GENERAL ELECTRIC COMPANY

Pittsfield, Massachusetts

HOUSATONIC RIVER
CONNECTICUT
COOPERATIVE AGREEMENT - TASK IV.B

PCB FATE AND TRANSPORT MODEL: ADDITIONAL MONITORING AND MODEL VERIFICATION

November 1994

LMSE-94/0701&337/042

LAWLER, MATUSKY & SKELLY ENGINEERS
Environmental Science & Engineering Consultants
One Blue Hill Plaza

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November 23, 1994

Mr. Charles G. Fredette
Water Compliance Unit
Department of Environmental Protection
79 Elm Street
Hartford, CT 06102

Re: Housatonic River Cooperative Agreement
Report Submitted on Task IV.B.

Dear Mr. Fredette:

Enclosed is a report prepared by LMS Engineers on behalf of General Electric entitled *Housatonic River Connecticut Cooperative Agreement, Task IV.B. - PCB Fate and Transport Model: Additional Monitoring and Model Verification.* As the title indicates, this report fulfills task IV.B. of the 1990 Cooperative Agreement between CDEP and GE.

I apologize for the delay in completion of this study; but as mentioned to you over the telephone, there were several unanticipated technical issues which required additional analyses to make the model more realistic. Even though a large effort was expended to make this model a useful tool for representing the river system and evaluating future trends, its inherent uncertainty should be considered in reviewing the results, including mathematical model representation/simplification of a complex natural system; uncertainty in physical/chemical variables necessary for model input; and a general lack of water column PCB data since the values are typically below analytical detection levels in the Connecticut portion of the river.

If you have questions on this report and would like to discuss it further, please contact me at (413) 494-3952.

Yours truly,

John D Ciampa

John D. Ciampa
Remediation Project Manager

Enclosure

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SUMMARY

S.1 INTRODUCTION

Task IV.B. of the Housatonic River Cooperative Agreement (HRCA) between the Connecticut Department of Environmental Protection (CDEP) and the General Electric Company (GE) specifies that GE will conduct additional monitoring of river sediments in 1992 for further calibration and verification of the fate and transport model. Tasks II.A. (Ambient Trend Monitoring) and III. (Extension of the PCB Fate and Transport Model From the Connecticut/ Massachusetts Border to Great Barrington, Massachusetts) of HRCA were completed in September 1991. Results of these tasks were presented in the report entitled Ambient Trend Monitoring and PCB Fate and Transport Model (LMS 1991) along with recommendations to implement Task IV.B.

Monitoring included extensive sediment and water column surveys. Surficial and deep sediment samples were collected in summer 1992 throughout the study area to evaluate how the sediment PCB concentrations have changed since the last major survey performed from 1975 to 1978 and to provide a basis for verification of the PCB fate and transport model. Six high-flow water column surveys were performed at Great Barrington and Falls Village in 1992 and 1993 to further evaluate PCB transport trends and to develop a reliable upstream PCB and total suspended solids (TSS) boundary condition for the model. Other components of these surveys included sampling to further evaluate sediment transport characteristics and to measure water quality parameters in Lakes Lillinonah and Zoar. Model parameters have been further developed using available data as well as current literature sources. The result of these efforts is a reasonably verified PCB fate and transport model and the performance of a 50-year model projections.

Importantly, the accuracy of model simulations are directly related to the accuracy of model parameters and boundary conditions. The most currently accepted theoretical approach for modeling, current literature sources for parameters, and all available data to estimate boundary conditions were used for this study. However, there is a degree of uncertainty inherent in these model inputs and theory, as discussed throughout this report. Nevertheless, results of this modeling effort may assist in evaluating general trends and approximations of future conditions.

S.2 MONITORING AND DATA TRENDS

Six deep core sediment samples were collected in Lakes Lillinonah and Zoar and in the Falls Village and Bulls Bridge impoundments. Various 1-in. increments of these cores were analyzed for PCBs, total organic carbon (TOC), and the radionuclide cesium-137 (^{137}Cs); results were compared with those from cores taken in 1986. PCB concentrations in the deep sediments were consistently lower in the 1992 samples than those taken in 1986. As PCBs are a stable compound and the sediments were not disturbed, an investigation was conducted into possible reasons for the decrease. The investigation was inconclusive and differences may be due to spatial variation between sampling locations.

Forty-nine surficial sediment samples were collected between Great Barrington, Massachusetts, and the Stevenson Dam in Connecticut. Samples were analyzed for PCBs, TOC, and physical characteristics. Compared to samples taken from 1975 to 1978, PCB and TOC concentrations have generally diminished, particularly in the two lakes. A reduction in surficial sediment PCBs strongly indicates a diminishing source in the water column. A reduction in TOC was not expected, but a review of historical water column data has shown diminishing concentrations in the water column as well. The reason for diminished TOC is not known but may be the result of changing land uses or upgrades to sewage treatment plants that discharge to the Housatonic River.

Six water column surveys were performed during high-flow events at Great Barrington, Massachusetts, and in Falls Village, Connecticut. Flows varied between 800 and 4000 cubic feet per second (cfs) during the surveys. Surveys were also performed at three stations in the Sheffield Flats region just upstream of the Massachusetts/Connecticut state line to evaluate sediment resuspension rates. Limited samples of total suspended solids (TSS) and TOC were also taken in Lakes Lillinonah and Zoar. Two surveys performed in spring 1992 coincided with reconstruction activities at the Rising Pond Dam, approximately 1 mile upstream of Great Barrington. These activities resulted in higher than normal TSS and PCB concentrations being detected at Great Barrington during the high flow surveys. Because these surveys were not representative of normal conditions, two additional surveys were performed in 1993. It is clear that the reconstruction activities at the Rising Pond Dam had only a transient impact on PCB transport at Great Barrington as subsequent sampling revealed a return to normal conditions.

Statistical analyses of TSS and PCB transport were performed for available data at Great Barrington, which is the upstream boundary of the PCB Fate and Transport Model. A statistically valid method of estimating daily TSS concentrations based on daily flow and PCB concentrations based on TSS is provided. This method is used to develop a model boundary condition that represents PCB and TSS concentrations during high-flow events. Over the years, PCB transport in the river has been reduced for several reasons including: the fact that PCBs are no longer used in manufacturing processes; improvements in sediment management; and natural processes in the river. However, because the majority of PCB data collected in

Housatonic River water are below the detection limit, statistical regressions did not find a statistically significant relationship between PCB and time. Several alternative sources of information were used to infer the rate at which PCB is diminishing in the water column as a function of time. A simple exponential "decay" model is assumed and an evaluation of PCB diminishment rates in surficial sediment, invertebrate data, and water column data consistently support a rate of approximately 5% reduction per year.

S.3 **PCB FATE AND TRANSPORT MODEL**

The Housatonic River PCB Fate and Transport Model (HOUSRM) presented in previous reports (LMS 1988, 1991) was based on monthly-averaged flows. Although such an approach was deemed reasonable, it could not simulate the effects of high-flow events on the fate and transport of PCBs. Because such events may have a significant effect on PCB fate and transport, the model was changed to accommodate event-specific boundary, flow, and sediment resuspension input. These changes, as well as updated information on sediment resuspension in the Sheffield Flats and revised solids concentrations in the sediment, required some refinements to the previously presented model calibration to TSS concentrations. Refinements to the calibration are performed for an 18-month period from April 1979 to October 1980, when TSS was measured daily at three stations in the Housatonic River. Model verification is performed for a 13.5-year period between 1979 to 1993. Extensive reviews of literature were performed to support the choice of model parameters and appropriate background PCB concentrations. A large effort has recently been performed to evaluate volatilization rates of PCB from the Great Lakes. Methods provided in these studies were used to calculate volatilization rates for HOUSRM. The primary focus of the verification is to show that the model reasonably simulates sediment PCB concentrations, which it does. HOUSRM is also shown to provide reasonable simulations of water column PCB and TSS during the verification period.

HOUSRM is also applied to a 50-year projection period from 1992 to 2042. Results indicate that PCB concentrations in the surficial bed sediments in the up-river regions studied will continue to decrease throughout the projection period and that surficial sediment PCB concentrations in the lakes are currently near equilibrium conditions and are not expected to diminish significantly in the next 50 years. Average water column PCB concentrations over the projection period vary from approximately 0.010 ug/l near Great Barrington to approximately 0.001 ug/l in Lakes Lillinonah and Zoar.

The limitations and uncertainties of the model are also described in this report. For example, the selection of PCB concentrations to represent the upstream and tributary inputs, which are critical to the model results, was limited by the fact that most of the PCB water column measurements at the upstream boundary (Great Barrington) showed no detectable PCBs and that no detected PCB water column data are available for the tributaries. In addition, there are uncertainties in the values selected for other key model parameters (e.g., volatilization, partitioning). It is important that these limitations and uncertainties be recognized in any application of the model's projections.

CHAPTER 1

INTRODUCTION

1.1 GENERAL BACKGROUND

The Housatonic River Cooperative Agreement (HRCA) between the Connecticut Department of Environmental Protection (CDEP) and the General Electric Company (GE) specifies activities to be performed by GE to implement the recommendations of the report entitled Chapter 6 of the Housatonic River PCB Sediment Management Study - Program for Monitoring the Natural Recovery of the River, April 1988, as modified by CDEP's review letter of 28 April 1989. The following three tasks in the Cooperative Agreement were performed by Lawler, Matusky & Skelly Engineers (LMS) in a prior report entitled "Ambient Trend Monitoring and PCB Fate and Transport Model" (September 1991):

Task II.A. Ambient Trend Monitoring

> Monitored the river and analyzed trends in sediment and PCB transport at Great Barrington, Massachusetts.

Task III. PCB Fate and Transport Model

> Extended LMS' PCB fate and transport model of the Housatonic River from the Connecticut/Massachusetts border to Great Barrington, Massachusetts.

Task IV.C. Proposal for Additional Monitoring and Model Verification

> A general plan was provided in the recommendations of LMS (1991) to carry out the requirements of Task IV.B. of HRCA, which is defined as additional monitoring of river sediments in 1992 for further calibration and verification of the fate and transport model.

A general plan to meet the Task IV.B. requirements was provided in LMS (1991). Comments on this general plan were received from CDEP and incorporated into the 20 February 1992 Task IV Monitoring Plan. One of the comments was a request from CDEP that GE evaluate the feasibility of special sampling and/or analytical techniques to quantify low background PCB levels in Housatonic River tributaries. GE provided a letter response to this comment which is incorporated into this report as Appendix A, along with CDEP's response.

This report presents the results of the Task IV.B. monitoring requirements, refines the calibration and verifies the Housatonic River Model (HOUSRM), and applies the model to project future PCB concentrations in the sediment and water column. Although previous work included calibration of the model for total suspended solids (TSS) by adjusting sediment fluxes (LMS 1991), some refinements to sediment flux values are made herein to accommodate the following changes:

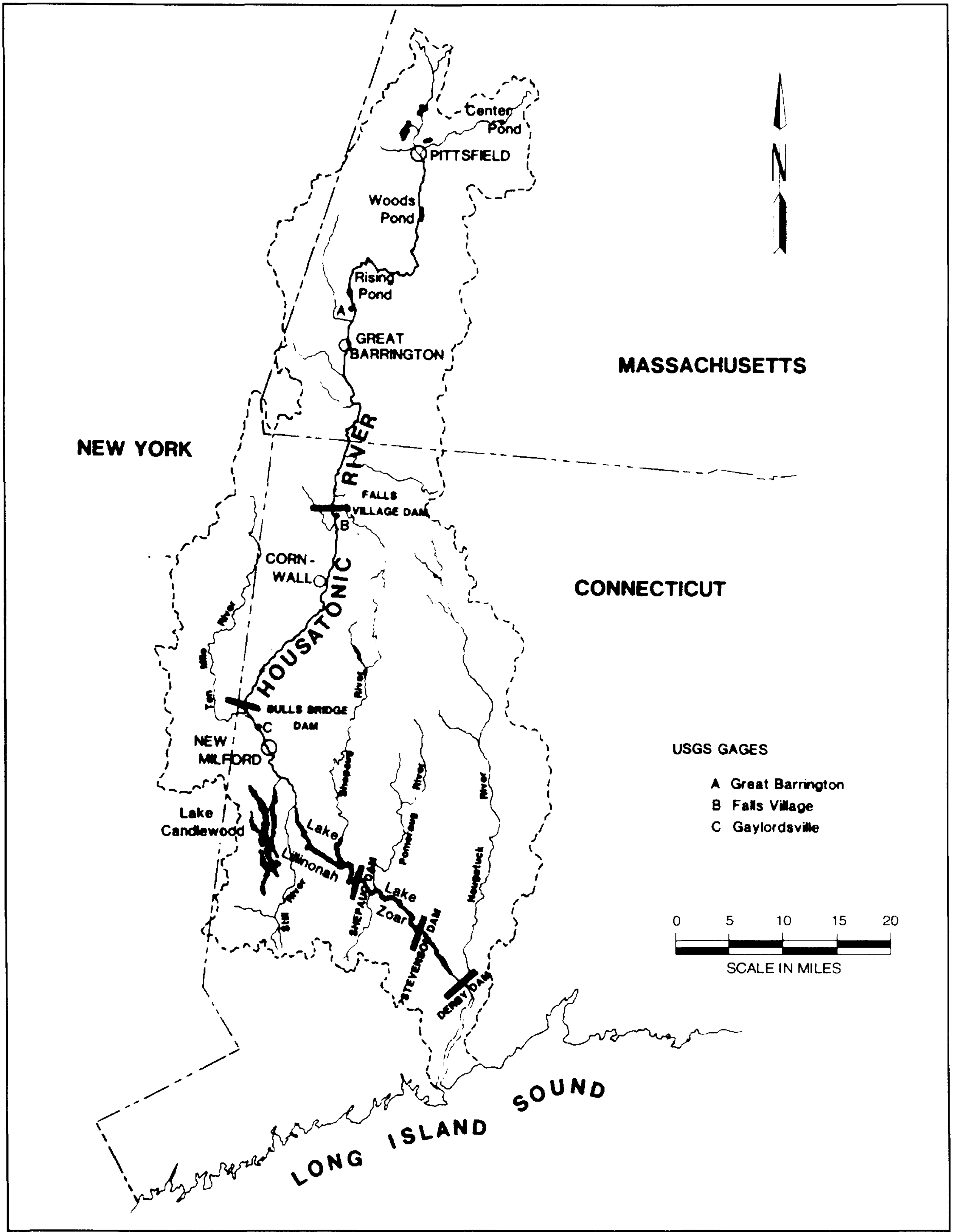
1. The prior model was based on monthly-averaged parameters of flow, resuspension and upstream TSS and PCB boundary conditions. The current model has been modified to include daily variations in the above parameters. This change was made so the model would accurately simulate high flow river conditions which may be important to the fate and transport of PCB.

2. The 1992 sediment surveys included measurements in each model segment of bulk density of bed sediment. As sediment resuspension rates are partially dependent on bulk density and prior values were based on estimations from limited data that differed from the 1992 measurements, resuspension rates were recalculated.

3. In LMS (1991), sediment resuspension rates in the Sheffield flats region of the Housatonic River were inferred from TSS data taken at another location (i.e., Great Barrington) because no such data was available for the area in question. The Task IV monitoring included special studies to evaluate sediment resuspension rates in the Sheffield flats and these are incorporated into the current model.

Figure 1-1 shows the Housatonic River from above Pittsfield, Massachusetts, to the Long Island Sound. The study area extends from Great Barrington, Massachusetts, to the Stevenson Dam in Connecticut. Dams, major tributaries, and major U.S. Geological Survey (USGS) gaging stations are also indicated.

All available current and historical data are presented and evaluated. HOUSRM input parameters are evaluated using a combination of extensive literature reviews and the available data. Many of the model's input parameters were evaluated in LMS' previous reports regarding the fate of PCBs in the Housatonic River (LMS 1988, 1991). However, all available data as well as literature sources have been used to confirm previous model parameters or in some cases improve on the selection of these parameters as well as to further develop the upstream and tributary PCB and TSS model boundary conditions. The result of this effort is the development of a modeling tool that can assist in projecting the fate of PCBs in the Housatonic River.



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Housatonic River and Watershed Area

Figure 1-1

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1.2 REPORT ORGANIZATION

Following is a brief summary of the chapters to follow:

- ***Chapter 2, Monitoring*** - Sediment and water column survey methods and materials and quality assurance/quality control (QA/QC) aspects are presented and discussed. Results of all LMS survey data from 1986 to 1993 are presented.

- ***Chapter 3, Data Trends and Historical Comparisons*** - Current and historical surficial and deep sediment PCB results are compared and evaluated. All available water column PCB, TSS, and total organic carbon (TOC) data are presented and evaluated. TSS and PCB data at Great Barrington are used to develop statistical functions describing TSS as a function of flow and season and PCB as a function of TSS. An estimate of the rate of water column PCB reduction with time is made for use in the model's upstream boundary condition.

- ***Chapter 4, PCB Fate and Transport Model*** - Theoretical basis of the WASTOX Model is provided. The rationale for choosing the model input parameters, constants, and boundary conditions is provided. Model calibration refinements, verification, sensitivity, and projections are provided.

- ***Chapter 5, Conclusions*** - The major conclusions of the report are summarized.

CHAPTER 2

MONITORING

2.1 SEDIMENT SURVEYS

Sediment surveys were performed during the summer of 1992. Surveys collected deep cores (two in Lake Zoar, two in Lake Lillinonah, and one each in the Falls Village and Bulls Bridge impoundments) as well as surficial sediments at 49 stations between the Division St. Bridge (DSB) at Great Barrington (MP 106.2) to the Stevenson Dam (MP 19.6). The following sections include the methods and materials, QA/QC results, and presentation and discussion of results.

2.1.1 Methods and Materials

Deep Core Surveys

On 5 and 6 August 1992 Ocean Surveys, Inc. (OSI), under subcontract to LMS, collected six core samples. Three-inch-diameter aluminum core tubes were pushed and/or tapped into the sediment by scuba divers. The core tubes were then removed by manual extraction, capped, and brought to the surface. The capped core tubes were stored in an upright position in an iced container and transported to the LMS laboratory in Nyack, New York, on 6 August 1992. Station locations were provided to OSI on USGS topographical maps along with descriptive information that indicated the distance upstream along the centerline of the river from a major structure (i.e., dam or bridge) or island (i.e., Bulls Bridge Island). Distances and water depths were measured manually with a survey chain. The latitude/ longitude of these six deep core stations were measured from the approximate station locations on the USGS maps.

At the Nyack laboratory the core samples were extruded from the tubes onto a clean laboratory bench, which was covered with aluminum foil, and cut with a Teflon knife into 1-in. increments. Approximately 10 dry grams of sample were taken and put into polyethylene containers for the radionoclide cesium-137 (^{137}Cs) analyses. The remainder of the sample for each increment was transferred to a wide-mouth glass sample bottle for PCB and TOC analyses. The analysis of each increment throughout the core length was not deemed necessary to identify parameter profiles. The 1986 core results were used as a guide in selecting numerous increments for PCBs, TOC, and ^{137}Cs analyses. A total of 97 increments for all six cores were selected for PCB/TOC analyses, and 40 increments for the four lake cores were chosen for ^{137}Cs analyses.

The 10-g samples were sent to Teledyne Isotopes, Inc., of Westwood, New Jersey, and analyzed for ^{137}Cs. Teledyne employs gamma ray spectroscopy, using a germanium detector, to count the gamma-emitting nuclides.

The remainder of the samples were sent to International Technology Corporation Analytical Services Division (ITAS) of Knoxville, Tennessee, for PCB and TOC analyses. The samples were analyzed for TOC using modified U.S. Environmental Protection Agency (EPA) method 9060. This method uses chemical wet oxidation followed by infrared detection. Samples were placed into glass ampules and mixed with a phosphoric acid/sodium persulfate solution. The phosphoric acid converts all inorganic carbon into carbon dioxide (CO_2), which is purged from the ampule with oxygen. The ampule is then sealed under oxygen and heated to approximately 100°C in a water bath for 30 min. The heating process converts the organic carbon into CO_2, which is trapped in the sealed ampule. The samples were analyzed by an O.I. Corporation TOC analyzer, Model 700; the carbon was quantified using infrared detection by measuring the absorbance of CO_2. Results should be considered nonpurgeable organic carbon as the sample preparation process may result in loss of volatile organic compounds (VOCs).

The samples were analyzed for PCBs by gas chromatography/electron capture detection (GC/ECD) based on EPA SW-846, 2nd edition, method 8080. An SP2250/2401 column on a Varian 3740 GC was used. GC sample peaks were compared to standard Aroclor solutions and quantified into three Aroclor groups: Aroclors 1016, 1232, 1242, and/or 1248; Aroclor 1254; and Aroclor 1260. The total Aroclors were also calculated as the sum of the detectable Aroclor groups.

Surficial Sediment Surveys

LMS used one of two different sample collection techniques to collect surficial sediment samples depending on depth of water. In shallow waters (less than ~10 ft deep) 3-in.-diameter aluminum coring tubes were pushed or tapped into the sediment from a small survey vessel. The coring tube was then pulled from the sediment, capped, cut to a manageable length, and stored in an upright position in an iced container. The aluminum tubes were steam cleaned prior to being used. In deeper waters, a stainless steel Ballcheck corer with a 2-in.-diameter tube was used. The Ballcheck corer is a gravity coring device that is released from the survey vessel and drops through the water column until it strikes and penetrates the sediment. A silastic ball automatically seals the top of the core tube during retrieval to minimize sample loss from the bottom of the core tube. Separate, stainless steel 2-in.-diameter by 36-in.-long tubes were used for each sampling. Prior to use, these core tubes were cleaned using the following procedure: soapy water rinse, distilled water rinse, nitric acid rinse, distilled water rinse, and methanol rinse. The tubes were then air dried, rinsed again with distilled water, and wrapped in aluminum foil.

Station location was determined using a Trimble differential global positioning system (DGPS), which provides accuracies of 1 to 5 m. Positioning data were collected continuously at each station for approximately 15 min.

Of the 49 cores taken, the top 3 in. of seven were analyzed in 1-in. increments; gross analyses of the top 3 in. were performed for the remaining 42 cores. Samples were analyzed for PCBs and TOC using the same methods discussed previously. In addition, several samples were also analyzed for particle size distribution using the American Society for Testing Materials (ASTM) designation D 422-63 (Reapproved 1990) [Standard Test Method for Particle-Size of Soils]. Dry and wet sediment densities were analyzed using the Engineering Methods (EM) 1110-2-1906 (30 November 1970) for measurement of unit weights, void ratio, porosity, and degree of saturation.

The seven 3-in. cores were separated into 1-in. increments at LMS' Nyack laboratory. Each increment was placed into a 250-ml wide-mouth glass bottle and labeled for PCB and TOC analyses.

Gross top 3-in. samples were placed into 250-ml wide-mouth glass bottles. For those samples requiring PCB, TOC, density, and particle-size analyses, two side-by-side core samples were taken. An intact core was provided to ITAS for bulk density measurements, of which only the top 3 in. were used for analysis. The other core was used for the remaining analyses. The top 3 in. were removed and mixed on a clean surface. Then a 60-ml glass vial was filled for PCB and TOC analyses and the remainder of the sample was placed into a 250-ml glass bottle for the particle-size analysis. Extra side-by-side cores were also taken for matrix spike quality control analyses. All samples were stored at 4°C and shipped to ITAS in iced, sealed coolers.

2.1.2 **Quality Assurance/Quality Control**

QA/QC of the sediment surveys included the following aspects:

- Detailed sampling plans were provided to field crew personnel.
- All sampling equipment was thoroughly cleaned prior to deployment and between sampling.

- All sediment samples were collected using materials that do not interfere with PCB analyses. Deep core samples were collected with aluminum coring tubes and surficial sediment samples were collected with either aluminum or stainless steel, depending on the method of sampling. All samples were sealed and stored in iced coolers during the surveys. Samples were stored at 4°C once they arrived at the LMS Nyack laboratory.

- Sample bottles and cores were clearly labeled and identification numbers entered into field data sheets.

- Sample handling at the LMS laboratory was performed only on clean aluminum foil surfaces and with clean Teflon or stainless steel spatulas.

- All shipments of samples from LMS to ITAS were accompanied by analysis request and chain-of-custody record forms.

- Field blanks to measure aluminum core cartridge contamination were performed by pouring field blank water through a core tube and then collecting the sample and analyzing for PCBs. These results are presented below:

PCB CONCENTRATIONS (μg/l) OF AQUEOUS FIELD BLANK SURFICIAL SEDIMENT ALUMINUM CORING TUBE

DATE	AROCLOR 1016, 1232, 1242, AND/OR 1248	AROCLOR 1254	AROCLOR 1260	TOTAL AROCLORS
28 Aug 92	ND (0.1)	ND (0.3)	ND (0.3)	ND (0.3)
4 Sep 92	ND (0.1)	ND (0.3)	ND (0.3)	ND (0.3)

ND = Not detected. Values in ( ) are the detection limit.

The results of this test indicated that PCB was not detected (ND) on the surface of the aluminum coring tube.

- Method blanks were performed to check whether any laboratory handling or analytical procedures contaminated samples. Method blanks were performed for PCBs and TOC; results are shown in Table 2-1. As indicated, no laboratory contamination problems were found.

- Several matrix spike/matrix spike duplicate (MS/MSD) analyses of river sediments were performed to demonstrate that PCBs can be quantitatively recovered from the sample matrix. Results are presented in Table 2-2. As shown, ITAS reported good recoveries and relative percent differences, indicating that there were no problems recovering spiked samples of Aroclor 1242.

TABLE 2-1

METHOD BLANKS FOR PCBs AND TOC SURFICIAL AND DEEP CORE SEDIMENTS

SAMPLE IDs	SAMPLE DATE	TOTAL AROCLORS (μg/g dry)	TOC (mg/kg)
MP 106.20-93.56 (Surficial)	8/25-26/92	ND (0.05)	ND (1) ND (1)
MP 91.28-77.50 (Surficial)	8/27-28/92	ND (0.05) ND (0.05)	ND (1) ND (1) ND (1)
MP 75.0-49.7 (Surficial)	9/1-2//92	ND (0.05)	ND (1)
MP 40.1-19.5 (Surficial)	9/3-4/92	ND (0.05)	ND (1)
Lake Zoar and Lake Lillinonah (Deep Core)	8/5/92	ND (0.05) ND (0.05)	ND (1) ND (1) ND (1)
Lake Lillinonah and Falls Village (Deep Core)	8/5/92	ND (0.05) ND (0.05)	ND (1) ND (1) ND (1)
Lake Lillinonah and Lake Zoar (Deep Core)	8/5/92		ND (1) ND (1) ND (1)
Bulls Bridge Lake and Lillinonah (Deep Core)	8/5/92	ND (0.05) ND (0.05)	ND (1) ND (1)

ND = Not detected. Values in ( ) are detection limit.

TABLE 2-2

MATRIX SPIKE RESULTS FOR SEDIMENTS
(Concentrations in $\mu g/g$)

AROCLOR	CONC. OF SPIKE		SAMPLE ID	SAMPLE RESULT	MS		MSD		
	MS	MSD			Conc.	%Recovery	Conc.	%Recovery	RPD
1242	1.2	1.2	RM106.20	ND (0.05)	1.0	83	1.0	83	0
1242	6.6	6.5	LZ(3-4)	ND (0.05)	6.0	91	5.6	86	6
1242	2.1	2.1	MP77.5	ND (0.05)	1.8	86	1.7	81	6
1242	1.8	1.8	MP53.1	ND (0.05)	1.6	89	1.4	78	13
1242	1.6	1.6	MP32.3	ND (0.05)	1.3	81	1.3	81	0
1242	2.3	2.3	MP21.5	ND (0.05)	2.0	87	1.9	83	5
1242	1.2	1.2	FV(21-22)	ND (0.05)	0.97	81	1.0	83	2
1242	6.8	6.8	LL(2-3)	ND (0.05)	6.0	88	5.6	82	7
1242	1.3	1.3	LZ(11-12)	ND (0.05)	1.1	85	1.2	92	8
1242	1.7	1.7	LL(18-19)	ND(0.05)	1.3	76	1.6	94	21
1242	2.0	2.0	BB(7-8)	0.05	1.8	90	1.7	85	6

MS - Matrix spike.
MJD - Matrix spike duplicate.
LZ - Lake Zoar.
MP - Mile Point.
FV - Falls Village.
LL - Lake Lillinonah.
BB - Bulls Bridge.
ND - Not Detected.
RPD - Relative percent difference.

- ITAS analyzed for PCB and TOC using acceptable EPA methodology. Samples and associated method blanks were treated to remove interferences using Florisil and mercury cleanup procedures.

2.1.3 Results

Deep Sediment Core Surveys

From 5 to 6 August 1992 OSI collected six cores (two each from Lakes Lillinonah and Zoar and one each from the Falls Village and Bulls Bridge impoundments). Table 2-3 summarizes the sample dates, locations, and penetration and recovery depths. Figure 2-1 shows the approximate locations of these sampling stations. The oversized maps in Appendix B provide accurate station locations as well as PCB concentrations. Attachment 2-1 (at the end of Chapter 2) includes all of the deep core Aroclor-specific PCB, TOC and ^{137}Cs results for the 1992 survey and also includes the deep core PCB and TOC results for surveys performed in 1986. Graphical presentations and comparisons with historical data are made in Chapter 3.

Surficial Sediment Surveys

Between 25 August and 4 September 1992, 49 surficial core sediment samples were collected between Great Barrington, Massachusetts (MP 106.2), and the Stevenson Dam (MP 19.5) in Connecticut. Of the 49 cores taken, seven were analyzed in 1-in. increments for the top 3 in; gross analyses of the top 3 in. were performed for the remaining 42 cores. Samples were analyzed for PCBs, TOC, and the physical characteristics of bulk density and particle size distribution. Table 2-4 summarizes the sample dates, locations, core type (i.e., gross or top 3 in. or 1-in. increments of top 3 in.), and analyses performed. Figure 2-1 shows the approximate station locations, and the oversized maps in Appendix B show the accurate locations as well as the PCB concentrations. Attachment 2-2 (at the end of Chapter 2) includes the Aroclor-specific PCB, TOC, bulk density, percent grain size, and sediment descriptions. Graphical presentations and comparisons with historical data are made in Chapter 3.

2.2 WATER COLUMN SURVEYS

2.2.1 Methods and Materials

A total of eight water column surveys were performed by LMS between March 1991 and April 1993. Because high river flow is generally the operative factor in riverine PCB transport, samples were collected during rainfall events, when river flow was increased. Surveys 1 and

TABLE 2-3

SAMPLE DATES, LOCATIONS, AND DESCRIPTIONS OF DEEP CORE SAMPLES

LAKE/ IMPOUNDMENT	DESCRIPTION	DATE OF SAMPLE COLLECTION	MILE POINT	CORE PENETRATION (in.)	RECOVERY DEPTH (in.)	WATER DEPTH (ft)	NORTHING[1] (m)	EASTING[1] (m)
Lake Zoar	1000 ft upstream of Stevenson Dam	8/6/92	19.7	29	25	55	4,582,926.83	652,597.56
Lake Zoar	300 ft upstream of Rt. 84 Bridge	8/6/92	26.1	18	14	25	4,588,707.32	646,402.43
Lake Lillinonah	1000 ft upstream of Shepaug Dam	8/5/92	29.8	44	37	94	4,589,853.66	642,262.20
Lake Lillinonah	300 ft upstream of Rt 133 Bridge	8/5/92	34.2	41	25	64	4,593,140.24	637,554.88
Bulls Bridge Impoundment	600 ft upstream of Bulls Bridge Island	8/5/92	53.2	25	23	10	4,615,204.88	624,292.68
Falls Village Impoundment	300 ft upstream of Dam apex and 40 ft west of centerline	8/5/92	77.7	28	52	43	4,646,878.05	635,152.44

[1] Based on Universal Transverse Mercator grid, Zone 18.

