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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 is 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 (30 m radius) is simulated by the CSTR-Chem. The region from the dredge to a distance of one mile (30 to 1600 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 1A 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:

$$\mathbf{Vs = w = 1/18v * ((r_{sp} / r\,w) - 1)) * g * a^{\wedge}2}$$

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 = $C_f * q^2$ (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 settling velocity was presented as a function of C_1*G (particle concentration * shear stress), 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, is 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) plotted the dye concentration 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.

<u>Water Column Mass Balance for Suspended Sediments[1]</u>

Suspended sediment concentrations in the well-mixed water volume that can be approximated as a CSTR can be approximated by:

$$V_{nf}\frac{dm}{dt} = qm_{in} - qm - v_s A_h m + \dot{M}_R \quad \text{(EQ 3)}$$

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)

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[1] This analysis consists of a mass balance for suspended sediments in the water column only.

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

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:

$$m = \frac{m_{in}q + \dot{M}_R}{l_m V_{nf}} \quad \text{(EQ 4)}$$

and

$$l_m = \frac{1}{q_{nf}} + \frac{v_s}{H} \quad \text{(EQ 5)}$$

where:

V_{nf} = volume of the near-field area (m^3)
? = 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

$$q_{nf} = \frac{V_{nf}}{Q_{nf}} \quad \text{(EQ 6)}$$

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.

$$q_{nf} = \frac{w^2 H}{uHw} = \frac{w}{u} \quad \text{(EQ 7)}$$

where:

u = linear velocity of water (m/s)

The solids concentration inside the CSTR before settling can be expressed as:

$$m_{added} = m_{in} + \frac{\dot{M}_R}{q} \qquad \text{(EQ 8)}$$

and the solids concentration lost to settling is:

$$m_{settled} = m_{added} - m_{out} \qquad \text{(EQ 9)}$$

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:

$$V_{nf} \frac{dc_{Total}}{dt} = qc_{Total,in} - qc_{Total} - v_s A_h F_{s,eq} c_{Total} + \dot{M}_R c_{sed} \qquad \text{(EQ 10)}$$

where:

V_{nf} = volume of the near-field area (m^3)

---

[2] Porewater contributions are assumed to be negligible and are not considered in this analysis.

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)
$c_{s,eq}$ = 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:

$$F_{s,eq} = \frac{K_d m \times 10^{-6}}{1 + K_d \times m \times 10^{-6}} \quad \text{.......(EQ 11)}$$

where:

K_d = two-phase contaminant partition coefficient (L/kg)
m =suspended solids concentration in the near-field

Under steady state conditions:

$$c_{Total} = \frac{q c_{Total,in} + \dot{M}_R c_{sed}}{q + n_s A_h F_{p,eq}} \quad \text{.......(EQ 12)}$$

The equilibrium concentrations in the dissolved phase and suspended phase along with the concentration on the particles can then be computed as:

$$c_{d,eq} = \frac{c_{Total}}{1 + K_d \times m \times 10^{-6}} \quad \text{.......(EQ 13)}$$

$$C_{p,eq} = C_{d,eq} \times K_d \times 10^{-6} \qquad \text{and} \qquad C_{s,eq} = C_{p,eq} \times m \quad \text{.......(EQ 14)}$$

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:

$$K_d = \frac{1 - F_{d,in}}{F_{d,in} \times m_{in} \times 10^{-6}} \text{......(EQ 15)}$$

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:

$$V_{nf}\frac{dc_d}{dt} = qc_{d,in} - qc_d + kV_{nf}\left(c_{d,eq} - c_d\right) \text{......(EQ 16)}$$

$$V_{nf}\frac{dc_s}{dt} = qc_{s,in} - qc_s - kV_{nf}\left(c_{s,eq} - c_s\right) - v_s A_h c_s + \dot{M}_R c_{sed} \text{......(EQ 17)}$$

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:

$$c_d = \frac{qc_{d,in} + kV_{nf}c_{d,eq}}{q + kV_{nf}} \qquad \text{(EQ 18)}$$

$$c_s = \frac{qc_{s,in} + \dot{M}_R c_{sed} + kV_{nf}c_{p,eq}}{q + kV_{nf} + n_s A_h} \qquad \text{(EQ 19)}$$

$$c_p = \frac{c_s}{m} \qquad \text{(EQ 20)}$$

The net contribution of dredging activities can be calculated as:

$$c_{Total,\,net} = \left(c_d + c_s\right) - \left(c_{d,in} + c_{s,in}\right) \qquad \text{(EQ 21)}$$

$$c_{d,net} = c_d - F_{d,in}c_{Total,in} \qquad \text{(EQ 22)}$$

$$\text{and} \quad c_{s,net} = c_s - (1 - F_{d,in})c_{Total,in} \qquad \text{(EQ 23)}$$

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 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 RI/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 1 through 14). 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 in sensitivity values when model sensitivity calculations were done for some parameters (e.g. River wide flow and sediment PCB concentration) along different sections of the river. Therefore, sensitivity values are only presented for section 1 of the river, for most of the other model parameters.

- 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 5). 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 6) and very low sediment PCB concentrations (Figure 8), 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}.

<u>Conclusions</u>

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 of particulate phase PCB to the dissolved phase 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.

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 of the sources strength is not significantly different from the sediment concentration.

<u>Suspended Solids – Kuo and Hayes Model (General Equation)</u>

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:

$$c_{avg} y_{plume} = 2 * \frac{g}{uh\sqrt{4pk_Y x/u}} e^{-\frac{wx}{hu}} * \frac{\sqrt{p}}{2\sqrt{u/(4pk_Y x)}} = \frac{g}{uh} e^{-\frac{wx}{hu}} \qquad \text{(EQ 26)}$$

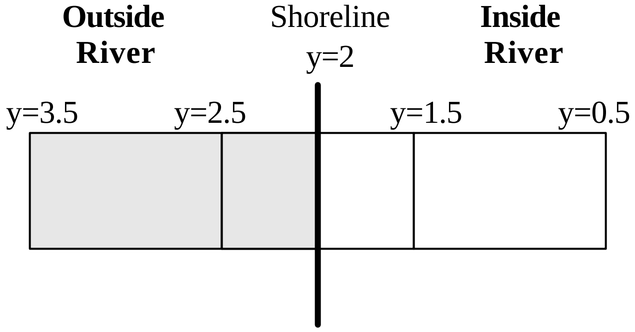
Where: y_{plume} = width of the plume (lateral extent of the plume) (m)

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

$$c(x,y) = \frac{g}{uh\sqrt{4pk_Y x/u}} e^{-\left[\frac{wx}{hu}\right]} \left(e^{-\left[\frac{uy^2}{4k_Y x}\right]} + e^{-\left[\frac{uy_{out}^2}{4k_Y x}\right]} \right) \qquad \text{(EQ 27)}$$

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:

$$y_{out} = (y_{shore} - y) \times 2 + y \qquad \text{(EQ 28)}$$

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:

$$y_{plume} = \sum_{-n}^{n} width_{(box,y=i)} \qquad \text{(EQ 29)}$$

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:

$$c(x,y) = \frac{g_{silt}}{uh\sqrt{4pk_Y x/u}} e^{-\left[\frac{uy^2}{4k_Y x} + \frac{w_{silt}x}{hu}\right]} + \frac{g_{coarse}}{uh\sqrt{4pk_Y x/u}} e^{-\left[\frac{uy^2}{4k_Y x} + \frac{w_{coarse}x}{hu}\right]}$$

or

$$c(x,y) = \frac{g_{total}}{uh\sqrt{4pk_Y x/u}} e^{-\left[\frac{uy^2}{4k_Y x}\right]} \left(f_{silt} e^{-\left[\frac{w_{silt}x}{hu}\right]} + (1 - f_{silt}) e^{-\left[\frac{w_{coarse}x}{hu}\right]} \right) \qquad \text{(EQ 30)}$$

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

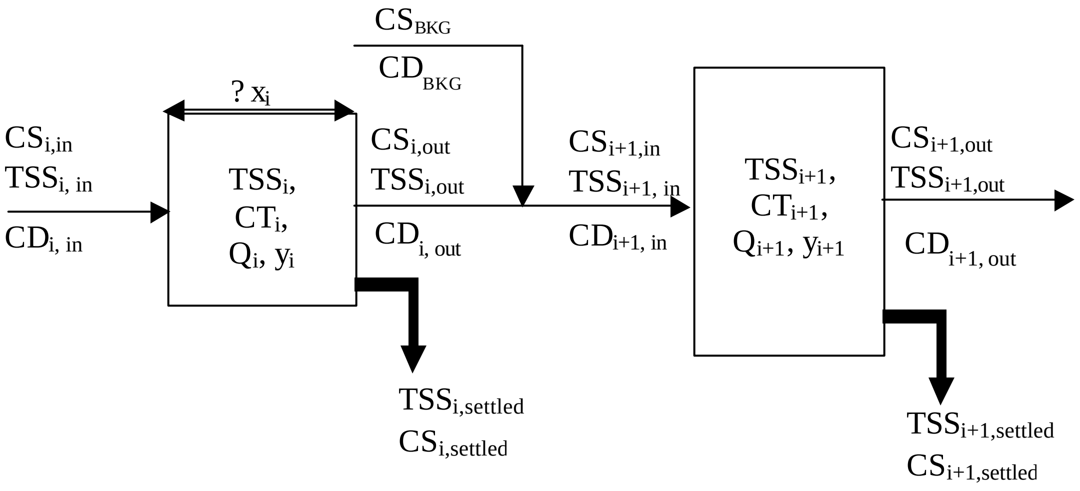
$$c(x,y)=\frac{g_{total}}{uh\sqrt{4pk_Y x/u}}\left(f_{silt}e^{-\left[\frac{w_{silt}x}{hu}\right]}+(1-f_{silt})e^{-\left[\frac{w_{coarse}x}{hu}\right]}\right)\left(e^{-\left[\frac{uy^2}{4k_Y x}\right]}+e^{-\left[\frac{uy_{out}{}^2}{4k_Y x}\right]}\right) \quad \text{(EQ 31)}$$

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:

$$c_{avg}y_{plume}=\frac{g_{silt}}{uh}e^{-\frac{w_{silt}x}{hu}}+\frac{g_{coarse}}{uh}e^{-\frac{w_{cosrse}x}{hu}}=\frac{g_{total}}{uh}\left(f_{silt}e^{-\left[\frac{w_{silt}x}{hu}\right]}+(1-f_{silt})e^{-\left[\frac{w_{coarse}x}{hu}\right]}\right) \text{(EQ 32)}$$

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:

$$F_{CT,BKG,1} = Q_1 CT_{BKG} \qquad F_{CD,BKG,1} = f_{BKG} F_{CT,BKG,1} \qquad F_{CS,BKG,1} = (1 - f_{BKG}) F_{CT,BKG,1}$$

$$F_{CT,Dredge,1} = Q_1 CT_{Dredging} \qquad F_{CD,Dredge,1} = f_{Dredge,1} F_{CT,Dredge,1} \qquad F_{CS,Dredge,1} = (1 - f_{Dredge,1}) F_{CT,Dredge,1}$$

$$F_{CT,1,in} = F_{CT,Dredge,1} + F_{CT,BKG,1} \qquad F_{CD,1,in} = F_{CD,Dredge,1} + F_{CD,BKG,1} \qquad F_{CS,1,in} = F_{CS,Dredge,1} + F_{CS,BKG,1}$$

(EQ 36) (EQ 37) (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:

$$F_{CT,BKG,i+1} = (Q_{i+1} - Q_i)CT_{BKG} * 10^{-6} \qquad \text{(EQ 39)}$$

$$F_{CT,i+1,in} = F_{CT,i,out} + F_{CT,BKG,i+1} \qquad \text{(EQ 40)}$$

$$F_{CD,i+1,in} = F_{CD,i,out} + f_{BKG} F_{CT,BKG,i+1} \qquad \text{(EQ 41)}$$

$$F_{CS,i+1,in} = F_{CS,i,out} + (1 - f_{BKG}) F_{CT,BKG,i+1} \qquad \text{(EQ 42)}$$

The average total and dissolved concentrations in the plume are calculated by dividing the flux by the volumetric flowrate as:

$$CT_{i,in} = \frac{F_{CT,i,in}}{Q_i} * 10^6 \qquad CD_{i,in} = \frac{F_{CD,i,in}}{Q_i} * 10^6 \qquad \text{(EQ 43, 44)}$$

The average concentration on the particles is calculated by dividing the flux by the volumetric flowrate and suspended solids concentration.

$$CS_{i,in} = \frac{F_{CS,i,in}}{Q_i * TSS_{i,in}} * 10^6 \qquad \text{(EQ 45)}$$

<u>Equations for Inside Conditions (Approaching Equilibrium)</u>

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:

$$q_i = \frac{\Delta x_i * y_i * h_i}{Q_i} * 3600 \qquad \text{(EQ 46)}$$

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:

$$CD_i = CD_{i,in} + (CD_{eq_i} - CD_{i,in}) \times (1 - e^{-lt_i}) \qquad \text{(EQ 49)}$$

$$CS_i = CS_{i,in} - \left(CS_{i,in} - CS_{eq_1}\right) \times (1 - e^{-lt_i}) \qquad \text{(EQ 50)}$$

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:

$$F_{CT,i,out} = CT_{i,out} * Q_i * 10^{-6} \qquad \text{(EQ 56)}$$

$$F_{CD,i,out} = CD_{i,out} * Q_i * 10^{-6} \qquad \text{(EQ 57)}$$

$$F_{CS,i,out} = CS_{i,out} * Q_i * TSS_{i,out} * 10^{-6} \qquad \text{(EQ 58)}$$

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:

$$CT(net)_{i,out} = CT_{i,out} - CT_{BKG} \qquad \text{(EQ 59)}$$

$$CD(net)_{i,out} = CD_{i,out} - CD_{BKG} \qquad \text{(EQ 60)}$$

$$CS(net)_{i,out} = \frac{CS_{i,out} * TSS_{i,out} - CS_{BKG} * TSS_{BKG}}{TSS_{i,out} - TSS_{BKG}} \qquad \text{(EQ 61)}$$

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:

$$\frac{CD_{BKG}}{CT_{BKG}} = f_{BKG} = \frac{1}{\left(1 + K_d \times TSS_{BKG} \times 10^{-6}\right)} \qquad \text{(EQ 62)}$$

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, however 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 and Concern Level , but not Control Level. 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 Concern Level, 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, 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 Concern Level over Evaluation Level and increases another two to four times between Concern Level and Control Level. These increases in mass per unit area are only significant for Control Level 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 an exceedance 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 Concern Level, the regulated PCB load of 600 g/day is the output flux simulated by HUDTOX. Similarly for the total PCB concentration this action level, which is 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 Evaluation Level and Concern 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 15. The profile shown in Figure 15 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 15. 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 16 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
Concern 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 Concern 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 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 13.

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:

$$S_{Paramater,Output} = \frac{(Output_i - Output_{default}) / Output_{default}}{(Paramter_i - Parameter_{default}) / Parameter_{default}} \qquad \text{(EQ 63)}$$

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 13. Direct and indirect relationships between the various inputs and outputs are indicated in Table 14. The relative sensitivities are qualitatively given in Table 13. The average of the absolute $S_{Parameter,Output}$ values are presented in Table 15.

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 17. 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 18. 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 18 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 19. 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 19 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 20. 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 21. 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 21.

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 21, 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 22.

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 22, 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 64 below is the equation for the net dissolved fraction (for a small ?x):

$$\frac{CD_{out}-CD_{BKG}}{CT_{out}-CT_{BKG}}=\frac{CD_{in}+\left(\frac{CT_{in}}{\left(1+K_d\times TSS_{in}\times 10^{-6}\right)}-CD_{in}\right)\times(1-e^{-lt})-CD_{BKG}}{CT_{in}-CT_{settled}-CT_{BKG}} \qquad \text{(EQ 64)}$$

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}, $e^{-?t}$.

$$f_{net,dissolved}=\frac{CD_{in}+\left(\frac{CT_{in}}{K}-CD_{in}\right)\times E-CD_{BKG}}{CT_{in}-CT_{settled}-CT_{BKG}} \qquad \text{(EQ 65)}$$

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 22. 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:

$$\frac{CD_{BKG}}{CT_{BKG}} = f_{BKG} = \frac{1}{\left(1 + K_d \times TSS_{BKG} \times 10^{-6}\right)} \qquad \text{(EQ 66)}$$

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 23. 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 24 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 24 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 25. 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 26. It should be noted that a log scale is used in Figure 26.

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 26, 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 27.

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 28.

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 28, 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 28. 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 29.

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:

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.
Concern 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.
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.*

Evaluation Level and Concern Level specify the Total PCB load at the far-field monitoring stations and 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 preliminary draft of the performance standard is not considered in the model runs.

Since the Total PCB action levels are specified as the export rate, HUDTOX model 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. To estimate the input loading term for HUDTOX then, 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. Control Level 3 (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

Control Level of the performance standard is 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 action level 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 16 and 17, 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 18.

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:

$$F_{NDdaily} = F_{ND} \times t_w \times 3600 \frac{\text{sec}}{hr}$$

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 19 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 20). 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 20 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 21). 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 21).

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 30). 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 21). 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 22). 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 22). 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 22.

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 23.

Concern Level – 600g/day Total PCB Flux Export Rate.

Similar to Evaluation Level , Concern Level 2 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 24 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 30). 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 25. 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:

Baseline Total PCB = Baseline Tri+ PCB × 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:

$$\text{Net Tri} + \text{PCB} = \frac{\left(\Delta F_{Tri+}\right)}{q} \times \frac{1\text{ hour}}{3600\text{ sec}} \times \frac{1\text{ day}}{14\text{ hour}} \times \frac{1\text{ ft}^3}{0.02832\text{ m}^3} \times \frac{1\text{ m}^3}{1000\text{ L}} \times \frac{10^{12}\text{ ng}}{1\text{ kg}}$$

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 resuspensi on = 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 PCB = 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; and
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 26). 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 10). 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 31 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 27). 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 28 through 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 32 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 Evaluation Level and Concern 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 31 shows 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 Concern Level (600 g/day Total PCB flux), the amount of solids needs to be suspended to 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, Control Level scenario 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 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 31A)[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 31A). For example, in River Section 1 during May 1 to November 30, 2007 dredging season, the input Total PCB flux was predicted to be approximately 27 percent higher than the output (Table 31A). Therefore, for an

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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.

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).
- Concern 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

Control Level of the performance standard is 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 19). 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 28). The loads are higher during dredging period (2006 to 2011) and 20 years beyond the completion of dredging (Figure 32). 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 32), 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 32). 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 33. 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 34 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 34). 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 34).

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 34). 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 34). 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 34). 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.

Concern Level – 600 g/day HUDTOX Simulation Results

In Concern Level, the Total PCB flux at the downstream monitoring stations 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 32). 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 35). 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 35). 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 35). 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 35). The dissolved phase Total PCB in the water column at Waterford is approximately 50 percent of the whole water Total PCB concentrations (Figure 35).

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 32. The predicted Tri+ PCB cumulative loads over TID and Schuylerville for 600 g/day scenario are below the MNA by the year 2014 (Figure 32). 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 33). Similar to the 350 ng/L scenario, this is due to the sediment ratios used in converting the Tri+ PCB to total PCB.

Concern Level of the performance standard 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:

$$\Delta\mathrm{TPCB}_i = \mathrm{MNA}_{\mathrm{base}_i} - \mathrm{sr01}_{\mathrm{base}_i}$$

where

$\Delta\mathrm{TPCB}_i$ = Average difference in Total PCB concentrations in month i (ng/L).

$\mathrm{MNA}_{\mathrm{base}_i}$ = Average baseline Total PCB concentration from MNA scenario for month i (ng/L).

$\mathrm{sr01}_{\mathrm{base}_i}$ = 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:

$$\Delta\mathrm{TPCBflux}_i = \Delta\mathrm{TPCB}_i \times q_{\mathrm{ave}_i} \times 0.02832\ \mathrm{ft}^3/\mathrm{m}^3 \times 3600\ \mathrm{sec/hour} \times 14\ \mathrm{hour/day} \times 1000\ \mathrm{m}^3/\mathrm{L} \times 10^{-9}\ \mathrm{g/ng}$$

where:

$\Delta\mathrm{TPCBflux}_i$ = Average difference in Total PCB flux for month i (g/day).

q_{ave_i} = Average flow rate for month i (ft3/sec).

$0.02832\ \mathrm{ft}^3/\mathrm{m}^3$ = 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 m^3/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 36). The adjusted Tri+ PCB loads over Schuylerville and Waterford are also plotted.

Evaluation Level – 300 g/day HUDTOX Simulation Results

Similar to Concern Level, 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 33). Figure 37 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 Control Level 1 (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 37). 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 37). 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 37).

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 32). 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 33). Again, this is due to the ratios of Tri+ PCB to Total PCB used in converting the Total PCB loads.

Similar to Concern 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 Action Levels

Figure 38 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 Evaluation Level and Concern 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 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 38).

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 34, 35, and 37). 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 action level. 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 Control Level 2 (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 32). 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 39). However, the highest dissolved phase Total PCB concentration was less than 350 ng/L (Figure 39). 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 Concern Level and 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 Concern Level to the fish tissue concentrations are largely confined to the dredging period in River Sections 1 and 2 (Figure 40). In River Section 3, the impact to the fish tissue concentrations lasts about three years beyond the dredging period to approximately 2014. Table 34 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 Control Level (350 ng/L) is larger than running the dredging operations at Control Level 2 (Figure 40). Predicted fish tissue concentrations for Control Level (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 34). 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.

Evaluation Level was not simulated since the Tri+ PCB loads to the Lower River are lower than both Concern Level and Control Level (Figure 32 and Table 30). Concern Level results 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 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 41). 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 (Concern 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 41 and Table 35). As for the 350 ng/L (Control Level 3) 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 35).

5.2 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 in the calculation assumptions, the twice 12 mg/L, *i.e.* 24 mg/L is set as the concentration limit for Concern Level. And the concentration limit of 12 mg/L is assigned to Evaluation Level. 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 mg/L since the PCB dissolved phase would also contribute to the concentration.

Evaluation Level	six hours continuously or 9 hours in a 24-hour period with a suspended solids concentration greater than 12 mg/L
Concern Level	daily dredging period or 24-hour period with a suspended solids concentration greater than 24 mg/L

No standard was formulated for higher action levels to avoid unnecessary shutdown of operations. Exceedance on far-field suspended solids Concern Level will not cause any engineering contingency directly unless it is confirmed that the PCB concentration is greater than 350 ng/L at the far-field station.

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 (see 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 34. 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 on Figures K-4 and K-5, respectively. Figure K-6 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 35 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 kinetics of PCB desorption 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. 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} (Table 1).

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 Table 1.

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 References

Ambrose, R. B., Jr., T. A. Wool, and F. Martin. 1993. The water quality analysis simulation program,WASP5,part A: model documentation. U.S. Environmental Protection Agency, Athens, GA.

Berens, A.R. and G.S. Huvard. 1981. Particle Size Distribution of Polymers by Analysis of Sorption Kinetics, *Journal of Dispersion Science and Technology*, Vol 2, pp. 359-387, 1981. As cited in Carroll, *et al*. (1994).

Borglin, S., A. Wilke, R. Jepsen, and W. Lick. 1996. Parameters Affecting the Desorption of Hydrophobic Organic Chemicals from Suspended Sediments. *Env. Tox. Chem.* Vol. 15, No. 10, pp. 2254-2262.

Brown, M. 1981. PCB Desorption from River Sediments Suspended During Dredging: An Analytical Framework. New York State Department of Environmental Conservation, Technical Paper No. 65. April 1981.

Carroll, K.M., M.R. Harkness, A.A. Bracco, and R.R. Balcarcel. 1994. Application of a Permeant/Polymer Diffusional Model to the Desorption of Polychlorinated Biphenyls from Hudson River Sediment. *Environ. Sci. Technol.* Vol 28, pp. 253-258. 1994.

Cornelissen, G., P.C.M. Van Noort, and A. J. Govers. 1997. Desorption kinetics of chlorobenzenes, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls: sediment extraction with Tenax® and effects of contact time and solute hydrophobicity. *Environ. Toxicol. Chem*. Vol 16, No. 7, pp. 1351-1357, 1997

DePinto, Joseph V., Wilbert Lick and John F. Paul. 1994. Transport and Transformation of Contaminants Near the Sediment-Water Interface. CRC Press, Inc. Boca Raton. 1994.

Farley, K.J., R.V. Thomann, T.F. Cooney, D.R. Damiani, and J.R. Wand. 1999. An Integrated Model of Organic Chemical Fate and Bioaccumulation in the Hudson River Estuary. Prepared for the Hudson River Foundation. Manhattan College, Riverdale, NY.

Filtration & Separation.com, 2003. website address, http://www.filtration-and-separation.com/ settling/settling.htm accessed on February 23, 2003.

Fischer, H.B, E.J. List, R. C.Y. Koh, J. Imberger, and N.H. Brooks. 1979. Mixing in Inland and Coastal Waters. Academic Press, New York, 1979.

Fox River Remediation Advisory Team (FRRAT). 2000. Evaluation of the Effectiveness of Remediation Dredging: The Fox River Deposit N Demonstration Project November 1998 – January 1999 Madison, Wisconsin, Water Resources Institute Special Report, WRI SR00-01. June 2000.

Gbondo-Tugbawa, S.S., CT Driscoll, JD Aber, GE Likens. 2001. Evaluation of an integrated biogeochemical model (PnET-BGC) at a northern hardwood forest ecosystem. *Water Resources Research* 37:1057-1070.

General Electric (GE). 2001. Comments of General Electric Company on the Feasibility Study and Proposed Plan for the Hudson River PCBs Superfund Site. April 2001. With Appendix A: Assessment of Sediment Resuspension and PCB Release During Dredging Activities, prepared for GE by QEA.

Ghosh, U., A.S. Weber, J.N. Jensen, and J.R. Smith. 2000. Relationship between PCB desorption equilibrium, kinetics, and availability during land biotreatment. *Environ. Sci. Technol.* Vol. 34, No. 12, pp. 2542-2548, 2000.

Gobas, F.A.P.C., M.N. Z'Graggen and X. Zhang. 1995. Time response of the Lake Ontario ecosystem to virtual elimination of PCBs. *Env. Science Technol.* 29(8):2038-2046.

Gobas, F.A.P.C. 1993. A model for predicting the bioaccumulation of hydrophobic organic chemicals in aquatic food-webs: Application to Lake Ontario. *Ecological Modelling* 69:1-17.

Herbich, J.B., and S.B. Brahme. 1991. Literature review and technical evaluation of sediment resuspension during dredging. Contract Report HL-91-1. Prepared for the US Army Engineer Waterways Experiment Station, Vicksburg, MS. Texas A&M University, College Station, TX.

Kuo, A. Y., C. S. Welch and R. J. Lukens. 1985. Dredge Induced Turbidity Plume Model, ASCE *Journal of Waterways, Ports, Coastal and Ocean Engineering*, Vol. 111, pp 476-494.

Kuo, A. Y. and D. F. Hayes. 1991. Model for Turbidity Plume Induced by Bucket Dredge, *Journal of Waterway, Port, Coastal, and Ocean Engineering*, Vol. 117, No. 6, Nov/Dec.

Martin, J. L. and S. C. McCutcheon. 1999. Hydrodynamics and Transport for Water Quality Modeling. Lewis Publishers, New York, 1999.

Orton P.M. and G.C. Kineke. 2001. Comparing Calculated and Observed Vertical Suspended-Sediment Distributions from a Hudson River Estuary Turbidity Maximum. Estuarine, *Coastal and Shelf Science*, Vol 52, pp. 401-410.

