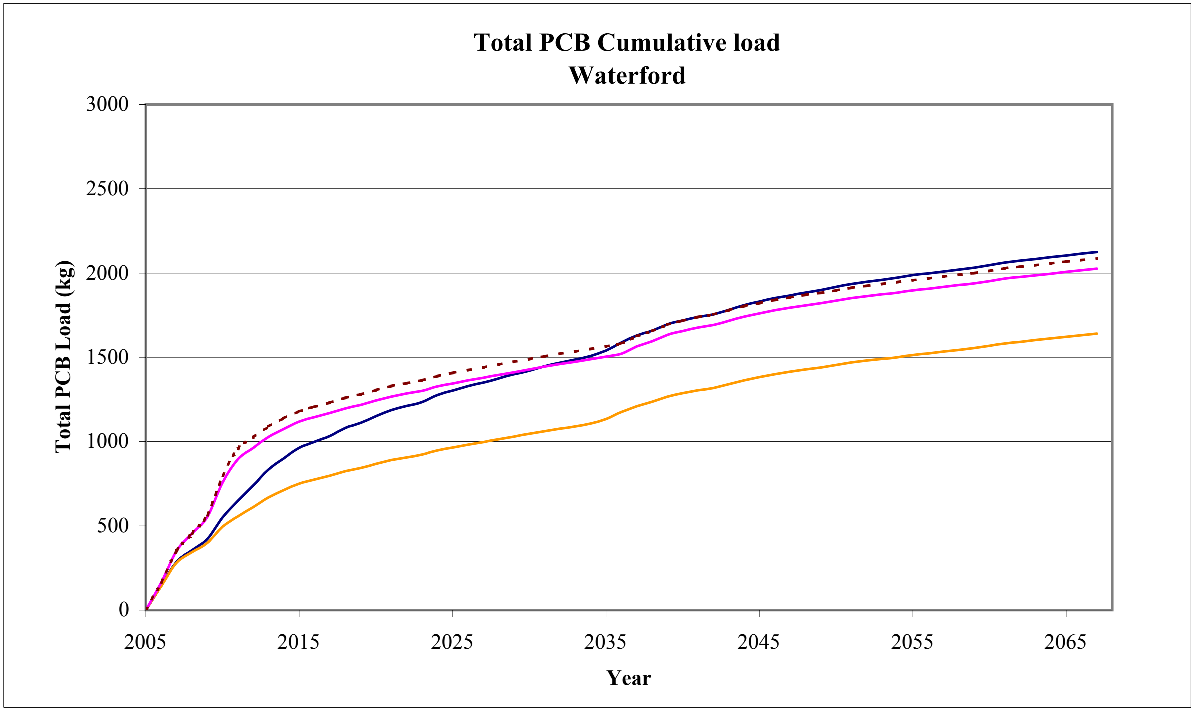
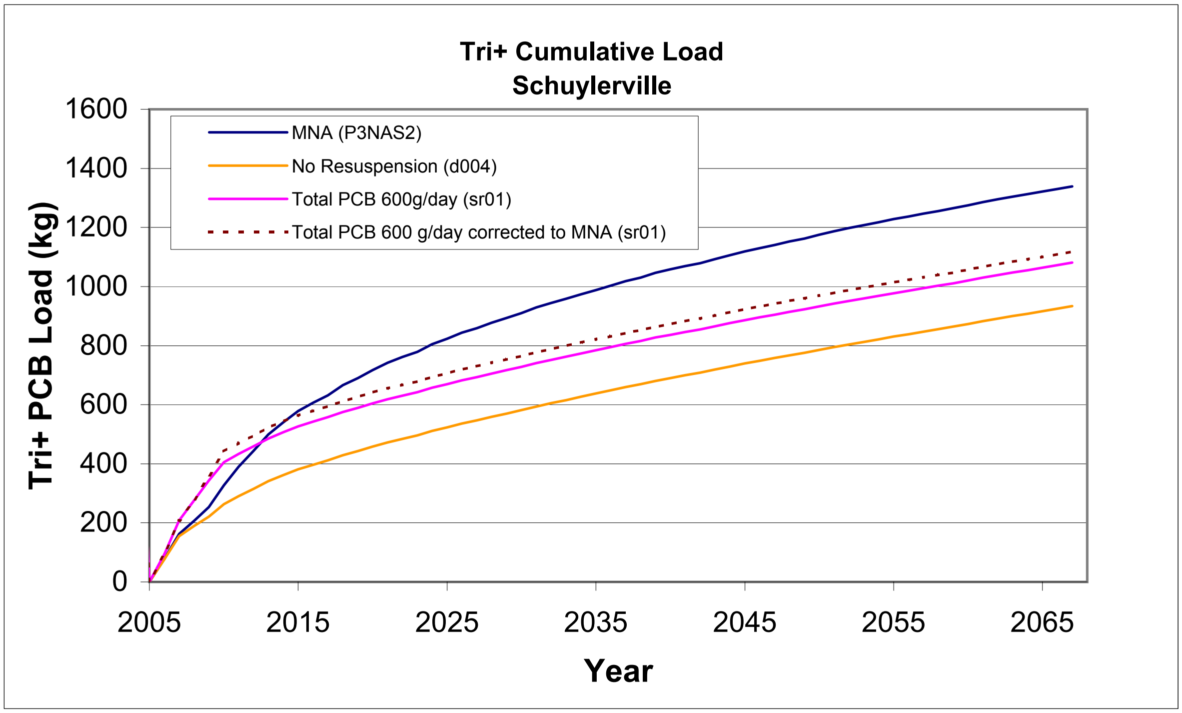


Figure 39 (Cont'd). Tri+ PCB and Total PCB Cumulative Load for 600 g/day (sr01) Scenario



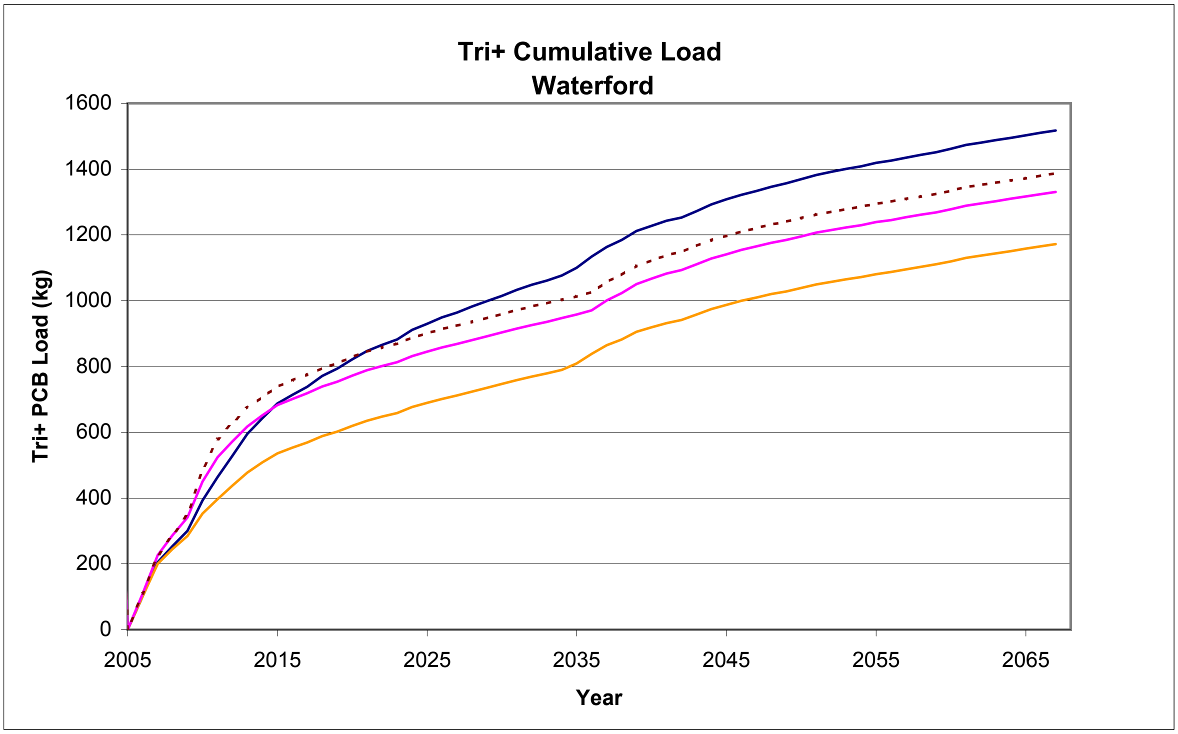


Figure 40
HUDTOX Forecast of Whole Water, Particulate, and Dissolved Total PCB Concentrations for Evaluation Level - 300 g/day Scenario

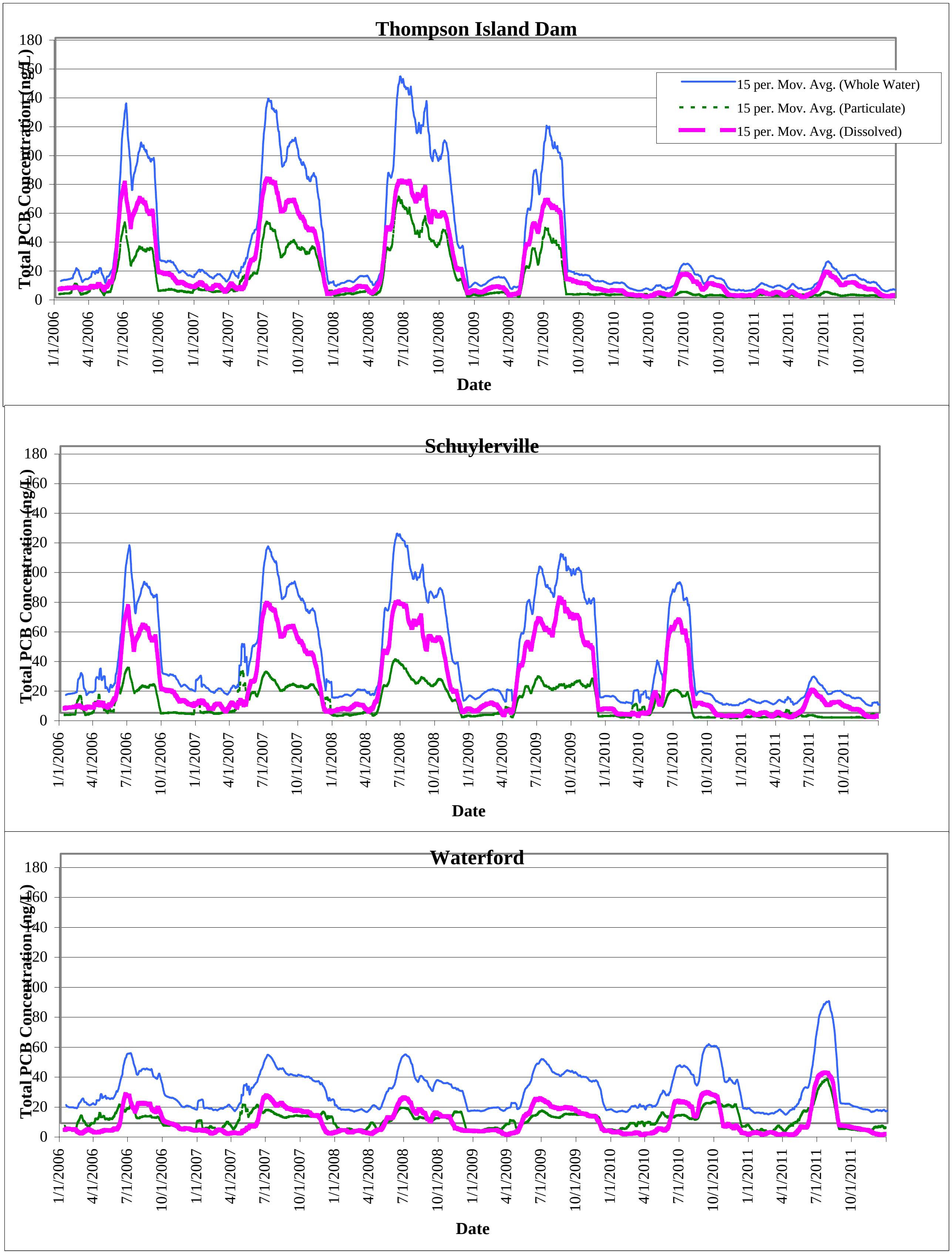


Figure 41

Comparison Between Upper Hudson River Remediation Scenario (Various Export Rates) and Monitored Natural Attenuation (MNA) Forecast for Thompson Island Dam, Schuylerville, and Waterford

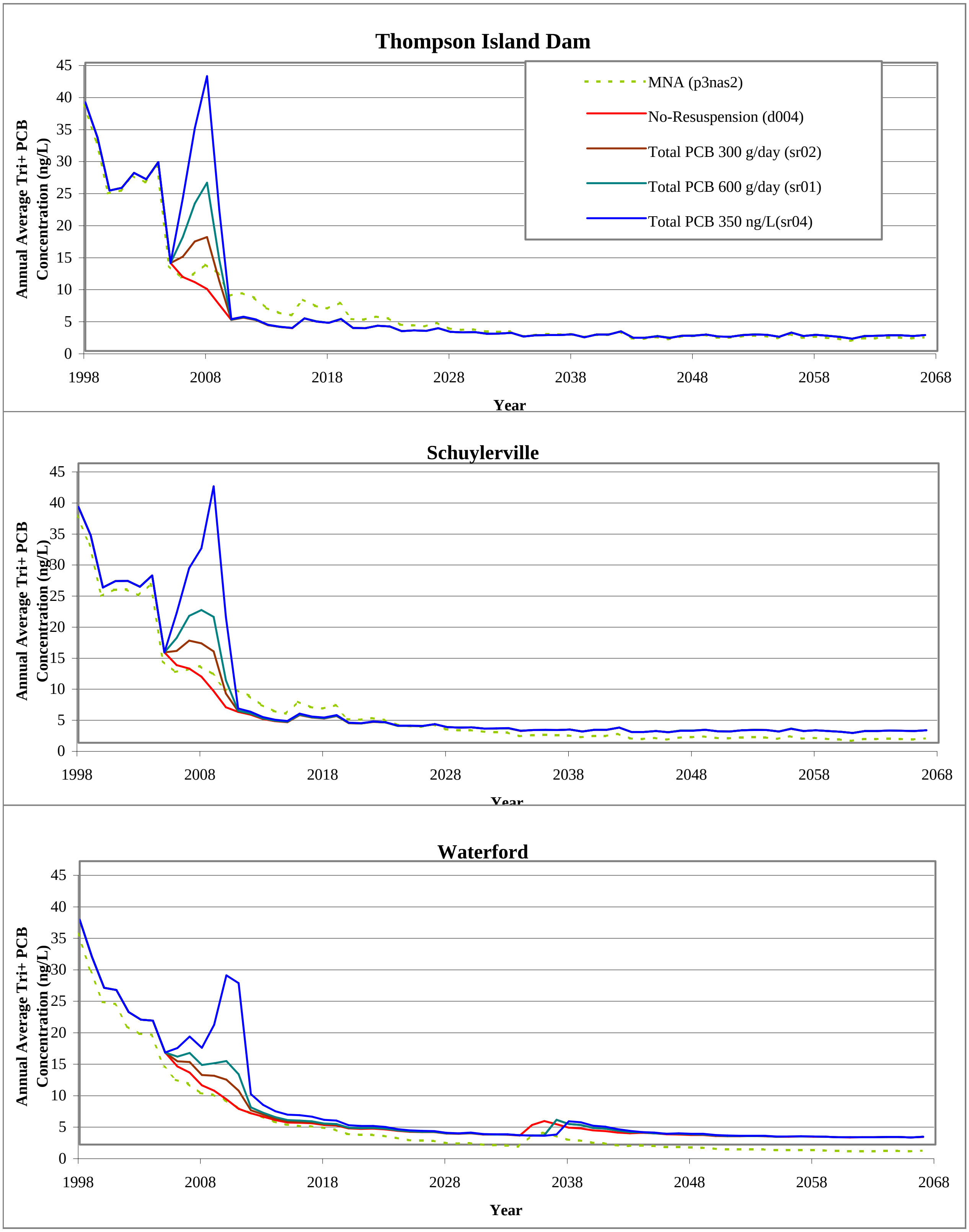


Figure 42
Total PCB Concentrations at Waterford for the Accidental Release Scenario

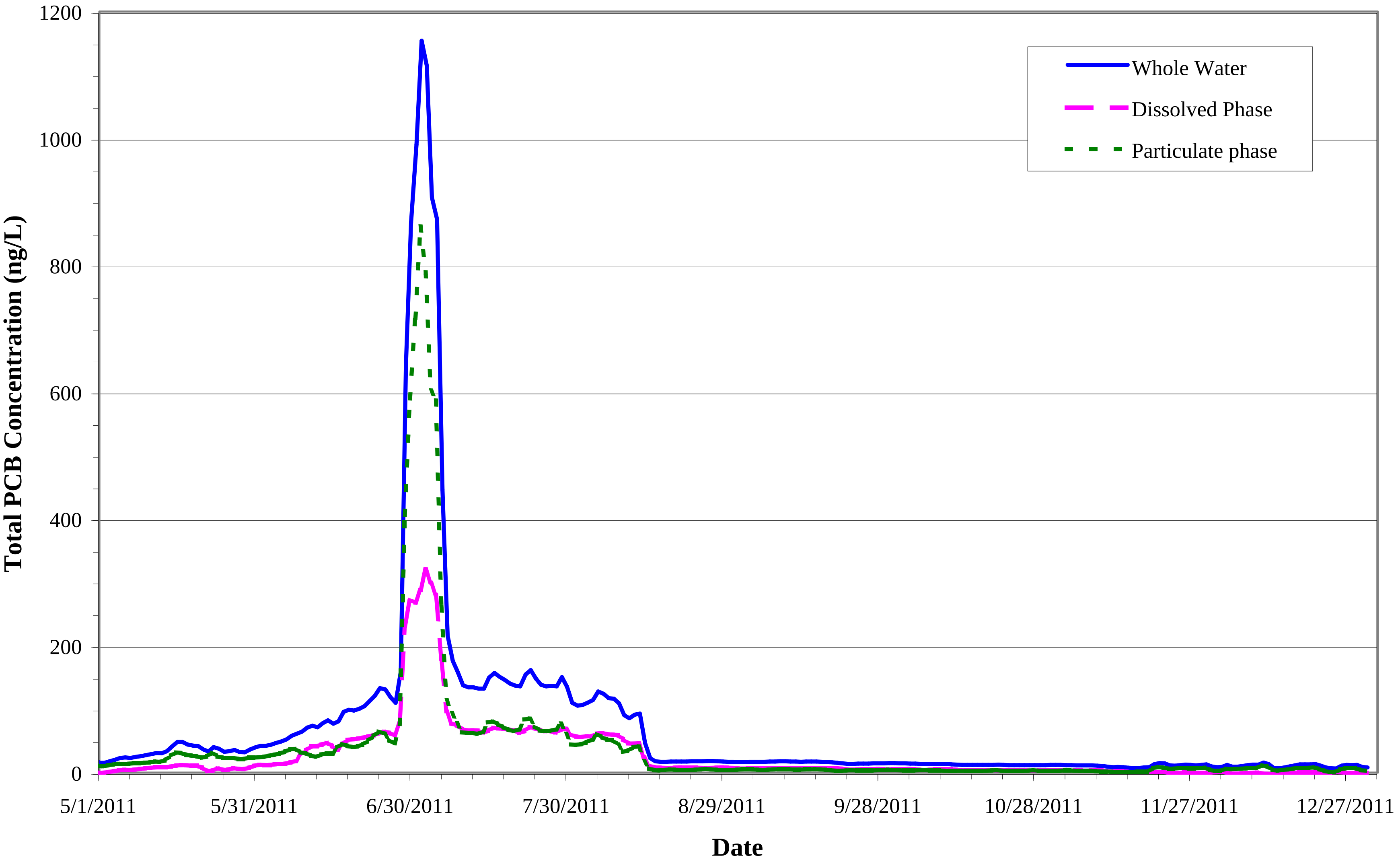
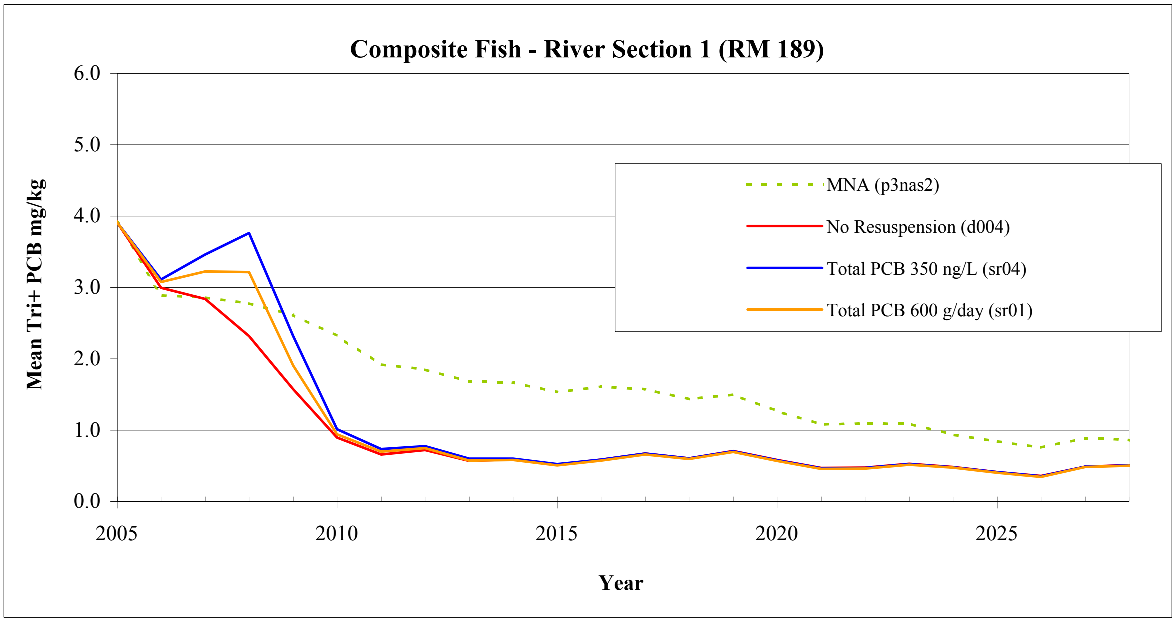


Figure 43

Composite Fish Tissue Concentrations for the Upper Hudson River



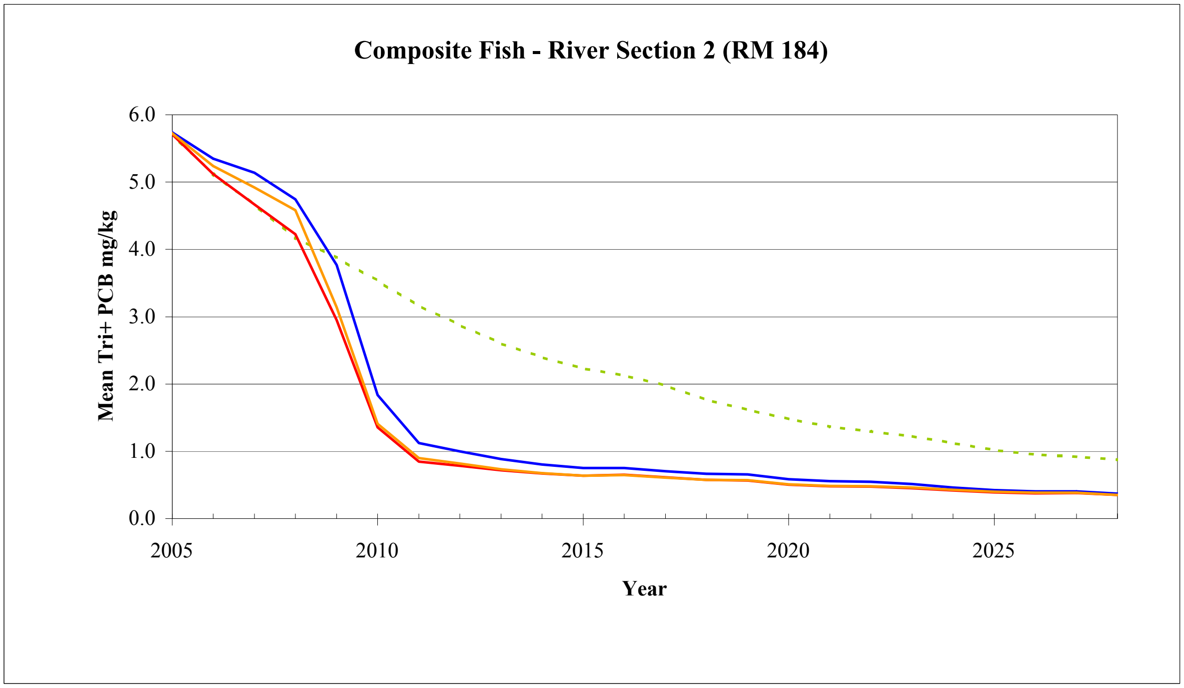
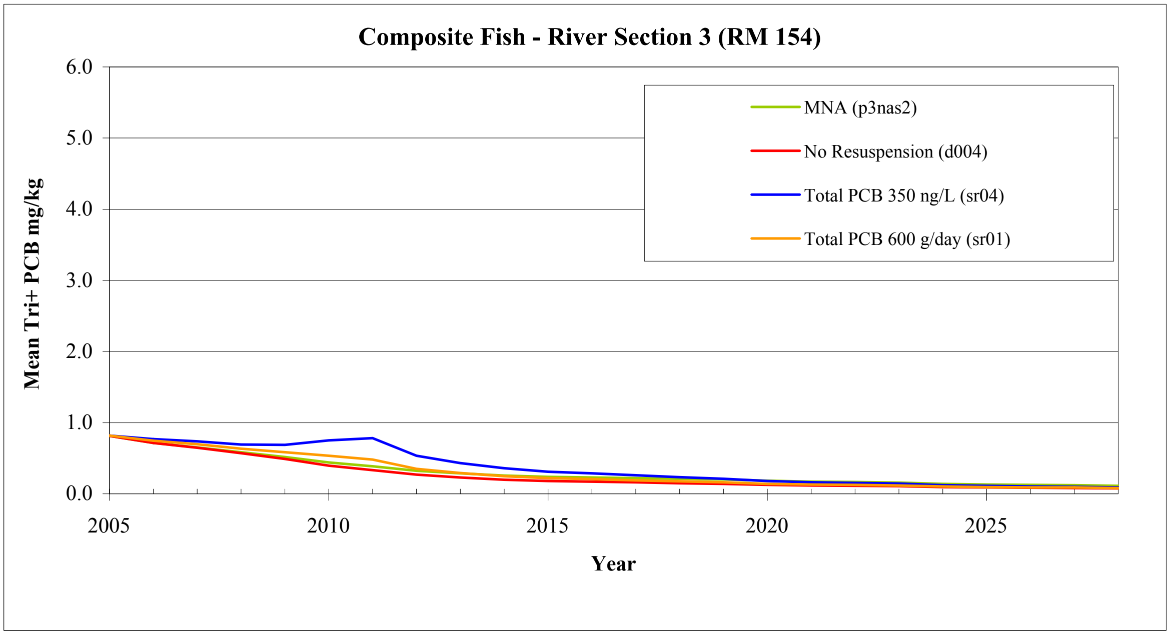
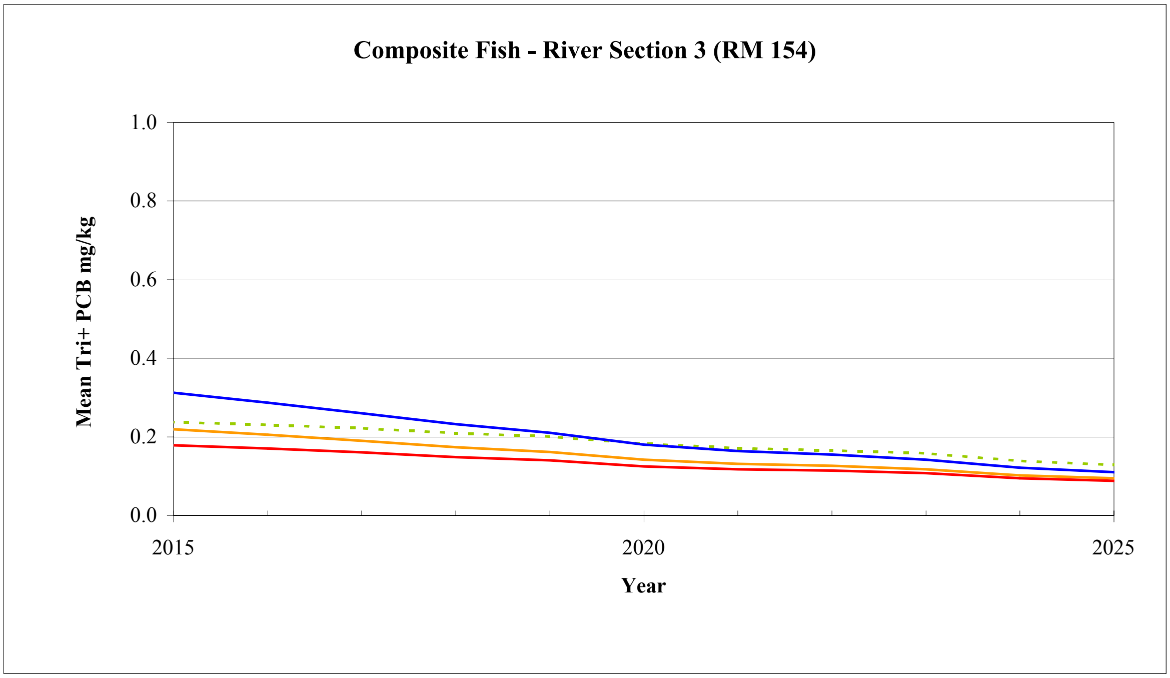


Figure 43 (Cont.)

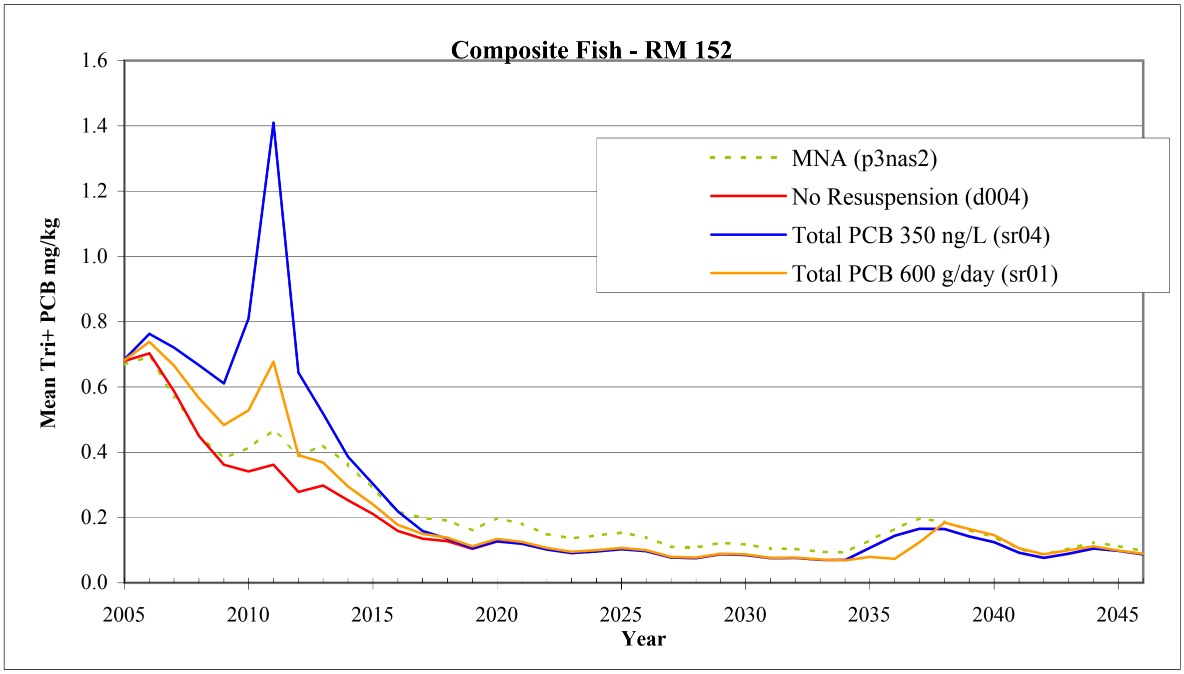
Composite Fish Tissue Concentrations for the Upper Hudson River

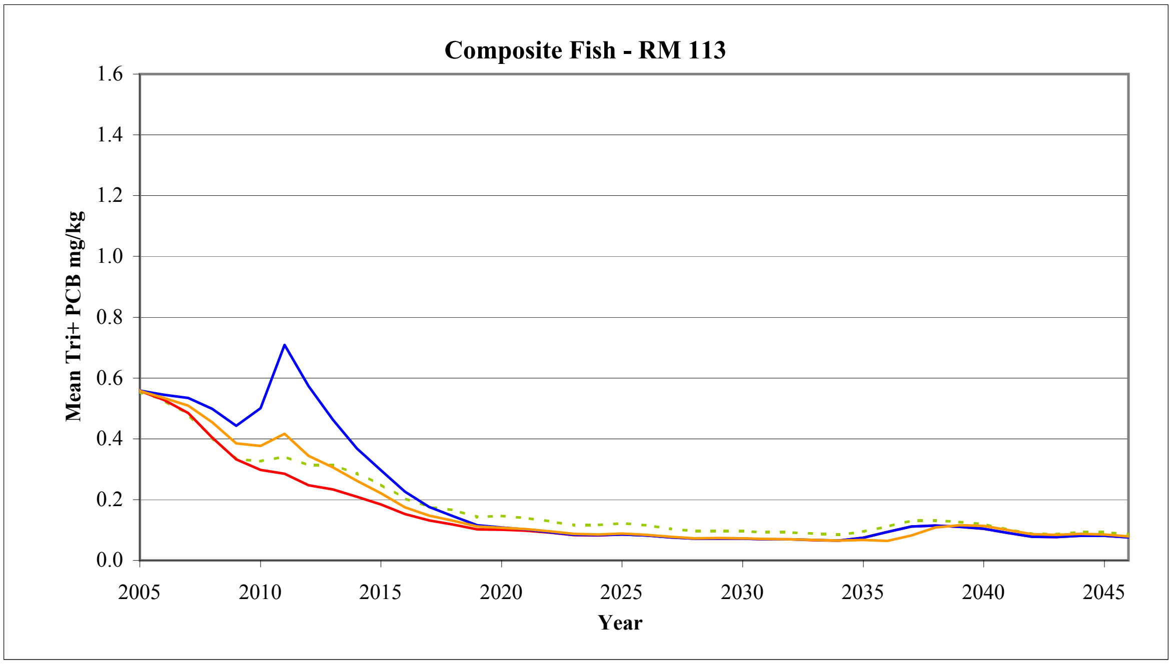




Notes:
Fish composite is 47% largemouthbass + 44% brown bullhead + 9% yellow perch
The bottom figure is portion of the top figure.