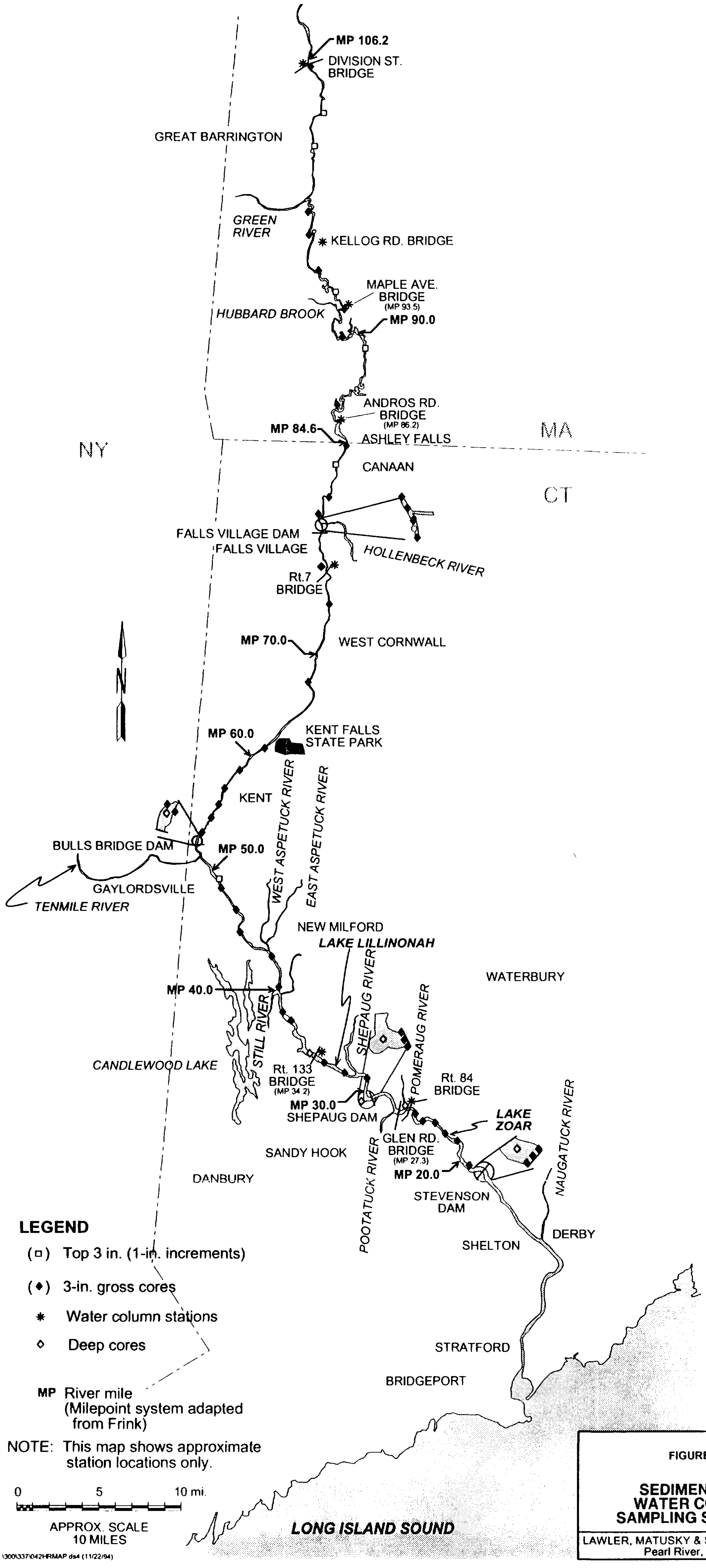


FIGURE 2-1

SEDIMENT AND WATER COLUMN SAMPLING STATIONS

LAWLER, MATUSKY & SKELLY ENGINEERS
Pearl River, New York

TABLE 2-4

SAMPLE DATES, LOCATIONS, AND PARAMETER SPECIFICATIONS FOR SURFICIAL SEDIMENT SAMPLES

MILE POINT	DATE OF SAMPLE COLLECTION	WATER DEPTH (FT)	NORTHING (M)	EASTING (M)	TYPE	ANALYSIS		
						PCB	TOC	PHYSICAL
106.2	08/25/92	3	4,676,608.9	635,728.32	G	X	X	X
103.1	08/25/92	4	4,673,479.5	635,917.06	I	X	X	
101.5	08/25/92	3	4,671,650.0	635,487.5	I	X	X	X
98.7	08/26/92	2	4,668,495.9	635,477.97	G	X	X	X
98.1	08/26/92	1.5	4,667,161.7	635,550.37	G	X	X	
96.0	08/26/92	2	4,665,045.6	635,762.87	G	X	X	
94.4	08/26/92	3	4,663,967.3	636,677.95	I	X	X	
93.56	08/26/92	3	4,663,084.9	637,220.26	G	X	X	X
91.28[c]	08/27/92	3	4,666,158.0	637,063.0	G	X	X	
89.7	08/27/92	3	4,661,030.9	638,216.44	I	X	X	
86.4	08/27/92	1	4,657,622.3	636,474.38	G	X	X	X
84.6	08/27/92	3	4,656,232	637,283.71	G	X	X	
82.7	08/27/92	2	4,653,467.8	636,378.77	I	X	X	X[a]
81.3	08/27/92	1.5	4,651,511.6	635,921.91	G	X	X	X[b]
78.4	08/27/92	2	4,648,095.2	634,964.38	G	X	X	
78.0	08/28/92	3	4,648,133.5	634,993.85	G	X	X	
77.9[c]	08/28/92	4	4,647,386.0	635,229.0	G	X	X	X
77.7	08/28/92	4	4,646,923.2	635,020.62	G	X	X	
77.5	08/28/92	8	4,646,807.1	634,901.94	G	X	X	
75.0	09/01/92	10	4,643,527.3	635,749.17	G	X	X	
71.8	09/01/92	1.5	4,638,467.7	636,184.57	G	X	X	
67.0[c]	09/01/92	0	4,632,072.0	634,145.0	G	X	X	X
61.0	09/01/92	0.1	4,624,973.6	630,096.47	G	X	X	
59.0	09/01/92	1.5	4,622,840.2	627,891.61	G	X	X	
57.0	09/01/92	2	4,620,149.2	626,148.04	G	X	X	
56.0	09/01/92	3	4,618,795.9	626,020.03	G	X	X	
55.0	09/01/92	8	4,617,493.3	625,159.06	G	X	X	
54.0	09/01/92	5	4,616,237.3	624,435.61	G	X	X	
53.2	09/01/92	3	4,615,050.8	624,207.42	G	X	X	X
53.1	09/01/92	3	4,615,108.5	624,129.02	G	X	X	
49.7	09/02/92	2	4,61,1304.6	626,428.29	I	X	X	
48.3	09/02/92	1	4,609,586.9	627,685.7	G	X	X	
47.1	09/02/92	1	4,608,097.9	628,764.14	G	X	X	
43.9[c]	09/02/92	2	4,603,518.0	632,121.0	G	X	X	
42.6[c]	09/02/92	2	4,600,458.0	632,807.0	G	X	X	
40.1[c]	09/03/92	6	4,676,609.0	635,739.0	G	X	X	
39.0	09/03/92	8	4,598,543.3	633,145.83	G	X	X	
38.7	09/03/92	16	4,597,587.4	633,490.23	G	X	X	
33.9	09/03/92	46	4,593,042	638,024.08	G	X	X	X
32.3	09/03/92	37	4,592,130.6	639,762.61	G	X	X	
31.0	09/03/92	35	4,591,708.4	641,835.72	G	X	X	
25.7	09/03/92	4	4,588,571.9	646,711.32	G	X	X	
24.7	09/03/92	5	4,587,480.4	647,172.06	G	X	X	
23.8	09/03/92	19	4,587,660.2	648,713.56	G	X	X	
22.7	09/03/92	31	4,586,523.8	650,025.75	G	X	X	X
21.5	09/03/92	31	4,585,745.1	650,975.59	G	X	X	
19.5	09/04/92	48	4,582,815.6	652,717.64	I	X	X	

G = Gross sample of top 3 in.; I = 1-in. increments of top 3 in.

[a] Bulk Density Only.

[b] Sieve Analysis Only.

[c] Station locations estimated as GPS signal blocked at these stations.

2, performed in March and August of 1991, were conducted in accordance with Task II.A. of the HRCA (Ambient Trend Monitoring) and methods and materials were reported in LMS (1991). The next six surveys (Surveys 3 to 8) were performed in accordance with Task IV.B. of the HRCA (Additional Monitoring and Model Verification) using methods and materials consistent with those already reported in our 1991 report.

Samples for the Task IV.B. surveys were collected from bridges using a Scientific Instruments, Inc., Model 5250 DH-59 sediment sampler for Survey 3 and a DH-76 sampler for the remaining surveys. The samplers are of a similar design and are intended for collection of depth-integrated samples. The DH-76 has twice the capacity of the DH-59 (1 quart vs 1 pint) and therefore required fewer "drops" to obtain the required sample volume. Hence, the reason for changing samplers. The samplers were lowered and raised at a uniform rate between the water surface and bottom using a hand-operated A-55 sounding reel. On contacting the streambed, the direction of travel is immediately reversed and the sampler rises to the surface. The glass sample bottle, which fits inside the sampler, is filled to approximately two-thirds its volume to prevent any collected suspended sediment or water from being displaced when the bottle is filled.

Table 2-5 summarizes the sample parameters and analytical and collection specifications for the water column surveys.

Upon retrieval of the sampler, the sample container was removed and sample was decanted into the appropriate pre-preserved bottles. Samples for dissolved organic carbon (DOC) were filtered in the field.

Upon completion of each sampling round, sample bottles were labeled, sealed, and stored in iced coolers, and field data sheets and chain-of-custody forms were filled out. Sealed coolers were shipped overnight to ITAS for analysis.

PCBs were analyzed by gas chromatography/electron capture detection (GC/ECD) based on EPA SW-846, 2nd edition, method 8080. An SP2250/2401 column on a Varian 3740 gas chromatograph was used. TSS was determined gravimetrically by filtration and measurement of the filter residue after drying at 103-105°C using EPA method 160.2. TOC and DOC content was determined by chemical wet oxidation, followed by infrared detection using EPA methods 415.1 and 9060.

TABLE 2-5

SAMPLE PARAMETERS AND ANALYTICAL AND COLLECTION SPECIFICATIONS

PARAMETER	ANALYSIS METHOD	VOLUME (ML)	BOTTLE	PRESERVATIVE	HOLDING TIME	COMMENTS
Total PCB	EPA SW-846 2nd Ed. Method 8080	1000	Amber glass w/Teflon-lined cap	4°C	7 days until extract 40 days until analysis	
Filtered PCB	EPA SW-846 2nd Ed. Method 8080	1000	Amber glass w/Teflon-lined cap		7 days until extract 40 days until analysis	Filtered at lab
TOC	EPA 415.1	40	Glass	H_2SO_4,4°C, pH<2	28 days	
DOC	EPA 415.1	40	Glass	H_2SO_4,4°C, pH <2	28 days	Filtered at site
TSS	EPA 160.2	1000	Plastic	4°C	7 days	

2.2.2 Quality Assurance/Quality Control

QA/QC of the water column surveys included the following aspects:

- ***Containers and Preservation***. All sample bottles were supplied to LMS by ITAS and were cleaned according to ITAS, Standard Operating Procedure No. QA841214RO-2, "Glassware Cleaning Procedure for Organic Prep." All samples to be analyzed for PCBs were stored in amber glass bottles with Teflon-lined caps and stored at 4°C. Extraction occurred within seven days of sampling; analysis was required within 40 days of extraction.

- ***Duplicate Sample Evaluation***. Duplicate samples were used to determine the precision of the analytical method as well as the percent recovery for the sample matrix. One MS/MSD was performed per 20 samples. If LMS did not take 20 samples during a survey, one MS/MSD was provided per survey.

- ***Matrix Spike Evaluations***. The observed recovery of the spiked sample vs the theoretical spike recovery was used to calculate the percent recovery value. Table 2-6 shows the results for these analyses and indicates good percent recovery and relative percent differences results.

- ***Field Blank***. ITAS supplied LMS with one field blank per survey. This blank sample was passed through the same sampling procedure as the regular water column sample to indicate any possible sources of contamination from the field procedures. Table 2-7 summarizes field blank results. Total and dissolved PCBs were not detected in any of the field blanks. TOC was not detected except during Survey 7 and low concentrations of TSS were detected in most field blanks, indicating that some solids were present in field blank water provided by ITAS or in the sampler. As PCBs were not detected these TSS concentrations do not affect the results.

- ***Method Blank***. ITAS performed method blanks to check whether any of their procedures caused contamination. Results are also shown in Table 2-7 and do not indicate any contamination problems from within the laboratory.

- ***Gas Chromatograph***. Calibration is performed with five concentrations and a blank and is verified with one concentration. Acceptable limits are within 10% of the calibration curve and was achieved for analyses. Calibration is performed initially and verification is performed on a daily basis.

In addition to the above QA/QC procedures, ITAS used rigorous data validation and data reporting procedures. Data validation is a systematic procedure in which a body of data must meet a set of criteria to verify its validity prior to its intended use. Checks are made for internal consistency, proper identification, and transmittal, calculation, and transcription errors.

TABLE 2-6

MATRIX SPIKE RESULTS FOR WATER COLUMN

(Concentration in μg/l)

AROCLOR	CONC. OF SPIKE	SAMPLE ID	SAMPLE RESULT	MS CONC.	MS % REC	MSD CONC.	MSD % REC	RPD
1254	30	DSB	ND (0.065)	42	140	ND (1.6)[1]	NC	NC
1242	30	DSB	ND (0.03)	22	73	22	73	0
1242	13	DSB	ND (0.06)	12	92	14	110	18
1242	27	DSB	ND (0.04)	23	85	24	89	5
1242	15	DSB	ND (0.03)	15	100	15	100	0

[1] This QA/QC sample was inadvertently not spiked.

MS - Matrix spike.
MSD - Matrix spike duplicate.
DSB - Division St. Bridge.
ND - Not detected. Value in ( ) is detection limit.
NC - Not calculable.

TABLE 2-7

FIELD BLANK AND METHOD BLANK SUMMARY

SURVEY	DATE	STATION	SAMPLE TYPE	AROCLOR 1016	AROCLOR 1254	AROCLOR 1260	TOTAL PCBs	TOTAL DISSOLVED PCBs	DOC	TOC	TSS
1	3/05/91	DSB-P	FB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)			ND (1)	8
2	8/19/91	DSB-P	FB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)			ND (1)	ND (1)
3	3/27/92	DSB-P	FB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)			ND (1)	7
3	3/27/92	FVB-C	FB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)			ND (1)	8
4	4/18/92	DSB-P	FB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)			ND (1)	3
4	4/19/92	FVB-C	FB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)			ND (1)	ND (1)
5	6/02/92	DSB-P	FB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)			ND (1)	2
5	6/02/92	FVB-C	FB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)			ND (1)	ND (1)
6	12/18/92	DSB-P	FB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)			ND (1)	10
6	12/18/92	FVB-C	FB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)			ND (1)	ND (1)
7	3/30/93	DSB-P	FB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)			ND (1)	ND (1)
8	4/23/93	DSB-P	FB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)	ND (0.065)		ND (15)	11
							ND (0.065)				
1	3/6/91	Lab	MB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)	ND (0.065)	ND (1)	ND (1)	ND (1)
2	8/20/91	Lab	MB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)	ND (0.065)	ND (1)	ND (1)	ND (1)
3	3/29/91	Lab	MB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)	ND (0.065)			
4	4/18/92	Lab	MB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)	ND (0.065)	ND (1)	ND (1)	ND (1)
4A	4/21/92	Lab	MB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)	ND (0.065)		ND (1)	ND (1)
5	6/2/92	Lab	MB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)	ND (0.065)		ND (1)	ND (1)
6	12/22/92	Lab	MB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)	ND (0.065)	ND (1)	ND (1)	ND (1)
7	4/3/93	Lab	MB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)	ND (0.065)			ND (1)
8	4/30/93	Lab	MB	ND (0.030)	ND (0.065)	ND (0.065)	ND (0.065)	ND (0.065)		ND (1)	ND (1)

FB: Field Blank.
MB: Method Blank.
ND: Not detected. Value in ( ) is detection limit.

Final review of the data is performed by the operations manager. Draft data reports are checked against the reviewed data to prevent transcription errors.

2.2.3 **Results**

Water column samples were collected by LMS between March 1991 to April 1993; all surveys were conducted during rain events. Table 2-8 summarizes the number and location of samples collected, survey dates, total rainfall, and maximum flow during the survey period. The Task II.A. surveys (1 and 2) were performed from the Division Street Bridge (MP 106.2) in Great Barrington. The Task IV.B. monitoring included the following stations and parameters:

SAMPLING STATION	STATION ABBREVIATION	MILE POINT	WATER BODY	PARAMETERS SAMPLED
Division St. Bridge	DSB-P	106.2	Housatonic River	PCB, DPCB, TOC, DOC, TSS
Rt. 7 Bridge at Falls Village	FVB-C	75.0	Housatonic River	PCB, DPCB, TOC, DOC, TSS
Rt 133 Bridge	LL-C	34.2	Lake Lillinonah	TOC, DOC, TSS
Glen Rd. Bridge	LZ-C	27.3	Lake Zoar	TOC, DOC, TSS
Kellog Rd. Bridge	KRM	97.6	Housatonic River	TSS
Maple Ave. Bridge	MAB	93.5	Housatonic River	TSS
Andrus Rd. Bridge	ARB	86.2	Housatonic River	TSS

DPCB = Dissolved PCB.
DOC = Dissolved organic carbon.
TOC = Total organic carbon.
TSS = Total suspended solids.

These station locations are also indicated on Figure 2-1. Photos 1 to 7 show these sampling stations. Stations LL-C and LZ-C did not include PCB analyses as concentrations were expected to be below detection. Stations KRM, MAB, and ARB are located in the Sheffield Flats region of the Housatonic River in lower Massachusetts, which is a meandering, oxbowed section. In LMS (1991) it was postulated that sediment load was added to the river in the Sheffield Flats due to bank erosion and bottom sediment resuspension. The purpose of the samples taken at these three stations was to provide data with which to evaluate sediment resuspension.

Surveys 4, 4a, and 5 were performed when the Rising Pond Dam (MP 107) was undergoing maintenance construction. Construction activities resulted in increased suspended sediment and

TABLE 2-8

SUMMARY OF HOUSATONIC RIVER WATER SURVEY ACTIVITIES (1991-1993)

SURVEY No.	DATES	RAINFALL TOTAL[1] (in.)	MAX. FLOW[2] (cfs)	No. OF SAMPLES TAKEN[3]					STATIONS SAMPLED
				PCB	DISSOLVED PCB	TOC	DOC	TSS	
1	3-5 Mar 1991	0.95 (a)	1310	6	2	6	1	14	DSB-P, DSB-cross section
2	19-22 Aug 1991	1.51 (a)	1050	9	2	9	3	9	DSB-P
3	26-27 Mar 1992	0.75 (p)	1200	7	2	7	2	13	DSB-P, FVB-C, ARB, KRB, MAB
4[5]	16-19 Apr 1992	1.21 (p)	905	12	6	16	10	28	DSB-P, FVB-C, LL-C, LZ-C, ARB, KRB, MAB
4a[4,5]	22 Apr 1992	0 (p)	985	2	2	2		4	DSB-P, FVB-C
5[5]	31 May-3 Jun 1992	1.43 (p)	625	15	8	19	12	25	DSB-P, FVB-C. LL-C, LZ-C, ARB, KRB, MAB
6	17-19 Dec 1992	0.49 (p)	1150	14	9	14	7	14	DSB-P, FVB-C
7	29-30 Mar 1993	1.81 (p)	3519	8	8	7	-	26	DSB-P, FVB-C, KRB, MAB, ARB
8	22-23 Apr 1993	2.11 (p)	2443	8	8	8	-	29	DSB-P, FVB-C, KRB, MAB, ARB
	Total No. of samples taken:			81	47	88	35	162	

---

[1] Total precipitation measured at Pittsfield Airport (p) or Albany Airport (a)

[2] Maximum flow during sampling at DSB-P.

[3] Not including field blanks, QA/QC, duplicates.

[4] Canceled survey due to lack of rain.

[5] These surveys were performed during construction activities at Rising Pond Dam (~1 mile upstream of DSB). These activities resulted in release of some sediment, making the survey results unrepresentative of normal river conditions.

Notes: DSB-P = Division St. Bridge-Platform (MP 106.2); FVB-C = Falls Village Rt. 7 Bridge-Center (MP-75.0); ARB = Ardrus Rd Bridge (MP 86.2); MAB = Maple Ave. Bridge (MP 93.5); KRB = Kellog Rd Bridge (MP 97.6); LL-C = Lake Lillinonah at Rt. 133 Bridge-Center (MP 34.2), LZ-C = Lake Zoar at Glen Rd Bridge-Center (MP-27.3).

Photo 1. Division Street Bridge (MP 106.2), looking upstream. Sounding reel and sampler indicated.

Photo 2. Route 7 Bridge near Falls Village (MP 75.0), looking downstream.

Originals in color.

Photo 3. Route 133 Bridge and Lake Lillinonah (MP 34.2).

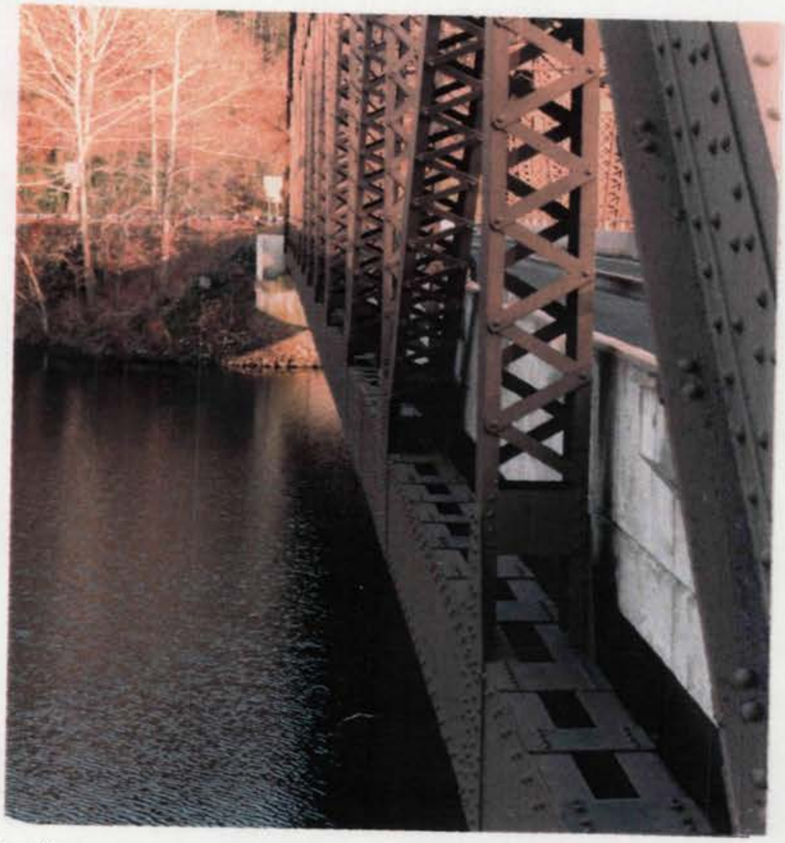


Photo 4. Downstream edge of Glen Road Bridge over Lake Zoar (MP 27.3).

Originals in color.

Photo 5. From Kellog Road Bridge (MP 97.6), looking upstream.

Photo 6. Maple Avenue Bridge (MP 93.5), looking downstream.

Originals in color.

Photo 7. From Andrus Road Bridge (MP 86.2), looking downstream.

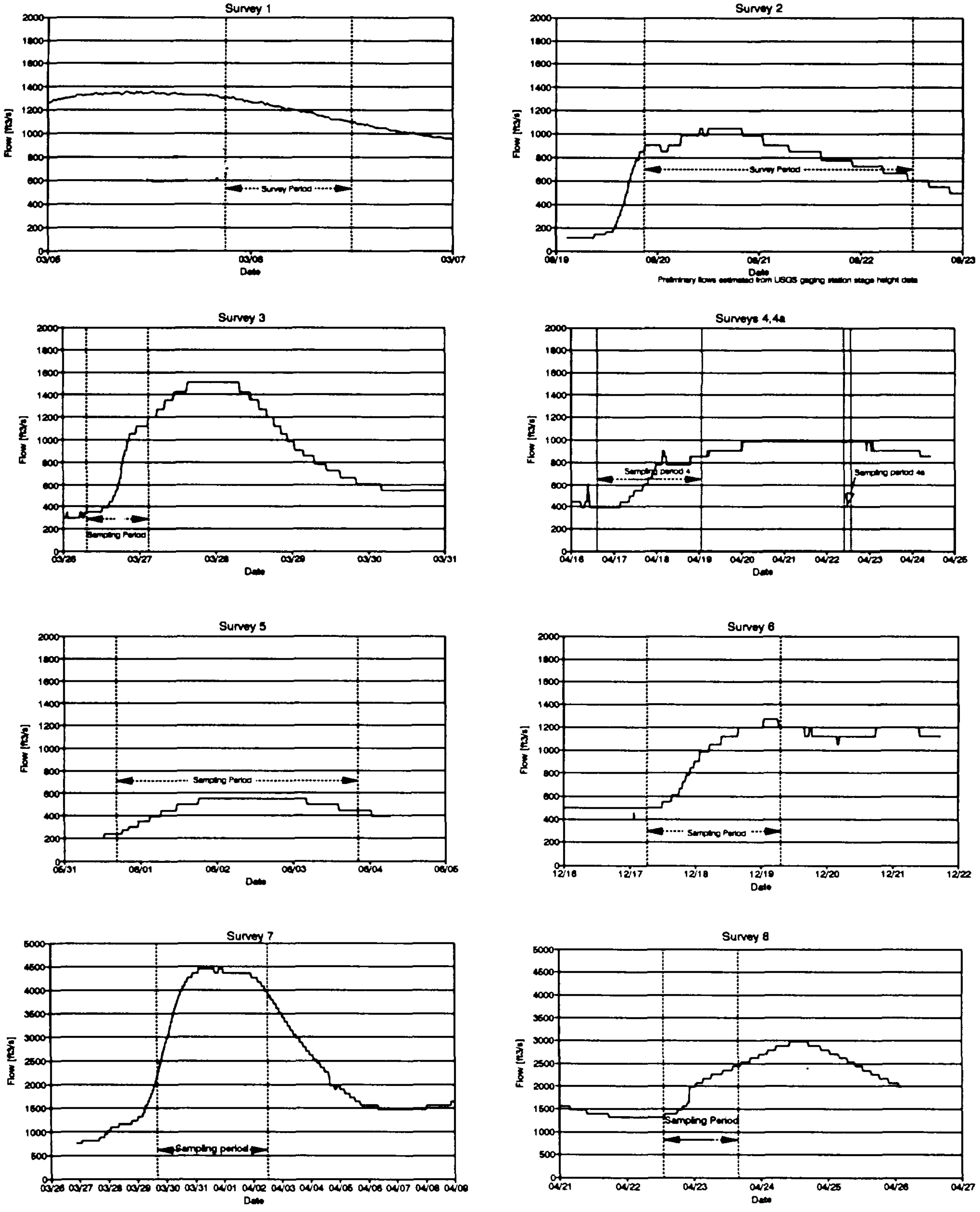
Originals in color.

PCB concentrations at DSB-P for these surveys. As the conditions during these surveys were not representative of normal river conditions, two additional surveys (7 and 8) were performed in 1993.

Attachment 2-3 (at the end of Chapter 2) provides a listing of results for all water quality samples collected by LMS. Figure 2-2 presents the hydrographs for each of the eight surveys. Figure 2-3 shows the daily flow record inclusive of all eight surveys and also indicates the survey periods. Figure 2-4 shows the distribution of PCBs, organic carbon, and TSS at Great Barrington (MP 106.2) and Falls Village (MP 75.0) with time. PCB and TSS results for Surveys 4 and 5 are noticeably higher than the other survey periods due to the construction activities at the Rising Pond Dam (MP 107). TOC results were highest during the survey with the highest flows, indicating that either increased runoff contributed organic carbon to the river or high riverine flow scoured organic carbon from the bottom sediments or banks, which was then transported downstream in the water column.

As discussed in Section 2.2.1, special studies of TSS were performed at three stations in the Sheffield Flats to provide data with which sediment resuspension fluxes could be evaluated. Figure 2-5 shows TSS results in the Sheffield Flats and also shows results of limited TOC/DOC analyses in Lakes Lillinonah and Zoar. During low flows, resuspension of sediments in the Sheffield Flats is not evident as TSS does not consistently increase between stations. During high flows, resuspension is indicated between the Maple Avenue Bridge (MP 93.5) and the Andrus Road Bridge (MP 86.2) as TSS concentrations increase from the upstream to the downstream station. Resuspension rates are evaluated in Section 4.2.3.

Survey Hydrographs in Housatonic River at Great Barrington (DSB)



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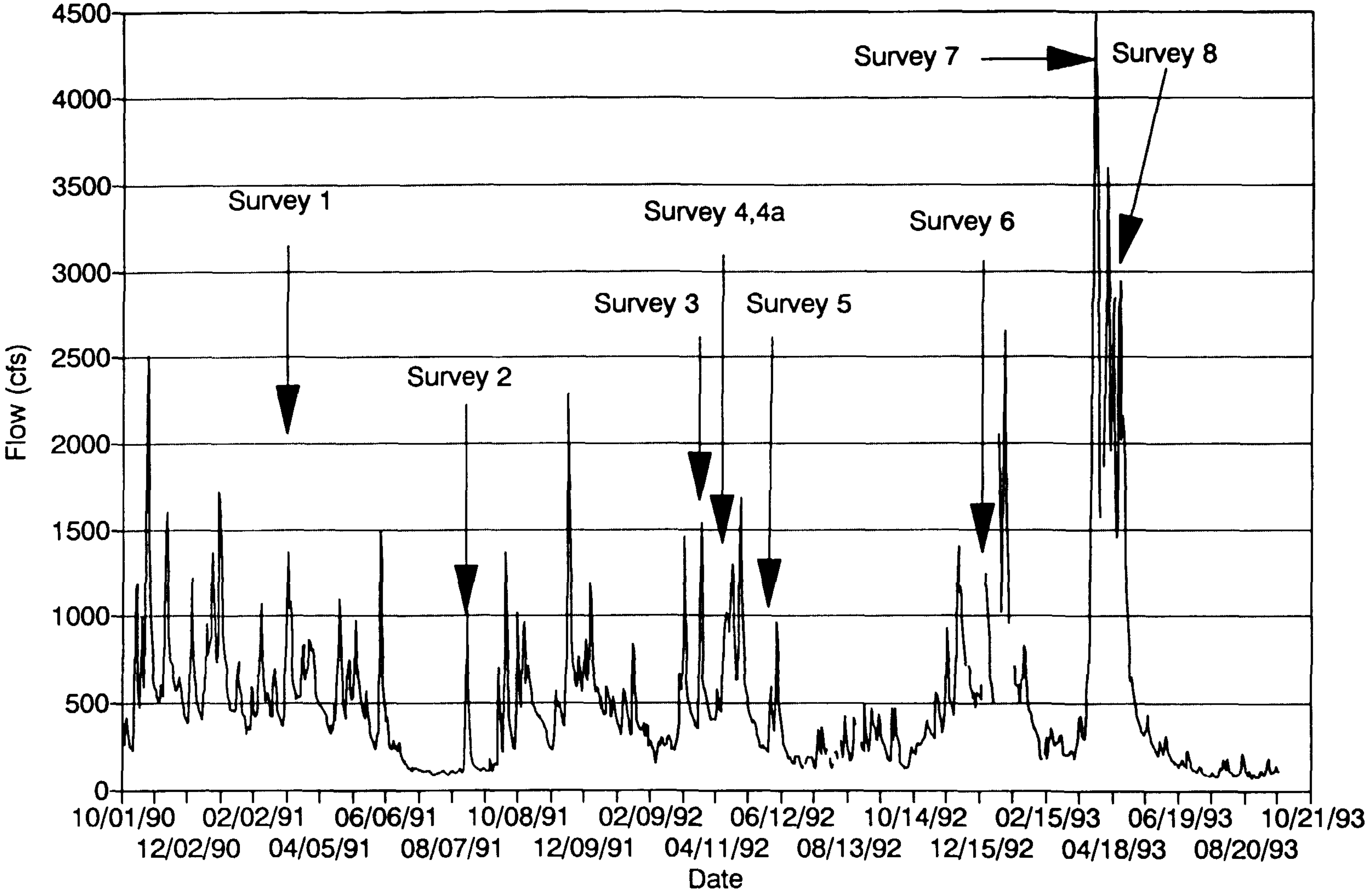
Survey Hydrographs in Housatonic River at Great Barrington (DSB)

Figure 2-2

1337.042TBLK ds4
disk HS4300 file SURV1-8.wq1



disk HS4300 file: allflow.WQ1 graph: Allflow 2

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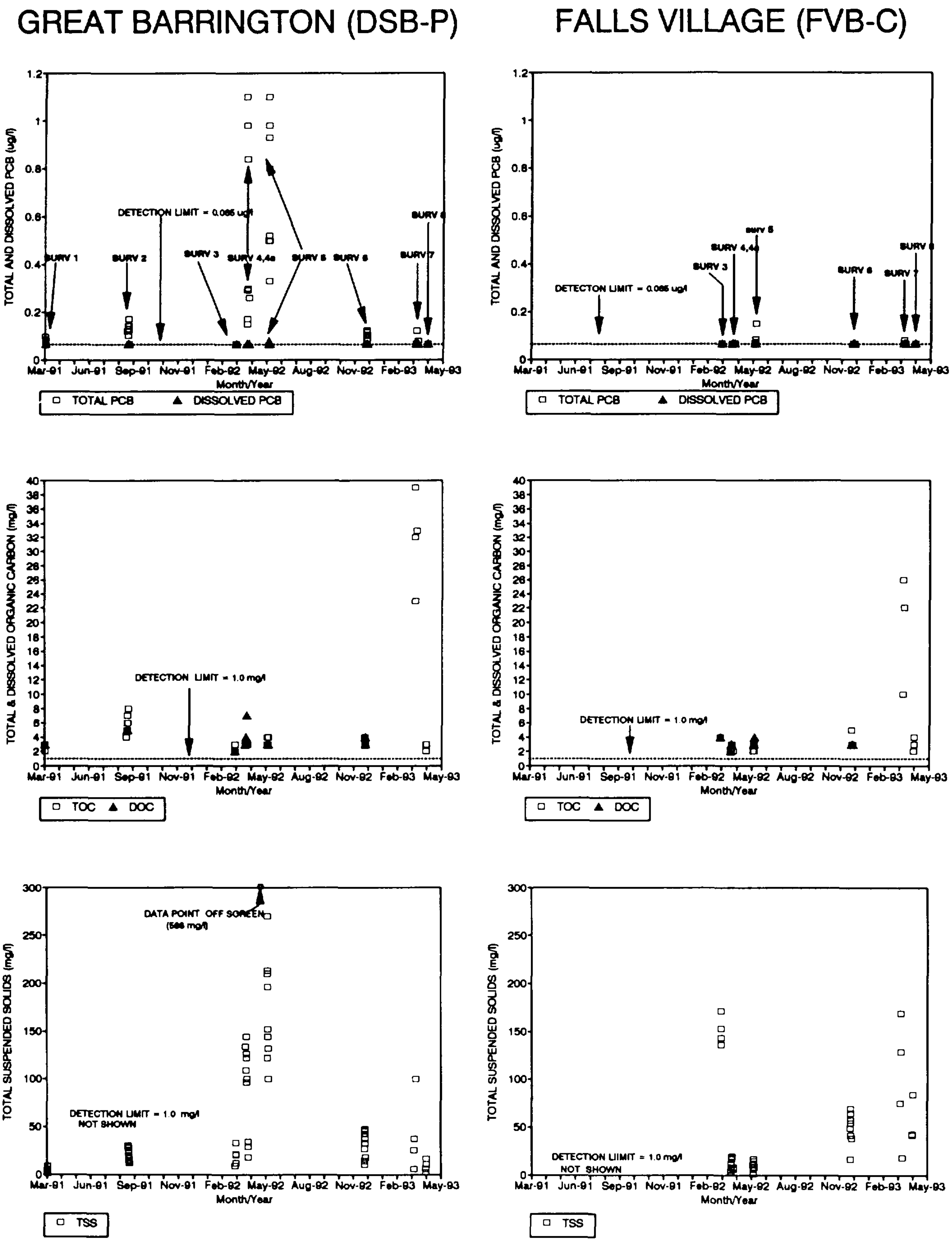
Flow in Housatonic River at Great Barrington (DSB)