QEA. 1999. PCBs in the Upper Hudson River. Volume 2: A Model of PCB Fate, Transport, and Bioaccumulation. Prepared for General Electric, Albany, New York by Quantitative Environmental Analysis, LLC. May 1999, and amended June 1999.

ten Hulscher, Th.E.M., B.A. Vrind, H. Van den Heuvel, L.E. Van der Velde, P.C.M. Van Noort, J.E.M. Beurskens, and H.A.J. Govers. 1999. Triphasic desorption of highly resistant chlorobenzenes, polychlorinated biphenyls, and polycyclic aromatic hydrocarbons in Field Contaminated Sediment. *Environ. Sci. Technol.* Vol. 33, No. 1, pp. 126-132, 1999.

ten Hulscher, Th.E.M., B.A. Vrind, P.C.M. van Noort, and H.A.J. Grovers. 2002. Resistant sorption of in situ chlorobenzenes and a polychlorinated biphenyl in river Rhine suspended matter. *Chemosphere*, Vol 49, pp. 1231-1238, 2002.

Thonon, Ivo, and Marcel Van Der Perk. 2002. *Measurement of Suspended Sediment Characteristics in an Embanked Flood Plain Environment of the River Rhine*, Erosion and Sediment Transport Measurement: Technological and Methodological Advances. Workshop in Oslo 19 – 21 June 2002.

U. S. Army Corps of Engineers (USACE). 1990. New Bedford Harbor Superfund Pilot Study: Evaluation of Dredging and Dredged Material Disposal. US Army Corps of Engineers, New England Division. May 1990.

USACE. 1998. Entrainment by Hydraulic Dredges - A Review of Potential Impacts. Dredging Operations and Environmental Research Technical Note, DOER-E1. U.S. Army Engineers Waterways Experiment Station (USAEWES).

USACE. 2001. Final 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.

US Environmental Protection Agency (USEPA). 1997. Phase 2 Report, Further Site Characterization and Analysis, Volume 2C – Data Evaluation and Interpretation Report (DEIR), Hudson River PCBs RI/FS. Prepared for USEPA Region 2 and USACE by TAMS Consultants, Inc., the Cadmus Group, Inc., and Gradient Corporation. February 1997.

USEPA. 1998. Further Site Characterization and Analysis. Volume 2C-A Low Resolution Sediment Coring Report (LRC), Addendum to the Data Evaluation and Interpretation Report, Hudson River PCBs Reassessment RI/FS. Prepared for USEPA Region 2, New York by TAMS Consultants, Inc., Gradient Corporation, and TetraTech, Inc. July 1998.

USEPA, 2000a. Phase 3 Report: Feasibility Study, Hudson River PCBs Reassessment RI/FS. Prepared for EPA Region 2 and the US Army Corps of Engineers (USACE), Kansas City District by TAMS Consultants, Inc. December 2000.

USEPA. 2000b. Further Site Characterization and Analysis, Revised Baseline Modeling Report (RBMR), Hudson River PCBs Reassessment RI/FS Volume 2D. Prepared for USEPA Region 2 and USACE, Kansas City District by TAMS Consultants, Inc., Limno-Tech, Inc., Menzie-Cura & Associates, Inc., and Tetra-Tech, Inc. January 2000.

USEPA, 2002. Responsiveness Summary Hudson River PCBs Site Record Of Decision. Prepared for USEPA Region 2 and USACE by TAMS Consultants, Inc. January 2002.

U.S. Geological Survey (USGS). 1969. Time-of Travel Study, Upper Hudson River, Fort Edward, New York to Troy Lock and Dam, Troy, New York. Report of Investigation, R1-10. 1969.

USGS. 2000. A mass-balance approach for assessing PCB movement during remediation of a PCB-contaminated deposit on the Fox River, Wisconsin. USGS Water Resources Investigations Report 00-4245. December 2000.

Warren, S.D., Boff, R.F., and Simpson, H.J. 1997. Volatilization of PCBs from Contaminated Sediments and Water. Final Report to NY State Department of Environmental Conservation, Lamont-Doherty Geological Observatory of Columbia University, Palisades, NY. October 1997.

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	0.10
		400 microns	0.005
DePinto *et al*, 1994	New Bedford Freshwater Sediment	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	0.10
	Thames River 2.50 g/cc	150 microns	1.84
		160 microns	2.10
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 sediments	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)		Slope (6 mile distance)
	including negative values	negative values treated as 0	
3	1.050	1.050	3E-05
4	0.676	0.694	2E-05
5	0.416	0.436	1E-05
6	0.223	0.244	8E-06
7	0.151	0.169	5E-06
8	0.147	0.168	5E-06
9	0.166	0.185	6E-06
10	0.234	0.254	8E-06
11	0.336	0.349	1E-05
12	0.577	0.582	2E-05
Dredging period Average	0.239	0.258	8E-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	8.0E-06	0.01	190
		west	0.9	8.0E-06	0.01	40
		center	3.5	8.0E-06	0.02	350
		east	2.4	8.0E-06	0.01	190
	4000	overall	2.6	8.0E-06	0.01	200
		west	1.1	8.0E-06	0.01	100
		center	3.7	8.0E-06	0.02	400
		east	2.6	8.0E-06	0.01	200
	5000	overall	2.7	8.0E-06	0.01	240
		west	1.2	8.0E-06	0.01	70
		center	3.9	8.0E-06	0.02	410
		east	2.7	8.0E-06	0.01	240
	8000	overall	3.0	8.0E-06	0.02	280
		west	1.6	8.0E-06	0.01	110
		center	4.2	8.0E-06	0.02	460
		east	3.1	8.0E-06	0.02	280
RM 190	2000	overall	2.9	8.0E-06	0.02	260
		west	3.0	8.0E-06	0.02	280
		center	4.0	8.0E-06	0.02	420
		east	1.7	8.0E-06	0.01	120
	4000	overall	3.1	8.0E-06	0.02	290
		west	3.2	8.0E-06	0.02	310
		center	4.2	8.0E-06	0.02	450
		east	1.9	8.0E-06	0.01	140
	5000	overall	3.2	8.0E-06	0.02	300
		west	3.3	8.0E-06	0.02	320
		center	4.3	8.0E-06	0.02	470
		east	2.0	8.0E-06	0.01	150
	8000	overall	3.5	8.0E-06	0.02	350
		west	3.6	8.0E-06	0.02	370
		center	4.6	8.0E-06	0.02	520
		east	2.3	8.0E-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)	100.00	100.00	100.00
V_{nf}	CSTR Volume (m^3)	188.40	188.40	188.40
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 (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)	1.80	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
			0.10	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	1.00	1.00
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	1.00	<0.01
		62 mg/kg (Section 2)	0.33	<0.01	1.00	<0.01
		29 mg/kg (Section 3)	0.28	<0.01	1.00	<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}	1.00	<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)	0.00	<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 Standard with and without Dissolved PCBs from Dredging as Modeled by CSTR-Chem

Section	Year	Dissolved PCB Concentration from dredging (ng/L)	g (source strength) (kg/s)	SS Flux (kg/day)	TPCB Flux (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 Standard with and without Coarse solids from Dredging as Modeled by CSTR-Chem

Section	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 (kg/day)	TPCB Flux (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

			Increase in PCB Mass from Settled Material (g/sq. m)			Length Weighted Average Concentration (ppm)		
Management Level	Condition at Far Field Station	River Section	Target Area	Sides of Target Area	2-Acres Below the Target Area	Target Area	Sides of Target Area	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
Concern	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
Concern	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
Concern	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	Section 1	Section 2	Section 3
350 ng/L	94	54	110
600 g/day	23	11	22

Table 13
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 14
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 at 2.3 mg/L.
3. Due to the stepwise characteristic of the model (particularly with the distance to 0.1% coarse material), linearity was defined as an r-squared value greater than 99%.

Table 15
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 16
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 baseline concentration was excluded since flow is not typical.

Table 17
Average Baseline Conditions at Schuylerville

Month	Mean flow, q[1] (cfs)	Mean baseline concentrations[2]		Mean baseline load (g/sec)
		TSS (mg/L)	TPCB (ng/L)	
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 baseline concentration was excluded since flow is not typical.

Table 18
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 baseline concentration was excluded since flow is not typical.

Table 19
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 20
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 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 21
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.

Table22

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 23
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 24
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 25
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 26
Percent Reduction at the Monitoring Locations Comparison for the 350 ng/L

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 - 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.
See 350ng_L load calculations-jun-nov ave.xls for detail calculations

[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) 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
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		
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
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
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%
Concern 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%

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.

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] (%)

[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 31A
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 32
Expected versus Model Prediction of PCB Flux for Concern 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 33
Expected versus Model Prediction of PCB Flux for Concern 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	130	13,910	100	99.7	10,664	300	319
	May 1-Nov 30, 2007	1-May-07	30-Nov-07	TID	130	260	27,820	101	202.5	21,667	300	324
	May 1-Nov 30, 2008	1-May-08	30-Nov-08	TID	110	220	23,540	95	189.6	20,287	300	303
	May 1-Aug 15, 2009	1-May-09	15-Aug-09	TID	100	100	10,700	98	98.1	10,492	300	314
Section 2 dredging	Aug 16 - Nov 30, 2009	16-Aug-09	30-Nov-09	Schuylerville	110	110	11,770	98	97.7	10,456	300	332
	May 1 - Aug 15, 2010	1-May-10	15-Aug-10	Schuylerville	90	90	9,630	89	89.4	9,565	300	304
Section 3 dredging	Aug 16 - Nov 30, 2010[3]	16-Aug-10	30-Nov-10	Waterford	150	150	13,650	125	124.6	11,464	300	336
	May 1 - Aug 15, 2011	1-May-11	15-Aug-11	Waterford	120	120	12,840	125	125.4	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 34

FISHRAND Forecast for Year to Reach Fish Tissue Concentration Difference of 0.5 mg/kg Relative to the No Resuspension - Upper River

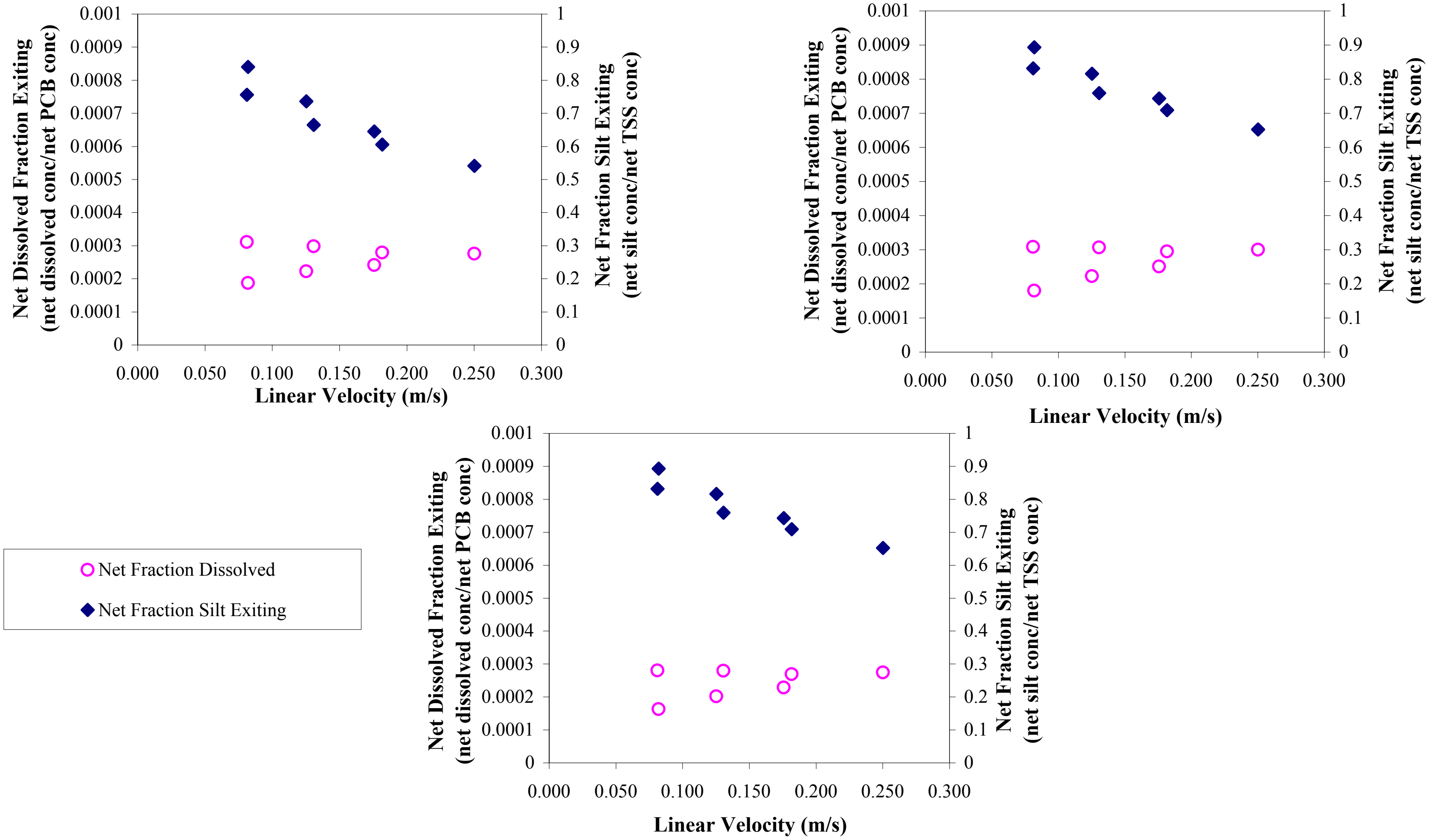
River Section	Total PCB 600 g/day (sr01)	Total PCB 350 ng/L (sr04)
Section 1 (RM 189)	2008-2009	2009-2010
Section 2 (RM 184)	2008	2010
Section 3 (RM 154)	Always < 0.5 mg/kg	2011

Table 35

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

Figures



Note: Net concentrations exclude background.

Figure 1

Sensitivity of Net Dissolved and Silt Fractions Exiting Near-Field with Variations in Linear Velocity and Depth for CSTR-Chem

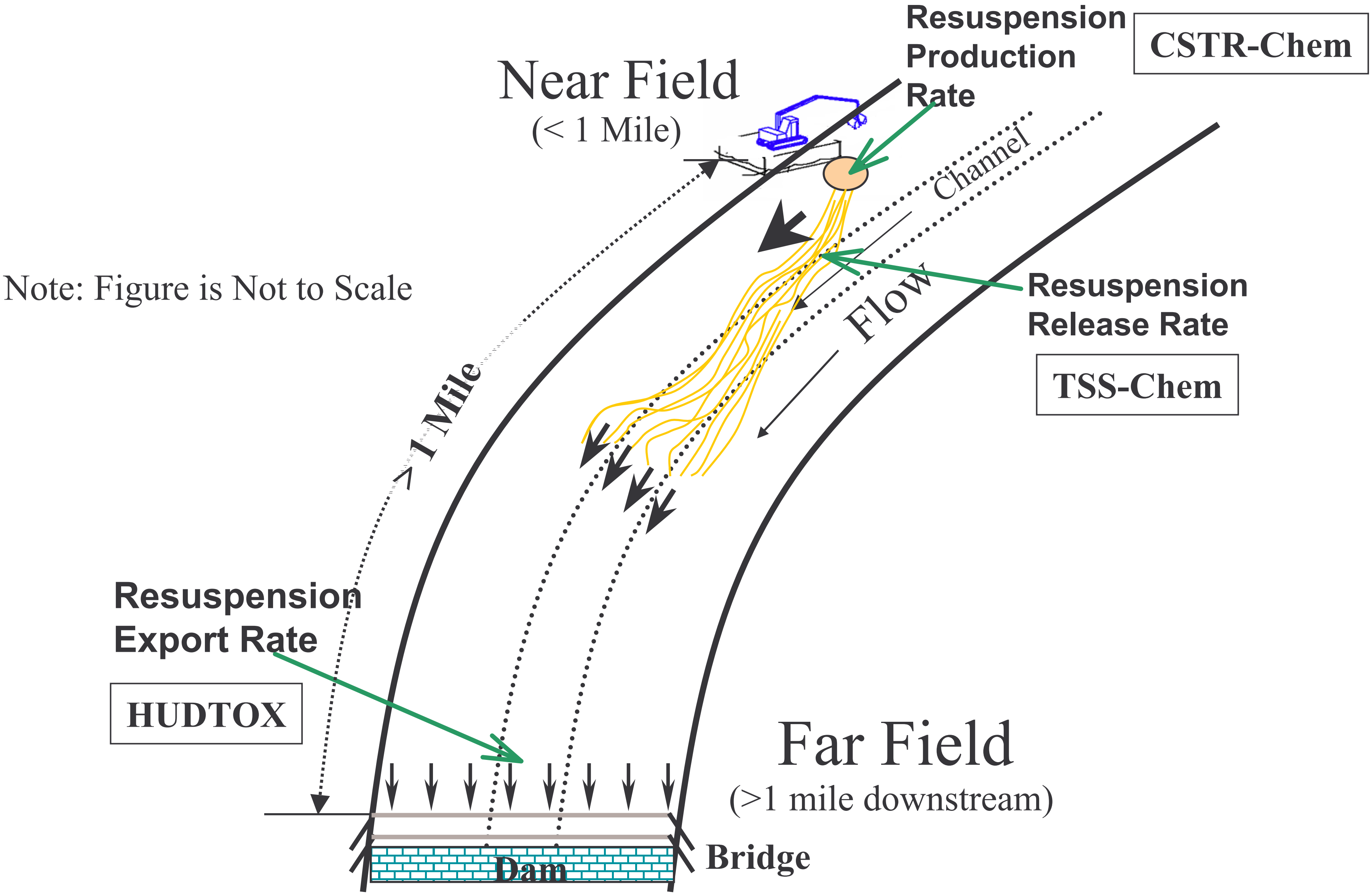
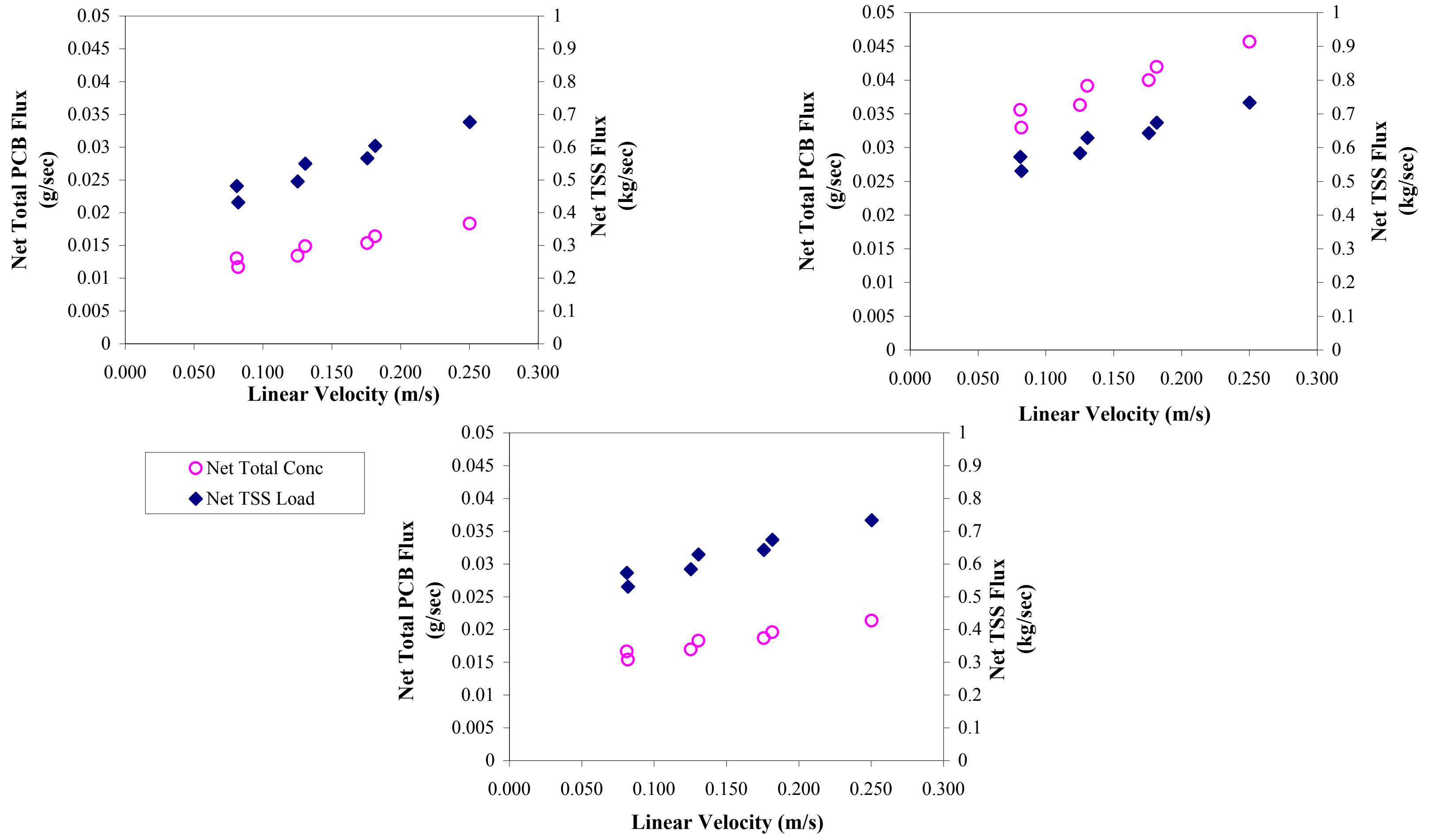


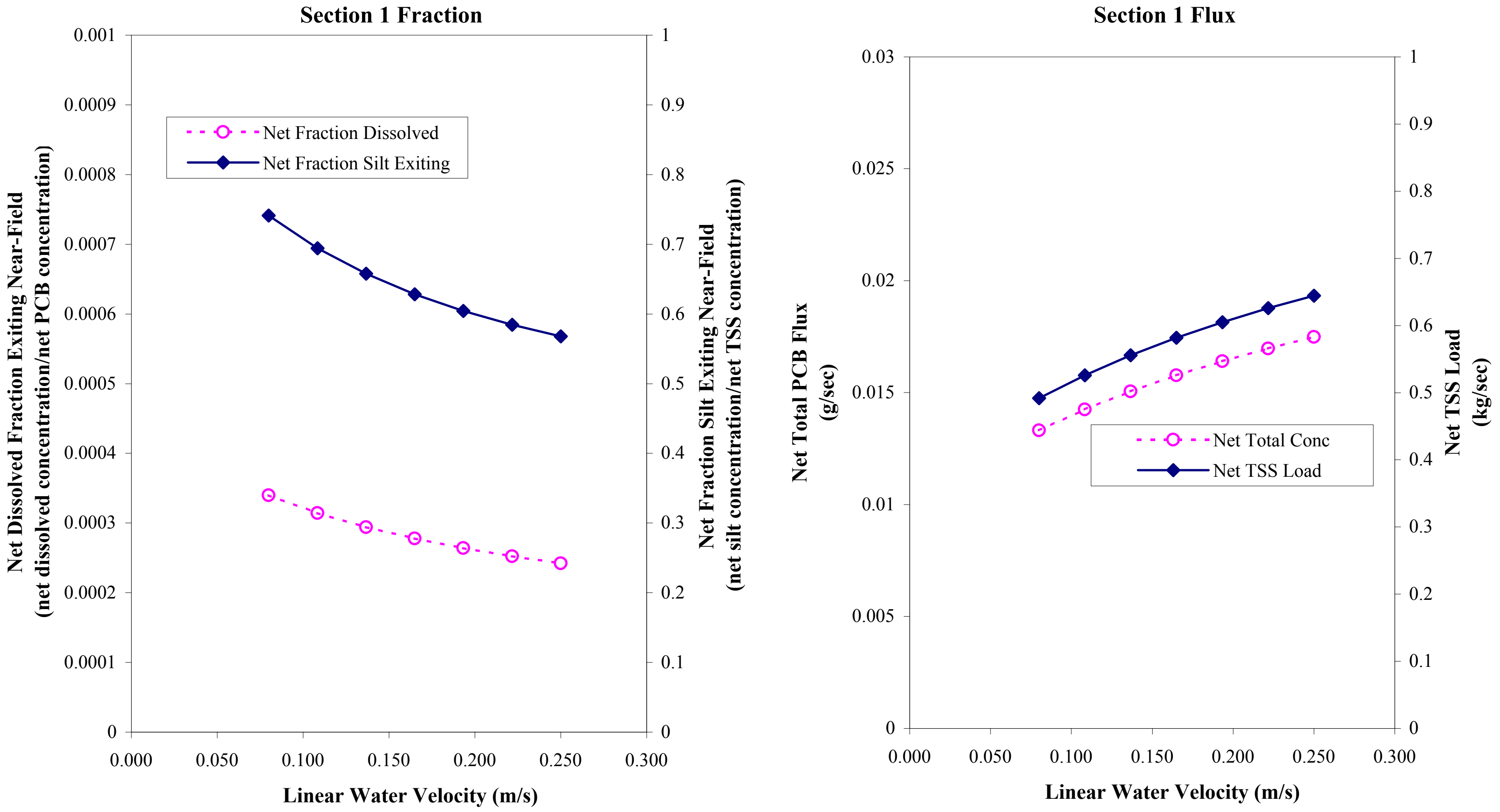
Figure 1A. Interaction Among the Transport Models



Note: Net concentrations exclude background.