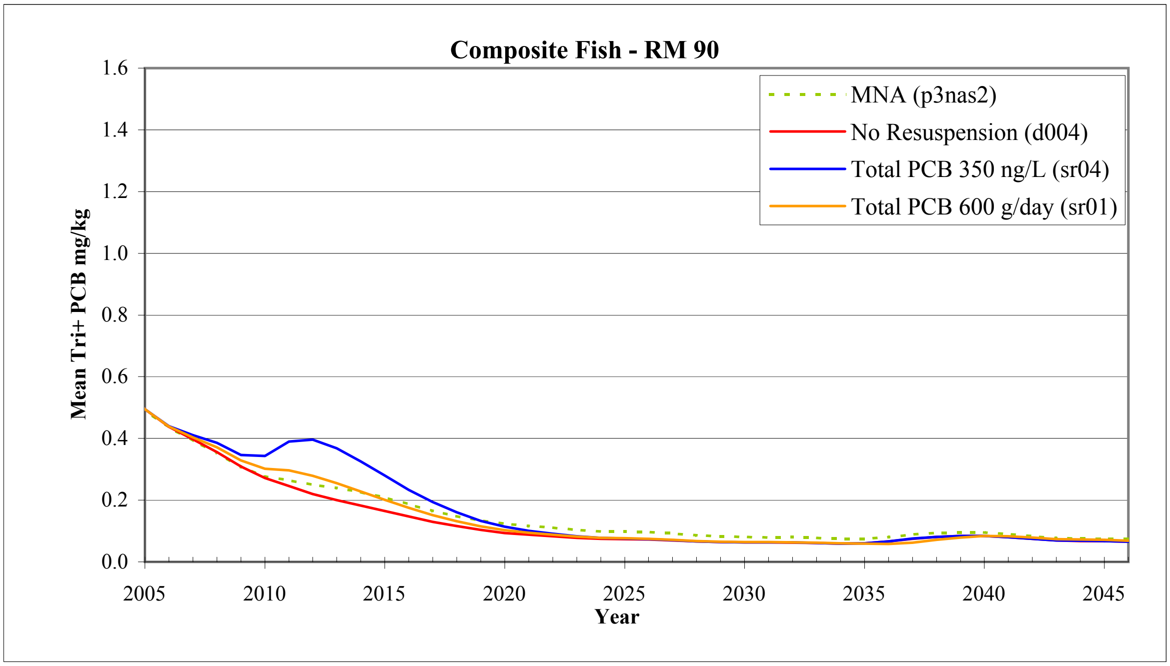
Figure 44
Composite Fish Tissue Concentrations for the Lower Hudson River

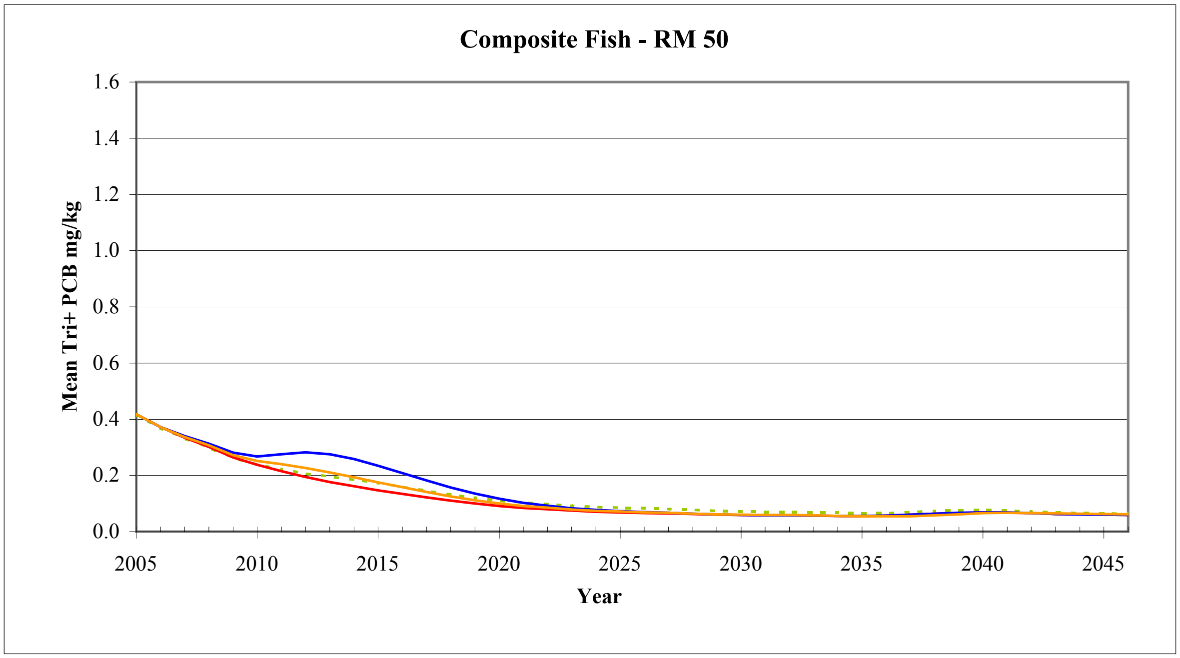




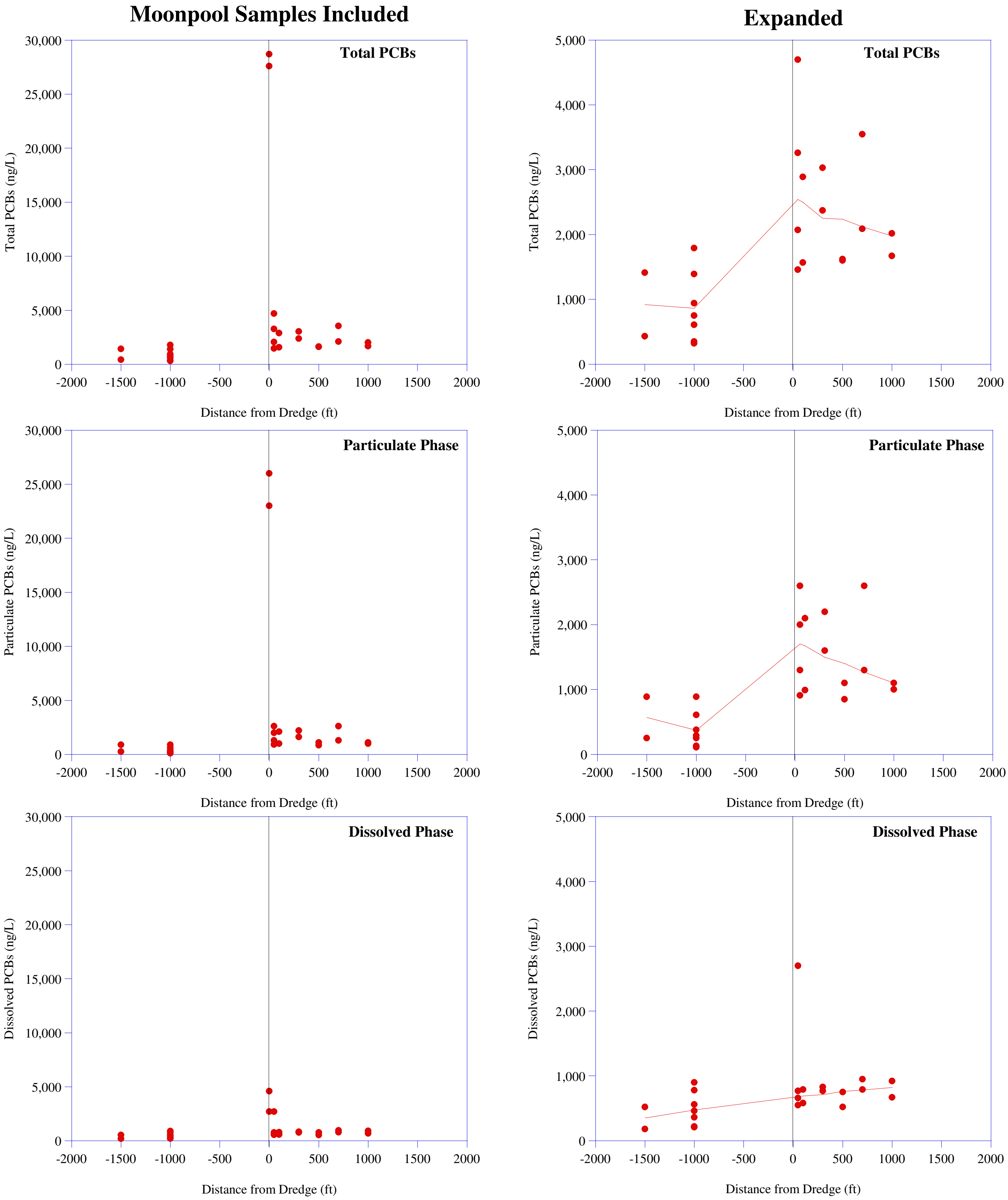
Note:
Fish composite is 47% largemouthbass + 44% brown bullhead + 9% yellow perch

Figure 44 (Cont.)
Composite Fish Tissue Concentrations for the Lower Hudson River



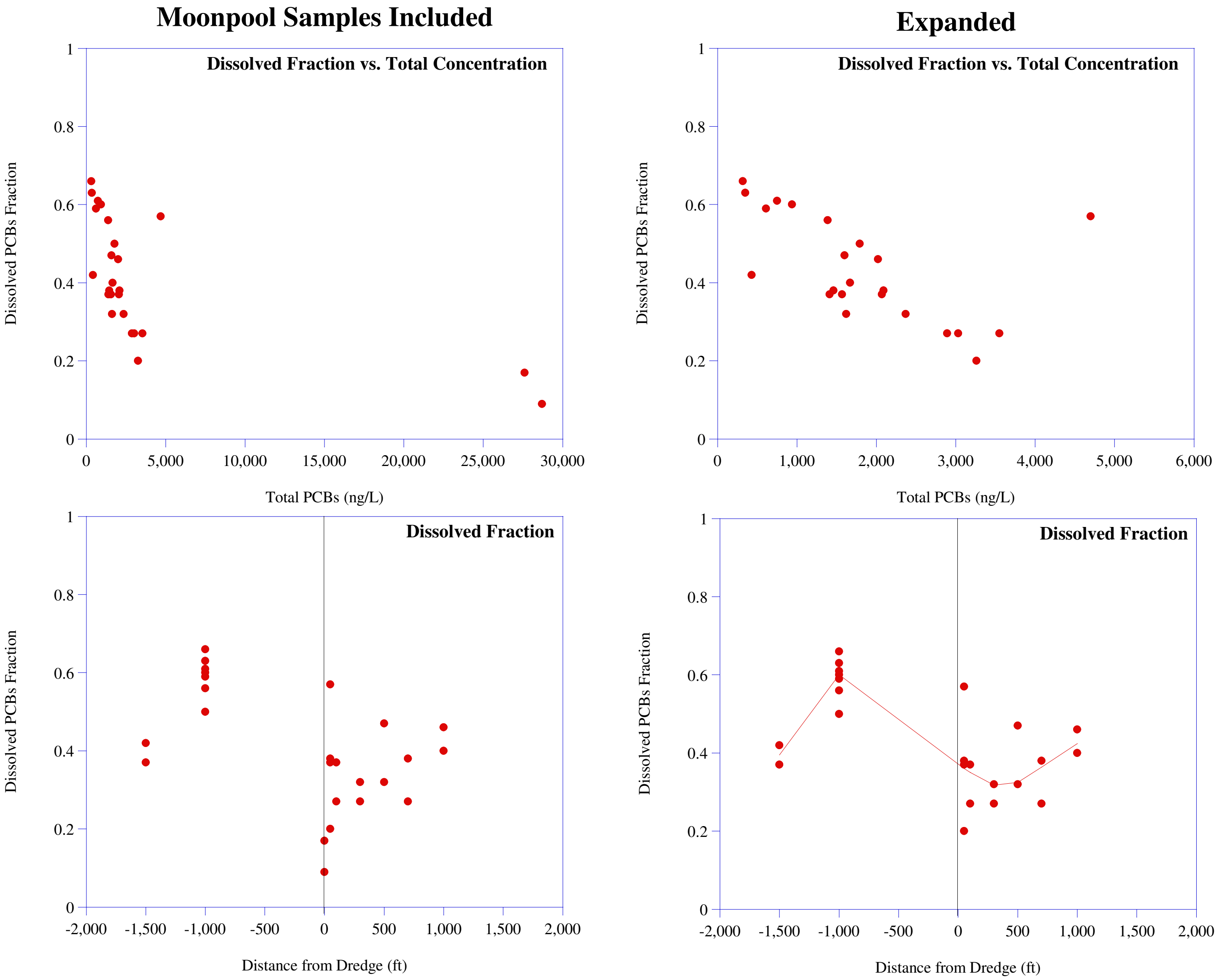


Note:
Fish composite is 47% largemouthbass + 44% brown bullhead + 9% yellow perch



Notes
1.The points at a distance of 0 ft are in the moonpool. The plots with the expanded scales do not include the moonpool samples.
2. Baseline is shown at -1,500 ft.
3. The expanded plots have weighted curves as visual aids to show the approximate mean conditions.

Figure 45
PCB Concentrations for New Bedford Harbor
Pilot Dredging Study



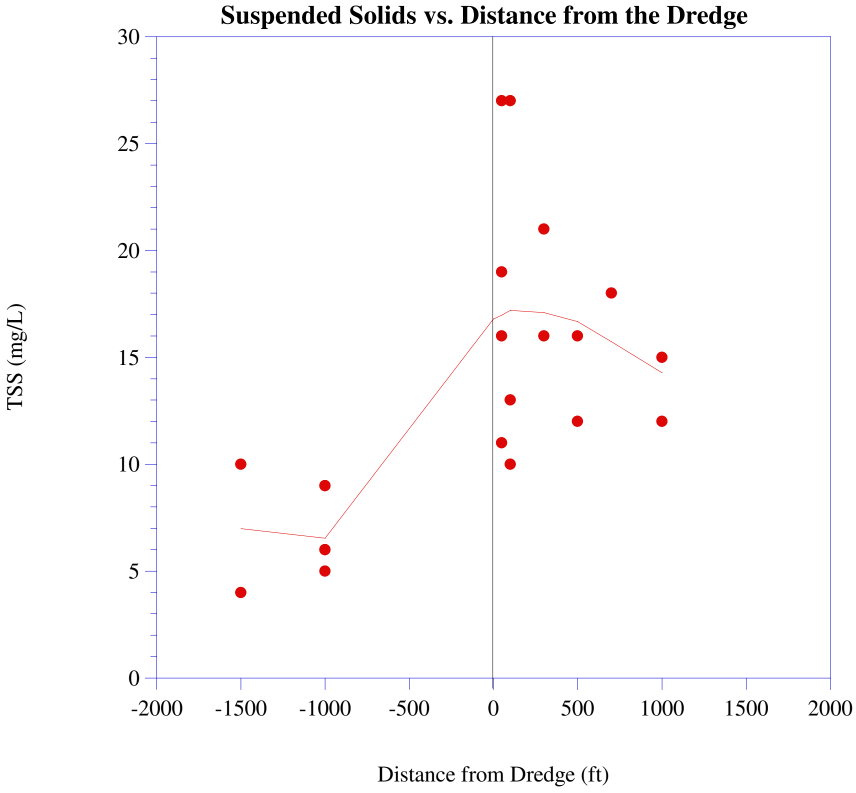
Notes

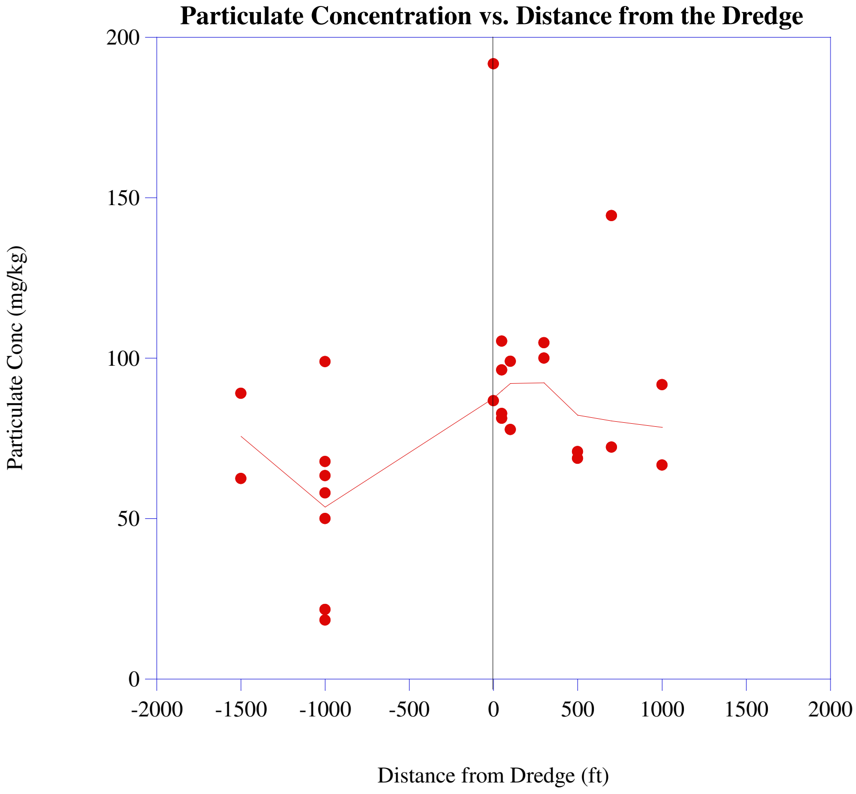
1.The points at a distance of 0 ft are in the moonpool. The plots with the expanded scales do not include the moonpool samples.

2. Baseline is shown at -1,500 ft.

3. The expanded plot has a weighted curves as a visual aid to show the approximate mean conditions.

Figure 46
Dissolved Fraction of PCB for
New Bedford Harbor Pilot Dredging Study





Notes

1.The points at a distance of 0 ft are in the moonpool.

2. Baseline is shown at -1,500 ft.

3. The plots have weighted curves as visual aids to show the approximate mean conditions.

Figure 47

TSS and PCB Concentrations for New Bedford Harbor Pilot Dredging Study

Attachment E

Engineering Contingencies Considerations

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Attachment E

Engineering Contingencies Considerations

1.0 Introduction

This attachment describes engineering contingencies that may be applied in the event that the action levels or the Resuspension Standard threshold are exceeded. The levels of the performance standard were developed using the statistical analysis of historical data, surface water quality modeling and applicable federal standards. The resuspension criteria will be used to govern the implementation of various engineering contingencies to minimize the release of PCBs during the remediation, to achieve the remediation goals as set forth in the Record of Decision (ROD) (USEPA, 2002), and to minimize the potential impact of dredging on ambient water quality. In the event that the resuspension criteria are exceeded, engineering contingencies will be implemented as necessary to minimize the potential impact of dredging on ambient water quality. A series of contingencies, ranging from increased monitoring frequency to cessation of dredging operation, have been proposed. These engineering contingencies will be implemented based on near-field and far-field water quality monitoring results.

The performance standard requires additional monitoring under certain conditions, the frequency and parameters for this additional monitoring of which are defined as a part of the performance standard. For other contingencies (*i.e.*, contingencies not specifically addressed in the performance standard), the specific technology cannot be selected, but must be a judgment that is specific to the problem encountered. Contingencies must be developed during the design stage for use in the event that water column concentrations exceed the performance standard. The performance standard does specify that if certain levels are exceeded, the cause of the exceedance will be examined and necessary changes must be made to the existing operations.

This attachment provides a brief overview of the performance standard (including a discussion of the monitoring locations needed to assess compliance with the standard), a summary of engineering contingencies used during similar projects, and a discussion of the engineering contingencies that may be applicable to the remediation.

Engineering contingencies for public and agricultural water intakes will be addressed in the Community Health and Safety Plan.

1.1 Performance Standard Monitoring Locations

Two types of monitoring locations are discussed throughout this attachment. Definitions are provided below:

Far-Field (Upper River and Lower River)

Far-field stations are fixed locations, typically located at dams and bridges. The primary contaminants to be monitored at these stations are PCBs and suspended solids. The results from monitoring at the far-field stations are the primary measure of PCB loss due to dredging, based on the assumption that only PCBs escaping each river section have the potential to cause significant downstream impacts.

Near-Field

Near-field monitoring locations are located within a short distance of the remedial operations, typically within a mile or so downstream. Depending upon the proximity of the various ongoing remedial operations to one another and the use of barriers, each remedial operation may have near-field monitoring locations associated with it. These near-field stations will be monitored continuously to determine the local impacts of dredging activities. The primary measurements in the near-field will be suspended solids concentrations and turbidity.

1.2 Resuspension Criteria

The resuspension criteria consist of three action levels and one standard providing limits on the PCB and suspended solids concentrations. Each of the resuspension criteria has associated monitoring requirements and engineering contingencies. The monitoring plan is summarized in Tables 1-2, 1-3 and 1-4 of the main document, showing the parameters required at each station and the frequency of sampling. Table 1-1 of the main document lists the concentration or load limits for each action level. Monitoring and resuspension criteria are fully described in the main body of the text and in Attachment F. An engineering evaluation of conditions in the river leading to elevated concentrations is recommended for Evaluation Level, but is mandatory for the Control Level and Resuspension Standard threshold. Similarly, implementation of engineering contingencies to reduce contaminant levels in the river is recommended at the Evaluation Level, but is mandatory for other the two other levels.

2.0 Monitoring and Contaminant Control Technologies Used At Other Sites

The monitoring and contaminant control technologies employed at three other PCB remediation sites are described below. The three sites are:

- St. Lawrence River Remediation Project at the Alcoa, Inc. Massena East Smelter Plant, New York, (Bechtal Environmental, 2000; 2002);
- New Bedford Harbor (Pre-Design Field Test), New Bedford, Massachusetts, (USACE, August, 2001); and
- Grand Calumet River, Gary, Indiana, (Earth Tech, Inc., 2002).

The technologies implemented at these three sites and reviewed in this attachment are containment (St. Lawrence River), dredging system design [hydraulic bucket design] (New Bedford Harbor), and monitoring (Grand Calumet River).

2.1 St. Lawrence River Remediation Project at the Alcoa, Inc. Massena East Smelter Plant, New York (Reynolds Metals)

In order to control the export of PCB-contaminated sediment at the St. Lawrence River Alcoa site, a containment system was installed as part of the remedial design. The containment system at this site included:

- A sheet pile wall that enclosed the entire remediation area;
- Silt curtains that provided secondary containment for the more highly contaminated Area C and also isolated uncontaminated portions of Area B from dredging areas; and
- Air gates (air curtain technology) that created an air-bubble curtain that acted as a circulation barrier while allowing for barge and tugboat access to areas enclosed by the silt curtain and pile wall.

Each of these components is discussed below.

Sheet Pile Wall

The wall consisted of interlocking steel sheeting embedded several feet or more into sediments and supported by H-beams (“king piles”) driven to greater depths. The sheeting and king piles were held together by a welded and bolted framework of steel braces and walers. The 3,800-foot finished wall consisted of about 200 king piles and 2,200 sheets. The maximum depth of water along the wall was about 32 feet.

The original design of the sheet pile wall specified that every fifth sheet would be driven to the water's surface to balance any differences in hydrostatic pressure between the inside of the wall and the outside environment. However, this was later changed and all sheets were raised to a height of about 2 ft above the river surface, minimizing the connection of turbid water inside the sheet pile wall with the river water outside the enclosure.

After the installation, a video survey was conducted to verify that there were no openings along the bottom of the wall or open seams in the sheeting. This survey identified a few small holes that were patched using sandbags. In addition, some of the sheeting was trimmed to reduce the height of all the sheets down to the 2 ft above water level (after installation) to reduce the surface area exposed to wind forces. Environmental monitoring data showed that the sheet pile wall functioned as designed and effectively contained the turbidity and suspended sediments generated during the dredging activities within the remediation area.

Silt Curtains

Silt curtains, consisting of 22-oz. PVC sheeting weighted on the bottom and suspended by polystyrene floatation buoys, were installed around Area C and a portion of Area B. The silt curtains were tied to H-beam anchor posts driven at a spacing of 100 feet, and anchored on the shoreline using a driven post or tree. The ballast for the curtains consisted of 3/8-in. galvanized anchor chain within a sealed pocket in the sheeting that could adapt to the bottom contours, thereby providing a complete vertical barrier. The curtain was suspended by cables attached to tensioners and anchor plates with reefing lines connected to the lower ballast chain to adjust the vertical height. A total of 1,222 feet and 996 feet silt curtains were used in Area B and Area C, respectively. The silt curtains effectively isolated the more contaminated Area C and prevented contamination of the clean portion of Area B.

The original design called for the installation of the silt curtain H-beam piles after the sheet pile wall was completed. However, due to the additional time required to install the sheet pile wall, this plan was changed for the clean part of Area B, and the silt curtain H-beam piles were driven while the sheet pile wall was being installed. A similar change for the contaminated part of Area B was not approved by the United States Environmental Protection Agency (USEPA).

Another change to the design of the silt curtain involved the addition of dual H-beams rather than a single H-beam to anchor the curtain. The original design specified that one H-beam would be placed at intervals along the inside of the curtain and timbers would be attached to the top of the beam to prevent barge traffic from hitting the curtain from the outside. The silt curtain manufacturer recommended placing dual H-beams at a spacing of 90 feet and then anchoring the curtain between the beams.

Air Gates

Air gates (air curtain technology) were used to create vertical circulation barriers that allowed boats to pass but restricted the movement of water between various parts of the remediation area. The air curtains consisted of 2-in. outside diameter (OD) steel pipe fitted with diffuser orifices on a helical, 9-inch spacing. The pipes had leg supports that raised them about a foot off the bottom. Geomembrane was laid beneath the pipes to minimize the disturbance of nearby sediment. Divers were used to place the liner, pipe and anchors, connect the supply lines and verify proper operation once the equipment was in place. A compressor station supplied air to the gates at a flow rate of about 1,000 cubic feet per minute (cfm) with flow pressures of 90 to 100 psig. The gates allowed for barge transit and limited the migration of turbid water across the barrier. A major objective of the gates was to contain the turbidity generated during the removal of Area C sediment. The gates accomplished this objective and otherwise functioned as designated for the duration of the project.

2.2 New Bedford Harbor (Pre-Design Field Test), New Bedford, Massachusetts

A pre-design field test was conducted at the New Bedford Harbor site to assess the effectiveness of hydraulic dredging as an engineering contingency to minimize the release of PCB contaminated material to the water column and to limit the transport of sediment away from the dredging area. The water quality monitoring data obtained during dredging activities indicated that the actual dredging process using a hydraulic excavator appeared to have a limited impact on the water column. The factors that minimized the release of material to the water column included the design of the bucket (tight closing with limited leakage), the configuration of the dredge (with a “moon-pool” work area enclosed behind a 36-inch silt curtain), and the controlled manner in which the operation was executed.

Factors that limited the transport of contaminated material away from the dredging area included the shallowness of the area (maximum depth of the dredged area was less than 10 feet (3 m)) at high tide and the limited currents (maximum currents generally measured less than 0.5 feet/sec.).

Activities performed in support of the dredging (e.g., the operation of support vessels such as tug boats) appeared to have a much greater impact on water quality than the dredging operations due to shallowness of the water, which measured about 4 to 5 feet in depth.

Normal fluctuations that occur in Upper Harbor due to changing environmental conditions appeared to be similar to, or greater in scale than, the overall impacts related to the actual dredging process.

2.3 Grand Calumet River, Gary, Indiana

Dredging activities are scheduled for completion in December 2003. The following was extracted from the Water Quality Certification Work Plan, dated July 2002.

Three water quality monitoring locations (Sites A, B, and C) are defined as the primary monitoring sites. A fourth monitoring location (Site D) is defined as the verification site.

- Site A is intended to monitor water quality upstream of dredging (located mid-channel of the Grand Calumet River at Transect 4 and will be re-located to Transect 2 as dredging progresses),

- Site B is located mid-channel, approximately 200 yards downstream of the open water dredge in Transect 12 to 36, and will be re-located as dredging progresses through cell D (or from Transect 12 to 36),

- The third station, Site C, is the downstream sample site and is located mid-channel downstream of Transect 36 (downstream of the limit of dredging), and

- A fourth sample location, Site D, also known as the verification sample site, will be situated 200 yards upstream of the open water dredge in transects 12 to 36, will be used to verify water quality exceedances, and used to determine if the exceedance is a result of the dredging operation or a different point source. This station was proposed in lieu of performing background sampling prior to initiating dredging. All water samples will be equal volume composites created from a total of three samples per location. The three samples per location will be taken from the water surface, at 50 percent of the water depth and at 80 percent of the water depth.

Three levels of monitoring will be utilized, including Level 3 Monitoring (*i.e.*, collection of composite water samples once per month from automatic samplers at Sites A and C and manually at Sites B and D for analysis of PCBs and other specified parameters). If results indicate no exceedances at Sites A, B and C, or if monitoring indicates exceedances at all three sites (A, B, and C), then it will be concluded that dredging is not the source and normal sampling will be conducted (once per month). If, however, results indicate exceedances at Sites B and C but not site A, then the water sample collected at Site D will be analyzed. If the sample from Site D indicates the parameters exceeded at Sites B and C are also exceeded at Site D, it will be assumed that the downstream exceedances at these sites are not a result of dredging and the normal frequency sample will be conducted. However, if no exceedances are found at Site D, it will be concluded that dredging is the source and enhanced monitoring consisting of additional sample collection at Sites A, B and C will be implemented at a rate of three times per week. When results indicate that the parameters of concern are less than the criterion for two months of consecutive samples, enhanced monitoring will be discontinued and the normal monitoring frequency will be resumed.

In addition to the increased sampling frequencies as a result of exceedances determined to be due to dredging, the Indiana Department of Environmental Management and the US Army Corps of Engineers will also implement a response action. If it is thought that an immediate threat to human health or aquatic life exists, the required response action will be issued within 72 hours, and this action will be implemented as quickly as possible, with a maximum time limit of one week to complete the implementation. If this schedule is not met, enhanced monitoring will be automatically implemented as described above, based on the parameters exceeded and the level of monitoring utilized when the exceedances occurred.

Possible response actions may consist of the following engineering contingencies:

- Decrease dredging operation,
- Install additional turbidity barriers or control mechanisms,
- Temporary cessation of dredging activities, and
- Conduct additional monitoring.

3.0 Engineering Contingencies for the Remediation

The required engineering contingencies for the Resuspension Performance Standard are described below. These include an increased monitoring frequency, engineering studies, containment technologies, operational modifications, equipment modifications and scheduling changes. With the exception of the monitoring frequency, specific implementations of the engineering contingencies must be planned during design.

The applicability of many of the containment technologies was evaluated in Appendix E.5 of the FS (USEPA, 2000). The advantage and limitation of each type of turbidity barrier were discussed. This information will be useful when choosing the appropriate containment system for a specific area to address the engineering contingency during the remediation.

3.1 Monitoring Contingencies

Monitoring frequency of the far-field stations will be increased at higher levels of exceedance to gain more information from which to evaluate conditions. The degree of increased frequency is detailed in Table 1-2, 1-3 and 1-4 of the main document for non-routine monitoring. The sampling method also changes for some stations—from grab samples to composites of hourly samples—to better capture the average water column concentration at the nearest representative far-field stations and to limit the number of analytical samples required.

3.2 Engineering Evaluations

In instances where water quality measurements exceed a resuspension criteria based on PCB concentration or load, an evaluation of the remedial operations should be conducted to determine the possible source and mechanism causing the exceedance, including:

- Examination of the barrier, if it is in use, for leaks and stability,
- Examination of the sediment transport pipeline if a hydraulic dredge is used,
- Examination of the turbidity associated with sediment transport barges and other support vehicles, and
- Sampling of PCB concentrations in the near-field.

The above-listed engineering studies will be mandatory in the event the Control Level and Resuspension Standard threshold are exceeded.

3.3 Barriers

Several types of barrier systems are described below:

- Fixed Structural Barriers,
- Non-Structural (Portable) Barriers,
- Other Portable Barrier Systems, and
- Control Zone Technology.

Fixed Structural Barriers

Fixed structural barriers, such as sheet piling, are particularly suitable for areas where there is a potential for high levels of resuspension. Sheet piling consists of a series of interlocking steel sections. The piles and panels are all driven into the riverbed to approximately the same depth. It is anticipated that turbidity barriers comprised of sheet piling will not be used areas where relatively shallow rock is present.

While fixed structural barriers provide considerable structural capacity, these systems are relatively expensive and usually require significant planning, equipment and manpower resources to install.

Non-Structural Barriers (Portable Barriers)

Non-structural barriers, such as silt curtains and silt screens (sediment curtains), can be considered for use to prevent the transport of sediments resuspended as a result of dredging activities Silt curtains are constructed of impervious materials that block or deflect the passage of water and sediments. Silt screens are similar to silt curtains; however, these barriers allow water to flow through while impeding the passage of a fraction of the suspended load. Typically, a silt curtain and silt screen are suspended by a flotation unit at the water's surface and held in a vertical position by a ballast chain within the lower hem of the skirt. Anchors attached to the barrier also serve to hold it in place.

The advantage of using non-structural barriers is that they can easily be deployed and re-located to new work areas after dredging at a specific location has been completed. Silt curtains are not considered appropriate in situations where the river current is greater than approximately 1.5 feet per second and/or where the depth of the river exceeds 21 feet. However, it should be noted that if the silt curtain is set up in a configuration that is closely parallel to river flow, the curtain could function effectively in currents approaching 3 feet per second.

Other Portable Barrier Systems

Other commercial products such, as the Portadam™ and Aqua-Barrier™ systems, are also available for construction site containment, diversion of water flow, erosion control, and flood control. These systems are low-cost alternatives to building earthen dams or using sheet piles, and are relatively easy to set up. These systems are generally applicable to water depths of less than 10 feet.

The Portadam™ system utilizes a free-standing steel support structure in conjunction with an impervious fabric membrane. The support members transfer fluid loading to an approximately vertical downward load, allowing for installation on a solid impenetrable foundation. This structure stands independently on the existing bed, eliminating the need for pile-driving equipment, cross bracing, or anchorage. The membrane is placed on the outer section of the support structure, and is rolled out all the way down to the level of the bed. Hydraulic loading on the membrane assists in the sealing and stability of the entire structure. Once installed, the work area enclosed by the structure can be de-watered.

The Aqua-Barrier™ and GeoCHEM Water Structures™ systems utilize water-filled, vinyl, polyester-reinforced tubes to provide mass for stability and they can be coupled together to form a barrier of any length. Punctures in the material can be easily patched with repair kits. They are lightweight, easy to transport, and re-usable. While these systems are not as sturdy as the Portadam™ system, they can be used in cold weather conditions and are reasonably resistant to sunlight exposure.

Air gates are used to facilitate the passage of dredging-related traffic to and from an enclosed (i.e., sheet piled or silt curtained) area. The technology employs a continuous release of bubbles to reduce the flow of water to and from an enclosure. The air is supplied from a blower or compressed air source. The effort and cost associated with the deployment and operation of air gates are low and the performance of air gates appear to be superior when compared to silt curtain gates.

Control Zone Technology

A Control zone is a secure dredging area that is maintained and sealed off to prevent the release of contaminants generated inside the zone. Application of control zone technology (CZT) allows the excavation of contaminated sediments without the release of particulate and soluble contaminants into the surrounding water environment. It also establishes an area that can be easily monitored to confirm that remediation goals are met. This type of technology is more stringent than other barrier technology, since it requires additional water treatment. CZT has only been tested on a pilot scale and the cost is likely to be prohibitive. This type of technology could be considered for limited use in the most highly contaminated areas.

3.4 Operation and Equipment Modifications

Depending on the level of resuspension observed, operational control and equipment modification which include the following should be considered:

- Limiting boat speeds to reduce prop wash,
- Restricting the size of boats that can be used in certain areas,
- Loading barges to less than their capacity where it is necessary to reduce draft,
- Selecting an alternate dredge with a lower resuspension rate,
- Selecting alternate equipment or method for placing backfill or capping material, and
- Use of smaller, shallow draft boats for the transport of crewmembers and the inspection of dredges.

3.5 Scheduling Changes

The baseline PCB water column concentrations are high during the months of May and June relative to the remainder of the dredging season. As documented in the baseline water column level study (Attachment A), the 95 percent upper confidence limits (95% UCL) on the mean of PCB concentrations at the TI Dam and Schuylerville ranged from 110 ng/L to 200 ng/L in May and June. Remedial activities in high-concentration areas during high flow conditions may result in increased water column PCB concentrations that fall above resuspension criteria, resulting in the implementation of engineering contingencies, for example a containment system capable of containing enough of the resuspended material to maintain acceptable water column concentrations. Areas with higher sediment concentration may need to be scheduled for remediation in later months of each year (i.e., under low flow conditions, when the baseline level of PCB concentration is relatively low) if the engineering contingencies chosen are not effective. Baseline water column concentrations should also be considered when scheduling remediation in areas nearest water treatment plants in order to maintain a margin of safety for the public water supply.

4.0 Implementation Strategies

Flowcharts depicting the implementation of the Resuspension Performance Standard are provided in Figures 3-1, 3-2 and 3-3 of the main document for the near-field suspended solids, far-field total PCBs and far-field suspended solids, respectively. These flowcharts present the interaction between the three aspects of the Resuspension Performance Standard: resuspension criteria, monitoring requirements and engineering contingency requirements.

5.0 References

Bechtel Environmental, Inc./Metcalf & Eddy, Inc. 2000. Final Dredging Program Design Report for the River Remediation Project at the Reynolds Metals Company, St. Lawrence Reduction Plant, Massena, New York, Revision 3. Prepared for Reynolds Metals Company. May 2000.

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USEPA. 2002. Responsiveness Summary: Hudson River PCBs and Record of Decision, Prepared for USEPA Region 2 and United States Army Corps of Engineers by TAMS Consultants. January 2002.

Attachment F

Measurement Technologies

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LIST OF FIGURES

APPENDIX

Attachment F

Measurement Technologies

1.0 Introduction

This section provides detailed descriptions of specific measurement techniques for the general continuous monitoring prescribed in the performance standard. These include:

- In-situ Turbidity Measurement,
- In-situ Total Suspended Sediment Measurement,
- Semipermeable Membrane Devices (SPMDs),
- Trace Organic Platform Sampler (TOPS), and
- ISCO® Portable Water and Wastewater Sampler.

The above-listed instruments are presented as examples of technology that may be used during construction to satisfy the requirements of the standard, but the selection of appropriate technology will be a part of the design process.

Several other issues related to the monitoring are presented in this attachment. Correlations between turbidity and suspended solids measurements are discussed, and development of a correlation between these parameters will be required in order to obtain a real-time indication of dredge-related impacts on the water column. Attachment F-1 presents the results of a literature search on this topic. Attachment F-2 provides a synopsis of PCB analytical methods and associated detection limits. The detection limits for PCB congener analysis will be low in order to obtain detections at each station and to allow for identification in congener patterns.

2.0 Measurement Techniques

All types of dredging (navigational and environmental remedial action) create sediment plumes in the water column. Of particular interest for the Hudson River remedial action are plumes associated with the following activities:

- The mechanical and/or hydraulic dredging (sediment removal) operation,
- Material handling of dredged materials,
- Boat and barge movements, and
- Open-water placement of backfill materials.

The regulatory agencies and the public are concerned about potential adverse effects caused by these plumes on humans and biological resources, either through impact to water quality or increased siltation. To gain a better understanding of the temporal and spatial dynamics of sediment plumes, and in order to implement the performance standard for resuspension, it is necessary to monitor the plumes created to determine their composition, extent, and duration. Numerous techniques have been used to monitor sediment plumes, ranging from collection of water samples using simple water samplers to highly complex systems involving state-of-the-art instrumentation. Given the variety of techniques available to monitor dredging-related plumes, it is necessary to understand the advantages and limitations of the various techniques in order to determine which techniques provide the most cost-effective approach for each specific monitoring requirement.

The resuspension performance standard (as defined in Section 1) includes specifications for both PCBs and suspended sediment monitoring. The PCB standard requires measurement of the total PCB concentration, specifically, the measurement of the dissolved phase and suspended phase concentrations for all PCB congeners (monochlorbiphenyls through decachlorobiphenyl). Suspended solids (sediment) standards have been defined in order to serve as a surrogate for the amount of PCBs in the water column in order to provide a real-time indication of PCB concentration. Another parameter that could potentially serve as a surrogate for PCBs is turbidity. Although turbidity has been historically used during the monitoring of dredging activities to estimate suspended sediment using empirical correlations, it is well recognized that achieved correlations are site-specific and subject to significant error.

The objectives of measuring the water quality parameters discussed above (PCBs, suspended solids, and turbidity) are twofold:

- First, determine the water quality associated with the plume; and
- Second, track the plume both in space and time.

Knowledge of the spatial extent of a given plume is necessary to determine areas of potential plume impact. Similarly, knowledge of the time history of a plume provides information on how long a plume is present in a particular area and the time required for the plume to dissipate. It is clear that both near-field and far-field monitoring are necessary.

It may be important to measure various physical parameters not directly associated with water quality such as currents, waves, and water elevations. Currents carry plumes from the area in which they were generated into adjacent waters. Therefore, data on the current structure can be used to estimate the movement and spatial extent of the plume. Waves increase turbulence in the water column, which can potentially introduce additional sediment into suspension and prevent material in suspension from settling out.

Measurement techniques for monitoring of plumes involve one of the following:

- The collection of water samples from the water column for analysis either in the field or the laboratory (ex-situ methods), or

- The placement of instruments in the water column to directly measure water quality parameters or other physical parameters (in-situ methods).

Off-site laboratory analysis is time-consuming, expensive, and cannot provide data in the short term (i.e., within a few hours or less of sample collection). At present, there are no in-situ methods available for directly measuring PCB congeners in the water column, therefore, sample collection and laboratory analysis are required.

Concentrations of PCBs in the water column are often present at parts-per-billion (μg/L) or parts-per-trillion (ng/L) levels. Conventional sampling, extraction, and analysis methods like liquid-liquid extraction or solid-phase extraction can require the sampling and processing very large volumes of water (e.g., 50 liters) for an analysis of adequate sensitivity to detect low concentrations. (See Attachment F-2 for a synopsis of PCB analytical methods and associated detection limits.)

The limitations inherent in methods for the direct measurement of contaminant water concentrations have often prompted the use of biomonitoring to assess the exposure of organisms in the water column to trace or ultra-trace levels of hydrophobic chemicals like PCBs. Because certain organisms often bioconcentrate these trace or ultra-trace levels of PCBs to relatively higher concentrations (parts per million) in their lipids, determination of the bioavailable portion of environmental pollutants like PCBs is critical to assessing the potential for detrimental biological impacts.

This organism-based approach also has inherent problems, including biotransformation and depuration of contaminants, and inapplicability in many exposure situations due to the effects of stress on the biomonitoring organisms that often lead to a lack of proportionality between the biomonitoring organism tissue concentrations and ambient exposure concentrations (Petty et al., 2000). Therefore, innovative approaches for sampling and analyzing trace and ultra-trace levels of water-borne PCBs are needed.

The major mechanisms that result in relatively high concentrations of PCBs in organisms are passive processes and include the following:

- biomembrane diffusion, and
- partitioning of the chemical between an organism's lipid tissue and its environment.

Employing a mimetic chemistry approach (i.e., use of processes in simple or uniform media to mimic complex biological systems), scientists at the United States Geological Survey's (USGS) Columbia Environmental Research Center (CERC) have developed a passive, integrative sampler that simulates hydrophobic chemical bioconcentration. The uncertainty of estimating ambient exposure concentrations from tissue concentrations in biomonitoring organisms is thereby avoided. This sampler, the semipermeable membrane device (SPMD), measures the concentration of dissolved phase PCBs in the water column. A second type of integrating sampler, the Trace Organic Platform Sampler (TOPS), has been developed by New York State Department of Environmental Conservation (NYSDEC). The TOPS concentrates hydrophobic organic compounds from surface waters and is designed to collect suspended and dissolved-phase organics.

2.1 Correlations Between Turbidity and Suspended Solids

This section describes techniques traditionally used to measure turbidity and suspended solids in waters, how the two parameters relate to each other and to various environmental impacts, and why one cannot be routinely substituted for the other. An additional literature review is presented in Attachment F-1.

The term total suspended solids (TSS), sometimes referred to simply as suspended solids (SS), encompasses both inorganic solids such as clay, silt, and sand, and organic solids such as algae and detritus. It is a measure of the dry weight of suspended solids per unit volume of water, and is reported in milligrams of solids per liter (mg/L). The suspended solids concentration is determined by filtering a known volume of water through a filter of specific pore size (45 μm), and then drying and weighing the material retained on the filter. USEPA Method 160.2 is often used for this 'TSS' measurement.