Figure 2-3

\337\042TBLK.ds4



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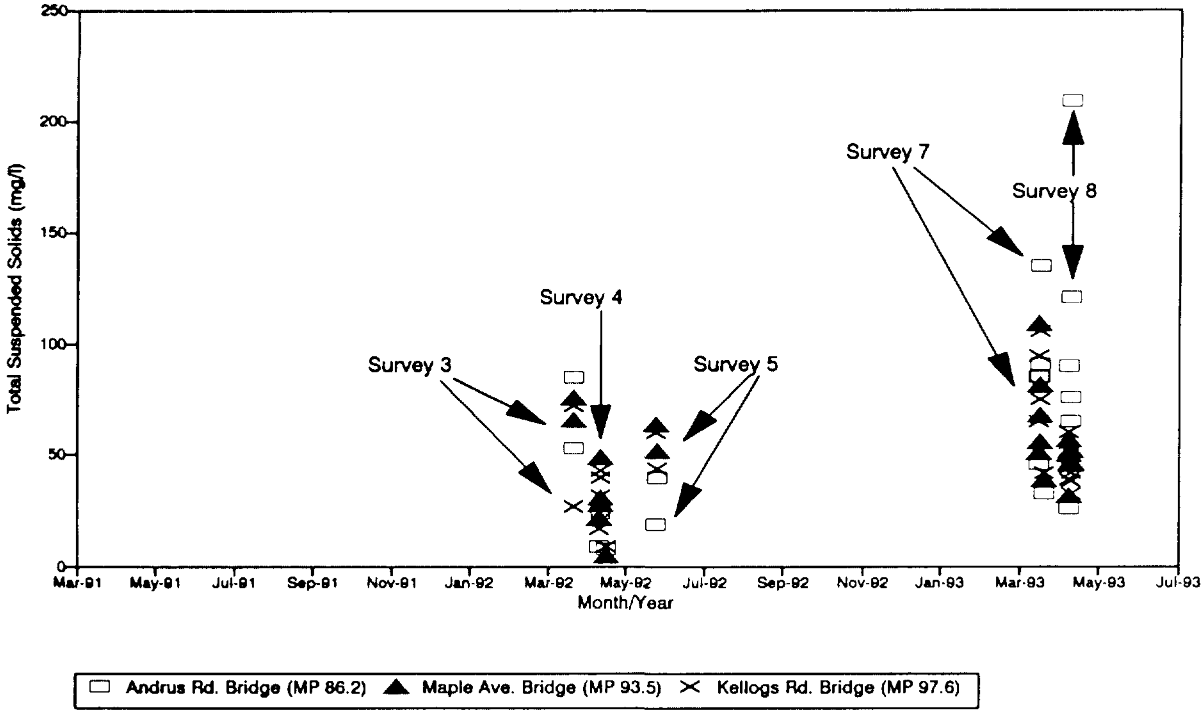
Housatonic River Water Column Survey Results

Figure 2-4

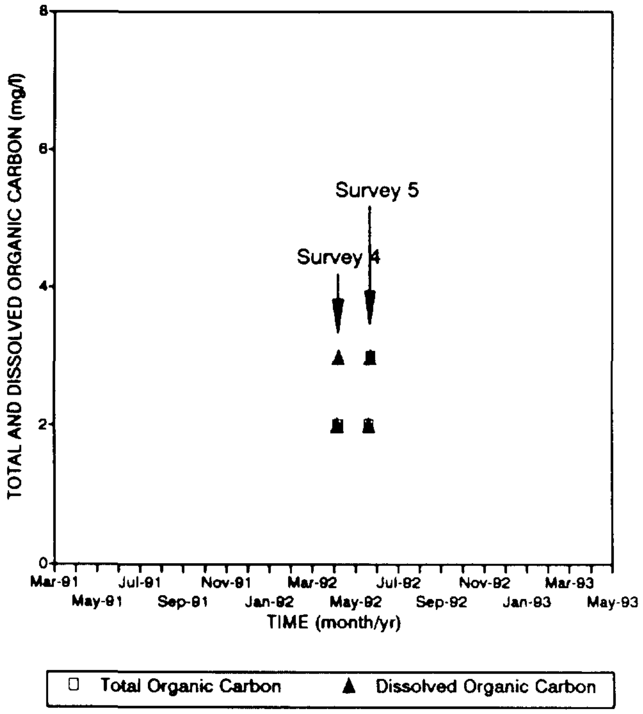
\337\042TBLK.ds4
disk HS4300 file kmepage wq1

Total Suspended Solids in the Sheffield Flats

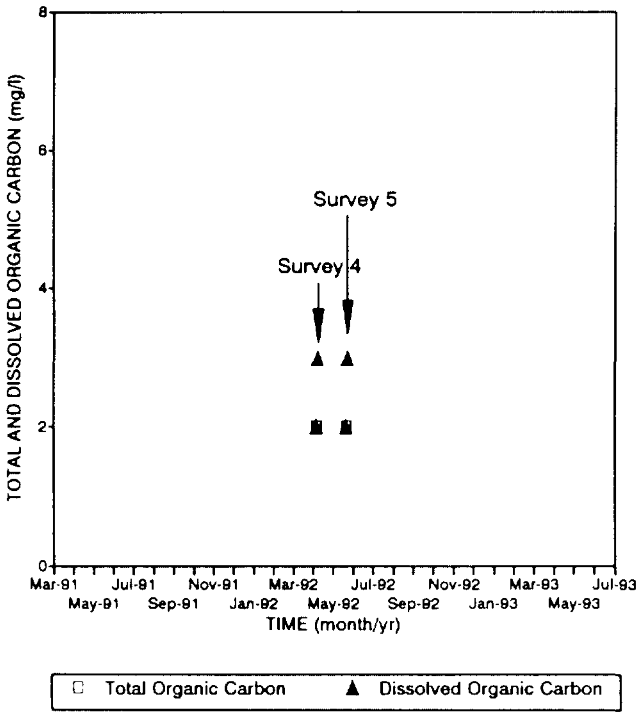


Aqueous Organic Carbon in:

LAKE LILLINONAH



LAKE ZOAR



LMS **LAWLER, MATUSKY & SKELLY ENGINEERS** Environmental Science & Engineering Consultants One Blue Hill Plaza • Pearl River, NY 10965	**Sheffield Flats TSS and Organic Carbon in Lakes**	**Figure 2-5**

ATTACHMENT 2-1

1992 AND 1986 HOUSATONIC RIVER DEEP CORE SURVEYS

Attachment 2-1

1992 HOUSATONIC RIVER DEEP CORE DATA

SAMPLE ID	DATE	RIVER MILE	CORE DEPTH (in)	AROCLOR 1248 mg/kg dry		AROCLOR 1254 mg/kg dry		AROCLOR 1260 mg/kg dry		TOTAL PCB mg/kg dry		TOC mg/kg dry	137 Cs pCi/gm dry	
31452	08/05/92	19.7	0-1	0.05	*	0.05	ND	0.25	*	0.30		39643.21	3.31E-01	
31453	08/05/92	19.7	1-2	0.06	*	0.05	ND	0.31	*	0.37		30108.90		
31454	08/05/92	19.7	2-3	0.05	ND	0.05	ND	0.10	*	0.10		30516.43		
31455	08/05/92	19.7	3-4	0.05	ND	0.05	ND	0.19	*	0.19		42791.31		
31456	08/05/92	19.7	4-5	0.09	*	0.05	ND	0.52	*	0.61		43146.37	4.06E-01	
31457	08/05/92	19.7	5-6	0.05	ND	0.05	ND	0.08	*	0.08		33990.48		
31458	08/05/92	19.7	6-7	0.05	ND	0.05	ND	0.14	*	0.14		43741.59		
31459	08/05/92	19.7	7-8	0.07	*	0.05	ND	0.49	*	0.56		38119.44		
31460	08/05/92	19.7	8-9	0.05	ND	0.05	ND	0.08	*	0.08		43699.93		
	08/05/92	19.7	9-10										1.27E+00	
31462	08/05/92	19.7	10-11	0.05	ND	0.05	ND	0.16	*	0.16		30134.45		
	08/05/92	19.7	11-12										3.96E-01	
	08/05/92	19.7	13-14										3.30E-01	
31466	08/05/92	19.7	14-15	0.05	ND	0.05	ND	0.21	*	0.21		34291.74		
31467	08/05/92	19.7	15-16	0.05	ND	0.05	ND	0.55	*	0.55		30504.71	1.35E+00	
31464	08/05/92	19.7	13-14	0.08	*	0.05	ND	1.10	*	1.20		32554.01		
31465	08/05/92	19.7	12-13	0.11	*	0.05	ND	1.80	*	1.80		45952.63		
31468	08/05/92	19.7	16-17	0.05	*	0.05	ND	1.20	*	1.20		22000.00		
31469	08/05/92	19.7	17-18	0.05	ND	0.05	ND	1.10	*	1.10		26308.35	2.00E-01	ND
31470	08/05/92	19.7	18-19	0.05	ND	0.05	ND	0.96	*	0.96		31347.96		
31471	08/05/92	19.7	19-20	0.05	ND	0.05	ND	0.05	ND	0.05	ND	12694.13	1.00E-01	ND
31472	08/05/92	19.7	20-21	0.05	ND	0.05	ND	0.05	ND	0.05	ND	16802.91		
31473	08/05/92	19.7	21-22	0.05	ND	0.05	ND	0.06	*	0.06		24444.44	2.00E-01	ND
31474	08/05/92	19.7	22-23	0.05	ND	0.05	ND	0.05	ND	0.05	ND	16977.93		
31477	08/05/92	26.1	0-1	0.05	ND	0.05	ND	0.05	ND	0.05	ND	1701.57	1.49E-01	
31478	08/05/92	26.1	1-2	0.05	ND	0.05	ND	0.05	ND	0.05	ND	2923.98		
31479	08/05/92	26.1	2-3	0.05	ND	0.05	ND	0.05	ND	0.05	ND	881.39		
	08/05/92	26.1	3-4										9.81E-02	
31481	08/05/92	26.1	4-5	0.05	ND	0.05	ND	0.05	ND	0.05	ND	2176.75		
	08/05/92	26.1	5-6										7.38E-02	
31483	08/05/92	26.1	6-7	0.05	ND	0.05	ND	0.05	ND	0.05	ND	1240.69		
31484	08/05/92	26.1	7-8	0.05	ND	0.05	ND	0.05	ND	0.05	ND	2644.10	2.00E-01	ND
31485	08/05/92	26.1	8-9	0.05	ND	0.05	ND	0.05	ND	0.05	ND	1612.47		
31486	08/05/92	26.1	9-10	0.05	ND	0.05	ND	0.05	ND	0.05	ND	2421.63	1.49E-01	
31487	08/05/92	26.1	10-11	0.05	ND	0.05	ND	0.05	ND	0.05	ND	1474.14		
31488	08/05/92	26.1	11-12	0.05	ND	0.05	ND	0.05	ND	0.05	ND	2296.68	1.57E-01	
31489	08/05/92	26.1	12-13	0.05	ND	0.05	ND	0.05	ND	0.05	ND	2201.13		
31490	08/05/92	26.1	13-14	0.05	ND	0.05	ND	0.05	ND	0.05	ND	2500.69	2.00E-01	ND

AROCLOR 1248 - Aroclor 1016, 1232, 1242 and/or 1248.
ND - Compound was analyzed for but not detected. The number is detection limit for the sample.
* - Sample exhibits alteration of standard Aroclor pattern.
^ = Aroclor pattern identified and/or calculated as Aroclor 1248.
E = Estimated value.

Attachment 2-1

1992 HOUSATONIC RIVER DEEP CORE DATA

SAMPLE ID	DATE	RIVER MILE	CORE DEPTH (in)	AROCLOR 1248 mg/kg dry		AROCLOR 1254 mg/kg dry		AROCLOR 1260 mg/kg dry		TOTAL PCB mg/kg dry		TOC mg/kg dry	137 Cs pCi/gm dry	
31411	08/05/92	29.8	0-1	0.08	*^	0.05	ND	0.62	*	0.70		67732.12	7.94E-01	
31412	08/05/92	29.8	1-2	0.09	*^	0.05	ND	0.69	*	0.78		45787.55		
31413	08/05/92	29.8	2-3	0.05	U^	0.05	ND	0.31	*	0.31		51210.43		
	08/05/92	29.8	3-4										9.22E-01	
31415	08/05/92	29.8	4-5	0.05	U^	0.05	ND	0.24	*	0.24		38240.13		
31417	08/05/92	29.8	6-7	0.11	*^	0.05	ND	0.54	*	0.65		46992.48	8.75E-01	
31419	08/05/92	29.8	8-9	0.38	*^	0.05	ND	1.30	*	1.70		46475.60		
	08/05/92	29.8	9-10										8.11E-01	
31421	08/05/92	29.8	10-11	0.25	*^	0.05	ND	1.30	*	1.60		43026.17		
	08/05/92	29.8	11-12										1.08E+00	
31423	08/05/92	29.8	12-13	0.26	*^	0.05	ND	1.20	*	1.50		52356.02	1.57E+00	
31424	08/05/92	29.8	13-14	0.05	ND	0.05	ND	0.10	*	0.10		10848.76	2.99E+00	
31425	08/05/92	29.8	14-15	0.05	ND	0.05	ND	0.12	*	0.12		9924.57	1.75E+00	
31426	08/05/92	29.8	15-16	0.09	*	0.05	ND	0.32	*	0.41		54192.81	2.95E+00	
31427	08/05/92	29.8	16-17	0.05	ND	0.05	ND	0.23	*	0.23		43307.09	1.46E+00	
31428	08/05/92	29.8	17-18	0.05	ND	0.05	ND	0.05	ND	0.05	ND	26130.65	8.20E-01	
31429	08/05/92	29.8	18-19	0.05	ND	0.05	ND	0.07	*	0.07		2422.56		
31430	08/05/92	29.8	19-20	0.05	ND	0.05	ND	0.05	ND	0.05	ND	1459.85	1.00E-01	ND
31431	08/05/92	29.8	20-21	0.05	ND	0.05	ND	0.05	ND	0.05	ND	2544.19		
	08/05/92	29.8	21-22										5.00E-02	
31433	08/05/92	29.8	22-23	0.05	ND	0.05	ND	0.05	ND	0.05	ND	1254.08		
31435	08/05/92	29.8	24-25	0.05	ND	0.05	ND	0.05	ND	0.05	ND	294.42		
	08/05/92	29.8	25-26										6.00E-02	
31437	08/05/92	29.8	26-27	0.05	ND	0.05	ND	0.05	ND	0.05	ND	494.78		
31380	08/05/92	34.2	0-1	0.05	ND	0.05	ND	0.22		0.22		31722.61	5.04E-01	
31382	08/05/92	34.2	1-2	0.05	ND	0.05	ND	0.25	*	0.25		33211.56		
31383	08/05/92	34.2	2-3	0.05	ND	0.08	ND	0.47		0.47		31669.54		
	08/05/92	34.2	3-4										4.72E-01	
31385	08/05/92	34.2	4-5	0.05	ND	0.05	ND	0.36		0.36		38535.65		
31386	08/05/92	34.2	5-6	0.05	ND	0.05	ND	0.77		0.77		41592.39		
31387	08/05/92	34.2	6-7	0.05	ND	0.05	ND	0.41	*	0.41		31270.57	1.01E+00	
31390	08/05/92	34.2	8-9	0.05	ND	0.05	ND	0.36	*	0.36		29146.79		
	08/05/92	34.2	9-10										5.64E-01	
31392	08/05/92	34.2	10-11	0.05	ND	0.05	ND	0.28	*	0.28		35460.99		
	08/05/92	34.2	11-12										6.58E-01	
31394	08/05/92	34.2	12-13	0.05	ND	0.05	ND	0.45	*	0.45		26413.10		
31395	08/05/92	34.2	13-14	0.05	ND	0.05	ND	0.49	*	0.49		26826.48	6.43E-01	
31397	08/05/92	34.2	14-15	0.05	ND	0.05	ND	0.36	*	0.36		33774.28		
31398	08/05/92	34.2	15-16	0.05	ND	0.05	ND	0.20	*	0.20		16696.81	7.44E-01	
31400	08/05/92	34.2	16-17	0.05	ND	0.05	ND	0.30	*	0.30		28954.99		
31401	08/05/92	34.2	17-18	0.06	*	0.05	ND	0.37	*	0.43		31578.95	8.25E-01	
31404	08/05/92	34.2	19-20	0.11	*	0.05	ND	0.56	*	0.67		29729.73	9.51E-01	
31406	08/05/92	34.2	20-21	0.06	*	0.05	ND	0.49	*	0.55		32042.72		
	08/05/92	34.2	21-22										8.95E-01	
31408	08/05/92	34.2	22-23	0.08	*	0.05	ND	0.38	*	0.46		24074.07		
31410	08/05/92	34.2	24-25	0.05	ND	0.05	ND	0.14	*	0.14		28335.91		
31403	08/05/92	34.2	18-19	0.09	*	0.05	ND	0.43	*	0.52		34373.35		

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E = Estimated value.

Attachment 2-1

1992 HOUSATONIC RIVER DEEP CORE DATA

SAMPLE ID	DATE	RIVER MILE	CORE DEPTH (in)	AROCLOR 1248 mg/kg dry	AROCLOR 1254 mg/kg dry	AROCLOR 1260 mg/kg dry	TOTAL PCB mg/kg dry	TOC mg/kg dry	137 Cs pCi/gm dry
31308	08/05/92	53.2	0-1	0.05 ND	0.05 ND	0.31 *	0.31	30383.09	
31309	08/05/92	53.2	1-2	0.05 ND	0.05 ND	0.19 *	0.19	20049.50	
31310	08/05/92	53.2	2-3	0.05 ND	0.05 ND	0.09 *	0.09	39930.12	
31312	08/05/92	53.2	4-5	0.05 ND	0.05 ND	0.10 *	0.10	19879.68	
31315	08/05/92	53.2	7-8	0.05 ND	0.05 ND	0.11 *	0.11	19572.95	
31317	08/05/92	53.2	9-10	0.05 ND	0.05 ND	0.10 *	0.10	11519.30	
31319	08/05/92	53.2	11-12	0.05 ND	0.05 ND	0.06 *	0.06	4570.51	
31320	08/05/92	53.2	12-13	0.05 ND	0.05 ND	0.06 *E	0.06	5044.47	
31321	08/05/92	53.2	13-14	0.05 ND	0.05 ND	0.06 *E	0.06	6683.60	
31322	08/05/92	53.2	14-15	0.05 ND	0.05 ND	0.24 *	0.24	5538.85	
31323	08/05/92	53.2	15-16	0.05 ND	0.05 ND	0.55 *	0.55	22375.92	
31324	08/05/92	53.2	16-17	0.05 ND	0.05 ND	0.32 *	0.32	15608.37	
31325	08/05/92	53.2	17-18	0.05 ND	0.05 ND	0.50 *	0.50	16743.55	
31326	08/05/92	53.2	18-19	0.05 ND	0.05 ND	0.25 *	0.25	13939.84	
31327	08/05/92	53.2	19-20	0.05 ND	0.05 ND	0.17 *	0.17	11020.47	
31328	08/05/92	53.2	20-21	0.05 ND	0.05 ND	0.16 *	0.16	14298.75	
31336	08/05/92	77.7	0-1	0.05 ND	0.05 ND	0.05 ND	0.05 ND	1377.24	
31337	08/05/92	77.7	1-2	0.05 ND	0.05 ND	0.05 ND	0.05 ND	2717.74	
31338	08/05/92	77.7	2-3	0.05 ND	0.05 ND	0.06 *	0.06	1989.39	
31340	08/05/92	77.7	4-5	0.05 ND	0.05 ND	0.05 ND	0.05 ND	2316.79	
31343	08/05/92	77.7	7-8	0.05 ND	0.05 ND	0.05 ND	0.05 ND	3373.31	
31344	08/05/92	77.7	8-9	0.05 ND	0.05 ND	0.05 ND	0.05 ND	1159.60	
31345	08/05/92	77.7	9-10	0.05 ND	0.05 ND	0.05 ND	0.05 ND	1353.18	
31346	08/05/92	77.7	10-11	0.05 ND	0.05 ND	0.05 ND	0.05 ND	1371.06	
31347	08/05/92	77.7	11-12	0.05 ND	0.05 ND	0.05 ND	0.05 ND	2119.97	
31348	08/05/92	77.7	12-13	0.05 ND	0.05 ND	0.05 ND	0.05 ND	3040.99	
31349	08/05/92	77.7	13-14	0.05 ND	0.05 ND	0.05 ND	0.05 ND	1581.32	
31350	08/05/92	77.7	14-15	0.05 ND	0.05 ND	0.05 ND	0.05 ND	1067.00	
31351	08/05/92	77.7	15-16	0.05 ND	0.05 ND	0.05 ND	0.05 ND	2146.74	
31353	08/05/92	77.7	17-18	0.05 ND	0.05 ND	0.05 ND	0.05 ND	1889.64	
31355	08/05/92	77.7	19-20	0.05 ND	0.05 ND	0.05 ND	0.05 ND	2017.65	
31357	08/05/92	77.7	21-22	0.05 ND	0.05 ND	0.05 ND	0.05 ND	1619.13	
31359	08/05/92	77.7	23-24	0.05 ND	0.05 ND	0.05 ND	0.05 ND	2458.81	
31361	08/05/92	77.7	25-26	0.05 ND	0.05 ND	0.05 ND	0.05 ND	2499.38	

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E = Estimated value.

Attachment 2-1

1986 HOUSATONIC RIVER DEEP CORE DATA

SAMPLE ID	DATE	RIVER MILE	CORE DEPTH (in)	AROCLOR 1248 mg/kg dry	AROCLOR 1254 mg/kg dry	AROCLOR 1260 mg/kg dry	TOTAL PCB mg/kg dry	TOC mg/kg dry
57535	1986	19.7	0.5	0.68	0.1 ND	1.2	1.88	61100
57536	1986	19.7	1.5	0.8	0.1 ND	1.4	2.2	63700
57537	1986	19.7	2.5	0.84	0.1 ND	1.3	2.14	60600
57538	1986	19.7	3.5	0.87	0.1 ND	1.1	1.97	49500
57539	1986	19.7	4.5	0.1 ND	0.1 ND	0.12	0.12	41000
57540	1986	19.7	5.5	0.3	0.1 ND	0.8	1.1	49800
57541	1986	19.7	6.5	0.62	0.1 ND	1.1	1.72	50400
57542	1986	19.7	7.5	0.67	0.1 ND	1.1	1.77	69600
57545	1986	19.7	8.5	0.59	0.1 ND	0.9	1.49	61400
57544	1986	19.7	9.5	0.1 ND	0.1 ND	0.95	0.95	58700
57543	1986	19.7	10.5	0.36	0.1 ND	1.9	2.26	39900
57546	1986	19.7	11.5	0.3	0.1 ND	2.3	2.6	59700
57547	1986	19.7	12.5	0.1 ND	0.1 ND	0.52	0.52	72400
57550	1986	19.7	13.5	0.42	0.1 ND	1.8	2.22	63000
57549	1986	19.7	14.5	0.76	0.1 ND	2.6	3.36	67600
57552	1986	19.7	15.5	0.58	0.1 ND	2.3	2.88	69300
57553	1986	19.7	16.5	0.51	0.1 ND	3.2	3.71	64200
57554	1986	19.7	17.5	0.1 ND	0.1 ND	2.4	2.4	86700
57555	1986	19.7	18.5	0.47	0.1 ND	1.52	1.99	95100
57556	1986	19.7	19.5	0.31	0.1 ND	2.8	3.11	77700
57557	1986	19.7	20.5	0.1 ND	0.1 ND	1.6	1.6	74500
57558	1986	19.7	21.5	0.1 ND	0.1 ND	0.85	0.85	66400
57559	1986	19.7	22.5	0.34	0.1 ND	1.2	1.54	42800
57560	1986	19.7	23.5	0.23	0.1 ND	0.89	1.12	44400
57561	1986	19.7	24.5	1.2	0.1 ND	4.7	5.9	76800
57562	1986	19.7	25.5	0.84	0.1 ND	3.3	4.14	65400
57563	1986	19.7	26.5	0.32	0.1 ND	2.7	3.02	68800
57564	1986	19.7	27.5	0.1 ND	0.1 ND	0.23	0.23	47000
57565	1986	19.7	28.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	51500
57566	1986	19.7	29.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	39400
57567	1986	19.7	30.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	21000
57602	1986	26.8	0.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	780
57601	1986	26.8	1.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	1140
57600	1986	26.8	2.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	780
57590	1986	26.8	3.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	635
57594	1986	26.8	4.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	630
57591	1986	26.8	5.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	530
57592	1986	26.8	6.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	520

ND - Compound was analyzed for but not detected. The number is detection limit for the sample.

Attachment 2-1

1986 HOUSATONIC RIVER DEEP CORE DATA

SAMPLE ID	DATE	RIVER MILE	CORE DEPTH (in)	AROCLOR 1248 mg/kg dry	AROCLOR 1254 mg/kg dry	AROCLOR 1260 mg/kg dry	TOTAL PCB mg/kg dry	TOC mg/kg dry
57589	1986	29.8	0.5	0.1 ND	0.1 ND	1.2	1.2	59900
57585	1986	29.8	1.5	0.1 ND	0.1 ND	1	1	62200
57576	1986	29.8	2.5	0.1 ND	0.1 ND	1.1	1.1	42700
57586	1986	29.8	3.5	0.1 ND	0.1 ND	1.2	1.2	42600
57581	1986	29.8	4.5	0.1 ND	0.1 ND	1.2	1.2	59700
57582	1986	29.8	5.5	0.1 ND	0.1 ND	1.5	1.5	55400
57587	1986	29.8	6.5	0.48	0.1 ND	1.6	2.08	46200
57578	1986	29.8	7.5	2.2	0.1 ND	2.1	4.3	44300
57588	1986	29.8	8.5	0.63	0.1 ND	2.4	3.03	46500
57579	1986	29.8	9.5	0.58	0.1 ND	2.9	3.48	46700
57583	1986	29.8	10.5	0.79	0.1 ND	3.5	4.29	53500
57580	1986	29.8	11.5	0.68	0.1 ND	2.2	2.88	50200
57584	1986	29.8	12.5	1.2	0.1 ND	3	4.2	53400
57577	1986	29.8	13.5	0.39	0.1 ND	1.3	1.69	66000
57569	1986	29.8	14.5	0.81	0.1 ND	4.6	5.41	62900
57568	1986	29.8	15.5	1.9	0.1 ND	6.3	8.2	81800
57574	1986	29.8	16.5	2.2	0.1 ND	3.8	6	69600
57575	1986	29.8	17.5	0.67	0.1 ND	4.7	5.37	86400
57573	1986	29.8	18.5	0.51	0.1 ND	1.9	2.41	55600
57572	1986	29.8	19.5	0.1 ND	0.1 ND	1.3	1.3	68100
57571	1986	29.8	20.5	0.1 ND	0.1 ND	0.63	0.63	40400
57516	1986	34.2	0.5	0.35	0.1 ND	1.1	1.45	50700
57505	1986	34.2	1.5	0.28	0.1 ND	0.89	1.17	49800
57522	1986	34.2	2.5	0.29	0.1 ND	1	1.29	46700
57527	1986	34.2	3.5	0.5	0.1 ND	1.4	1.9	43300
57515	1986	34.2	4.5	0.1 ND	0.1 ND	1.1	1.1	48100
57530	1986	34.2	5.5	0.1 ND	0.1 ND	1	1	44700
57517	1986	34.2	6.5	0.1 ND	0.1 ND	1.3	1.3	41300
57521	1986	34.2	7.5	0.1 ND	0.1 ND	1.1	1.1	43300
57525	1986	34.2	8.5	0.1 ND	0.1 ND	1.3	1.3	40300
57526	1986	34.2	9.5	0.1 ND	0.1 ND	1.8	1.8	40100
57510	1986	34.2	10.5	0.1 ND	0.1 ND	1.8	1.8	40600
57509	1986	34.2	11.5	0.73	0.1 ND	1.6	2.33	42300
57506	1986	34.2	12.5	0.73	0.1 ND	2	2.73	35700
57507	1986	34.2	13.5	0.93	0.1 ND	2.6	3.53	40000
57508	1986	34.2	14.5	1.1	0.1 ND	3.2	4.3	38700
57511	1986	34.2	15.5	1.1	0.1 ND	3.7	4.8	41300
57512	1986	34.2	16.5	1.4	0.1 ND	3.4	4.8	49600
57533	1986	34.2	17.5	1	0.1 ND	2	3	49400
57534	1986	34.2	18.5	0.25	0.1 ND	0.71	0.96	31100

ND - Compound was analyzed for but not detected. The number is detection limit for the sample.

Attachment 2-1

1986 HOUSATONIC RIVER DEEP CORE DATA

SAMPLE ID	DATE	RIVER MILE	CORE DEPTH (in)	AROCLOR 1248 mg/kg dry	AROCLOR 1254 mg/kg dry	AROCLOR 1260 mg/kg dry	TOTAL PCB mg/kg dry	TOC mg/kg dry
57532	1986	53.2	0.5	0.1 ND	0.1 ND	0.19	0.19	6760
57529	1986	53.2	1.5	0.1 ND	0.1 ND	0.33	0.33	6930
57524	1986	53.2	2.5	0.1 ND	0.1 ND	0.19	0.19	4840
57519	1986	53.2	3.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	1360
57504	1986	53.2	4.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	1270
57514	1986	53.2	5.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	1460
57513	1986	53.2	6.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	1820
57503	1986	53.2	7.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	1470
57518	1986	53.2	8.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	1640
57502	1986	53.2	9.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	1030
57501	1986	53.2	10.5	0.1 ND	0.1 ND	0.1 ND	0.1 ND	915
57523	1986	53.2	11.5	0.1 ND	0.1 ND	0.52	0.52	40800
57528	1986	53.2	12.5	0.1 ND	0.1 ND	1.1	1.1	7720
57531	1986	53.2	13.5	0.1 ND	0.1 ND	1.3	1.3	11600
57598	1986	77.7	0.5	0.1 ND	0.1 ND	0.29	0.29	8400
57597	1986	77.7	1.5	0.1 ND	0.1 ND	0.32	0.32	7300
57595	1986	77.7	2.5	0.1 ND	0.1 ND	0.3	0.3	4800
57596	1986	77.7	3.5	0.1 ND	0.1 ND	0.19	0.19	2980
57593	1986	77.7	4.5	0.1 ND	0.1 ND	0.22	0.22	8700
57599	1986	77.7	5.5	0.1 ND	0.1 ND	0.16	0.16	1620
57603	1986	77.7	6.5	0.1 ND	0.1 ND	0.19	0.19	2220

ND - Compound was analyzed for but not detected. The number is detection limit for the sample.

ATTACHMENT 2-2

1992 HOUSATONIC RIVER SURFICIAL SEDIMENT DATA

Attachment 2-2

1992 HOUSATONIC SURFICIAL SEDIMENT DATA

SAMPLE ID	DATE	RIVER MILE	SAMPLE DEPTH (in)	AROCLOR 1248 mg/kg dry	AROCLOR 1254 mg/kg dry	AROCLOR 1260 mg/kg dry	TOTAL PCB mg/kg dry	DEPTH AVERAGE TOT PCB mg/kg dry	TOC mg/kg dry	DEPTH AVERAGE TOC mg/kg dry	DRY BULK DENSITY (PCF)	% GRAIN SIZE BY WEIGHT GRAVEL	SAND	SILT	CLAY	DESCRIPTION
32004	08/25/92	103.1	0-1	0.05 ND	0.05 ND	0.83 *	0.83		22046.43							Lt. Fluff, Sand
32004	08/25/92	103.1	1-2	0.09 ND	0.18 ND	2.5 *	2.5	1.81	40286.48	33709.33						Lt. Fluff, Sand
32004	08/25/92	103.1	2-3	0.11 ND	0.18 ND	2.1 *	2.1		38795.07							Lt. Fluff, Sand
32005	08/25/92	101.5	0-1	0.05 ND	0.05 ND	0.96 *	0.96		20404.96							Sand, Gravel
32005	08/25/92	101.5	0-2	0.05 ND	0.05 ND	1.1 *	1.1	0.88	17961.38	21228.79						Sand, Gravel
32005	08/25/92	101.5	2-3	0.05 ND	0.05 ND	0.59 *	0.59		25320.02							Sand, Gravel
32010	08/26/92	94.4	0-1	0.05 ND	0.05 ND	0.32 *	0.32		4190.32							Gravel, Sand, Fluff
32010	08/26/92	94.4	1-2	0.05 ND	0.05 ND	0.43 *	0.43	0.38	6427.27	5810.39						Gravel, Sand, Fluff
32010	08/26/92	94.4	2-3	0.05 ND	0.05 ND	0.38 *	0.38		6813.57							Gravel, Sand, Fluff
32015	08/27/92	89.7	0-1	0.05 ND	0.05 ND	0.51 *	0.51		5295.68							Packed Sand, Fluff
32015	08/27/92	89.7	1-2	0.05 ND	0.05 ND	0.4 *	0.4	0.40	3514.94	3667.46						Packed Sand, Fluff
32015	08/27/92	89.7	2-3	0.05 ND	0.05 ND	0.28 *	0.28		2191.78							Packed Sand, Fluff
33752	08/27/92	82.7	0-1	0.05 ND	0.05 ND	0.1 *	0.1		9015.07							Sand
33753	08/27/92	82.7	1-2	0.05 ND	0.05 ND	1 *	1	0.39	8636.30	8256.92	79.6					
33753	08/27/92	82.7	2-3	0.05 ND	0.05 ND	0.07 *	0.07		7119.39							
33780	09/02/92	49.7	0-1	0.05 ND	0.05 ND	0.07 *	0.07		13169.98							Sand, Silt
33780	09/02/92	49.7	1-2	0.05 ND	0.05 ND	0.06 *	0.06	0.07	21351.23	16190.69						Sand, Silt
33780	09/02/92	49.7	2-3	0.05 ND	0.05 ND	0.09 *	0.09		14050.86							Sand, Silt
33801	09/04/92	19.5	0-1	0.05 ND	0.05 ND	0.06 *	0.06		44483.99							Silt, Clay
33801	09/04/92	19.5	1-2	0.05 ND	0.05 ND	0.14 *	0.14	0.13	39271.69	43192.91						
33801	09/04/92	19.5	2-3	0.05 ND	0.05 ND	0.18 *	0.18		45823.05							Silt, Clay

ROCLOR 1248 - Aroclor 1016, 1232, 1242 and/or 1248.