Figure 2

Sensitivity of Net Total PCB Flux and Net TSS Flux Exiting Near-Field with Variations in Linear Velocity and Depth for CSTR-Chem



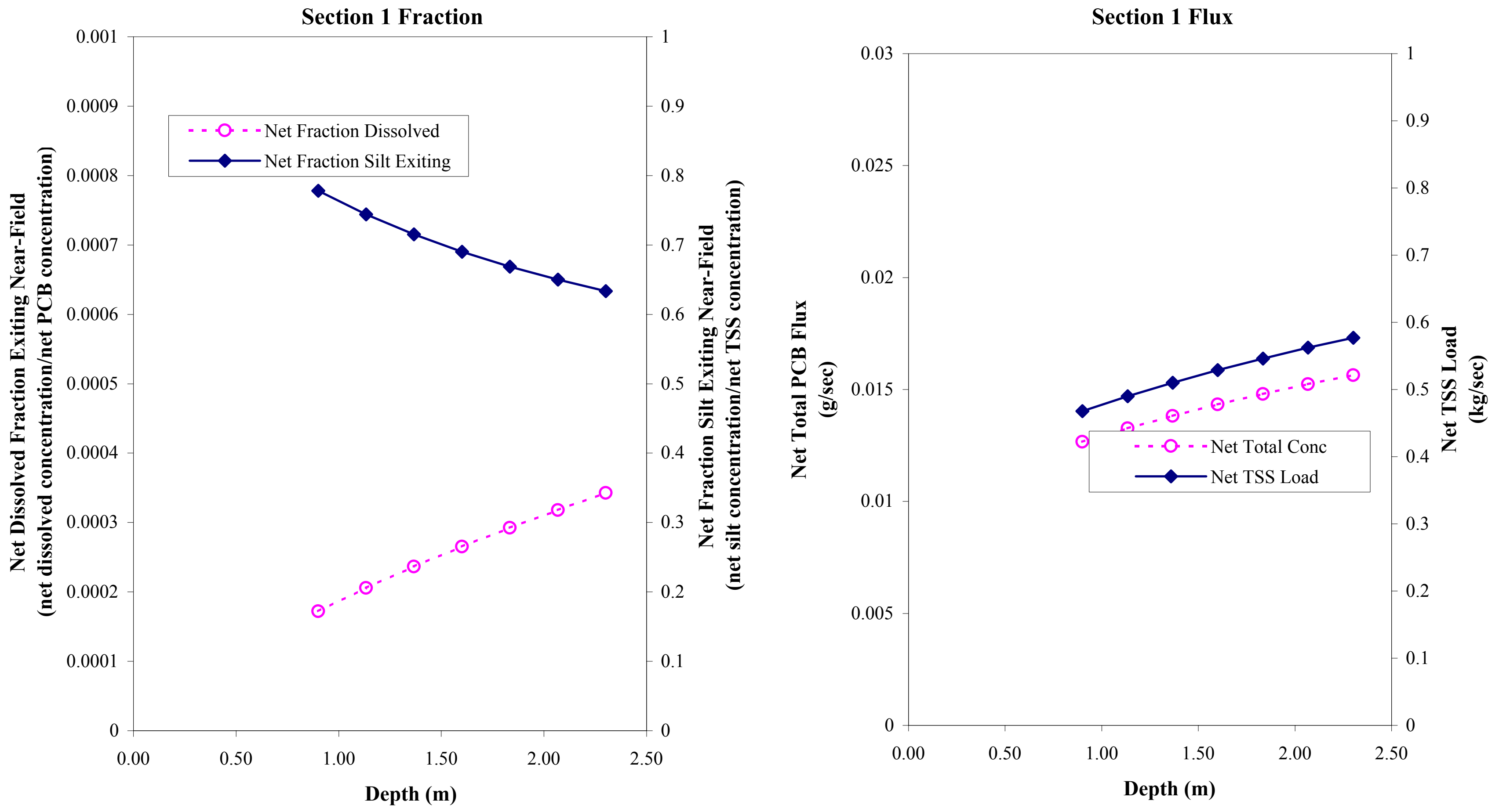
Section 1 Fraction

Section 1 Flux

Note: Net concentrations exclude background.

Figure 3

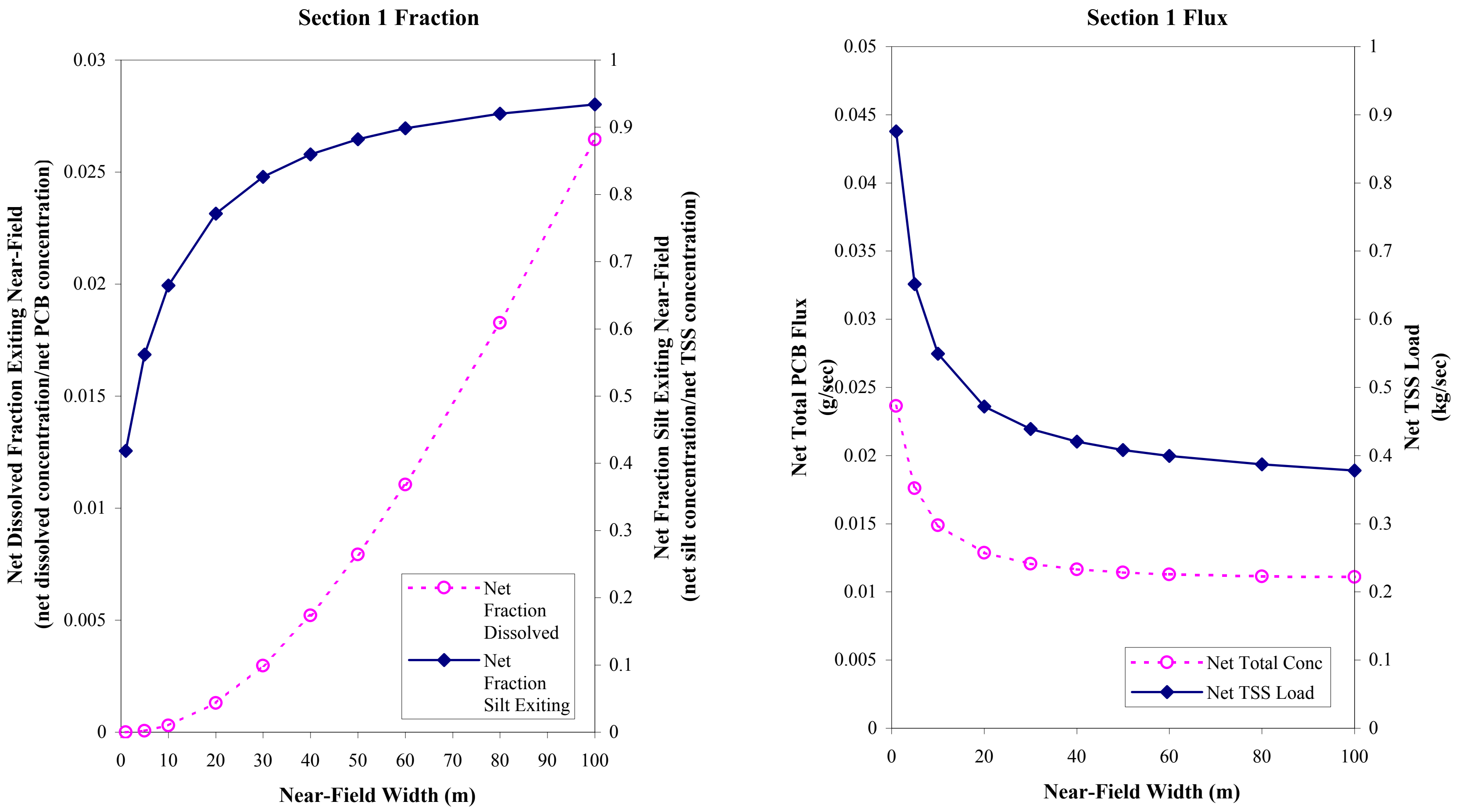
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Velocity for CSTR-Chem



Note: Net concentrations exclude background.

Figure 4

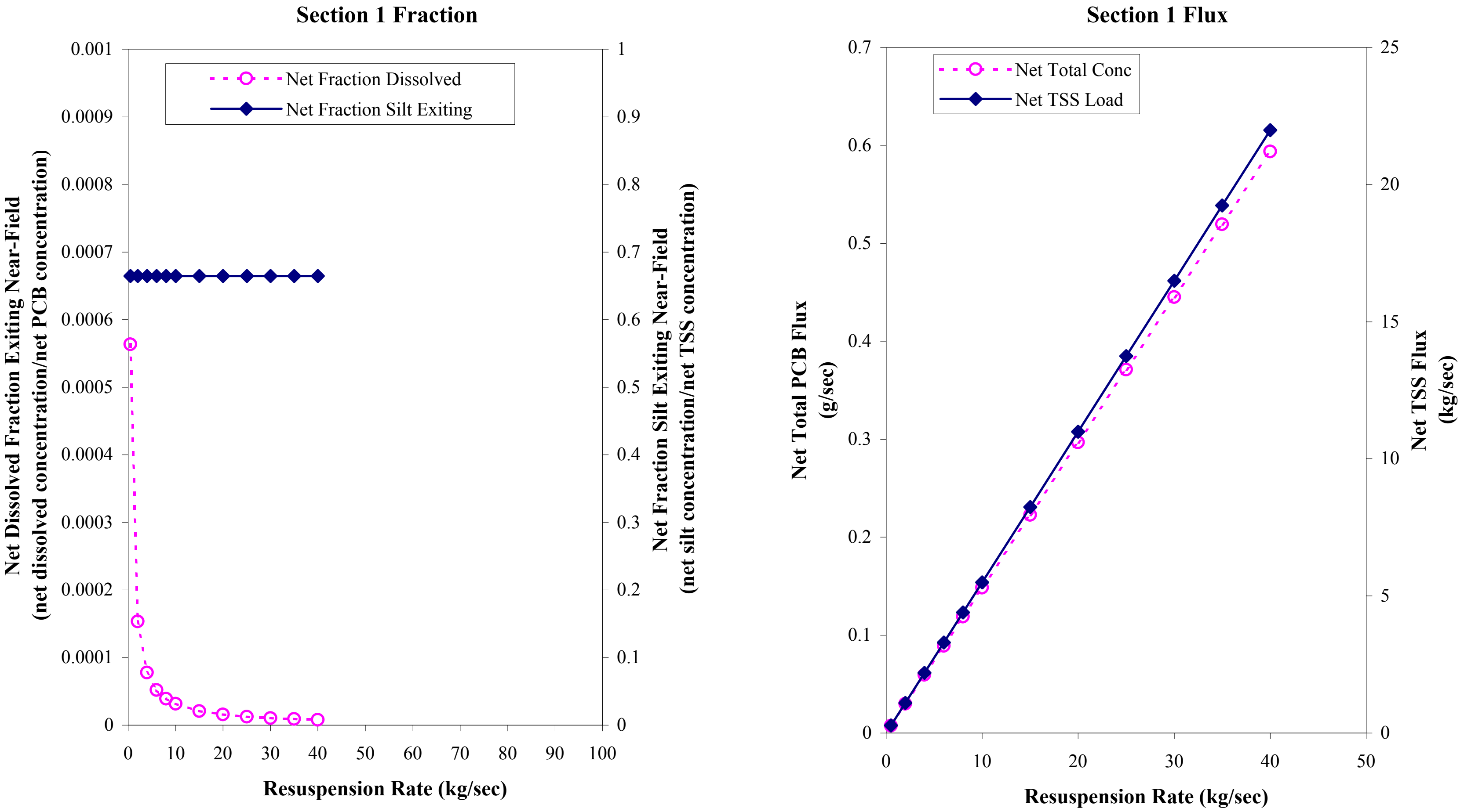
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Depth for CSTR-Chem



Note: Net concentrations exclude background.

Figure 5

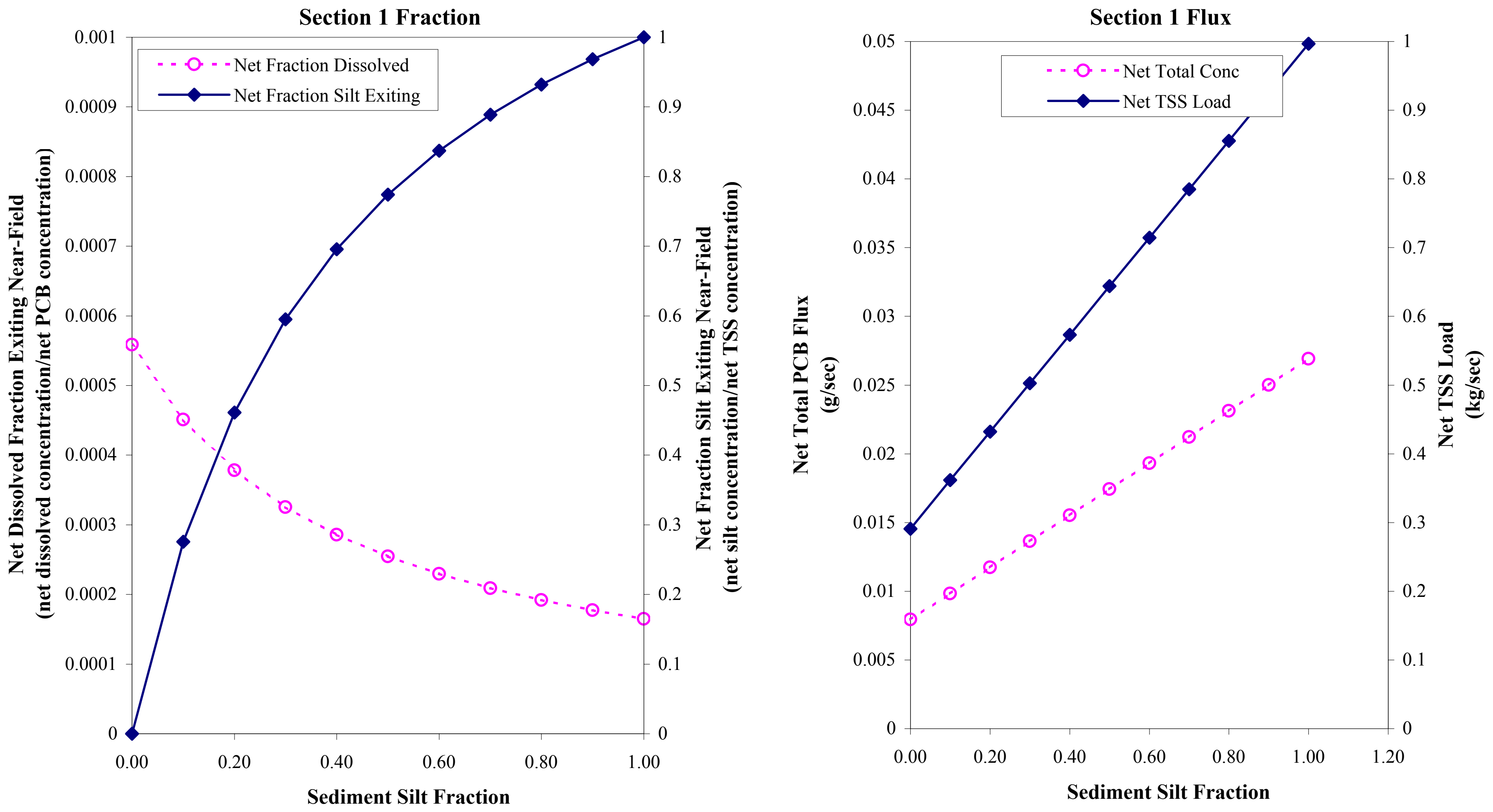
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Near-Field Width for CSTR-Chem



Note: Net concentrations exclude background.

Figure 6

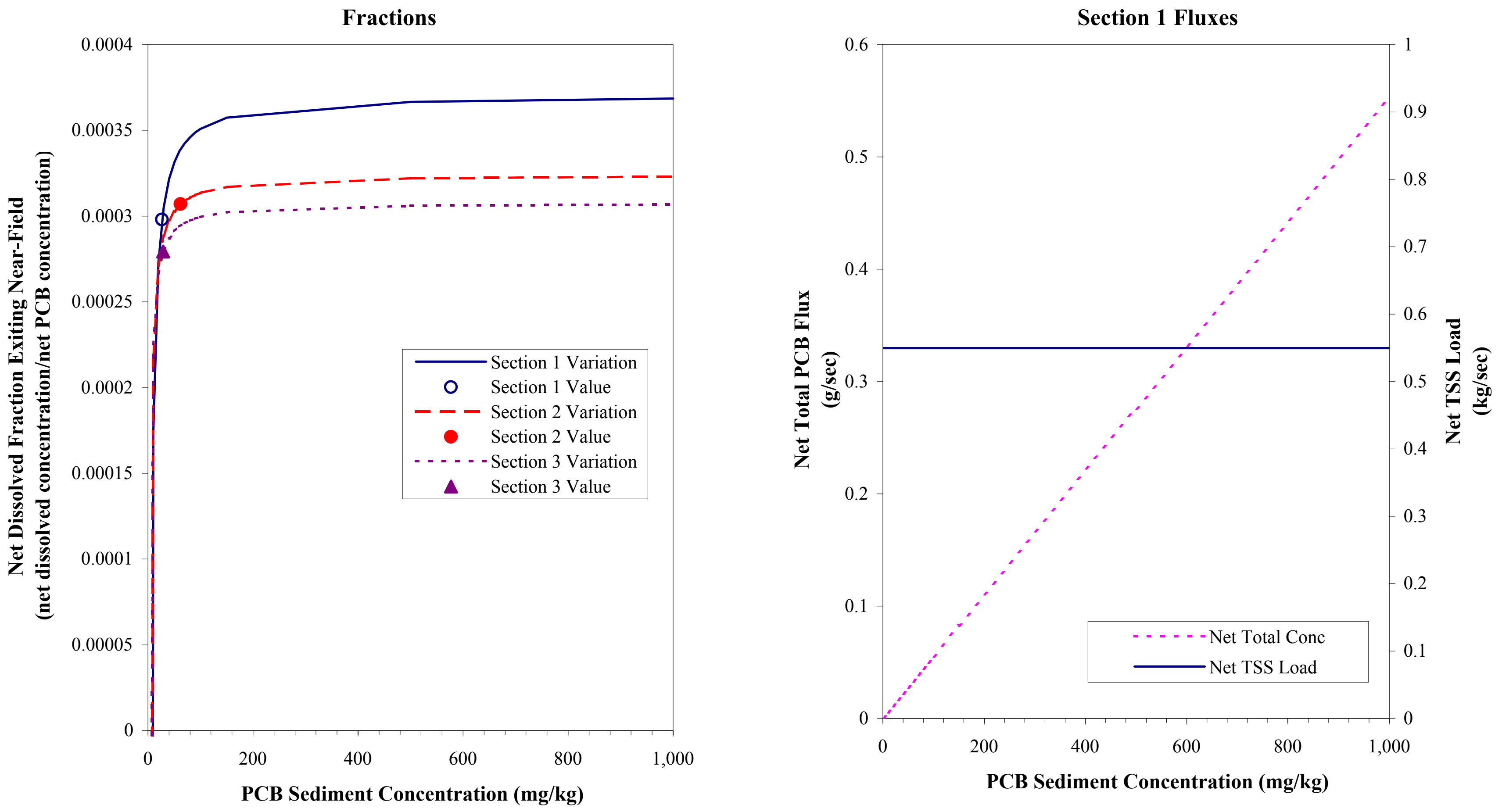
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Resuspension Rate for CSTR-Chem



Note: Net concentrations exclude background.

Figure 7

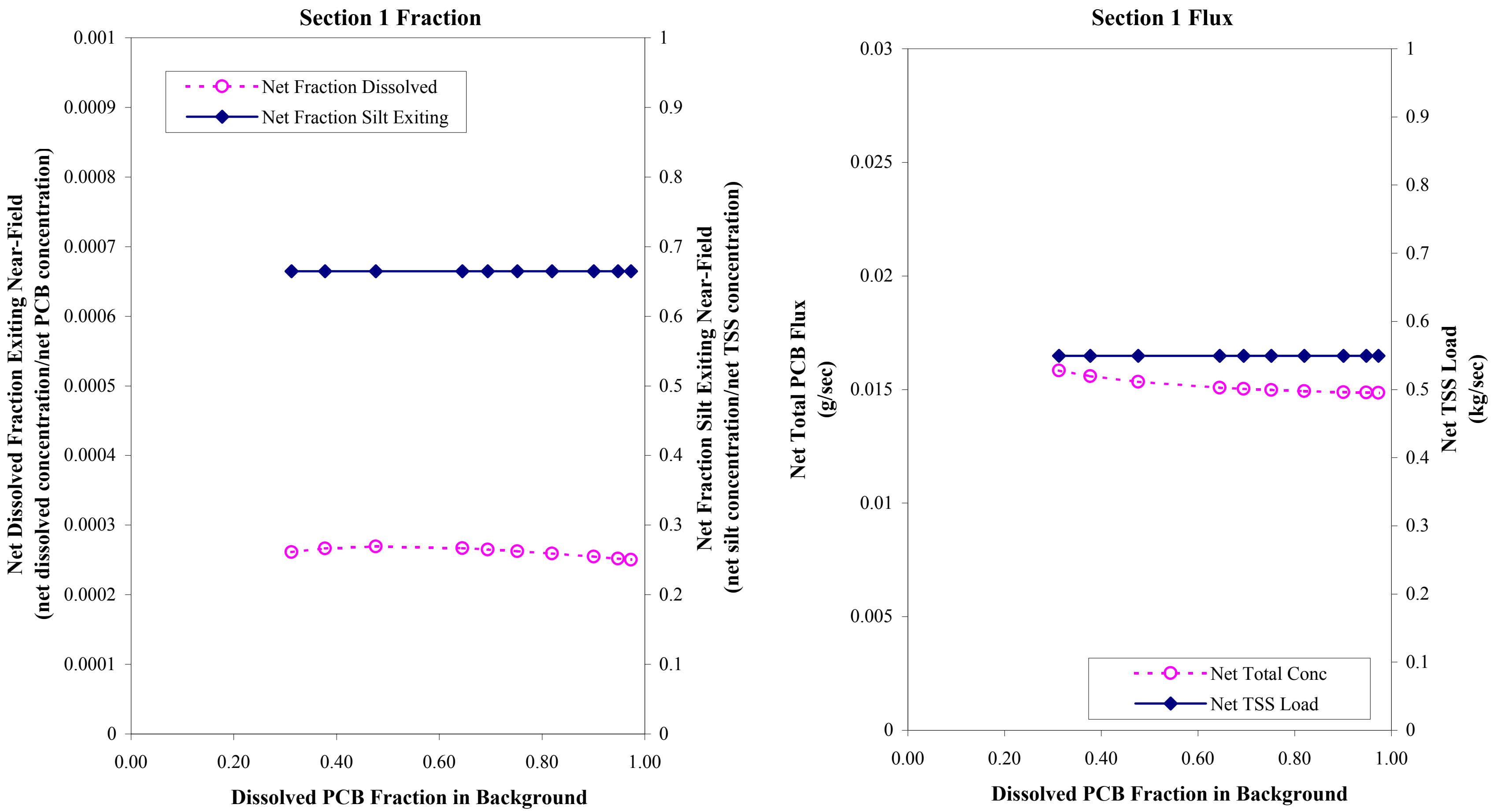
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Sediment Silt Fraction for CSTR-Chem



Note: Net concentrations exclude background.

Figure 8

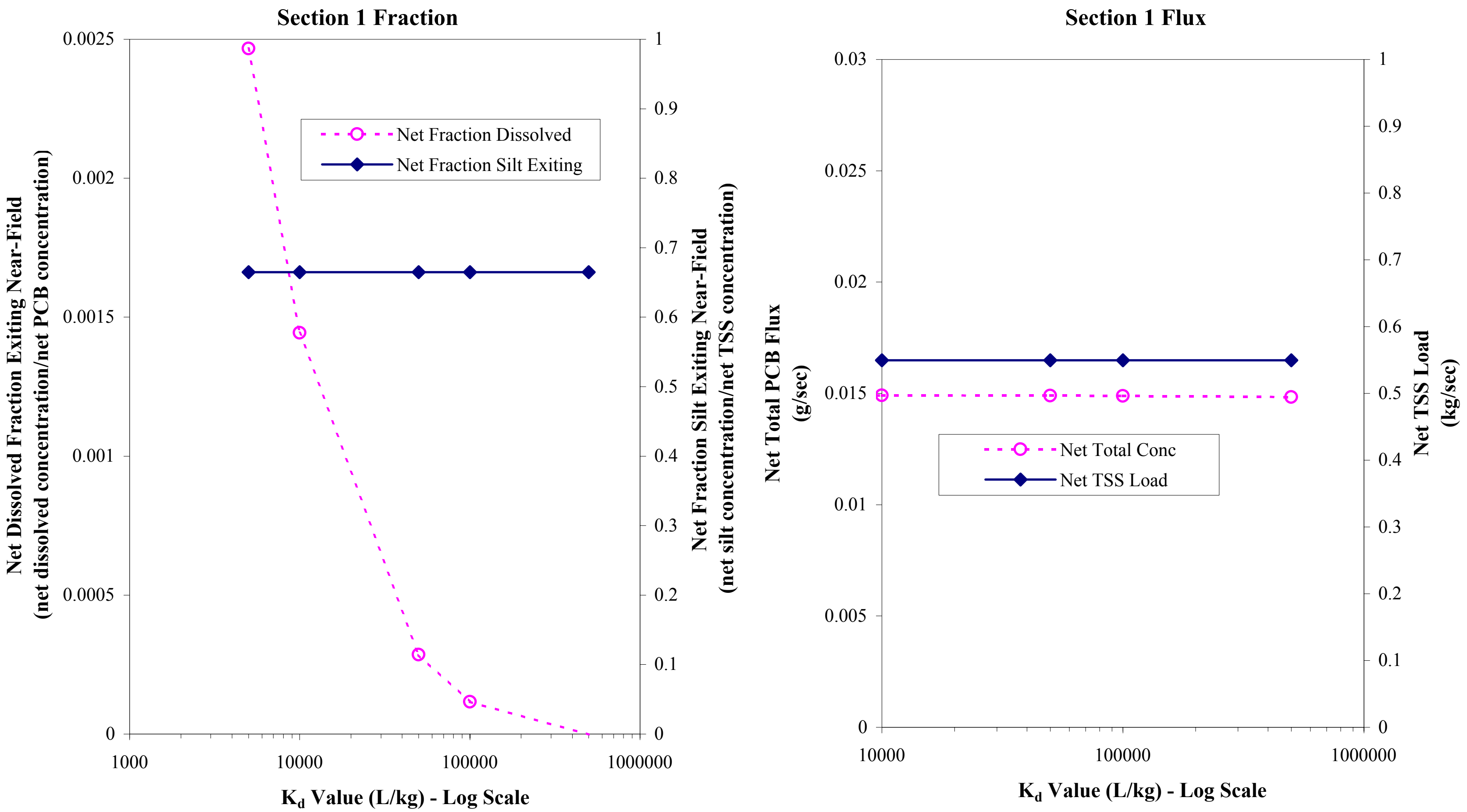
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of PCB Sediment Concentration for CSTR-Chem



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 9

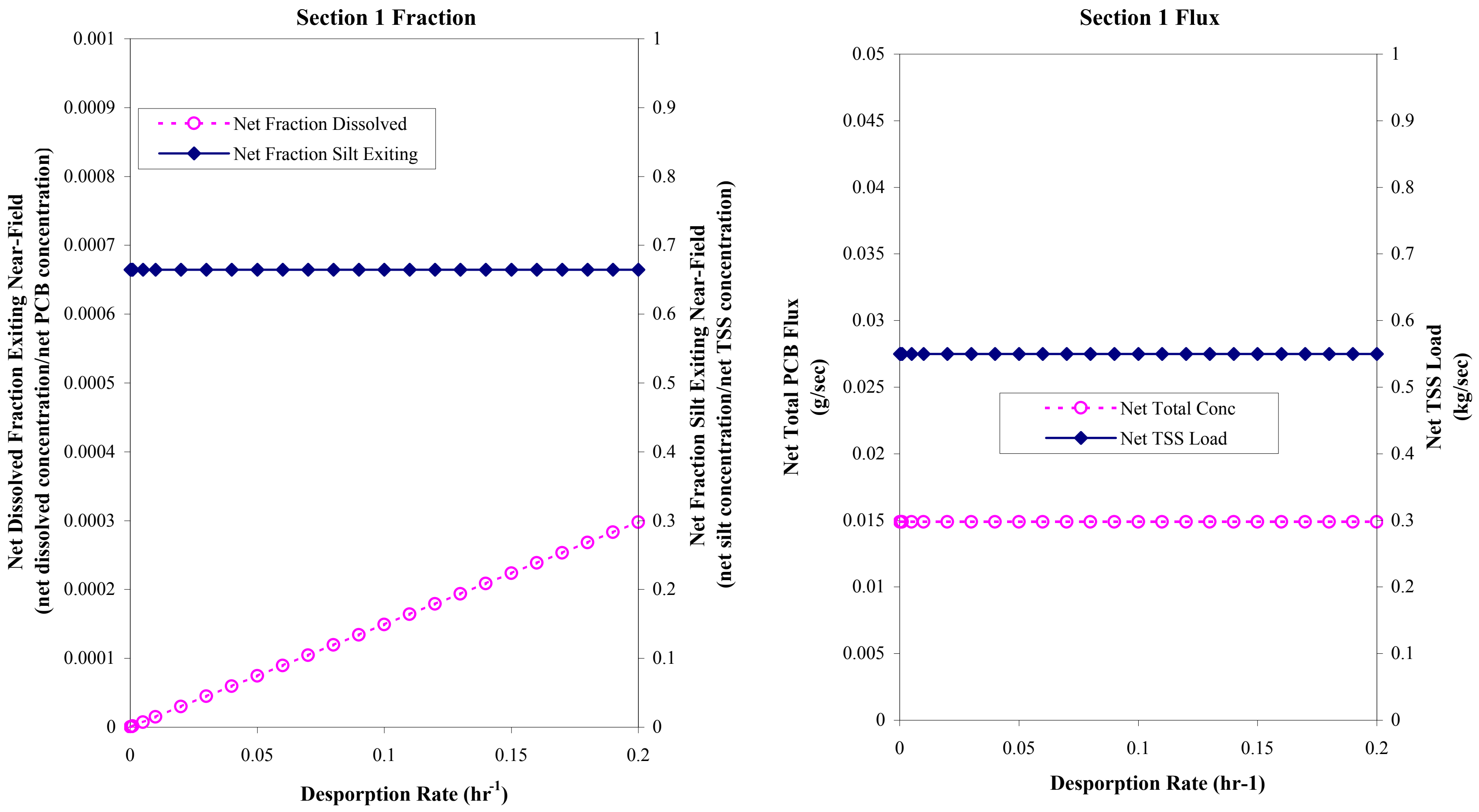
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Dissolved PCB Fraction in the Background and TSS Background Concentrations for CSTR-Chem