Although popularly called suspended solids (the terminology used in this report), this method is more accurately termed non-filterable solids (or residue), because the size of separation (about 0.45 μm) is not the same as the boundary between suspended and dissolved solids. The suspended solids/dissolved solids boundary varies among molecules, but is generally around 0.1 μm. Another drawback of this method is that laboratories often perform this analysis using a 100 mL aliquot of the total sample provided, typically a 250-mL sample bottle. There is the potential that some of the solids adhered or adsorbed to the surfaces of the container, yielding a reported result with a low bias relative to the ‘true’ value. The method used by USGS to measure suspended sediment, ASTM Method D3977-97, may be preferable.

Turbidity is an optical property of water that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample. It is caused by water molecules, dissolved substances, and organic and inorganic suspended matter.

Turbidity measurements can be used as an operational aid in monitoring dredging and backfill placement operations as an adjunct to the more costly and time-consuming suspended solids measurements in a laboratory. The primary reason for wanting to use turbidity measurements instead of suspended solids is that turbidity measurements are immediate; nephelometric turbidity readings can be performed in a matter of minutes.

The collection and analysis of a suspended solids sample requires the following actions:

- Transport to the laboratory
- Analysis of the sample
    - filtering
    - drying
    - weighing
- Calculation of the suspended solids value

The transport and analysis process can take from 3 to 24 hours to complete. In the time it takes to get results of the laboratory analysis, the suspended solids of the discharge or water body of interest will have changed. Therefore, laboratory measurements for suspended solids cannot be easily used to detect and correct short-term problems or performance standard violations.

It is for this reason that turbidity measurements have historically been substituted for suspended solids. Turbidity is easy to measure quickly, but the following problems are associated with using turbidity as a surrogate for suspended solids:

- There is no universal relationship between it and suspended solids
- There is no universal relationship among turbidity measurements made on different water-sediment suspensions
- There is no universal relationship among turbidity measurements made on the same suspension with different instruments.
- Turbidity does not correlate well with many categories of environmental impact.

However, turbidity can be used to indicate suspended solids concentration on a site-specific basis, if certain specific techniques are used.

Two factors that prevent the development of a simple, universal relationship between suspended solids and turbidity are that the two parameters measure different things and their values are functions of different variables, . The suspended solids parameter depends on the total weight of particles in suspension, and is a direct function of the number, size, and specific gravity of the particles. In contrast, while turbidity is a direct function of the number, surface area, and refractive index of the particles, it is also an inverse function of their size (for constant suspended solids) (Thackston and Palermo, 2000).

The problems associated with the correlation of turbidity and suspended solids are based on two factors associated with calibration:

- The calibration changes with changes in grain size of the sediment.
- The calibration changes with sediment color.

A landmark paper co-authored by the inventor of one of the most widely used turbidity meters noted the following:

- The calibration changed by a factor of 10 based on color alone
- The change in calibration that is linear with sediment grain size (Sutherland et al., 2000).

For example, the calibration would change by a factor of 20 between white 5 micron sediment particles and gray 10 micron sediment particles. Such changes in sediment properties are not uncommon in nature. Since sediment color and grain size are not characteristics that are generally known during the course of a monitoring period, spot calibrations from samples are likely to contain unknown errors as sediment properties change in space and time (Agrawal and Pottsmith, 2000).These errors can reach several hundred percent and greater. Laser sensors described below in Section 2.3: In-situ Total Suspended Sediment Measurement overcome both these errors, making it easier to monitor suspended sediments.

2.2 In-situ Turbidity Measurement

Turbidity is the apparent “cloudiness” of water produced as light is scattered by particulate matter or dissolved material in the water. Presently established methods for measuring suspended sediments via optical turbidity are rooted in the research performed by Whipple and Jackson around the year 1900, which lead to a candle-based turbidity standard called the Jackson Turbidity Unit (JTU). Devices commonly used to measure turbidity include the Jackson candle turbidimeter, absorptimeters, transmissometers, and nephelometers (McCarthy, Pyle, and Griffin 1974). All but the nephelometer measure the effects of both the absorption and the scattering of light. The nephelometer measures scattered light only, and is the most commonly used device in colloidal chemistry, drinking water treatment, and water quality management. Turbidity measured by such an instrument is reported in nephelometric turbidity units (NTU).

A transmissometer projects a narrow beam of light through a volume of water and measures the intensity of the beam as it exits the volume of water. If particles are present in the water, they will attenuate the beam of light such that the light exiting the volume of water is less than the light entering the volume of water. The amount of attenuation can be measured, and with the appropriate calibration, these measurements can be used to estimate the suspended-particle concentration using an empirically-derived calibration curve. At low particle concentrations, transmissometers are very sensitive to small changes in particle concentration and/or size; however, at high-particle concentrations, transmissometers become saturated and lose their sensitivity to variations in concentration. Therefore, while transmissometers are very useful at measuring low-particle concentrations, they are inadequate for measurements at suspended solids levels above approximately 150 mg/L (Zaneveld, Spinrad, and Bartz 1979).

Nephelometers project a beam of light into a volume of water and measure the amount of light scattered out of the beam. The amount of light scattered is almost entirely dependent on the amount and size of particulate matter present in the volume of water. Ideally, a nephelometer would measure the amount of light scattered at all angles. Such a nephelometer is impractical, however, and standard nephelometers measure the scattered light at only one angle. Nephelometers use a device such as a photomultiplier tube or silicon photodiode to measure light that has been scattered at a specific angle, usually 90 degrees, from the main light path. The light source is usually a tungsten filament lamp or a light-emitting diode, and the light path is designed to minimize the amount of stray light that reaches the detector. Thus, a zero signal means that no light scattered at 90 degrees from the main light path and implies no turbidity.

Nephelometers used for in-situ measurements are, in general, referred to as optical backscatter sensors (OBSs). OBSs measure the amount of infrared light backscattered from a volume of water. While suspended sediment will reflect infrared light, organic matter will not (Tubman 1995). This characteristic of OBSs makes them well suited for the monitoring of sediment plumes because it does not bias the data by including organic matter. Because an OBS measures backscatter, its design is simple and compact relative to that of a transmissometer. More importantly, an OBS is capable of measuring significantly higher particle concentrations than a transmissometer, though it lacks the accuracy of the transmissometer at low-particle concentrations. Like the transmissometer, particle concentrations in the water can be estimated from OBS measurements using empirically determined calibration curves.

The ability of a particle to scatter light depends on the size, shape, and relative refractive index of the particle, as well as on the wavelength of the light (Lillycrop, Howell, and White 1996). The reading taken by the instrument depends on many design parameters, including the light source, detector, electrical circuit, sample container, and optical arrangement. As a result, two samples with equal suspended solids concentrations but different size distributions of particles will produce very different turbidity readings on the same nephelometer, and two different nephelometers may produce different turbidity readings on the same sample, even if they were calibrated on the same standard (Vanous 1978; Hach 1972). Although the original Jackson candle turbidimeter was standardized with a specific fine silica suspension in which one JTU equaled 1.0 mg/L of suspended solids, modern turbidimeters are no longer standardized against the Jackson candle, and the term JTU is no longer used. The Jackson candle turbidimeter is no longer an accepted standard method (*Standard Methods* 20th edition, APHA et al.).

Modern turbidimeters are standardized against a formazin suspension with a value of 40 NTU. The standards should be prepared according to *Standard Methods* 20th edition (APHA et al.) The 400-NTU stock suspension should be prepared monthly, and the 40-NTU standard turbidity suspension should be prepared daily. Experience shows that this turbidity can be repeatedly prepared within an accuracy of "1 percent (Hach 1972). The formazin turbidity standard is assigned a value of 40 NTU and can be diluted to any desired value.

One of the main benefits of measuring turbidity is that turbidity sensors are relatively simple, inexpensive, and robust. The objective of most turbidity measurements is to identify the presence of suspended solids and quantify the suspended solids based on a correlation between turbidity and suspended solids. Historically, the standard practice has been to use turbidity measurements to estimate suspended solids. Such estimates are accurate only under the following conditions:

- All measurements being compared are taken using the same turbidity sensor.

- The turbidity sensor is calibrated with a reference standard and suspended material from the area where the measurements are being taken.

- Particle size and composition of the suspended material do not change significantly during the measurement period.

Turbidity can also be measured in the field by collecting water samples and using portable instruments to analyze the samples. While these instruments are typically less expensive than in-situ sensors, the measurements take longer and may not represent true in-situ conditions, since particles may settle out of suspension prior to analysis. The cost of these instruments is approximately $1,500 to $2,000.

2.3 In-situ Total Suspended Sediment Measurement

Historically, suspended solids have been measured by collecting water samples and analyzing the samples in an off-site laboratory. Water samples can be collected using a bottle sampler or a submerged pump. Independent of the collection method, care must be taken to ensure that suspended particulate matter does not settle out of suspension or flocculate during collection or prior to analysis. Off-site laboratory analysis is time-consuming and cannot provide data in the short term. However, this approach is considered to be the most accurate and reliable method for measuring suspended solids. The alternative has been to estimate suspended solids based on other measurements such as turbidity or acoustic backscatter, both of which have limitations as discussed above.

New technology, Laser In-Situ Scattering and Transmissometry (LISST) has been recently developed that can measure suspended solids in-situ more accurately than can be achieved using correlations with turbidity. The instrument, the LISST-25, measures the scattering of a laser beam by particles in a volume of water. It should be noted, that laser diffraction measurements have been used to measure and characterize suspended sediments and floc-sizes in situ since 1985 (see, e.g. Bale and Morris, 1987; McCabe et al.,1993; Agrawal and Pottsmith, 1994; Gentien et al.,1995; Bale, 1996; van der Lee, 1998).

The LISST-25 is a small, self-contained unit that is suitable for field deployment and has real-time data return capabilities (Sequoia Scientific, Inc.). The instrument is capable of measuring particle total volume, particle total area, and the Sauter mean diameter within a particle range of 1.2 to 250 mm. These parameters are defined as follows:

- Particle total volume is the volume of material per volume of water.
- Particle total area is the projected cross-sectional area of the particles per volume of water.
- Sauter mean diameter is the ratio of the particle total volume to the particle total area.

If the density of the suspended particulate matter is assumed, it is possible to calculate the suspended solids concentration by multiplying the particle total volume by the assumed density.

Other models in the product line of the LISST instrument are capable of measuring the particle size distribution, in addition to the above-listed capabilities. The LISST-100 is the first in-situ laser that simultaneously measures the beam attenuation coefficient, the volumetric concentration (ml/L), and in-situ particle size spectra. It is designed to be submerged to a maximum depth of 300 m and is equipped with a built-in data logger.

The LISST-100 measures the particle size distribution in 32 logarithmically-spaced size classes in the range of 1.25 to 250 Fm (a LISST-100 type B). Other versions of the instrument can measure size ranges of 2.5 to 500 Fm and 7.5 to 1,500 Fm, spanning a 200:1 dynamic range in all cases. A detailed description of the design and the operational principles of the LISST-100 can be found in Agrawal and Pottsmith (1994), Agrawal et al.(1996) or Traykovski et al. (1999). However, the basic principles are explained very briefly below.

The LISST-100 measures the angular distribution of forward-scattered light energy over a path length of 5 cm, using a collimated laser beam with a wavelength of 670 nm. The energy of the scattered light is detected on 32 logarithmically-spaced ring detectors and stored in a built-in data logger. When data collection is complete, these raw data are off-loaded and mathematically inverted. The inversion yields the area distribution of the suspended particles in 32 size classes. By multiplying the area distribution by the diameter of each size class, the particle volume distribution is obtained. The absolute volume concentration (ml/L), is found by summing the volume distributions in all 32 size classes and dividing by an instrument-dependent calibration constant. The part of the light not scattered is detected by a photo-diode in the center of the ring detector, thus yielding the optical transmission, T, of the water. From the optical transmission, the beam attenuation coefficient at 670 nm, c(670), can be calculated using Eq. (1)

$$c(670)(m^{-1}) = -1/0.05 \text{ m} \times \ln(T) \ldots\ldots\ldots\ldots (1)$$

The processed data output from the LISST-100 thus consists of a particle volume distribution in 32 size classes, an absolute volume concentration (ml/L) and a beam attenuation coefficient at 670 nm. The LISST-100 also records the temperature and pressure. From the particle volume distribution, statistical parameters such as the mean and standard deviation can then be calculated. All software necessary for obtaining and analyzing raw data is supplied by the manufacturer of the LISST-100, Sequoia Scientific Inc., USA. (See Figure 1.)

Although the LISST instruments have not been used extensively in field studies of plumes when compared with turbidimeters, some documented information on their performance does exist (Melis, T., 2002, Mikkelsen, O., 2000). A recent study comparing the LISST to traditional methods of measuring suspended-sediment concentrations indicated that the LISST provided accurate measurements of the total volume concentration of suspended sediments (Traykovski et al, 1999). Once the accuracy and limitations of these systems are thoroughly documented by site-specific testing at the Hudson River PCBs Superfund Site, which could occur during the two-to three-year baseline/pre-dredge monitoring period if this device is selected for use, this instrument could prove very useful for the in-situ monitoring of sediment plumes in the Hudson River during Phase 1 and Phase 2 dredging activities. The cost of the monitoring equipment is approximately $15,000 to $30,000 for the LISST-25 and LISST-100. Because of the cost, some limited use of these instruments is warranted such at the far-field stations and for daily readings at the near-field stations.

2.4 Semipermeable Membrane Devices (SPMDs)

An SPMD is a passive sampling device that consists of a thin film of the neutral lipid, triolein, sealed inside a layflat, thin-walled tube of nonporous *(i.e*, no fixed pores; only transient thermally mediated cavities) low-density polyethylene (LDPE). The diameters of the transient cavities range up to approximately 10 Å, effectively precluding the sampling of any contaminant molecules associated with dissolved organic matter or particulates. This cavity size limitation has an important consequence: in general, only dissolved chemicals with molecular masses less than about 600 are sampled by SPMDs; this molecular mass limitation is very similar to that imposed by the pores of biomembranes.

At saturation, the capacity of an SPMD for a hydrophobic compound like PCBs is generally related to the compound's octanol-water partition coefficient (K_{ow}). The higher the K_{ow} is for a compound, the greater the capacity for that compound the SPMD has. Due to the very high concentration factors that are possible using an SPMD, even ultra-trace levels of the hydrophobic contaminants in the water column are readily analyzed.

Standard SPMDs are designed to sequester and concentrate hydrophobic compounds like PCBs and PAHs, but not ionic species such as ionic metals, salts of organic acids, or very polar organic chemicals. Neutral organic chemicals that are hydrophobic (i.e., with log K_{ow} values ≥ 3) will be concentrated significantly above ambient levels. In reality, any compound with a log $K_{ow} \geq 1$ will be concentrated by the SPMD, but for compounds with log K_{ow} values ≤ 3, there is no significant advantage in using SPMDs in lieu of other sampling techniques.

When placed in an aquatic environment, SPMDs passively accumulate hydrophobic organic compounds, such as PCBs. The LDPE tubing mimics a biological membrane by allowing the selective diffusion of organic compounds. Triolein is a major nonpolar lipid found in aquatic organisms. The passive sampling of the hydrophobic organic chemicals is driven by the mechanism of membrane- and lipid-water partitioning (See Figure 2).

SPMDs can be deployed for long periods of time (on the order of days to months) and can be used to estimate the time-weighted mean concentrations of the hydrophobic organic compounds in the water body. The SPMD is placed on a rack, which is then placed within a protective "shroud." Once the rack is added to the shroud, the device is ready for use in the water. An SPMD can be oriented vertically or horizontally as illustrated below:

An SPMD will effectively sample 0.5 to 10 L of water per day, depending on the chemical's hydrophobicity (as quantified by its water solubility or octanol-water partitioning coefficient, K_{ow}) and other factors. A compound with log K_{ow} of 6 would need 200 days at an effective sampling rate of 10 L per day to reach 90 percent of equilibrium. However, during the first 50 days, the uptake rate into the SPMD is linear.

The concentrations of these chemicals in rivers can change daily or even hourly. To get a true picture of the concentration of contaminants present in the water column, it would be necessary to collect and analyze and significant number of samples. The SPMD allows the calculation of a cumulative time-average of the concentration of each contaminant while the SPMD was in the water.

The ambient "truly dissolved" water concentration (C_w) can be estimated based on the concentration in the SPMD (C_{SPMD}), the volume of the SPMD ($_{VSPMD}$), the effective sampling rate (R_s), and the time of deployment (t):

$$C_w = C_{SPMD}\ V_{SPMD} / (R_s * t)$$

After a typical deployment period of approximately 15 to 30 days, the SPMDs are removed from the aquatic environment and recovered via dialysis using a nonpolar solvent such as hexane. This extract is then reduced, cleaned up, and enriched. The cleanup procedure typically includes gel permeation chromatography. This process removes any lipid and polyethylene waxes that might have carried over during the dialysis extraction. Further clean-up can be performed during enrichment on an activated alumina and silica gel column. The enriched extract is then analyzed for target compounds using chromatographic techniques.

A major portion of the sequestered residues can be recovered by opening the ends of the SPMD polyethylene tube and rinsing out the lipid with an organic solvent. However, analytes are generally recovered by dialyzing the intact SPMD (which requires removing periphytic growths, minerals, and debris from the exterior membrane surface) in an organic solvent such as hexane. Using this approach, contaminant residues present in the membrane (sometimes representing as much as 50 percent of the total) are also recovered for analysis and the dialysis process separates nearly all of the bulk lipid from the chemicals of interest.

A problem inherent with the deployment of SPMDs lies in the biofouling layer, the coating found on the membrane exterior. This biofouling layer can impede flux across the membrane, thus slowing the effective sampling rate (R_s). This impedance factor is specific to each SPMD at any given point in time. Impedance for a specific deployment can be quantified by measuring the loss of a surrogate compound (contained within the SPMD) during deployment.

The SPMD sampling rates are directly proportional to the SPMD membrane surface area. For example, a standard 1-g triolein SPMD (surface area about 450 cm^2) may extract 5 L of water per day for a PCB congener, whereas a standard triolein SPMD with half the surface area (225 cm^2) (0.5-g of lipid) can be expected to extract 2.5 L of water per day of the same congener, assuming similar conditions of exposure.

Due to the highly sensitive nature of the SPMDs, assembly and placement of the devices requires considerable care. According to Huckins *et al*. (1996), the following quality control (QC) procedures must be followed during the SPMD preparation phase:

- Use of synthetic triolein or lipid, with all new lots or batches analyzed for contaminants, ampulated, and stored in a freezer until use;

- Accurate delivery of small volumes of triolein requires the use of a micropipettor equipped with a total displacement plunger;

- Batch-extraction of SPMD tubing with nanograde hexane or cyclohexane just prior to use in SPMD construction;

- Enclosure of triolein in SPMD layflat tubing using a heat sealer, which results in a molecular weld;

- After assembly, SPMDs are sealed in clean, gas-tight paint cans (solvent rinsed to remove cutting oils) or gas phase sampling bags (Tedlar®) for transport to deployment sites.

Placement of the devices is important due to a variety of factors. According to Huckins *et al*. (1996), the following quality control (QC) procedures must be followed during the deployment phase:

- Use of plastic components should be minimized, with the exception of Teflon, due to the possible presence of leachable organic residues;

- The design of the structure to hold the SPMD should minimize abrasion of the membrane; and

- Since the SPMD membrane generally controls uptake, current velocity is usually only a concern in terms of abrasion and tethering.

Another important phase to consider is the recovery and storage of SPMDs. According to Huckins *et al*. (1996), the following QC procedures must be followed during this phase:

- As soon as SPMDs are recovered from the environment, they should be sealed in the original can or Tedlar bag and placed on ice. The devices should be shipped to the processing laboratory overnight; and

- SPMDs should be stored in the original container at –20^{o} C until they are analyzed.

During dredging activities in the Hudson River, SPMDs could be deployed at the far-field stations for periods of 15 days. The dissolved phase PCB concentration in the water column over the two- week period can then be determined. It should be noted that these measurements should be regarded as qualitative and used to measure relative changes in the water column concentration over successive two-week periods.

2.5 Trace Organic Platform Sampler (TOPS)

The detection of trace organic compounds in the water column is generally very problematic because many target compounds are typically present at concentrations that are below the detection limits of conventional analytical methods. In these instances, a non-detect result generally represents a failure in field sampling and/or laboratory analysis to measure these target compounds at environmentally relevant concentrations. Available analytical methods require large sample volumes to resolve concentrations in the picogram to femtogram per liter range. In environmental settings where concentrations are known to be exceedingly low, collection of large grab samples can be logistically difficult and cumbersome. Field processing of samples in these settings greatly simplifies the collection process while significantly lowering detection limits.

In order to overcome these difficulties, the NYSDEC developed the TOPS as a tool to obtain water column samples. The TOPS is composed of a set of plumbing, pumps, and sensors that concentrate hydrophobic organic compounds from surface waters. The device is designed to collect suspended solids using glass fiber cartridge filters (1 micron pore size), and to capture dissolved-phase organics (*e.g.,* dissolved phase hydrophobic organic compounds like PCBs) using the synthetic resin Amberlite XAD-2 (XAD). The 1 micron pore size filters were chosen for two reasons:

- They are readily available in desirable configurations, and
- They were assumed to be efficient at capturing most of the suspended solids in river settings.

XAD is a polymeric adsorbent of hydrophobic cross-linked polystyrene copolymer supplied as 20-60 mesh beads. The beads are an agglomeration of many microspheres, providing a continuous gel phase and a continuous pore phase. The XAD surface area is 300 m^2/g, and the open cell porous structure allows water to easily penetrate the pores of the resin. During the adsorption process, the hydrophobic portion of the adsorbate molecule is preferentially adsorbed on the hydrophobic polystyrene surface of the resin, while the hydrophilic section of the adsorbate remains oriented in the aqueous phase. Compounds adsorbed do not penetrate into the microsphere phase; they remain at the surface where they can be easily eluted. Unlike liquid/liquid extraction procedures, it is easy to scale up XAD sampling systems to treat exceptionally large volumes of water. These large water volumes have a greater likelihood of containing a detectable mass of the target organic analyte than smaller volumes.

The best use of the TOPS is to obtain whole-water concentrations of extremely dilute hydrophobic organic compounds. With adequate support, the TOPS is a very powerful field tool that can be deployed from ships or fixed locations where sample size is unlimited. In such cases, there is virtually no detection limit as more analyte can be obtained simply by pumping more water. The TOPS typically processes more than 5,000 liters in order to achieve adequate detection of target compounds. Where field setup is inconvenient and concentrations are expected to be relatively high, TOPS can be used in bench-top mode. Samples on the order of tens of liters can be brought in from the field and batch processed.

In its original configuration, the TOPS was run by an on-site operator for a fixed length of time (as short as one day) or at fixed intervals to sample wastewater effluent, coastal waters, and other environments with a low level of suspended sediments. The USGS, in cooperation with the NYSDEC, modified the TOPS for operation in river environments where suspended sediment concentrations are relatively high. Additional TOPS modifications allow for remote, automated, and flow-weighted operation (USGS, 2003 and NYSDEC, 2003).

The TOPS uses 110 VAC and processes water through cartridge filters (available in 4 or 10 inch lengths), and through XAD columns at a maximum rate of 620 mL/min. The TOPS can process water at a much greater rate through the filter (3,200 mL/min) than through the XAD, so significant amounts of suspended solids may be captured even in waters with low levels of suspended solids. Since the pump rates through the glass fiber filters and through the XAD are independent, sampling rates can be adjusted depending on the turbidity of the water.

Remote and automated operation was made possible by adding a Campbell CR10X data logger that performs the following tasks:

- Monitors stream stage,
- Triggers sample collection based on stream discharge, and
- Monitors flow through the XAD resin and filter and backpressure associated with the filter.

A modem connected to the data logger allows a user to dial into the site to initiate, monitor, or stop sampling. Hydrologic events rarely occur at convenient times, so data logger programming includes a set of conditions under which the TOPS will begin sampling automatically. These conditions usually take the form of a threshold change in river stage over time, but could include a variety of other programmable triggers, including river discharge. Ending the sampling activities performed by the TOPS can also be accomplished either manually or automatically. Automatic termination based on river stage is set for when the stage falls 80 percent of the difference between the event start stage and peak stage.

The collection of composite samples during periods of changing river discharge is best accomplished by flow-weighting the volume of water collected. Flow-weighting is a method by which the volume of sample water collected is proportional to the volume of water passing the sample station. Flow-weighting, as compared to fixed interval sampling, avoids the over-representation of conditions present during the beginning and end of the event and under-sampling of the the mass flux of contaminants passing during the hydrologic peak.

The contaminant flux can be determined by multiplying the contaminant concentration derived from the flow-weighted samples by the mean river discharge during the sampling period, and then converting to the appropriate units. In practice, flow-weighting is accomplished by collecting a fixed volume or sub-sample of river water every time a pre-set volume of river water passes the sampling station. This pre-set river water volume is an educated guess based on the anticipated river discharge maximum, expected duration of the event, and minimum sample volume required. Real time discharge data is required to collect a flow-weighted sample. The interval for collection of discharge data is dependent upon a variety of factors, but is principally dictated by the pre-set volume of river water used to trigger a sub-sample; in NYSDEC's application under the Contaminant Assessment and Reduction Project (CARP), discharge data were typically collected once per minute.

To allow sampling when suspended sediment concentrations are high, another pump was added to the sampling system that delivers a flow-weighted sample to a settling/compositing tank. In this configuration, the TOPS draws water from the tank instead of directly from the river. The tank sits on a scale which is monitored by the data logger. The mass of the water in the tank is used to control when the TOPS turns on and off and when the river water pump should turn off. The tank allows material that would otherwise prematurely clog the TOPS filter to settle. Settled material in the tank is collected and filtered at the end of the event, and composited for analysis with the TOPS filter. The advantages of using an additional pump in the sampling process include:

- The use of pumping rates that keep material in suspension without compromising the integrity of the TOPS filter;
- The ability to purge the sampling line before and after a sampling interval; and,
- The removal of the TOPS from the role of collecting a flow-weighted sample.

The addition of the settling tank to the TOPS system is primarily designed to extend the life of the TOPS cartridge filter; material settling to the bottom of the tank avoids TOPS filtration, thereby reducing the amount of material on the filter and prolonging filter life. Besides this obvious advantage, the tank has several additional benefits that improve the quality of sample collection. Without the tank, the main TOPS pump must collect and process the sample directly from the river, which requires the main pump to pull water from the river at a rate of at least 2 ft/sec to keep material in suspension. The filter may be able to process the volume of water required, but when the filtration is time constrained, the result is an increase in backpressure from the filter to the point where the TOPS shuts down. Additionally, as the filter accumulates sediment and backpressure builds, the effective pumping rate decreases with time, introducing bias into the sample collection in that the efficiency of the point intake to collect suspended material changes over time.

By removing the main TOPS pump from service as the direct collector of river water, the pump rate of the main TOPS pump can be significantly slowed. Slower filtration reduces backpressure from the cartridge filter and extends processing time. Slower pump rates also reduce the formation of air bubbles in the sampling line produced from the degassing of sample water under rapidly changing pressure conditions. Air bubbles can adversely impact the accuracy of the flow meters, which are critical in determining contaminant concentrations. The tank also gives the operator time to get to the site in the event that maintenance is needed. Sub-samples can be composited in the tank at the following times:

- At the beginning of the event before,
- During installation of the TOPS cartridge filter and XAD, and
- During the event to change a clogged filter.

By remotely monitoring river conditions and TOPS backpressure, sub-samples can be collected without interruption over the course of the hydrologic event.

A further advantage the tank- and sub-sample pump combination has over direct TOPS pumping is that the sub-sample pump can flush excess water remaining in the line following collection of a sub-sample without adversely affecting TOPS processing or pumping sample water back to the river. Without intake line flushing, the sub-sample water collected directly by the TOPS may be partially or entirely made up of water that remains in the sample line from the previous sub-sample. In addition, part or all of the sample water collected may not adequately represent the suspended sample fraction in that settling of suspended material occurs in the sample intake line between sub-samples – this is particularly a problem in locations requiring long sections of vertical or near vertical sample line.

Wound glass fiber cartridge filters are capable of filtering large volumes of water without clogging, but have the disadvantage of allowing more suspended material to pass through than conventional plate filters with the same nominal pore size. Experiments conducted to test the efficiency of the 10-inch cartridge filters (both 0.5 and 1 micron nominal pore size) indicate the efficiency changes with the volume of water processed, often times in unexpected ways, but generally in response to material loading of the filter. Over the course of these tests, both filter pore sizes trapped between 85 and 89 percent of the total mass of sediment sampled with pre-filter concentrations ranging from 3 to 82 mg/L. The TOPS can be equipped with a series of solenoid valves to periodically divert a sub-sample of water to a sample container. These valves and containers can be placed after the filter to assess the overall trapping efficiency of the filter.

A conventional automatic sampler is used with the TOPS to help interpret and support the organics data collected by the TOPS. This sampler collects discrete sample pairs for analysis of suspended sediment concentration and particulate and dissolved organic carbon concentrations. Sediment and organic carbon samples are collected at the beginning, end, and peak of the hydrologic event, in addition to measured changes in stage (e.g. every 0.5 feet of stage change).

2.6 ISCO® Portable Water and Wastewater Samplers

All of the portable samplers manufactured by ISCO can be divided into two groups: the full-size sampler and the compacted sampler. The compacted samplers are specially designed for locations with limited access, for example a manhole. The full-size sampler requires a larger space for installation. The open-channel flow conditions at the far-field monitoring stations in the Hudson River would be appropriate for a full-size sampler.

The Model 3710 sampler is a composite-only portable sampler that combines simple operation and high volume capacity for single-bottle sampling. The unit collects composites samples, based on time or flow interval, in a 2.5 gallon glass or polyethylene bottle or a 4 gallon polyethylene bottle. Up to 24 sampling stop and resume times can be preset for unattended, automatic sampling. The controller can be set up for uniform time interval, non-uniform time interval, and flow-paced sampling with or without time delay.

The Model 3700 sampler collects sequential or composite samples based on time, flow rate, or storm conditions. It is an ideal choice if the parameter monitoring and logging capabilities are not needed. The exclusive LD90 provides automatic compensation for changes in head height, plus automatic suction line rinsing to prevent cross contamination. Basic and extended programming modes are provided for uniform time intervals, non-uniform time intervals, stormwater runoff sampling, multiple bottle compositing, and split sampling. The bottle configurations for composite sampling are the same as for Model 3710. Sequential sampling bottle configurations include 24 x 1 liter polypropylene or 350 ml glass, 12 x 1 liter polyethylene or glass, and 4 x 1 gallon polyethylene or glass.

Both the Model 3710 and Model 3700 pumps maintain the USEPA-recommended 2 feet per second (fps) line velocity at head heights up to 16 ft, with ¼-inch suction line. For higher lifts, the 6700 series is recommended. The 6712 Portable Sampler is the most sophisticated full-size sampler that ISCO produces. Samples can be delivered at the USEPA-recommended velocity of 2 fps, even at a head height of 26 feet.

The plug-in 700 Series Modules and the new SDI-12 interface make it easy to add flow and parameter monitoring to the basic system. The 6712 Controller allows the user to select different programming modes to assure the most suitable routine for specific application. The included 4MB of memory gives the user great flexibility for logging environmental data. Choice of 11 different glass and plastic bottle configurations ranges from 24 x 1 liter to 1 x 5.5 gallon.

All the samplers require the power of 12 VDC. Ni-cad lead-acid batteries can be purchased from ISCO. But depending on the sampling frequency and the volume of one sample, the battery can last only 1 to 3 days. To meet the 2-week continuous sampling requirement set for the routine monitoring, the most convenient and economic way to provide the power for the sampler will be to provide the electricity to the sampling location.

The purchasing costs are as follows:

- $1,975 for Model 3710,
- $2,425 for Model 3700; and
- $2,700 for Model 6712.

To analyze PCB appropriately, the laboratory requires a 16-L sample. The 5-gallon container is needed to collect sufficient amount of water sample. Given the features of these samplers and the needs of this project, Model 3700 and Model 3712 would be the better choice. The details regarding how to deploy the samplers during remediation monitoring should be fully addressed in the design phase.

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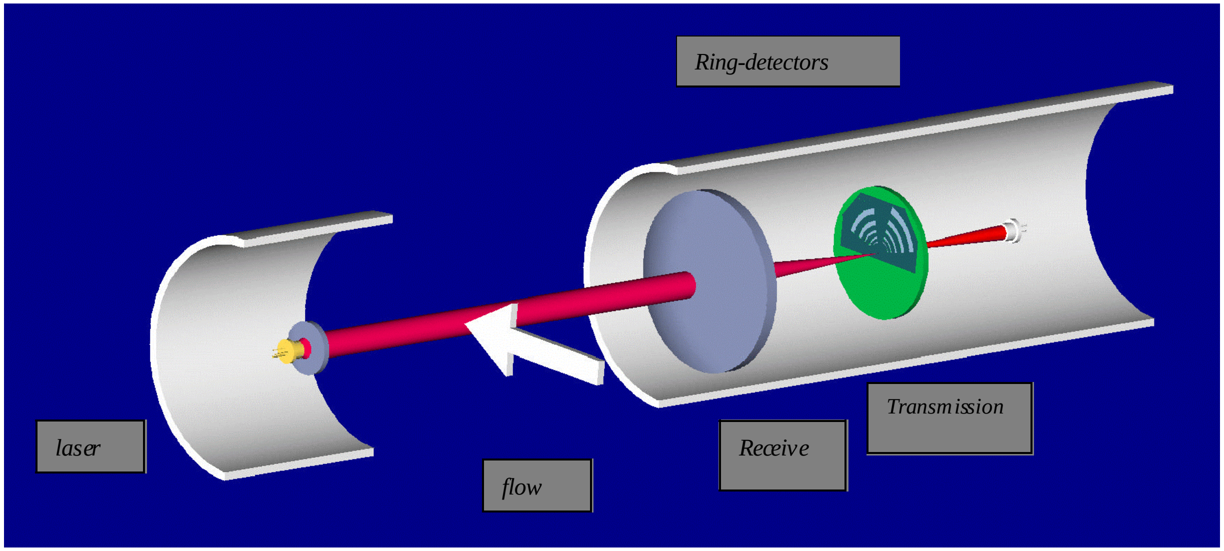


Figure 1 Laser diffraction principles – a cut away view of the basic LISST-100 instrument.

A collimated laser beam illuminates particles (left to right). Multi-angle scattering is sensed by a specially constructed photo-diode array placed in the focal plane of the receiving lens. The array detector has 32 concentric rings, placed in alternate quadrants. An aperture in the center passes the attenuated beam for measurement of optical transmission.

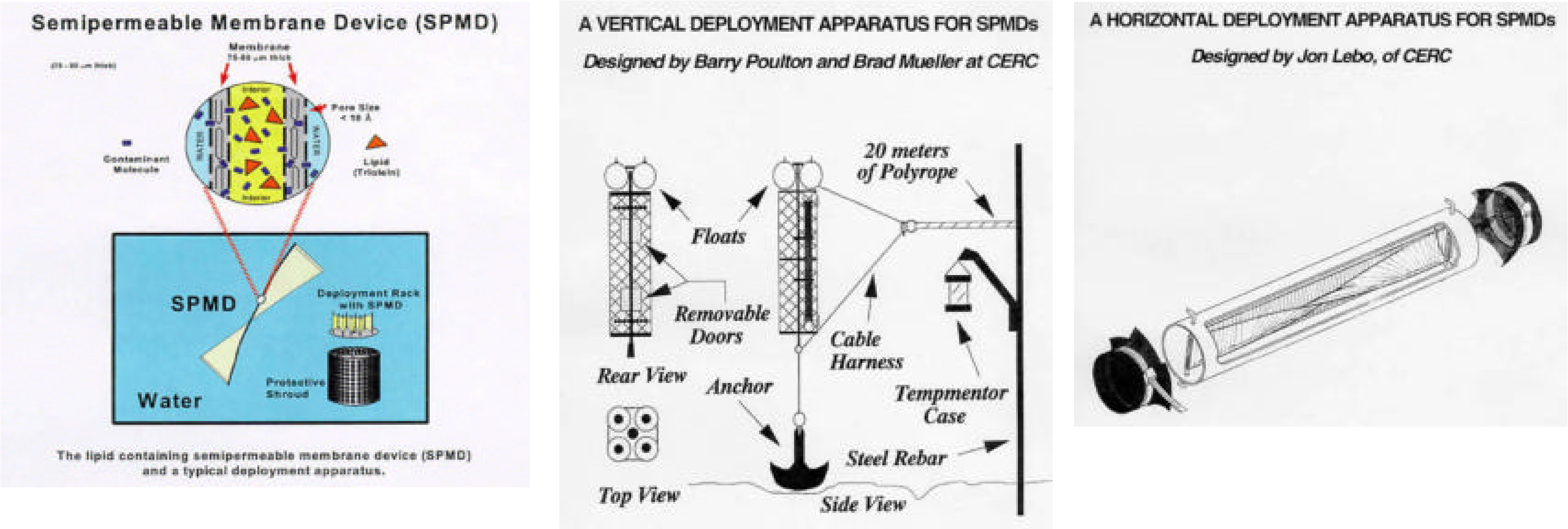


Figure 2. SPMD Apparatus

Attachment F-1

Literature Review

Attachment F-1
Literature Review

1.0 Introduction

PCB concentrations cannot be measured quickly or easily in the field, requiring time-consuming laboratory analyses. Turbidity and total suspended solids (TSS) can be measured relatively quickly and easily using real-time monitoring devices. To develop an estimate of the real-time PCB concentration in the vicinity of the dredging operations, the development of relationships between turbidity and TSS and TSS and PCB concentrations will be investigated.

Analysis of TSS and PCB data from a set of GE water column monitoring samples did not yield a correlation between the two parameters. Based on this observation, the PCB concentrations in the near-field will be projected using modeled solids concentrations (obtained using the DREDGE and/or SED20 models), consideration of the travel time, average concentrations in each river section, and an estimate of the time to reach equilibrium between the dissolved and suspended phases. It is not anticipated that PCB concentrations will be measured in the near-field during remediation.

PCB concentrations will be measured at the far-field stations, via sampling and analysis, and the levels will be compared with the TSS levels from the near-field stations to determine if a correlation exists. Phase 1 of the remediation will provide information that can be used to further refine any observed relationship between near-field solids and far-field PCB concentrations; refinements could be incorporated in the Final Phase 2 Engineering Performance Standards. The papers below were reviewed to investigate the feasibility and applicability of such a correlation.

2.0 Paper List

1. Chattooga River Watershed Ecological/Sedimentation Project (Pruitt at al., 2001)

2. Improved Methods for Correlating Turbidity and Suspended Solids for Monitoring (Thackston et al., 2000)

3. St. Lawrence River Sediment Removal Project Environmental Monitoring Plan: Section 2: Pre-Sediment Removal Data Collection (BBL Environmental Services, Inc., 1995)

4. Use of Acoustic Instruments for Estimating Total Suspended Solids Concentrations in Streams—The South Florida Experience (Patino et al., USGS, 2003)

5. Appendix K: Water Quality Monitoring Pre-Design Field Test Dredge Technology Evaluation Report, New Bedford Harbor Superfund Site, Section K.6.2 (USACE, 2001)

6. Suspended Solids Flux Between Salt Marsh and Adjacent Bay: A Long-term Continuous Measurement (Suk et al., 1999)

3.0 Chattooga River Watershed Ecological/Sedimentation Project (Pruitt at al., 2001)

The purpose of this study was to conduct a sediment-yield evaluation and analyses to determine if sediment was a primary cause of physical and biological impairment to streams within the Chattooga River watershed, located in northeast Georgia, northwest South Carolina, and southwest North Carolina. This goal was achieved by sampling sediments and aquatic ecology from different areas of the watershed and correlating the data by site.