D - Compound was analyzed for but not detected. The number is detection limit for the sample.

Sample exhibits alteration of standard Aroclor pattern.

Attachment 2-2

1992 HOUSATONIC SURFICIAL SEDIMENT DATA

SAMPLE ID	DATE	RIVER MILE	SAMPLE DEPTH (in)	AROCLOR 1248 mg/kg dry	AROCLOR 1254 mg/kg dry	AROCLOR 1260 mg/kg dry	TOTAL PCB mg/kg dry	TOC mg/kg dry	DRY BULK DENSITY (PCF)	% GRAIN SIZE BY WEIGHT				DESCRIPTION
										GRAVEL	SAND	SILT	CLAY	
32002	08/25/92	106.2	0-3	0.05 ND	0.05 ND	0.12 *	0.12	20551.26	60.5	0	95.5	4.0	0.5	Tan, Grey Sandy Clay
32006	08/26/92	98.7	0-3	0.05 ND	0.06 ND	0.88 *	0.88	32500.51	48.4	3.5	49.7	43.3	3.5	Lt. Fluff, Sand
32008	08/26/92	98.1	0-3	0.05 ND	0.05 ND	0.05 ND	0.05 ND	3830.50						Gravel
32009	08/26/92	96.0	0-3	0.05 ND	0.05 ND	0.05 ND	0.05 ND	687.32						Gravel, Sand
32011	08/26/92	93.56	0-3	0.05 ND	0.05 ND	0.2 *	0.2	3371.37	95.0	0	84.8	13.8	1.4	Sand, Gravel, Clay
32014	08/27/92	91.28	0-3	0.05 ND	0.05 ND	0.23 *	0.23	1630.09						Sandy, Fluff, Gravel
32016	08/27/92	86.4	0-3	0.05 ND	0.05 ND	0.9 *	0.9	13431.40	85.2	0.9	47.6	48.5	3.0	Mud, Clay, Fluff
33751	08/27/92	84.6	0-3	0.05 ND	0.05 ND	0.3 *	0.3	10694.25						
33754	08/27/92	81.3	0-3	0.05 ND	0.05 ND	1.1 *	1.1	12397.33		0	50.1	47.7	2.2	Clay, Silt
33755	08/27/92	78.4	0-3	0.05 ND	0.05 ND	0.44 *	0.44	13129.82						Clay, Silt
33756	08/28/92	78.0	0-3	0.05 ND	0.05 ND	0.33 *	0.33	22694.35						Clay, Silt
33757	08/28/92	77.9	0-3	0.05 ND	0.05 ND	0.44 *	0.44	18327.22	58.9	0	30.3	66.6	3.1	Silt, Clay
33759	08/28/92	77.7	0-3	0.05 ND	0.05 ND	0.25 *	0.25	14827.89						Silt, Clay
33761	08/28/92	77.5	0-3	0.05 ND	0.05 ND	0.32 *	0.32	25889.97						
33763	09/01/92	75.0	0-3	0.05 ND	0.05 ND	0.05 ND	0.05 ND	6677.19						
33764	09/01/92	71.8	0-3	0.05 ND	0.05 ND	0.05 ND	0.05 ND	8999.47						
33765	09/01/92	67.0	0-3	0.05 ND	0.05 ND	0.06 *	0.06	4797.15	64.0	0	76.0	22.3	1.7	Silt, Clay, Rocks
33767	09/01/92	61.0	0-3	0.05 ND	0.05 ND	0.07 *	0.07	11473.60						Sand, Silt, Clay
33768	09/01/92	59.0	0-3	0.05 ND	0.05 ND	0.05 ND	0.05 ND	5672.01						Sand, Clay
33769	09/01/92	57.0	0-3	0.05 ND	0.05 ND	0.19 *	0.19	30165.91						Silt, Clay
33770	09/01/92	56.0	0-3	0.05 ND	0.05 ND	0.16 *	0.16	17924.07						Sand, Clay
33771	09/01/92	55.0	0-3	0.05 ND	0.05 ND	0.14 *	0.14	34805.89						Clay, Silt
33772	09/01/92	54.0	0-3	0.05 ND	0.05 ND	0.37 *	0.37	31007.75						Clay, Silt
33776	09/01/92	53.2	0-3	0.05 ND	0.05 ND	0.23 *	0.23	9563.41	88.7	3.4	77.1	18.0	1.5	
33774	09/01/92	53.1	0-3	0.05 ND	0.05 ND	0.18 *	0.18	21134.20						Silt, Clay
33781	09/02/92	48.3	0-3	0.05 ND	0.05 ND	0.1 *	0.1	18129.08						Silt, Sand
33773	09/02/92	47.1	0-3	0.05 ND	0.05 ND	0.06 *	0.06	17799.35						Silt
33782	09/02/92	43.9	0-3	0.05 ND	0.05 ND	0.05 ND	0.05 ND	8067.72						Sandy
33783	09/02/92	42.6	0-3	0.05 ND	0.05 ND	0.09 *	0.09	12636.79						Sandy, Silt
33784	09/03/92	40.1	0-3	0.05 ND	0.05 ND	0.05 ND	0.05 ND	1830.07						Sandy, Silt
33785	09/03/92	39.0	0-3	0.05 ND	0.05 ND	0.09 *	0.09	27438.26						Silt
33786	09/03/92	38.7	0-3	0.05 ND	0.05 ND	0.12 *	0.12	20947.89						Silt
33787	09/03/92	33.9	0-3	0.05 ND	0.05 ND	0.18 *	0.18	31729.24	52.4	4.6	41.0	50.2	4.2	
33790	09/03/92	32.3	0-3	0.05 ND	0.05 ND	0.05 ND	0.05 ND	13888.89						
33791	09/03/92	31.0	0-3	0.05 ND	0.05 ND	0.07 *	0.07	9559.21						Sand, Silt
33792	09/03/92	25.7	0-3	0.05 ND	0.05 ND	0.09 *	0.09	26278.61						Sand, Silt
33793	09/03/92	24.7	0-3	0.05 ND	0.05 ND	0.06 *	0.06	17327.69						Sand, Silt
33794	09/03/92	23.8	0-3	0.05 ND	0.05 ND	0.05 ND	0.05 ND	16396.57						Sand, Silt, Clay
33795	09/03/92	22.7	0-3	0.05 ND	0.05 ND	0.06 *	0.06	26839.63	35.1	3.9	45.9	45.6	3.7	Sand
33797	09/03/92	21.5	0-3	0.05 ND	0.05 ND	0.07 *	0.07	19444.44						Silt

AROCLOR 1248 - Aroclor 1016, 1232, 1242 and/or 1248.

ND - Compound was analyzed for but not detected. The number is detection limit for the sample.

* - Sample exhibits alteration of standard Aroclor pattern.

ATTACHMENT 2-3

GE HOUSATONIC RIVER SAMPLING PROGRAM, TASK IV - LMS

Attachment 2-3

GE Housatonic River Sampling Program, Task IV - LMS

								Total PCB				Dissolved						
Survey	Date	Time	Station	Sample Round	Sample Type	Sample Depth [ft]	Instant. Flow at DSB [ft3/s]	Aroclor 1016,1232 1242,and/or 1248 [ug/l]	Aroclor 1254 [ug/l]	Aroclor 1260 [ug/l]	Aroclor Total [ug/l]	Aroclor 1016,1232 1242,and/or 1248 [ug/l]	Aroclor 1254 [ug/l]	Aroclor 1260 [ug/l]	Aroclor Total [ug/l]	DOC [mg/l]	TOC [mg/l]	TSS [mg/l]
1	3/05/91	11:55	DSB-P		FB			ND .030	ND .065	ND .065	ND .065						ND 1	8
1	3/05/91	21:19	DSB-P	1	R	INTEGRATED	1310	ND .030	ND .065	.097	.097						3	3
1	3/06/91	00:45	DSB-P	2	R	INTEGRATED	1260	ND .030	ND .065	.068	.068						2	ND 1
1	3/06/91	01:50	DSB-E-CS		R	INTEGRATED	1240											2
1	3/06/91	01:57	DSB-P-CS		R	INTEGRATED	1260											2
1	3/06/91	02:04	DSB-P-W-CS		R	INTEGRATED	1230											8
1	3/06/91	02:09	DSB P-WW-CS		R	INTEGRATED	1230											7
1	3/06/91	03:05	DSB-P	3	R	INTEGRATED	1230	ND .030	ND .065	.086	.086	ND .030	ND .065	ND .065	ND .065		3	8
1	3/06/91	03:05	DSB-P	3	D	INTEGRATED	1230											7
1	3/06/91	03:05	DSB-P	3	D2	INTEGRATED	1230											9
1	3/06/91	06:15	DSB-P	4	R	INTEGRATED	1190	ND .030	ND .065	.082	.082						3	5
1	3/06/91	09:00	DSB-P	5	R	INTEGRATED	1140	ND .030	ND .065	.086	.086	ND .030	ND .065	ND .065	ND .065	3	2	5
1	3/06/91	12:00	DSB-P	6	R	INTEGRATED	1090	ND .030	ND .065	ND .065	ND .065						3	ND 1
1	3/06/91	13:10	DSB-E-CS		R	INTEGRATED	1080											4
1	3/06/91	13:10	DSB-E-CS		D	INTEGRATED	1080											14
1	3/06/91	13:17	DSB-P-CS		R	INTEGRATED	1080											4
1	3/06/91	13:17	DSB-P-CS		D	INTEGRATED	1080											11
1	3/06/91	13:23	DSB-W CS		R	INTEGRATED	1070											8
1	3/06/91	13:23	DSB-W-CS		D	INTEGRATED	1070											8
1	3/06/91	13:30	DSB-WW-CS		R	INTEGRATED	1070											3
1	3/06/91	13:30	DSB-WW-CS		D	INTEGRATED	1070											9
2	8/19/91	20:10	DSB-P		FB			ND .030	ND .065	ND .065	ND .065						ND 1	1
2	8/19/91	20:45	DSB-P	1	R	INTEGRATED	905	ND .030	ND .065	.120	.120						4	29
2	8/19/91	20:45	DSB-P	1	D	INTEGRATED	905											30
2	8/20/91	00:02	DSB-P	2	R	INTEGRATED	905	ND .030	ND .065	.100	.100						5	28
2	8/20/91	00:02	DSB-P	2	D	INTEGRATED	905											28
2	8/20/91	08:05	DSB-P	3	R	INTEGRATED	985	ND .030	ND .065	.100	.100						7	25

Attachment 2-3

GE Housatonic River Sampling Program, Task IV - LMS

Survey	Date	Time	Station	Sample Round	Sample Type	Sample Depth [ft]	Instant. Flow at DSB [ft3/s]	Total PCB Aroclor 1016,1232 1242,and/or 1248 [ug/l]	Total PCB Aroclor 1254 [ug/l]	Total PCB Aroclor 1260 [ug/l]	Total PCB Aroclor Total [ug/l]	Dissolved Aroclor 1016,1232 1242,and/or 1248 [ug/l]	Dissolved Aroclor 1254 [ug/l]	Dissolved Aroclor 1260 [ug/l]	Dissolved Aroclor Total [ug/l]	DOC [mg/l]	TOC [mg/l]	TSS [mg/l]
2	8/20/91	08:05	DSB-P	3	D	INTEGRATED	985											28
2	8/20/91	11:00	DSB-P	4	R	INTEGRATED	985	ND .030	ND .065	.130	.130						7	23
2	8/20/91	11:00	DSB-P	4	D	INTEGRATED	985											23
2	8/20/91	17:00	DSB-P	5	R	INTEGRATED	1050	ND .030	ND .065	.120	.120	ND .030	ND .065	ND .065	ND .065	5	6	17
2	8/20/91	17:00	DSB-P	5	D	INTEGRATED	1050											18
2	8/20/91	22:00	DSB-P	6	R	INTEGRATED	985	ND .030	ND .065	.140	.140						5	15
2	8/20/91	22:00	DSB-P	6	D	INTEGRATED	985											17
2	8/21/91	07:20	DSB-P	7	R	INTEGRATED	850	ND .030	ND .065	.130	.130	ND .030	ND .065	ND .065	ND .065	5	5	14
2	8/21/91	07:20	DSB-P	7	D	INTEGRATED	850											15
2	8/21/91	11:30	DSB-P	8	R	INTEGRATED	850	.040	ND .065	.130	.170						5	17
2	8/21/91	11:30	DSB-P	8	D	INTEGRATED	850											19
2	8/21/91	11:30	DSB-P	8	BD2	INTEGRATED	850											13
2	8/21/91	11:30	DSB-P	8	BD	INTEGRATED	850	ND .030	ND .065	.140	.140						6	13
2	8/22/91	11:05	DSB-P	9	R	INTEGRATED	610	ND .030	ND .065	ND .065	ND .065					8	7	12
3	3/26/92	23:50	DSB-P	1	R	INTEGRATED	375	ND .030	ND .065	ND .065	ND .065						2	9
3	3/27/92	06:30	DSB-P		FB			ND .030	ND .065	ND .065	ND .065						ND 1	7
3	3/27/92	06:40	DSB-P	2	R	INTEGRATED	700	ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065	2	2	20
3	3/27/92	06:40	DSB-P	2	D	INTEGRATED	700											21
3	3/27/92	09:30	FVB-C	1	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065						4	153
3	3/27/92	10:45	ARB	1	R	INTEGRATED	1050											85
3	3/27/92	11:15	MAB	1	R	INTEGRATED	1120											66
3	3/27/92	11:50	KRB	1	R	INTEGRATED	1120											72
3	3/27/92	12:25	DSB-P	3	R	INTEGRATED	1130	ND .030	ND .065	ND .065	ND .065						3	12
3	3/27/92	14:20	FVB-C	2	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065	4	4	143
3	3/27/92	14:20	FVB-C	2	D	INTEGRATED												136
3	3/27/92	15:10	DSB-P	4	BD	INTEGRATED	1120	ND .030	ND .065	ND .065	ND .065							
3	3/27/92	15:40	DSB-P	4	R	INTEGRATED	1200	ND .030	ND .065	ND .065	ND .065						3	33
3	3/27/92	16:40	KRB	2	R	INTEGRATED	1200											27
3	3/27/92	17:05	MAB	2	R	INTEGRATED	1200											76

Attachment 2-3

GE Housatonic River Sampling Program, Task IV - LMS

Survey	Date	Time	Station	Sample Round	Sample Type	Sample Depth [ft]	Instant. Flow at DSB [ft3/s]	Total PCB Aroclor 1016,1232 1242,and/or 1248 [ug/l]	Total PCB Aroclor 1254 [ug/l]	Total PCB Aroclor 1260 [ug/l]	Total PCB Aroclor Total [ug/l]	Dissolved Aroclor 1016,1232 1242,and/or 1248 [ug/l]	Dissolved Aroclor 1254 [ug/l]	Dissolved Aroclor 1260 [ug/l]	Dissolved Aroclor Total [ug/l]	DOC [mg/l]	TOC [mg/l]	TSS [mg/l]
3	3/27/92	17:25	ARB	2	R	INTEGRATED	1270											53
3	3/27/92	18:00	FVB-C		FB			ND .030	ND .065	ND .065	ND .065						ND 1	8
3	3/27/92	18:00	FVB-C	3	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065						4	171
4	4/16/92	17:20	LZ-C	1	R	INTEGRATED										2	2	4
4	4/16/92	18:45	LL-C	1	R	INTEGRATED										2	2	2
4	4/16/92	20:40	FVB-C	1	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065					2	2	3
4	4/16/92	23:00	DSB-P	1	R	INTEGRATED	410	ND .070	ND .065	1.100	1.100					3	3	134
4	4/17/92	07:35	DSB-P	2	R	INTEGRATED	444	ND .100	ND .065	.980	.980	ND .030	ND .065	ND .065	ND .065		3	109
4	4/17/92	07:35	DSB-P	2	D	INTEGRATED	444					ND .030	ND .065	ND .065	ND .065			109
4	4/17/92	09:55	FVB-C	2	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		2	5
4	4/17/92	09:55	FVB-C	2	D	INTEGRATED						ND .030	ND .065	ND .065	ND .065			12
4	4/17/92	13:10	KRB	1	R	INTEGRATED	551											17
4	4/17/92	14:10	MAB	1	R	INTEGRATED	551											22
4	4/17/92	14:35	ARB	1	R	INTEGRATED	551											9
4	4/17/92	15:50	FVB-C	3	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065					3	2	8
4	4/18/92	07:00	DSB-P		FB			ND .030	ND .065	ND .065	ND .065						ND 1	3
4	4/18/92	07:00	DSB-P	3	R	INTEGRATED	780	ND .030	ND .065	.150	.150						3	126
4	4/18/92	07:00	DSB-P	3	D	INTEGRATED	780											144
4	4/18/92	09:25	KRB	2	R	INTEGRATED	780											43
4	4/18/92	09:45	MAB	2	R	INTEGRATED	780											49
4	4/18/92	10:05	ARB	2	R	INTEGRATED	780											26
4	4/18/92	10:45	FVB-C	4	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		3	17
4	4/18/92	10:45	FVB-C	4	D	INTEGRATED												18
4	4/18/92	11:30	DSB-P	4	BD	INTEGRATED	780	ND .060	ND .065	.840	.840							
4	4/18/92	12:10	DSB-P	4	R	INTEGRATED	780	ND .030	ND .065	.290	.290	ND .030	ND .065	ND .065	ND .065	4	3	122
4	4/18/92	13:20	KRB	3	R	INTEGRATED	780											40
4	4/18/92	13:45	MAB	3	R	INTEGRATED	780											31
4	4/18/92	14:10	ARB	3	R	INTEGRATED	780											25
4	4/18/92	14:35	FVB-C	5	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		2	16

Attachment 2-3

GE Housatonic River Sampling Program, Task IV - LMS

								Total PCB				Dissolved						
Survey	Date	Time	Station	Sample Round	Sample Type	Sample Depth [ft]	Instant. Flow at DSB [ft3/s]	Aroclor 1016,1232 1242,and/or 1248 [ug/l]	Aroclor 1254 [ug/l]	Aroclor 1260 [ug/l]	Aroclor Total [ug/l]	Aroclor 1016,1232 1242,and/or 1248 [ug/l]	Aroclor 1254 [ug/l]	Aroclor 1260 [ug/l]	Aroclor Total [ug/l]	DOC [mg/l]	TOC [mg/l]	TSS [mg/l]
4	4/18/92	17:05	LL-C	2	R	INTEGRATED										3	2	4
4	4/18/92	17:50	LZ-C	2	R	INTEGRATED										3	2	6
4	4/18/92	19:40	ARB	4	R	INTEGRATED	850											24
4	4/18/92	20:15	MAB	4	R	INTEGRATED	850											28
4	4/18/92	20:45	KRB	4	R	INTEGRATED	850											32
4	4/18/92	21:15	DSB-P	5	R	INTEGRATED	850	ND .030	ND .065	.170	.170	ND .030	ND .065	ND .065	ND .065		3	96
4	4/19/92	06:15	DSB-P	6	R	INTEGRATED	905	ND .030	ND .065	.300	.300					7	3	100
4	4/19/92	07:50	FVB-C		FB			ND .030	ND .065	ND .065	ND .065						ND 1	1
4	4/19/92	07:50	FVB-C	6	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065					3	3	19
4a	4/22/92	09:05	DSB-P	1	R	INTEGRATED	985	ND .030	ND .065	.260	.260	ND .030	ND .065	ND .065	ND .065		3	29
4a	4/22/92	10:45	FVB-C	1	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		2	6
4a	4/22/92	13:05	DSB-P	2	R	INTEGRATED	985											34
4a	4/22/92	13:05	DSB-P	2	D	INTEGRATED	985											18
4a	4/22/92	14:10	KRB	1	R	INTEGRATED	985											9
4a	4/22/92	14:35	MAB	1	R	INTEGRATED	985											5
4a	4/22/92	15:00	ARB	1	R	INTEGRATED	985											8
4a	4/22/92	15:30	FVB-C	2	R	INTEGRATED												8
4a	4/22/92	15:30	FVB-C	2	D	INTEGRATED												7
5	5/31/92	19:00	DSB-P	1	R	INTEGRATED	238	.080	ND .065	1.000	1.080						3	588
5	5/31/92	20:05	FVB-C	1	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065						2	10
5	6/01/92	07:07	DSB-P	2	R	INTEGRATED	395	ND .070	ND .065	.980	.980	ND .030	ND .065	ND .065	ND .065		3	270
5	6/01/92	08:40	FVB-C	2	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		2	8
5	6/01/92	11:40	DSB-P	3	R	INTEGRATED	530	ND .070	ND .065	.800	.800	ND .030	ND .065	ND .065	ND .065		4	210
5	6/01/92	11:40	DSB-P	3	D	INTEGRATED	530					ND .030	ND .065	ND .077	.077			213
5	6/01/92	12:25	KRB	1	R	INTEGRATED	530											60
5	6/01/92	12:40	MAB	1	R	INTEGRATED	530											64
5	6/01/92	13:05	ARB	1	R	INTEGRATED	530											19
5	6/01/92	13:30	FVB-C	3	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		3	8
5	6/01/92	13:30	FVB-C	3	D	INTEGRATED						ND .030	ND .065	ND .065	ND .065			1

Attachment 2-3

GE Housatonic River Sampling Program, Task IV LMS

								Total PCB				Dissolved						
Survey	Date	Time	Station	Sample Round	Sample Type	Sample Depth [ft]	Instant. Flow at DSB [ft3/s]	Aroclor 1016,1232 1242,and/or 1248 [ug/l]	Aroclor 1254 [ug/l]	Aroclor 1260 [ug/l]	Aroclor Total [ug/l]	Aroclor 1016,1232 1242,and/or 1248 [ug/l]	Aroclor 1254 [ug/l]	Aroclor 1260 [ug/l]	Aroclor Total [ug/l]	DOC [mg/l]	TOC [mg/l]	TSS [mg/l]
5	6/01/92	15:45	LL-C	1	R	INTEGRATED										2	2	6
5	6/01/92	16:20	LZ-C	1	R	INTEGRATED										2	2	ND 1
5	6/01/92	17:50	FVB-C	4	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065	3	3	6
5	6/01/92	18:55	DSB-P	4	R	INTEGRATED	600	.060	ND .065	.870	.930	ND .030	ND .065	ND .065	ND .065	3	3	122
5	6/01/92	20:00	DSB-P	4	BD	INTEGRATED	600	ND .040	ND .065	.500	.500							
5	6/02/92	06:25	DSB-P		FB		600	ND .030	ND .065	ND .065	ND .065						ND 1	2
5	6/02/92	06:50	DSB-P	5	R	INTEGRATED	625	.050	ND .065	.470	.520					3	3	152
5	6/02/92	07:05	DSB-P	5	D	INTEGRATED	625											196
5	6/02/92	07:55	FVB-C		FB			ND .030	ND .065	ND .065	ND .065						ND 1	ND 1
5	6/02/92	08:15	FVB-C	5	R	INTEGRATED		ND .030	ND .065	.083	.083					3	2	12
5	6/02/92	08:30	FVB-C	5	D	INTEGRATED												16
5	6/02/92	12:30	FVB-C	6	R	INTEGRATED		ND .030	ND .065	.072	.072	ND .030	ND .065	ND .065	ND .065		3	12
5	6/02/92	12:30	FVB-C	6	D	INTEGRATED						ND .030	ND .065	ND .065	ND .065			
5	6/02/92	13:17	ARB	2	R	INTEGRATED	625											40
5	6/02/92	13:35	MAB	2	R	INTEGRATED	625											52
5	6/02/92	14:50	KRB	2	R	INTEGRATED	625											44
5	6/02/92	15:20	DSB-P	6	R	INTEGRATED	625	ND .040	ND .065	.330	.330					3	3	144
5	6/02/92	16:25	FVB-C	7	R	INTEGRATED		ND .030	ND .065	.072	.072						3	14
5	6/02/92	16:25	FVB-C	7	D	INTEGRATED												12
5	6/03/92	06:35	DSB-P	7	R	INTEGRATED	498	.040	ND .065	.460	.500	ND .030	ND .065	ND .065	ND .065	3	4	132
5	6/03/92	06:35	DSB-P	7	D	INTEGRATED	498					ND .030	ND .065	ND .065	ND .065			100
5	6/03/92	08:07	FVB-C	8	R	INTEGRATED		ND .030	.069	.078	.147					4	3	8
5	6/03/92	09:30	LL-C	2	R	INTEGRATED										3	3	10
5	6/03/92	10:05	LZ-C	2	R	INTEGRATED										3	2	10
6	12/17/92	09:45	DSB-P	1	R	INTEGRATED	498	ND .030	ND .065	ND .065	ND .065						3	10
6	12/17/92	11:15	FVB-C	1	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065						3	16
6	12/17/92	20:35	DSB-P	2	R	INTEGRATED	728	ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065	4	3	14
6	12/17/92	21:45	FVB-C	2	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065	3	5	49
6	12/17/92	22:50	DSB-P	3	R	INTEGRATED	850	ND .030	ND .065	ND .065	ND .065						4	27

Attachment 2-3

GE Housatonic River Sampling Program, Task IV - LMS

								Total PCB				Dissolved						
Survey	Date	Time	Station	Sample Round	Sample Type	Sample Depth [ft]	Instant. Flow at DSB [ft3/s]	Aroclor 1016,1232 1242,and/or 1248 [ug/l]	Aroclor 1254 [ug/l]	Aroclor 1260 [ug/l]	Aroclor Total [ug/l]	Aroclor 1016,1232 1242,and/or 1248 [ug/l]	Aroclor 1254 [ug/l]	Aroclor 1260 [ug/l]	Aroclor Total [ug/l]	DOC [mg/l]	TOC [mg/l]	TSS [mg/l]
6	12/18/92	06:45	FVB-C	3	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065						3	54
6	12/18/92	07:45	DSB-P	4	R	INTEGRATED	1050	ND .030	ND .065	.079	.079	ND .030	ND .065	ND .065	ND .065	3	3	37
6	12/18/92	07:45	DSB-P	4	D	INTEGRATED	1050	ND .030	ND .065	.079	.079							
6	12/18/92	12:40	DSB-P		FB			ND .030	ND .065	ND .065	ND .065						ND 1	10
6	12/18/92	12:40	DSB-P	5	R	INTEGRATED	1120	ND .050	ND .065	.114	.114	ND .030	ND .065	ND .065	ND .065	4	3	47
6	12/18/92	12:40	DSB-P	5	D	INTEGRATED	1120											46
6	12/18/92	15:10	FVB-C		FB			ND .030	ND .065	ND .065	ND .065						ND 1	ND 1
6	12/18/92	15:10	FVB-C	4	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		3	69
6	12/18/92	15:10	FVB-C	4	D	INTEGRATED												57
6	12/18/92	21:00	DSB-P	6	R	INTEGRATED	1200	ND .030	ND .065	.100	.100	ND .030	ND .065	ND .065	ND .065		3	45
6	12/18/92	21:00	DSB-P	6	D	INTEGRATED	1200											33
6	12/18/92	22:20	FVB-C	5	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		3	64
6	12/18/92	22:20	FVB-C	5	D	INTEGRATED												41
6	12/18/92	23:30	DSB-P	7	R	INTEGRATED	1200	ND .030	ND .065	.122	.122						3	42
6	12/19/92	07:50	DSB-P	8	R	INTEGRATED	1200	ND .030	ND .065	.084	.084	ND .030	ND .065	ND .065	ND .065		3	18
6	12/19/92	07:50	DSB-P	8	BD	INTEGRATED	1200	ND .030	ND .065	.103	.103							
6	12/19/92	09:45	FVB-C	6	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065	3	3	38
7	3/29/93	16:10	DSB-P	1	R	INTEGRATED	2166	ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		39	6
7	3/29/93	17:10	KRB	1	R	INTEGRATED												95
7	3/29/93	17:40	MAB	1	R	INTEGRATED												109
7	3/29/93	18:05	ARB	1	R	INTEGRATED												46
7	3/29/93	18:40	FVB-C	1	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065			75
7	3/29/93	20:10	ARB	2	R	INTEGRATED												85
7	3/29/93	20:30	MAB	2	R	INTEGRATED												51
7	3/29/93	20:50	KRB	2	R	INTEGRATED												65
7	3/29/93	21:20	DSB-P	2	R	INTEGRATED	2704	ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		32	25
7	3/30/93	06:15	DSB-P		FB			ND .030	ND .065	ND .065	ND .065						15	ND 1
7	3/30/93	06:20	DSB-P	3	R	INTEGRATED	3519	ND .030	ND .065	.120	.120	ND .030	ND .065	ND .065	ND .065		23	37
7	3/30/93	07:05	KRB	3	R	INTEGRATED												106

Attachment 2-3

GE Housatonic River Sampling Program, Task IV - LMS

								Total PCB				Dissolved						
Survey	Date	Time	Station	Sample Round	Sample Type	Sample Depth [ft]	Instant. Flow at DSB [ft3/s]	Aroclor 1016,1232 1242,and/or 1248 [ug/l]	Aroclor 1254 [ug/l]	Aroclor 1260 [ug/l]	Aroclor Total [ug/l]	Aroclor 1016,1232 1242,and/or 1248 [ug/l]	Aroclor 1254 [ug/l]	Aroclor 1260 [ug/l]	Aroclor Total [ug/l]	DOC [mg/l]	TOC [mg/l]	TSS [mg/l]
7	3/30/93	07:20	MAB	3	R	INTEGRATED												82
7	3/30/93	07:35	ARB	3	R	INTEGRATED												135
7	3/30/93	08:35	FVB-C	2	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		26	129
7	3/30/93	09:10	ARB	4	R	INTEGRATED												85
7	3/30/93	09:30	MAB	4	R	INTEGRATED												56
7	3/30/93	09:40	KRB	4	R	INTEGRATED												75
7	3/30/93	11:20	KRB	5	R	INTEGRATED												81
7	3/30/93	11:35	MAB	5	R	INTEGRATED												68
7	3/30/93	11:50	ARB	5	R	INTEGRATED												91
7	3/30/93	12:20	FVB-C	3	R	INTEGRATED		ND .030	ND .065	.079	.079	ND .030	ND .065	ND .065	ND .065		10	169
7	4/02/93	09:40	FVB-C	4	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		22	18
7	4/02/93	10:36	ARB	6	R	INTEGRATED												33
7	4/02/93	10:55	MAB	6	R	INTEGRATED												39
7	4/02/93	11:10	KRB	6	R	INTEGRATED												42
7	4/02/93	11:40	DSB-P	4	R	INTEGRATED	3987	ND .030	ND .065	.076	.076	ND .030	ND .065	ND .065	.065		33	100
8	4/22/93	17:10	DSB-P	1	R	INTEGRATED	1396	ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		3	6
8	4/22/93	17:45	KRB-C	1	R	INTEGRATED												39
8	4/22/93	18:00	MAB-C	1	R	INTEGRATED												32
8	4/22/93	18:15	ARB-C	1	R	INTEGRATED												26
8	4/22/93	18:45	FVB-C	1	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		2	43
8	4/22/93	20:00	ARB-C	2	R	INTEGRATED												50
8	4/22/93	20:20	MAB-C	2	R	INTEGRATED												50
8	4/22/93	20:30	KRB C	2	R	INTEGRATED												45
8	4/22/93	20:50	DSB P	2	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065							
8	4/22/93	20:50	DSB-P	2	R	INTEGRATED	1558					ND .030	ND .065	ND .065	ND .065		2	2
8	4/22/93	22:00	FVB-C	2	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		2	41
8	4/22/93	22:30	ARB-C	3	R	INTEGRATED												90
8	4/22/93	22:45	MAB-C	3	R	INTEGRATED												57
8	4/22/93	23:00	KRB-C	3	R	INTEGRATED												60

Attachment 2-3

GE Housatonic River Sampling Program, Task IV - LMS

								Total PCB				Dissolved						
Survey	Date	Time	Station	Sample Round	Sample Type	Sample Depth [ft]	Instant. Flow at DSB [ft3/s]	Aroclor 1016,1232 1242,and/or 1248 [ug/l]	Aroclor 1254 [ug/l]	Aroclor 1260 [ug/l]	Aroclor Total [ug/l]	Aroclor 1016,1232 1242,and/or 1248 [ug/l]	Aroclor 1254 [ug/l]	Aroclor 1260 [ug/l]	Aroclor Total [ug/l]	DOC [mg/l]	TOC [mg/l]	TSS [mg/l]
8	4/23/93	06:55	DSB-P	3	R	INTEGRATED	2258	ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		3	11
8	4/23/93	07:15	KRB-C	4	R	INTEGRATED												38
8	4/23/93	07:25	MAB-C	4	R	INTEGRATED												52
8	4/23/93	07:40	ARB-C	4	R	INTEGRATED												209
8	4/23/93	08:40	FVB-C	3	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		4	84
8	4/23/93	09:00	ARB-C	5	R	INTEGRATED												121
8	4/23/93	09:15	MAB-C	5	R	INTEGRATED												47
8	4/23/93	09:30	KRB-C	5	R	INTEGRATED												45
8	4/23/93	11:40	KRB-C	6	R	INTEGRATED												33
8	4/23/93	11:50	MAB-C	6	R	INTEGRATED												52
8	4/23/93	12:00	ARB-C	6	R	INTEGRATED												65
8	4/23/93	14:40	DSB-P	4	FB		2443	ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065			11
8	4/23/93	14:50	DSB-P	4	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		3	16
8	4/23/93	15:05	KRB-C	7	R	INTEGRATED												42
8	4/23/93	15:15	MAB-C	7	R	INTEGRATED												46
8	4/23/93	15:25	ARB-C	7	R	INTEGRATED												76
8	4/23/93	15:50	FVB-C	4	R	INTEGRATED		ND .030	ND .065	ND .065	ND .065	ND .030	ND .065	ND .065	ND .065		3	84

Footnotes:

DSB-P = Division Street Bridge-Platform (MP 106.2)
FVB-C = Falls Village Rt. 7 Bridge-Center (MP 75.0)
ARB = Andrus Road Bridge (MP 86.2)
MAB = Maple Avenue Bridge (MP 93.5)
KRB = Kellog Road Bridge (MP 97.6)
LL-C = Lake Lillinonah at Rt. 133 Bridge-Center (MP 34.2)
LZ-C = Lake Zoar at Glen Rd. Bridge-Center (MP 27.3)
R = Regular
FB = Field Blank
D = Duplicate
BD = Blind Duplicate
D-PCB = Dissolved PCB
ND = Sample analyzed but not detected. Value indicated is the detection limit.