Note: Net concentrations exclude background.
Background TSS was held constant at 2.3 mg/L

Figure 10

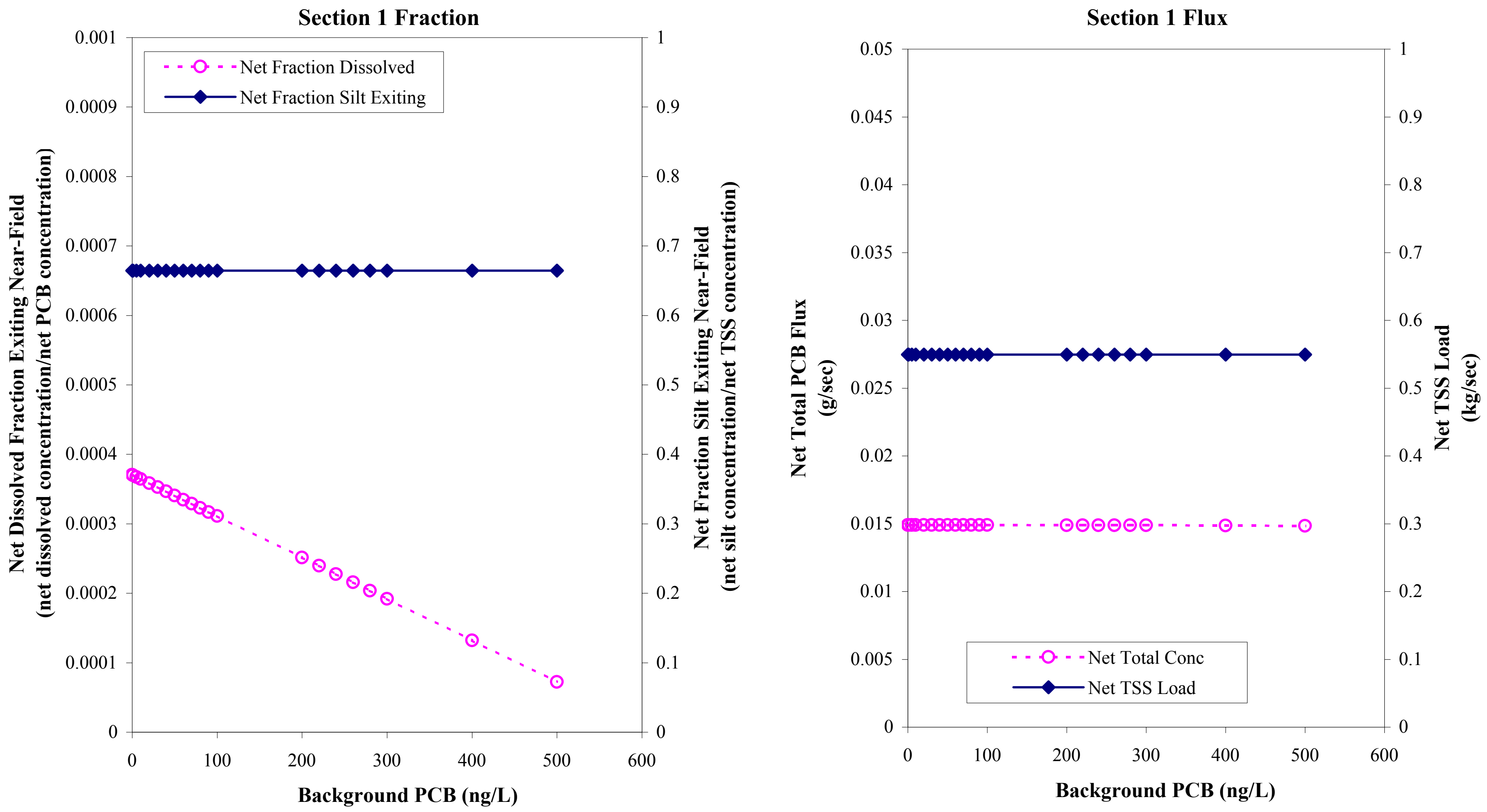
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Dissolved PCB Fraction in the Background and Kd Value for CSTR-Chem



Note: Net concentrations exclude background.

Figure 11

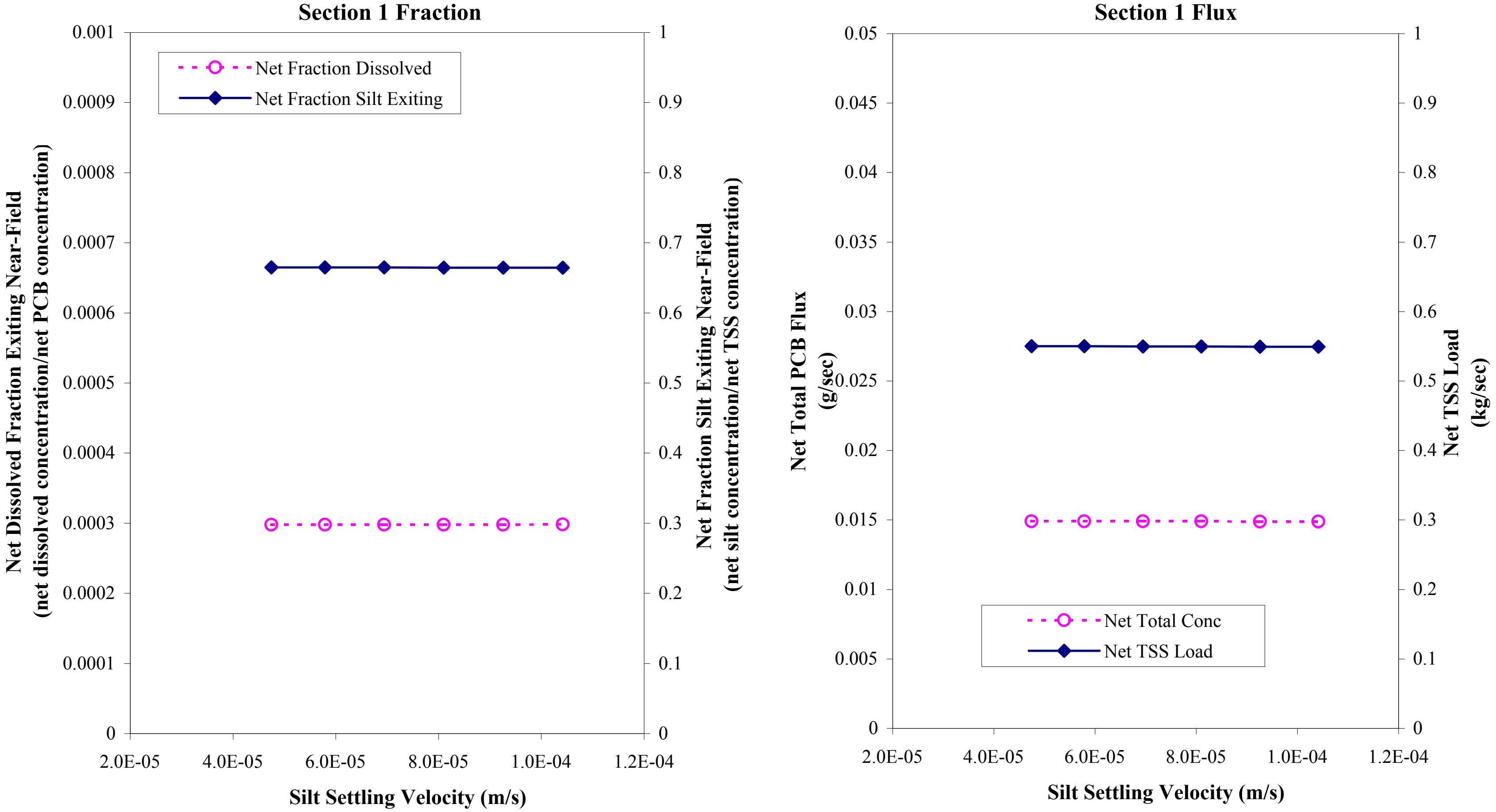
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Desorption Rate for CSTR-Chem



Note: Net concentrations exclude background.

Figure 12

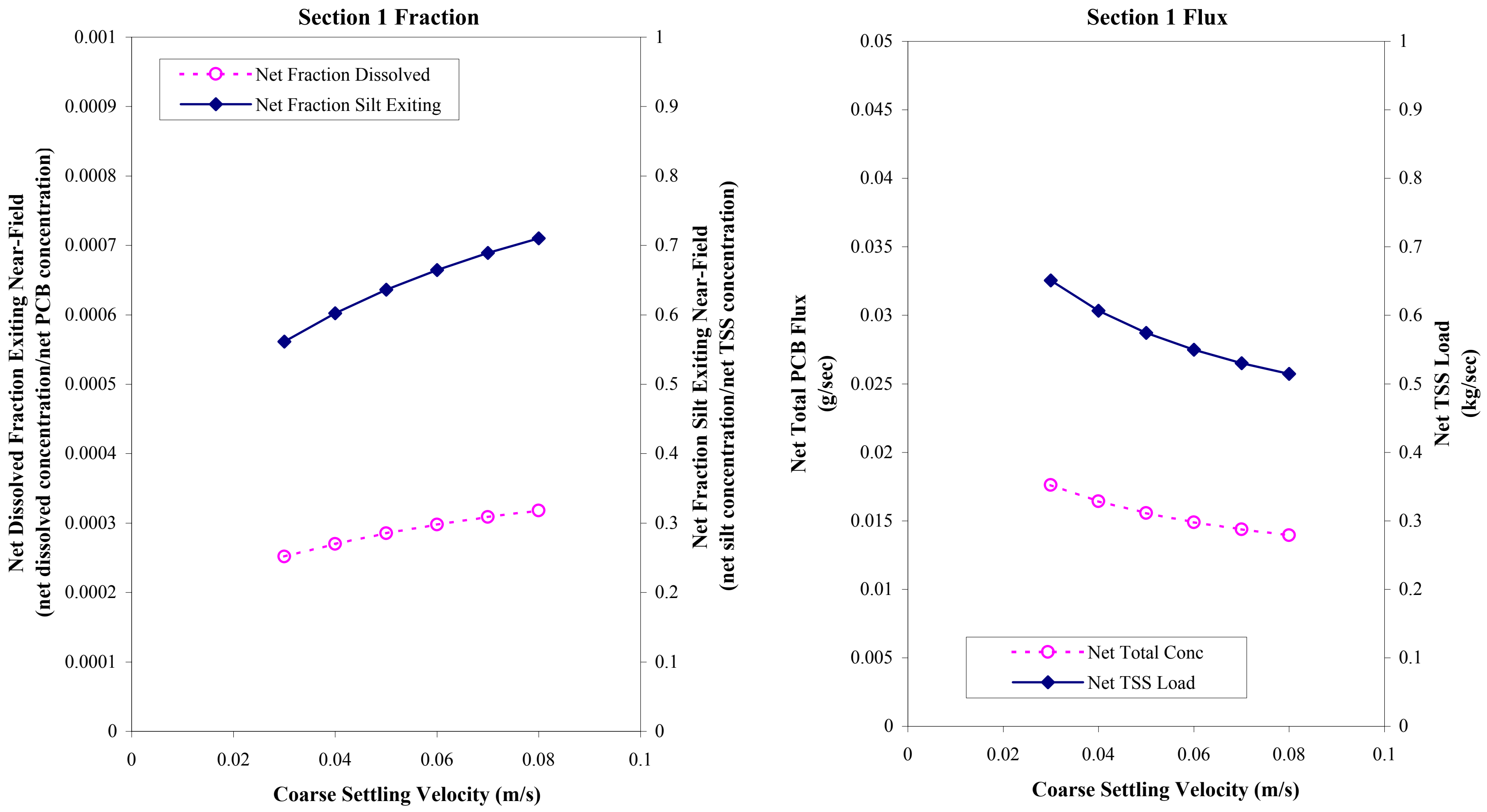
Net Dissolved PCB Fraction, Net Silt Fraction, Net Total PCB Flux and Net TSS Flux Exiting Near-Field as Functions of Background PCB Concentration for CSTR-Chem



Note: Net concentrations exclude background.

Figure 13

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 14

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 15
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)

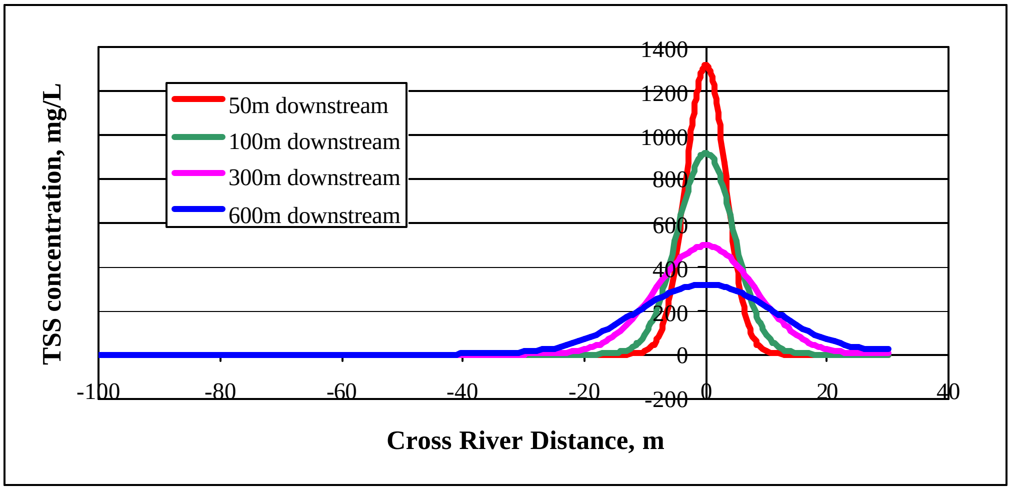
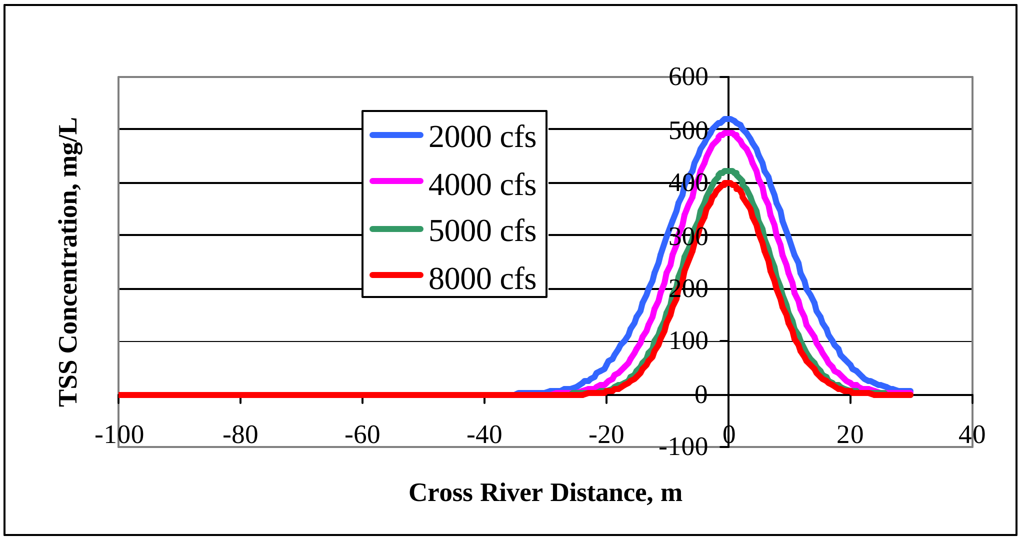
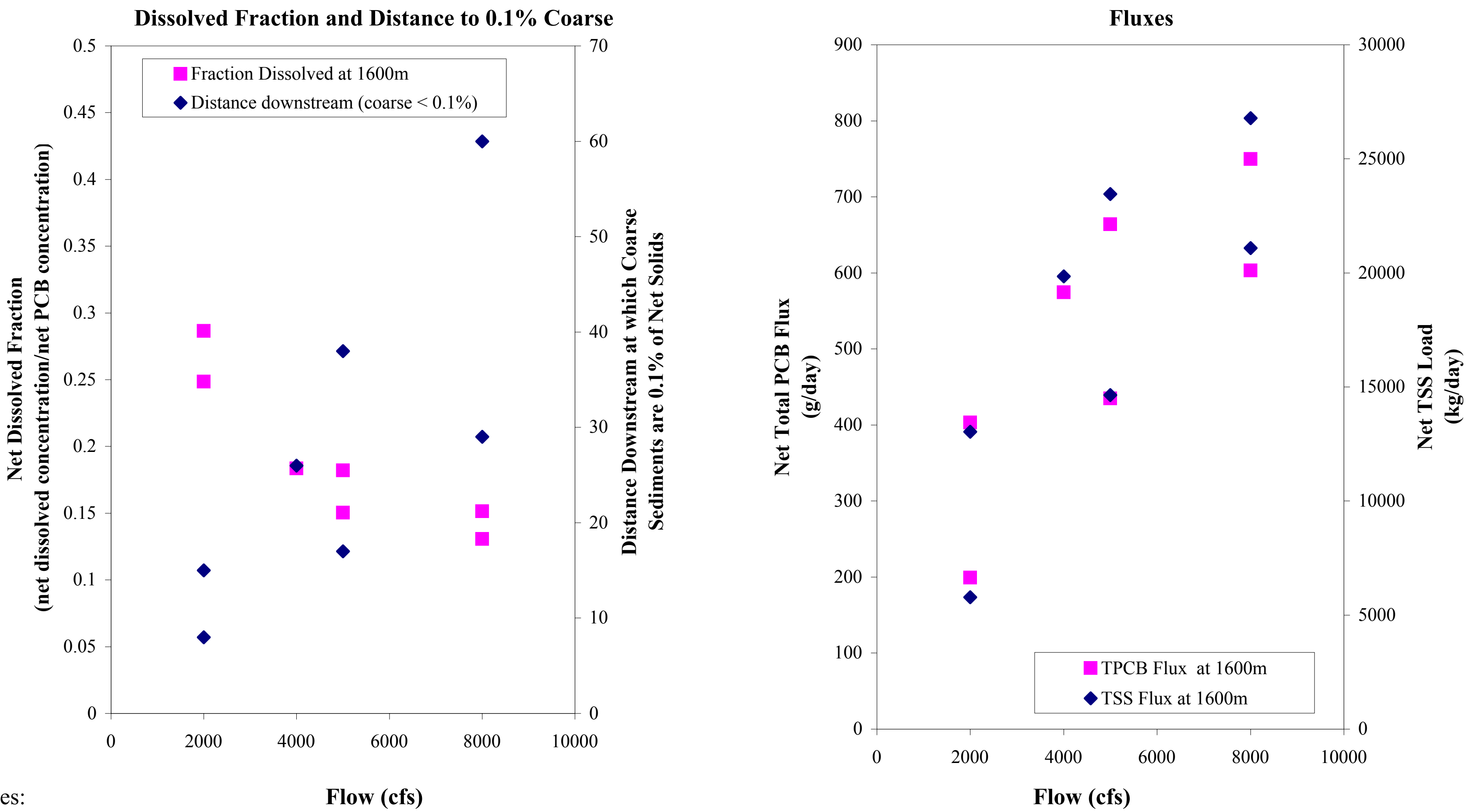


Figure 16
Estimated TSS Concentration at 300 m Downstream of the Dredge Head in Section 1 (PCB concentration at the far-field station is 500 ng/L)

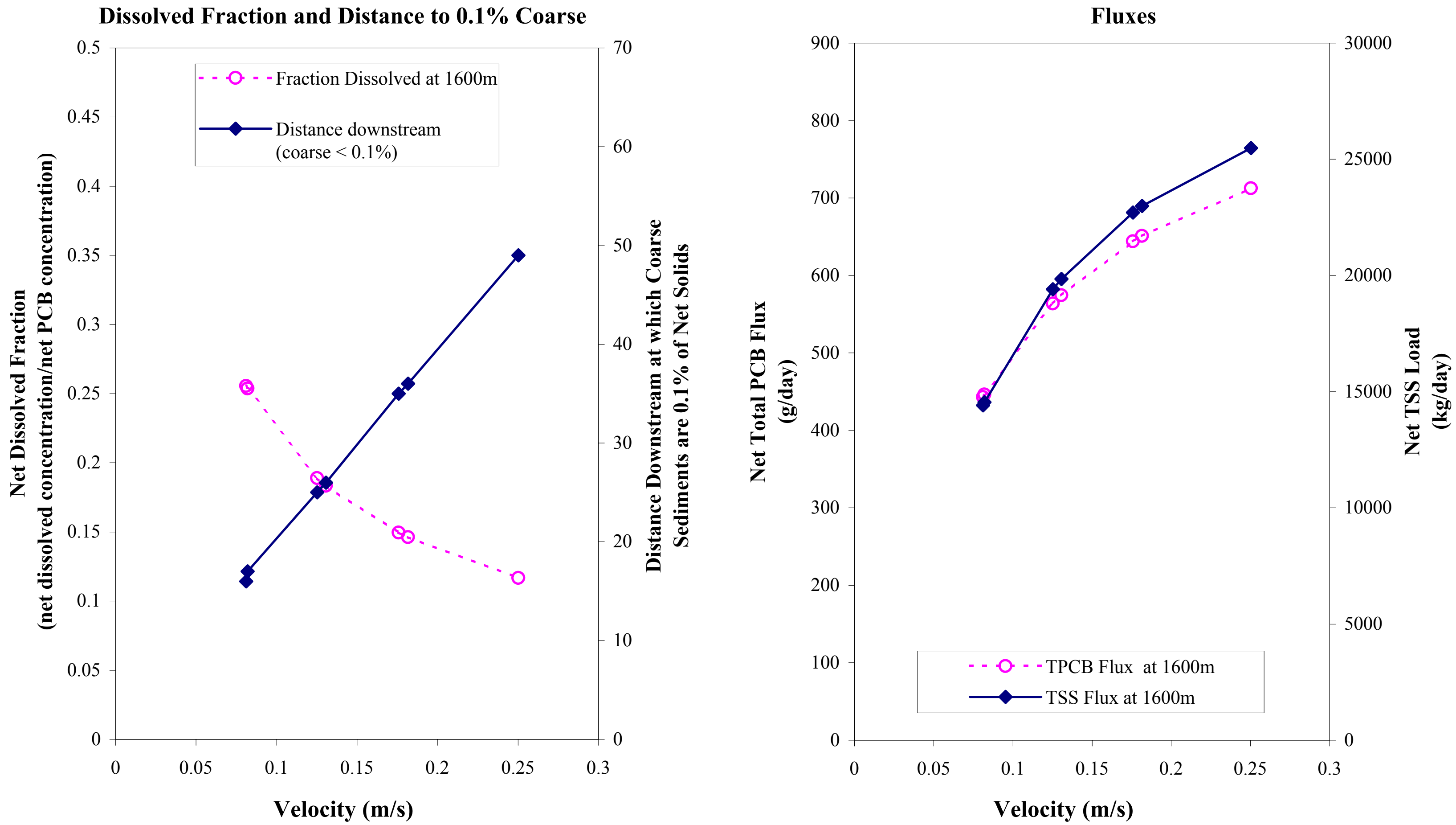




Notes:
1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 17

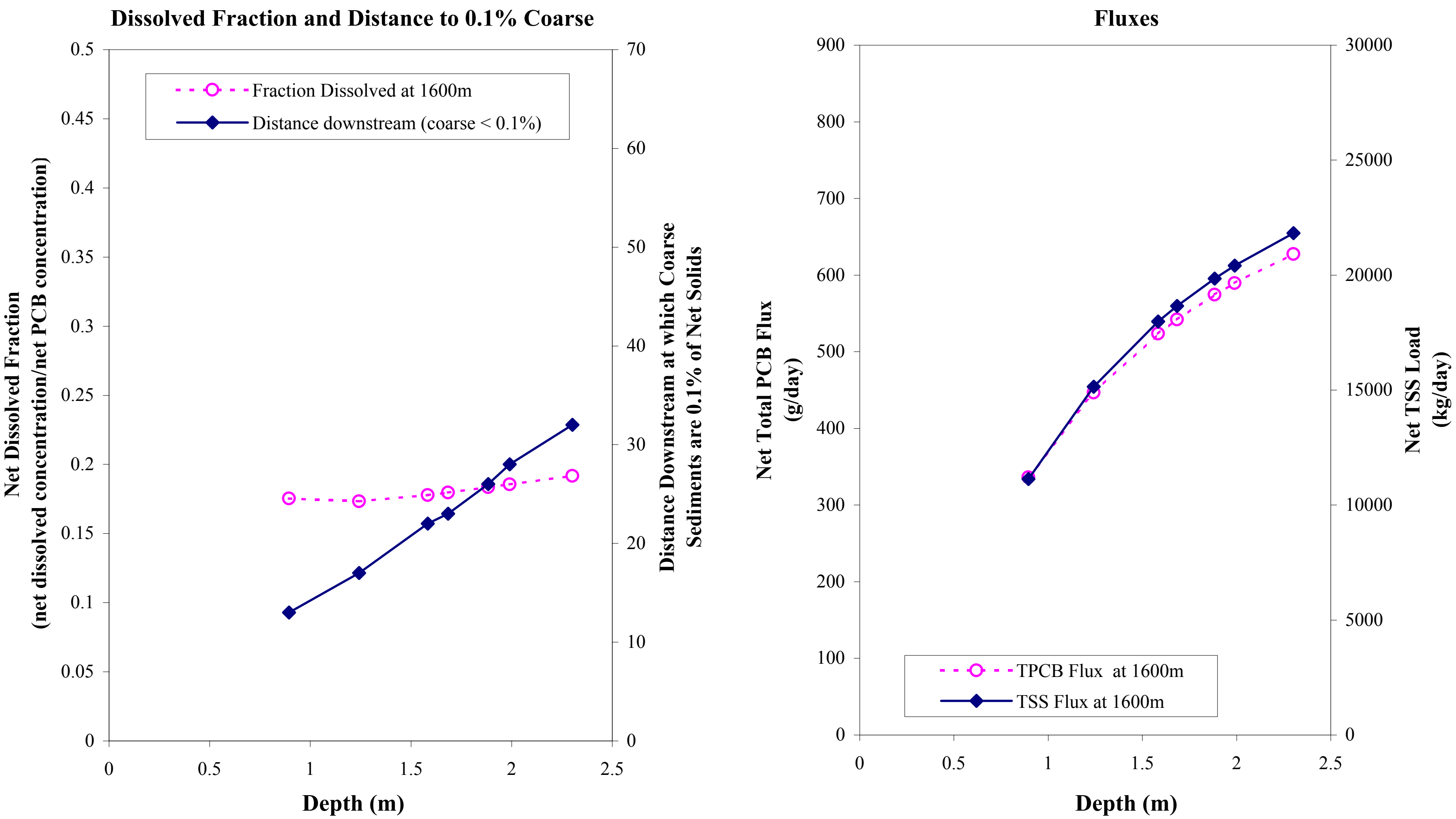
Net Dissolved PCB Fraction, Distance to Coarse < 0.1%, Net Total PCB Flux and Net TSS Flux at 1600 meters as Functions of Riverwide Volumetric Flow (Velocity-Depth Pairs) for the TSS-Chem