For the aquatic ecological analysis, a total of three reference sites and 56 other sites from six subwatersheds (Headwaters, Lower Chattooga, Middle Chattooga, Stekoa Creek, West Fork, and Warwoman Creek) were sampled. Biological sampling methods were focused on benthic macroinvertebrates and used modified rapid bioassessment protocols. Reference sites were chosen prior to sampling based on habitat condition, *in-situ* water chemistry, and surrounding land use. Two of the reference sites were located on the Chattooga River, and one on the upper Chattahoochee River located outside of the Chattooga watershed. Data from all stations were analyzed using a multimetric approach: 17 metrics were calculated from the raw data, and ultimately the five of those that had the greatest ability to detect impairment were selected.

For sediment sampling, 17 stream reaches were selected for storm flow investigations based on the following criteria: relative degree of biological impairment as measured using modified rapid bioassessment protocols, position within the watershed, relative geomorphic condition, and access logistics. Storm flow investigations were performed during three storm events in March 1998, June 1999, and March 2000. A total of 58 observations were made across the 17 stations.

Total suspended sediment (TSS) was analyzed through the filtration of whole water samples and in accordance with USEPA Method 160.2. Bedload samples were collected using a 6-inch cable-suspended bedload sampler or a 6-inch wading type bedload sampler. The samples were transported to the laboratory in 1-liter containers, and processed for particle size determination in the laboratory using the EPA-SESD wet sieve method. Laboratory results of dry-weight bedload samples ($M_{b,\ grams}$) were converted to bedload transport rate (Q_b, tons/day) by the following equation:

$$Q_B = K(W_T/T)M_T$$

where:
Q_B = bedload discharge (tons/day)
K = converts grams/second/foot to tons/day/foot
W_T = wetted surface (ft)
T = total time sampler on bottom (seconds)
M_T = total mass of samples (grams)

The amount of bedload sediment measured over the course of the three storm events averaged 13.32 tons/day, with mean particle sizes ranging from fine sand to very coarse sand. On average, the bedload sediments only accounted for 14% of the total sediment load. The TSS averaged 85.3 tons/day over the course of the three storm events, making up 86% of the total sediment load on average. Total sediment load (bedload sediment + TSS) was compared to discharge and road density (road length/corresponding drainage area). Road density is a factor that represents the net impacts of road construction and maintenance, interception of subsurface interflow, routing of other non-point sources to the stream, and entrainment, mobilization, and transport of sediment to the stream.

Study results indicated that the biological conditions in most of the streams sampled showed little or no impairment due to sedimentation effects. 78% rated “very good” or “good,” 19% rated “fair,” and 3% rated “poor.” None rated as very poor. Although some sedimentation or habitat effects of sedimentation were evident at many sites, a negative biological response was not always presented. The most degraded biological community was observed in the Stekoa Creek subwatershed. Data indicated that impaired streams contained a higher concentration of bedload and suspended load sediments when compared to the reference streams. Study results also indicated that the road density and sediment sources associated with the road density were the source of 51% of the total sediment loading.

Good correlation was observed between the biological index and the normalized TSS data. Data suggest that a TSS concentration normalized to discharge/mean discharge greater than 284 mg/l adversely affected the biological community structure. However, based on regional concentrations, a normalized TSS concentration of 58 mg/l or less during storm flow provides an adequate margin of safety and is protective of aquatic macroinvertebrates in the area. Corresponding turbidity limits of 22 and 69 NTU represent the margin of safety and threshold of biological impairment.

Reference

Pruitt, B. A.; Melgaard, D. L; Howard, H.; Flexner, M. C.; Able, A. “Chattooga River Watershed Ecological/Sedimentation Project,” *FISC Proceedings*, Federal Interagency Sedimentation Conference, Reno, Nevada, March 26-30, 2001.

4.0 Improved Methods for Correlating Turbidity and Suspended Solids for Monitoring (Thackston et al., 2000)

This article describes techniques that are traditionally used to measure turbidity and suspended solids in water, how the two parameters relate to one another and to various environmental impacts, and why one cannot be routinely substituted for the other. This paper also outlines techniques describing the use of quick turbidity measurements as aid to monitoring dredging and dredged material disposal operations.

Turbidity and suspended solids are common parameters of concern for regulatory agencies, and thus are often included in the environmental monitoring plans for dredging operations. Because suspended solids measurements cannot be made quickly and easily in the field, turbidity measurements are often taken instead. While turbidity can be measured quickly, there is no universal correlation between the two parameters, or between turbidity measurements taken from different suspensions or the same suspension with a different instrument. However, turbidity can be used as an indicator on a site-specific basis.

Total suspended solids (TSS) include both inorganic solids and organic solids. TSS is a measure of the dry weight of suspended solids per unit volume of water, and is reported in milligrams of solids per liter of water (mg/l).

Turbidity is an optical property of water that causes light to be scattered and absorbed rather than transmitted in straight lines through the sample, and is reported in Nephelomatic Turbidity Units (NTUs). The source of turbidity in a sample includes suspended inorganic and organic matter, water molecules, and dissolved substances. The ability of a particle to scatter light depends on the size, shape, relative refractive index of the particle, and the wavelength of the light.

There is no universal correlation of TSS and turbidity, but sediment-specific correlations are useful as a real-time indicator of suspended solids. Such correlations have been developed in the laboratory using whole sediment samples. Generally, any samples used to produce a correlation between TSS and turbidity must be suspension-specific, not just site-specific. The sample must approximate the suspension to be representative of the size, number, shape, and type of particles present.

Most discharge or monitoring permits that are associated with dredging operations are based on TSS rather than turbidity because TSS correlates well with environmental impact and is at least roughly comparable from site to site and sediment to sediment.

It has been suggested that there are three general situations where a TSS-turbidity correlation curve may serve as an aid in the routine monitoring of a dredging operation:

- Solids resuspension in the immediate vicinity of the dredge (20-50m) where most solids will be continuously replenished by dredging actions.

- Containment area effluent, where only the finer particles will be present due to the settling of larger, heavier particles near the point of inflow for the contaminant disposal facility. For this case, a laboratory settling column and test procedure would be required to obtain a representative sample.

- Open-water dredged material placement where the larger, heavier solids will begin to settle to the bottom immediately upon leaving the dredge discharge pipe, hopper, or barge usually in a well-defined plume. This case requires the use of a laboratory column-settling test to obtain a representative sample.

Reference

Thackston, E. L.; Palermo, M. R. "Improved Methods for Correlating Turbidity and Suspended Solids for Monitoring," *DOER Technical Notes Collection* (ERDC TN-DOER-E8), U.S. Army Engineer Research and Development Center, Vicksburg, MS, 2000.

5.0 St. Lawrence River Sediment Removal Project Environmental Monitoring Plan: Section 2: Pre-Sediment Removal Data Collection (BBL Environmental Services, Inc., 1995)

The goal of the pre-sediment removal data collection program was to verify bottom conditions, obtain background water quality information, and obtain a location survey of the sediment control system in the St. Lawrence River at the GM Massena site. One of the tasks planned to accomplish these objectives was pre-dredging turbidity monitoring.

To perform real-time monitoring that allowed for a rapid response to changing river conditions, a water quality parameter that is easily measured and correlates with sediment resuspension during removal activities must be chosen. Turbidity was the parameter selected in this case.

A downstream total suspended solids (TSS) maximum limit of 25 mg/l above background was defined as the conservative action limit based on two variables: previous environmental dredging projects and a 1994 site-specific bench-scale laboratory correlation between TSS and turbidity.

The 1994 bench scale experiment established a site-specific correlation between TSS and turbidity for the GM Massena site, resulting in the use of real-time turbidity measurements as a surrogate for TSS measurements. The laboratory-produced correlation, which is based on a combination of all data points from the treatability test (including some elevated TSS results (> 300 mg/l) from the beginning of the settling test), is described by the equation 1 below:

$$\text{Turbidity (NTU)} = 7.3745 + (0.61058 \text{ X TSS}) + (0.00094375 \text{ X TSS}^2) \qquad (1)$$

with a correlation coefficient of $r^2 = 0.941$

Turbidity monitoring data collected in 1994 indicated that the St. Lawrence River can be characterized as having a relatively low suspended solids content (based on the evaluation of background river water samples, which contain < 10 mg/l TSS) and low turbidity readings. A regression analysis was rerun by BB&L only including data that fell within the expected working range, defined as: TSS < 60 mg/l and turbidity > 60 NTU. The regression equation 2 calculated is defined below:

$$\text{TSS (mg/l)} = [0.63\text{x x (turbidity in NTU)}] + 6.8 \qquad (2)$$

with a correlation coefficient of $r^2 = 0.43$

Based on the revised regression (2), a turbidity of 28 NTU would correlate to a value less than 25 mg/l TSS concentration. Dredging activities would not take place when the measured TSS background was above 60 mg/l. So, due to the nearly linear relationship that exists between turbidity and TSS for the St. Lawrence River in the subject area, a turbidity increase of 28 NTUs from upstream to downstream was defined as the action level for the St. Lawrence Sediment Removal Project during waterborne activities.

Real-time turbidity measurements were obtained from three monitoring locations, one 50 feet upstream of the western extent of the control system and two between 200 and 400 feet downstream of the eastern-most active installations, during the mobilization and installation of the Phase I sediment control system to evaluate any potential short-term effects of the operations. Measurements were collected near 50% water depth. Turbidity was also monitored if visible sediment releases were observed during sheet pile installations.

Reference

"St. Lawrence River Sediment Removal Project Environmental Monitoring Plan." Prepared for General Motors Powertrain by BBL Environmental Services, Inc. May 1995.

6.0 Use of Acoustic Instruments for Estimating Total Suspended Solids Concentrations in Streams—The South Florida Experience (Patino et al., USGS, 2003)

An acoustic velocity meter (AVM) and an acoustic Doppler velocity meter (ADVM) were used in a study to estimate the total suspended solids (TSS) concentration in two southern Florida streams. The AVM system provides information on automatic gain control (AGC), which is an index of the strength of the acoustic signal recorded by the instrument as the acoustic pulse travels across a stream. The ADVM system provides information on acoustic backscatter strength (ABS), which is an index of the strength of return acoustic signals recorded by the instrument. Both the AGC and the ABS values increase as the concentration of suspended material increases.

The AVM system was installed in 1993 in the L-4 Canal, a man-made channel in northwestern Broward. The canal is approximately 40 feet wide and averages between 7 and 8 feet in depth. The water velocities in this canal range from –0.5 to 2.5 feet per second. The ADVM system was installed in 1997 in the North Fork Stream (a tidal channel), located in Veterans Park in southeastern Florida. The stream is about 280 feet wide and averages 8 feet in depth, with water velocities that range from about –1.5 to 1.5 feet per second and a salinity that varies from fresh to brackish (0.2 to 15 mg/l).

Depth integrated samples for TSS were collected at the L-4 Canal site using a DH-59 sampler and equal discharge increment (EDI) methodology, and samples at the North Fork site were collected using a point sampler at the same depth as the ADVM system and located 9 feet away from the transducer faces (near the start of the sampling volume). TSS concentrations ranged from 22 to 1,058 mg/l at the L-4 Canal site, and from 3 to 25 mg/l at the North Fork site.

Regression analysis techniques were used to develop empirical and site-specific relationships between the AGC and ABS results and the TSS and the two sites. The equation below describes those relationships:

$$\mathrm{TSS} = 10^{\{A*[a + b*\log(\text{salinity}) + C*\log(\text{temperature})] + d*\log(\text{velocity}) + e\}}$$

The relationships obtained using the site-specific equations produced good correlations, with coefficients of 0.91 and 0.87 at the L-4 Canal and North Fork sites, respectively. The results suggest that this technique is feasible for estimating TSS concentrations in streams using information from acoustic instruments.

Reference

Patino, E.; Byrne, M. J. “Use of Acoustic Instruments for Estimating Total Suspended Solids Concentrations in Streams—The South Florida Experience,” U.S. Geological Survey, Ft. Myers, FL. Available at **http://water.usgs.gov/osw/techniques/TSS/Patino.pdf**, downloaded in Feburary 2003.

7.0 Section K.6.2 – Correlation Analysis found in Appendix K: Water Quality Monitoring Pre-Design Field Test Dredge Technology Evaluation Report, New Bedford Harbor Superfund Site (USACE, 2001)

A Pre-Design Field Test was undertaken in order to evaluate the performance of a dredge system under consideration for use at the New Bedford Harbor Superfund Site. The objectives of the test focused on the performance of the dredge system. This report section evaluates the impacts on water quality associated with the test; the following tasks were performed for the evaluation:

- Predictive modeling was used to aid in the design of the water quality monitoring field program and to assess the utility of modeling for the full-scale remediation effort.

- Field monitoring was performed to assess sediment resuspension during the dredging operation, to collect water samples for laboratory analysis, and to ground-truth the predictive modeling.

- Laboratory analysis of water samples for TSS and PCBs was performed to assess water quality impacts.

- A correlation assessment between the field and laboratory data was performed.

Three correlation studies were performed on the data obtained from the monitoring samples:

- TSS vs. total particulate PCBs – Analysis of the data revealed an excellent correlation between the two parameters. The study yielded a coefficient of fit for the linear relationship of 0.84, suggesting that TSS could serve as a good indicator of the particulate PCB concentrations associated with operations similar in scope to the pre-design work.

- Total particulate PCBs vs. total dissolved PCBs – Analysis of the data yielded a poor correlation between these parameters. An exponential function provided a better fit to the data.

- TSS vs. total dissolved PCBS – Analysis of the data provided a poor correlation between these parameters. An exponential function provided a better fit to the data.

A review of the individual dissolved/particulate data pairs indicated the following:

- For the reference samples, the dissolved phase and particulate PCB concentrations were generally similar on a per liter basis, with the dissolved-phase concentration sometimes exceeding the particulate concentration.

- For the samples impacted by the dredging operations, the total particulate PCB concentration was generally increased to a much greater degree than the dissolved-phase PCB concentration.

Analysis of the monitoring data also suggested the following:

- A moderate correlation between the total suspended solids measured in the lab and the turbidity measured in the field. The linear coefficient of fit for these data was 0.56. Measurement of both parameters from the same water parcel would be expected to increase the strength of the correlation.

- Given the different correlations indicated by the data, turbidity to TSS and TSS to PCB, the results suggest that field measurement of turbidity could be used as an indicator of the mobilization and transport of particulate-bound PCBs during the full-scale remediation activity.

Reference

USACE. 2001. "Appendix K: Water Quality Monitoring Pre-Design Field Test Dredge Technology Evaluation Report, New Bedford Harbor Superfund Site," *Pre-Design Field Test – Dredge Technology Evaluation Report*, New Bedford Harbor Superfund Site, New Bedford, Massachusetts. Prepared by Foster Wheeler Environmental Corporation, Boston, Massachusetts. August 2001.

8.0 Suspended Solids Flux Between Salt Marsh and Adjacent Bay: A Long-Term Continuous Measurement (Suk et al., 1999)

The goal of this study was to establish an improved methodology to determine the suspended solids flux between Schooner Creek, NJ, a tidal salt marsh, and Great Bay, adjacent to it. The most significant difference in methods used in this study was related to data collection. Field data were collected continuously from March to October 1996.

A suite of instruments, including a current velocity sensor, a turbidity sensor, an automatic water sampler, a pressure transducer, and a data logger were placed in (and around) a location 300 m from the mouth of Schooner Creek, to measure the velocity, water surface elevations, and suspended solids concentrations of the creek. Water velocity was measured at a depth corresponding to the mid-depth of the creek at high tide. The instruments were placed in the water on the deeper side of the creek so that they would remain submerged.

Total suspended solids (TSS) in the stream were quantified using turbidity as an indicator. A feasibility study performed prior to the experiment's initiation that examined 593 water samples over 25 different time periods found that that the measured suspended solids concentrations were statistically related to the measured turbidity. The average correlation coefficient for flood and ebb time periods averaged 0.827, indicating that turbidity measurements would provide surrogate measurements of the suspended solids concentration.

The water flux rate was derived from measurements taken by the submerged instruments and calculated as a product of the current velocity and the area of the wetted cross section, and cumulative flow volumes were calculated using the average flow rate for successive time intervals.

The TSS flux was calculated as the product of the water flux and the TSS concentration. Two TSS fluxes were calculated:

- TSS fluxes for the entire recording period (periods of balance and imbalance) using TSS concentrations derived from the overall regression relationship.

- TSS fluxes for periods of time where the calculated water fluxes were more balanced, yielding net flux values that were not strongly impacted by a water imbalance.

Analysis indicated that the flow data are not continuous, and there are several different natural and artificial factors that may attribute to a water imbalance, though the researchers decided that net water import or export during a particular time was most likely due to the measurement of an incomplete cycle of water exchange across marsh boundaries other than the creek mouth.

The study also calculated a minimum number of water sample sets needed to produce a reasonably good TSS-turbidity regression relationship. To do so, varying combinations of water sample sets were used to develop a number of different regression relationships. The regression relationships were then used in the flux calculations, and the relative error was calculated.

The following observations were produced from the study:

- Data analysis indicated that the cumulative and cycle fluxes calculated for the entire recording period are considerably uncertain due to an imbalance in the calculated water fluxes.

- Data analysis indicated that the coefficient of correlation between the cumulative TSS fluxes per tidal cycle and the average TSS concentration differences was 0.71. The flow-weighted average TSS concentration resulting from all of the water balance periods during the flood tide was higher than that during the ebb tide, contributing to a net import of TSS.

- Data suggested that, for this study, a reasonably good overall TSS-turbidity regression was established when five data sets with correlation coefficients greater than or equal to 0.80 were used.

Reference

Suk, N. S.; Guo, Q.; Psuty, N. P. “Suspended Solids Flux Between Salt Marsh and Adjacent Bay: A Long-term Continuous Measurement,” *Estuarine, Coastal, and Shelf Science*, Vol. 49, pp. 61-81, 1999.

Attachment F-2

PCB Analytical Methods
Detection (Reporting) Limits in Water

Attachment F-2
PCB Analytical Methods
Detection (Reporting) Limits in Water

1. **CLP Method OLM04.1** (September 1998)
   Contract-required quantitation limit is 1 Fg/L for all Aroclors
   (CRQL for Aroclor 1221 is 2 Fg/L)
   Laboratories can report lower detections (e.g., 0.5 J [Fg/L])

2. **SW-846 Method 8082** (Rev 0, December 1996)
   MDLs (method detection limits) for Aroclors range from 0.054 to 0.90 Fg/L
   (Method provides no data as to Aroclor-specific MDLs)

3. **PCB Congeners - Dual Column GC/ECD** (Laboratory-specific)
   STL/Colchester Vt (formerly Aquatec)
   Detects inidividual PCB congeners at a detection limit of 0.001 Fg/L
   (Monochlorobiphenyls at 0.005 Fg/L)
   (Other labs have other methods with varying detection limits)

4. **NYSDEC Analytical Services Protocol Low-Concentration Method (91-6)**
   CRQL is 0.2 Fg/L for Aroclors except for 1221 (0.4 Fg/L)

5. **USEPA Method 505**, Revision 2.1 - 1995 (Organohalide Pesticides and PCBs by microextraction/GC)
   - MDL for Aroclors 1016, 1248, 1254 - about 0.1 Fg/L
   - MDL for Aroclor 1260 - about 0.2 Fg/L
   - MDL for Aroclor 1242 - about 0.3 Fg/L
   - MDL for Aroclor 1232 - about 0.5 Fg/L
   - MDL for Aroclor 1221 - about 15.0 Fg/L

   (from Method 505 Revision 2.0, USEPA EMSL, 1989)

6. **USEPA Method 508**, Revision 3.1 (1995). Determination of Chlorinated Pesticides in Water by GC/ECD.

   - Note to method summary states that the extraction is similar to Method 608 (q.v.), and the extract can be analyzed by 508, 525, or 608; however, no performance data for Aroclors were collected as part of method development for 508.

   - EDLs (reporting limits) for most single-component pesticides are in the 0.01 Fg/L to 0.05 Fg/L range (a few are higher and a few are lower).

- This method is supposedly being used by Waterford for monitoring its drinking water supply. The detection and reporting limits would have to be developed on a laboratory-specific basis. Multi-component analytes (such as Aroclors, and also toxaphene and chlordane) typically have higher reporting limits than single-component pesticides.

7. **USEPA Method 680** (PCBs by GC/MS)
   Arocolor detection limits are about 100 Fg/L

8. **USEPA Method 608** (Pesticides/PCBs by dual column GC)
   Aroclor Detection limits 0.5 Fg/L (1.0 Fg/L for Aroclor 1221)

9. **USEPA Method 525.2** (1995 revision)
   Method uses solid/liquid extraction by either disk or cartridge and analysis using quadropole MS or ion trap. MDLs are presented for method analytes for each of the four possible combinations; except Aroclor MDLs only by disk and ion trap. Sensitivity is better for more chlorinated arolcors. MDLs range from 0.018 Fg/L for 1260 to 0.054 Fg/L for Aroclor 1221.

10. **USEPA Method 1668A** (December 1999) - Chlorinated Biphenyl Congeners in Water, Soil, Sediment, and Tissue by HRGC/HRMS.

    - Detection limits (EMDLs) and reporting limits (EMLs) are provided for more than 150 congeners in both water and non-aqueous matrices.

    - Method is more sensitive for less-chlorinated congeners.

    - Reporting limits for individual congeners range from 50 to 1000 pg/L (10 pg/L for BZ#2) in water (detection limits [EMDLs] are typically 1/3 to ½ the reporting limit [EML]).

    - Reporting limits range from 5 to 100 ng/kg (except 1 ng/kg for BZ#2) in non-aqueous samples (detection limits [EMDLs] are typically 1/5 to ½ the reporting limit [EML]).

11. **Green Bay Method.** Original method not reviewed (or obtained). *Not included in the GE August Design Support Sediment Sampling and Analysis Plan (Revision 1, August 2002).* Reportedly a single-column PCB congener GC/ECD method.

General notes on units of measure:

- g/L = parts per thousand (10^{-3});
- mg/L = parts per million (10^{-6});
- Fg/L = parts per billion (10^{-9});
- ng/L = parts per trillion (10^{-12});
- pg/L = parts per quadrillion.(10^{-15}).

Attachment F-3

Memo Regarding PCB Analyses; Whole Water Extracts vs. Separated Particle and Filtrate Extracts

February 25, 2003

To: Kelly Robinson, Earthtech (TAMS)
From: Richard Bopp, RPI
Re: PCB Analyses; Whole Water Extracts vs Separated Particle and Filtrate Extracts

Background

Since I first analyzed Hudson River water samples for PCBs in the late 1970s, I have been interested in particle/water partitioning. Consequently, I have always filtered the samples and extracted and analyzed the particles and filtrate separately. In addition, based on considerations of analytical sensitivity, I have always analyzed large volume (typically 18 liter) water samples. These procedures were adopted by the USEPA for the water column PCB samples that we collected and processed as part of the Hudson River PCBs Reassessment.

Several other important datasets rely on an EPA-approved whole water extraction and analysis of much smaller volume (typically 1 liter) samples. These include

- The USGS monitoring in the upper Hudson. This program provides the longest historical record of water column PCB levels.

- The GE monitoring between Rogers Island and Schuylerville conducted under consent order with the NYSDEC as part of the remnant deposits monitoring program. This set of samples, collected approximately weekly since 1997 provides, by far, the most detailed picture of PCB transport ever developed (J. Tatten, Master’s Project, RPI, 2000; Task 3 Final Report to NYSDEC, Contract C003844, 2000).

In 1993 I was at RPI and supervising the collection and processing of the water column samples for the Hudson River PCBs Reassessment. As I recall, I suggested that on one of the transects we collect duplicate samples for PCB analysis through NYDSEC at the NYSDOH labs. In addition, since their standard procedure was whole water extraction, it was arranged that at least some of the samples also be analyzed as separate particle and filtrate fractions. This would allow a more direct comparison with the EPA sample analysis and provide a test of my general impression that whole water extraction would not be particularly efficient at recovering particle-associated PCBs. The suggestion was welcomed at NYSDEC and collaboration was facilitated by the fact that I had been employed there in 1990-91.

Analysis and interpretation of the data from this exercise was to form the basis of the Master’s project of Christine Juliano. After an initial data gathering and analysis effort, Christine decided to work on a different project and completed her Master’s. My preliminary look at the data indicated that whole water extraction missed a significant fraction of the particle-associated PCBs. Although based on very limited data, I have used this observation often to support my geochemical bias toward separate particle and filtrate extraction and analysis.

Over the past month, I have had two requests for a more quantitative assessment of this data. Both were related to water column monitoring associated with the proposed dredging. The first was from Kelly Robinson at Earth Tech (TAMS), the primary EPA contractor on the Upper Hudson River PCB project. A few days later, Roger Sokol of the NYSDOH requested similar information specifically for monitoring the Waterford, NY drinking water supply and raw water intake on the Hudson. I was able to locate files prepared by Christine Juliano that contained water column PCB data from the upper Hudson consistent with events described above.

More Detailed Information

The sample ID format and numbering used in the files indicates that the samples were collected during EPA transect 4 (April 12 to April 14, 1993) at Stillwater (0007), Waterford (0008), the Hoosic River (0012), Mohawk River (0013), and Green Island Bridge (site 0014). Two of the samples, Waterford and Green Island, have data for whole water and separate particle and filtered water analyses. Further confirmation of the identification of these samples comes from the fact that the TSS levels in the files prepared by Christine Juliano are identical to those reported for samples TW-0004-0008 (34.0 mg/l) and TW-0004-0014 (39.8 mg/l) in the EPA Database. More specific collection information can most likely be retrieved from the detailed field notes kept by Rensselaer personnel and submitted to TAMS a part of the official record of our work with EPA on the reassessment. The rest of this report will refer to the Waterford (004-0008, 04/13/93) and Green Island (004-0014, 04/13/93) samples.

As I recall, I was informed that the separation of particulate and dissolved phases for the NYSDOH analysis was accomplished by pouring the water sample through a soxhlet extraction thimble. This simple procedure should be comparable to separation by more standard filtration techniques that typically employ pre-fired glass fiber filters. The corresponding EPA samples that we collected were filtered by Kevin Reed of RPI through pre-fired Whatman GF/F filters. Soxhlet extraction thimbles used in PCB analyses are also treated to minimize blanks. Paper thimbles are typically pre-extracted and glass fiber thimbles are pre-fired.

Results

- In terms of total PCBs, the DOH values reported for the whole water extracts were about half of the (particulate + dissolved) PCBs in the replicate samples (Table 1).
- At the congener level, whole water extraction yielded results lower than (P + D) in every case with only one exception (BZ 24, 27). Figures 1 (Waterford) and 2

(Green Island) present data for a range of more abundant congeners that together comprise over half the total PCBs.

- The figures also show that the differences between whole water and (P + D) results tend to be less for the lower chlorinated congeners. This is consistent with a simple model of the whole water extraction process – complete recovery of dissolved PCBs and less efficient recovery of particulate phase PCBs.
- Based on this first order model applied at the congener level, the whole water extraction missed 61 ± 20% of the particle-associated PCBs in the Waterford sample (Table 2) and 72 ± 13% in the Green Island sample (Table 3).

Implications

- The above analysis provides support for the logical assumption that whole water extraction will result in an underestimate of total PCBs. It is also logical to assume that the degree of under-recovery would depend significantly on the details of the procedure (the number of extraction cycles, the solvent used, the percentage of solvent removed between extraction cycles, the degree of sample agitation etc.).
- If the simple model presented above is applied, the degree of under-recovery will also depend on the TSS in the sample. Using an average particle extraction efficiency of 33% (based on the DOH analyses) and an average upper Hudson PCB particle/water distribution coefficient of 10^5 (Bopp et al., Final Report to NYSDEC, Contract C00708, 1985), first-order error estimates can be made.

TSS (mg/l)	% of PCB on Particles	% under-recovery of total PCBs
2	17	11
10	50	33
40	80	53
100	91	61

- This analysis raises the possibility that historical (USGS) estimates of PCB transport in the upper Hudson that focused on high flow, high TSS, high transport events may be low by on the order of 50% and suggests a low bias to any transport estimates that utilize the weekly GE water column monitoring data.
- The potential for significant under-recovery of PCBs when using whole water extractions should be considered in the design of any future monitoring program.

Cc: Roger Sokol, NYSDOH

Tables

Table 1. 'Total PCBs in samples collected April 12 -14, 1993 (all PCB concentrations in ng/l)

	Waterford	(0008)	Green I	(0014)
	DOH	EPA	DOH	EPA
Particulate	225.4	159.8	227.7	144.5
Dissolved	74.4	75.0	50.9	53.5
P + D	299.8	234.8	278.6	198.0
Whole Water	159.9		110.6	
TSS (mg/l)	34.0		39.8	

Table 2. 'Waterford

	004-0008 Whole Water	004-0008 Particulate	004-0008 Filtered Water	sum P+F		%P missed		%T missed
CONGENER								
BZ-10,BZ-4	17	9.5	13	22.5		58		24
BZ-19	4.8	2.3	3.6	5.9		48		19
BZ-18	12	5.1	6.9	12		0		0
BZ-15,BZ-17	11	8.5	5.8	14.3		39		23
BZ-16,BZ-32	4.3	3.5	2.8	6.3		57		32
BZ-31	7.5	12	4.2	16.2		73		54
BZ-28	8.3	14	4.6	18.6		74		55
BZ-20,BZ-33,BZ-53	3.6	5.6	2.1	7.7		73		53
BZ-52	6.4	9.5	3	12.5		64		49
BZ-49	5.6	8.8	2.2	11		61		49
BZ-47	4.4	7.6	1	8.6		55		49
BZ-44	3.7	6.2	1.5	7.7		65		52
BZ-37,BZ-42,BZ-59	1.2	3.2	1	4.2		94		71
BZ-41	3.1	5.3	1.2	6.5		64		52
BZ-70	4.8	11	1.6	12.6		71		62
BZ-66,BZ-95	7.8	18	2.1	20.1		68		61
BZ-110,BZ-77,BZ-136	2.3	6.4	***0.5***	6.9		72		67
Totals	107.8	136.5	57.1	193.6		61		45
					Std. Dev.	20	Std. Dev.	19
BZ-24,BZ-27	7.7	2.7	4	6.7		-37		-15

Table 3. Green Island

CONGENER	004-0014 Whole Water ng/L	004-0014 Particulate ng/L	004-0014 Filtered Water ng/L	sum P + F		%P missed		%T missed
BZ-10,BZ-4	13	8.5	9.9	18.4		64		29
BZ-19	3.8	1.7	3	4.7		53		19
BZ-18	7.9	5.1	5.2	10.3		47		23
BZ-15,BZ-17	7.4	8.9	4.1	13		63		43
BZ-16,BZ-32	3.3	3.5	2.2	5.7		69		42
BZ-31	5.3	13	2.5	15.5		78		66
BZ-28	5.9	15	2.7	17.7		79		67
BZ-20,BZ-33,BZ-53	3	5.7	1.7	7.4		77		59
BZ-52	4.6	8.6	2.1	10.7		71		57
BZ-49	4.1	8.6	1.5	10.1		70		59
BZ-47	3.2	6.7	***0.5***	7.2		60		56
BZ-44	3.7	6.2	1.5	7.7		65		52
BZ-37,BZ-42,BZ-59	1	3.1	1	4.1		100		76
BZ-41	2.2	9.4	1	10.4		87		79
BZ-70	3.3	10	1	11		77		70
BZ-66,BZ-95	5.3	15	1.1	16.1		72		67
BZ-110,BZ-77,BZ-136	1.7	6.4	1	7.4		89		77
TOTALS	78.7	135.4	42	177.4		72		55
					Std. Dev.	13	Std. Dev.	18
BZ-24,BZ-27	5.2	2.3	2.8	5.1		-4		-2

Figures

Figure 1
WATERFORD

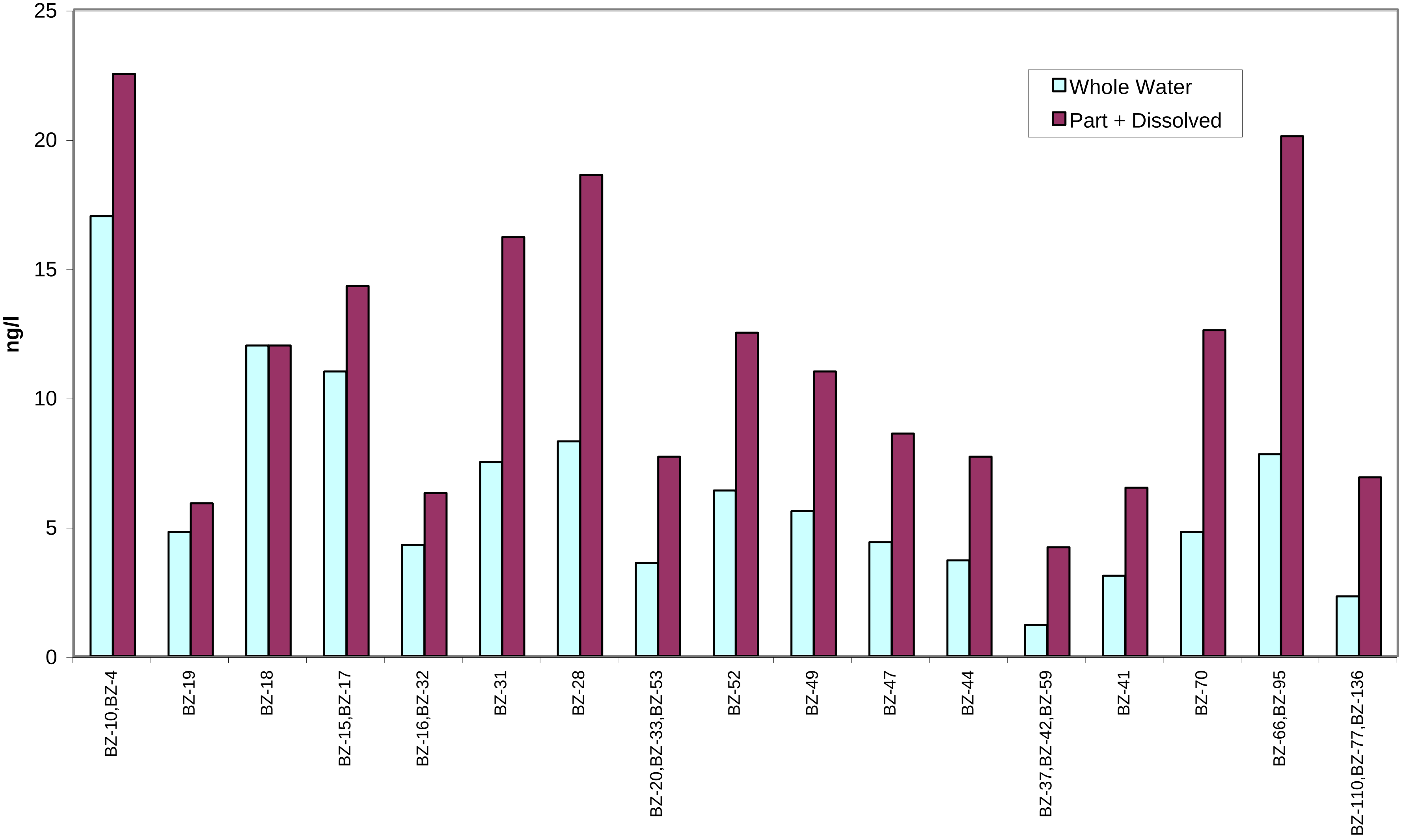
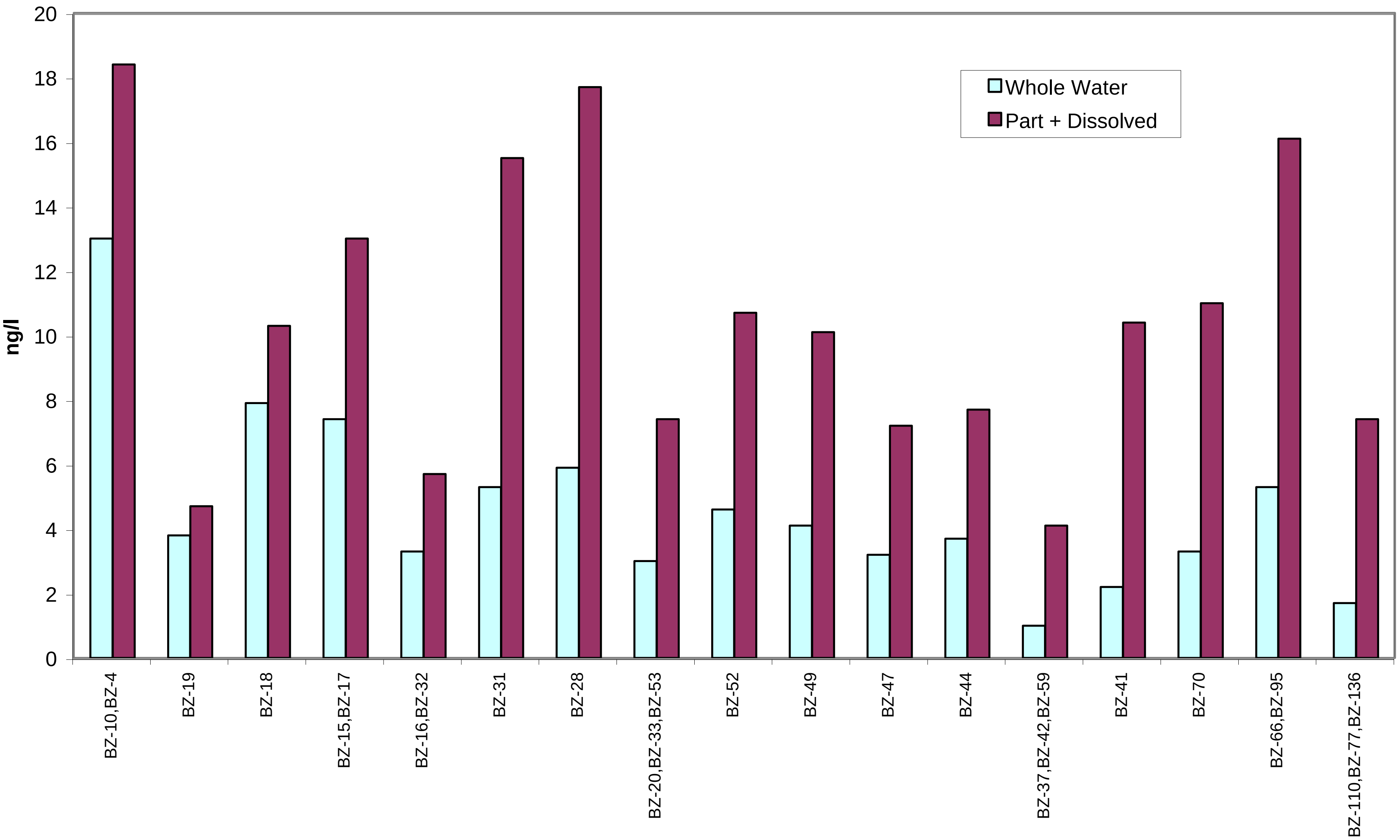


Figure 2
GREEN ISLAND



Attachment G

Statistical Justification of the Sampling Frequency for Phase 1 Monitoring Program

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Statistical Justification of the Sampling Frequency for Phase 1 Monitoring Program

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LIST OF FIGURES (continued)

Attachment G

Statistical Justification of the Sampling Frequency for Phase 1 Monitoring Program

1.0 Introduction

The monitoring plan for the Resuspension Performance Standard is summarized in Tables 1-2, 1-3 and 1-4 of the main document. This attachment describes the adequacy of the sampling frequencies required as part of the routine monitoring programs, which are derived using United States Environmental Protection Agency (USEPA)-defined methods for assessing statistical uncertainty (USEPA, 2000). The analyses cover only routine monitoring and the minimum levels of contingency monitoring as defined in the Resuspension Standard. Additional monitoring related to the required engineering studies at the Control Levels (as well as exceedance of the standard threshold) may be required, depending on the anticipated cause of the exceedance. The design of these additional monitoring programs may be developed during the remedial design period. Alternatively, *ad hoc* monitoring plans may be developed by the design team during the actual dredging operation in response to observations made at the time.