Stations DSB-W-CS, DSB-WW-CS, DSB-P-CS, DSB-E-CS are for TSS samples taken along cross section (CS) at Division Street Bridge at West (W), West of W (WW), Platform (P), and East (E) stations.

CHAPTER 3

DATA TRENDS AND HISTORICAL COMPARISONS

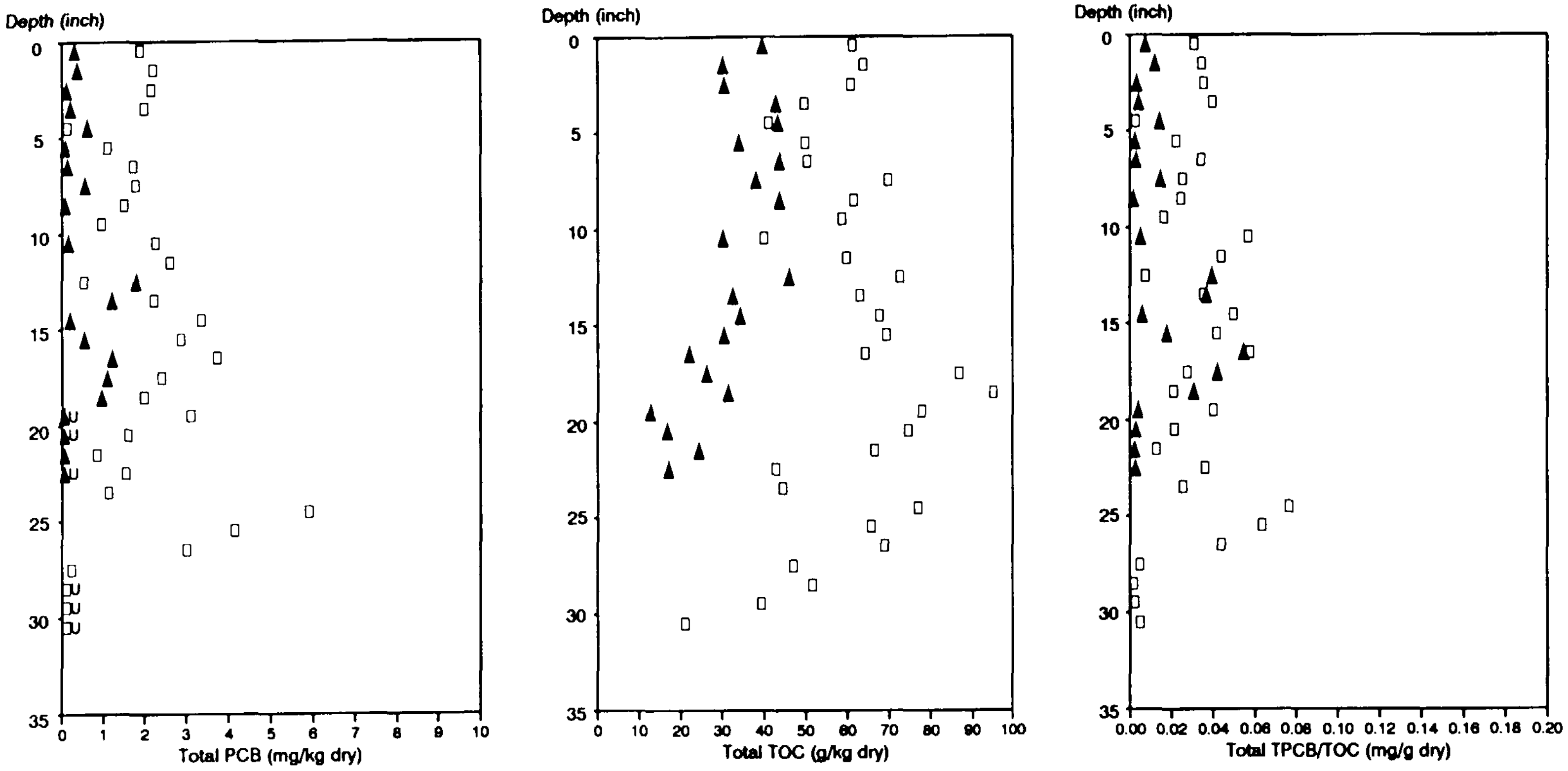
In this chapter data collected by LMS are combined with historical data to identify trends. Results are discussed separately for deep sediment cores, surficial sediment, and the water column.

3.1 DEEP SEDIMENT CORES

Deep sediment core samples were collected by OSI (under subcontract to LMS) in 1986 and 1992. The six station locations indicated in Table 2-3 for the 1992 samples are approximately the same stations that were sampled in 1986. Numerous 1-in. increments were analyzed for PCBs and TOC. In 1986 the radionuclide ^{137}Cs was analyzed in each of the two lakes and in the two impoundments. As ^{137}Cs was not detected in the sediments of either the Falls Village or Bulls Bridge impoundments, it was not analyzed for the 1992 samples. Figures 3-1 through 3-6 show the PCB and TOC results for the 1986 and 1992 samples. Also, as PCBs have a high affinity for organic matter, the plots also show PCB normalized to TOC concentration. Figure 3-7 shows the comparative ^{137}Cs profiles. Similar profiles are evident at the Stevenson Dam and Shepaug Dam, where ^{137}Cs was analyzed for in 1986 and 1992. The following table summarizes the depth-averaged PCB and TOC results for the 1986 and 1992 survey periods and the 1976-1977 deep core surveys performed by the U.S. Geological Survey (USGS) and Connecticut Agricultural Experiment Station (CAES):

		DEPTH-AVERAGED PCB (μg/g)			**DEPTH-AVERAGED TOC (mg/kg)**		
WATER BODY	**MILE POINT**	**USGS/CAES[a] 1976-1977**	**LMS 1986**	**LMS 1992**	**USGS/CAES[a] 1976-1977**	**LMSE-1986**	**LMS 1992**
Lake Zoar	19.7		1.9	0.47		59,981	31,894
	19.48	0.32			44,750		
	19.4	2.15					
	19.3	2.2					
Lake Zoar	26.1		ND (0.1)	ND (0.05)		716	2,006
	24.85	0.06			28,500		
Lake Lillinonah	29.8		3.0	0.26		56,862	8,976
	29.64	0.79			145,275		
	29.6	1.2					
	29.56	0.84			151,300		
	29.52	0.49					
Lake Lillinonah	34.2		2.2	0.41	159,300	43,000	30,811
	33.92	0.43			26,667		
Bulls Bridge Dam	53.2		0.032	0.20		6,401	16,072
Falls Village Dam	77.7		0.24	ND (0.05)		5,146	2,005

[a] Samples taken in 6-in. increments for top 24 to 30 in.



Note: ▯ - 1986 Survey (York Labs)

▲ - 1992 Survey (ITAS)

1986 PCB detection limit = 0.1 mg/kg dry

1992 PCB detection limit = 0.05 mg/kg dry

U - Sample was analyzed but not detected

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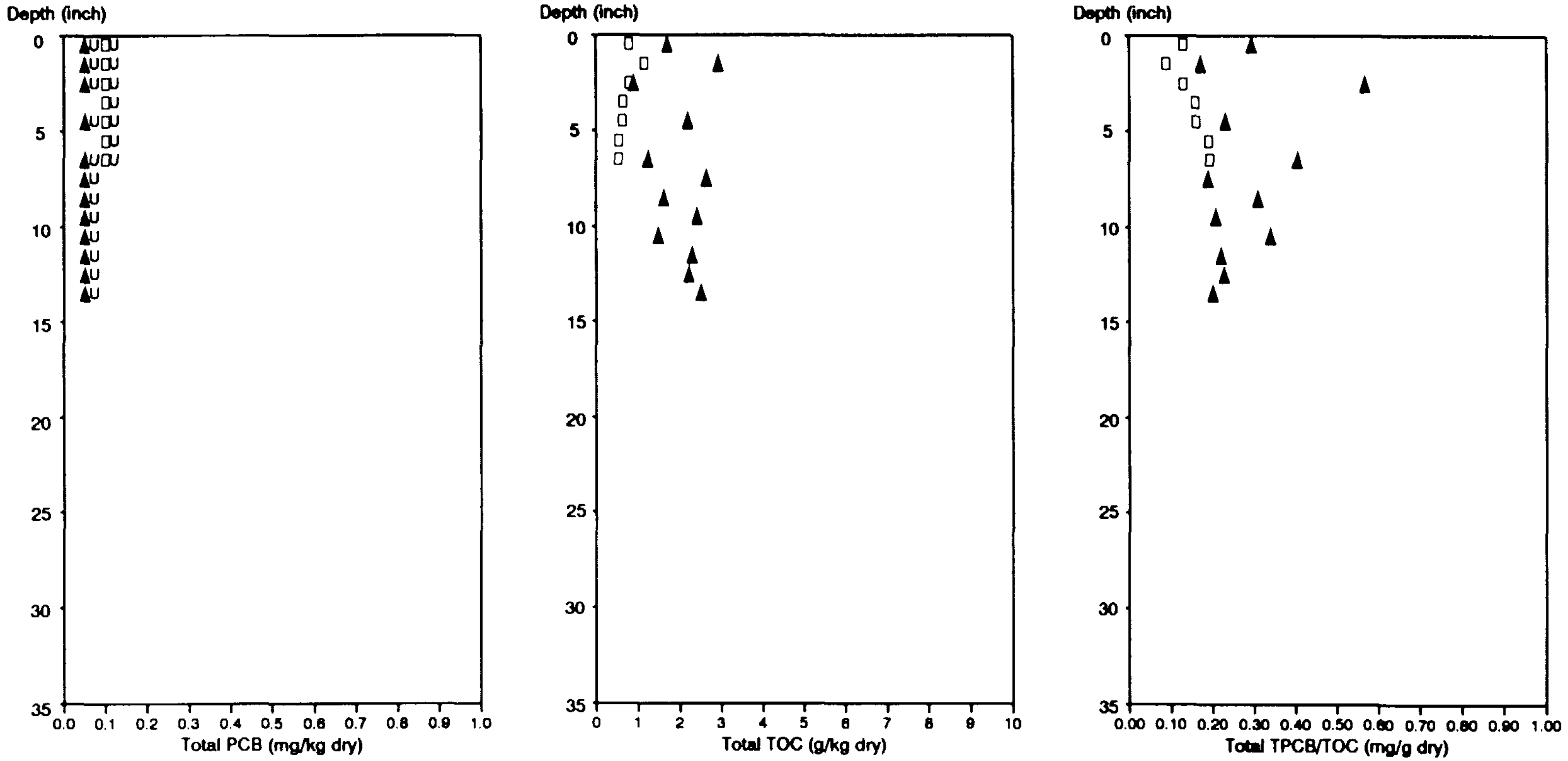
Deep Core PCB and TOC Profiles
Lake Zoar - MP 19.7

Figure 3-1

\337\042TBLK.ds4
disk: HS4300



Note: ☐ - 1986 Survey (York Labs)

▲ - 1992 Survey (ITAS)

1986 PCB detection limit = 0.1 mg/kg dry

1992 PCB detection limit = 0.05 mg/kg dry

U - Sample was analyzed but not detected

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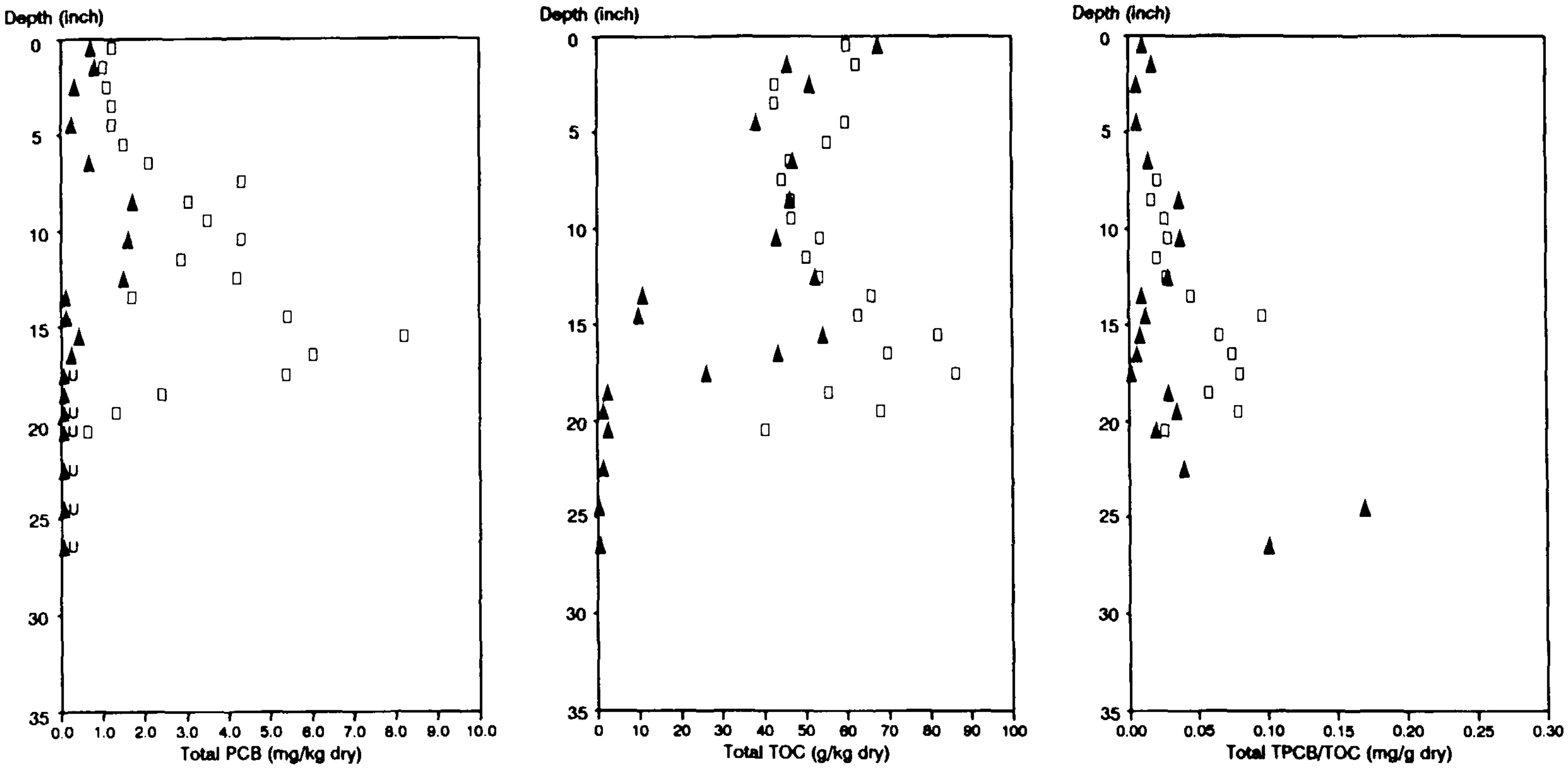
Deep Core PCB and TOC Profiles
Lake Zoar - MP 26.8

Figure 3-2

\337\042TBLK.de4
disk: HS4300 file: test.wq1



Note: ▯ - 1986 Survey (York Labs)

▲ - 1992 Survey (ITAS)

1986 PCB detection limit = 0.1 mg/kg dry

1992 PCB detection limit = 0.05 mg/kg dry

U - Sample was analyzed but not detected

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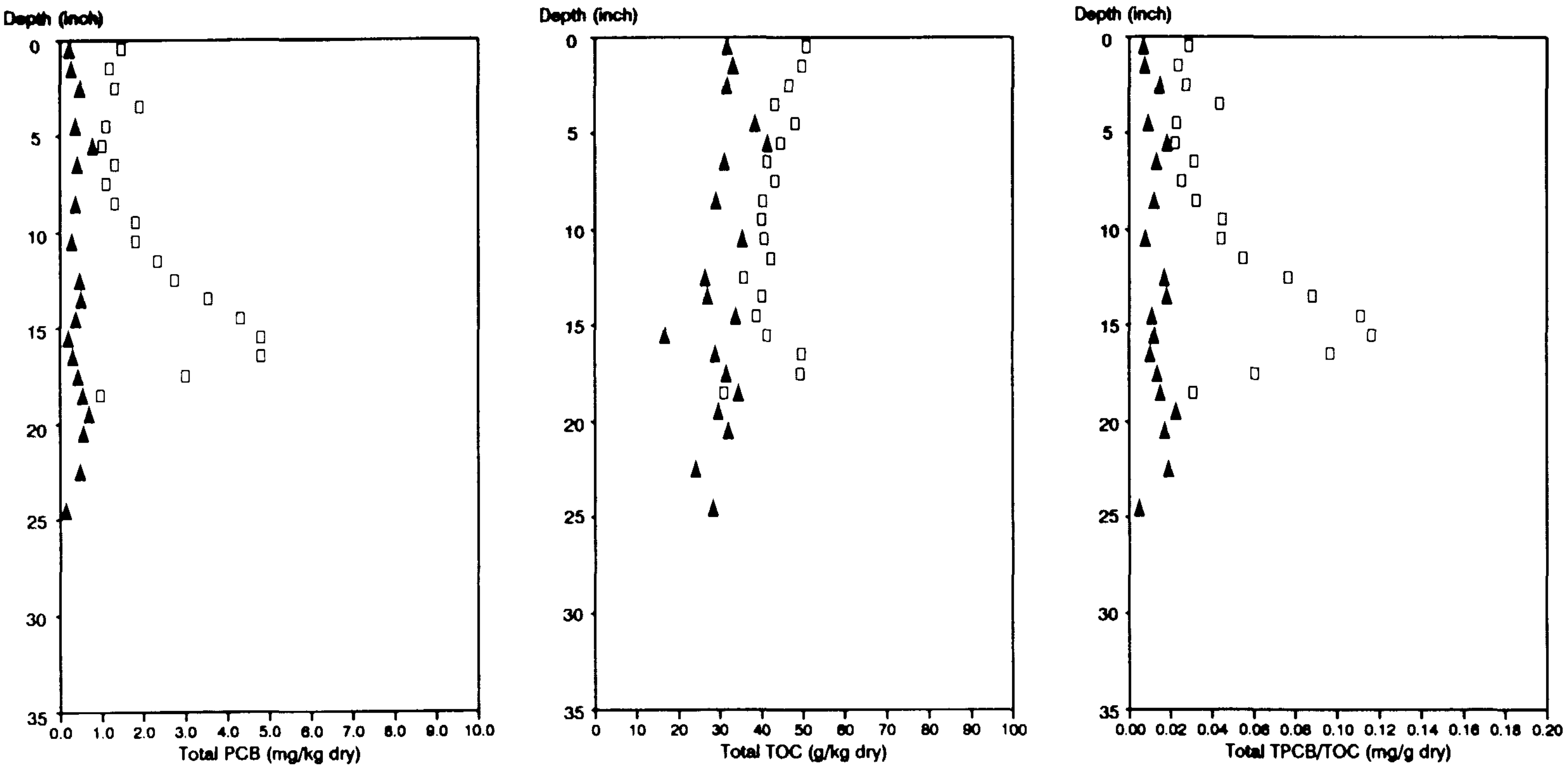
Deep Core PCB and TOC Profiles
Lake Lillinonah - MP 29.8

Figure 3-3



Note: ▯ - 1986 Survey (York Labs)
▲ - 1992 Survey (ITAS)
1986 PCB detection limit = 0.1 mg/kg dry
1992 PCB detection limit = 0.05 mg/kg dry
U - Sample was analyzed but not detected

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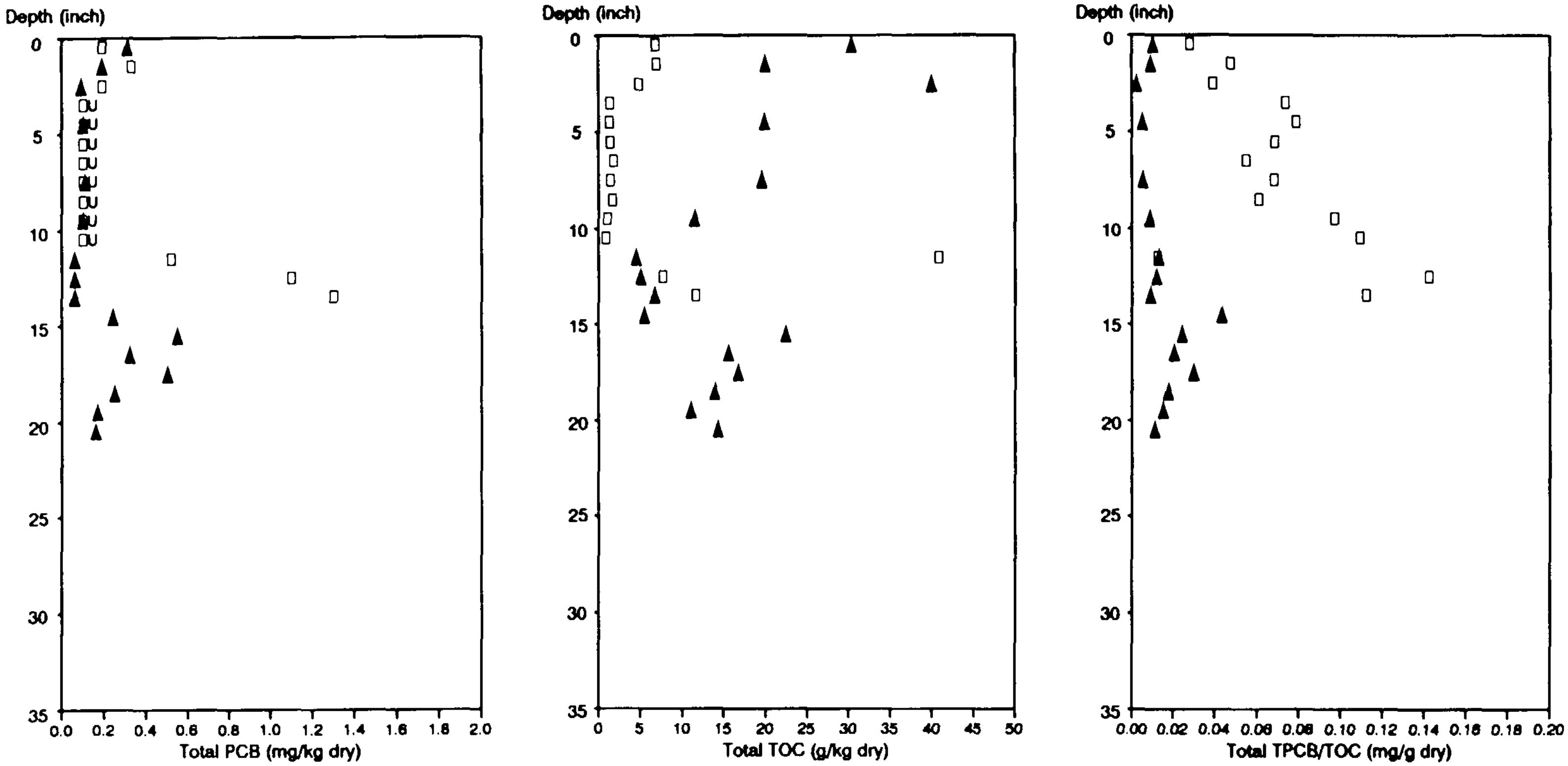
Deep Core PCB and TOC Profiles
Lake Lillinonah - MP 34.2

Figure 3-4

\337\042TBLK.da4
disk: HS4300 file: last.wq1



Note: ▯ - 1986 Survey (York Labs)

▲ - 1992 Survey (ITAS)

1986 PCB detection limit = 0.1 mg/kg dry

1992 PCB detection limit = 0.05 mg/kg dry

U - Sample was analyzed but not detected

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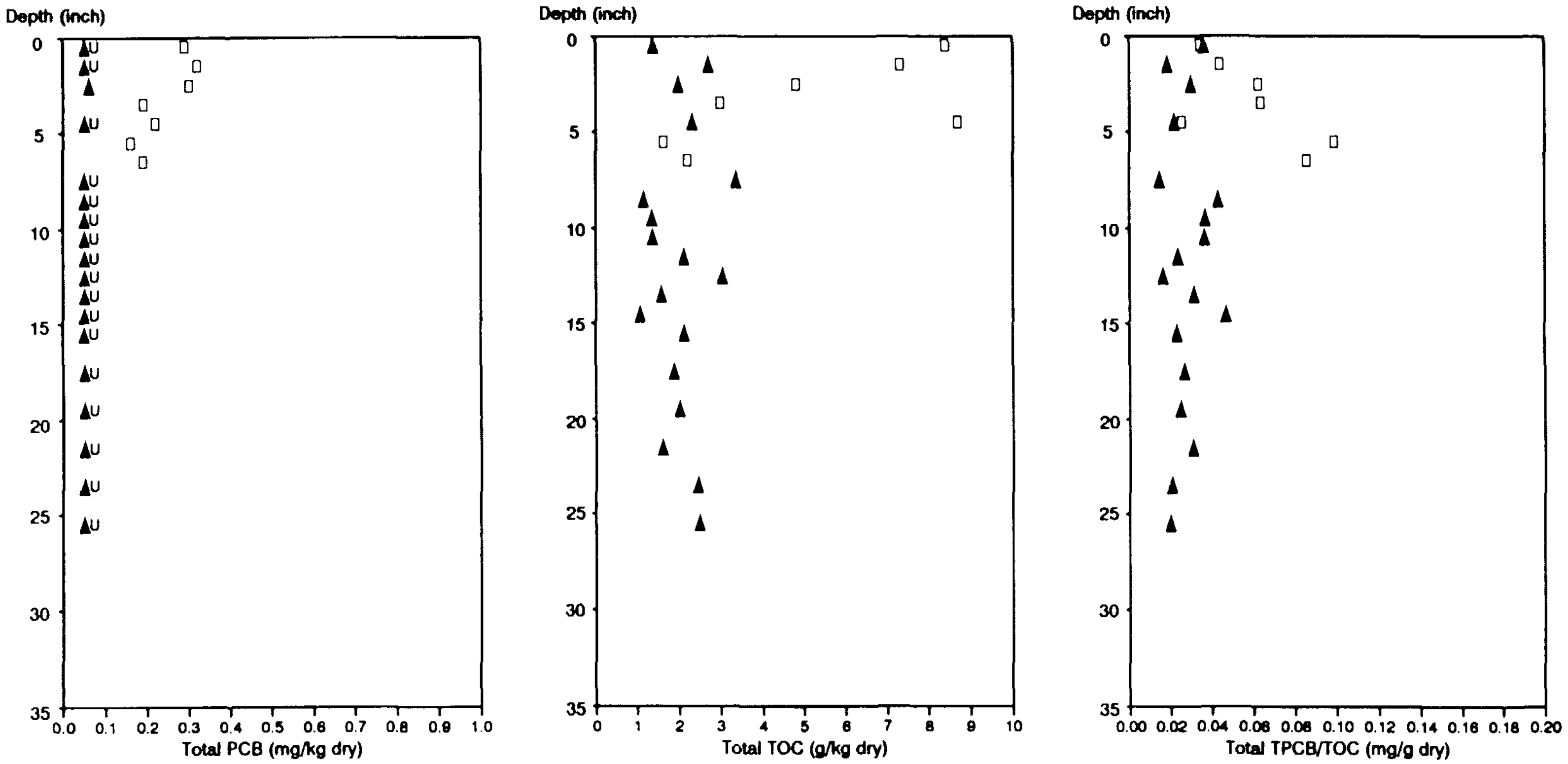
Deep Core PCB and TOC Profiles
Bulls Bridge Impoundment - MP 53.2

Figure 3-5

\337\042TBLK.ds4
disk: HS4300 f\ [illegible] esLwq1



Note: ▯ - 1986 Survey (York Labs)
▲ - 1992 Survey (ITAS)
1986 PCB detection limit = 0.1 mg/kg dry
1992 PCB detection limit = 0.05 mg/kg dry
U - Sample was analyzed but not detected

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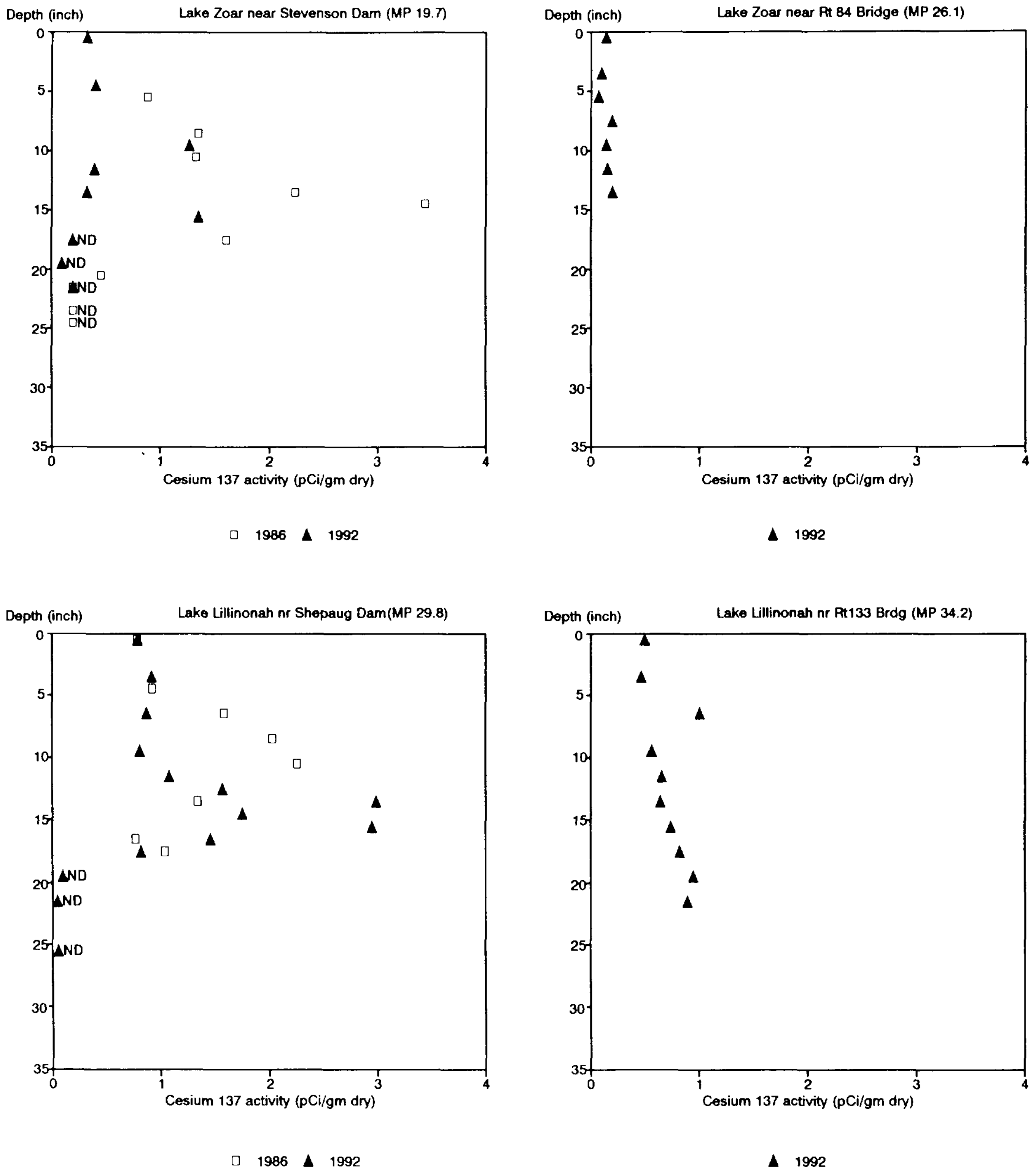
Deep Core PCB and TOC Profiles
Falls Village Impoundment - MP 77.7

Figure 3-6

\337\042TBLK.ds4
disk HS4300 file test.wq1



ND = Sample analyzed but not detected. Detection limit is plotted

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Cesium 137 Profiles for Sediments in Lake Zoar and Lake Lillinonah

Figure 3-7

1337.042TBLK ds4
disk HS4300 file hrcesium wq1

As indicated in the figures and above table, PCB concentrations were generally lower in 1992 than in 1986. A decrease in subsurface PCB was not expected since Aroclors 1260 and 1254 are relatively stable and the deeper sediments are not anticipated to interact with the overlying water column. The ^{137}Cs results for cores near the dams of the large lakes do not indicate that the sediment was disturbed because the ^{137}Cs patterns were similar for the 1986 and 1992 samples. TOC concentrations were lower in 1992 for four of the six cores. Differences in TOC may be due to spatial variability and/or the imprecision of the TOC analysis (i.e., the TOC analytical protocol does not contain rigorous quality assurance procedures, as does the PCB analytical protocol, thereby lending less confidence to the precision of results). These results led us to question the consistency of PCB analytical methods used for both surveys, as the 1986 samples were analyzed by York Labs and the 1992 samples were analyzed by ITAS. LMS investigated the possibility that the difference in 1986 and 1992 PCB concentrations may have occurred as a result of inconsistencies or errors in laboratory methodology. The investigation focused on possible systematic differences in the way in which the laboratories processed the samples, including preparation, analysis, and quantification of PCBs in the two data sets. Specifically, the following items were compared for both laboratories:

- Sample preparation
- Sample analysis
- Preparation of calibration standards
- Source and age of standards
- Instrument calibration
- Quality assurance data

Based on the information provided by each of the laboratories there was no apparent indication that differences were due to laboratory differences. Both labs used acceptable EPA methodology to analyze for PCBs. However, given the limited amount of data, it was not possible to confirm whether the difference between the two data sets is the result of sampling, handling and/or analyses. Appendix C includes the detailed data review that was performed by LMS and its subcontractor, Data Validation Services.