Notes:
1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 18

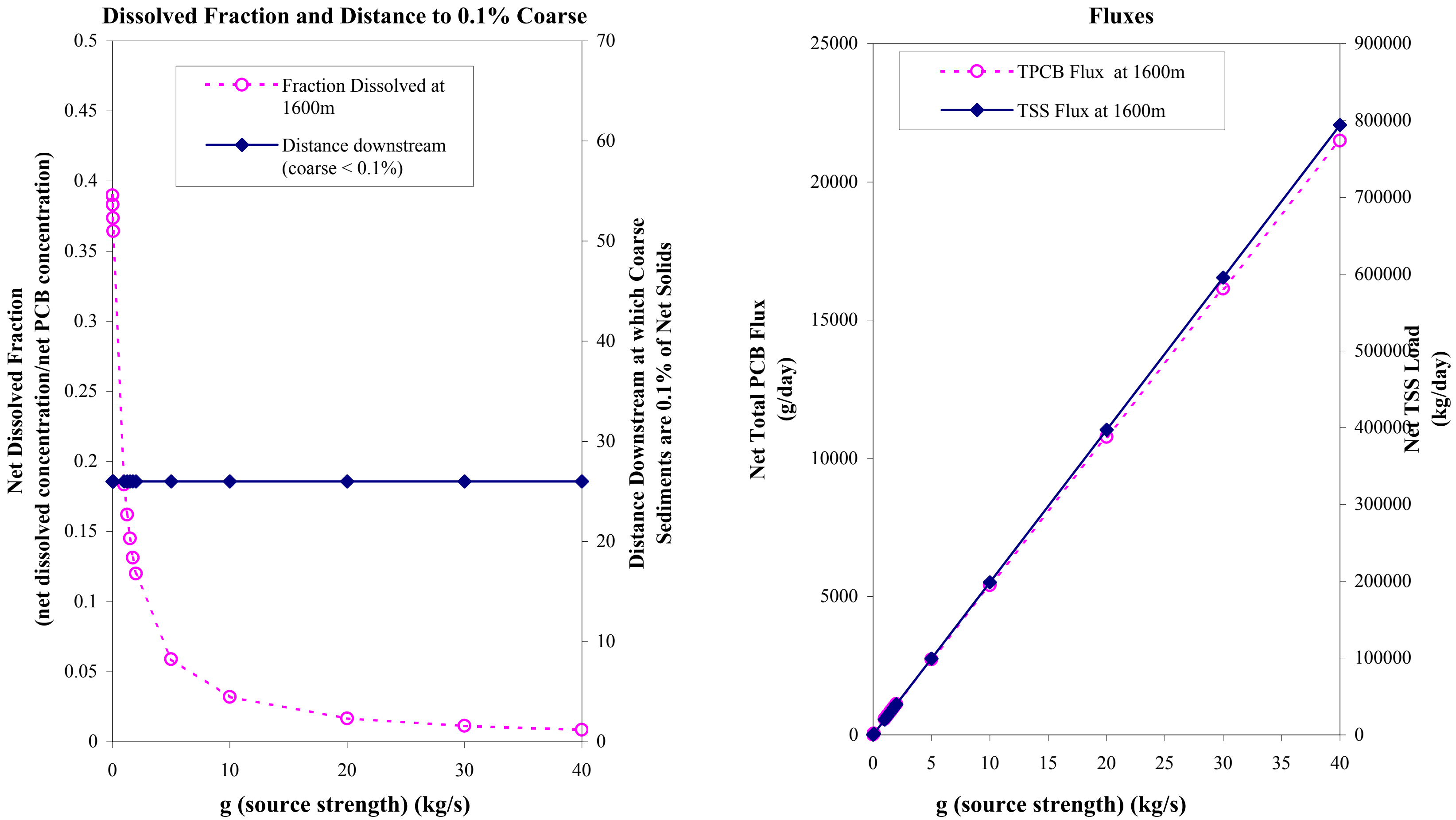
Net Dissolved PCB Fraction, Distance to Coarse < 0.1%, Net Total PCB Flux and Net TSS Flux at 1600 meters as Functions of Velocity for the TSS-Chem



Notes:
1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 19

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



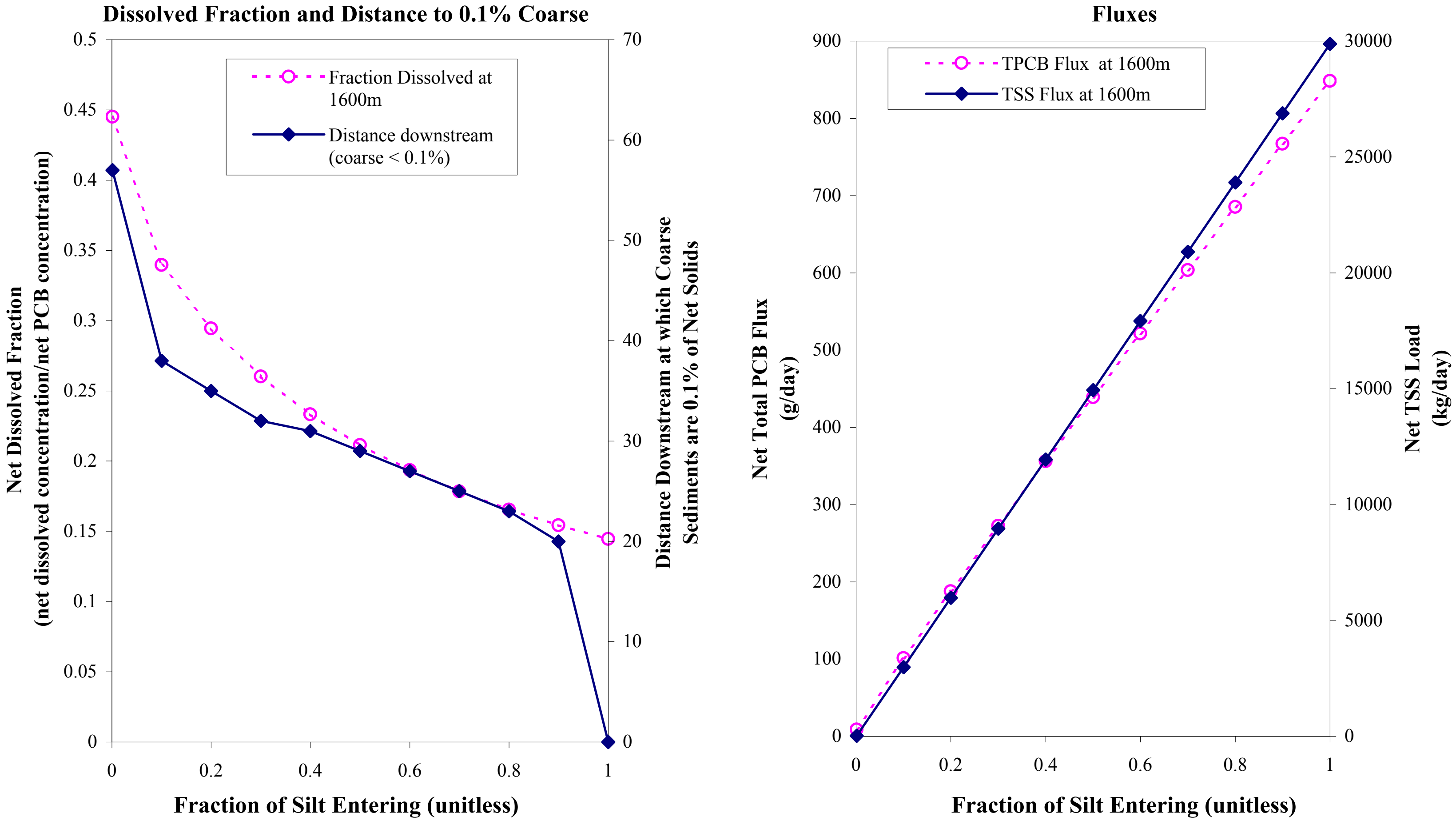
Notes:

1. Net concentrations exclude background.

2. Fluxes are based on 14 hours per day.

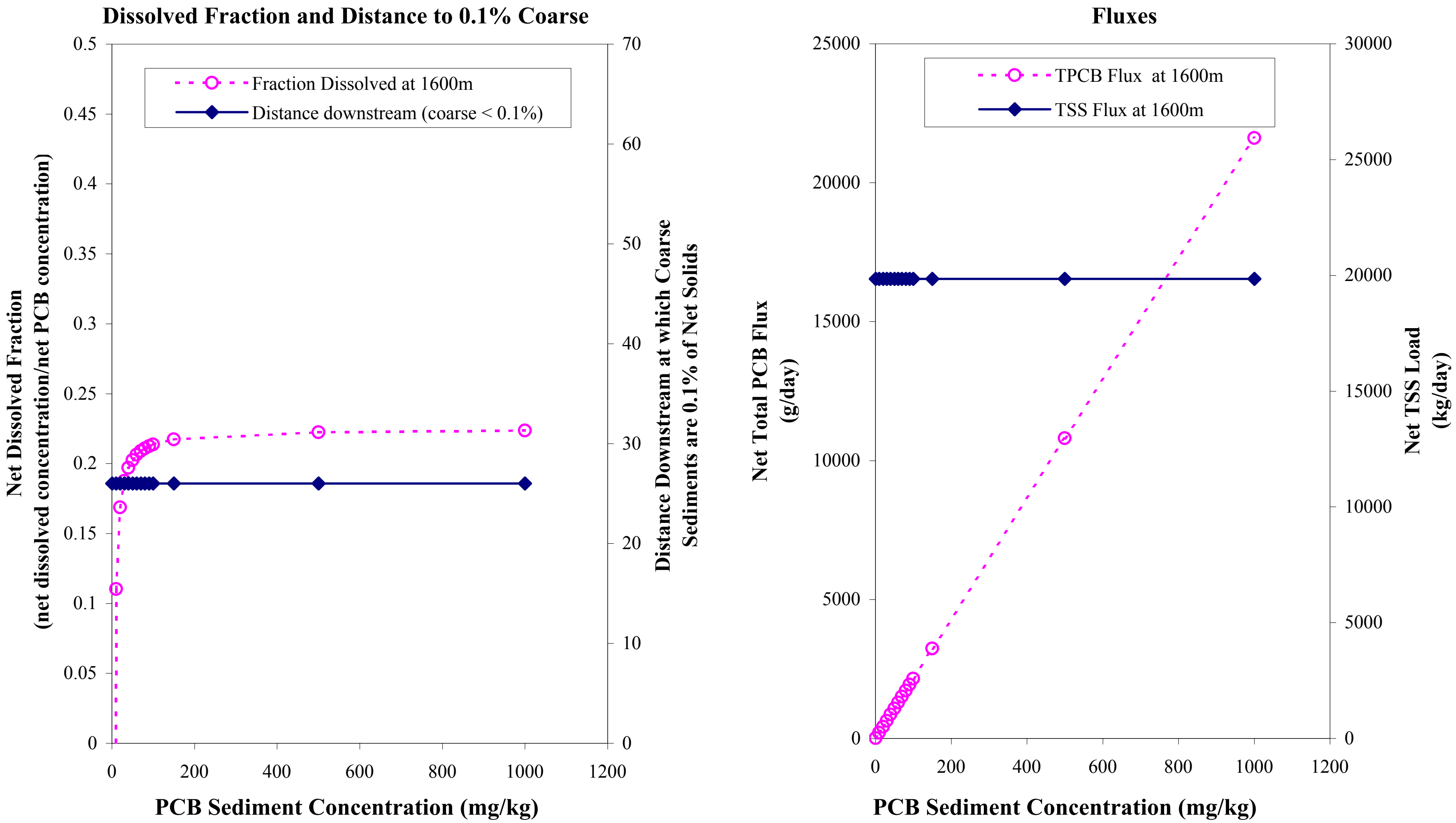
Figure 20

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.

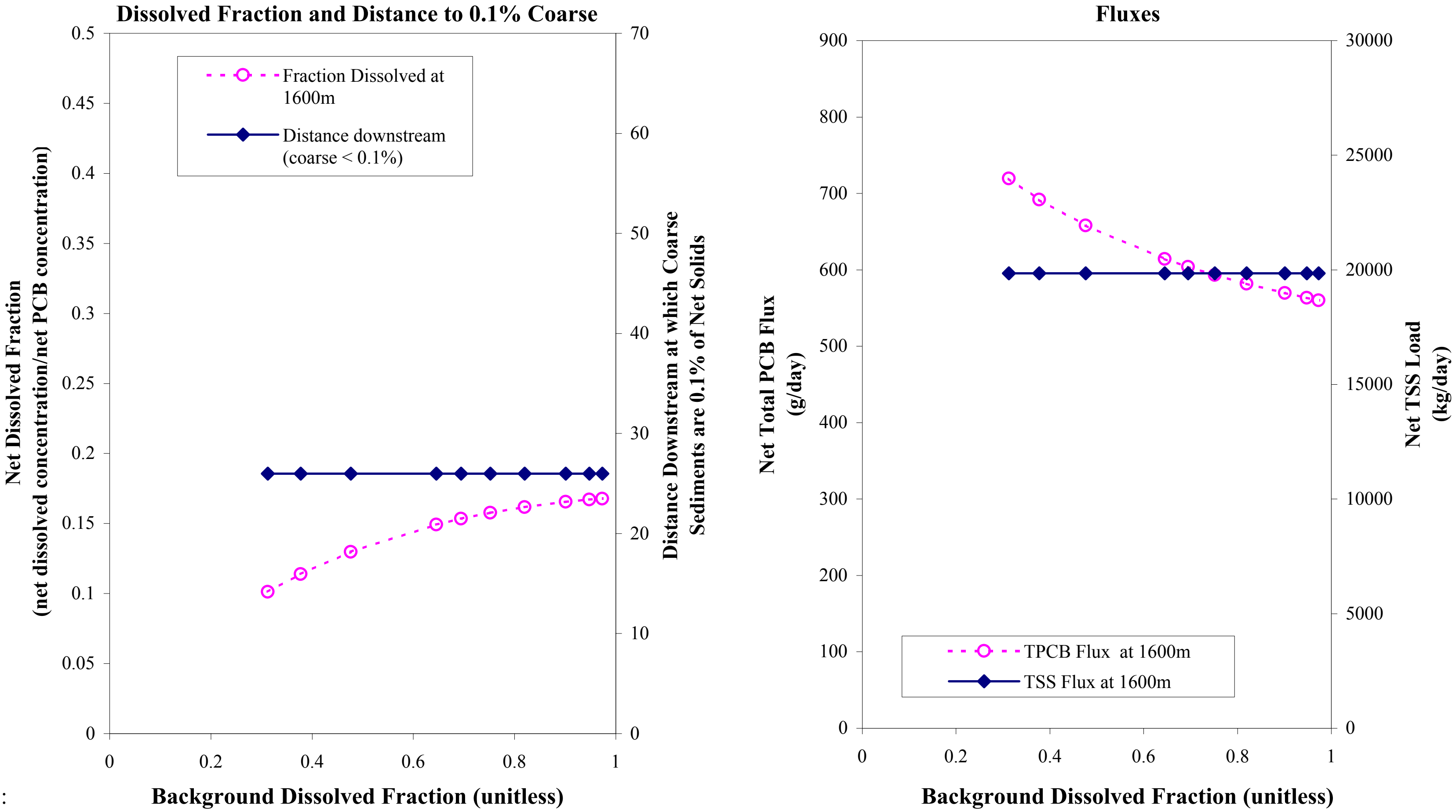
Figure 21
Net Dissolved PCB Fraction, Distance to Coarse < 0.1%, Net Total PCB Flux and Net TSS Flux at 1600 meters as Functions of Silt Fraction Entering for the TSS-Chem



Notes:
1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

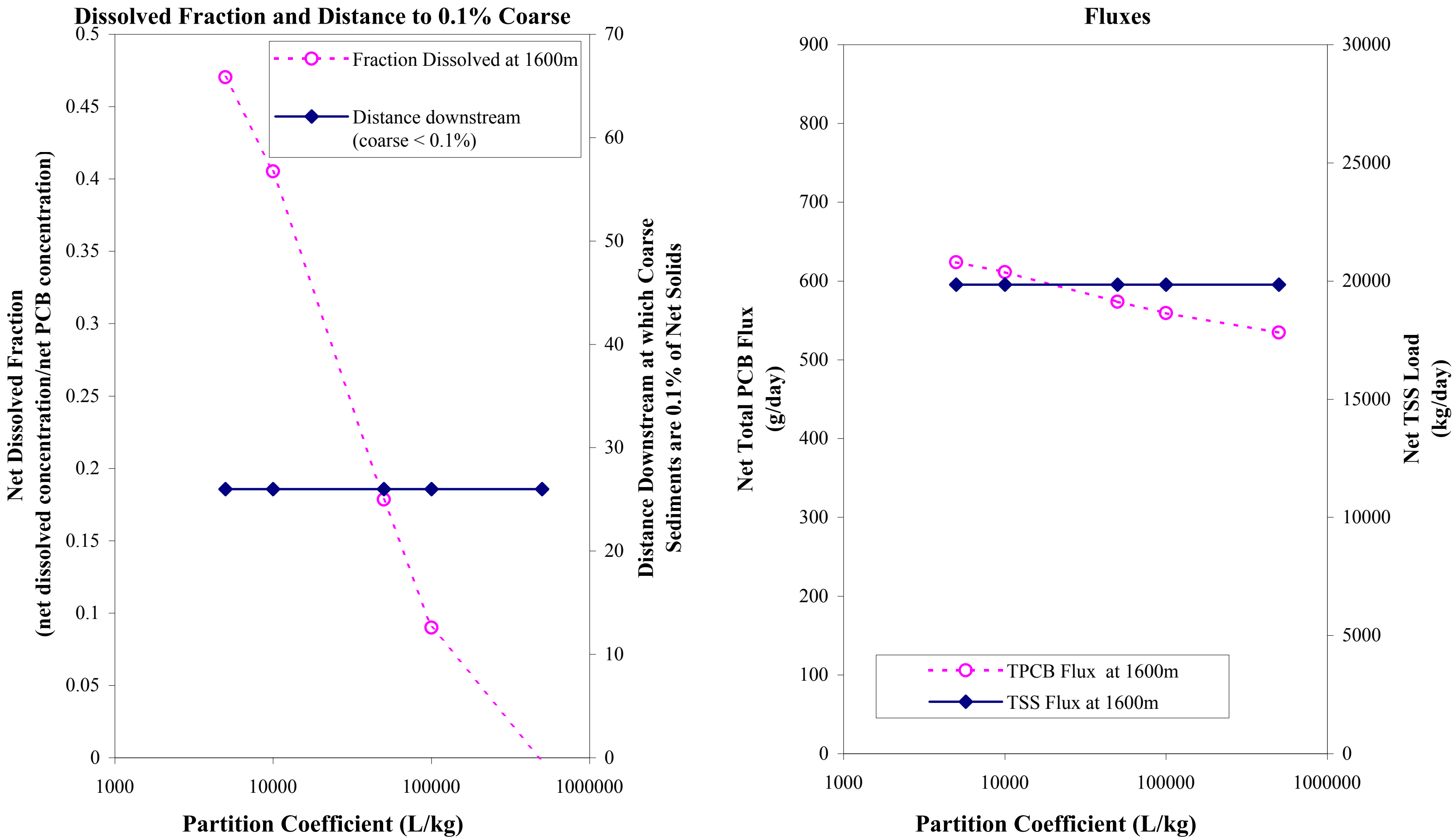
Figure 22

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 23
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

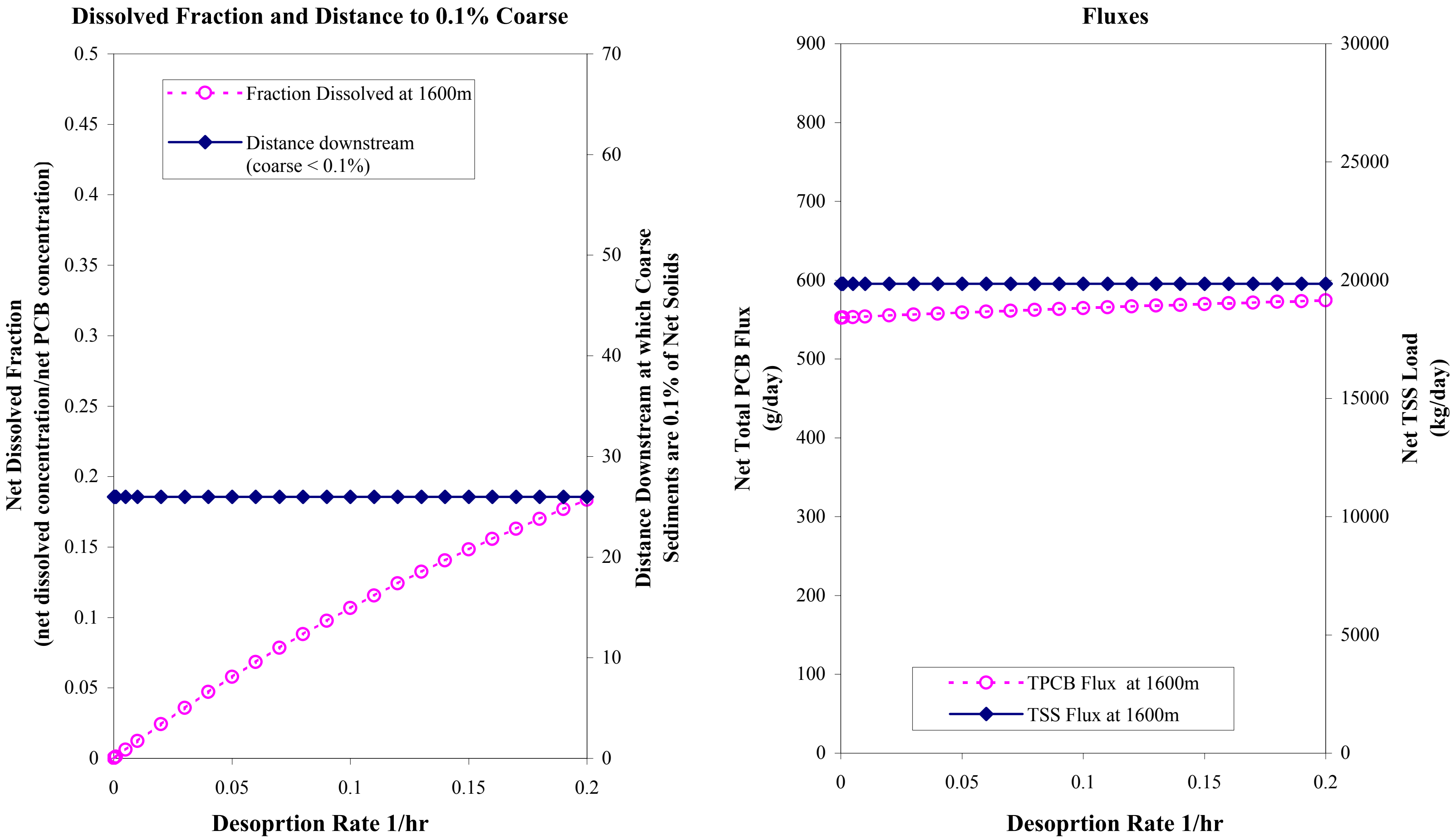


Notes:

1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 24

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

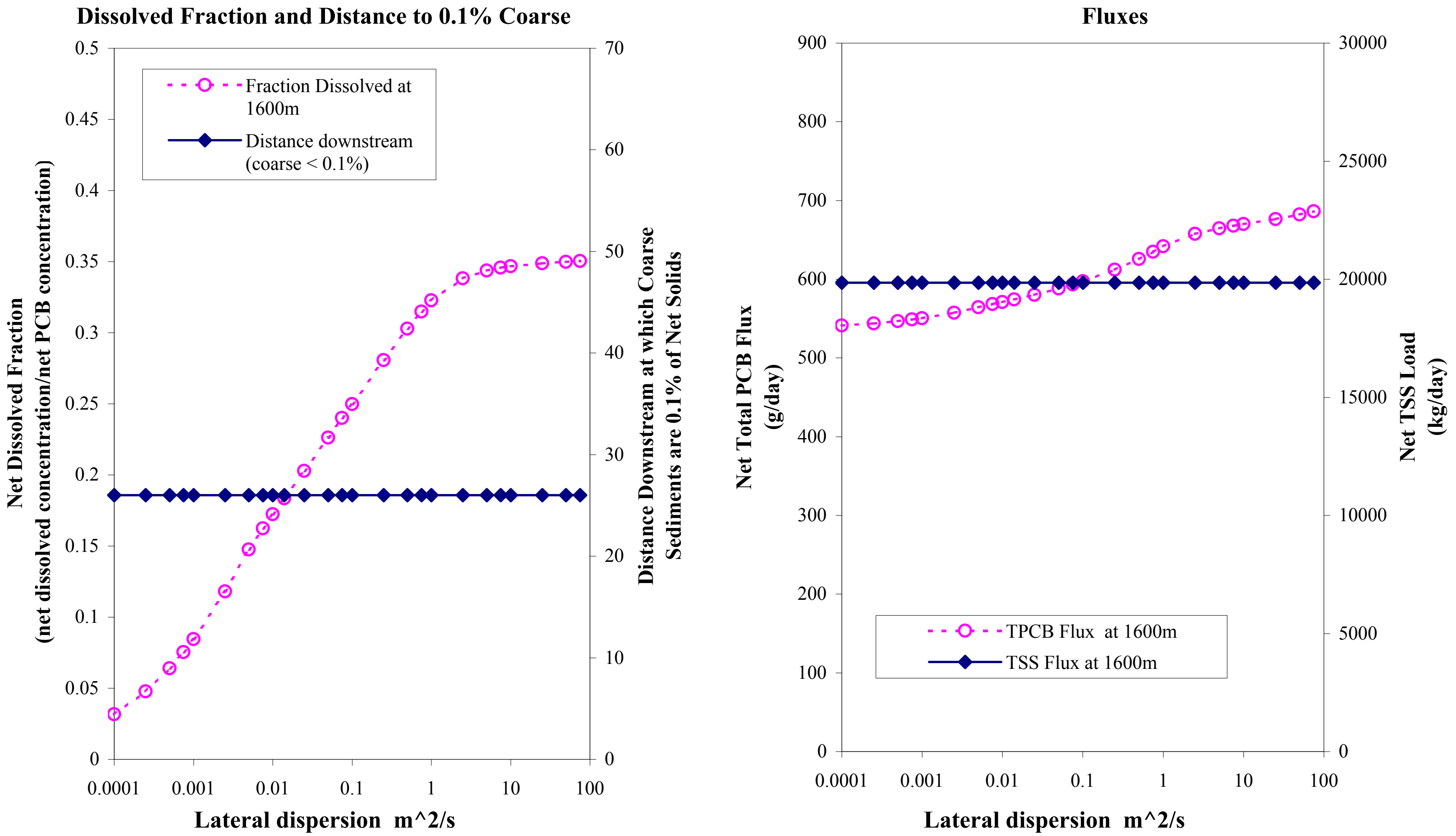


Notes:

1. Net concentrations exclude background.
2. Fluxes are based on 14 hours per day.

Figure 25

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



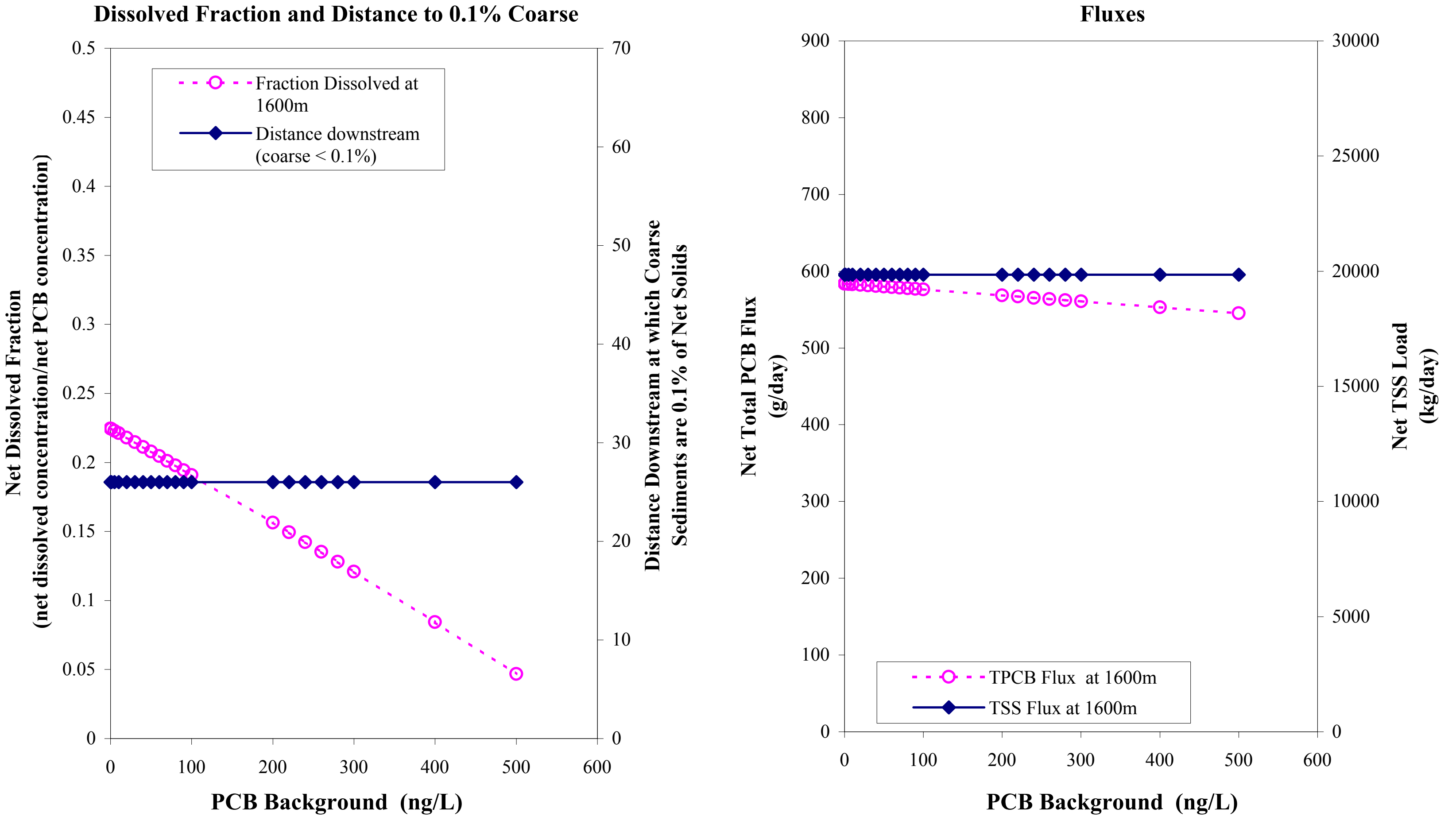
Notes:

1. Net concentrations exclude background.

2. Fluxes are based on 14 hours per day.

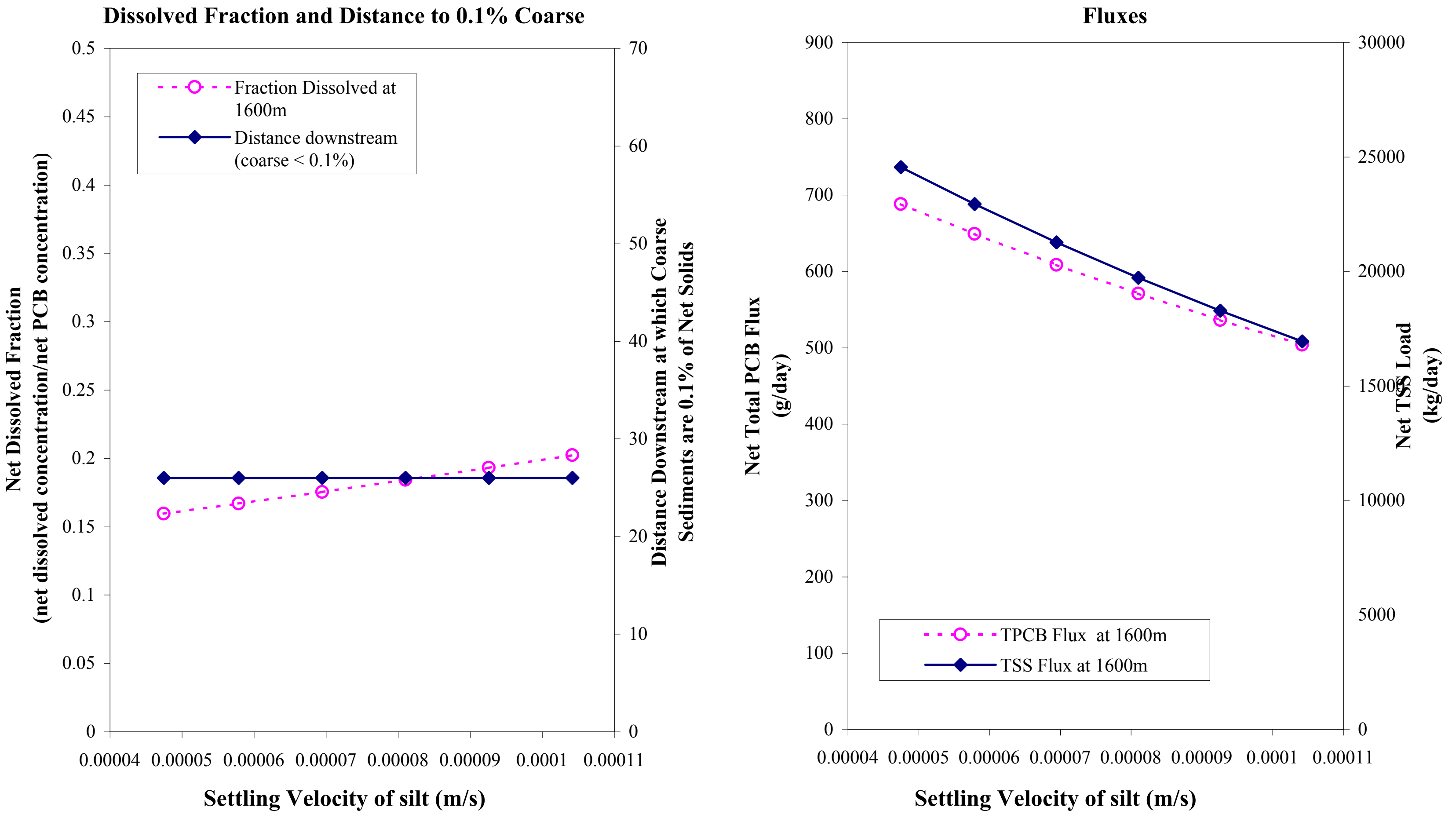
Figure 26

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 27
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



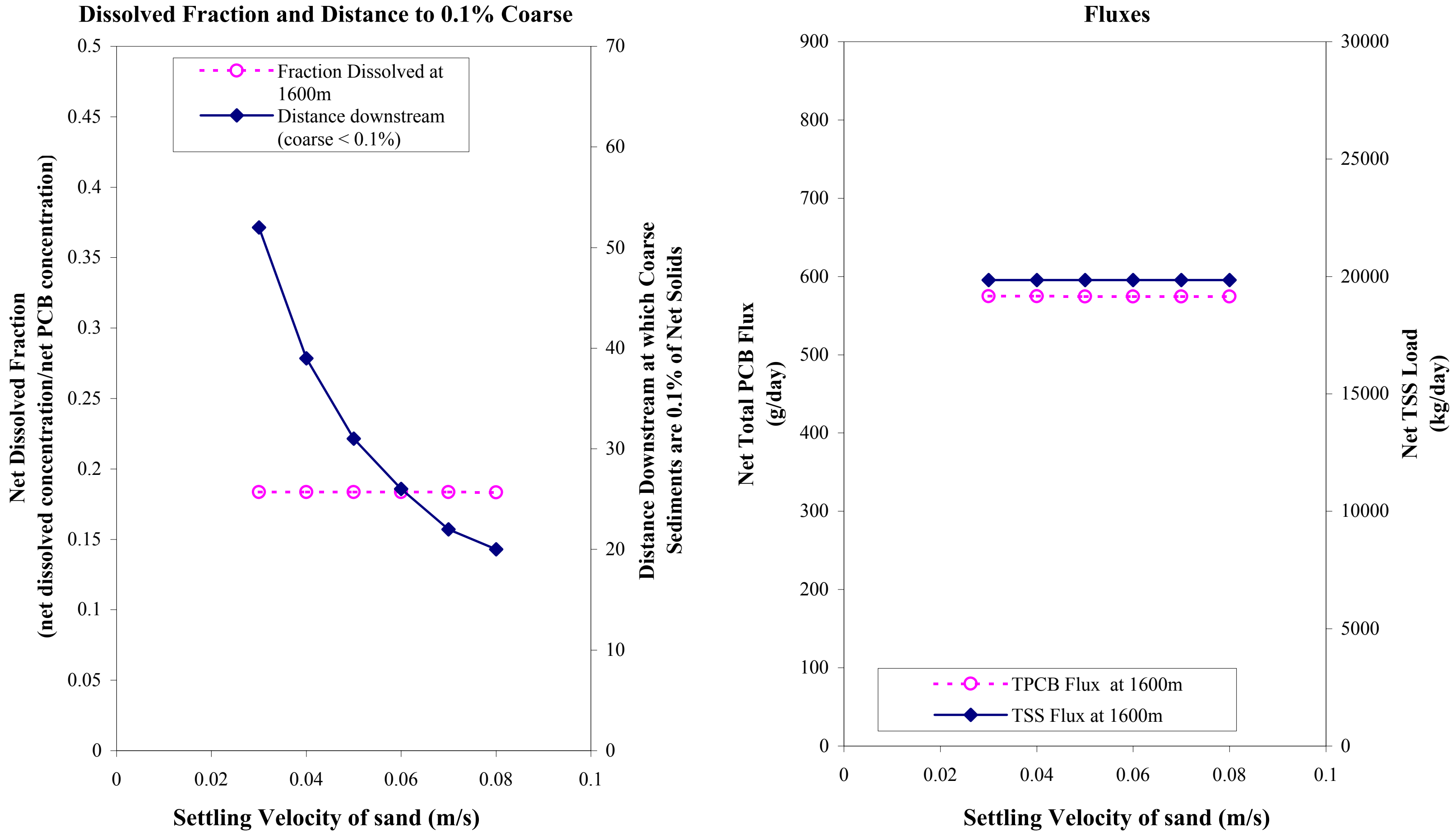
Notes:

1. Net concentrations exclude background.

2. Fluxes are based on 14 hours per day.

Figure 28

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 29

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

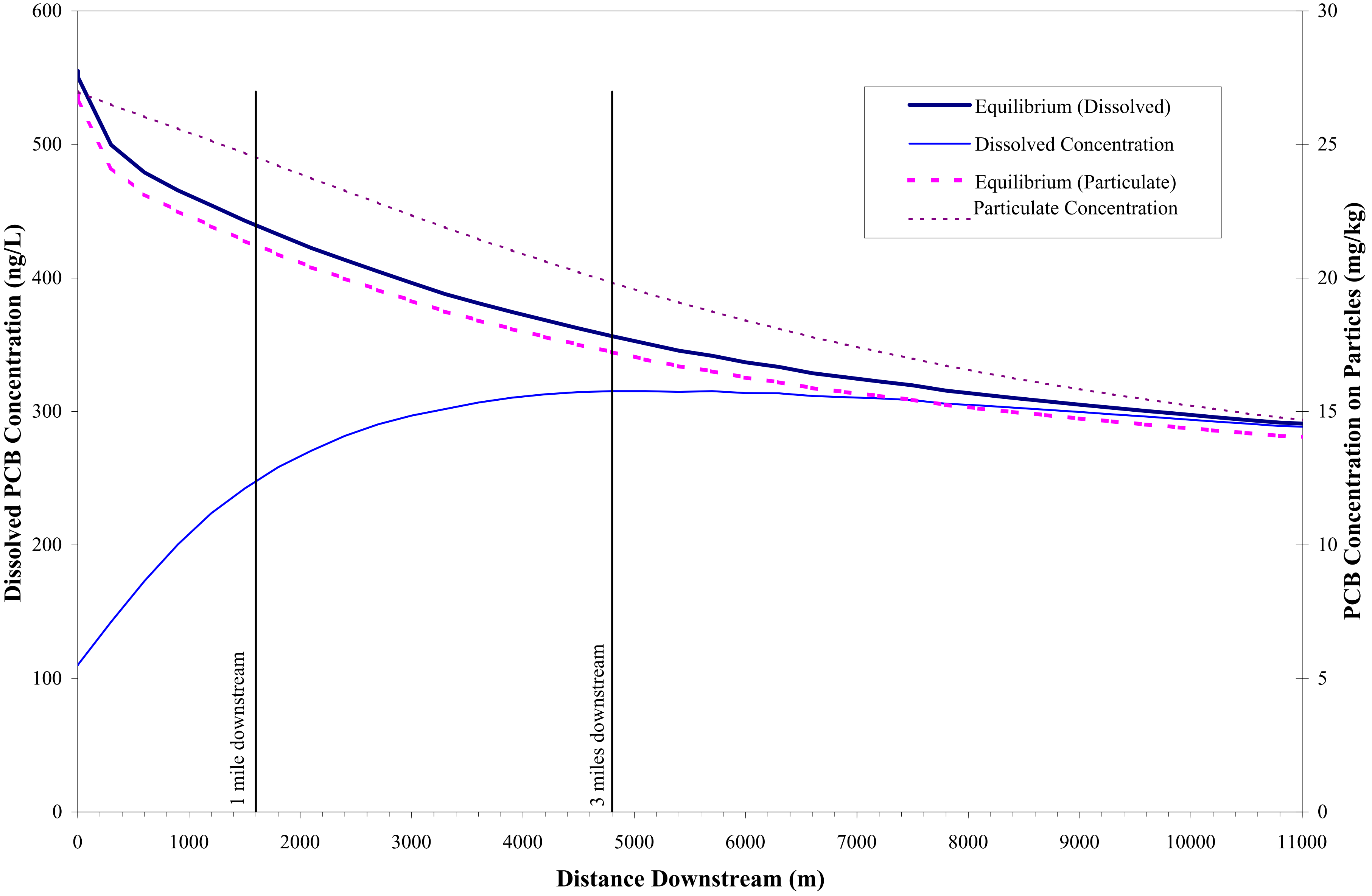
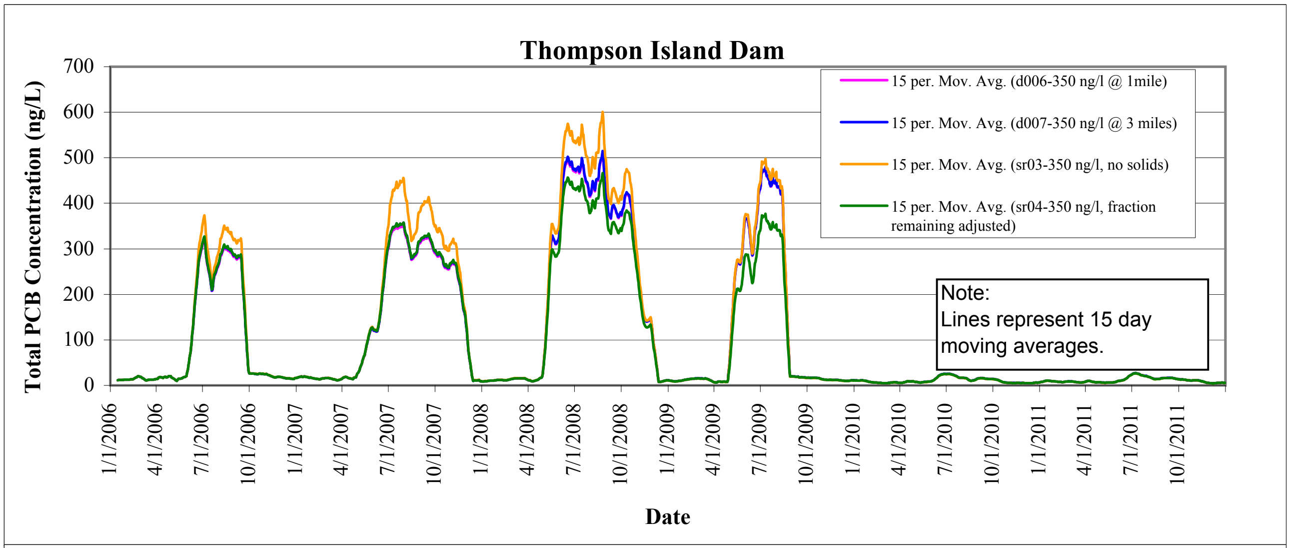
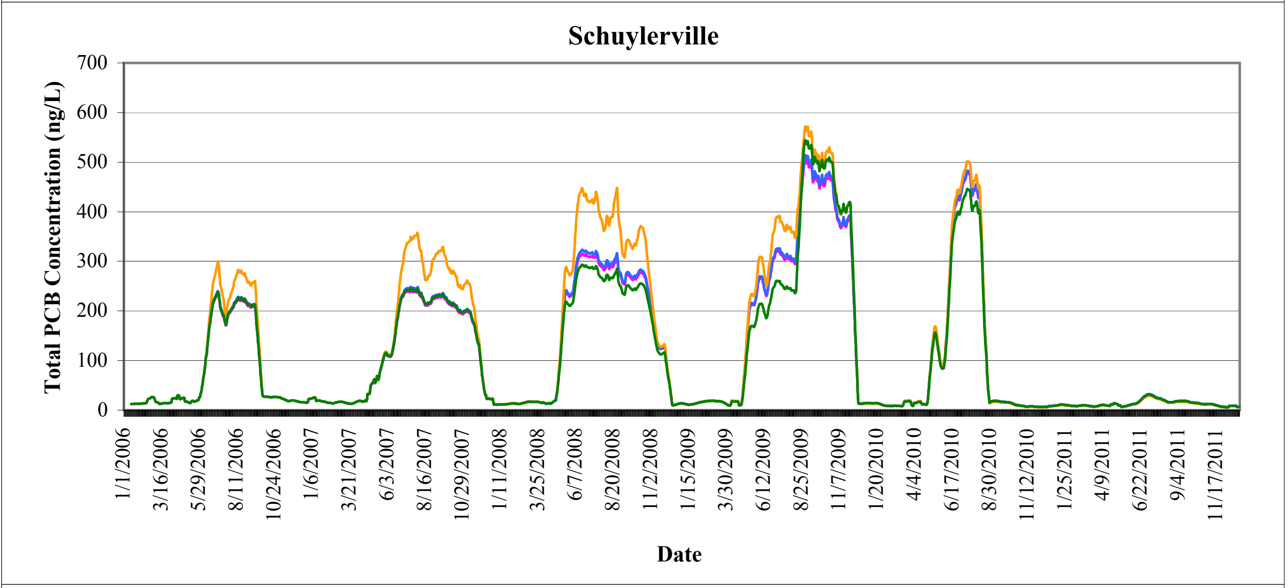


Figure 30
PCB Concentrations Downstream of Dredge for 350 ng/L scenario
Section 1 at 1 mile and 3 miles

Figure 31
Whole Water Total PCB Concentration for Different 350 ng/L Input Formulations





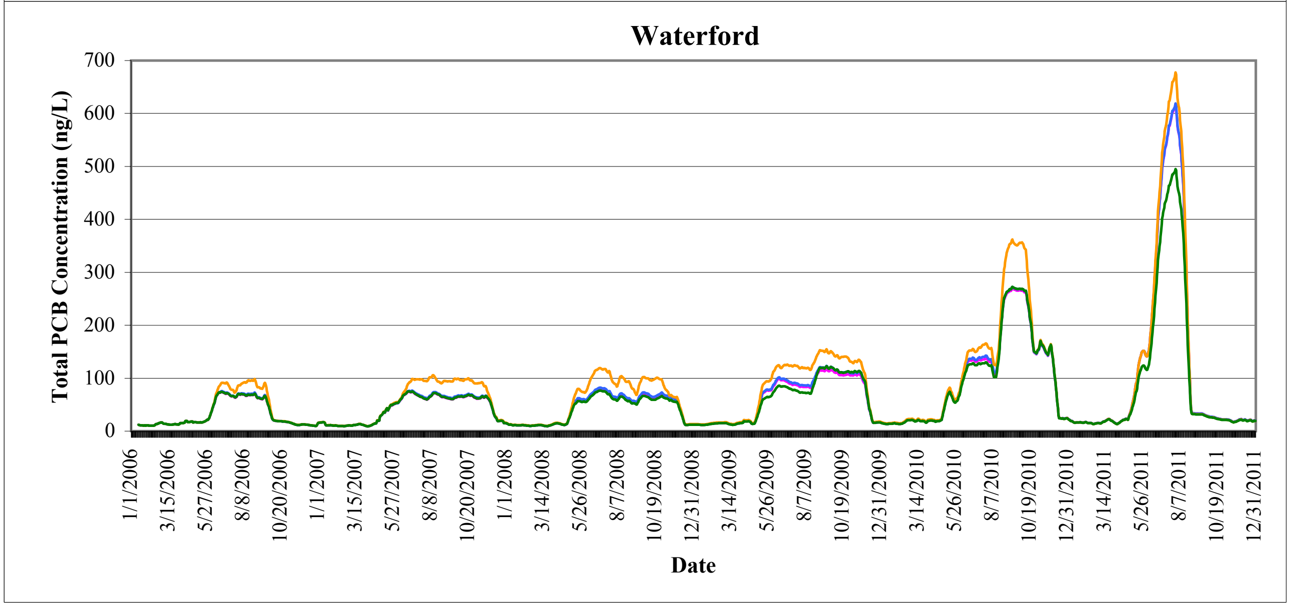


Figure 32
Tri+ PCB Cumulative Load for Different Dredging Scenarios

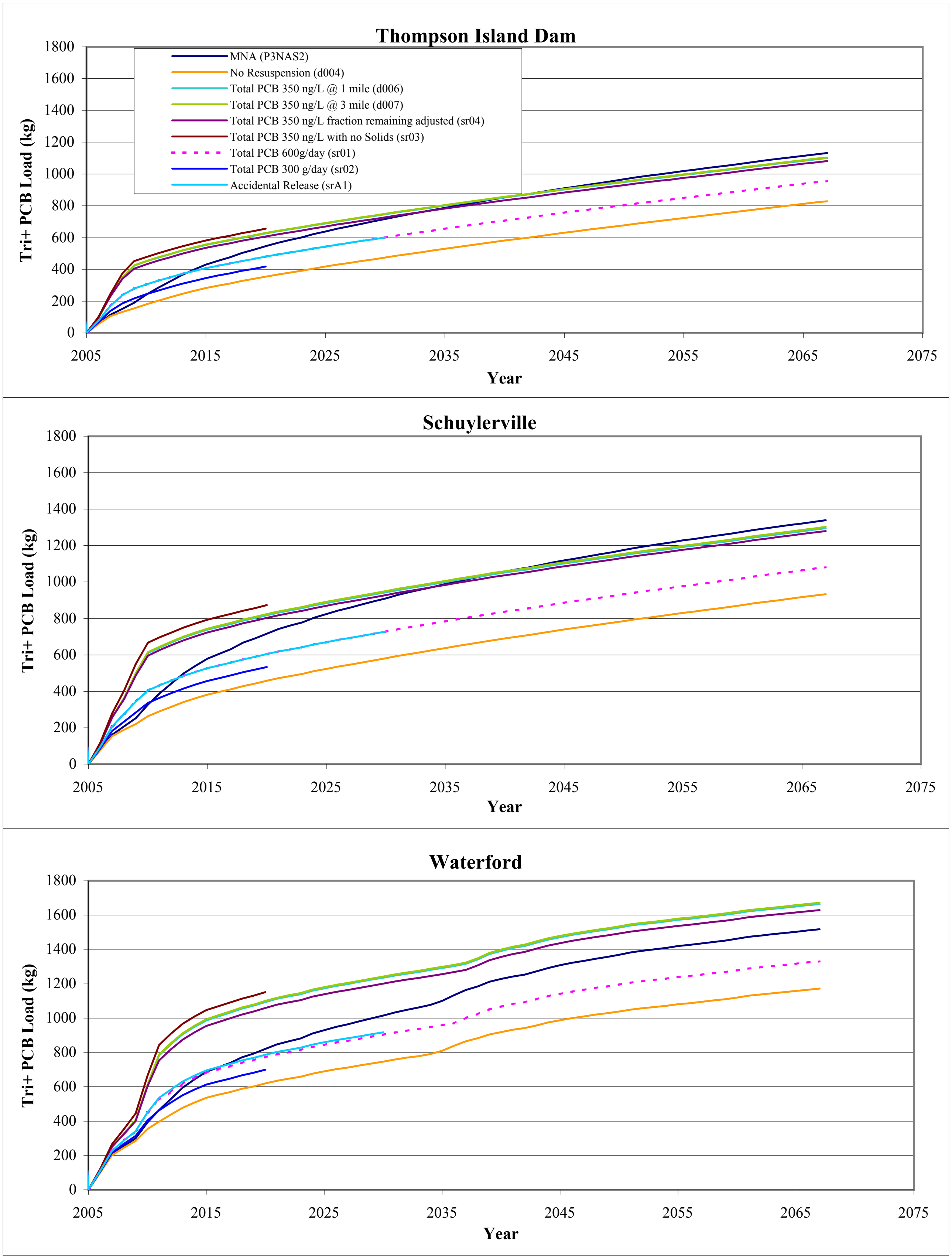


Figure 33

Total PCB Cumulative Load for Different Dredging Scenarios

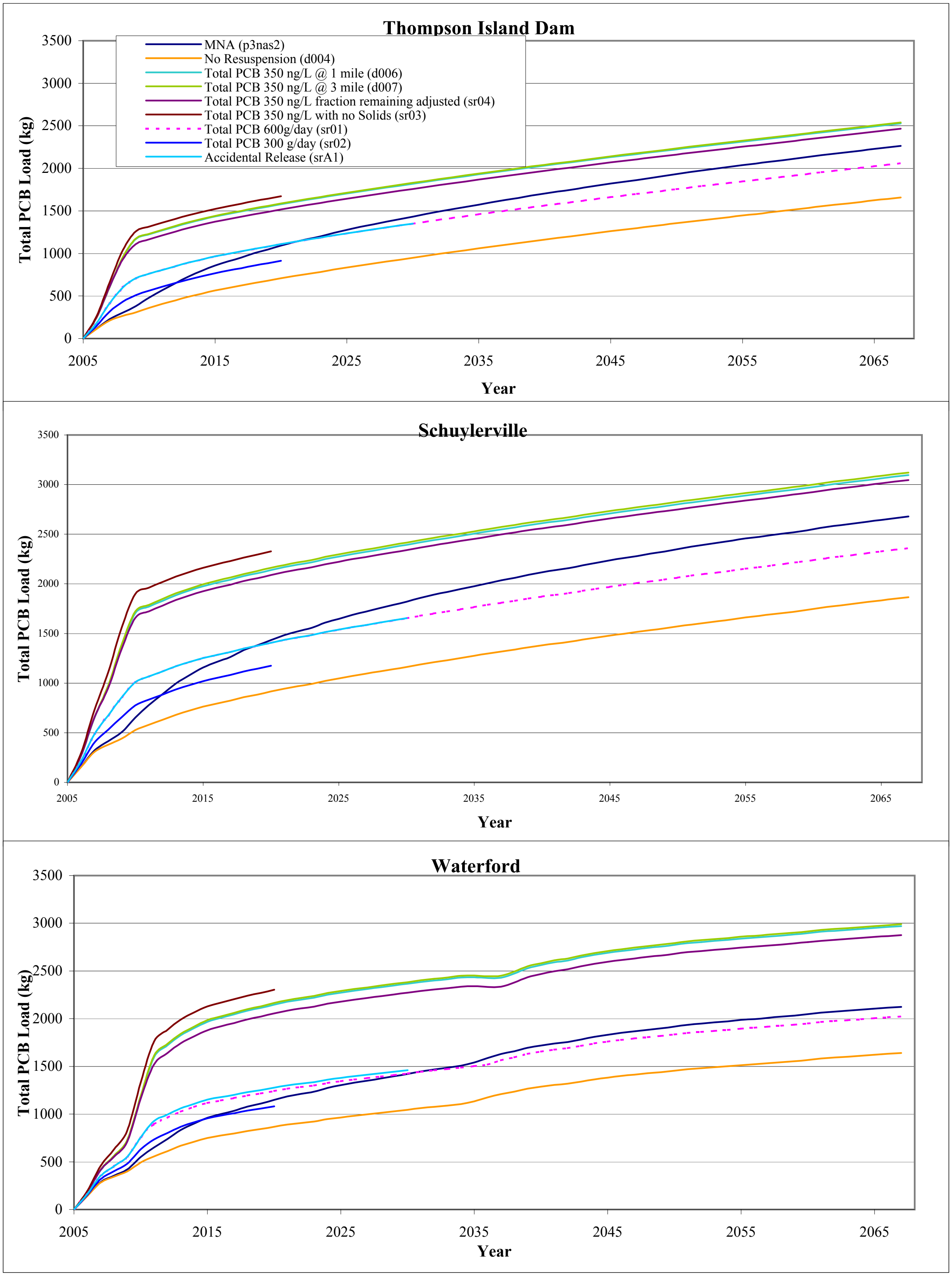


Figure 34
Whole Water, Particulate, and Dissolved Total PCB Concentrations for the 350 ng/L Dredging Scenario (sr04)