A particular limitation to the analysis presented in this attachment is that little information on the variance of river conditions in response to dredging-related releases. Little data exist on which to develop the estimate of variance. As a result, the variation of baseline conditions was used as a means to estimate the variance for dredging operations. These estimates for sampling requirements and the associated error rates will require review once additional data become available during Phase 1.

2.0 Estimates of the Tolerable Error for the Monitoring Sampling Frequency Using Decision Error Feasibility Trials (DEFT) Software

The USEPA's guidance on data quality objectives (USEPA, 2000) was used in the development of the monitoring program for the Phase 1 dredging operation. This guidance describes a seven-step process for identification of the decision points and data needs associated with the environmental problem to be addressed. With regard to PCB releases via resuspension during the Phase 1 operation, there is a major concern to be resolved: How can the USEPA verify that PCB concentrations in the Upper Hudson River are in compliance with the resuspension criteria?

The focus of this analysis will be to design the appropriate sampling program, particularly the optimal sampling frequency that must be implemented to address the above-mentioned concern.

In the following discussion, the data quality objectives (DQO) process (USEPA QA-G4; USEPA, 2000) is applied as outlined below:

1. State the Problem
2. Identify the Decision
3. Identify the Inputs to the Decision
4. Define the Boundaries of the Study
5. Develop a Decision Rule
6. Specify Tolerable Limits on Decision Errors
7. Optimize the Design for Obtaining Data

A separate discussion is provided for each question. A summary of the sampling requirements is provided in Section 1 of the Resuspension Performance Standard.

3.0 Development of Data Quality Objectives

3.1 Statement of the Problem

The USEPA needs to verify that water column concentrations of PCBs in the Upper Hudson are below the Resuspension Standard criteria, thereby permitting unfettered dredging operations. If PCB concentrations are not within acceptable levels, then additional monitoring and possible modifications to the engineering operations may be required.

The USEPA staff represents the decision makers who will consult with General Electric Company (GE), the New York State Department of Environmental Conservation (NYSDEC), water supply operators, local government representatives, and non-government organizations.

The conceptual model is defined as follows:

- PCB loads and concentrations within the Upper Hudson are currently derived from sediment-based sources that contribute about 50 to 200 ng/L to the water column under typical flow conditions. These concentrations constitute baseline conditions. Dredging of contaminated sediments will add to this water column burden to some degree. Anticipated load additions due to dredging are expected to be less than 300 g/day (Evaluation Level threshold) under normal routine dredging for a 6-year remediation program. This is especially true for Phase 1, since the operation is planned at only half of the annual production rate anticipated for Phase 2.

- Although the mean daily Total PCB load increase due to dredging is expected to be well below 300 g/day, instantaneous conditions may result in momentary fluxes that are much higher. Consistent Total PCB loads higher than 300 g/day are considered indicative of problems in the dredging operation and warrant further study. Exceedance of the 300 g/day threshold does not constitute an immediate risk to human or ecological health but rather will delay the recovery of the river if allowed to continue for long periods of time. Similarly, exceedance of the 600 g/day action level does not represent an immediate risk to human or ecological health, but, as is the case a 300 g/day load, an extended amount of time above this action level will delay the river's recovery.

- Total PCB concentrations in excess of 350 ng/L alone do not represent a risk to downstream users so long as levels remain below the drinking water maximum contaminant level (MCL) of 500 ng/L (total) PCBs. However, the proximity of this level (350 ng/L) to the MCL warrants more careful scrutiny and closer observation if 350 ng/L is exceeded due to the short transit time from the dredging area to the nearest public water supply intakes (two to seven days).

- Suspended solids data will provide an indication of increased PCB contamination in the water column. Net far-field suspended solids concentrations must be below 12 mg/L to be at routine levels and below 24 mg/L to be at or below the Evaluation Level. Net near-field suspended solids concentrations (as defined in the Resuspension Standard) must be below 60 mg/L, 100 mg/L, or 700 mg/L, depending on the location of the station relative to the dredge and the river section in which dredging is occurring. The duration of the exceedances provides an indication of the severity of the exceedance and the required response.

3.2 Identify the Decision

Depending on the magnitude of the dredging-related PCB load increase, the USEPA may decide to do one or more of the following as described in Section 1 of this document:

- Increase monitoring frequency;
- Modify monitoring techniques;
- Modify dredging operations;
- Add additional engineering controls to the dredging operation; or
- Suspend the dredging operation until the PCB release problem has been resolved

The primary question governing this decision is: Are water column concentrations in compliance with the resuspension criteria? If water column concentrations are not in compliance, required actions involve collection of additional samples to further define the PCB loads if the requirements of the first decision statement are met, with further increases in monitoring and the possibility or requirement of engineered modifications to the operation, as described in the standard.

3.3 Identify the Inputs to the Decision

To determine net PCB loads due to dredging (i.e., the total load less the baseline), the following data are needed:

- Instantaneous and mean daily river flow at all monitoring locations
- PCB concentrations at multiple monitoring locations, including the first far-field station downstream of the dredging operation and extending to Waterford.
- PCB concentration at a location upstream of the dredging operation (specifically Rogers Island)
- Suspended solids concentrations
- Total organic carbon (TOC) on suspended solids
- Dissolved organic carbon content (DOC; *i.e.*, TOC on filtered water samples)

- Historical concentrations of PCBs, suspended solids, TOC on suspended solids at each of the main monitoring locations

The first six items listed above are used to characterize the actual conditions during dredging. The seventh item is used to provide a basis for comparison to establish the net load relative to the historical baseline conditions. The difference between baseline conditions and conditions measured during dredging is the net increase in PCB concentration due to dredging activities at each monitoring location. The product of the mean daily flow and this concentration difference yields an estimate of the net load increase for comparison against the load-based criteria. Suspended solids and PCB concentration data will be used together to examine the usefulness of a suspended solids-PCB correlation to estimate PCB levels based on suspended solids monitoring alone.

The methods for sample analysis include:

- PCB congeners with a detection limit of 0.5 ng/L total PCBs. The effective congener detection limit is roughly 0.05 ng/L Currently this can only be achieved by one of the following: EPA's dual column GC/ECD method, Standard Method 1668A or GE's modified Green Bay Method.

- Total Suspended Sediment with a detection limit of 0.1 mg/L, by Analytical Method ASTM D3977-97, Standard Test Method for Determining Sediment Concentration in Water Samples, or equivalent. No subsampling of a sampling container is permitted.

- Organic carbon on the suspended solids can be done via a Total Organic Carbon method or by a combustion technique but must be sensitive down to 0.1% (1000 mg/kg) on the suspended solids.

- Dissolved organic carbon method should have a detection limit of 0.5 mg/L, such as ASTM Method D4839-03 [0.1 mg/L] or EPA 415.2 [.05 mg/L].

3.4 Define the Boundaries of the Study

The boundaries of the site are defined as the shorelines of the Hudson River, excluding its tributaries, between the Fennimore Bridge at Hudson Falls and the Federal Dam at Troy. The Fennimore Bridge is included as the upper boundary, rather than the northern end of Rogers Island, because of the potential for PCB releases associated with the remediation of the GE Hudson Falls facility that will be taking place at the same time or just prior to the sediment remediation.

In recognition of the need to simplify monitoring, both project data needs and ease of access will be considered when choosing monitoring locations. The following stations, all of which are accessible by bridge, were selected based on access considerations:

- Fennimore Bridge
- Rogers Island
- Schuylerville
- Stillwater
- Waterford

These locations also roughly divide the river into 10 to 15 mile segments, providing sufficient resolution to identify potential PCB sources by location. The separation of these locations also allows natural hydrodynamic processes to homogenize PCB concentrations in the river, simplifying the sampling process.

Given that most of the dredging is scheduled for the Thompson Island (TI) Pool, an additional monitoring location is identified at the TI Dam so as to better identify loads originating in this reach.

Because dredging-related releases will depend on many factors related to dredge operation, sediment type and location with in the river, the PCB load is expected to vary significantly over time. Daily monitoring is considered a minimum basis for determining compliance with the lowest (most stringent) secondary criterion of 300 g/day. When this threshold is exceeded, a higher frequency of monitoring will used to document and understand the sources of PCBs to the water column.

The loads released by dredging are expected to vary rapidly over time and thus will need to be reviewed daily. Sampling when routine conditions are expected will measure the daily variability. The weekly variability, as defined by a 7-day running mean calculated daily, will be used to test compliance with the load-based criteria. This technique will allow confirmation of compliance with the long-term load criterion while also collecting data to demonstrate that more significant exceedances of PCB concentration criteria (*e.g.*, exceeding 350 or 500 ng/L) have not occurred.

The transit time of water from the TI Pool to Waterford is expected to vary from two to seven days, depending inversely on flow. As a result of the normal dispersion and settling processes, the intensity of any short-term PCB release is expected to be diminished as the river travels from TI Pool to Waterford. Thus, for a dredging operation in the TI Pool, the discrete sample collected at TI Dam has not undergone the same level of integration as a sample obtained at Waterford. Thus collecting samples along the Upper Hudson serves to examine both short-term (one hour duration) and longer-term (one- to two-day duration) PCB loads and PCB concentrations. Both measures are needed to assess the success of the resuspension controls.

The sampling program must reflect the need to assess gradual increases in long-term impacts, such as PCB mass transported downstream and the consideration of acute PCB concentrations at downstream public water supplies. The long-term averages (7-day period) and daily results are required to assess such long term impacts. To address the protection of downstream water supplies, 24-hour turn-around times are needed for the two monitoring stations downstream of, but closest to, the dredge operation. For Phase 1, these are expected to be the TI Dam and Schuylerville stations. Based on the above considerations, and those of the standard, the decision units are the loads as measured weekly and the concentrations measured daily.

The results from the two far-field stations closest to the dredging operations provide some indication of what the downstream PCB levels. However, due to the highly variable nature of the PCB release process, samples must still be collected from locations farther downstream and the concentrations confirmed to be in compliance with the standard. These samples can have a longer turn around time, on the order of 7 days from collection to result, since their role is primarily confirmational. These samples are necessary during Phase 1 but may be dropped in Phase 2, depending on the success of the suspended solids monitoring and the actual PCB loss rates.

3.5 Develop a Decision Rule

The decision rules are derived from the performance standard criteria described in Volume 1 of the document and justified in Sections 2 and 3 of Volume 2 of the document. The decision rule is designed to test compliance with the standard criteria.

The arithmetic mean is selected as the primary measure since it reflects an integration of several measures and representative of the integrated PCB load over the averaging period. Compliance with each of the resuspension criteria is the primary focus of this DQO discussion.

3.6 Specify Tolerable Limits on Decision Errors

Current estimates of PCB release due to dredging, as developed in other attachments to this document, indicate that PCB loads and concentrations are likely to fall below the action level criteria during most of the operation. More specifically, the estimates of PCB release indicate that when the PCB loads and concentrations are viewed on a daily or weekly basis, momentary flux variations will average out so as to fall below the action level criteria. Additionally, the threshold criteria developed for the decision rules do not represent conditions immediately dangerous to human health or the environment. Based on this, the null hypothesis for the decision rule is taken as the condition that the river is in compliance (*i.e.*, the river flux or concentration of total PCBs is below the criteria value). This approach also takes into consideration that daily monitoring will continue, and that confirmation of any day's decision about dredging releases and water column concentration will be obtained in the next sample taken.

USEPA's Decision Error Feasibility Trials Software (DEFT (USEPA, 2001)) was used to develop the sampling requirements for this program. The results of this analysis are presented in Table 1.As defined in USEPA (2001):

- A *false acceptance* decision error occurs when the sample data lead you to decide that the baseline condition is probably true when it is really false.
- A *false rejection* decision error occurs when the limited amount of sample data lead you to decide that the baseline condition is probably false when it is really true.
- The *gray region* is a range of true parameter values within the alternative condition near the Action Level where it is "too close to call."

False acceptances were minimized because it is the more serious error. In general, decisions that were more critical, such as confirmation of exceedance of the Resuspension Standard which requires the shut down of operations, or exceedance of the Control Level which requires intense monitoring and implementation of engineering evaluations and solutions, required a large number of samples and had greater certainty than the less critical decisions. For the suspended solids measurements, it was clear that the implementation of a continuous monitor capable of estimating suspended solids concentrations would be needed to provide a reasonable amount of certainty in these decisions. The low level of certainty is tolerable only because any decisions made as a result of an exceedance of the suspended solids will be confirmed by measurements of PCB concentrations in the impacted water column.

For PCB measurement-based decisions, a false acceptance rate of 5 percent or less was sought, with lower rates sought when an incorrect decision would yield an unnecessary halting of the operation or an engineering improvement. The rate of 5 percent was selected as an acceptable error for the lower action level criteria, since exceedance of the action level criteria only initially induces additional monitoring which will quickly confirm the exceedance. This error rate reflects a balance between setting the monitoring requirements as low as possible while still providing protection.

3.7 Optimize the Design for Obtaining Data: Results of the Analysis

The final sampling requirements for the standard were developed using DEFT (USEPA, 2001), a program to estimate sampling requirements based on a project-specific error rate. Table 1 summarizes the analysis of the various criteria, acceptable *gray region* around each criterion, the sampling frequency required by the resuspension standard, and the false acceptance and false rejection levels. The table is organized by measurement type (*i.e.*, PCB and suspended solids). For all criteria except the confirmation of the 500 ng/L exceedance, the null hypothesis assumed that river conditions were in compliance.

Two important assumptions were made to develop the error rate values in the table. There is no site-specific data on the expected variance of water column conditions related to dredging. As a result, the extensive analysis of variance compiled in Attachment A was used. A nominal coefficient of variance was assumed for PCBs and suspended solids based on the variance observed under baseline conditions. For PCB measurements (both

Total PCBs and Tri+), the coefficient of variance is assumed to be 25 percent. For suspended solids, the coefficient of variance was assumed to be 75 percent.

This section also includes a set of figures illustrating the statistical calculations used to estimate the error rates. Figures 1 to 25 represent the calculations for each line in Table 1.

Table 1 shows that the higher level of sampling associated with the higher action levels and the and Resuspension Standard yield low false error rates, reflecting the need to be accurate before taking costly actions or improvements. In some instances, the false rejection rate is fairly high, indicating that additional sampling may be unnecessarily triggered. However, this represents a protective approach from the perspective of ensuring the safety of public water supplies. Additionally, the higher monitoring rates will quickly confirm the need to remain at the action level thought to be exceeded.

Higher error rates were estimated in the transition from routine conditions to the Evaluation and Control Levels, reflecting the relative low sampling rate required for routine sampling. Also shown in the table is the one week confirmation result (*i.e.,* the error rate for the combination of one week of routine monitoring and one week at the action level). In each instance, the false acceptance error was brought below 5 percent, thereby confirming the need to sample at the higher rate or indicating that sampling at the routine rate may be resumed.

The results for the monitoring requirements implemented after exceedance of the standard demonstrate the need for the intensive sampling specified. In this instance the river is assumed be in exceedance of the standard. Four additional discrete samples (Figure 7) do not provide sufficient certainty given that the next day's decision will involve the temporary halting of the dredging operations. However, by collecting hourly composites, the power of the same four analyses is greatly improved and the 5 percent false acceptance rate is attained.

Table 1 also presents the results for the long-term integrative samples. These samples will serve to confirm the results of the daily routine monitoring, or indicate that more frequent sampling is warranted. The results assume the automated collection of eight samples per day over a one- to two-week period.

The results for suspended solids illustrate the need to use a continuous sampling system such as a turbidity probe. In the lower portion of the table, results for the discrete sampling program are compared with those that can be achieved with a continuous probe taking a reading once every 15 minutes. In almost all cases, the continuous reading probe provided more than an order of magnitude improvement in the expected error rate. Better rates can be achieved using the continuous probes by simply taking data more frequently.

Note that this analysis does not consider any uncertainty introduced by use of a probe over discrete samples. Nonetheless, given a semi-quantitative relationship between the probe and the actual suspended solids levels, it is highly likely that the probes will provide a substantial reduction in the expected error rates for suspended solids monitoring, reducing unnecessary additional PCB sampling prompted by a false indication.

Figures 26 through 28 show the Total PCB sampling requirements for the evaluation and control levels to achieve 5 percent false acceptance and false rejection rates if automatic samplers were used. Using the automated sampler, one composite sample with 24 aliquots (i.e., 1 aliquot per hour) is collected each day. At the evaluation level, to achieve the false acceptance and false rejection rate of 5 percent, 2 composite samples with 24 aliquots of each sample are needed (Figure 26). This means that data from at least two days are needed to be certain that the evaluation level is exceeded. Three composite samples with 24 aliquots each sample are needed to be certain that that 600 g/day Total PCB load action level is exceeded at the control level (Figure 27). For a concentration exceedance at the control level, four composite samples with 24 aliquots each sample are needed to achieve false acceptance and false rejection rates of 5 percent (Figure 28).

Table 2 summarizes the various criteria, the associated gray region, the sampling frequency required by the resuspension standard, and the false acceptance and false rejection levels when the automatic sampler is used. Figures 29 through 34 illustrate the statistical calculations used to estimate the error rates for each line of Table 2. Using the automatic sampler, the error rates for most of the sampling requirements are less than 1 percent. The highest error rate was about 2 percent for the false rejection of the sampling requirement from evaluation to control level. However, this value is still below 5 percent error rate. This analysis shows that the power of the sampling program for Total PCB using automatic sampler is greatly improved.

4.0 References

USEPA, 2000. Guidance for the Data Quality Objectives Process EPA/600/R-96/055. August 2000.

USEPA, 2001. Data Quality Objectives Decision Error Feasibility Trials Software (DEFT) - USER'S GUIDE. EPA/240/B-01/007. September 2001.

Tables

Table 1
Summary of Sampling Frequency Requirements and Expected Error Rates

Analysis	Transition	Detail	Sampling Time Period	Action Level	Number of Samples[1]	Grey Region Limit	False Rejection Error Limit - a (%)	False Acceptance Error Limit - b (%)	Figure Number
Total PCB Sampling Requirements (25% CV)									
Far Field									
	Routine to Evaluation Level	Routine to > 300 g/day	1 week	300 g/day	7 (1 sample/day for 1 week)	400 g/day	7.5	5	1
	Routine to Control Level	Routine to > 600 g/day	1 week	600 g/day	7 (1 sample/day for 1 week)	700 g/day	25	15	2
	Confirmation of the Control Level	Confirmation of > 600 g/day	1 week routine + 1 week	600 g/day	28 (7 samples routine + 21 samples control level)	700 g/day	5	4	3
	Routine to Control Level	Routine to > 350 ng/L	1 week	350 ng/L	7 (1 sample/day for 1 week)	400 ng/L	27.5	20	4
	Confirmation of the Control Level	Confirmation of > 350 ng/L	1 week routine + 1 week	350 ng/L	28 (7 samples routine + 21 samples control level)	400 ng/L	10	5	5
	Evaluation to Control Level	300 g/day to > 600 g/day	1 week evaluation + 1 week	600 g/day	35 (14 samples evaluation level + 21 samples control level)	700 g/day	4	2	6
	Resuspension Standard Threshold	Confirmation of > 500 ng/L[2]	1 day routine + 1 day	500 ng/L	5 (1 sample routine + 4 samples confirmation)	400 ng/L	15	30	7
		Confirmation of > 500 ng/L (24 hours)[2]	1 day	500 ng/L	4 composites of 6 aliquots each	400 ng/L	5	7	8
	Routine to Control Level	Continuous Total PCB 1-week or 2-week deployment	1 week or 2 weeks	350 ng/L	2 composites of 56 aliquots each	400 ng/L	6.5	5	9
Suspended Solids Sampling Requirements (75% CV)									
Far Field									
	Routine to Evaluation Level	Far-field - Baseline to > 12 mg/L	1 day (3 hrs for 24 hrs)	14 mg/L	8 (discrete)	21 mg/L	27.5	12.5	10
			1 day (15 min for 24 hrs)	14 mg/L	96 (continuous)	21 mg/L	0.1	0.1	11
	Routine to Control Level	Far-field - Baseline to > 24 mg/L	1 day (3 hrs for 24 hrs)	26 mg/L	8 (discrete)	39 mg/L	27.5	12.5	12
			1 day (15 min for 24 hrs)	26 mg/L	96 (continuous)	39 mg/L	0.1	0.1	13
	Evaluation to Control Level	Far-field - 12 mg/L to > 24 mg/L	1 day evaluation + 1 day	26 mg/L	16 (discrete)	39 mg/L	15	5	14
			1 day evaluation + 1 day	26 mg/L	192 (continuous)	39 mg/L	0.5	< 0.5	15
Near Field									
	Routine to Control Level	Near Field - River Sections 1 and 3	6 hours (1 sample per 3 hours)	100 mg/L	3 (discrete)	150 mg/L	35	25	16
		Baseline to > 100 mg/L	6 hours (1 sample per 15 min)	100 mg/L	24 (continuous)	150 mg/L	6.6	5	17
	Routine to Control Level	Near Field - River Section 2	6 hours (1 sample per 3 hours)	60 mg/L	3 (discrete)	90 mg/L	35	25	18
		Baseline to > 60 mg/L	6 hours (1 sample per 15 min)	60 mg/L	24 (continuous)	90 mg/L	6.6	5	19
	Evaluation to Control Level	Near Field - River Sections 1 and 3	1 day (3 hrs for 15 hrs)	100 mg/L	5 (discrete)	150 mg/L	27.5	20	20
		Baseline to > 100 mg/L	1 day (15 min for 15 hrs)	100 mg/L	60 (continuous)	150 mg/L	0.7	0.5	21
	Evaluation to Control Level	Near Field - River Section 2	1 day (3 hrs for 15 hrs)	60 mg/L	5 (discrete)	90 mg/L	27.5	20	22
		Baseline to > 60 mg/L	1 day (15 min for 15 hrs)	60 mg/L	60 (continuous)	90 mg/L	0.7	0.5	23
	Routine to Evaluation Level	Near Field	3 hours (1 sample per 3 hours)	700 mg/L	2 (discrete)	1000 mg/L	40	30	24
		Baseline to > 700 mg/L	3 hours (1 sample per 5 min)	700 mg/L	36 (continuous)	1000 mg/L	16.5	5	25

Note

[1] Sampling frequency at the different action level can be found in Table 1-2 of Volume 1 of the document

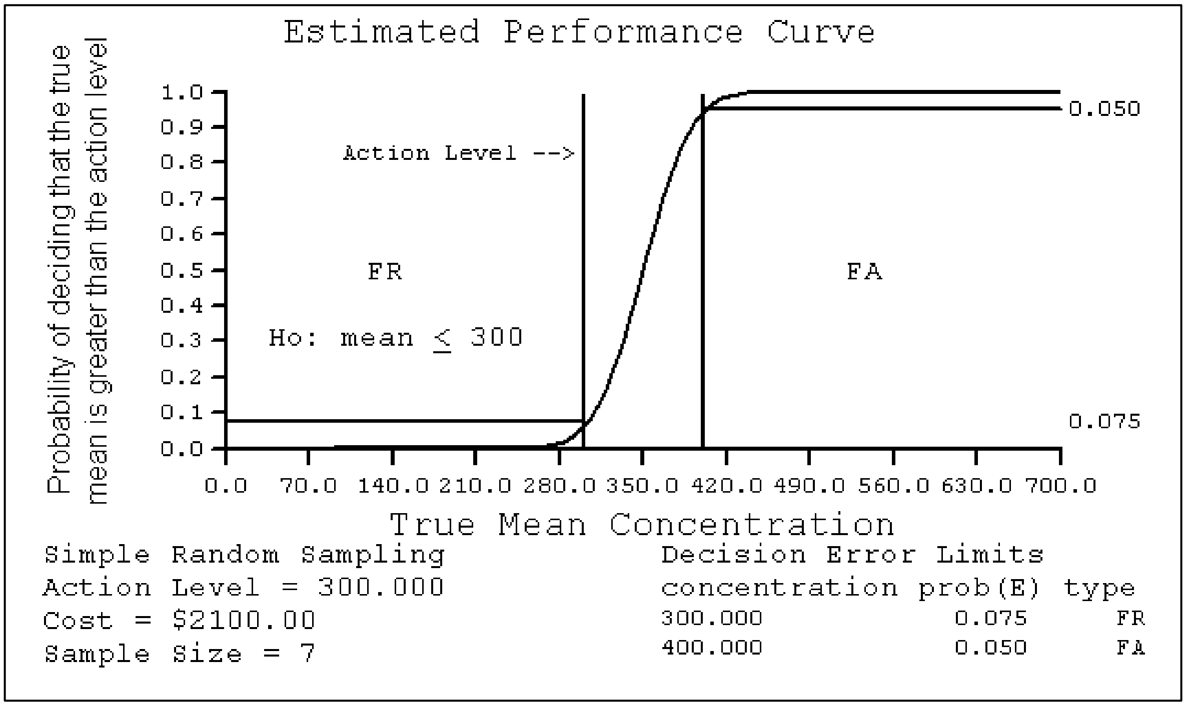
[2] Null hypothesis for the 500 ng/L assumed that river conditions were not in compliance, for all other action levels, the null hypohesis assumed that river conditions were in compliance. See text for discussions.

Table 2
Summary of Sampling Frequency Requirements and Expected Error Rates for Automatic Sampler

Analysis	Transition	Detail	Sampling Time Period	Action Level	Number of Samples	Grey Region Limit	False Rejection Error Limit - a (%)	False Acceptance Error Limit - b (%)	Figure Number
Total PCB Sampling Requirements (25% CV) **Far Field**									
	Routine to Evaluation Level	Routine to > 300 g/day	1 week	300 g/day	7 composites of 24 aliquots each (1 sample/day for 1 week)	400 g/day	0.1	<0.1	29
	Routine to Control Level	Routine to > 600 g/day	1 week	600 g/day	7 composites of 24 aliquots each (1 sample/day for 1 week)	700 g/day	0.5	0.1	30
	Confirmation of the Control Level	Confirmation of > 600 g/day	1 week routine + 3 day	600 g/day	10 (7 samples routine + 3 samples control level)	700 g/day	0.5	<0.5	31
	Routine to Control Level	Routine to > 350 ng/L	1 week	350 ng/L	7 composites of 24 aliquots each (1 sample/day for 1 week)	400 ng/L	1	1	32
	Confirmation of the Control Level	Confirmation of > 350 ng/L	1 week routine + 3 day	350 ng/L	10 (7 samples routine + 3 samples control level)	400 ng/L	0.5	<0.5	33
	Evaluation to Control Level	300 g/day to > 600 g/day	2 day evaluation + 3 day	600 g/day	5 (composite sampling every 1 hour, 1 sample/day)	700 g/day	2	1	34

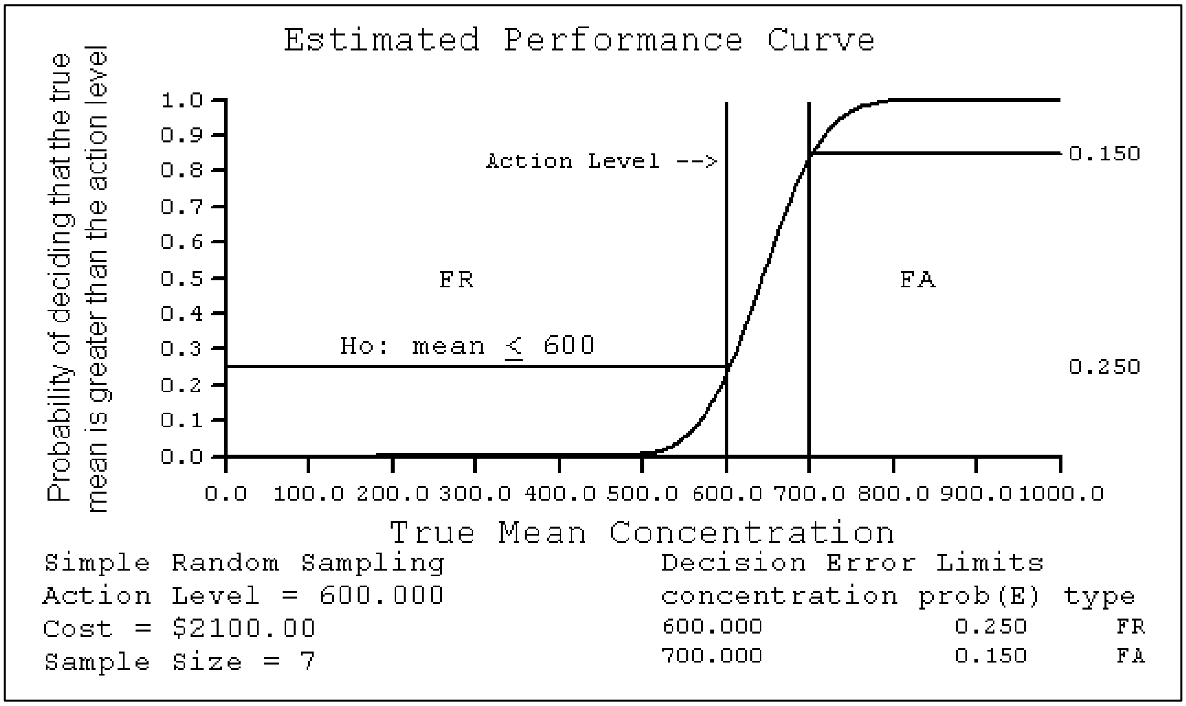
Figures

Figure 1
Routine to Evaluation Level
Action level of 300 g/day



```
Simple Random Sampling          Decision Error Limits
Action Level = 300.000          concentration prob(E) type
Cost = $2100.00                 300.000          0.075   FR
Sample Size = 7                 400.000          0.050   FA
```

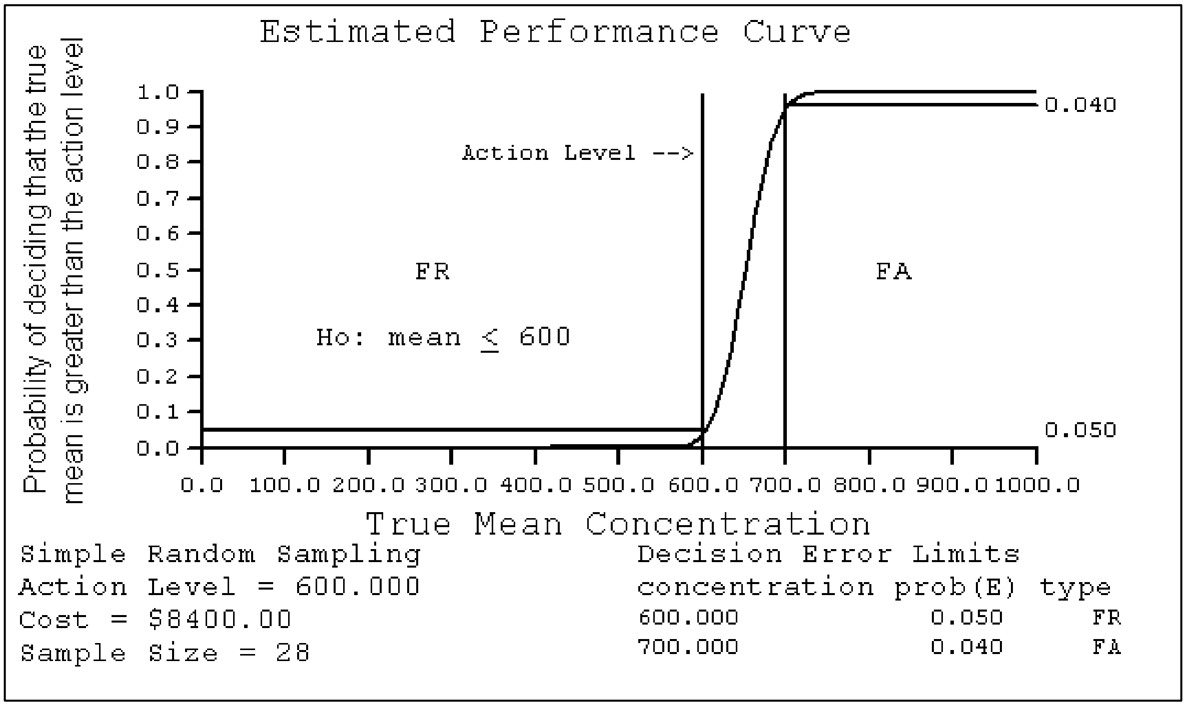
Figure 2
Routine to Control Level
Action Level of 600 g/day



```
Simple Random Sampling          Decision Error Limits
Action Level = 600.000          concentration prob(E) type
Cost = $2100.00                 600.000          0.250   FR
Sample Size = 7                 700.000          0.150   FA
```

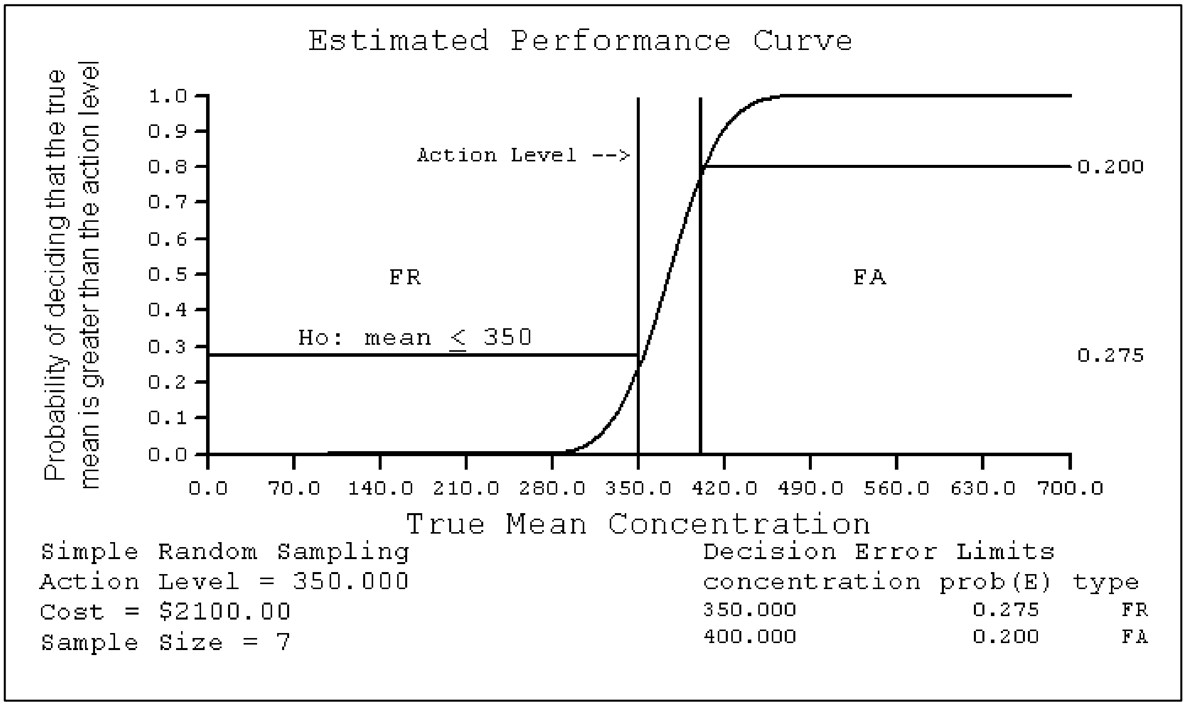
Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Figure 3
Confirmation of the 600 g/day
Action Level of 600 g/day



```
Simple Random Sampling          Decision Error Limits
Action Level = 600.000          concentration prob(E) type
Cost = $8400.00                 600.000           0.050   FR
Sample Size = 28                700.000           0.040   FA
```

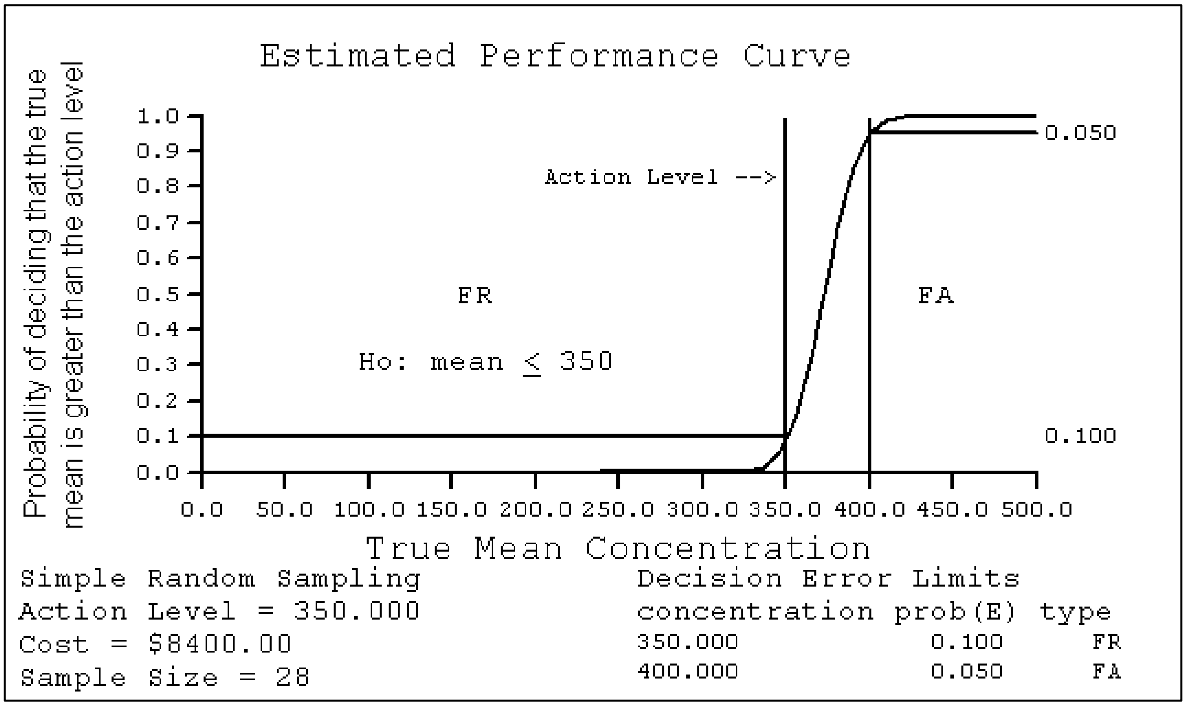
Figure 4
Routine to Control Level
Action Level of 350 ng/L



```
Simple Random Sampling          Decision Error Limits
Action Level = 350.000          concentration prob(E) type
Cost = $2100.00                 350.000           0.275   FR
Sample Size = 7                 400.000           0.200   FA
```