Additionally, as York Labs quantified PCB concentrations based on peak areas and ITAS used peak heights, these differences were also evaluated to determine whether quantification methodology could explain the observed differences. A 1992 sample at MP 29.8 in Lake Lillinonah was chosen to compare the resulting concentrations based on peak heights and areas. The following table summarizes the results that LMS obtained by re-evaluating the chromatograms using both the peak area and peak height methods. Additionally, the sample results obtained by York Labs in a 1986 sample collected near the 1992 sample is shown.

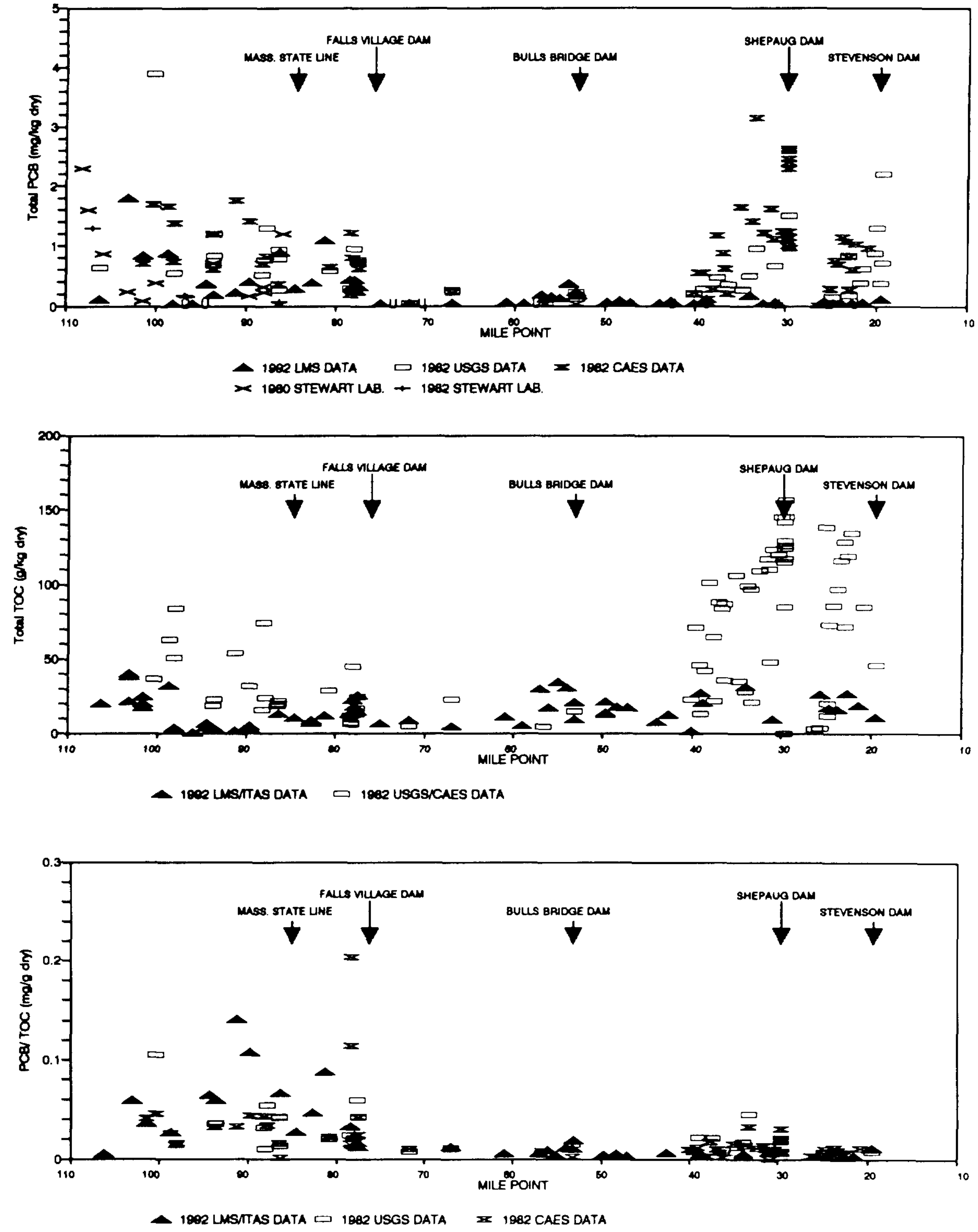
		Aroclor 1260 (mg/kg)				Aroclor 1260 (mg/kg)
DEPTH INCREMENT (in.)	1992 ITAS SAMPLE ID	ITAS BASED ON PEAK HEIGHT	LMS BASED ON PEAK AREA	LMS BASED ON PEAK HEIGHT	1986 YORK SAMPLE ID	YORK BASED ON PEAK AREA (mg/kg)
4.5	TT3600	0.24	0.23	0.22	57581	1.2
10.5	TT3603	1.3	1.46	1.31	57583	3.5
15.5	TT3607	0.32	0.33	0.28	57568	6.3

The observed small differences between the two calculation methods do not suggest that quantification methodology is the reason for the observed differences between the 1986 and 1992 samples.

The previous summary table on page 3-1 indicates a relatively wide range of USGS/CAES PCB results for core samples taken in the same vicinity. Therefore, given that systematic differences were not identified between the York and ITAS labs, observed differences may be due to spatial variability or other unknown factors.

3.2 SURFICIAL SEDIMENT

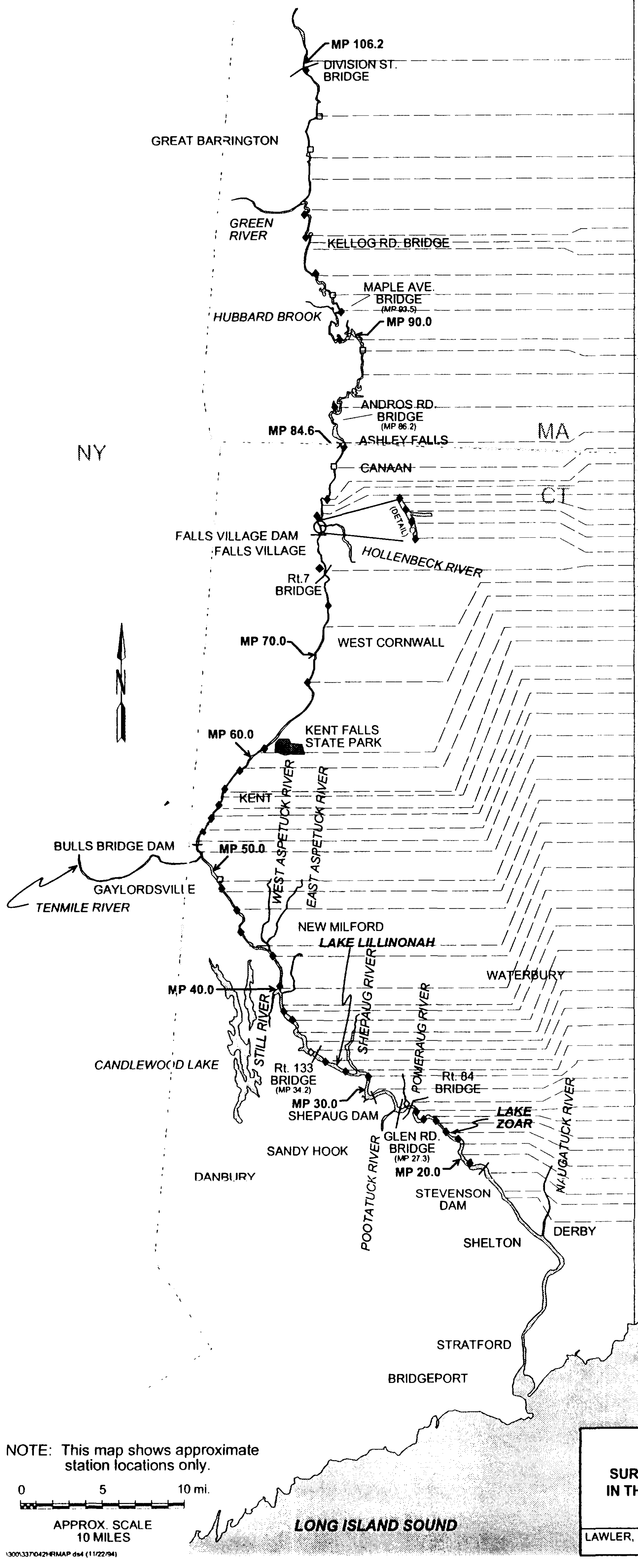
Surficial sediment samples were collected at 148 stations by CDEP and USGS between 1975 and 1978 throughout the Housatonic River between Pittsfield, Massachusetts (MP 139.8), and the Stevenson Dam (MP 19.5) (Frink 1982). These samples were analyzed for PCB, TOC, and percent grain size. In 1980 and 1982 sediment samples were collected by Stewart Laboratories at 226 stations covering 62 river miles from Dalton, Massachusetts, to the Connecticut state line and analyzed for PCBs (Stewart 1982). These historical samples were primarily of the top 6 in. of surficial sediment. In 1992 LMS collected surficial sediment samples (top 3 in.) from 49 stations between Great Barrington, Massachusetts, and the Stevenson Dam in Connecticut. These samples were primarily analyzed for PCBs and TOC, and a subset were analyzed for bulk density and percent grain size. Results of current and historical PCB and TOC analyses are shown in Figure 3-8. Figure 3-9 provides a map of all historical and current surficial sediment PCB data and station locations. Compared to historical data, 1992 surficial sediments show an apparent diminishment of PCB concentrations in the Massachusetts section of the river, the Fall Village Reservoir and especially in Lakes Lillinonah and Zoar. The word "apparent" is used to describe these trends because the historical surficial sediments were collected from the top



Sample Depth: LMS/ITAS 0-3 inch   USGS and CAES 0-6 inch

U - Sample analyzed but not detected. 1992 pcb detection limit = 0.05 ppm

LMS **LAWLER, MATUSKY & SKELLY ENGINEERS** Environmental Science & Engineering Consultants One Blue Hill Plaza • Pearl River, NY 10965	**Housatonic River Surficial Sediment**	**Figure 3-8** 337-042 TBLK ds4 disk HS4300 file sur_plt.wq1



Total PCB Concentration (mg/g)		
LMS 1992[1]	LMS 1986[1]	Frink[2] USGS/CAES 1975-1978
0.12		0.64
1.81		
0.88		0.70
		2.8
0.88		1.66
ND (0.05)		0.74
		0.55
		1.38
ND (0.05)		
0.38		
0.20		0.89
		1.76
0.40		1.41
		0.81
		0.53
0.30		
0.39		
1.10		
		0.62
0.44		0.24
0.33		1.22
0.44		
0.25	0.50	0.84
0.32		0.62
ND (0.05)		
ND (0.05)		0.045
0.06		0.245
0.07		
ND (0.05)		
0.19		
		0.04
0.16		
0.14		
0.37		
0.23	0.44	0.14
0.18		0.13
0.07		
0.10		
0.06		
ND (0.05)		
0.09		
ND (0.05)		0.21
		0.55
0.09		0.28
0.12		0.12
		0.64
		0.57
0.31	1.40	0.99
0.18		1.50
ND (0.05)		1.42
0.07		0.60
0.60	1.20	1.12
		0.01
0.09		0.15
0.06		0.41
ND (0.05)	ND (0.10)	0.97
0.06		0.52
0.07		0.50
0.00	2.17	1.05
0.13		0.71
		2.20
		0.71

[1] Top 3 in.
[2] Top 6 in. - some values are averages of several samples in the same vicinity.
ND = not detected. Value in ( ) is detection limit.

NOTE: This map shows approximate station locations only.

FIGURE 3-9

SURFICIAL SEDIMENT PCB IN THE HOUSATONIC RIVER

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\300\337\042HRMAP ds4 (11/22/94)

6 in. of sediment and current samples are from the top 3 in. Furthermore, analyses were performed using different laboratories. Thus, the noted trends may contain some element(s) of uncertainty that are not evident from the data. Similar trends are apparently evident for TOC, particularly in the two lakes. The surficial sediment PCB is apparently decreasing most rapidly in Lakes Lillinonah and Zoar.

These results indicate that suspended solids, which are the source of surficial sediment in depositional areas, contain a temporally decreasing concentration of PCBs. An unanticipated result is the marked decrease of surficial sediment TOC concentration in the lakes, indicative of either a dimished source of organic matter or an increase rate of organic matter decay. Historical TOC water quality data indicate a concentration decrease in 1980, which may provide the reason for the TOC decrease in surficial sediment. These data will be presented and discussed in Section 3.3, Water Column.

Historical measurements of percent sand, silt, and clay were performed by Frink (1982), and a limited number of bulk density analyses were performed. These bulk density measurements were used by Frink to develop the following relationship ($r^2 = 0.84$, $n = 24$):

$$BD = 14.18 + 0.843\ (Sand) \qquad \textbf{(Equation 3-1)}$$

where:

BD = bulk density (lb/ft^3)
Sand = percentage of sand in sample

The relationship was used in LMS (1991) and LMS (1989) to estimate bulk density throughout the study area. Table 3-1 summarizes the 1992 measurements of percent grain size and bulk density and the 1975-1978 measurements of percent grain size and the bulk density as calculated using Equation 3-1. Regressions of bulk density vs percent sand, silt, and clay were performed for the 1992 data but the number of data points (10) was insufficient to provide good statistical correlation.

Comparisons of the two data sets indicate a higher average percentage of clay and silt in 1975-78 (9 and 46.9%, respectively) as compared to 1992 (2.5 and 36.1%, respectively). Frink (1982) concluded that the distribution of PCBs in the sediments of Lakes Lillinonah and Zoar was correlated with the distribution of fine-grained sediments. Thus, such a difference in grain size distribution might be expected to affect the flux of PCBs between the sediment and water

TABLE 3-1

SURFICIAL SEDIMENT PHYSICAL MEASUREMENTS

	LMS MEASUREMENTS (1992)					MEASUREMENTS REPORTED BY FRINK (1982) (SAMPLED IN 1975 TO 1978)			
		PERCENT GRAIN SIZE BY WEIGHT[c]					PERCENT GRAIN SIZE BY WEIGHT[a]		
MILE POINT	BD (lb/ft^3)	GRAVEL	SAND	SILT	CLAY	BD[b] (lb/ft^3)	SAND	SILT	CLAY
106.20	60.5	0.0	95.5	4.0	0.5	89.2	89.0	8.0	4.0
98.70	48.4	3.5	49.7	43.3	3.5	42.0	33.0	64.0	2.0
93.56	95.0	0.0	84.8	13.8	1.4	40.3	31.0	60.0	9.0
86.40	85.2	0.9	47.6	48.5	3.0	23.5	11.0	60.0	29.0
82.70	79.6								
81.30		0.0	50.1	47.9	2.2	44.5	36.0	55.0	9.0
77.90	58.9	0.0	30.3	66.6	3.1	60.5	55.0	39.0	6.0
67.00	64.0	0.0	76.0	22.3	1.7	76.6	74.0	21.0	5.0
53.20	88.7	3.4	77.1	18.0	1.5	83.3	82.0	12.0	6.0
33.90	52.4	4.6	41.0	50.2	4.2	32.7	22.0	63.0	15.0
22.70	35.1	3.9	45.9	46.5	3.7	20.9	8.0	87.0	5.0
AVERAGE:	66.8	1.6	59.8	36.1	2.5	51.4	44.1	46.9	9.0

[a] Station closest to indicated mile point.

[b] Calculated from 14.18 + 0.843 (sand).

[c] 1992 Grain size according to ASTM D 422: gravel = 2-64 mm; sand = 0.062-2 mm; silt = 0.004-0.062 mm; clay = <0.004 mm.

BD = Bulk density (weight of oven-dried soil per total volume of wet soil mass).

column. However, the above grain-size comparisons are based on a limited number of samples and therefore are not conclusive. Changes in grain-size distribution may be due to changes in land use or improvements in wastewater treatment or may reflect the historical erosion of fine top soils from agricultural lands, leaving the coarser sediments remaining currently.

3.3 WATER COLUMN

3.3.1 Historical Data

Historical water quality data have been collected by USGS and the U.S. Environmental Protection Agency (EPA) in the Housatonic River and its tributaries from the early 1970s to the present. EPA data are available from its Storet database, and USGS data are available in a CD-ROM database, Quality of Water - East, provided by Earth Info, Inc. Retrievals from both data-bases were performed for all stations in the Housatonic River and its tributaries. The Storet database was accessed for the following parameters:

USGS/EPA PARAMETER CODE	PARAMETER DESCRIPTION
00680	TOC
00681	DOC
39516	PCBs in whole water
39517	PCBs in filtered fraction of water
39518	PCBs in suspended fraction of water
80154	TSS

Of the above parameters, the only one measured consistently was TOC. The station name, average TOC concentration, number of samples, and dates of sampling by EPA Region I are summarized in Table 3-2. As indicated, the data were collected mostly in the early 1970s. The Earth Info., Inc., database was also queried for the above parameters; TSS, TOC, DOC, and some PCB data were found. Table 3-3 summarizes the TSS, TOC, and PCB data collected by USGS. Figure 3-10 shows the temporal trend of TOC at several stations in the Housatonic River; Figure 3-11 shows the TOC temporal trend for three tributaries to the Housatonic River (Still, Shepaug, and Naugatuck rivers). An obvious trend in the data is the decrease in TOC since 1979 at most of the Housatonic River stations. The following table summarizes average TOC prior to and after May 1979:

TABLE 3-2

TOC DATA COLLECTED BY EPA REGION I

STATION NAME	AVG TOC[a] (MG/L)	NO. OF SAMPLES	SAMPLE DATES		MILE POINT[b]
			BEGIN	END	
Housatonic River at Ashley Falls	8.4	21	70/6/15	72/8/7	86
Housatonic River near New Milford	7	27	70/5/25	72/9/11	42
Lake Lillinonah	21	34	70/5/27	73/8/23	29.6-43
Lake Zoar near Southbury	5.3	7	72/5/15	72/8/21	25
Still River	16.3	64	70/5/25	76/9/14	40
Pootatuck River	5.2	25	70/5/27	72/10/2	27
Shepaug River	6.8	23	70/5/27	72/10/10	32
West Aspetuck River	6.2	21	70/5/25	72/9/11	43
Salmon Creek	5.9	23	70/6/15	72/8/7	78

[a] Values may be average of several sampling sites in vicinity of indicated station.
[b] Tributary mile points are at confluence with Housatonic River

TABLE 3-3

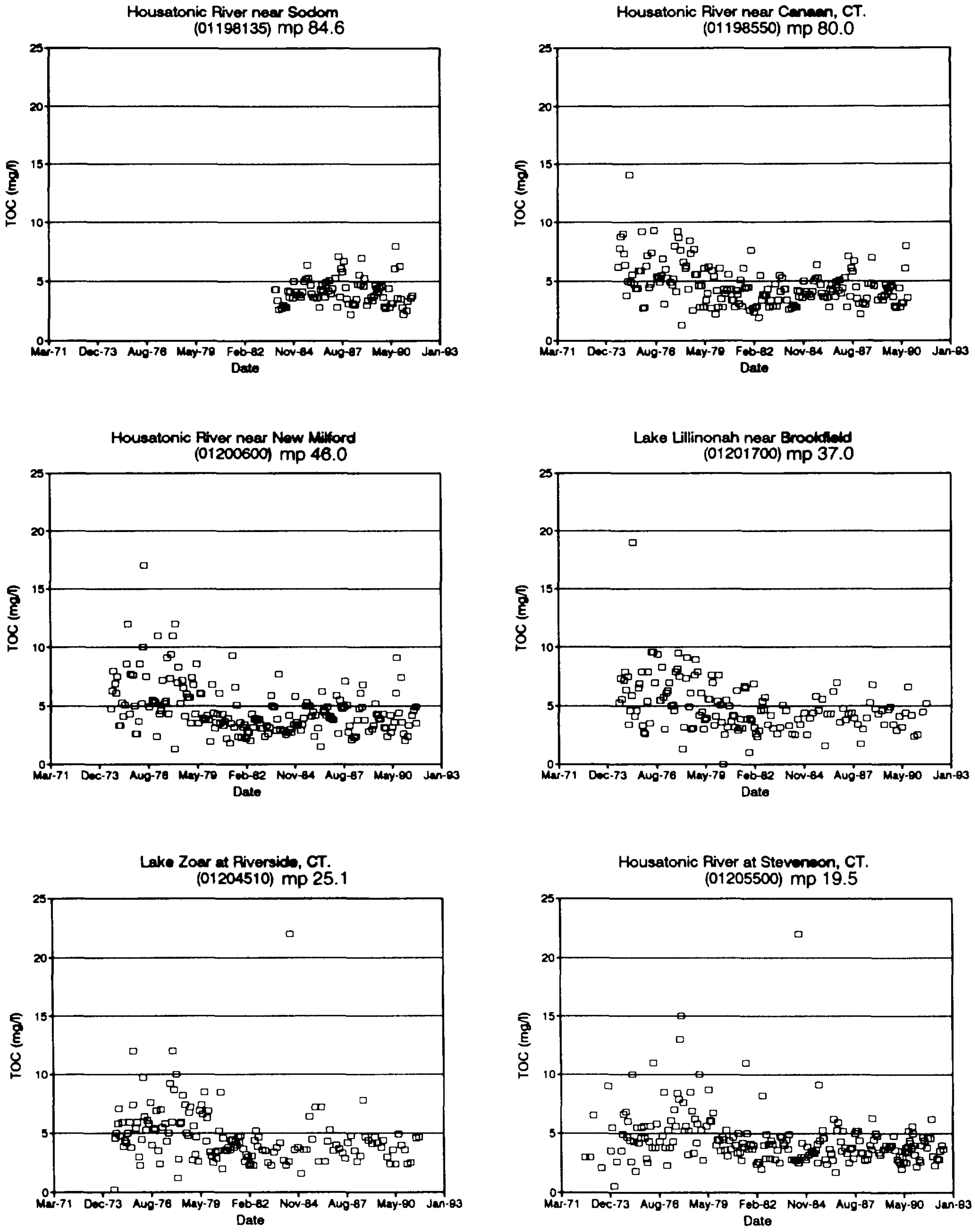
SUMMARY OF WATER QUALITY DATA FROM USGS

STATION NAME	USGS STATION No.	MILE POINT[b]	TOTAL SUSPENDED SOLIDS			TOTAL ORGANIC CARBON			TOTAL PCB		YEARS
			MEAN (mg/l)	STANDARD DEVIATION (mg/l)	No. OF SAMPLES	MEAN (mg/l)	STANDARD DEVIATION (mg/l)	No. OF SAMPLES	MEAN (μg/l)	No. OF SAMPLES	
Housatonic River at Great Barrington	01197500	106.2	12.7	21.5	188						1979-1980
Housatonic River at Ashley Falls, MA	01198130	84.85	66.0	52.3	4						1986-1988
Housatonic River near Sodom	01208736	84.6				4.1	1.2	85			1983-1991
Housatonic River near Canaan	01198550	80	139.7	42.0	3	4.7	1.8	182			1966-1987
Housatonic R near Falls Village	01199000	75.9	27.6	42.4	181	5.6	4.9	7	0.0	7	1979-1980
Housatonic River near Kent	01199290	58.1	45.5	93.8	313						1985-1987
Housatonic R at Gaylordsville	01200500	50.6	29.9	75.0	224						1979-1980
Housatonic R at Stevenson	01205500	19.5	9.0	8.7	136	4.4	2.2	224	0.0	5	1974-1992
Green River near Great Barrington	01198000	99	7.3	11.1	24	4.1	1.2	85			1967-1972
Pomperaug River - all stations	01204000	26.5	7.0	2.9	3	2.9	1.7	13	0.0	5	1978-1979
East Aspetuck River at New Preston	01201050	43	11.7	11.3	10	6.6	2.1	8			1977-1978
Hollenbeck River at Huntsville	01198800	78.3				7.1	9.3	7			1971-1974
Wangum Lake Brook near South Canaan[c]	01198880					3.4	3.5	7	0.0	6	1971-1974
Housatonic River near New Milford[a]	01200600	46	20.9	26.2	169	4.7	2.2	194			1974-1991
Still River at Brookfield Junction[a]	01201485	40	31.6	36.5	190	7.5	2.8	207			1974-1992
Lake Lillinonah near Brookfield[a]	01201700	37	16.8	41.4	126	4.9	2.2	151			1974-1991
Shepaug River near Roxbury[a]	01203000	32	11.7	9.6	173	5.0	1.7	203			1974-1992
Pootatuck River - all stations[a]	01203502	27				7.6	5.3	6			1976
Lake Zoar at Riverside[a]	01204510	25.1	15.3	15.6	133	4.7	2.4	152			1974-1991
Naugatuck River at Ansonia[a]	01208736	18.0	21.1	31.1	183	6.4	2.6	206			1974-1992

[a] TSS is calculated as total solids minus total dissolved solids.

[b] Tributary mile points are at confluence with Housatonic River.

[c] Tributary to Hollenbeck River



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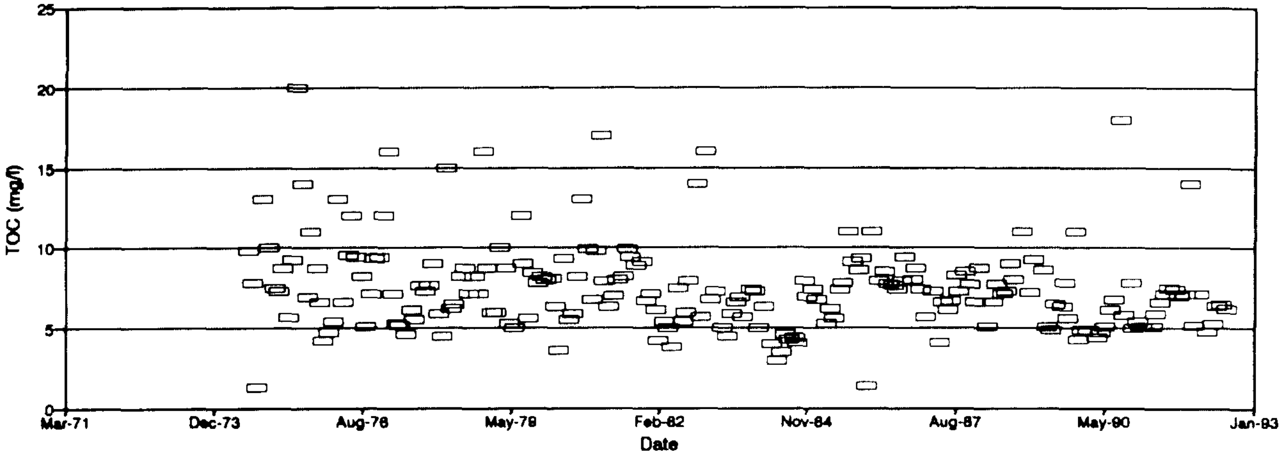
Historical Water Column TOC in the Housatonic River

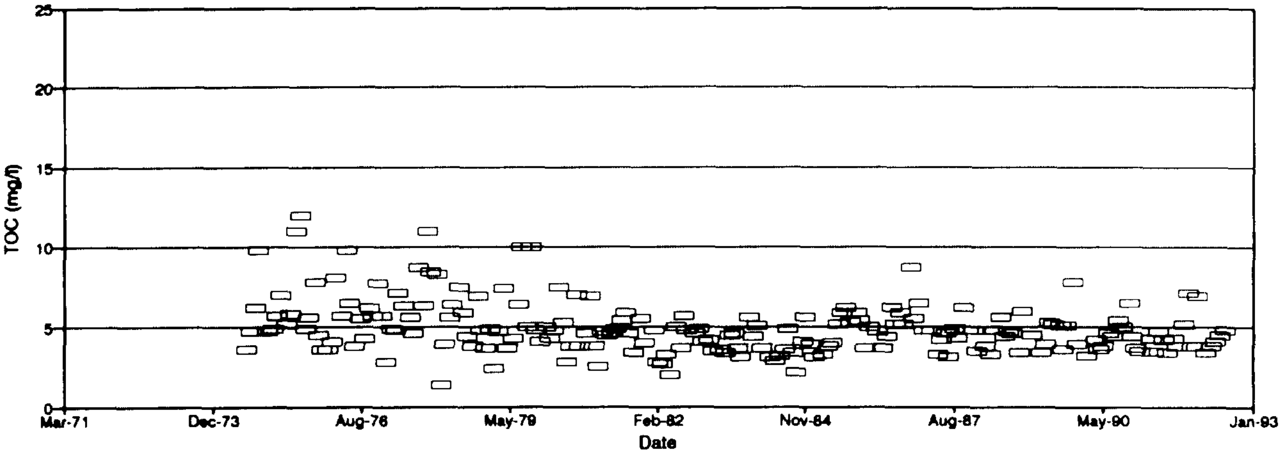
Figure 3-10

337\042TBLK ds4
disk HS4300 file HRPARAM2 wq1

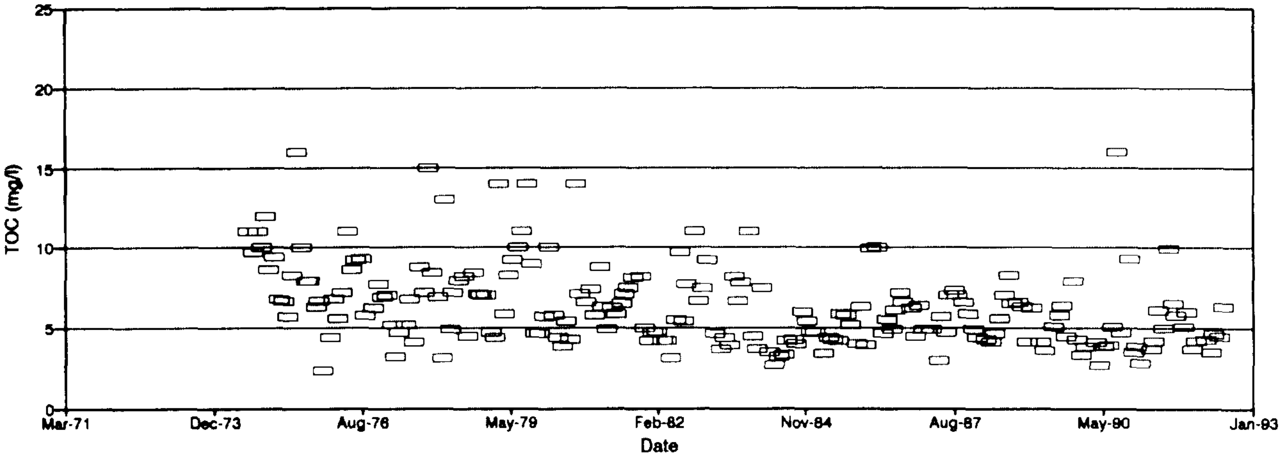
Still River at Brookfield Junction
(01201485)



Shepaug River near Roxbury, CT.
(01203000)



Naugatuck River at Ansonia, CT.
(01208736)



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Historical Water Column TOC in Tributaries of the Housatonic River

Figure 3-11

337-042 TBLK ds4
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STATION	AVERAGE TOC (mg/l) PRIOR TO 1 MAY 1979	AVERAGE TOC (mg/l) AFTER 1 MAY 1979	MILE POINT
Housatonic River near Canaan, CT	5.9	4.1	80
Housatonic River near New Milford	6.4	4.0	46
Lake Lillinonah near Brookfield	6.2	4.2	37
Lake Zoar at Riverside	5.6	4.2	25.1
Housatonic River at Stevenson, CT	5.4	4.0	19.5
Average	5.9	4.1	

Such a decrease in water column TOC provides an explanation for part of the decrease in observed depositional surficial sediments. As incidated, TOC concentrations in the Housatonic River currently average about 4.1 mg/l; prior to 1 May 1979 they generally were found at an average concentration of about 5.9 mg/l. This 31% decrease could be the result of upgraded treatment at sewage treatment plants, changes in land usage, or other factors. As PCBs are highly partitioned to particulate organic carbon, such changes in water column TOC would be expected to ultimately affect surficial sediment PCB and TOC concentrations. However, it is not clear how such changes would affect deep sediment PCBs as these are not expected to interact significantly with surficial sediments.

Several sources of water column PCB and TSS data are available for the Housatonic River that were not completely available in the above databases. Table 3-4 summarizes all of the available water column PCB data for the Housatonic River between Great Barrington and the Stevenson Dam, including the PCB data summarized in Table 3-3. The data in this table are used in Section 3.3.2 to evaluate temporal PCB trends at Great Barrington, which serves as the upstream model boundary. Figure 3-12 shows the temporal trend for all total PCB measured in the study area. A decreasing trend appears evident but, as will be discussed in Section 3.3.2, cannot be shown with statistical significance.

3.3.2 Statistical Trends

The primary objective of the statistical trends analysis was to develop a means to define the upstream aqueous TSS and PCB boundary conditions for the Housatonic River Model. This boundary condition relationship is to be used for the model verification and projections.