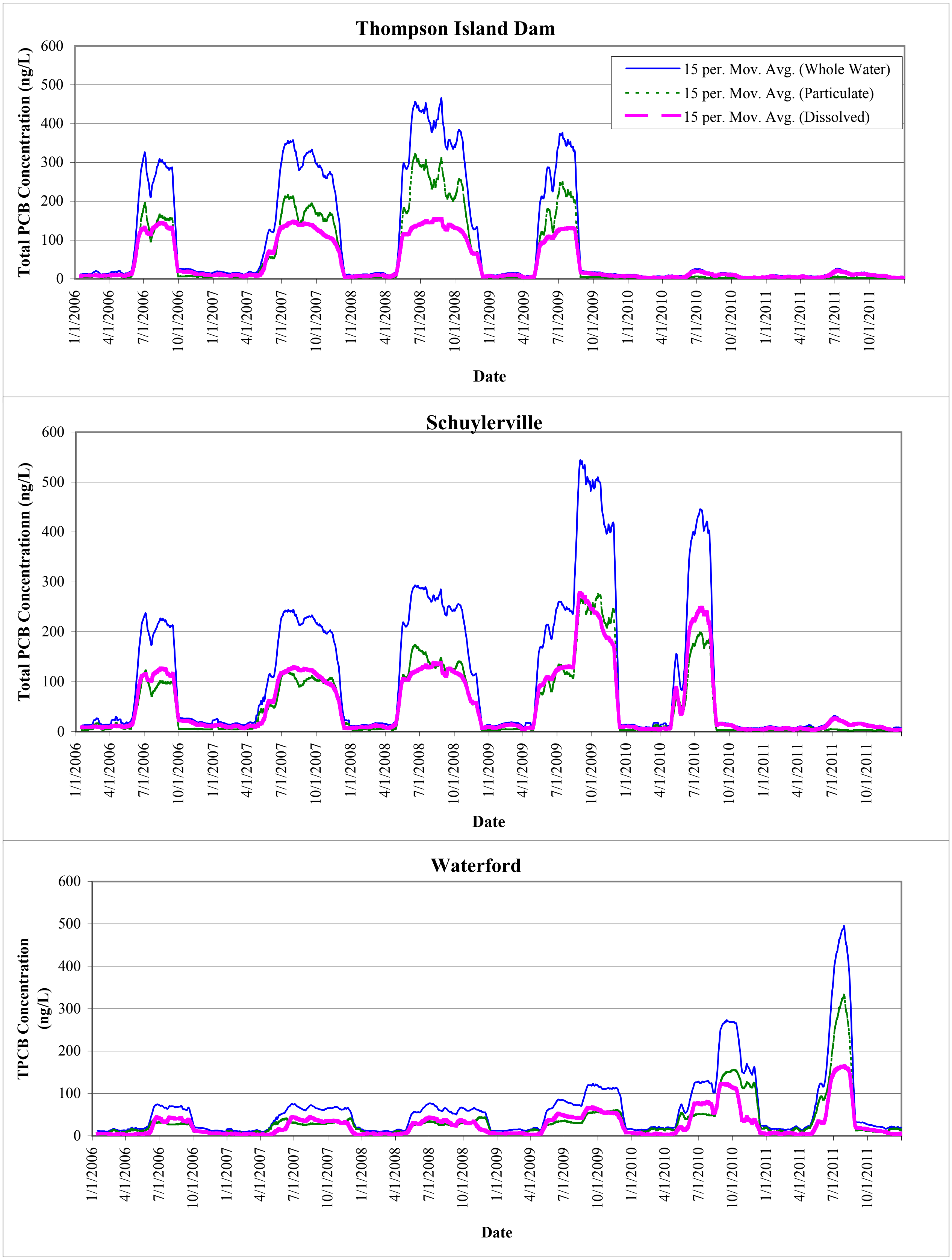


Figure 35
Whole Water, Particulate and Dissolved Total PCB Concentration for Concern Level - 600 g/day Total PCB Flux Dredging Scenario (sr01)

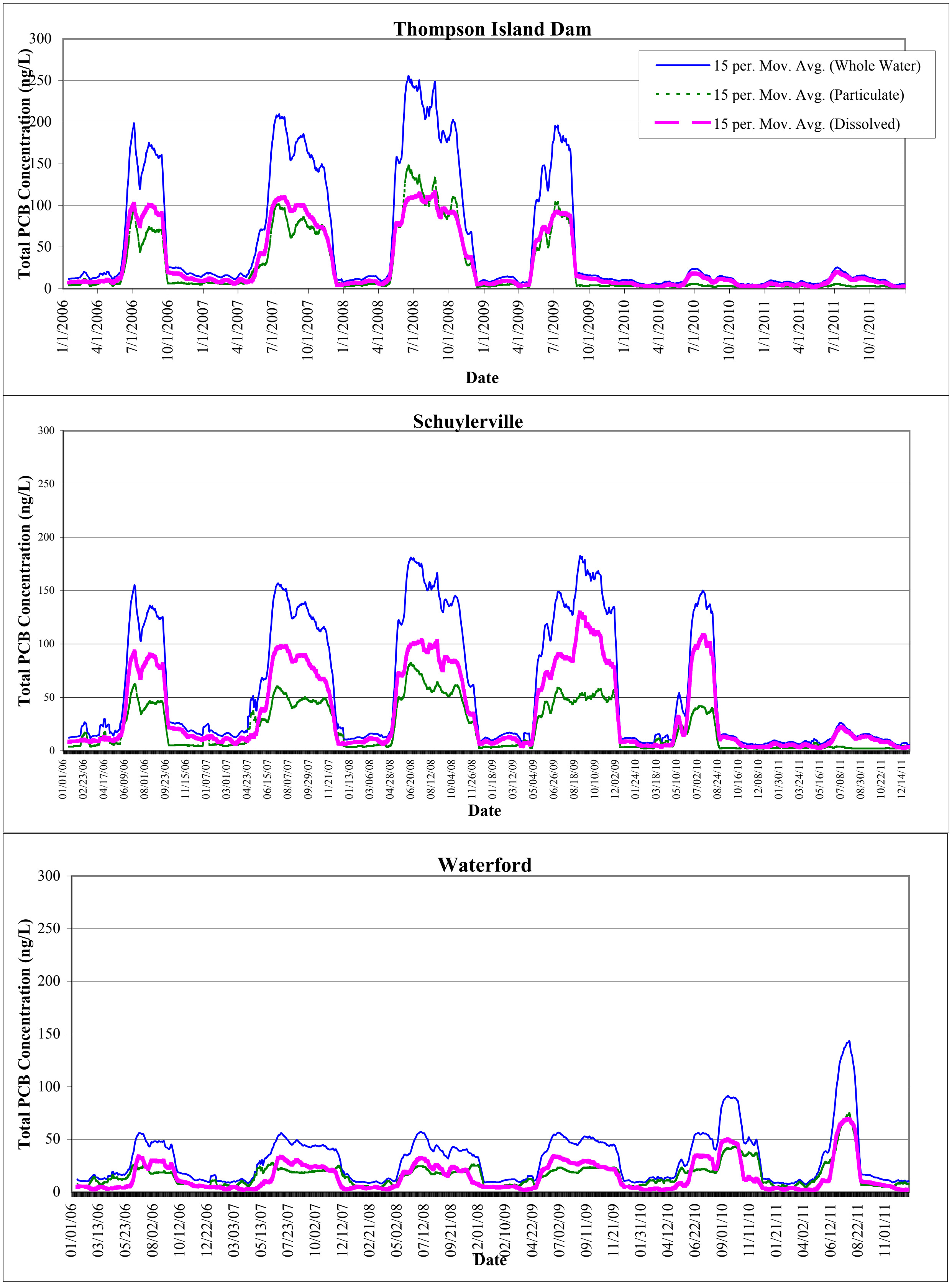
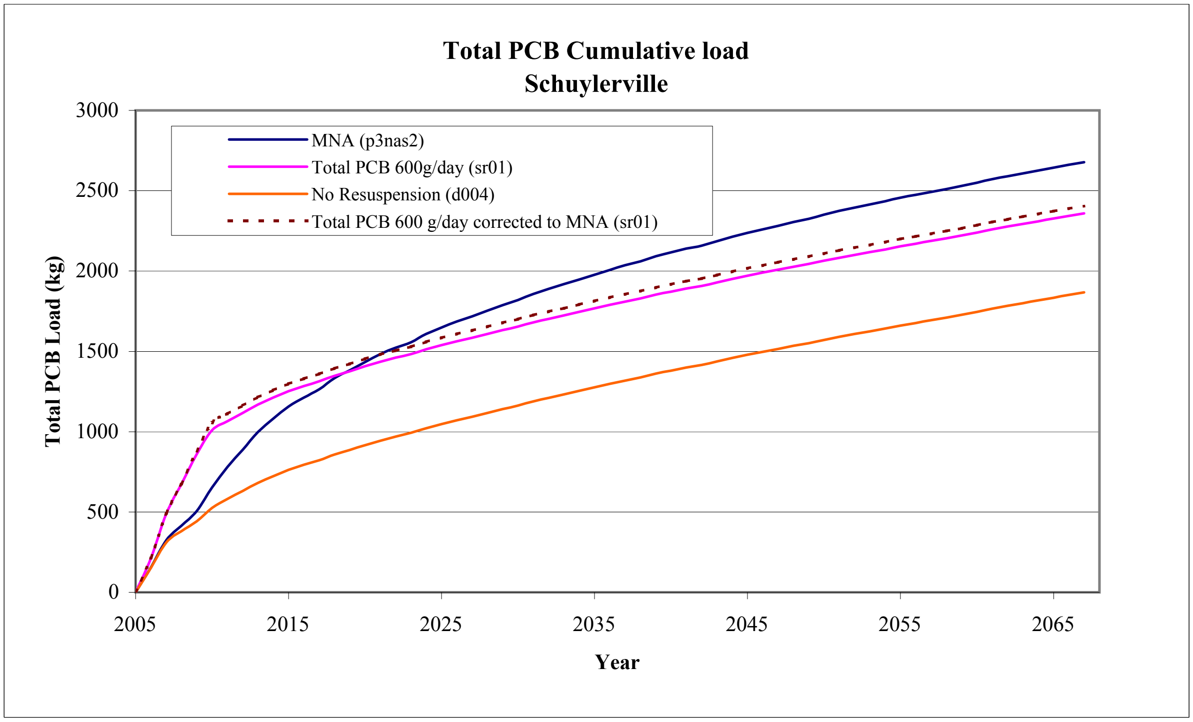


Figure 36. Tri+ PCB and Total PCB Cumulative Load for 600 g/day (sr01) Scenario



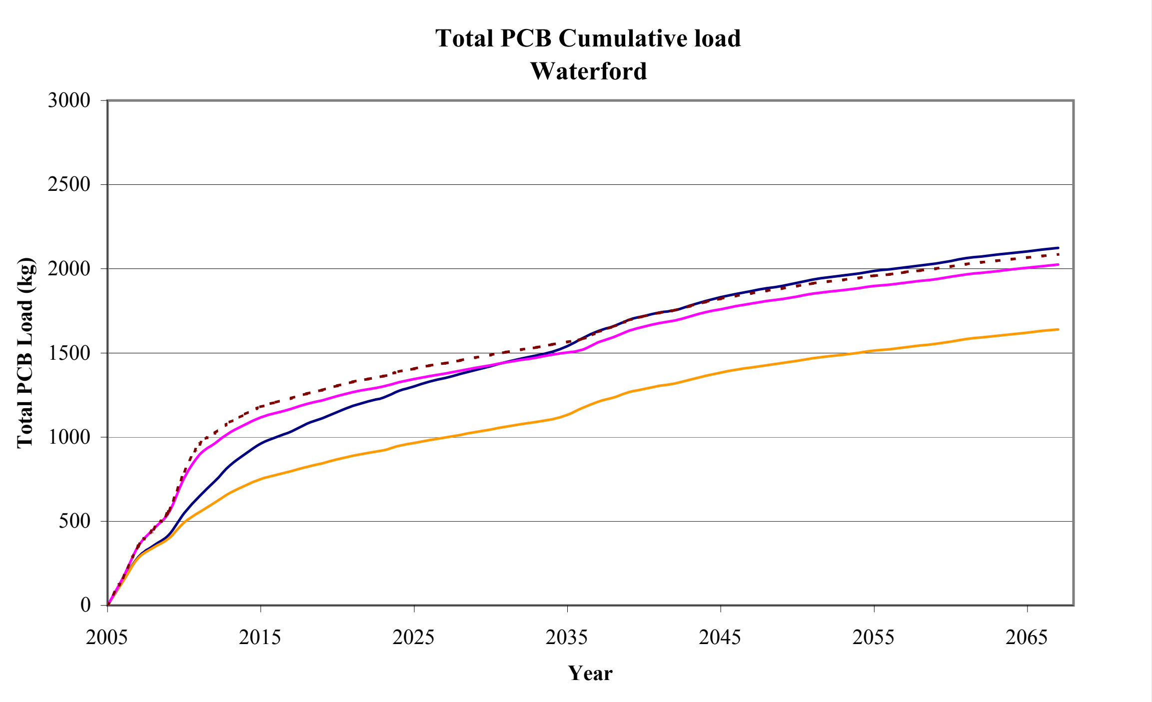
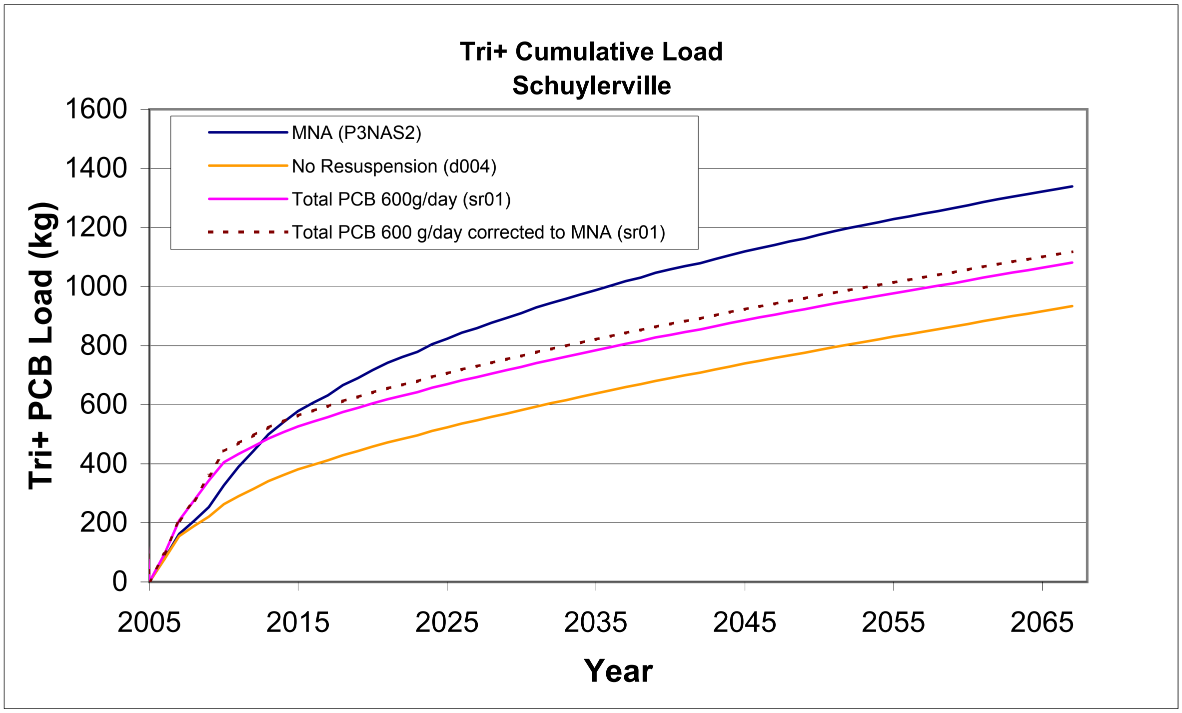


Figure 36 (Cont'd). Tri+ PCB and Total PCB Cumulative Load for 600 g/day (sr01) Scenario



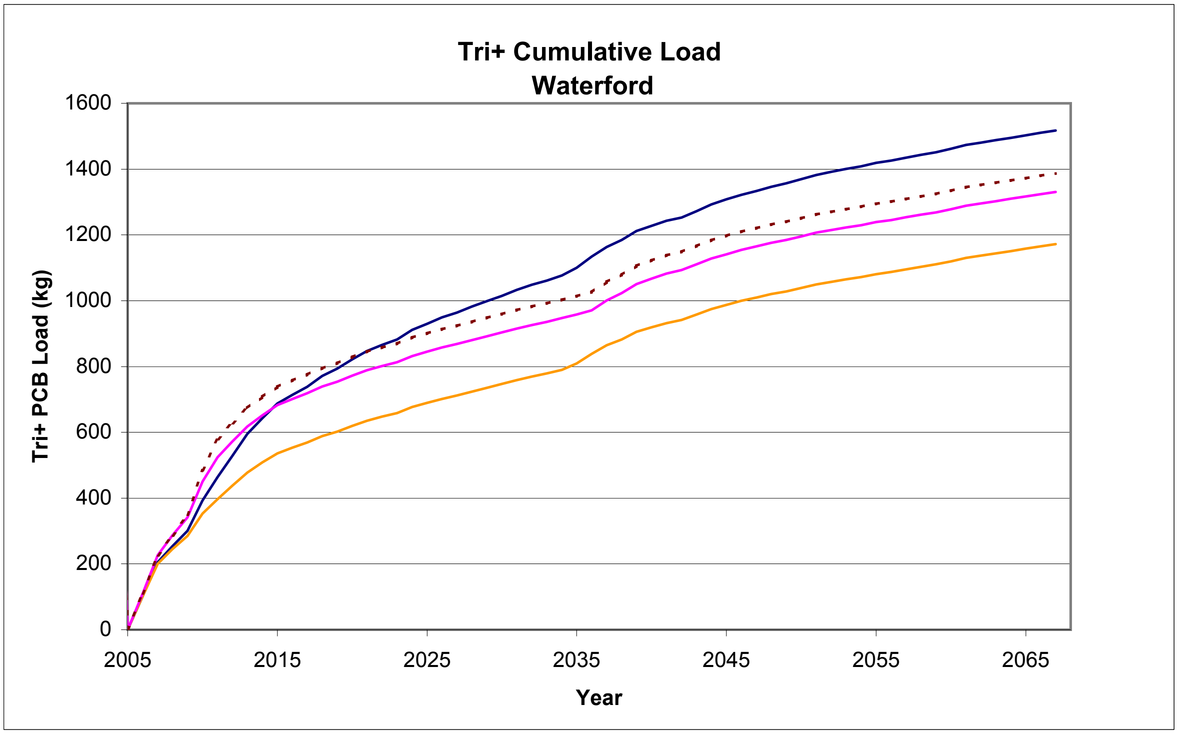


Figure 37
HUDTOX Forecast of Whole Water, Particulate, and Dissolved Total PCB Concentrations for Evaluation Level - 300 g/day Scenario

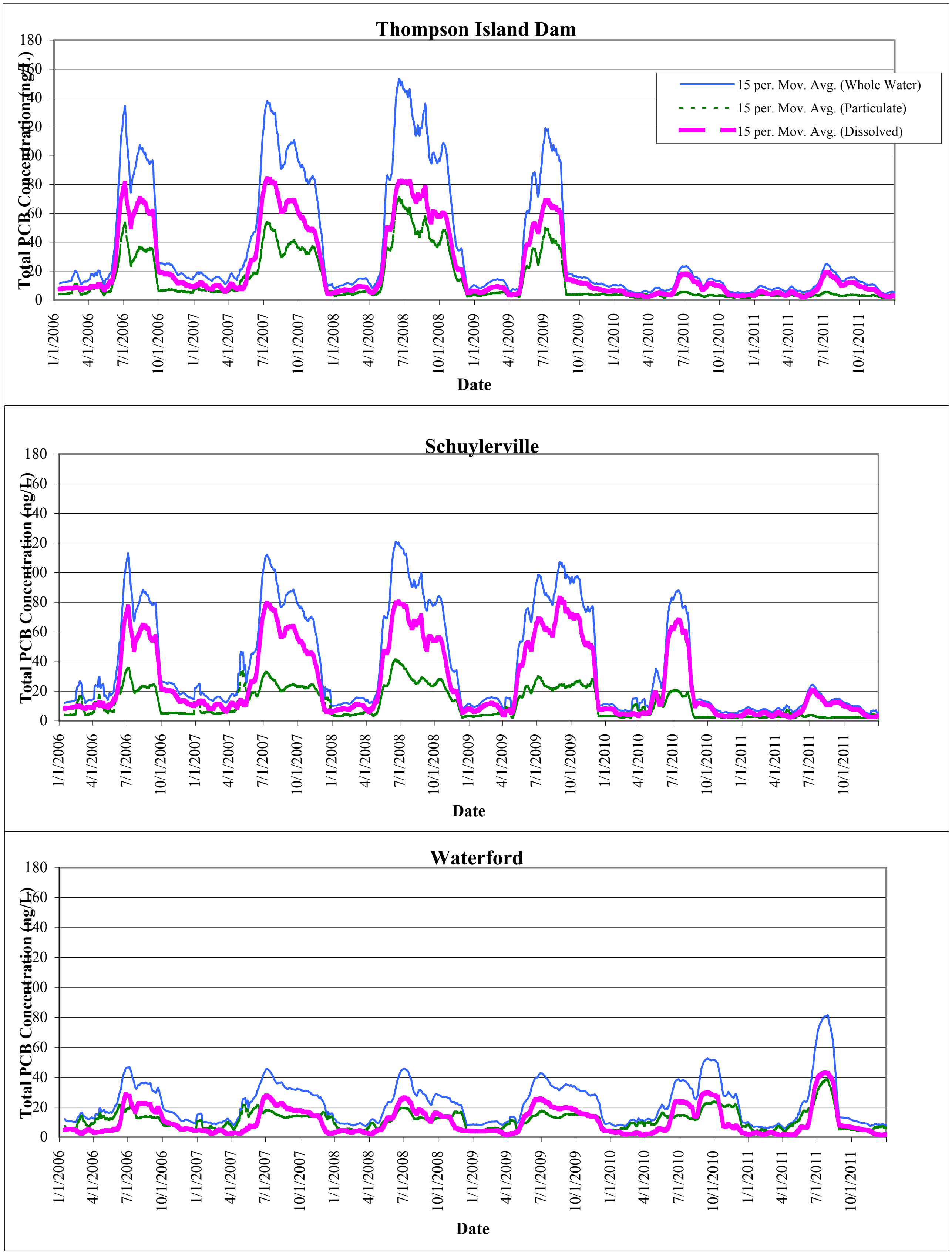


Figure 38

Comparison Between Upper Hudson River Remediation Scenario (Various Export Rates) and Monitored Natural Attenuation (MNA) Forecast for Thompson Island Dam, Schuylerville, and Waterford