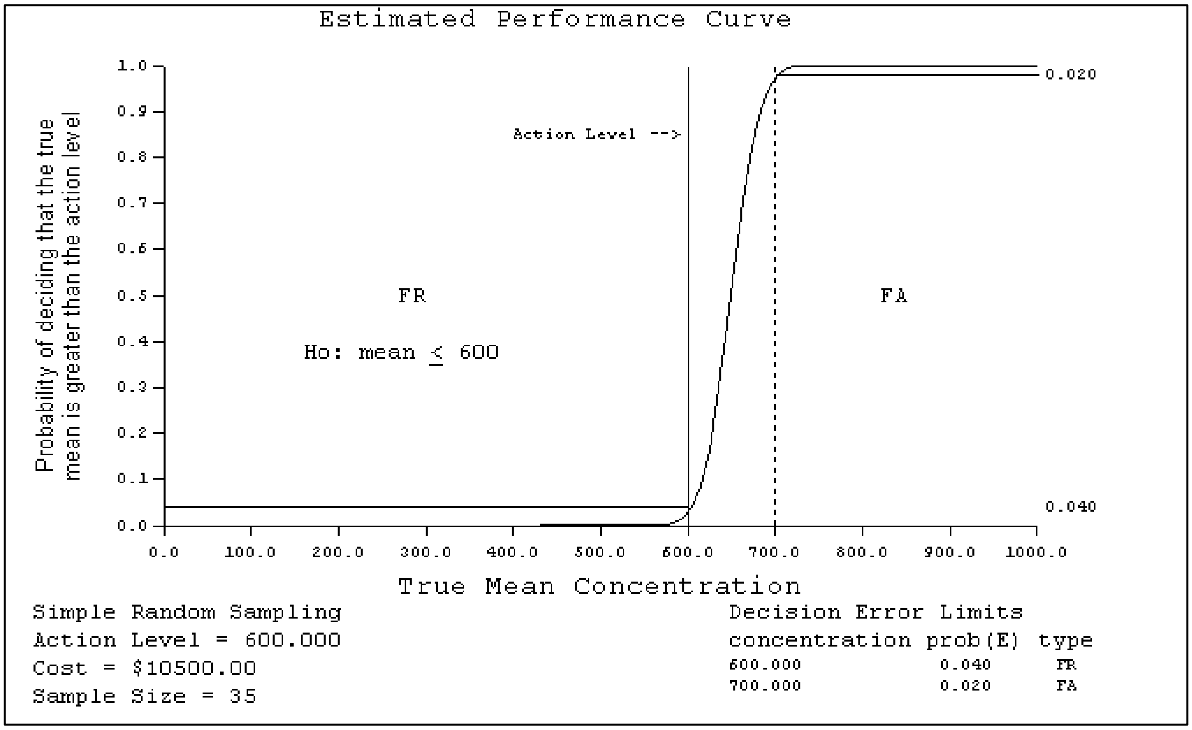
Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Figure 5
Confirmation of the 350 ng/L
Action Level of 350 ng/L



```
Simple Random Sampling          Decision Error Limits
Action Level = 350.000          concentration prob(E) type
Cost = $8400.00                 350.000          0.100  FR
Sample Size = 28                400.000          0.050  FA
```

Figure 6
Evaluation Level to Control Level
300 g/day to 600 g/day



```
Simple Random Sampling          Decision Error Limits
Action Level = 600.000          concentration prob(E) type
Cost = $10500.00                600.000          0.040  FR
Sample Size = 35                700.000          0.020  FA
```

Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Figure 7
Resuspension Threshold
Confirmation of 500 ng/L

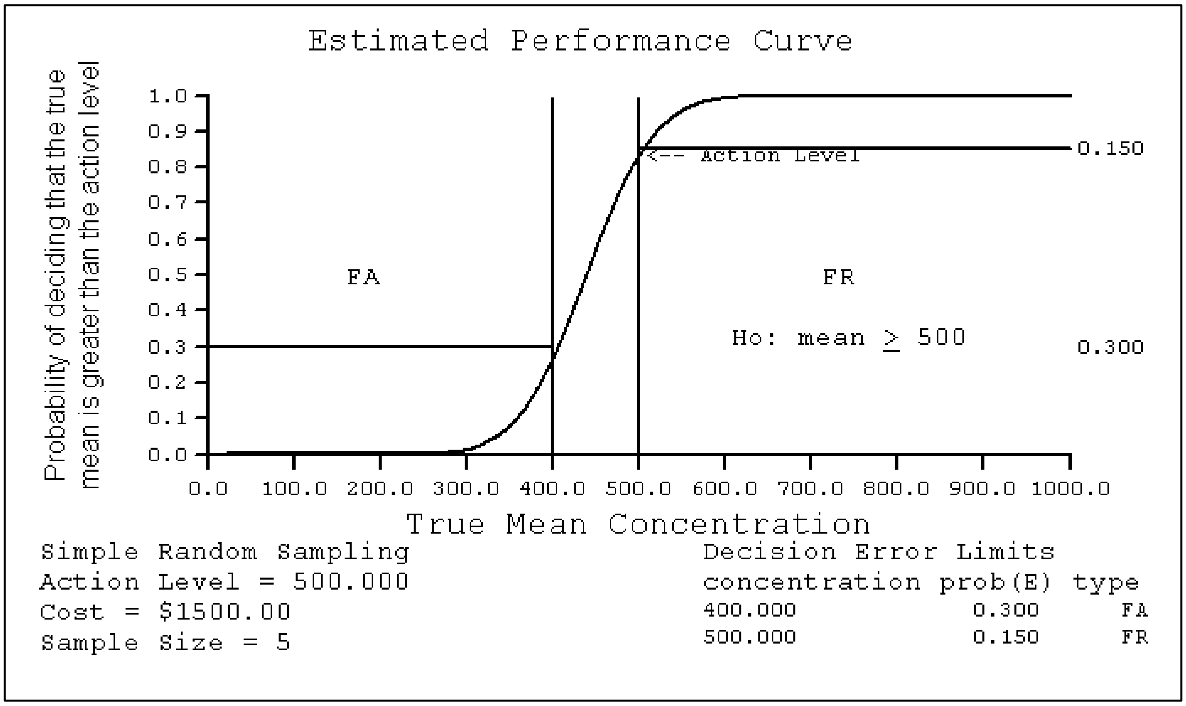
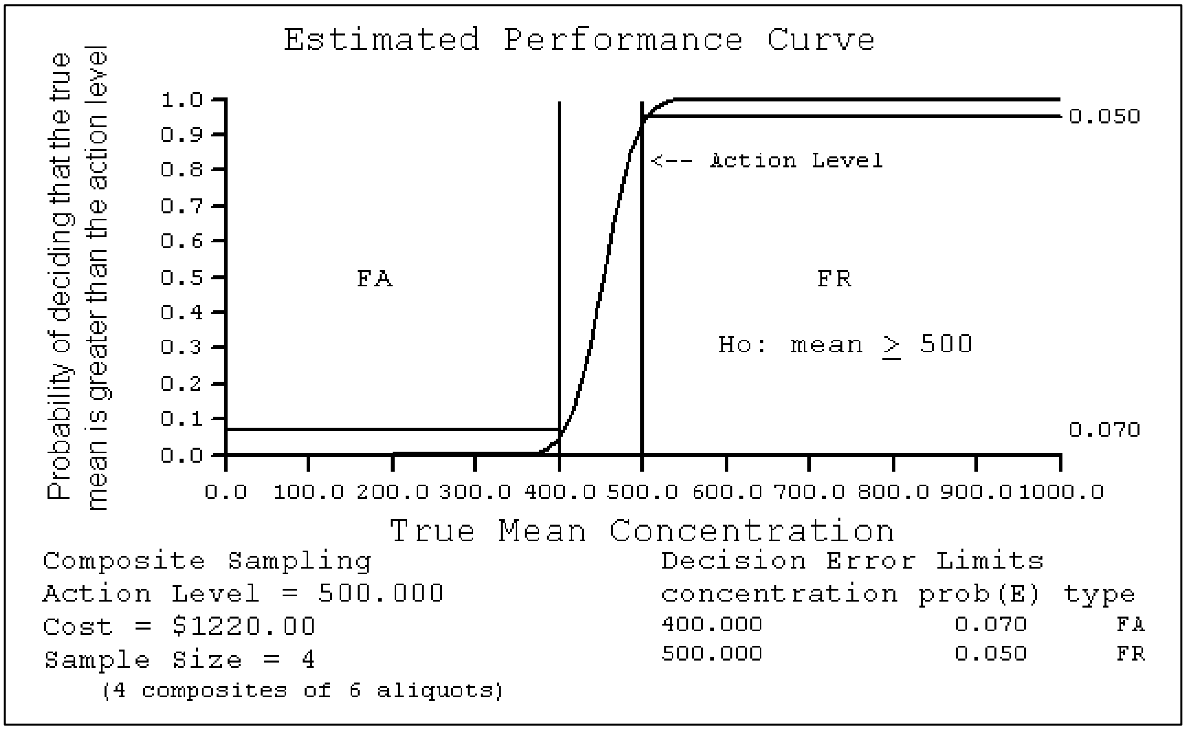
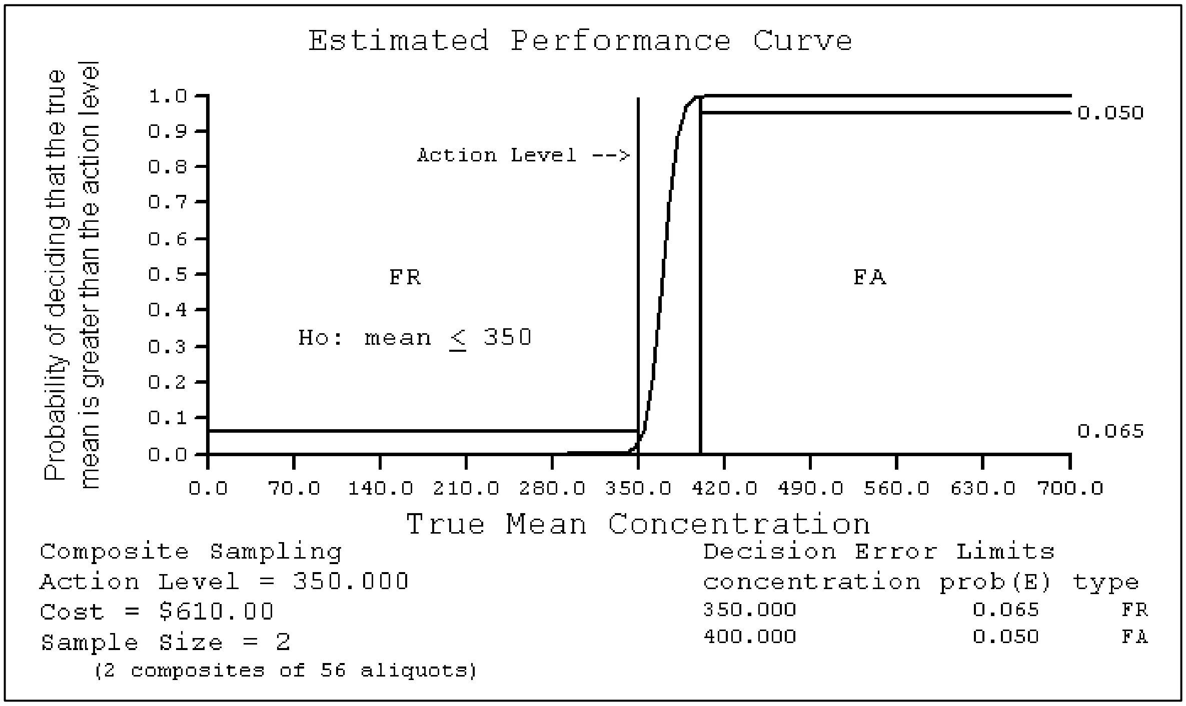


Figure 8
Resuspension Threshold
Confirmation of 500 ng/L (24 hours; 4 samples of 6 aliquots)



Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Figure 9
Routine to Control Level (350 ng/L, 2-week deployment) or Evaluation Level to Control Level (350 ng/L, 1-week deployment)
Continuous total PCB sampling requirements



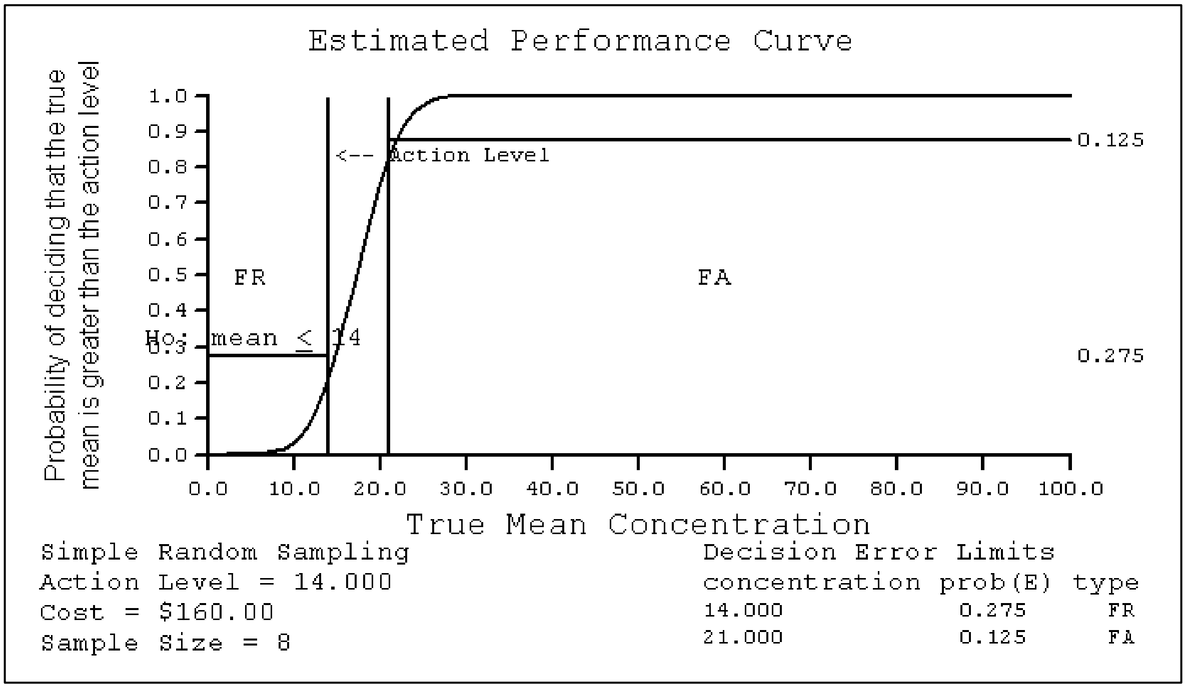
Composite Sampling
Action Level = 350.000
Cost = $610.00
Sample Size = 2
(2 composites of 56 aliquots)

Decision Error Limits

concentration	prob(E)	type
350.000	0.065	FR
400.000	0.050	FA

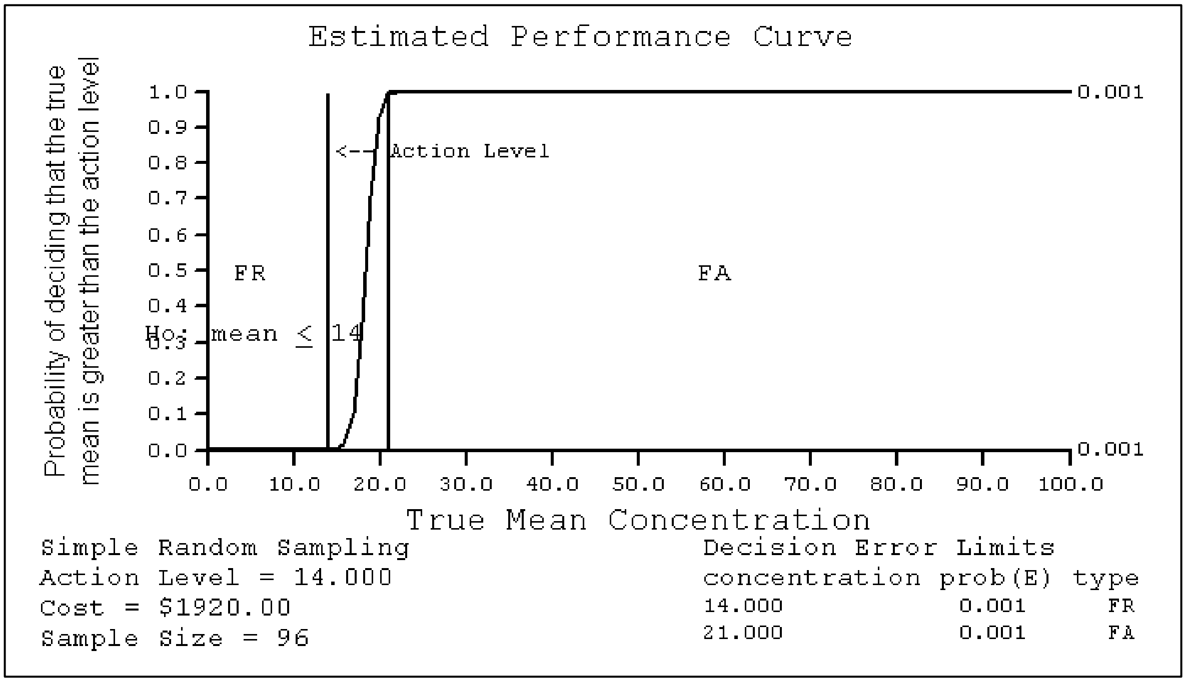
Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Figure 10
Routine to Evaluation Level
(Far-field Baseline to >12 mg/L with discrete samples every 3 hrs for 24 hrs)



```
Simple Random Sampling                          Decision Error Limits
Action Level = 14.000                           concentration prob(E) type
Cost = $160.00                                  14.000          0.275   FR
Sample Size = 8                                 21.000          0.125   FA
```

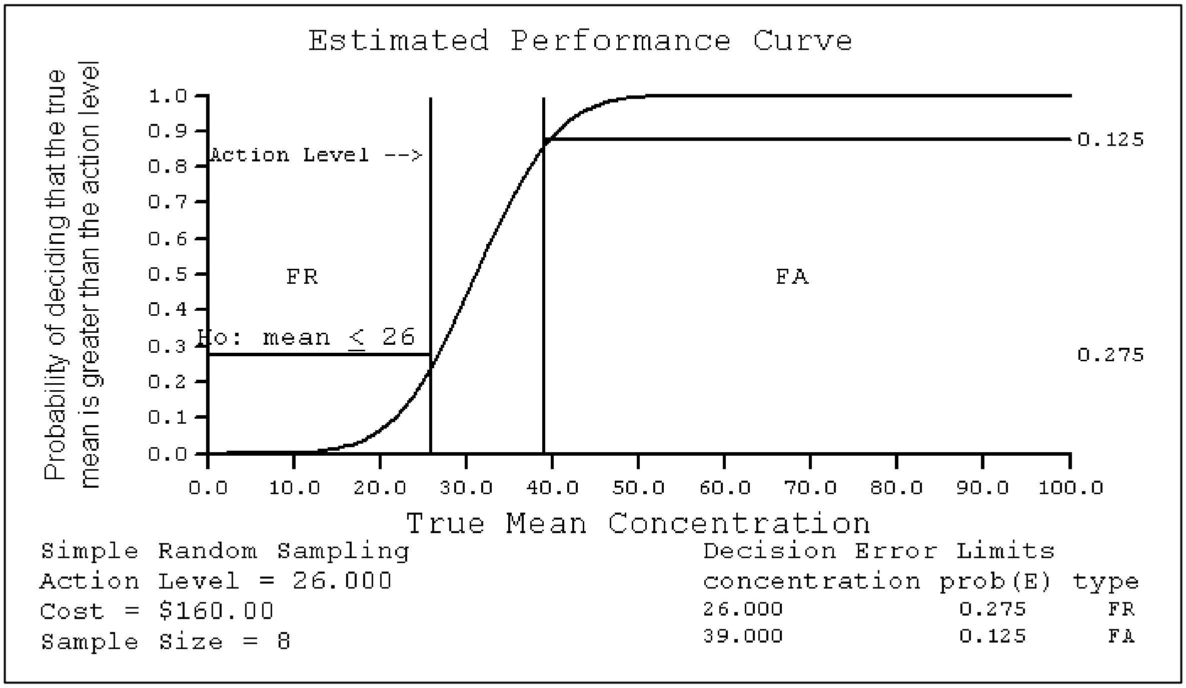
Figure 11
Routine to Evaluation Level
(Far-field baseline to >12 mg/L with continuous sampling every 15 min for 24 hrs)



```
Simple Random Sampling                          Decision Error Limits
Action Level = 14.000                           concentration prob(E) type
Cost = $1920.00                                 14.000          0.001   FR
Sample Size = 96                                21.000          0.001   FA
```

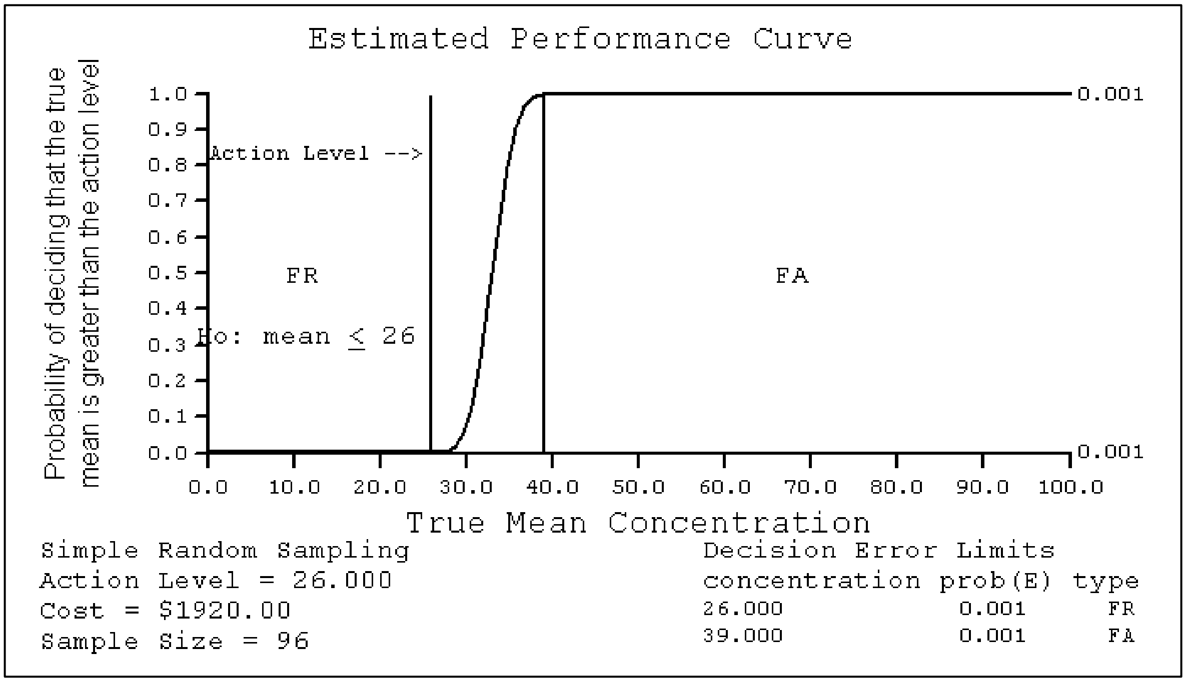
Note: The analysis is based on a baseline of Schuylerville conditions (Average TSS concentration from May-Nov of 2.4 mg/L with an average standard deviation from May-Nov of 1.87 mg/L) and coefficient of variation equal to 75 percent.

Figure 12
Routine to Control Level
(Far-field Baseline to >24 mg/L with discrete samples every 3 hrs for 24 hrs)



```
Simple Random Sampling                     Decision Error Limits
Action Level = 26.000                      concentration prob(E) type
Cost = $160.00                             26.000          0.275   FR
Sample Size = 8                            39.000          0.125   FA
```

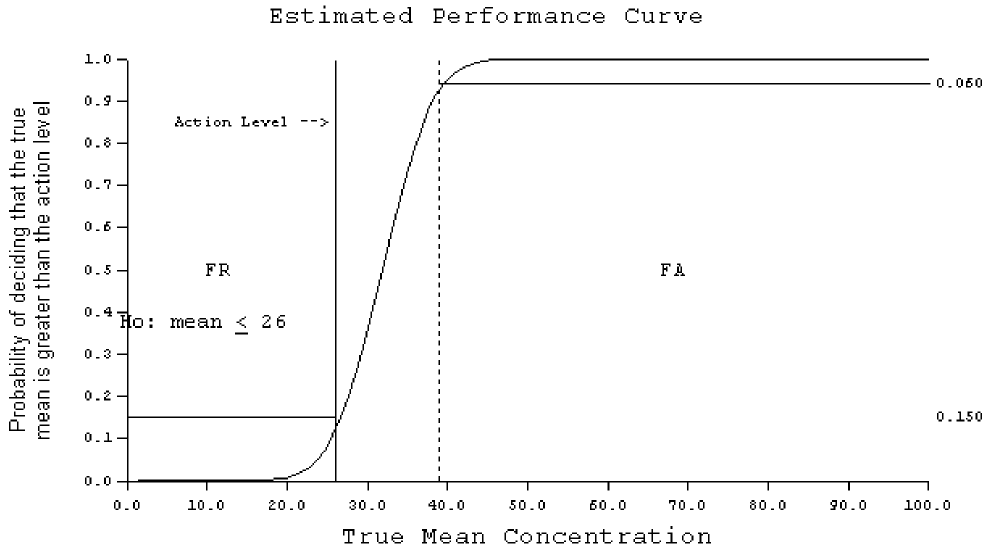
Figure 13
Routine to Control Level
(Far-field baseline to >24 mg/L with continuous sampling every 15 min for 24 hrs)



```
Simple Random Sampling                     Decision Error Limits
Action Level = 26.000                      concentration prob(E) type
Cost = $1920.00                            26.000          0.001   FR
Sample Size = 96                           39.000          0.001   FA
```

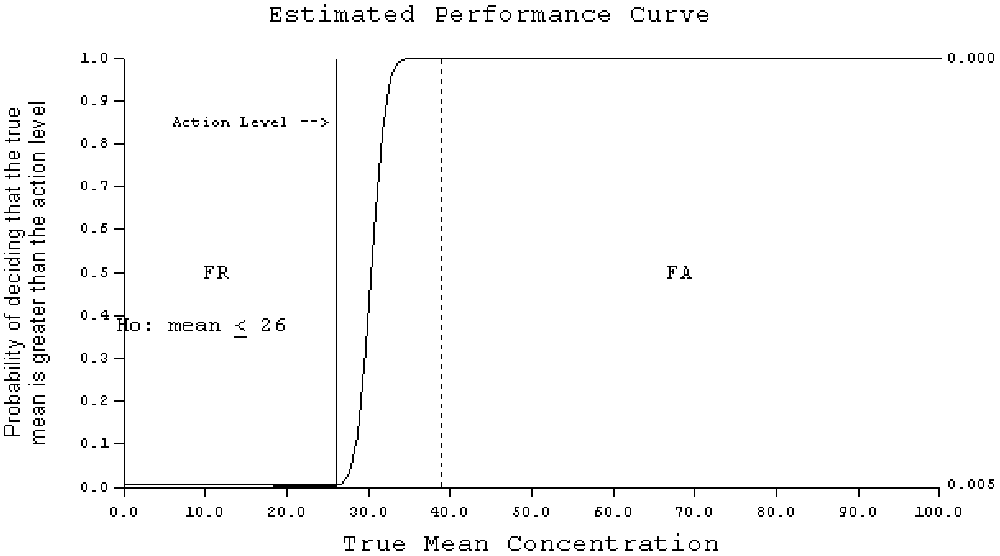
Note: The analysis is based on a baseline of Schuylerville conditions (Average TSS concentration from May-Nov of 2.4 mg/L with an average standard deviation from May-Nov of 1.87 mg/L) and coefficient of variation equal to 75 percent.

Figure 14
Evaluation to Control Level
(Far-field Evaluation to Control Level with discrete samples every 3 hours for 24 hours)



```
Simple Random Sampling                       Decision Error Limits
Action Level = 26.000                        concentration prob(E) type
Cost = $320.00                               26.000        0.150   FR
Sample Size = 16                             39.000        0.060   FA
```

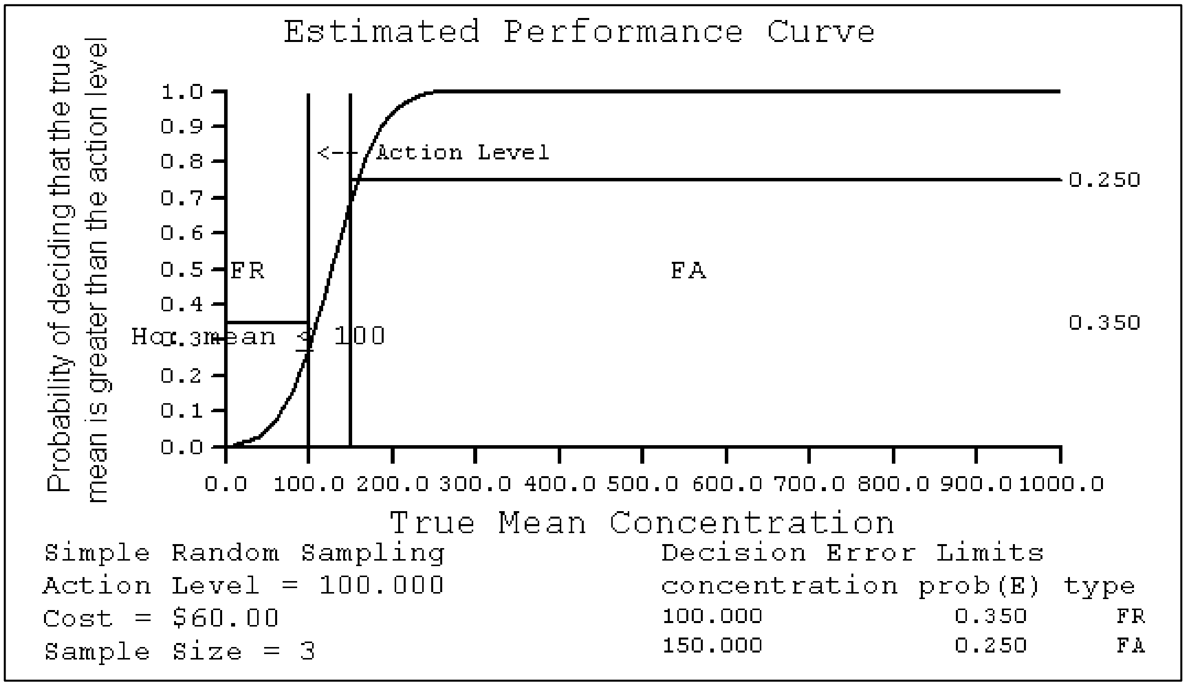
Figure 15
Evaluation to Control Level
(Far-field Evaluation to Control Level with continuous sampling every 15 min for 24 hours)



```
Simple Random Sampling                       Decision Error Limits
Action Level = 26.000                        concentration prob(E) type
Cost = $3840.00                              26.000        0.005   FR
Sample Size = 192                            39.000        0.000   FA
```

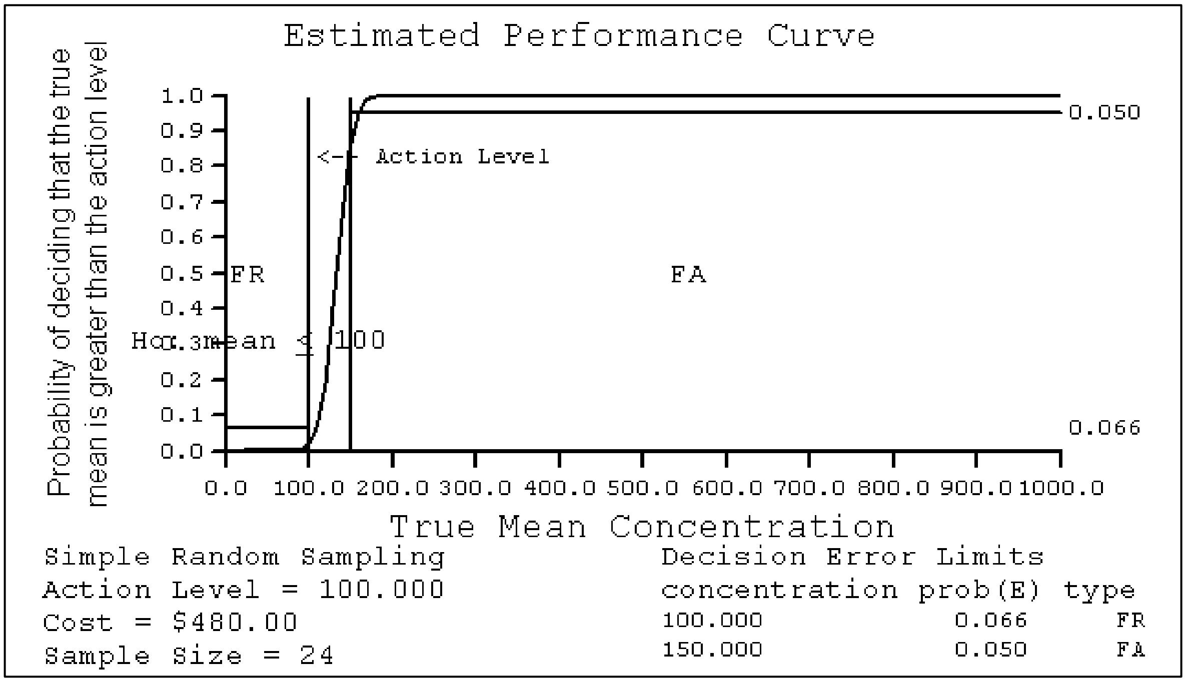
Note: The analysis is based on a baseline of Schuylerville conditions (Average TSS concentration from May-Nov of 2.4 mg/L with an average standard deviation from May-Nov of 1.87 mg/L) and coefficient of variation equal to 75 percent.

Figure 16
Routine to Control Level Near-field River Sections 1 and 3
(baseline to >100 mg/L with discrete samples every 3 hours for 6 hours)



```
Simple Random Sampling              Decision Error Limits
Action Level = 100.000              concentration prob(E) type
Cost = $60.00                       100.000         0.350    FR
Sample Size = 3                     150.000         0.250    FA
```

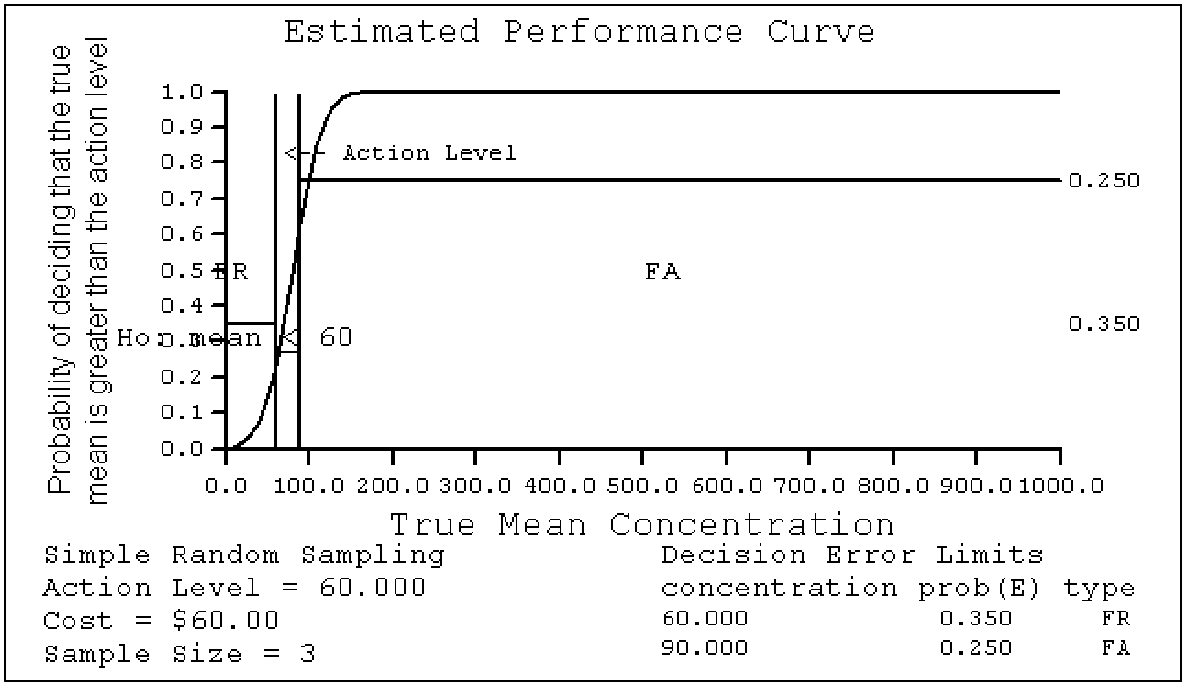
Figure 17
Routine to Control Level Near-field River Sections 1 and 3
(baseline to >100 mg/L with continuous sampling every 15 min for 6 hrs)



```
Simple Random Sampling              Decision Error Limits
Action Level = 100.000              concentration prob(E) type
Cost = $480.00                      100.000         0.066    FR
Sample Size = 24                    150.000         0.050    FA
```

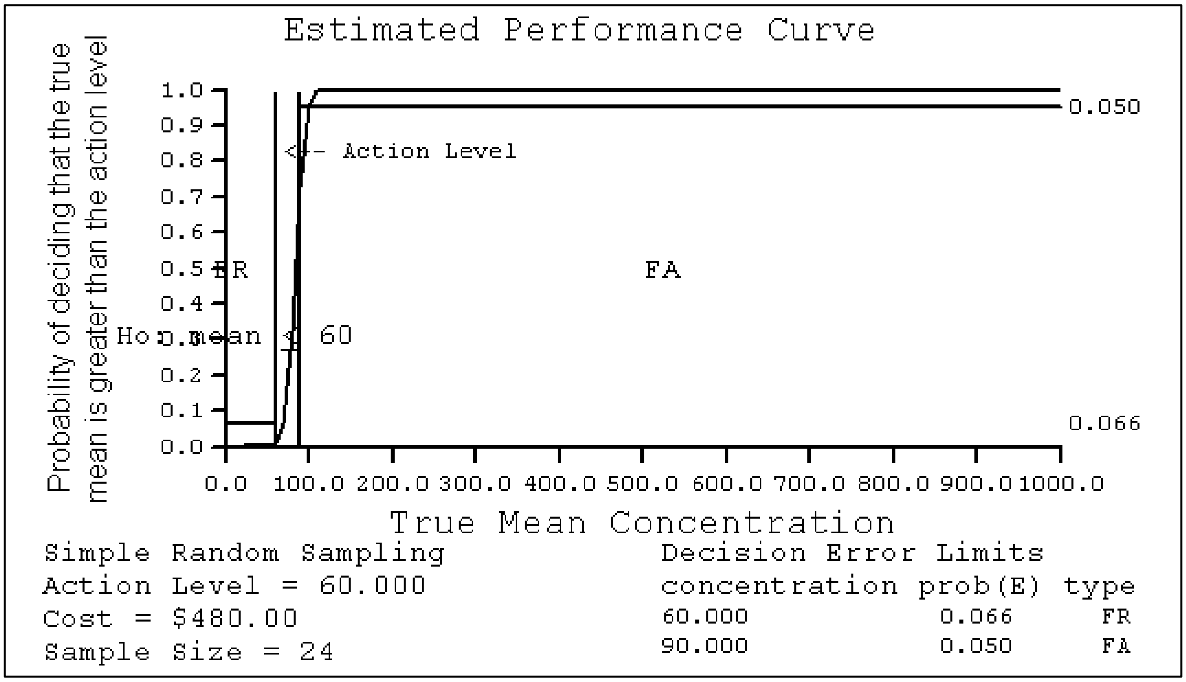
Note: The analysis is based on a coefficient of variation equal to 75 percent.

Figure 18
Routine to Control Level Near-field River Section 2
(baseline to >60 mg/L with discrete samples every 3 hours for 6 hours)



```
Simple Random Sampling              Decision Error Limits
Action Level = 60.000               concentration  prob(E)  type
Cost = $60.00                       60.000         0.350    FR
Sample Size = 3                     90.000         0.250    FA
```

Figure 19
Routine to Control Level Near-field River Section 2
(baseline to >60 mg/L with continuous sampling every 15 min for 6 hrs)



```
Simple Random Sampling              Decision Error Limits
Action Level = 60.000               concentration  prob(E)  type
Cost = $480.00                      60.000         0.066    FR
Sample Size = 24                    90.000         0.050    FA
```

Note: The analysis is based on a coefficient of variation equal to 75 percent.