Two data sources were used for this analysis; 18 months of daily TSS measurements at Great Barrington and all available data for PCB and TSS at Great Barrington, as discussed further. A relationship between TSS and flow was developed from 18 months of daily TSS measurements at Great Barrington, Falls Village, and Gaylordsville from April 1978 through

Table 3-4

Water Column PCB Data

Date of sample collection	Time [hrs]	Site number	Mile Point [from LI Sound]	PCB dissolved [ug/l=ppb]	PCB total [ug/l=ppb]	PCB particulate [ug/l=ppb]	Instant stream flow [ft3/s]	TSS Suspended Sediment [mg/l=ppm]	Source of Data
10/04/79	16:30	01197500	106.1	-	0.5				A
11/27/79	11:00	01197500	106.1	ND(0.1)	0.2		1280	22	A
03/18/80	09:00	01197500	106.1	ND(0.1)	0.2		1000	63	A
03/18/80	10:00	01197500	106.1	ND(0.1)	0.1				A
03/18/80	11:00	01197500	106.1	ND(0.1)	0.2				A
03/18/80	12:15	01197500	106.1	ND(0.1)	0.2				A
03/18/80	13:30	01197500	106.1	0.1	0.3				A
03/18/80	15:15	01197500	106.1	0.1	0.4		1820	76	A
03/22/80	07:00	01197500	106.1	0.2	0.6		2980	226	A
04/04/80	13:30	01197500	106.1	ND(0.1)	0.1		1060	20	A
04/10/80	08:30	01197500	106.1	ND(0.1)	0.1				A
04/10/80	11:45	01197500	106.1	ND(0.1)	0.1		2410	124	A
04/10/80	14:55	01197500	106.1	0.1	0.1				A
06/30/80	12:00	01197500	106.1	0.1	0.4		631	18	A
06/01/84	17:30	01197500	106.1	0.4	0.2		7650	67	B
01/27/86	11:45	01197500	106.1	ND(0.1)	0.2		2200	62	B
03/31/87	13:15	01197500	106.1	ND(0.1)	0.2		1940	41	B
04/05/87	11:00	01197500	106.1	0.1	0.5		5290	113	B
08/19/88	08:00	01197500	106.1	0.2	0.2		153	12	B
07/20/89		01197500	106.1	ND(.064)	0.096		330	7.7	C
08/24/89		01197500	106.1	0.26	0.43		110	6.3	C
09/27/89		01197500	106.1	ND(.06)	0.1		180	10.2	C
11/02/89		01197500	106.1	0.06	0.07		260	8.6	C
12/13/89		01197500	106.1	ND(.06)	ND(.06)		182	2.7	C
02/22/90		01197500	106.1	0.07	0.07		465	4.2	C

Disk: HS4300 File:PCB2a-1.WQ1

Table 3-4

Water Column PCB Data

Date of sample collection	Time [hrs]	Site number	Mile Point [from LI Sound]	PCB dissolved [ug/l=ppb]	PCB total [ug/l=ppb]	PCB particulate [ug/l=ppb]	Instant stream flow [ft3/s]	TSS Suspended Sediment [mg/l=ppm]	Source of Data
04/23/90		01197500	106.1	ND(.05)	0.08		448	6.1	C
10/02/90	09:55	01197500	106.1	ND(0.07)	ND(0.065)		259	ND(1)	C
11/05/90	11:40	01197500	106.1	ND(0.03)	ND(0.03)		461	4	C
12/05/90	12:00	01197500	106.1	ND(0.06)	0.14		987	5	C
01/02/91	12:40	01197500	106.1	ND(0.065)	ND(0.065)		1412	ND(1)	C
02/06/91	09:50	01197500	106.1	ND(0.065)	ND(0.065)		614	ND(1)	C
03/11/91	14:00	01197500	106.1	ND(0.065)	-		646	ND(1)	C
04/02/91	13:15	01197500	106.1	ND(0.065)	ND(0.065)		825	ND(1)	C
05/07/91	13:40	01197500	106.1	1.2(1)	0.093		983	6.5	C
06/03/91	13:15	01197500	106.1	ND(0.065)	0.15		309	5	C
07/08/91	13:45	01197500	106.1	0.20(1)	0.083		127	3	C
08/05/91	13:45	01197500	106.1	ND(0.065)	ND(0.065)		93	5.5	C
09/11/91	09:30	01197500	106.1	ND(0.065)	0.45		74	ND(1)	C
03/05/91	21:00	01197500	106.1	-	0.097		1310	3	D
03/06/91	00:30	01197500	106.1	-	0.068		1260	ND(1)	D
03/06/91	03:05	01197500	106.1	ND(0.065)	0.086		1230	8	D
03/06/91	04:05	01197500	106.1				1220	9	D
03/06/91	06:15	01197500	106.1	-	0.082		1190	5	D
03/06/91	09:00	01197500	106.1	ND(0.065)	0.086		1140	5	D
03/06/91	12:00	01197500	106.1	-	ND(0.065)		1090	ND(1)	D
02/27/82	14:45	W11	106.1	ND(0.03)	ND(0.03)	<0.03	510	2.4	E[1]
03/13/82	14:00	W11	106.1	ND(0.03)	ND(0.03)	<0.03	686	5.2	E[1]
03/14/82	12:30	W11	106.1	ND(0.03)	ND(0.03)	<0.03	952	6.2	E[1]
03/15/82	14:15	W11	106.1	ND(0.03)	ND(0.03)	<0.03	967	5.1	E[1]
03/16/82	14:00	W11	106.1	ND(0.03)	ND(0.03)	<0.03	880	5.5	E[1]

Disk: HS4300 File:PCB2a-1.WQ1

Table 3-4

Water Column PCB Data

Date of sample collection	Time [hrs]	Site number	Mile Point [from LI Sound]	PCB dissolved [ug/l=ppb]	PCB total [ug/l=ppb]	PCB particulate [ug/l=ppb]	Instant stream flow [ft3/s]	TSS Suspended Sediment [mg/l=ppm]	Source of Data
04/20/82	09:00	W11	106.1	0.04	0.14	0.1	2960	19	E[1]
04/20/82	11:00	W11	106.1	0.04	0.13	0.09	2890	17	E[1]
04/21/82	13:00	W11	106.1	0.04	0.10	0.06	2094	9.7	E[1]
04/21/82	16:00	W11	106.1	0.03	0.10	0.07	2046	11	E[1]
04/22/82	12:00	W11	106.1	0.02	0.07	0.05	1760	8	E[1]
04/23/82	12:00	W11	106.1	ND(0.03)	0.04	0.04	1460	5.6	E[1]
04/23/82	15:00	W11	106.1	ND(0.03)	0.04	0.04	1352	5.3	E[1]
04/24/82	18:00	W11	106.1	ND(0.03)	0.03	0.03	1101	5	E[1]
01/27/86	13:15	0119830	84.85	ND(0.1)	0.1			123	F
03/31/87	14:10	0119830	84.85	0.1	0.1			91	F
04/05/87	11:45	0119830	84.85	ND(0.1)	ND(0.1)			47	F
08/19/88	10:00	0119830	84.85	ND(0.1)	0.1			3	F
01/27/86	14:00	01198550	79.1	ND(0.1)	0.1			186	G
03/31/87	14:45	01198550	79.1	ND(0.1)	ND(0.1)			104	G
04/05/87	12:15	01198550	79.1	ND(0.1)	ND(0.1)			129	G
01/27/86	14:30	01199105	73.9	ND(0.1)	0.1		4980	130	H
03/31/87	15:30	01199105	73.9	ND(0.1)	ND(0.1)		3770	92	H
04/05/87	13:00	01199105	73.9	ND(0.1)	ND(0.1)		9280	235	H
08/19/88	12:00	01199105	73.9	ND(0.1)	ND(0.1)		985	10	H
02/27/82	13:10	SB	122	ND(0.03)	-	<0.03	820	7.5	I
03/14/82	14:00	SB	122	ND(0.03)	0.045	0.045	1320	54	I
03/15/82	15:30	SB	122	ND(0.03)	0.048	0.048	1500	46	I
03/15/82	16:30	SB	122	ND(0.03)	0.048	0.048	1525	44	I
03/16/82	13:20	SB	122	ND(0.03)	0.048	0.048	1440	34	I
04/20/82	11:15	SB	122	ND(0.03)	0.07	0.07	4800	90	I

Disk: HS4300 File:PCB2a-1.WQ1

Table 3-4

Water Column PCB Data

Date of sample collection	Time [hrs]	Site number	Mile Point [from LI Sound]	PCB dissolved [ug/l=ppb]	PCB total [ug/l=ppb]	PCB particulate [ug/l=ppb]	Instant stream flow [ft3/s]	TSS Suspended Sediment [mg/l=ppm]	Source of Data
04/20/82	14:20	SB	122	ND(0.03)	0.05	0.05	4800	91	I
04/21/82	14:40	SB	122	ND(0.03)	0.04	0.04	3900	53	I
04/22/82	12:15	SB	122	ND(0.03)	0.04	0.04	2900	54	I
04/23/82	13:15	SB	122	ND(0.03)	0.05	0.05	2250	46	I
04/24/82	16:45	SB	122	ND(0.03)	0.04	0.04	1750	35	I
08/19/91	20:45	01197500	106.1	-	-		905	30	D
08/19/91	20:45	01197500	106.1	ND(0.065)	0.12		905	29	D
08/20/91	00:02	01197500	106.1	-	-		905	28	D
08/20/91	00:02	01197500	106.1	ND(0.065)	0.1		905	28	D
08/20/91	08:05	01197500	106.1	-	-		985	28	D
08/20/91	08:05	01197500	106.1	ND(0.065)	0.1		985	25	D
08/20/91	11:00	01197500	106.1	-	-		985	23	D
08/20/91	11:00	01197500	106.1	ND(0.065)	0.13		985	23	D
08/20/91	17:00	01197500	106.1	-	-		1050	18	D
08/20/91	17:00	01197500	106.1	ND(0.065)	0.12		1050	17	D
08/20/91	22:00	01197500	106.1	-	-		985	17	D
08/20/91	22:00	01197500	106.1	ND(0.065)	0.14		985	15	D
08/21/91	07:20	01197500	106.1	-	-		850	15	D
08/21/91	07:20	01197500	106.1	ND(0.065)	0.13		850	14	D
08/21/91	11:30	01197500	106.1	-	-		850	19	D
08/21/91	11:30	01197500	106.1	ND(0.065)	0.17		850	17	D
08/22/91	11:05	01197500	106.1	ND(0.065)	ND(0.065)		610	12	D
03/26/92	23:50	01197500	106.1	ND(0.065)	ND(0.065)		375	9	D
03/27/92	06:40	01197500	106.1	-	-		700	21	D
03/27/92	06:40	01197500	106.1	ND(0.065)	ND(0.065)		700	20	D

Disk: HS4300 File:PCB2a-1.WQ1

Table 3-4

Water Column PCB Data

Date of sample collection	Time [hrs]	Site number	Mile Point [from LI Sound]	PCB dissolved [ug/l=ppb]	PCB total [ug/l=ppb]	PCB particulate [ug/l=ppb]	Instant stream flow [ft3/s]	TSS Suspended Sediment [mg/l=ppm]	Source of Data
03/27/92	12:25	01197500	106.1	ND(0.065)	ND(0.065)		1130	12	D
03/27/92	15:40	01197500	106.1	ND(0.065)	ND(0.065)		1200	33	D
12/17/92	09:45	01197500	106.1	ND(0.065)	ND(0.065)		498	10	D
12/17/92	20:35	01197500	106.1	ND(0.065)	ND(0.065)		728	14	D
12/17/92	22:50	01197500	106.1	ND(0.065)	ND(0.065)		850	27	D
12/18/92	07:45	01197500	106.1	-	0.079		1050	-	D
12/18/92	07:45	01197500	106.1	ND(0.065)	0.079		1050	37	D
12/18/92	12:40	01197500	106.1	-	-		1120	46	D
12/18/92	12:40	01197500	106.1	ND(0.065)	0.114		1120	47	D
12/18/92	21:00	01197500	106.1	-	-		1200	33	D
12/18/92	21:00	01197500	106.1	ND(0.065)	0.1		1200	45	D
12/18/92	23:30	01197500	106.1	ND(0.065)	0.122		1200	42	D
12/19/92	07:50	01197500	106.1	ND(0.065)	0.084		1200	18	D
03/29/93	16:10	01197500	106.1	ND(0.065)	ND(0.065)		2166	6	D
03/29/93	21:20	01197500	106.1	ND(0.065)	ND(0.065)		2704	25	D
03/30/93	06:20	01197500	106.1	ND(0.065)	0.12		3519	37	D
04/02/93	11:40	01197500	106.1	ND(0.065)	ND(0.065)		3987	100	D
04/22/93	17:10	01197500	106.1	ND(0.065)	ND(0.065)		1396	6	D
04/22/93	20:50	01197500	106.1	ND(0.065)	ND(0.065)		1558	2	D
04/23/93	06:55	01197500	106.1	ND(0.065)	ND(0.065)		2258	11	D
04/23/93	14:50	01197500	106.1	ND(0.065)	ND(0.065)			16	D
03/27/92	09:30	FVB-C	75	ND(0.065)	ND(0.065)			ND(1)	J
03/27/92	09:30	FVB-C	75	ND(0.065)	ND(0.065)			153	J
03/27/92	14:20	FVB-C	75	-	-			136	J
03/27/92	14:20	FVB-C	75	ND(0.065)	ND(0.065)			143	J

Disk: HS4300 File:PCB2a-1.WQ1

Table 3-4

Water Column PCB Data

Date of sample collection	Time [hrs]	Site number	Mile Point [from LI Sound]	PCB dissolved [ug/l=ppb]	PCB total [ug/l=ppb]	PCB particulate [ug/l=ppb]	Instant stream flow [ft3/s]	TSS Suspended Sediment [mg/l=ppm]	Source of Data
03/27/92	18:00	FVB-C	75	ND(0.065)	ND(0.065)			171	J
12/17/92	11:15	FVB-C	75	ND(0.065)	ND(0.065)			16	J
12/17/92	21:45	FVB-C	75	ND(0.065)	ND(0.065)			49	J
12/18/92	06:45	FVB-C	75	ND(0.065)	ND(0.065)			54	J
12/18/92	15:10	FVB-C	75	-	-			57	J
12/18/92	15:10	FVB-C	75	ND(0.065)	ND(0.065)			69	J
12/18/92	22:20	FVB-C	75	-	-			41	J
12/18/92	22:20	FVB-C	75	ND(0.065)	ND(0.065)			64	J
12/19/92	09:45	FVB-C	75	ND(0.065)	ND(0.065)			38	J
03/29/93	18:40	FVB-C	75	ND(0.065)	ND(0.065)			75	J
03/30/93	08:35	FVB-C	75	ND(0.065)	ND(0.065)			129	J
03/30/93	12:20	FVB-C	75	ND(0.065)	0.079			169	J
04/02/93	09:40	FVB-C	75	ND(0.065)	ND(0.065)			18	J
04/22/93	18:45	FVB-C	75	ND(0.065)	ND(0.065)			43	J
04/22/93	22:00	FVB-C	75	ND(0.065)	ND(0.065)			41	J
04/23/93	08:40	FVB-C	75	ND(0.065)	ND(0.065)			84	J
04/23/93	15:50	FVB-C	75	ND(0.065)	ND(0.065)			84	J
02/24/82	10:00	ARB	84.85	ND(0.03)	ND(0.03)	ND(0.03)	234	1	P[1]
02/24/82	14:30	ARB	84.85	ND(0.03)	0.03	0.03	405	3.8	P[1]
02/27/82	08:15	ARB	84.85	ND(0.03)	ND(0.03)	ND(0.03)	273	1.4	P[1]
03/13/82	11:00	ARB	84.85	ND(0.03)	0.033	0.033	358	8.2	P[1]
03/14/82	10:30	ARB	84.85	ND(0.03)	0.032	0.032	427	9	P[1]
03/15/82	11:20	ARB	84.85	ND(0.03)	0.028	0.028	457	6.4	P[1]
03/15/82	18:15	ARB	84.85	ND(0.03)	0.022	0.022	457	4.4	P[1]
03/16/82	19:40	ARB	84.85	ND(0.03)	0.07	0.07	550	8.6	P[1]

Disk: HS4300 File:PCB2a-1.WQ1

Table 3-4

Water Column PCB Data

Date of sample collection	Time [hrs]	Site number	Mile Point [from LI Sound]	PCB dissolved [ug/l=ppb]	PCB total [ug/l=ppb]	PCB particulate [ug/l=ppb]	Instant stream flow [ft3/s]	TSS Suspended Sediment [mg/l=ppm]	Source of Data
04/20/82	04:00	ARB	84.85	0.08	0.23	0.15	2320	7.5	P[1]
04/20/82	07:00	ARB	84.85	0.07	0.2	0.13	2080	8.9	P[1]
04/20/82	17:00	ARB	84.85	0.05	0.13	0.08	1740	7.8	P[1]
04/21/82	12:00	ARB	84.85	0.06	0.17	0.11	1520	5.7	P[1]
04/22/82	09:00	ARB	84.85	0.02	0.1	0.08	1310	6.6	P[1]
04/22/82	21:00	ARB	84.85	0.02	0.1	0.08	1115	9.4	P[1]
04/23/82	10:00	ARB	84.85	0.02	0.06	0.04	830	6.8	P[1]
04/24/82	12:00	ARB	84.85	0.04	0.11	0.07	705	3.3	P[1]

Disk: HS4300 File:PCB2a-1.WQ1

Table 3-4

Site number descriptions:

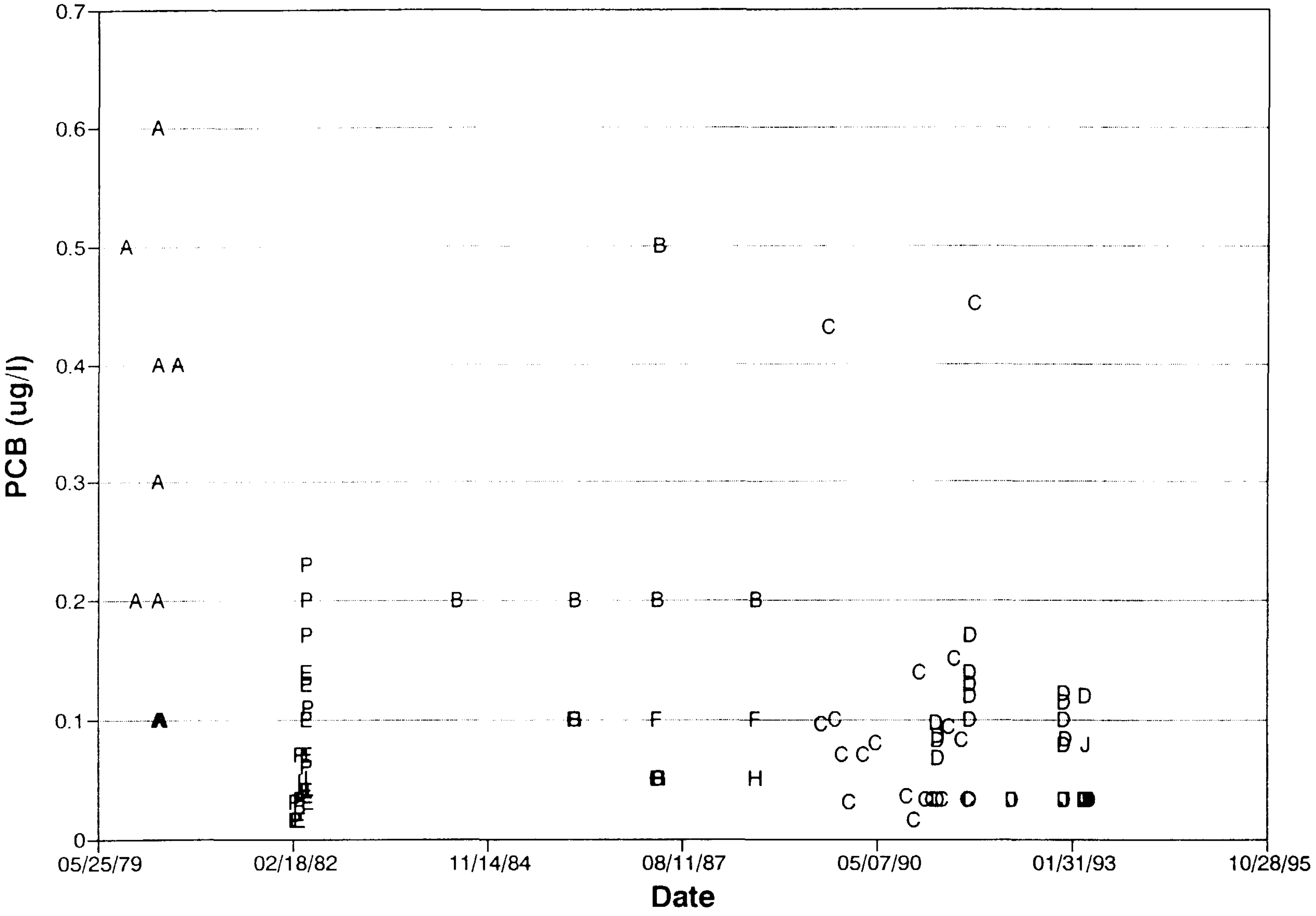
Source of Data	Site Number/ Abbrev.	Description
A	01197500	Housatonic River at Division St bridge, Great Barrington, MA (Frink et al. 1982)
B	01197500	Housatonic River at Division St bridge, Great Barrington, MA (Kulp 1991)
C	01197500	Housatonic River at Division St bridge, Great Barrington, MA (Blasland & Bouck, 1992)
D	01197500	Housatonic River at Division St bridge, Great Barrington, MA (LMS 1994 [this report])
E	1197500	Housatonic River at Division St bridge, Great Barrington, MA (Stewart 1982)
F	01198130	Housatonic River at Ashley Falls, MA (Kulp 1991)
G	01198550	Housatonic River near Canaan, Connecticut (Kulp 1991)
H	01199105	Housatonic River near Falls Village (Kulp 1991)
P	ARB	Housatonic River at Andrus Rd bridge, Ashley Falls, MA (Stewart, 1982)
J	1199105	Housatonic River at Falls Vilage (LMS 1994 [this report])
I	SB	Housatonic River at Sweitzer Bridge (Stewart 1982)

[1] Filterable and nonfilterable PCB data are measured, while Total PCB is calculated. Total PCB (ug/l) = filterable PCB (ug/l) + nonfilterable PCB (ug/l). All ND values were added as 0 to obtain total PCB.

Notes:

Numbers in () are the detection limit (ND)). For Frink data (Source A) the detection limit is assumed to be equal to 0.1 ug/l as no value is given in source document.

Data collected by LMS during reconstruction activities at the Rising Pond Dam between between 16 April to 3 June 1992 are not included in this table. See Attachment 2-3 for this data.



NOTE: Nondetected samples plotted as half of detection limit. Letter symbols indicate source of data as defined in Table 3-4.

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Housatonic River
Temporal Trend for Water Column PCB

Figure 3-12

1337\042TBLK ds4
\HS4300 PCB2-1

September 1979 (Frink 1982). Statistical analyses were conducted using SAS and NCSS, Version 5.03.

The first step in the analysis was to determine the relationship between freshwater flow and TSS. As TSS was expected to be dependent on prevailing flow, as well as the flows for one or more preceding days, only the 18-month, daily samples could be used for this analysis. The analysis was accomplished by first plotting the daily average freshwater flow over time for Great Barrington, Gaylordsville, and Falls Village (top plot in Figure 3-13). As might be expected, total flow (cfs) increased in a downriver direction and peaks in flow were progressively delayed. Because there was close correspondence between the three locations and the Great Barrington location was of primary concern, only the Great Barrington data were analyzed further.

Next, daily TSS values at Great Barrington over time were overlaid on the plot of daily average flow (bottom plot in Figure 3-13). This revealed a close correspondence of TSS to rapid increases in flow. After a peak flow event, TSS values appeared to decrease at a more rapid rate than the flow. This suggested that TSS should be modeled as a function of the flow differential between the current day and the preceding day. The flow differential (ΔQ) was calculated as Flow_t - Flow_{t-1}, where *t* is time in days.

Examination of the TSS plot over time also revealed what appeared to be a seasonal effect. During mid-September through mid-March, overall TSS levels appeared to be lower than those observed during the rest of the year. Such seasonal effects would not be unexpected. For example, during the winter, snow, ice cover, and frozen river banks will minimize the amount of sediment washed into the river, thereby lowering overall TSS levels. During the fall, fallen leaves could have a similar effect.

Version 6 of the Statistical Analysis Software (SAS) system [SAS Institute 1990] was used to fit the model:

$$TSS = \beta_0 + (\beta_1 \times \Delta Q) + (\beta_2 \times Season) \qquad \textbf{(Equation 3-2)}$$

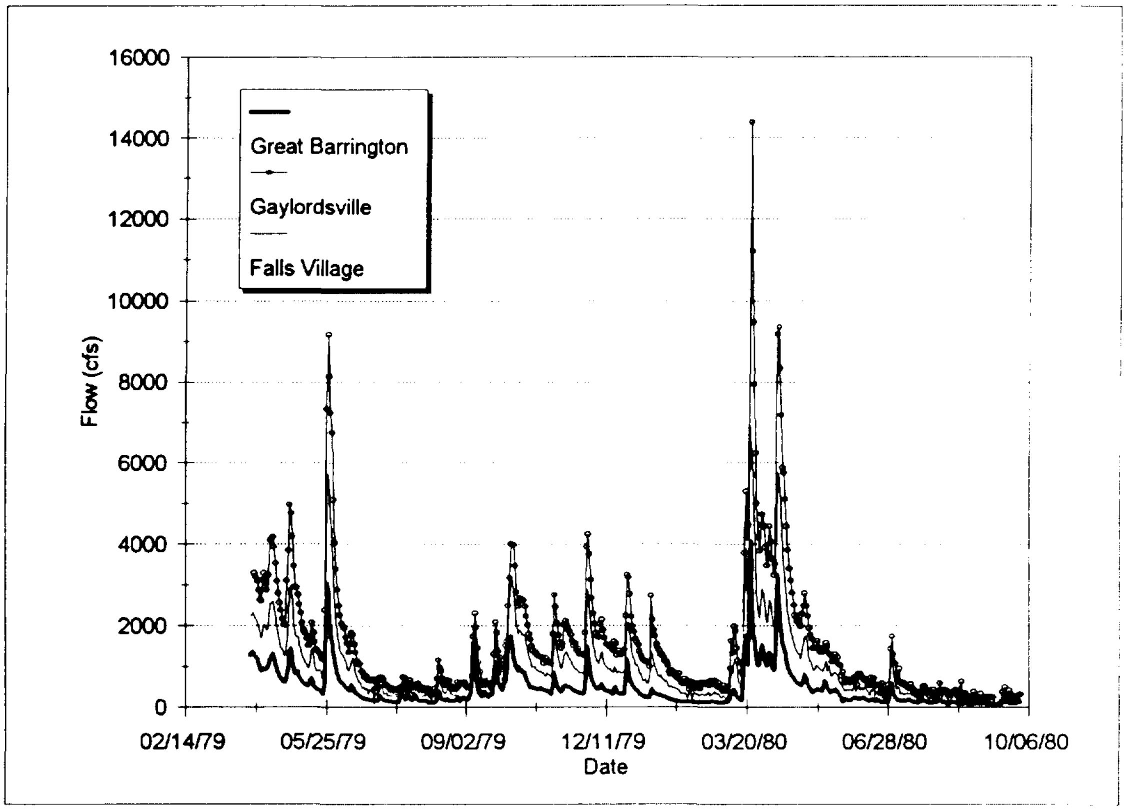
where

ΔQ = Flow_t - Flow_{t-1}

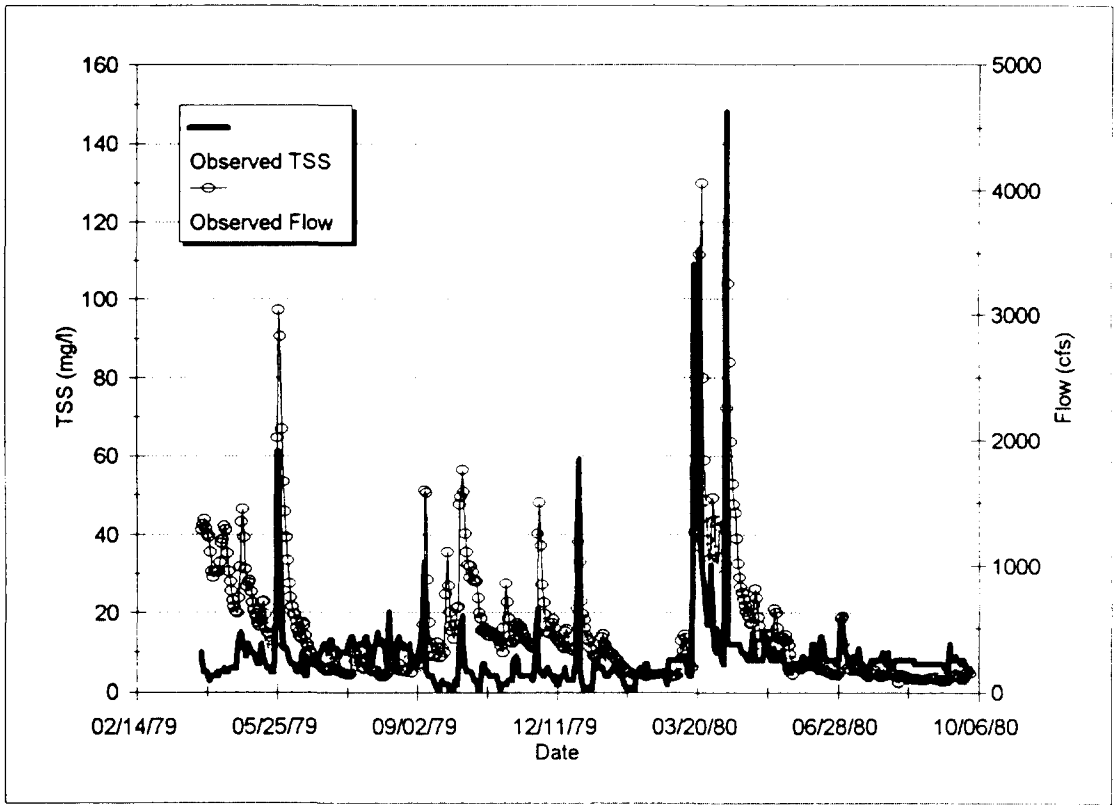
Season = 1 for 15 September through 15 March and 0 at all other times

β = regression constant and coefficients

Housatonic River flow at Great Barrington, Falls Village, and Gaylordsville.



Housatonic River TSS and flow at Great Barrington.



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Observed Flow at Great Barrington, Falls Village, and Gaylordsville and TSS at Great Barrington (Apr 1979-Oct 1980)

Figure 3-13

337-042TBLK ds4
disk HS4300 file TSS_Q wb1

The regression analysis for ascending flows, i.e., $\Delta Q \geq 0$, yielded the following results (see Table 3-5 for definitions of the following statistical terms):

SOURCE	DF	SS	MS	F	Prob. > F
Model	2	36,924.3	18,462.2	173.90	0.0001
Error	204	21,658.1	106.2		
Corrected Total	206	58,582.4			

The overall $r^2 = 0.6303$ and model coefficients were:

VARIABLE	DF	ß EST.	S.E.	T	Prob.
Intercept	1	8.8793	0.9280	9.57	0.0001
ΔQ	1	0.0467	0.0026	17.85	0.0001
Season	1	-6.9056	1.5267	-4.52	0.0001

The regression analysis for descending flows, i.e., $\Delta Q < 0$, yielded the following:

SOURCE	DF	SS	MS	F	Prob. > F
Model	2	3,321.4	1,660.7	70.97	0.0001
Error	338	7,909.8	23.4		
Corrected Total	340	11,231.2			

The overall $r^2 = 0.2957$ and model coefficients were:

VARIABLE	DF	ß EST.	S.E.	T	Prob.
Intercept	1	7.8004	0.3564	21.89	0.0001
ΔQ	1	-0.0165	0.0020	-8.40	0.0001
Season	1	-4.2841	0.5561	-7.70	0.0001

TABLE 3-5

DEFINITIONS OF STATISTICAL TERMINOLOGY

STATISTICAL TERM		DEFINITION
DF	=	Degrees of freedom. The number of variates that can be entered before the values of the remainder of the variates are fixed by the necessity to produce a certain total.
SS	=	Sum of squares. The sum of squared deviations from the mean.
MS	=	Mean square. The average dispersion around the mean. Computed as MS/DF.
F	=	F ratio. Ratio of Model MS to Error MS.
Prob> F	=	Probability of exceeding F ratio. Determined from F distribution with Model DF and Error DF.
Est.	=	Estimated coefficient (ß in equation 3-2). Intercept is Y value when X=0; coefficients for remaining variables indicate amount of change in Y with 1 unit change in X.
S.E.	=	Standard error of coefficient. A measure of the amount of variability associated with the estimated coefficient.
T	=	Student's T. Ratio of estimated coefficient to its standard error.
Prob	=	Probability of exceeding T-value. Determined from student's T distribution.

The P (Prob.) value gives the probability that the observed statistic could have arisen by chance alone. For example, a probability level of 0.01 indicates that there is only 1 chance in 100 that the observed values could have arisen by chance alone. By convention, most scientific studies accept occurrences of 0.05 (1 chance in 20) or less as statistically significant.