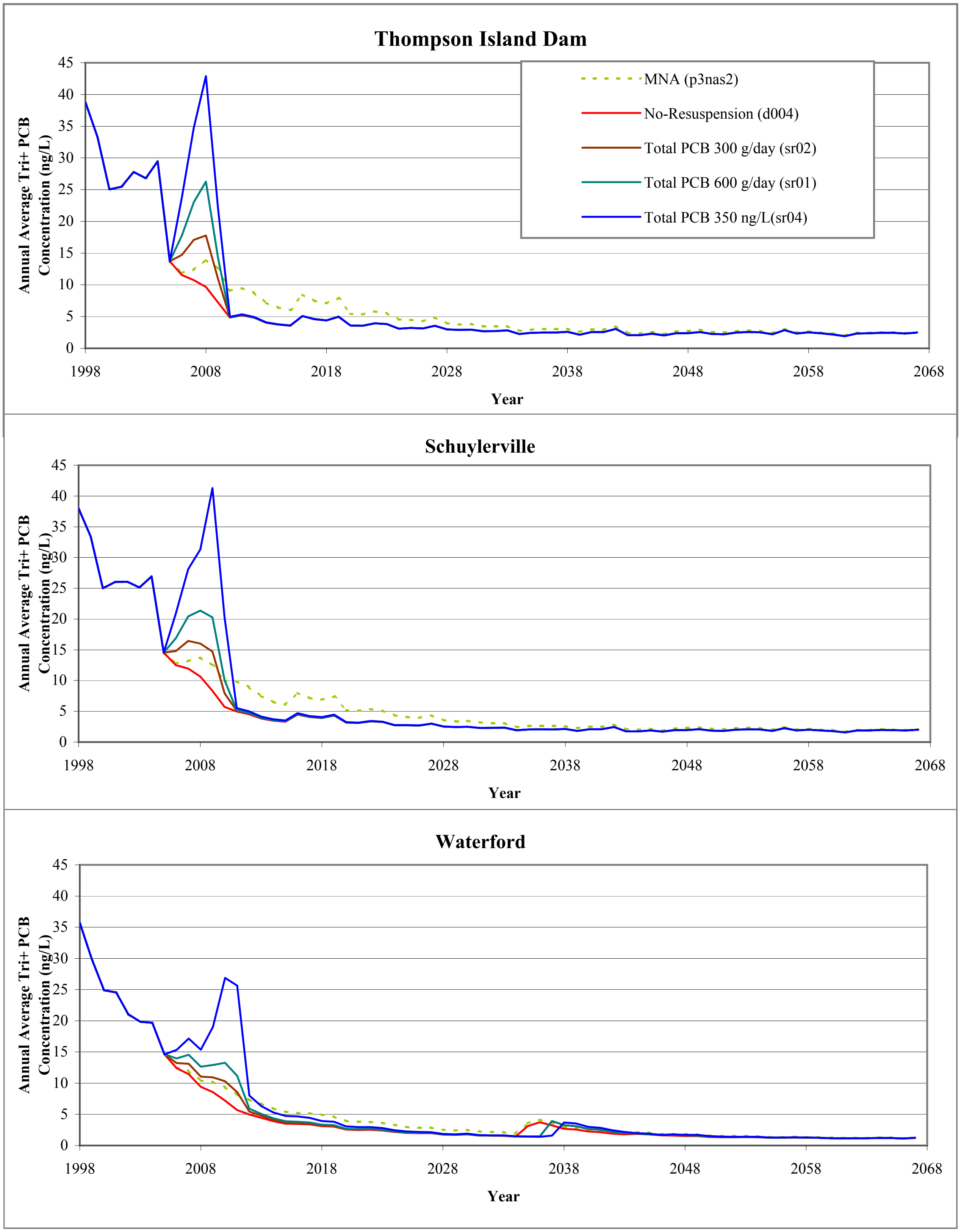


Figure 39
Total PCB Concentrations at Waterford for the Accidental Release Scenario

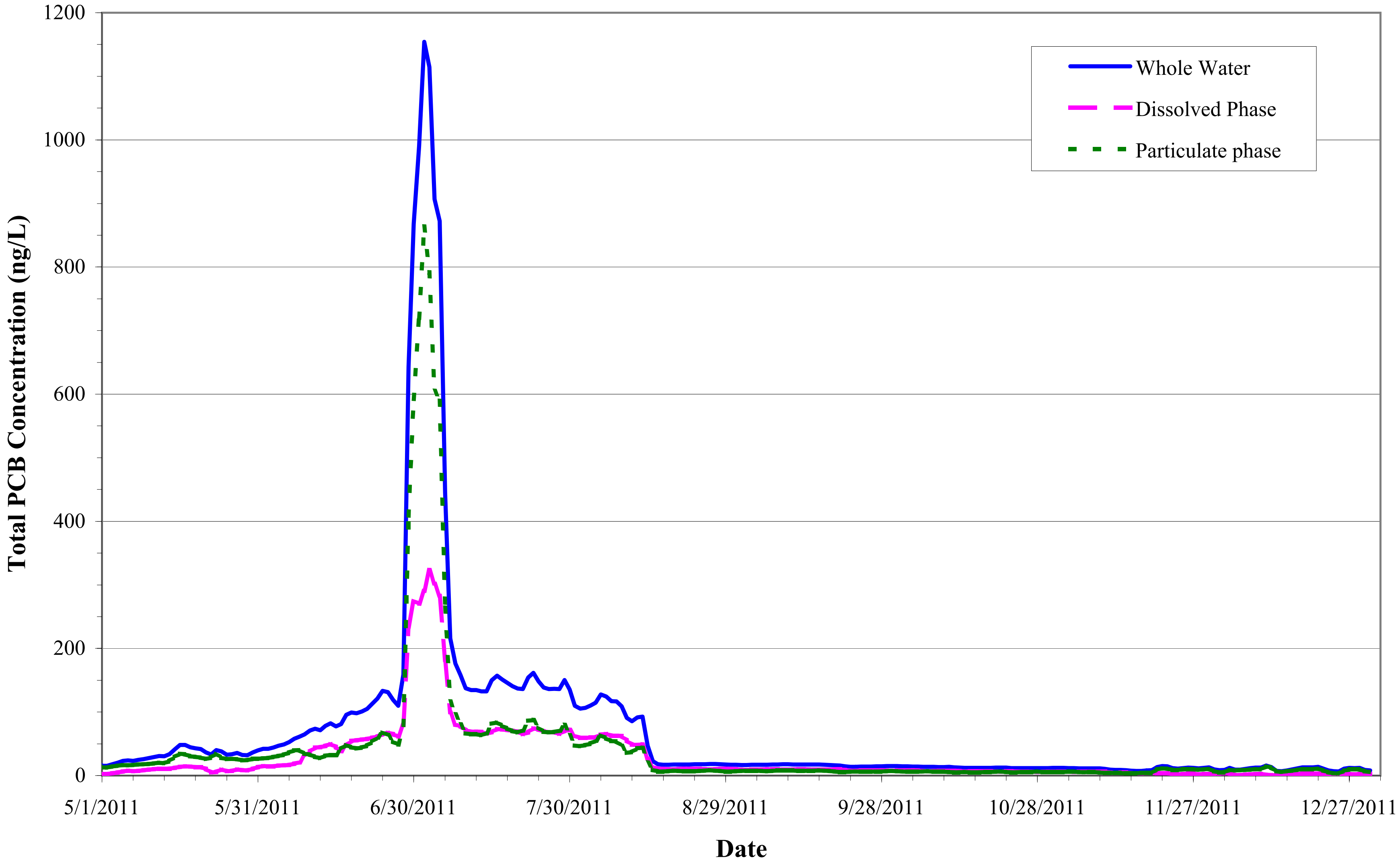
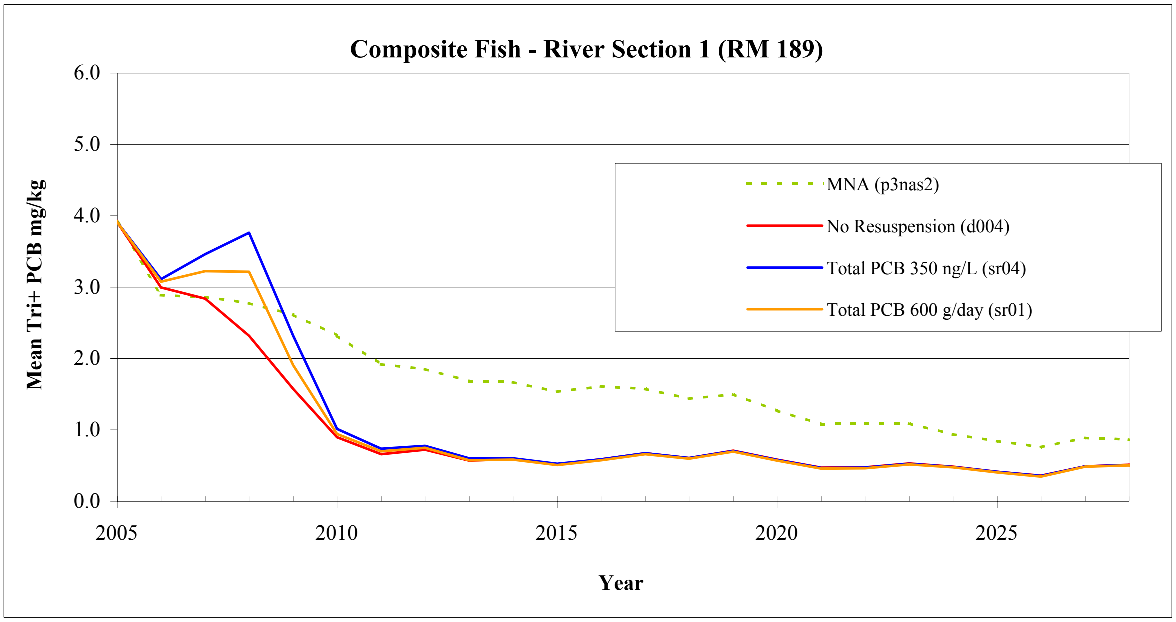
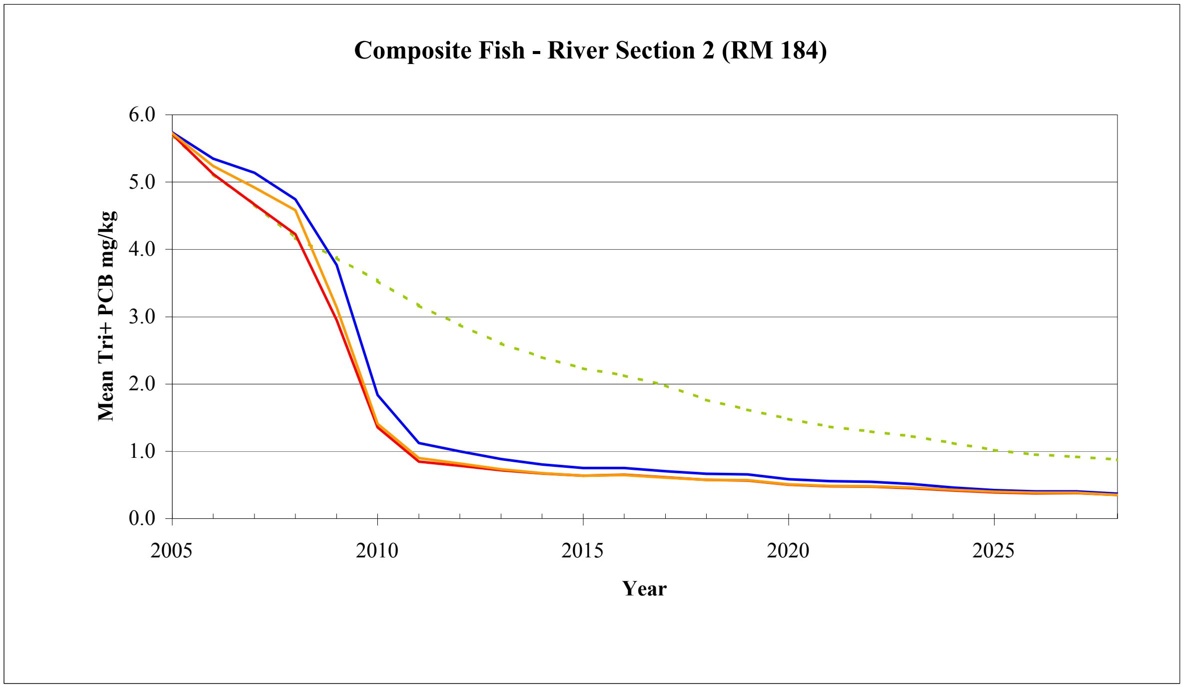


Figure 40

Composite Fish Tissue Concentrations for the Upper Hudson River

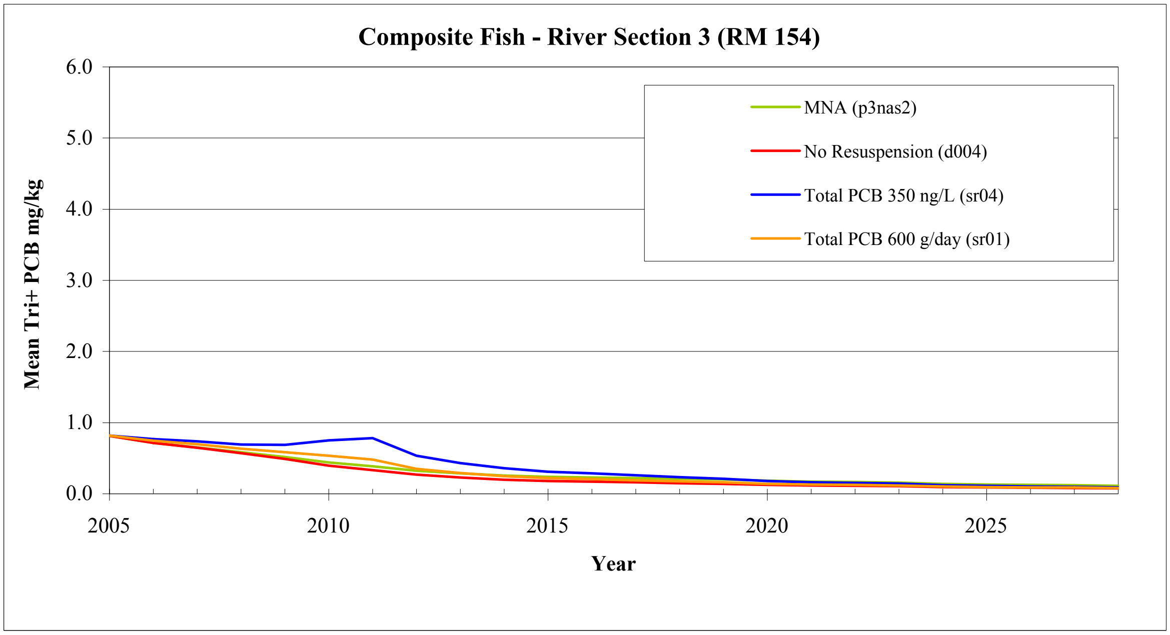


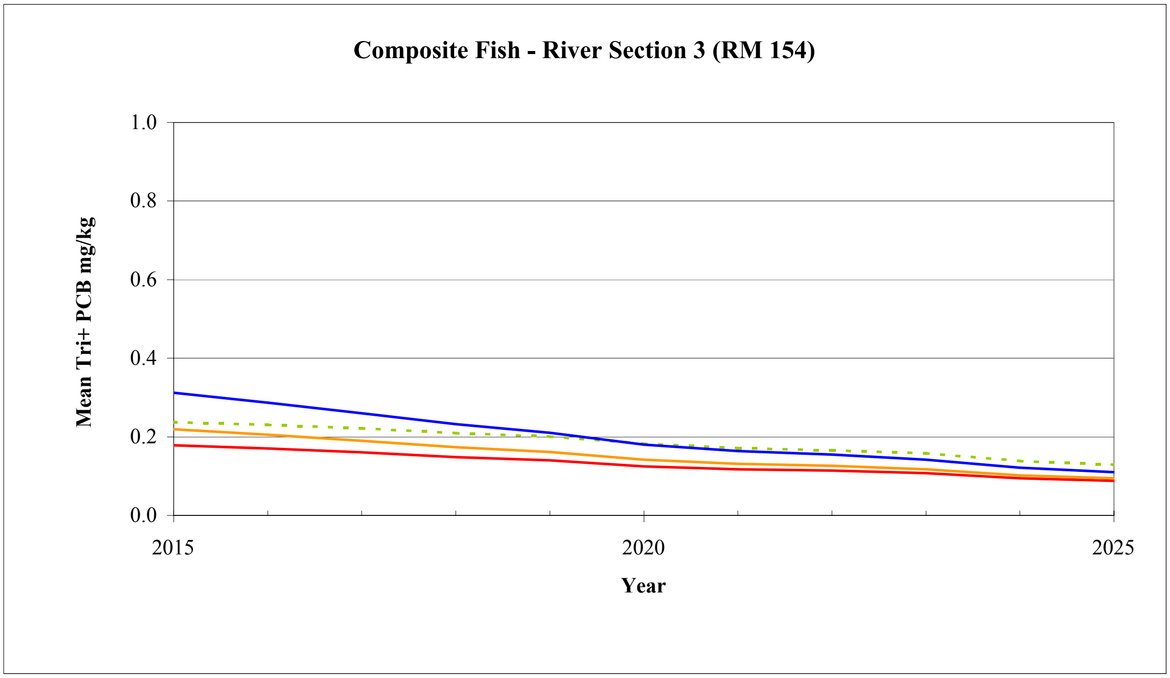


Note:
Fish composite is 47% largemouthbass + 44% brown bullhead + 9% yellow perch

Figure 40 (Cont.)

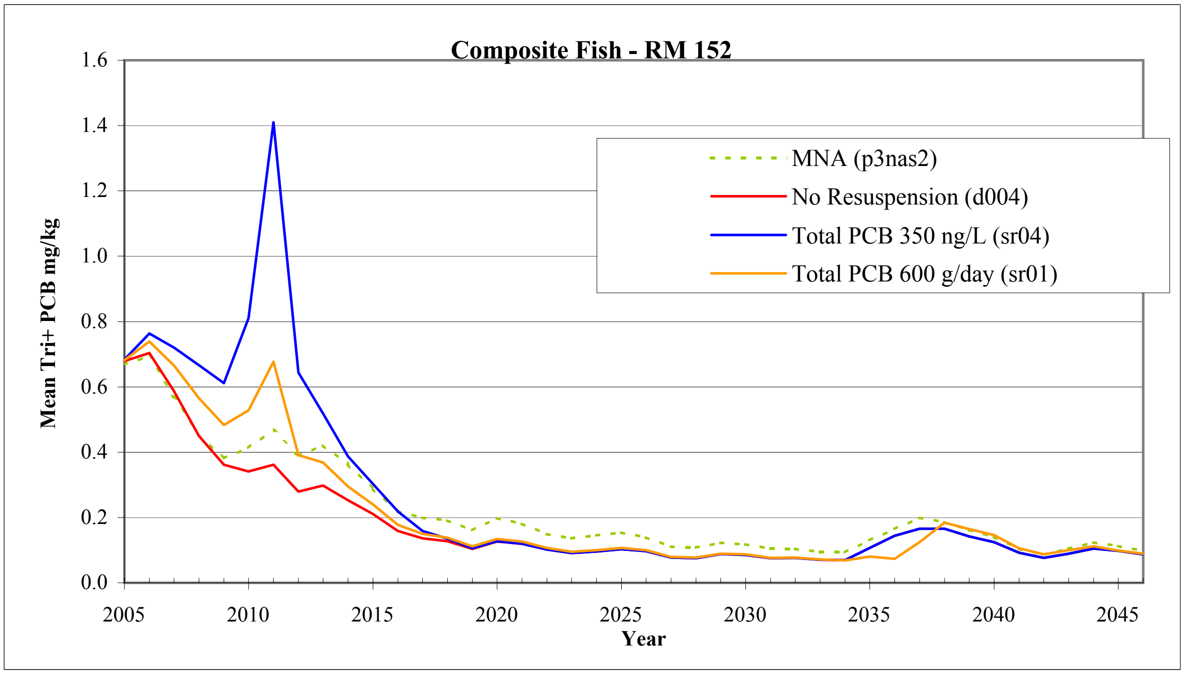
Composite Fish Tissue Concentrations for the Upper Hudson River

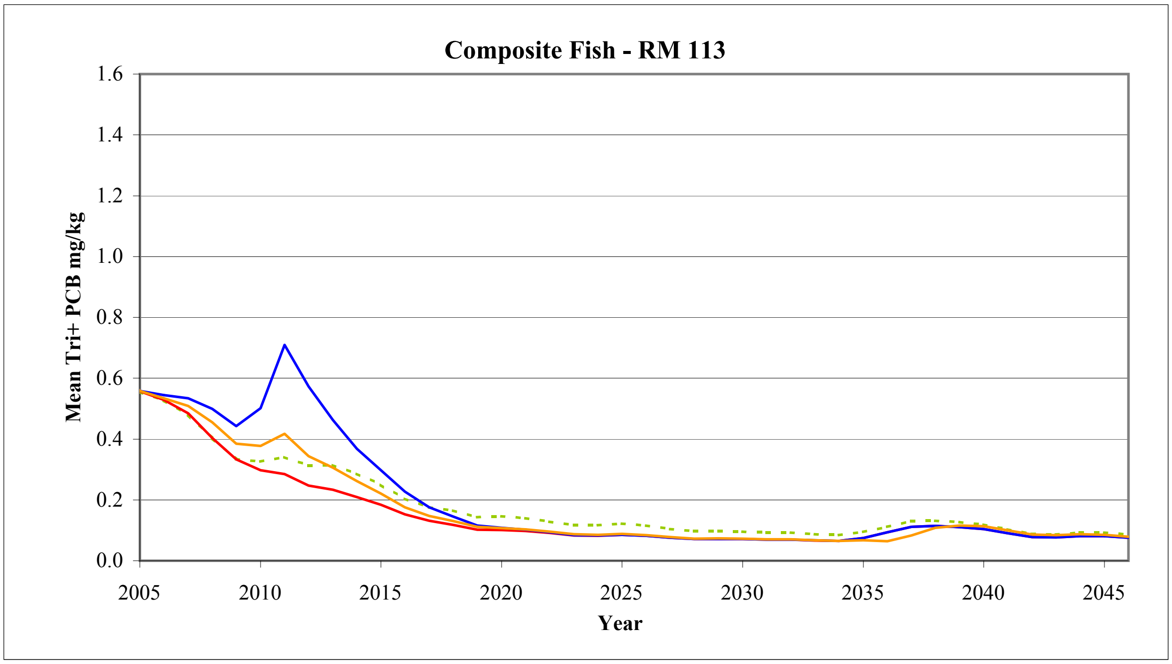




Notes:
Fish composite is 47% largemouthbass + 44% brown bullhead + 9% yellow perch
The bottom figure is portion of the top figure.

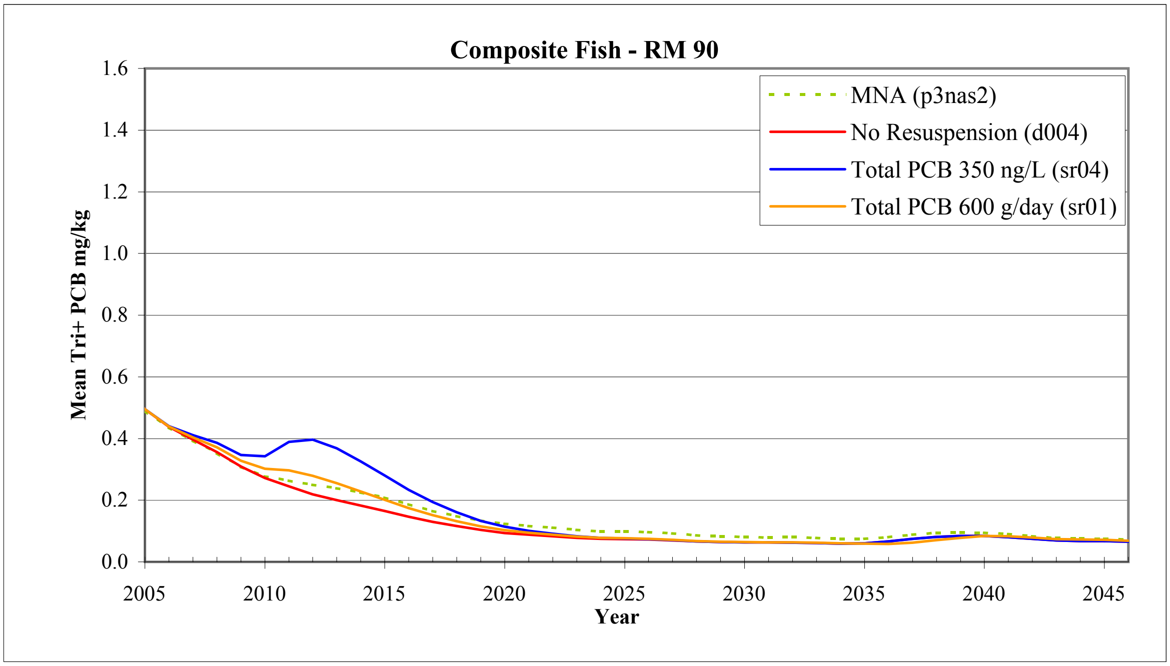
Figure 41
Composite Fish Tissue Concentrations for the Lower Hudson River

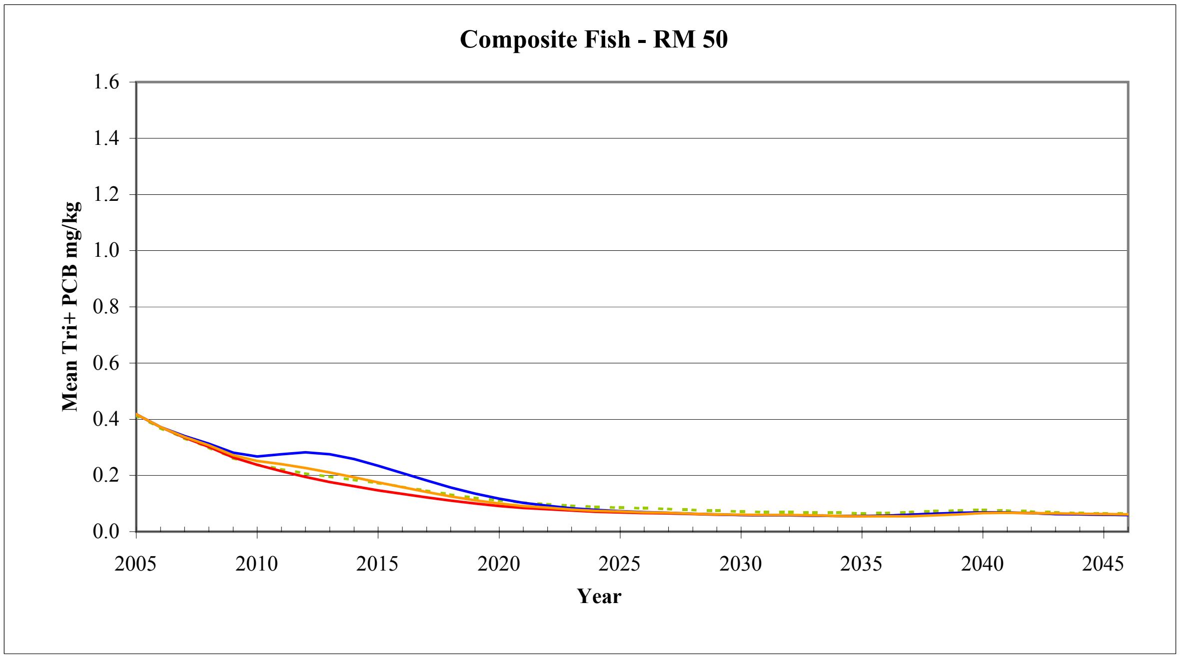




Note:
Fish composite is 47% largemouthbass + 44% brown bullhead + 9% yellow perch

Figure 41 (Cont.)
Composite Fish Tissue Concentrations for the Lower Hudson River





Note:
Fish composite is 47% largemouthbass + 44% brown bullhead + 9% yellow perch