Figure 20
Evaluation to Control Level Near-field River Sections 1 and 3
(baseline to >100 mg/L with discrete samples every 3 hours for 15 hours)

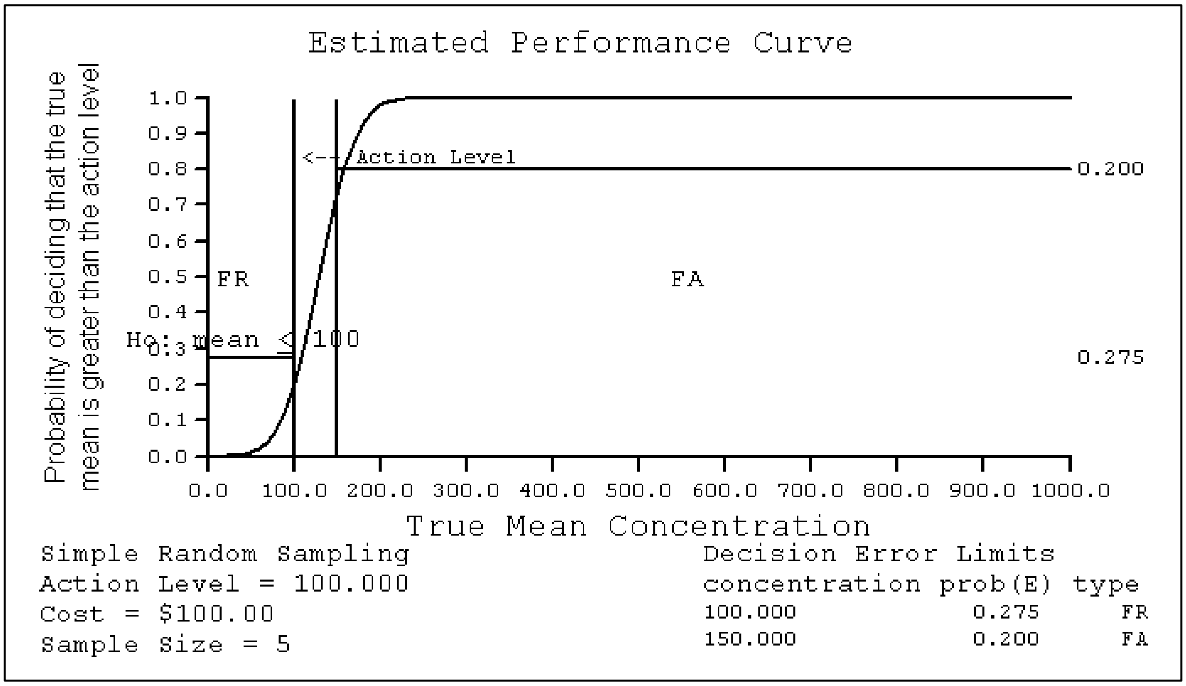
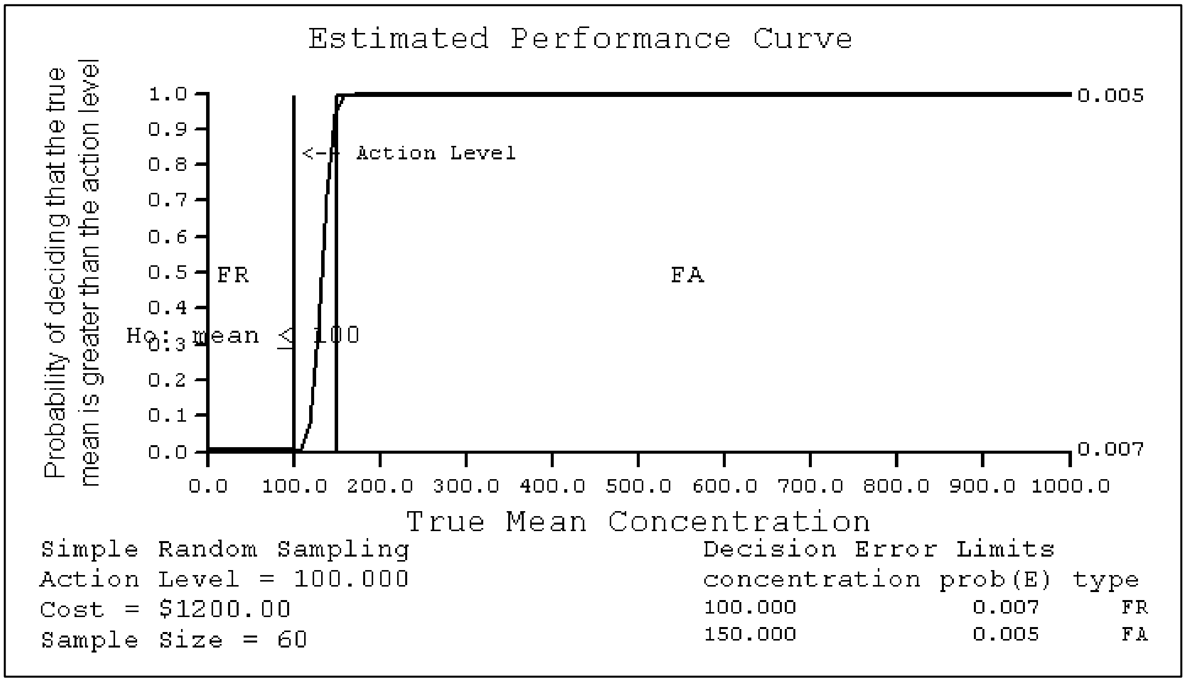
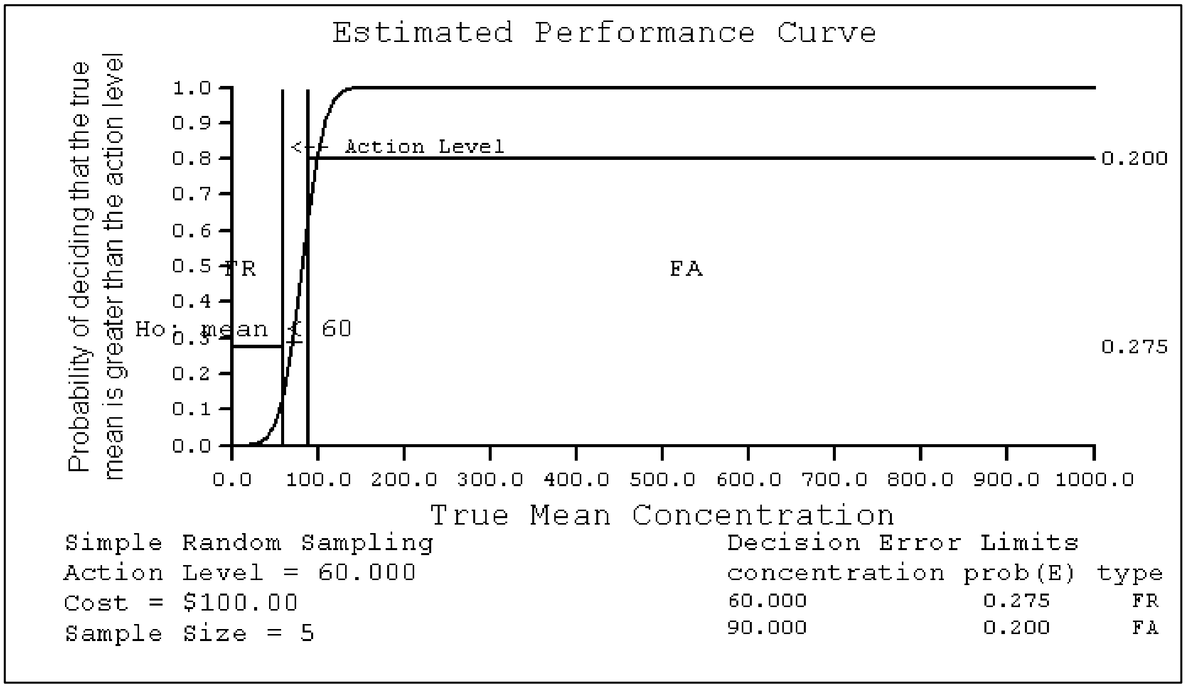


Figure 21
Evaluation to Control Level Near-field River Sections 1 and 3
(baseline to >100 mg/L with continuous sampling every 15 min for 15 hrs)



Note: The analysis is based on a coefficient of variation equal to 75 percent.

Figure 22
Evaluation to Control Level Near-field River Section 2
(baseline to >60 mg/L with discrete samples every 3 hours for 15 hours)

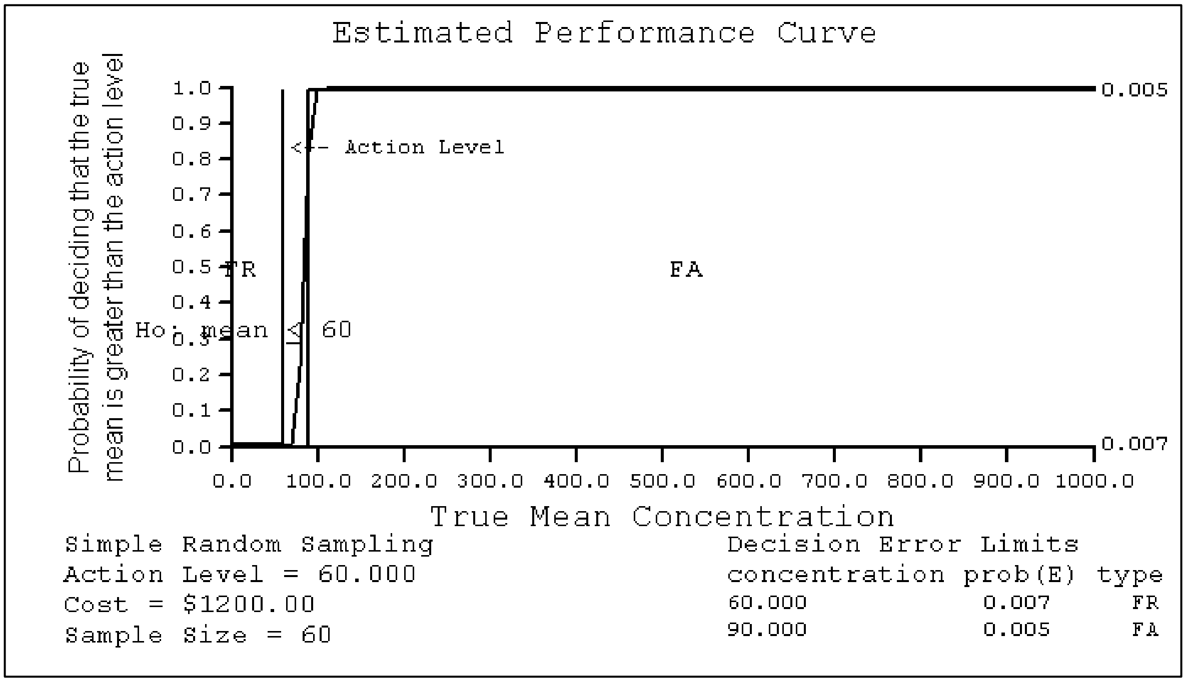


Simple Random Sampling
Action Level = 60.000
Cost = $100.00
Sample Size = 5

Decision Error Limits

concentration	prob(E)	type
60.000	0.275	FR
90.000	0.200	FA

Figure 23
Evaluation to Control Level Near-field River Section 2
(baseline to >60 mg/L with continuous sampling every 15 min for 15 hrs)



Simple Random Sampling
Action Level = 60.000
Cost = $1200.00
Sample Size = 60

Decision Error Limits

concentration	prob(E)	type
60.000	0.007	FR
90.000	0.005	FA

Note: The analysis is based on a coefficient of variation equal to 75 percent.

Figure 24
Routine to Evaluation Level
(Near-field baseline to >700 mg/L with discrete samples every 3 hrs for 3 hrs)

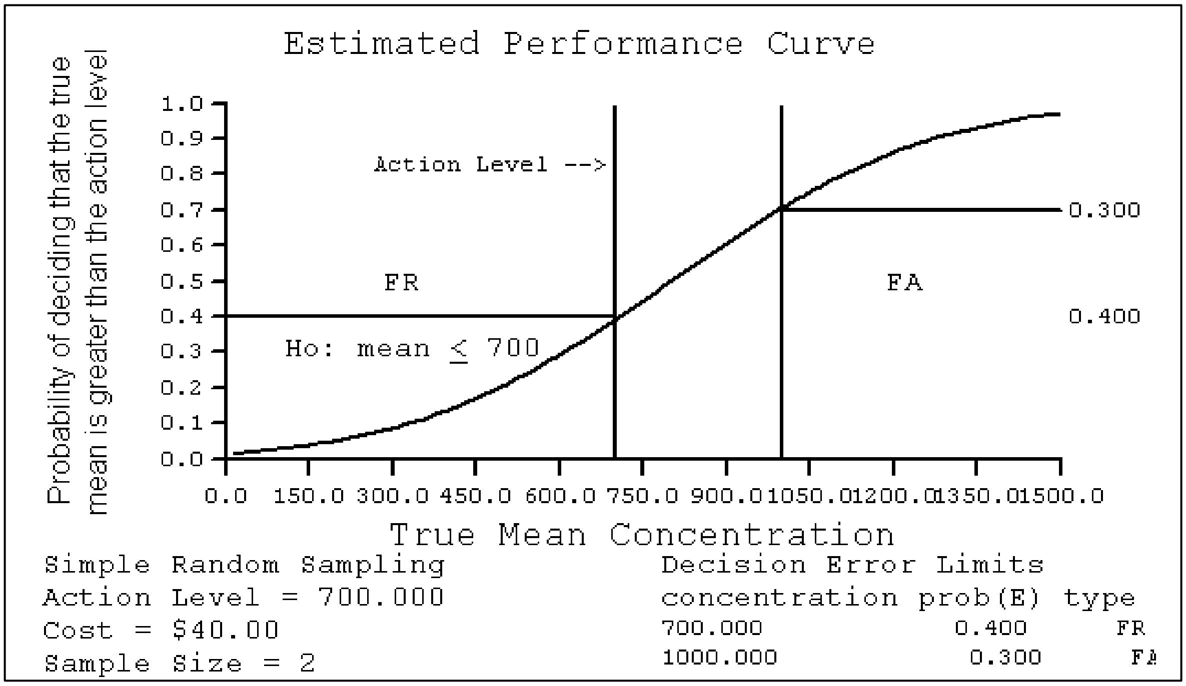
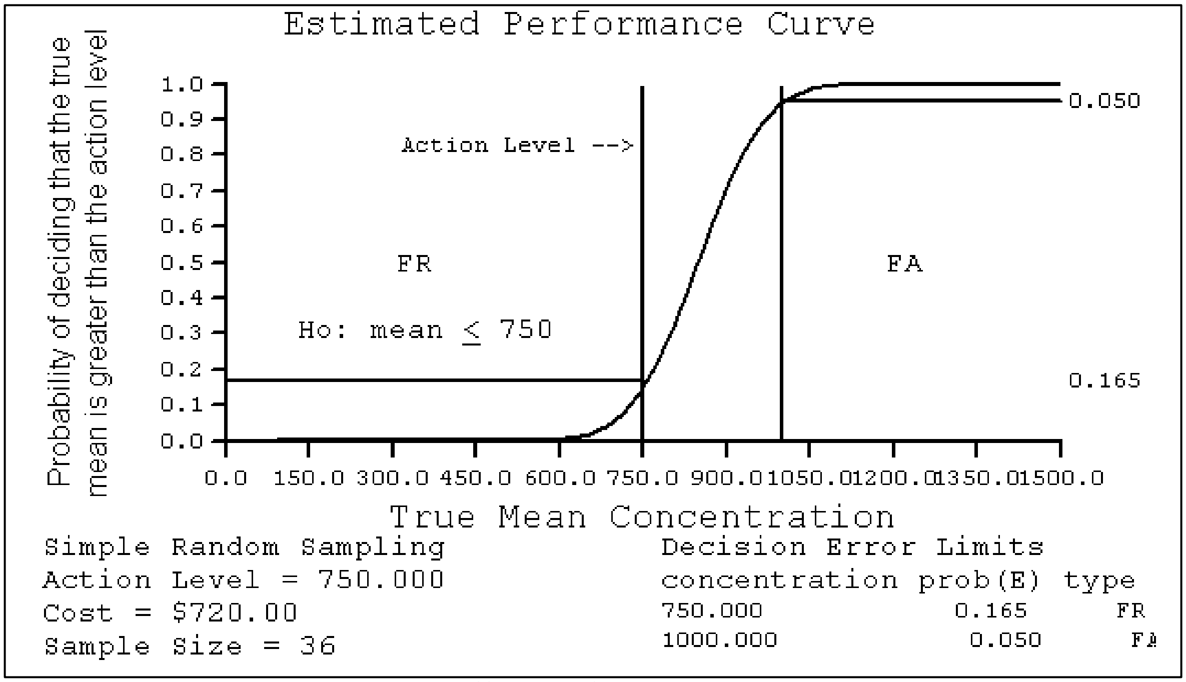


Figure 25
Routine to Evaluation Level
(Near-field baseline to >700 mg/L with continuous sampling every 15 min for 3 hrs)



Note: The analysis is based on a coefficient of variation equal to 75 percent.

Figure 26
Automatic Sampler at the Evaluation Level (300 g/day)
(1 sample per hour for 24 hours)

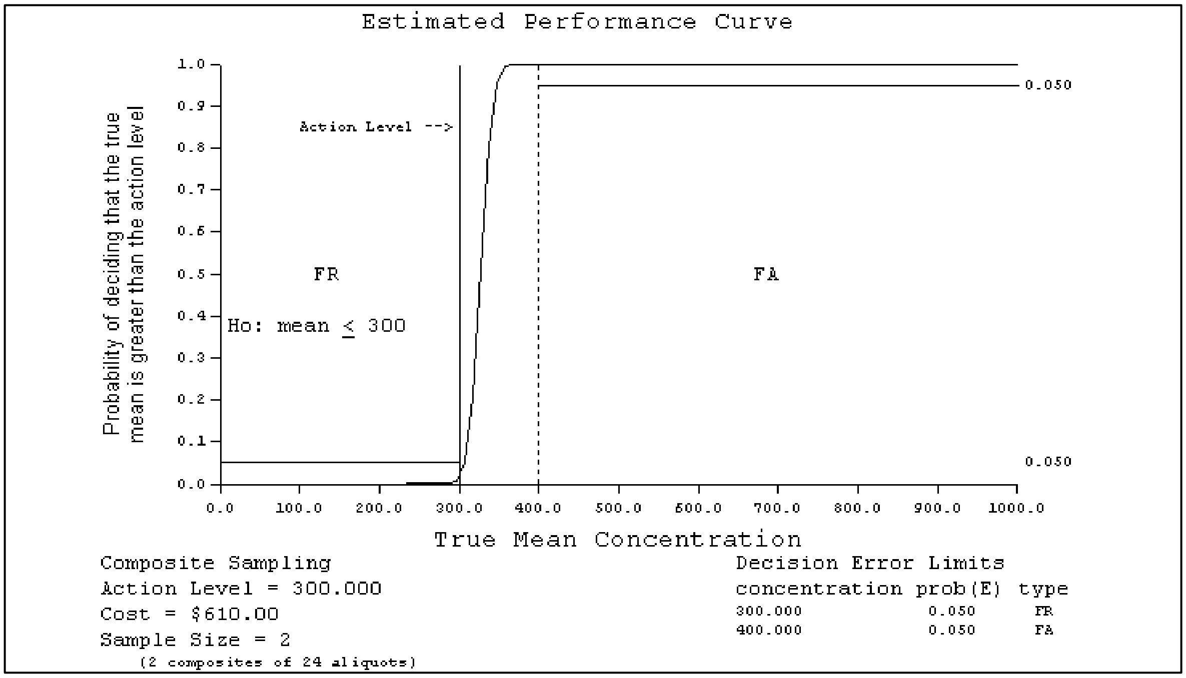
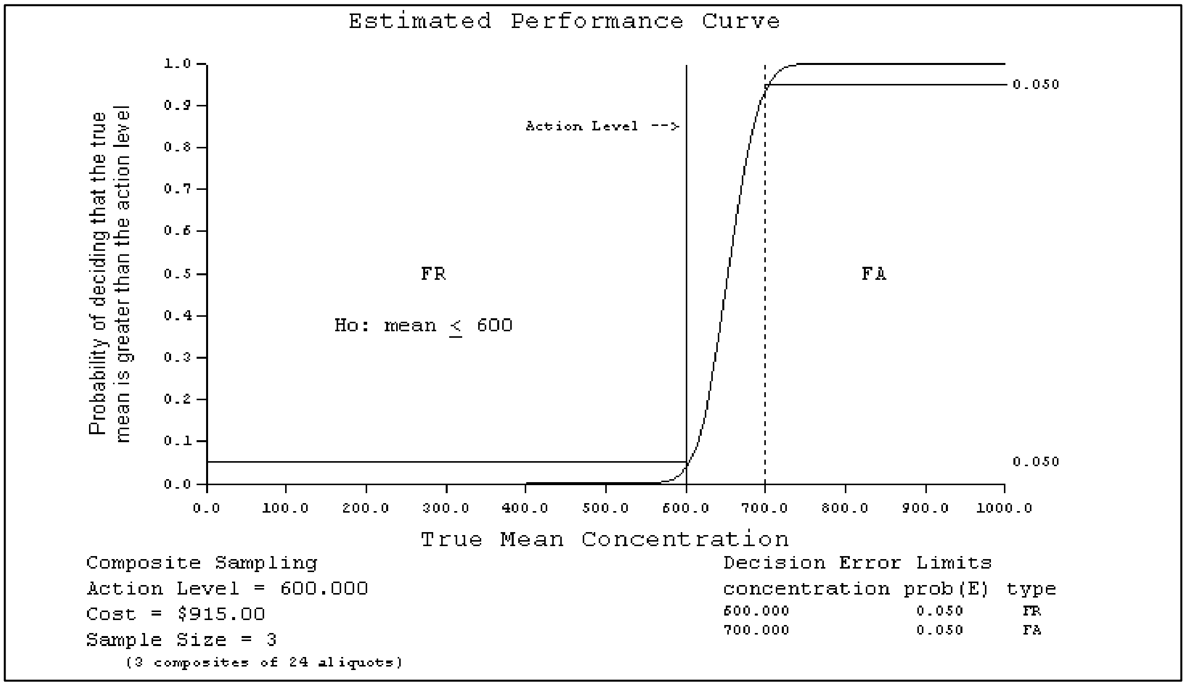
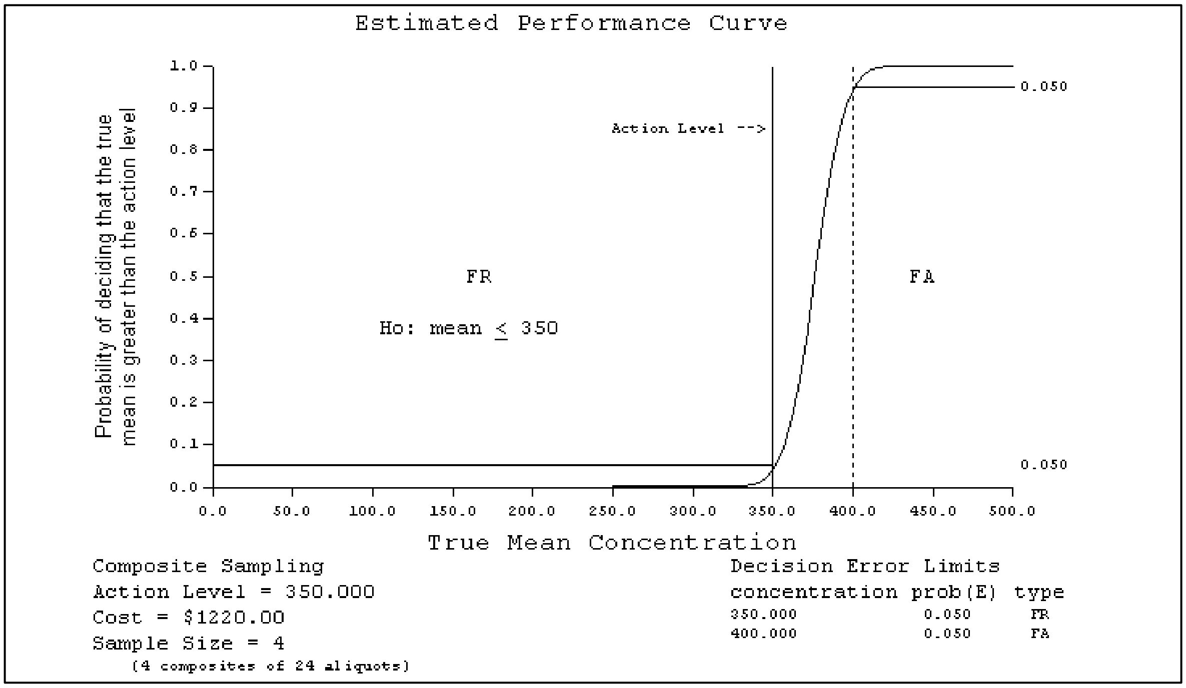


Figure 27
Automatic Sampler at the Control Level (600 g/day)
(1 sample per hour for 24 hours)



Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Figure 28
Automatic Sampler at the Control Level (350 ng/L)
(1 sample per hour for 24 hours)

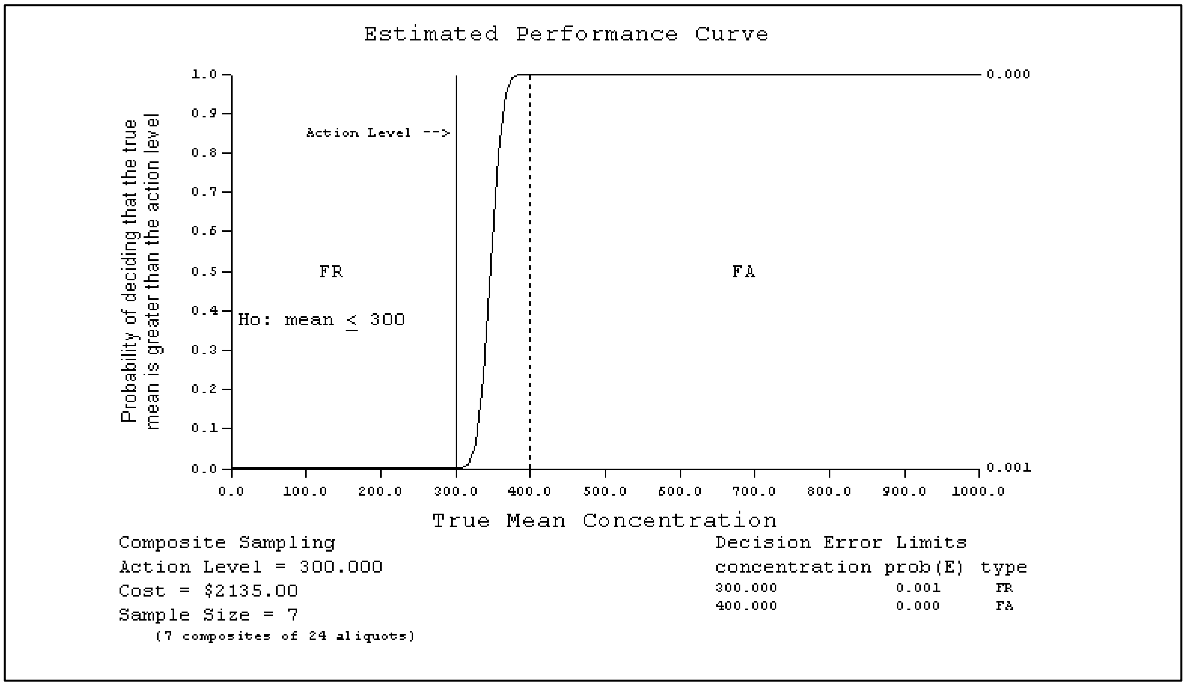


Composite Sampling
Action Level = 350.000
Cost = $1220.00
Sample Size = 4
(4 composites of 24 aliquots)

Decision Error Limits

concentration	prob(E)	type
350.000	0.050	FR
400.000	0.050	FA

Figure 29
Routine to Evaluation Level with Automatic Sampler
Action level of 300 g/day



Composite Sampling
Action Level = 300.000
Cost = $2135.00
Sample Size = 7
(7 composites of 24 aliquots)

Decision Error Limits

concentration	prob(E)	type
300.000	0.001	FR
400.000	0.000	FA

Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Figure 30
Routine to Control Level with Automatic Sampler
Action level of 600 g/day

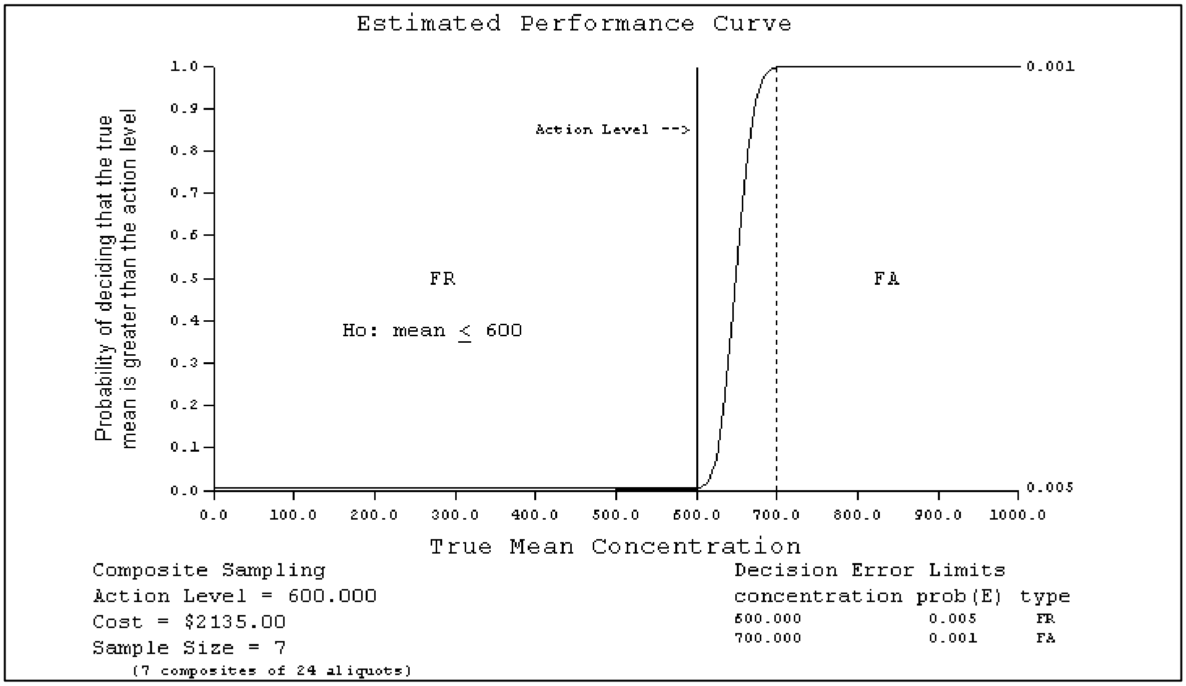
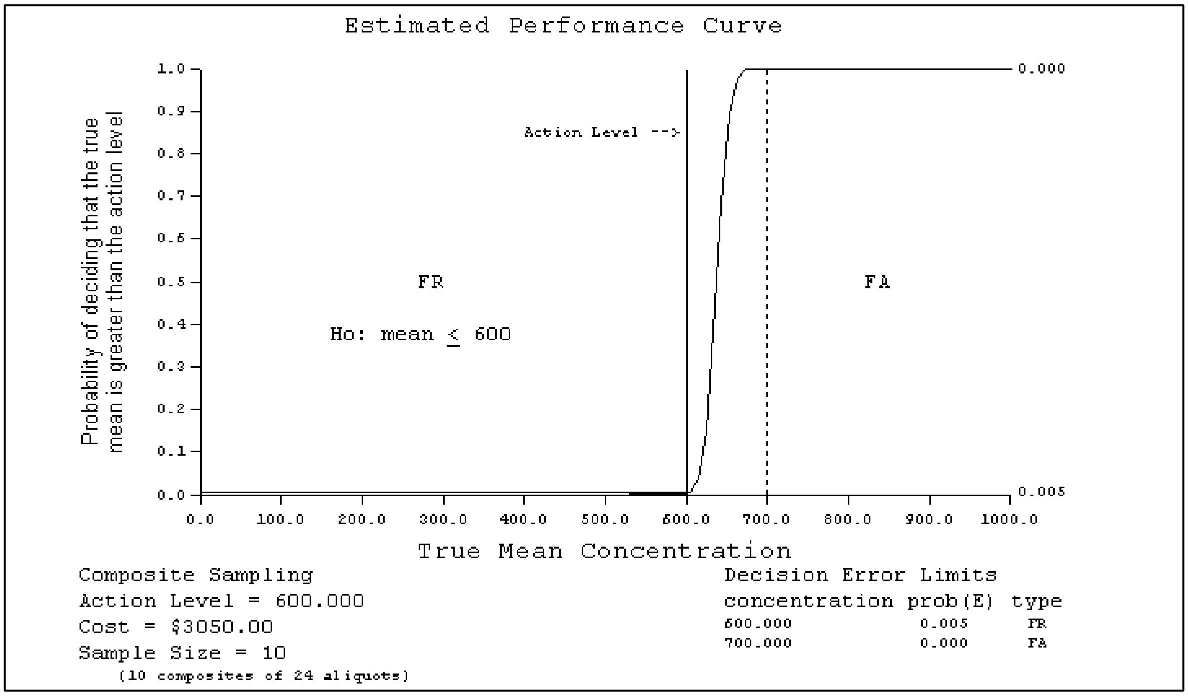


Figure 31
Confirmation of the 600 g/day with Automatic Sampler
Action level of 600 g/day



Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Figure 32
Routine to Control Level with Automatic Sampler
Action level of 350 ng/L

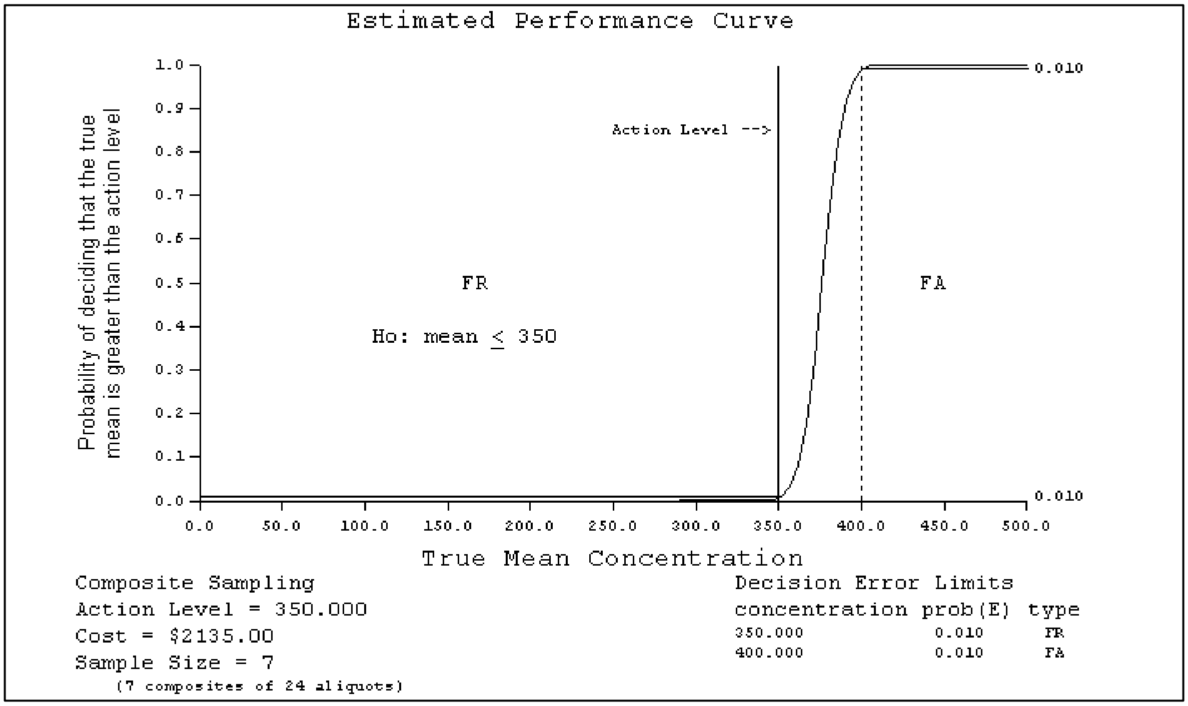
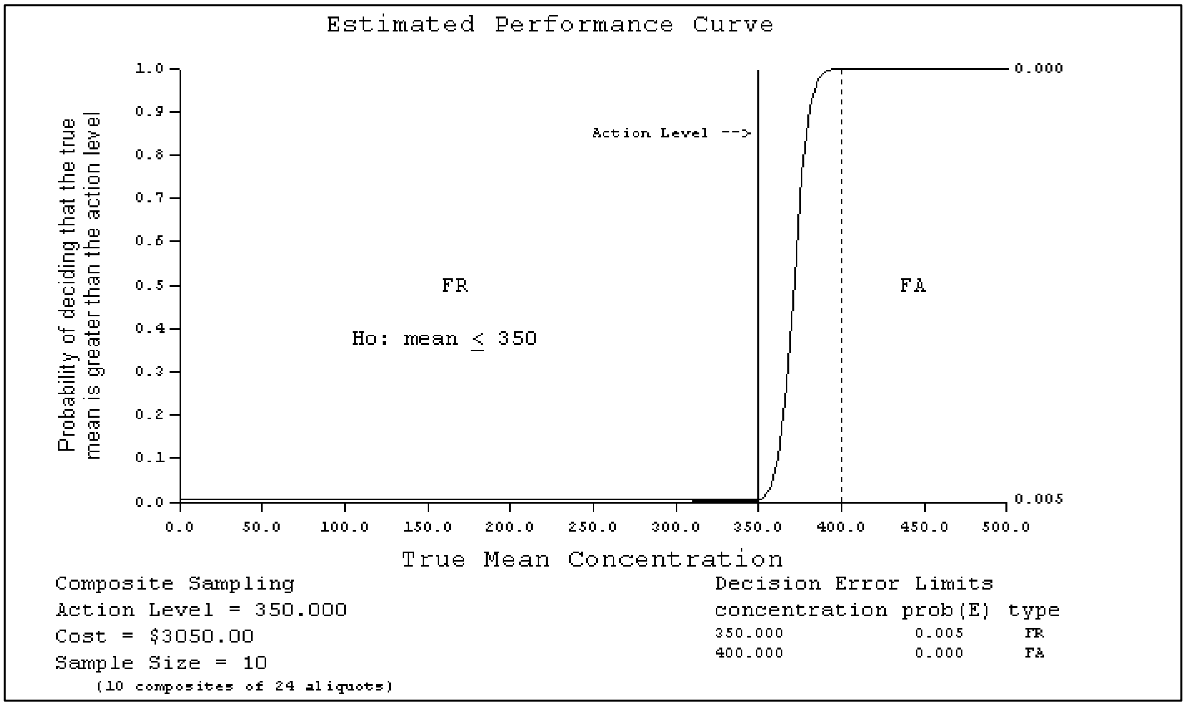
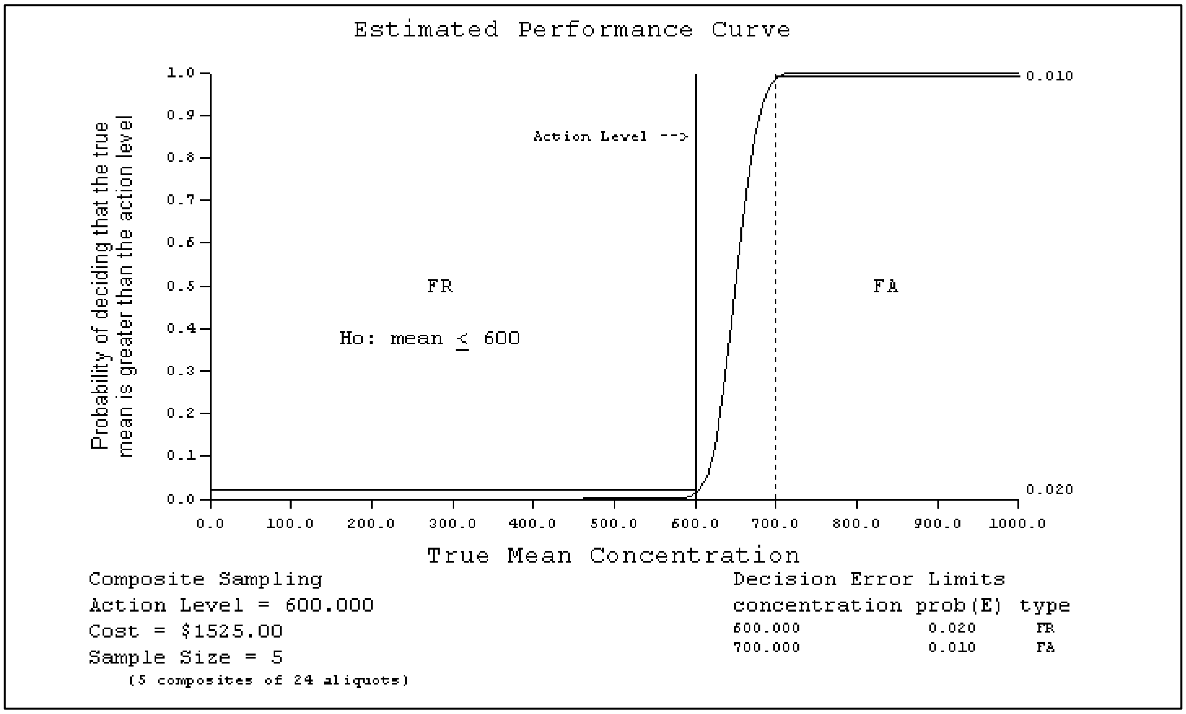


Figure 33
Confirmation of the 350 ng/L with Automatic Sampler
Action level of 350 ng/L



Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Figure 34
Evaluation to Control Level with Automatic Sampler
Action Level 600 g/day



Note: Figures generated from DQO – DEFT using a coefficient of variation for all total PCB cases of 25 percent.

Attachment H

Estimated Cost and Feasibility of the Phase 1 Monitoring Program

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Attachment H

Estimated Cost and Feasibility of the Phase 1 Monitoring Program

1.0 Abstract

Cost estimates for the Phase 1 monitoring program were calculated assuming that the major costs for the monitoring program are the labor costs to collect the samples and the analytical costs. On this basis, the estimated cost of the Phase 1 monitoring program is approximately $3,000,000. The estimated cost of the Phase 1 monitoring program cannot be used as a basis for estimating the monitoring costs for the remainder of the remediation. The Phase 1 monitoring program is designed to measure compliance with the standard and to evaluate and refine the implementation of the standard. The sampling efforts for the second objective are designated as “special studies.” The results of the monitoring in Phase 1 will determine the extent to which the Phase 1 monitoring program requirements can be reduced (after the completion of Phase 1) and still measure compliance with the resuspension criteria with an acceptable degree of certainty.

2.0 Introduction

A number of different sampling and data collection events of which the Phase 1 monitoring program is included, will occur as part of the remediation of the Hudson River PCBs Site. Components of the Phase 1 monitoring program include various water column sampling and analyses to assess different techniques and measurement types for monitoring and verifying compliance with the Resuspension Performance Standard; and also to generate additional data to improve understanding of the sediment and contaminant transport processes which may occur during the dredging program. Ongoing monitoring during dredging operations subsequent to Phase 1 (Phase 2 monitoring) will include monitoring conducted from the second year of the dredging program through its completion. It is anticipated that the Phase 2 monitoring program will not be as intensive as the Phase 1 program, as it is expected that data obtained during Phase 1 will enable either the number of samples, or the analytical parameters, to be reduced while still ensuring compliance with the resuspension criteria.

In addition to compliance monitoring, the Phase 1 monitoring program includes five special studies for the resuspension standard. These are as follows:

- Near-field PCB Release Mechanism (Dissolved vs. Particulate)
- Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement for the Near-field and Far-field Stations (Bench Scale)
- Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement for the Near-field and Far-field Stations (Full Scale)
- Non-Target, Downstream Area Contamination
- Phase 2 Monitoring Plan

These studies are intended to:

- Determine the Total PCB water column concentrations and the nature of contaminant release from the remedial operations (dissolved or suspended phase release).
- Determine and maintain a semi-quantitative relationship between TSS and a real-time surrogate measurement.
- Determine the extent of downstream contamination in the non-target areas.
- Establish alternate strategies to more efficiently handle the requirements of the monitoring program.

Costs for these special studies are also provided where sufficient scope for the study is available.

The estimated costs of the Phase 1 program cannot be used to project the monitoring costs for the rest of the remedial program, since it is likely that the Phase 1 program is be more sample- and analytical-intensive than the Phase 2 monitoring program will be.

The cost estimate provided in this analysis focuses on the two main elements of the program: labor and laboratory analytical cost. The cost estimate for the Phase 1 monitoring program is based on specific scenarios for implementing the monitoring program, which are described in detail below. Standard laboratory rates are used to estimate the analytical costs; however, it is likely that lower rates can be negotiated for this program (due to the large quantity of analyses being performed). The final cost of the Phase 1 monitoring program will also be dependent on the degree to which the operations are in compliance with the resuspension criteria.

Alternate strategies may be developed to more efficiently handle the requirements of the monitoring program. Other modifications to the monitoring program, which reduce the costs of the program, will be acceptable, as long as all data quality objectives are met and the modification is not so substantial as to cause the resuspension criteria to be reevaluated. The standard requires that a special study establishing any proposed alternate strategies for sampling be demonstrated concurrently with the Phase 1 program.

3.0 Phase 1 Compliance Monitoring Cost Estimate

It is assumed that the primary costs for the Phase 1 monitoring program will be labor costs associated with the sample collection and laboratory analytical costs. It is also assumed that the quality assurance/quality control requirements will be limited due to the quick turnaround requirements. Estimated costs for these elements for the monitoring program described in the Resuspension Performance Standard were developed and are described below. The labor costs are a function of two variables: the level of effort (i.e., the personnel-hours required to collect the samples), and the labor rates (dollars per hour). Similarly, the analytical costs are a function of the number of analyses of each type performed (e.g., PCB analysis, TSS, total organic carbon), and the unit cost for each of these analyses.

The calculated cost estimates for the Phase 1 monitoring presented assumes that two field laboratories will be established to perform the total suspended solids (TSS) analyses. As the facilities (a mobile office trailer) and equipment (scale, oven, filters, and glassware) are relatively simple and inexpensive, costs for the field laboratories (which will likely be less than $10,000 for each) are not included in this estimate. Costs for the technicians to perform the analyses are not included in this estimate; however, the costs for the TSS analysis are addressed as a laboratory analytical cost (based on the cost of an off-site laboratory performing the TSS analyses). The estimated samples required and the laboratory analytical costs for routine and non-routine monitoring are provided in Tables 1 through 3.

In the discussion below, a number of the sampling activities are discussed relative to the ‘operations’ which are occurring at the time. In this context, ‘operations’ means any remedial activities that involve sediment disturbance. These activities will be primarily the dredging activites, but may also include other activities such as debris removal and installation or removal of containment other than silt curtains.

3.1 Labor Costs - Level of Effort (LOE)

The level of effort for both the routine monitoring and non-routine monitoring efforts are presented below. Each (routine and non-routine) is further subdivided into the LOE estimate for near-field and far-field sample collection.

3.2 Routine Monitoring with Automated Suspended Solids Collection

3.2.1 Far-Field (Including Baker’s Falls)

If the 1 suspended sample per every 3 hours is collected by mechanical means (i.e., by an ISCO sampler), there is a significant reduction in LOE requirements of the Ft Edward, TI Dam, Schuylerville, Stillwater and Waterford stations, for all action levels. Using automated samplers will not change the LOE requirements of the remaining stations. Under these conditions, the field crews would manually collect the whole-water PCB, DOC and grab suspended solids samples. The field crew would also be responsible for picking up the automated suspended solids samples, replenishing sample vials in the ISCO devices and delivering the samples to the field laboratories. One field crew could sample multiple stations during each shift, with a reasonable breakdown of stations being Ft Edward/TI Dam and Schuylerville/Stillwater/ Waterford.

The LOE breakdown for routine monitoring is shown in Table 4.

It may be possible for 1 crew to collect the samples at all 5 stations, but when considering possible problems related to collection at the TI Dam, a more conservative estimate is more appropriate.

3.2.2 Near-Field

One crew should be able to handle up to five operations of near field sampling. Above that, a second crew will be required. Each crew will consist of two samplers and one boat operator. The crew will collect the samples, fill out required paperwork and transport the samples to the field labs described above.

The LOE breakdown (for five operations) for routine monitoring is shown in Table 5.

The major assumption of this estimate is that the dredging operations are within close proximity to one another (i.e., all are within the same pool). Additional personnel will be required if operations are being conducted in two or more pools.

3.2.3 Routine Monitoring LOE Summary

Based on the near-field and far-field estimates and the assumptions listed above, the LOE for routine monitoring is between 10 and 16 people per day (the variability is contingent on specifics of operations) to collect samples, fill out paperwork and transport the samples to one of two field labs for the duration of the program.

3.3 Non-Routine Monitoring with Automated Suspended Solids Collection

3.3.1 Far-Field (Including Baker's Falls)

For non-routine sampling with automated suspended solids collection, the station assignments of the field crews must change as a result of the additional sampling requirements and consideration of river mile. The realignment would be Ft Edward/TI Dam/Schuylerville and Stillwater/Waterford. The Sampling Level dictates the number of additional crews required. Under most instances, 1 additional crew is added for each sampling event. For example, a second crew is added during Evaluation Level monitoring and a third crew is added for Concern Level evaluation. For Threshold Level monitoring, a fourth crew is added to collect the 4 required samples.

The LOE breakdown is for non-routine monitoring is shown in Table 4.

Additional reductions in LOE requirements for both routine and non-routine monitoring may be possible if technicians at the field laboratories are made responsible for picking up automated suspended solids samples from the ISCO samplers.

3.3.2 Near-Field

The hourly suspended solids sample collection requirement of the non-routine monitoring would require one crew per two operations, with an additional person added to each crew to shuttle samples to the field laboratories.

The LOE breakdown (assuming six operations) is for non-routine monitoring is shown in Table 5.

With two or fewer operations, only one additional person (relative to routine monitoring) per shift would be required; five additional people per shift would be required for three or four operations; nine people per shift for five or six operations, and so on. The maximum number of additional people would be 17 people per shift at a maximum of 10 operations.

The major assumption of this estimate is that dock space can be accessed nearby the operations so that the time required to get the samples to shore for transport to the labs is not a significant factor. As with Routine Monitoring, the estimate assumes that operations are being conducted in the same pool, and the LOE is estimated only for sample collection, documentation and transport to the field labs.

A concern of the non-routine sampling is the immediate need for the additional personnel if the surrogate relationship is not in compliance. The range of people required for non-routine sampling (personnel in addition to the full-time staff doing routine monitoring) is significant, starting at 9 people (Evaluation Level, one or two operations) up to a maximum of 33 additional personnel (Control Level, 10 operations). At the maximum level, the size of the field crew essentially doubles. From a resource management standpoint, maintaining a pool of 30 qualified and trained individuals to be ready to sample with less than 12 hours notice would be difficult, at best.

3.3.3 Non-Routine Monitoring LOE Summary

Based on the near-field and far-field estimates and the assumptions listed above, the LOE for non-routine monitoring is between 14 and 56 people per day (the variability is contingent on specifics of operations) to collect samples, fill out paperwork and transport the samples to one of two field labs for the duration of the program.

4.0 Cost Parameters

Labor Rates

It is assumed that the average cost for sampling technicians during an 8-hour shift will be $416 ($52/hour loaded rate, based on a $20/hour direct rate and an overhead factor of 1.6).

Laboratory Analysis – Estimated Quantities

The estimated laboratory analysis quantities for far-field (Upper Hudson River and Lower Hudson River) and near-field laboratory analyses are provided in Tables 1 through 3.

Laboratory Analysis - Unit Costs

The estimated unit costs for laboratory analyses are listed below.

PCB Congeners (standard turnaround time)	$	300
24-hour Turnaround Time	$	600
72-hour Turnaround Time	$	525
Suspended Solids 3-hour Turnaround Time	$	20
Dissolved Organic Carbon	$	35
Suspended Organic Carbon	$	60

The PCB congener rates above assume a 100 percent surcharge for 24-hour turnaround time, and a 75 percent surcharge for 72-hour turnaround.

5.0 Special Studies

The monitoring programs for the resuspension and residual standards are organized to separate sampling necessary to measure compliance with the standard from sampling efforts needed to evaluate and refine the implementation of the standard. This has been accomplished by designating the second category of sampling efforts as “special studies.” The special studies will be conducted for limited periods of time to gather information for specific conditions that may be encountered during the remediation or to develop an alternate strategy for monitoring. Specific conditions may include different dredge types, contaminant concentration ranges, and varying sediment textures. Each of these studies is integral to the Phase 1 evaluation, the development of Phase 2, and is also tied to compliance issues.

There are a total of five special studies for the resuspension standard. These are as follows:

- Near-field PCB Release Mechanism (Dissolved vs. Particulate)
- Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement for the Near-field and Far-field Stations (Bench Scale)
- Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement for the Near-field and Far-field Stations (Full Scale)
- Non-Target, Downstream Area Contamination
- Phase 2 Monitoring Plan

Costs for the near-field PCB, semi-quantitative relationship (bench scale) and non-target downstream area contaminant special studies are provided. The full scale semi-quantitative relationship is included in the cost of compliance monitoring. No cost estimates can be calculated for the Phase 2 monitoring plan special studies because the s scope of the study has not been defined.

5.1 Near-field PCB Release Mechanism (Dissolved vs. Particulate)

The special study to characterize near field PCBs will consist of collecting samples in the vicinity of a remedial operation once a day for approximately seven days. This would be one event. It is estimated that approximately five events would be needed to characterize the different conditions during remediation. The samples would be collected from upstream, in two transects across the plume downstream from the dredge and within the containment, if present. The samples will be depth integrated. There will be five sample locations along each transect. Most of the samples will be collected for whole water analysis, but a subset will be filtered and both the suspended and dissolved phase sent for analysis. An acoustic sensor will be used to define the extent of the plume

It is assumed that two boats with a crew of three technicians will be required each day of sampling at a single location for a full day. One boat will be responsible for defining the extent of the plume and identifying the sampling locations while the other boat collects the samples.

Thus the LOE breakdown (for the 7-day operations) is:

2 crew x 3 people x 1 shifts per day = 6 people per day for the duration of the program.

The estimated costs are provided in Table 6.

5.2 Development of a Semi-Quantitative Relationship between TSS and a Surrogate Real-Time Measurement for the Near-field and Far-field Stations (Bench Scale)

To determine an initial relationship between TSS and a surrogate (turbidity or laser particle analysis) it is proposed that three types of sediment (silty, fine sand and medium sand) be collected for detailed analysis. For each sediment type one bucket full of sediment will be required.

For labor costs, assume that one field crew of 2 people can collect and handle the 3 buckets of sediment in an 8-hour day. Thus:

1 crew x 2 people x 1 day = 2 man days, to collect the material.

Therefore the labor costs are approximately $832.

To conduct the bench study from this material, the following cost estimate is based on the USACE Long Tube Settling Test (LTST) and the batch test as described in a paper by Earhart (Earhart, 1984).

As per the USACE methodology, the LTST takes a full 15 days to determine compression settling results, however, the test could be run for just a few days to determine the turbidity-TSS correlations only.

Assuming three sediment samples are tested, the costs are as follows:

$4000	Column construction (one LTST column as per EM 111-2-5027)
$3000	Labor and supplies to do a column settling test for one sediment sample assuming a column run of 3 days (note: the cost for multiple columns in use simultaneously would be less) x 3 samples
$3000	Earhart method correlations (for each sediment sample) x 3 samples

$10000 report preparation and QC reviews for all testing.

Summarizing, for 3 samples:

$4000 + $9000 + $9000 + $10000 = $32,000.

The total estimated cost for this study is approximately $33,000.

5.3 Non-Target, Downstream Area Contamination

For a study involving 40 sediment trap locations that are distributed over a 5 acre area, and with each of the 40 locations has co-located sediment traps, the following is an estimate of costs including the cost of the sampling equipment, labor, and sample handling.

There are very few easily identifiable vendors for sediment traps. However, based on a quote from Aquatic Research Instruments from Hope ID, the price for one sediment trap would be about $175. It was indicated that purchasing by volume could affect this price, but using that quote for estimation purposes:

$175 per sediment trap x 80 traps = $14,000. Add another $500 for necessary sundry equipment (stakes & rope which are necessary for trap deployment), and the total cost for equipment is $19,000.

For labor costs, assume that it will take one 2-man crew 3 days to deploy the 80 traps, 1 day per week to collect and manage the samples for the 3-week program, and one day for demobilization, the labor estimate would be:

1 crew x 2 people x 7 days = 14 man days.

This estimate assumes 10 or 12-hour days. Therefore, the labor costs can be estimated as approximately $12,000 (14 man days, 12 hours with over time).

Assuming the study duration is three weeks approximately 160 samples, the lab analytical costs will be approximately $48,000.

The total estimated cost per study is approximately $79,000. For five studies (assuming the traps can be reused), the total cost for this special study is approximately $319,000.

6.0 Reasonable Estimate of Monitoring Program Cost

The weekly costs for far-field (Upper Hudson River and Lower Hudson River) and near-field laboratory analyses are provided in Tables 1 through 3. The daily cost for far-field and near-field labor are provided in Tables 4 and 5. The costs per day are summarized in Table 7.

The cost of the monitoring program will depend on the amount of time that is spent at each monitoring level. It is assumed that Phase 1 will last for 30 weeks and have 210 days of operation. Far-field monitoring will be conducted every day during Phase 1. Near-field monitoring will be conducted only on the days of operation.. During Phase 1, on average four operations will be ongoing throughout to meet the production goal of half the annual production rate. If the monitoring level is routine through Phase 1, the cost of the monitoring program will be approximately $4,000,000.

Cost if Routine Throughout Phase 1	
Upper River Far-Field	$987,425
Lower River Far-Field	$ 14,400
Near-Field	$527,072
Total	$1,528,897

It is likely that some amount of non-routine monitoring will be required during Phase 1, although extended periods of higher level monitoring (Control Level or Threshold) are not foreseen because the amount of resuspension export can be controlled by changes to the remediation like maintaining strict adherence to operating procedures. It is unlikely that the concentrations at Waterford will exceed 350 ng/L Total PCB if Phase 1 is conducted in River Section 1 and the baseline concentrations stay relatively low. Therefore, it is likely that the Lower River Far-Field monitoring will be at the Routine Level throughout Phase 1. For a reasonable estimate of Upper River Far-Field monitoring, it is assumed that Routine Level monitoring will be needed for 26 of the 30 weeks and Control Level monitoring will be needed for the remaining four weeks. Similarly for Near-Field monitoring, it is assumed that all stations will be in compliance for 26 weeks and non-routine monitoring will be required for four weeks. This near-field non-compliant monitoring is somewhat high assuming four stations will be out of compliance at each of the 4 operations, but this additional cost may address the limited far-field monitoring that will accompany exceedances of the near-field suspended solids resuspension criteria and engineering evaluations. The estimated costs the special studies (for near-field PCBs, bench scale for a semi-quantitative relationship and non-target contaminant) are presented in Table 8. A reasonable estimate of the monitoring program cost for Phase 1 is also provided in Table 8.

The present worth cost estimated for the selected remedy in the feasibility study (FS, [USEPA, 2000]) is $470,000,000. During Phase 1, approximately 10 percent of the total volume to be removed will be dredged. Assuming that the cost of Phase 1 will be in proportion to the amount of sediment dredged, the cost for the Phase 1 operations will be approximately $47,000,000. For both the minimum monitoring requirements and the reasonable estimate, the monitoring program represents less than 10 percent of the total cost of the Phase 1 program.

The Phase 1 monitoring encompasses more than merely demonstrating compliance with the resuspension criteria and has been developed to provide answers to questions such as the nature of the PCB releases. This data generated during the Phase 1 monitoring program can be used throughout the remediation and justifies the cost of the program. The water column monitoring cost estimated in the FS for the selected remedy was substantially lower than the estimated cost of the Phase 1 program presented herein; however, the performance standard requirements were added during development of the ROD in response to public comments and the additional costs associated with meeting fixed standards and answering the questions raised by the public are accounted for in this estimate. One important goal of the monitoring program during Phase 1 is to gather data to demonstrate that the water column concentrations and loads can be assessed with confidence using fewer or less costly measurements (suspended solids or turbidity, as opposed to PCB analysis). If a semi-quantitative relationship is demonstrated during Phase 1, the monitoring program can be reduced accordingly for Phase 2.

The costs used in this estimate are conservative. The analytical costs used in these estimates are higher than what may be negotiated given the large amount of samples. The amount of labor needed for the monitoring program could differ from what is estimated here. For instance, if the laboratory were to filter the whole water samples for the levels other than routine, there would not be a need to add additional people for far-field sampling (with perhaps an addition of two people to shuttle samples to the lab). In addition, the monitoring program has been developed to conform to a series of data quality objectives. This allows for alteration of the monitoring plan as long as all of the data quality objectives are met. As a result, less costly means of achieving these objectives may be developed. Similarly, the costs for operating two field laboratories for seven months (assuming staffing by one technician each for 24 hours per day, seven days per week) may be on the order of about $550,000 (total for two field labs – based on the same labor rates as above; and trailer rental and equipment costs of about $10,000 for each field lab); this may be less costly than the estimate herein, which is based on off-site laboratory costs for the TSS analyses.

7.0 Feasibility and Other Considerations

The benefit of using ISCO samplers lies in labor cost savings, as the collection of the 8 daily TDS samples at the far-field stations will be automated. Under this proposed sampling plan, whole-water PCB and the associated TDS sample will still be collected manually, with depth-integrated samplers. Field personnel will also be required to gather the ISCO-generated samples and to replenish sample bottles in the ISCO. The schedule for this must be determined so as to accommodate overall QC requirements. This task could effectively be shared between the crews collecting the PCB samples and the field laboratory personnel.

The ISCO samplers must be positioned in locations that are within product specifications (e.g., distance from and height above the river) and, to prevent tampering, the ISCOs must be properly secured. Electric power will have to be provided to the locations, unless models employing low-voltage DC-current are employed.

Another benefit of the automated samplers is the elimination of variation between samples, caused by differences in sampling technique of the individual sampler or by differences in sampling location. They also eliminate the need for people to be out on bridges or near dams in the dark or inclement weather.

However, the primary advantage of this program is the elimination of managing large pools of samplers, many being “on-call” for extended periods. Coordinating personnel required to collect samples at increasingly higher action levels becomes much easier than the previous program. Under the current plan, a small pool of individual collect the whole-water PCB samples, reducing the potential for variability in sample technique and thereby providing the best opportunity to meet data quality objectives.

The use of ISCOs will require the inlet lines be permanently mounted within the river and safe from recreational traffic. At the 4 bridge stations, inlet tubing could be attached to bridge abutments or to buoys near the bridge. At the TID station, recreational traffic is not necessarily an issue; so weighted tubing could be strung from the sampler to buoys positioned at a safe distance upriver of the dam. This will allow for precise positioning of intakes to address concerns about flow at that station.

Routine maintenance will likely be required on the ISCO intake ports, as well as after storm events, to clear accumulated debris carried by the current. This may also involve repositioning the intake ports due to drift or to high flows. This task can be best accomplished through the use of a johnboat transported by vehicle between stations and launched nearby the station.

This proposed program makes efficient use of sampling crews by pairing up locations for each PCB sampling event. For example, under Routine monitoring conditions, 1 crew of 2 individuals will sample the Ft. Edward and TID stations (upriver crew), while another crew of 2 people (downriver crew) will sample the Schuylerville, Stillwater and Waterford stations. The travel time between the Ft Edward and TID stations is approximately 10 minutes, meaning that this crew should have a relatively easy time collecting the samples from both stations. The upriver crew only samples 2 stations due to unique problems presented at the TID station. The downriver crew will sample 3 stations, however the short travel time (approximately 10 minutes between each station) and the relative ease of collection at these stations warrant the additional station. Each of these stations require sampling from bridges that have wide sidewalks and guard rails for safety.

Another factor to consider is the placement of the mobile labs. If the labs are situated near the TID station and near the Waterford station, the crew could deliver the upstream sample to the lab for processing then move downriver to collect samples at the next station.

With respect to meeting the required turn around times for sample analysis, the proposed extraction method for PCB analysis is solid-phase extraction (SPE). Although the extraction time varies somewhat based on the physical characteristics of the sample (e.g., suspended matter which may tend to slow down the process), it appears that the actual process can be completed in an hour or so. Add to that the analysis itself, which may take a minimum of an hour (based on the time from injection of the sample through the completion of the analysis). However, it needs to be considered that extraction for 1-L samples is fairly automated; the 8-L extraction requires manual intervention during the extraction.

It thus appears that 24-hour TAT for PCBs for the proposed 1-L method is at least theoretically achievable. Whether or not this would require the lab to run additional shifts (add a second and/or third shift) or weekend shifts is a separate issue that would be contingent upon the scheduling of sample delivery to the laboratory, as well as how many samples had to be processed at once.

A hidden advantage in the decrease in sampling staff is a net decrease in the potential for safety incidents. The smaller pool of samplers in this program will become acquainted with specific safety issues at each site, which will help in minimizing accidents. For additional safety measures, a communication system should be employed, such as hand-held radios or a higher gain system that could be tied into the field laboratories, as well. All field personnel should be required to carry cellular telephones (with service that covers the area in question) to contact local authorities. The Hudson valley presents unique problems to cellular customers, so care should be paid as to which cellular carrier is chosen. The Minimal safety equipment for the crewmembers will be steel-toed boots, hard hats, safety glasses, nitrile gloves and PFDs.

8.0 Conclusions

The Phase 1 monitoring plan developed for the performance standard measures compliance with the resuspension criteria and provides important information on the nature and impact of the remediation on the river. The estimate cost of the water column monitoring is approximately $3,000,000. The costs developed for Phase 1 cannot be applied to the entire remediation, because modifications to the monitoring program may be made for Phase 2; it is likely that these modifications will result in cost reductions after the Phase 1 program data are reviewed and the Phase 2 monitoring program is optimized.

9.0 References

Earhart, H.G. 1984. "Monitoring total suspended solids by using nephelometry," Environmental Management 8(1), pp. 81-86.

USEPA, 2000. Phase 3 Report: Feasibility Study, Hudson River PCBs Reassessment RI/FS. Prepared for USEPA Region 2 and the US Army Corps of Engineers (USACE), Kansas City District by TAMS Consultants, Inc. December 2000.

Tables

Table 1
Sampling Cost on a Weekly Basis - Upper River Far-Field Stations

Routine Monitoring Number of Samples per Day Only	Lab Turn-Around Time (hr.)	Laboratory Analyses				Integrating Sampler for PCBs	Laboratory Analyses				Integrating Sampler for PCBs
		Congener-Spec. PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)^3		Congener-Spec. PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)^3	
RM 197.0 - Bakers Falls Br.	72	1	1	1			525	95	20		
RM 194.2 - Ft Edward	72	7	7.5	7.5	56	0.5	3,675	713	150	20	150
RM 188.5 - TI Dam	24	7	7.5	7.5	56	0.5	4,200	713	150	150	150
RM 181.4 - Schuylerville	24	7	7.5	7.5	56	0.5	4,200	713	150	150	150
RM 163.5 - Stillwater	72	7	7.5	7.5	56	0.5	3,675	713	150	150	150
RM 156.5 – Waterford	72	7	7.5	7.5	56	0.5	3,675	713	150	150	150
Analytical Cost/Week		36	38.5	38.5	280	2.5	19,950	3,658	770	620	750
Total Analytical Cost/Week		**38.5 or 5.5 /day**					**25,748 or 3,678 /day**				

Evaluation Level Number of Samples per Day Only	Lab Turn-Around Time (hr.)	Laboratory Analyses				Integrating Sampler for PCBs	Laboratory Analyses				Integrating Sampler for PCBs
		Congener-Spec. PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)^3		Congener-Spec. PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)^3	
RM 197.0 - Bakers Falls Br.	72	1	1	1			525	95	20		
RM 194.2 - Ft Edward	72	7	7.5	7.5	56	0.5	3,675	713	150	20	150
RM 188.5 - TI Dam	24	14	0.5	0.5	56	0.5	8,400	48	10	150	150
RM 181.4 - Schuylerville	24	14	0.5	0.5	56	0.5	8,400	48	10	10	150
RM 163.5 - Stillwater	72	7	7.5	7.5	56	0.5	3,675	713	150	10	150
RM 156.5 – Waterford	72	7	7.5	7.5	56	0.5	3,675	713	150	150	150
Analytical Cost/Week		50	24.5	24.5	280	2.5	28,350	2,328	490	340	750
Total Analytical Cost/Week		**52.5 or 7.5 /day**					**32,258 or 4,608 /day**				

Control Level Number of Samples per Day Only	Lab Turn-Around Time (hr.)	Laboratory Analyses				Integrating Sampler for PCBs	Laboratory Analyses				Integrating Sampler for PCBs
		Congener-Spec. PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)^3		Congener-Spec. PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)^3	
RM 197.0 - Bakers Falls Br.	72	1	1	1			525	95	20		
RM 194.2 - Ft Edward	72	7	7.5	7.5	56	0.5	3,675	713	150	20	150
RM 188.5 - TI Dam	24	21	1	1	56	1	12,600	95	20	150	300
RM 181.4 - Schuylerville	24	21	1	1	56	1	12,600	95	20	20	300
RM 163.5 - Stillwater	72		7	7	56	7		665	140	20	3,675
RM 156.5 – Waterford	72		7	7	56	7		665	140	140	3,675
Analytical Cost/Week		50	24.5	24.5	280	16.5	29,400	2,328	490	350	8,100
Total Analytical Cost/Week		**66.5 or 9.5 /day**					**40,668 or 5,810 /day**				

Threshold Number of Samples per Day Only	Lab Turn-Around Time (hr.)	Laboratory Analyses				Integrating Sampler for PCBs	Laboratory Analyses				Integrating Sampler for PCBs
		Congener-Spec. PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)^3		Congener-Spec. PCBs Whole Water	DOC & Susp. OC	SS	SS (1/3-hours)^3	
RM 197.0 - Bakers Falls Br.	72	1	1	1			525	95	20		
RM 194.2 - Ft Edward	72	1	1	1	8	1/2-weeks	525	95	20	20	21
RM 188.5 - TI Dam	24	4	1	1	8	1	2,400	95	20	20	600
RM 181.4 - Schuylerville	24	4	1	1	8	1	2,400	95	20	20	600
RM 163.5 - Stillwater	24	4	5	5	8	1	2,400	475	100	20	600
RM 156.5 – Waterford	24	4	5	5	8	1	2,400	475	100	100	600
Analytical Cost/Day		18	14	14	40	4	10,650	1,330	280	180	2,421
Total Analytical Cost/Day		**22 /day**					**14,861 /day**				

Table 2
Sampling Cost on a Weekly Basis - Lower River Far-Field Stations

Lower River Sampling Requirements on a Weekly Basis

Routine Monitoring	Lab Turn-Around Time (hr.)	No. of Analyses/Week			Cost of Analyses/Week		
		Congener-specific PCBs Whole	DOC & Susp. OC	SS	Congener-specific PCBs Whole Water	DOC & Susp. OC	SS
Mohawk R. at Cohoes	72	0.25	0.25	0.25	131	24	5
RM 140 - Albany	72	0.25	0.25	0.25	131	24	5
RM 77 - Highland	72	0.25	0.25	0.25	131	24	5
Analytical Cost/Week		0.75	0.75	0.75	394	71	15
Total Analytical Cost/Week					480		

Non-Routine Monitoring	Lab Turn-Around Time (hr.)	No. of Analyses/Week			Cost of Analyses/Week		
		Congener-specific PCBs Whole	DOC & Susp. OC	SS	Congener-specific PCBs Whole Water	DOC & Susp. OC	SS
Mohawk R. at Cohoes	24	1	1	1	600	95	20
RM 140 - Albany	24	1	1	1	600	95	20
RM 77 - Highland	24	1	1	1	600	95	20
Analytical Cost/Week		3	3	3	1800	285	60
Total Analytical Cost/Week					2145		

Note:
(1) Non-routine monitoring will be triggered only when Waterford or Troy have total PCB concentration greater than 350 ng/L.

Table 3
Sampling Cost on a Weekly Basis - Upper River Near-Field Stations

Near-Field Sampling Requirements on a Weekly Basis
Routine Monitoring (with use of continuous reading probe to indicate suspended solids concentrations)

No. of Operations	No. of SS Laboratory Analyses	Cost of SS Laboratory Analyses
1	35	700
2	70	1400
3	105	2100
4	140	2800
5	175	3500
6	210	4200
7	245	4900
8	280	5600
9	315	6300
10	350	7000

Non-Routine Monitoring

	Number of SS Laboratory Samples with 4-Hour Turn-Around per Week				
	Number of Stations with Exceedences of the Standard				All Stations
No. of Operations	1	2	3	4	5
1	49	98	147	196	245
2	98	196	294	392	490
3	147	294	441	588	735
4	196	392	588	784	980
5	245	490	735	980	1,225
6	294	588	882	1,176	1,470
7	343	686	1,029	1,372	1,715
8	392	784	1,176	1,568	1,960
9	441	882	1,323	1,764	2,205
10	490	980	1,470	1,960	2,450

	Cost of SS Laboratory Samples with 4-Hour Turn-Around per Week				
	Number of Stations with Exceedences of the Standard				All Stations
No. of Operations	1	2	3	4	5
1	980	1,960	2,940	3,920	4,900
2	1,960	3,920	5,880	7,840	9,800
3	2,940	5,880	8,820	11,760	14,700
4	3,920	7,840	11,760	15,680	19,600
5	4,900	9,800	14,700	19,600	24,500
6	5,880	11,760	17,640	23,520	29,400
7	6,860	13,720	20,580	27,440	34,300
8	7,840	15,680	23,520	31,360	39,200
9	8,820	17,640	26,460	35,280	44,100
10	9,800	19,600	29,400	39,200	49,000

Table 4
Labor Cost on a Daily Basis - Far-Field Stations

Routine Monitoring Station	No.of people	No. of shift/day	No. of people/day	Labor /day
Baker's Falls (1)	2	0.1	0.2	
Ft Edward/TID	2	1	2	
Schuyl/Still/Wat	2	1	2	
Total			4.2	$ 1,747

Evaluation Level Station	No.of people	No. of shift/day	No. of people/day	Labor /day
Baker's Falls (1)	2	0.1	0.2	
Ft Edward/TID/Schuyl	2	2	4	
Still/Wat	2	1	2	
Total			6.2	$ 2,579

Contol Level Station	No.of people	No. of shift/day	No. of people/day	Labor /day
Baker's Falls (1)	2	0.1	0.2	
Ft Edward/TID/Schuyl	2	3	6	
Still/Wat	2	1	2	
Total			8.2	$ 3,411

Threshold Station	No.of people	No. of shift/day	No. of people/day	Labor /day
Baker's Falls (1)	2	0.1	0.2	
Ft Edward/TID/Schuyl	2	3	6	
Ft Edward/TID/Schuyl	2	1	2	
Still/Wat	2	3	6	
Still/Wat	2	1	2	
Total			16.2	$ 6,739

Notes:
(1) Other stations includes Bakers Falls Bridge and Lower Hudson.

Table 5
Labor Cost on a Daily Basis - Near-Field Stations

Near-Field Sampling Requirements on a Weekly Basis
Routine Monitoring

No. of Operations	No.of people	No. of shift/day	No. of people/day	Labor /day
1-5	3	2	6	$ 2,496
5-10	6	2	12	$ 4,992

Non-Routine Monitoring

No. of Operations	No.of people	No. of shift/day	No. of people/day	Labor /day
1-2	4	2	8	$ 3,328
3-4	8	2	16	$ 6,656
5-6	12	2	24	$ 9,984
7-8	16	2	32	$ 13,312
9-10	20	2	40	$ 16,640

Table 6
Near-Field Total PCB Concentration Special Studies

Assumptions:
Assume 4 different types of dredges.
One sampling event will be conducted for each dredge type and one debris removal
Sampling will be conducted once per day for one full work week.
There are 7 days per work week.
5 locations are occupied in the transect.
There are 2 transects:one outside the containment and one 100 m downstream of containment
One subsample is located in water depth greater than 10 ft., others less than 10 ft.
At the one deeper location one sample is collected 0-10 ft, one deeper than 10 ft.
At least three samples will be taken within containment and composited
Samples will be vertically integrated.
All work is done in containment.

		Congener-Specific PCBs					
		Whole Water	Dissolved Phase	Suspended Phase	DOC & Susp. OC	SS	Probe Turbidity
Number of upstream samples		1			1	1	1
Number of samples per transect		4	2	2	6	6	6
Number of transects	2						
Number of samples with containment			1	1	1	1	1
Number of Analyses per Day		10	5	5	15	15	15
Number of Days per Event	7						
Total Number of Analyses per Event		70	35	35	105	105	
Analytical Cost Per Event		$ 21,000	$ 10,500	$ 10,500	$ 9,975	$ 2,100	
Total Analytical Cost per Event	$ 54,075						
Number of Technicians per Day	6	(2 boat crews of 3)					
Total Labor Costs per Event	$17,472						
Total Cost per Event (Labor+Analytical):	$ 71,547						
Number of Events	5						
Total for Study	$ 357,735						

Table 7
Summary of Labor and Lab Analytical Costs by Action Level

Phase 1 Costs/Day

Upper River Far-Field Level	Analytical	Labor	Total
Routine	3,678	1,747	5,425
Evaluation	4,608	2,579	7,187
Control	5,810	3,411	9,221
Threshold	14,861	6,739	21,601

Lower River Far-Field Level	Analytical
Routine	69
Non-Routine	306

Near Field Non-Compliant Stations	Routine Analytical	Routine Labor	Non-Routine Analytical 1	Non-Routine Analytical 2	Non-Routine Analytical 3	Non-Routine Analytical 4	Non-Routine Labor
1	100	2,496	140	280	420	560	3,328
2	200	2,496	280	560	840	1,120	3,328
3	300	2,496	420	840	1,260	1,680	6,656
4	400	2,496	560	1,120	1,680	2,240	6,656
5	500	2,496	700	1,400	2,100	2,800	9,984
6	600	4,992	840	1,680	2,520	3,360	9,984
7	700	4,992	980	1,960	2,940	3,920	13,312
8	800	4,992	1,120	2,240	3,360	4,480	13,312
9	900	4,992	1,260	2,520	3,780	5,040	16,640
10	1,000	4,992	1,400	2,800	4,200	5,600	16,640

Table 8
Reasonable Estimate of Phase 1 Season Monitoring Plan Costs

Assume:

Half Production (4-operations on average)

Far-Field Sampling on all days; Near-Field on days of operation

210	days of operation	
30	weeks/Phase 1	
7	days/week far-field sampling	
26	weeks of Routine Monitoring Upper River Far-Field	987,425
4	weeks of Control Monitoring Upper River Far-Field	258,184
30	weeks of Routine Monitoring Lower River Far-Field	14,400
26	weeks of Routine Near-Field Monitoring	527,072
4	weeks of Non-Routine Near-Field Monitoring at 4 Stations	249,088
	Monitoring Cost:	2,036,169
	Special Study for Total PCBs	357,735
	Special Study for Total PCBs	33,000
	Special Study for Total PCBs	319,000
	Monitoring Cost & Special Study:	2,745,904