Therefore, TSS may be predicted from the following:

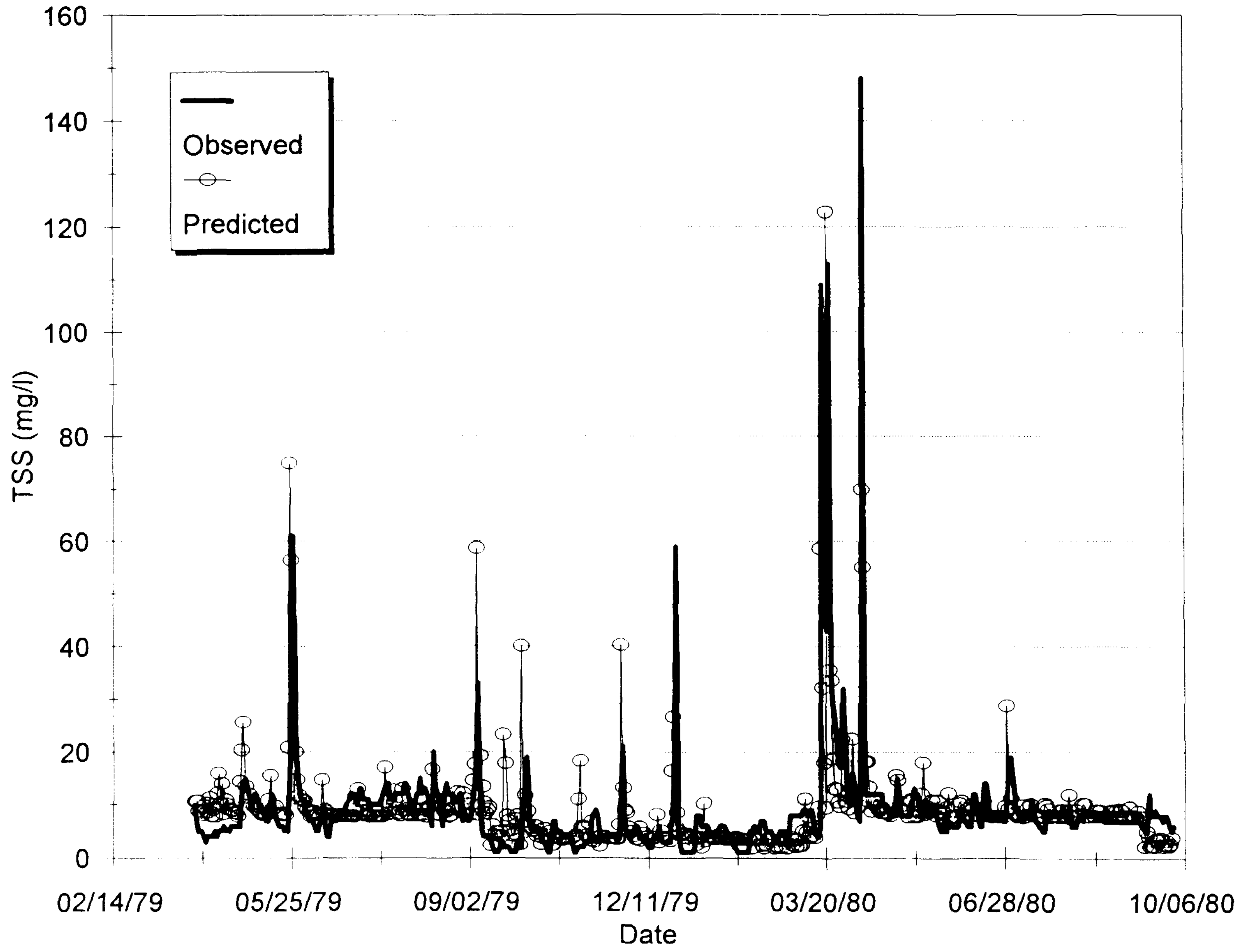
$$\begin{gathered}\textit{For } \Delta Q \geq 0 \\ TSS = 8.879 + 0.0467\ \Delta Q - 6.906\ \textit{Season}\end{gathered} \qquad \textbf{(Equation 3-3)}$$

$$\begin{gathered}\textit{For } \Delta Q < 0 \\ TSS = 7.800 - 0.0165\ \Delta Q - 4.284\ \textit{Season}\end{gathered} \qquad \textbf{(Equation 3-4)}$$

where Season = 1 if the day of the year is between 15 September through 15 March, otherwise Season = 0. It should be noted, however, that the season effect was based solely on the single 18-month data set. It is not known if this time period is consistent for other years. Warmer or cooler temperatures could alter the timing. For example, a warmer spring may cause thaw and runoff before 15 March. If so, the application of the seasonal coefficient may cause underestimation of the TSS level. Additional years of daily freshwater flow and TSS are needed to more precisely determine the timing of the seasonal effect at Great Barrington.

The TSS concentrations predicted by this model are shown in Figure 3-14 along with the observed TSS concentrations. Overall, there appears to be reasonable agreement between the predicted and observed daily TSS values.

The next step in the analysis was to relate the TSS values to PCB concentration for measurements taken at Great Barrington. Previous analyses had used stepwise multiple linear regression to determine the relationship between time, distance from river mouth, flow, and TSS with PCB. The only relationship that these previous analyses found to be statistically significant was that of PCB to TSS (LMS 1991). Re-examination of previously used and more recent data, using multiple regression analysis, yielded similar findings. The only statistically significant predictor of PCB concentration was TSS. Even this relationship was not especially strong, linear regression analysis indicated an r^2 of 0.340. This indicates that only 34% of the total variability in the observed PCB concentrations could be explained by variation in TSS.



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Housatonic River
Observed and Predicted TSS at Great Barrington

Figure 3-14

\337\042TBLK ds4
disk HS4300 file test.wq1

Closer examination of the PCB values suggested several reasons for the large amount of variability in the observed data. First, the data reported by Frink et al. (1982) appeared to yield substantially higher PCB values than the more recent studies. This may be partially due to the fact that higher flow events were sampled during this study, which resuspended more sediments and produced higher PCB concentrations. It is also not unexpected that average PCB concentrations would be actually higher at the time of the Frink study (1979-1980), since this is closer to the time when PCBs were actively used at the GE facility in Pittsfield. Differences in laboratories or analytical methods could also account for the difference. By eliminating this set of observations, the overall fit of PCB with TSS was substantially improved. However, by removing this data, possible temporal trends were also removed, and thus the PCB vs TSS relationship is based on more recent data.

A second factor contributing to the total variability was the presence of large numbers of observations reported as not detected (ND). This inability to measure PCB concentrations in low levels effectively truncates the PCB and TSS relationship at the lower end of the distribution. Observations made at low flows, with lower TSS, are frequently found to be nondetectable. Therefore, by separating the observations at low flows vs high flows and treating them separately, a further improvement in model fit was achieved. Inspection of the PCB concentration at various freshwater flow rates suggested that below 750 cfs, PCB concentrations were nondetectable at Great Barrington.

As will be discussed further in Chapter 4, the PCB concentration used when flow is less than 750 cfs depends on the time period of application. For the model verification (October 1979 to April 1993), the October 1979 PCB concentration during flows less than 750 cfs was estimated to be approximately 0.030 μg/l from surficial sediment PCB data. For the 50-year model projection (1992 to 2042), the 1992 surficial sediment data were used to estimate a low-flow (i.e., less than 750 cfs) PCB concentration of 0.020 μg/l. Details of these calculations are provided in Section 4.2.9.

Multiple regression analysis of PCB concentrations at flows greater or equal to 750 cfs yielded the following statistically significant model:

SOURCE	DF	SS	MS	F	Prob. > F
Constant	1	0.4155	0.4155		
Model	1	0.1213	0.1213	32.34	<0.001
Error	46	0.1725	0.0004		
Total	47	0.2938	0.0006		

The overall $r^2 = 0.4128$ and model coefficients were:

VARIABLE	DF	EST.	S.E.	T	Prob.
Intercept	1	0.0480	0.0119	4.04	0.0002
TSS	1	0.0021	0.0004	5.69	<0.0001

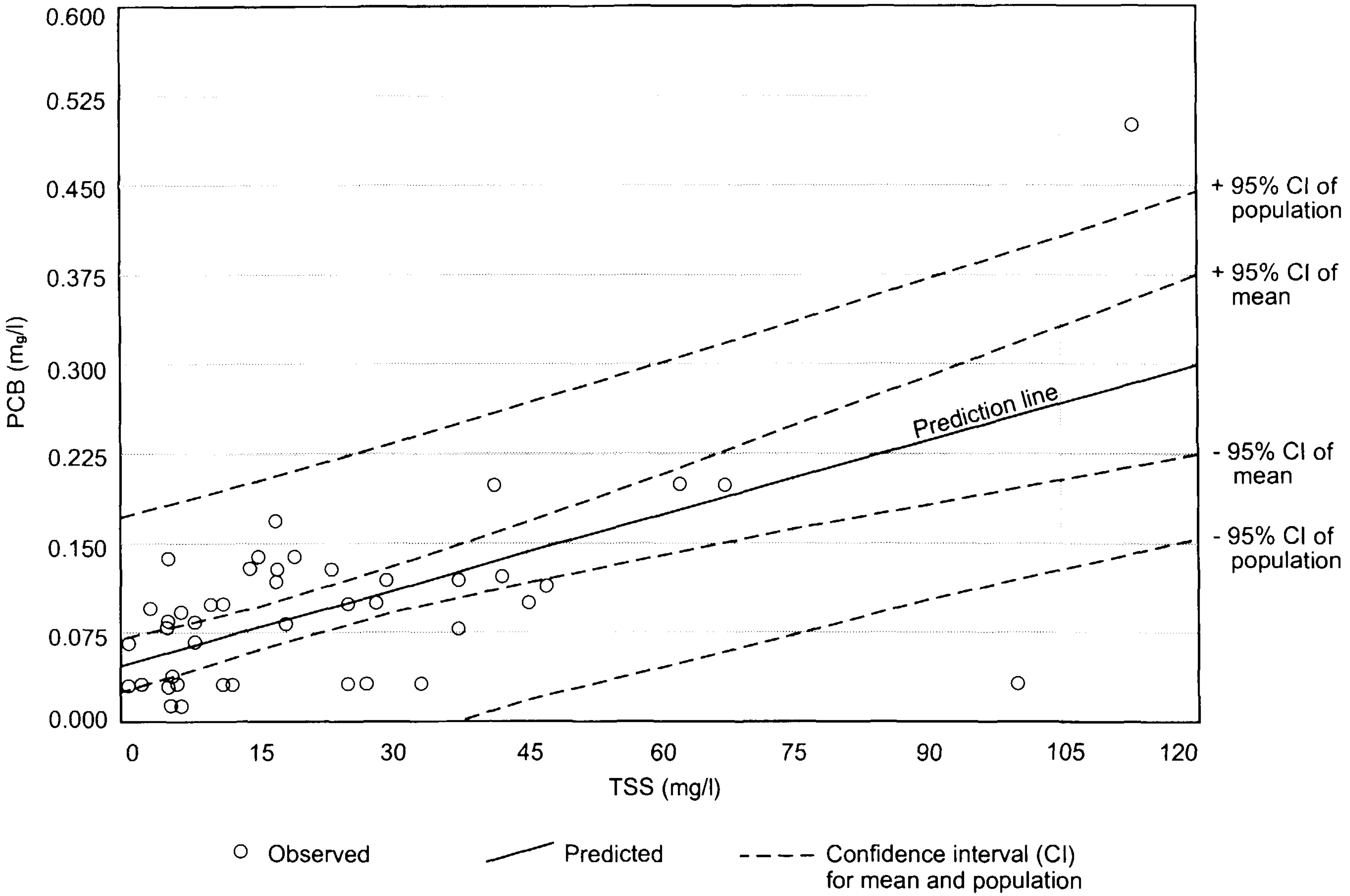
Therefore, for flows less than 750 cfs, the initial PCB concentration for the time period of interest is estimated as provided above. For flows greater than 750 cfs, the following equation applies:

$$PCB = 0.048 + 0.0021 \times TSS \qquad \textbf{(Equation 3-5)}$$

Figure 3-15 shows the fit of Equation 3-5 to the data for the 18 month period from March 1979 to October 1980. A plot of predicted PCB concentrations corresponding to the 18-month period of daily flow record at Great Barrington is presented in Figure 3-16.

It should be noted that *Time (Days* from 4 October 1979), which had been included in our previous model, was not included in the current model. Although this term indicated a slight decrease in PCB concentrations over time, it was not statistically significant in the previous model or in the current analysis. The large number of nondetected values in the database (Table 3-4) makes it difficult to discern a trend relative to time for the water column data.

However, decreasing PCB concentrations in surficial sediment and insect larvae strongly suggest that water column PCB is also decreasing in concentration. The following section evaluates PCB decay rates for these other media and compares them to the statistically weak relationship in the water column.



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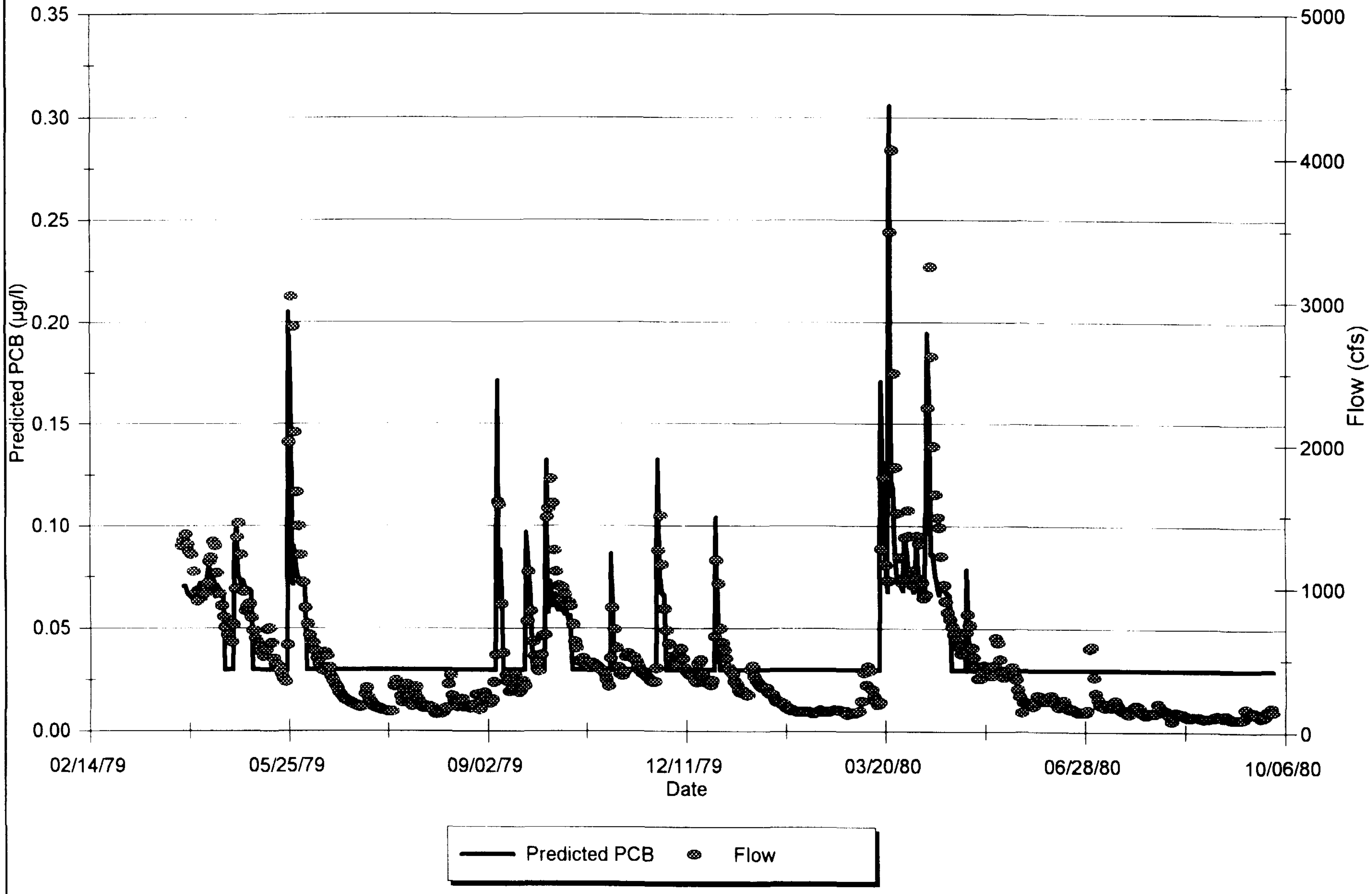
PCB vs TSS for Flows Greater than 750 cfs

Figure 3-15

337042pc ds4



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Predicted PCB Concentration and Observed Flow at Great Barrington

Figure 3-16

337\042TBLK ds4

3.3.3 Reduction of PCBs With Time

Three data sets are used to evaluate the rate at which PCB concentrations change with time:

(1) Surficial sediment PCB concentration from 1975-1978 to 1992 between Great Barrington (MP 106.2) and the Stevenson Dam (MP 19.5)

(2) Invertebrate filter-feeder PCB concentrations between 1978 and 1993 at Cornwall (MP 66)

(3) Water column PCB concentration data at Great Barrington from 1979 to 1993

A simple model of exponential decay is assumed:

$$c_t = c_o e^{-kt} \qquad \textbf{(Equation 3-6)}$$

where:

c_t = predicted PCB concentrations at time t (μg/l)
c_o = PCB concentration at t= 0 (μg/l)
k = PCB reduction rate (1/d)
t = time (days from t= 0)

Surficial Sediment PCB Data

Model segment-averaged PCB concentrations of the 1975-1978 samples are compared to the 1992 samples. Model segmentation is discussed in Chapter 4. Reduction rate (k) is calculated by rearranging Equation 3-6 as follows:

$$k = ln\ (c_t - c_o)/t \qquad \textbf{(Equation 3-7)}$$

c_t is taken as the 1992 data and c_o is the 1975 to 1978 data. The value of t is the time period between the midpoint of the 1975 to 1978 sampling surveys (30 January 1976) and the 1992 survey (1 September 1992). Table 3-6 provides the calculated reduction rate for each segment and shows the average reduction rate for the study area of -0.0001232/day, which corresponds to a loss of 4.5% per year. This value is consistent with the reduction rate of 5.0% per year

TABLE 3-6

EVALUATION OF PCB REDUCTION RATE IN SURFICIAL SEDIMENT

MODEL SEGMENT	DESCRIPTION	Avg PCB - Measured 01/30/76 c_0 (mg/kg)	Avg PCB - Measured 09/01/92 c_t (mg/kg)	ΔT (days)	REDUCTION RATE (1/day) "k"
12	Great Barrington	1.10	0.97	6059	-0.000021
13	Christian Hill	1.38	0.88	6059	-0.000074
14	Sheffield Flats	0.57	0.17	6059	-0.000200
15	Sheffield Flats	0.72	0.46	6059	-0.000074
16	MA/CT Line	0.70	0.75	6059	0.000011
17	Falls Village Reservoir	0.68	0.31	6059	-0.000130
18	Kent	0.15	0.06	6059	-0.000151
19	Bulls Bridge Reservoir	0.20	0.22	6059	0.000016
20	Gaylordsville/New Milford	0.22	0.09	6059	-0.000148
21	Lake Lillinonah	0.89	0.18	6059	-0.000264
22	Lake Zoar	0.70	0.10	6059	-0.000321
Average					-0.0001232

$$k = (\ln c_t - \ln c_0)/\Delta T$$

used in LMS (1991). However, this evaluation is limited by the fact that the 1975 to 1978 samples were from the top 6-in. of surficial sediment and the 1992 samples were taken from the top 3 in.

Invertebrate Filter-Feeder Data

PCB concentrations in benthic invertebrates in the Housatonic River at Cornwall (MP 66) have been monitored from 1978 to 1993 by CDEP and the Academy of Natural Sciences of Philadelphia (The Academy of Natural Sciences of Philadelphia 1993). Insects included caddisflies and predatory insects (stoneflies and dobsonflies). The caddisfly is a filter-feeding organism with a lifespan of approximately 1 year. Samples were collected in the spring. These insects use an external "net" to capture waterborne particles upon which it feeds. Thus, given their 1-year lifespan and feeding mechanism, PCB concentrations in the caddisfly would be expected to be representative of the year-to-year PCB concentrations in the water column. Because predatory insects have a longer life span (approximately 2 years) and they feed on other organisms, PCB concentrations in stoneflies and dobsonflies would not be as directly related to year-to-year changes in water column PCB. Thus, only the caddisfly data are used in this analysis.

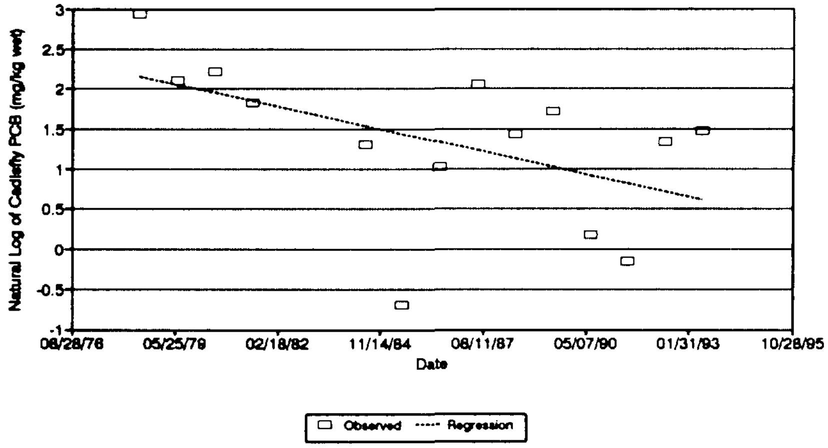
For the exponential decay expression given in Equation 3-6, a linear regression of *ln c* vs *t* provides the slope that is equal to the decay rate. Figure 3-17 shows the caddisfly data and also shows the regression fit relative to the data. Although PCBs appear to have declined in more recent years, the correlation coefficient (r^2) of 0.267 for the small data population (12 degrees of freedom) indicates that the fit is not statistically significant. The estimated reduction rate is -0.00028/day or a reduction of 10.2% per year.

Water Column PCB Data

All available water column PCB data from 1979 to 1993 (excluding the surveys from 16 April to 3 June 1992, which were affected by construction activities at the Rising Pond Dam) for the Great Barrington station (MP 106.2) were analyzed to identify a temporal trend (see Table 3-4 for data). Figure 3-18 shows a plot of the PCB concentrations as well as regression statistics for the *ln*-transformed data. Nondetections are considered to be the detection limit divided by 2. The coefficients of determination (r^2) of 0.127 for non *ln*-transformed data and 0.079 for *ln*-transformed data were obtained. At a 95% probability level, there is no significant trend of total PCB as a function of time. Furthermore, the regression results on detectable concentrations only resulted in an r^2 of 0.086, which does not show a significant trend. However, the results are suggestive of a declining trend in PCB concentrations. The

Date	PCB Conc. in Cadisfly Conc mg/kg wet	Ln of Conc mg/kg wet
06/15/78	18.9	2.94
06/15/79	8.2	2.10
06/15/80	9.2	2.22
06/15/81	6.2	1.82
06/15/84	3.7	1.31
06/15/85	0.5	-0.69
06/15/86	2.8	1.03
06/15/87	7.9	2.07
06/15/88	4.2	1.44
06/15/89	5.6	1.72
06/15/90	1.2	0.18
06/11/91	0.86	-0.15
06/15/92	3.83	1.34
06/08/93	4.35	1.47

Semi-log Regression Results
Cadisfly



Regression Statistics

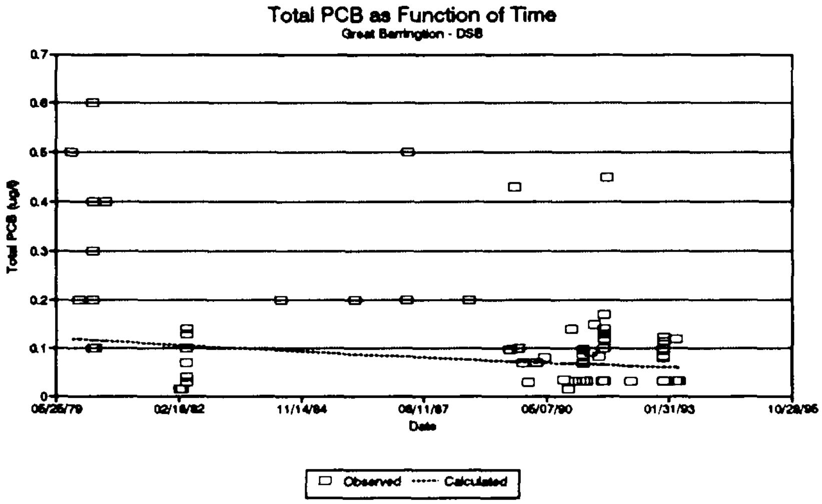
Regression Output:

Constant	10.24205
Std Err of Y Est	0.878573
R Squared	0.267397
No. of Observations	14
Degrees of Freedom	12

X Coefficient(s)	-0.00028
Std Err of Coef.	0.000135

Caddisfly PCB Regression Results

Figure 3-17



Natural Log transformed PCB Data
Regression Output

Constant		-2.11976
Std Err of Y Est		0.881928
R Squared		0.078917
No. of Observations		86
Degrees of Freedom		84
X Coefficient(s)	-0.00014	
Std Err of Coef.	5.23E-05	

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Regression of Water Column PCB vs Time at Great Barrington

Figure 3-18

1337\042TBLK ds4
disk HS4300 file PCBALL.wq1

exponential reduction rate [k] (i.e., slope of the *ln*-transformed PCB data vs time) is 0.00014/day or 5.1% per year, which is consistent with the value of 4.5% per year as determined from surficial sediment data and 5% per year used in LMS (1991).

The following table summarizes the reduction rates obtained using the above three methods and the rate used previously in LMS (1991):

METHOD	EXPONENTIAL REDUCTION RATE (1/DAY)	COMMENT
Surficial sediment	-0.000145	
Invertebrate caddisfly	-0.00028	Not statistically significant but suggestive of decline
Water column at Great Barrington	-0.00014	Not statistically significant but suggestive of decline
Estimate used in 1991 modeling report	-0.000137	5% per year

As indicated, there is consistency between the various methods and what was used previously. Thus, we are continuing to use the 1991 estimate of 5% per year, or 0.000137/day for the current model application.

CHAPTER 4

PCB FATE AND TRANSPORT MODEL

In this chapter the Housatonic River Model (HOUSRM) is described as a series of steps: parameters are evaluated, refinements to the model calibration are made, the model is verified, and model projections of sediment and water column PCB are made. Calibration of the model for TSS was performed in LMS (1991) and was based on monthly average flow, sediment resuspension values, and the upstream TSS boundary condition. The current model has been improved by using event-specific hydrological, resuspension, and boundary condition inputs. This change from a monthly-averaged model to an event-specific model as well as revisions to bulk density values and the evaluation of resuspension in the Sheffield Flats required some refinements to the flow-dependent sediment resuspension values used in LMS (1991).

4.1 DESCRIPTION OF WASTOX MODEL

The model applied to this study of the Housatonic River, WASTOX2 (Version 2.51), is a revised version of the modeling framework WASTOX developed at Manhattan College for the U.S. Environmental Protection Agency (EPA) (Connolly and Winfield 1984). The original Version 1.0 of WASTOX was used for the Chapter 6 report (LMS 1988). WASTOX2 was also used in LMS (1991). All subsequent reference to the WASTOX model refers to the most current version (2.51).

The model was developed to: (1) provide a tool for performing waste load allocations and (2) evaluate how long it would take a contaminated water system to recover to some specified level. The model's latter function is the primary application for this study. The results of these projections will be discussed in Section 4.6.

The model is used to determine the fate of the contaminant by considering the processes of transport, transfer, and reaction as defined below:

- **Transport** is the physical movement of the chemical caused by the net advective movement of water, mixing, and the scouring and deposition of solids to which the chemical may be adsorbed. It is specified by the flow and dispersion characteristics of the natural water system and the settling velocity and resuspension rate of the solids in the system.

- **Transfer** is the movement of the chemical between the air, water, and solid phases of the system. It includes the processes of volatilization, adsorption/desorption, and diffusion.

- **Reaction** is the transformation or degradation of the chemical. It includes biodegradation and the chemical reaction processes of photolysis, hydrolysis, and oxidation. These reaction mechanisms are not used in HOUSRM as decay rates of PCB by these processes have not been fully evaluated as of yet.

The general expression for the mass balance equation about a specified volume, V, is:

$$V \frac{dc}{dt} = J + \Sigma R + \Sigma T + \Sigma W$$

(Equation 4-1)

where:

c = concentration of chemical (e.g., PCBs)

t = time

J = transport through the volume

T = transfer from one phase to another

R = reactions within the volume

W = wasteload inputs

The model is assumed to be one-dimensional along the longitudinal axis of the Housatonic River; however, it represents each water segment overlying a segment of active bed sediment. River flow advects water through the overlying water segments and is the driving force for the resuspension of solids from the bed segment. We assume that there is no direct advection from one bed sediment segment to another, i.e., bedload is negligible.

The total concentration of PCBs either in the water column or bed consists of the free dissolved, dissolved but adsorbed to DOC, and particulate components:

(Equation 4-2)

$$c_t = \phi \, c_d + m \, c_p + c_{doc} \, [DOC]$$

where

c_t = total concentration of PCBs (M/L^3)*

ϕ = porosity [$L^3{}_{water}/L^3{}_{(solids\ +\ water)}$] (i.e., void space)

c_d = water-specific concentration of dissolved PCBs

m = solids concentration (M/L^3)

c_p = solid-specific concentration of particulate PCBs (M/M) [e.g., μg of PCB/g of solids]

c_{doc} = DOC-specific concentration of PCBs (M/M) [e.g., μg PCB/g DOC]

DOC = concentration of dissolved organic carbon (M/L^3)

The subscripts t, d, p, and doc refer to total, dissolved, particulate and DOC-sorbed PCB, respectively.

For the water column, where ϕ is essentially equal to 1, no porosity correction is required; however, for the sediment, where ϕ is typically about .7 - .8, this correction is important.

For PCBs in natural water systems, the sediment sorption isotherm is assumed to be linear and the relationship between the particulate and dissolved components is governed by the solids partition coefficient ($\P_s$) with units (L^3/M):

$$\P_s = \frac{c_p}{c_d} \qquad \textbf{(Equation 4-3)}$$

The exchangeable partition coefficient ($\P_s^x$) describing the linear isotherm at a fixed solids concentration has been shown for numerous chemicals to depend on the concentration of adsorbing solids as a result of interactions between the moving solid particles. The exchangeable partition coefficient applies only to the "reversible fraction of adsorbed chemical and not to the fraction of chemical that is resistant to desorption. The following empirical equation describes this effect (Di Toro 1985):

---

*Units are denoted as M = mass, L = length, T = time.

$$\P_s^x = \frac{F_{oc}\P_{oc}^x}{1 + mF_{oc}\P_{oc}^x/\nu_x} \qquad \textbf{(Equation 4-4)}$$

where:

m = concentration of solids (M/L^3)

F_{oc} = weight fraction of organic carbon of the total solids concentration ($M_{organicC}/M_{solids}$)

$\P_{oc}^x$ = the exchangeable (x) organic carbon (oc) partition coefficient ($M_{Toxicant}/M_{organic\ carbon} \div M_{Toxicant}/L^3{}_w$)

υ_x = dimensionless reaction rate constant (ratio of adsorption reaction rate constant to particle interaction induced desorption rate constant); equals 1.4 (Di Toro 1985)

The theory that partitioning is a function of adsorbing solids concentration has been questioned and is further discussed in Section 4.2.5. Furthermore the empirical effect of the resistant fraction of PCB is also discussed in Section 4.2.5.

For organic chemicals, $\P_{oc}^x$ has been shown to be approximately equal to the product of the fraction organic carbon (F_{oc}) of the solids and the octanol-water partition coefficient (K_{ow}) of the chemical (Connolly and Winfield 1984).

The model uses this solids-dependent partitioning to compute the particulate and dissolved components of PCBs in the water column. In the sediment, a constant partition coefficient defined by F_{oc} and K_{ow} is used. A resistant fraction of the chemical can also be included in the model but as discussed in Section 4.2.5, data on the resistant fraction of PCB in the Housatonic River has not been collected, and thus, an alternative approach is used.

The model also includes partitioning of PCBs to DOC. Once PCBs partition to DOC they are transported in the same manner as dissolved PCB but are not subject to volatilization. The DOC partition coefficient ($\P_{doc}$) and DOC concentration are input directly to the model as constants. The DOC sorption isotherm is also assumed to be linear and the relationship between the DOC-sorbed and dissolved components is governed by the DOC partition coefficient ($\P_{doc}$) with units (L^3/M):

$$\P_{doc} = \frac{c_{doc}}{c_d} \qquad \text{(Equation 4-5)}$$

The bulk fraction of PCBs in the dissolved phase, f_d, is expressed as the water-specific concentration of dissolved PCBs and the porosity as expressed by the following equation:

$$f_d = \frac{\phi \, c_d}{c_t} = \frac{\phi}{\phi + \P_s m + \P_{doc} \, DOC} \qquad \text{(Equation 4-6)}$$

The bulk fraction of PCBs in the particulate phase, f_p, is similarly expressed as:

$$f_p = \frac{m \, c_p}{c_t} = \frac{\P_s m}{\phi + \P_s m + \P_{doc} \, DOC} \qquad \text{(Equation 4-7)}$$

The bulk fraction of PCBs sorbed to DOC, f_{doc}, is expressed as:

$$f_{doc} = \frac{c_{doc} \, [DOC]}{c_t} = \frac{\P_{doc} \, [DOC]}{\phi + \P_{doc} \, [DOC] + \P_s \, m} \qquad \text{(Equation 4-8)}$$

The combined fraction dissolved ($f_{(d+doc)}$) is the sum of equations 4-6 and 4-8.

As the wasteload inputs are assumed to be zero at present, the mass balance equation for PCBs in a water column segment is then written as:

$$\frac{dc_{t,w}}{dt} = - Qc_{t,w} + E \frac{dc_{t,w}}{dx} - v_s f_{p,w} A \, c_{t,w} \qquad \text{(Equation 4-9)}$$

$$+ \, v_u f_{p,b} A c_{t,b} - k_{t,w} V c_{t,w}$$

where:

first subscripts t, p, or d denote total, particulate, or dissolved phase; second subscripts w or b denote water or bed segment

V = segment volume (L^3)

Q = river flow (L^3/T)

x = longitudinal distance (L)

E = dispersion coefficient (L^2/T)

v_s = solids settling rate (L/T)

A = surface area between water and sediment segments (L^2)

v_u = solids resuspension rate (L/T)

$k_{t,w}$ = transfer/reaction rate coefficient ($1/T$)

The five terms of this equation represent advection, dispersion, settling, resuspension, and transfer/reaction of PCBs, respectively.

The bed sediment is modeled explicitly as an active layer of sediment of some prescribed depth (h) below which is the model boundary with the inactive bed. The active layer is assumed to be at equilibrium so that a solids mass balance states that the net settling and resuspension flux at the sediment-water interface is equal to the burial flux of sediment from the active to the inactive layer:

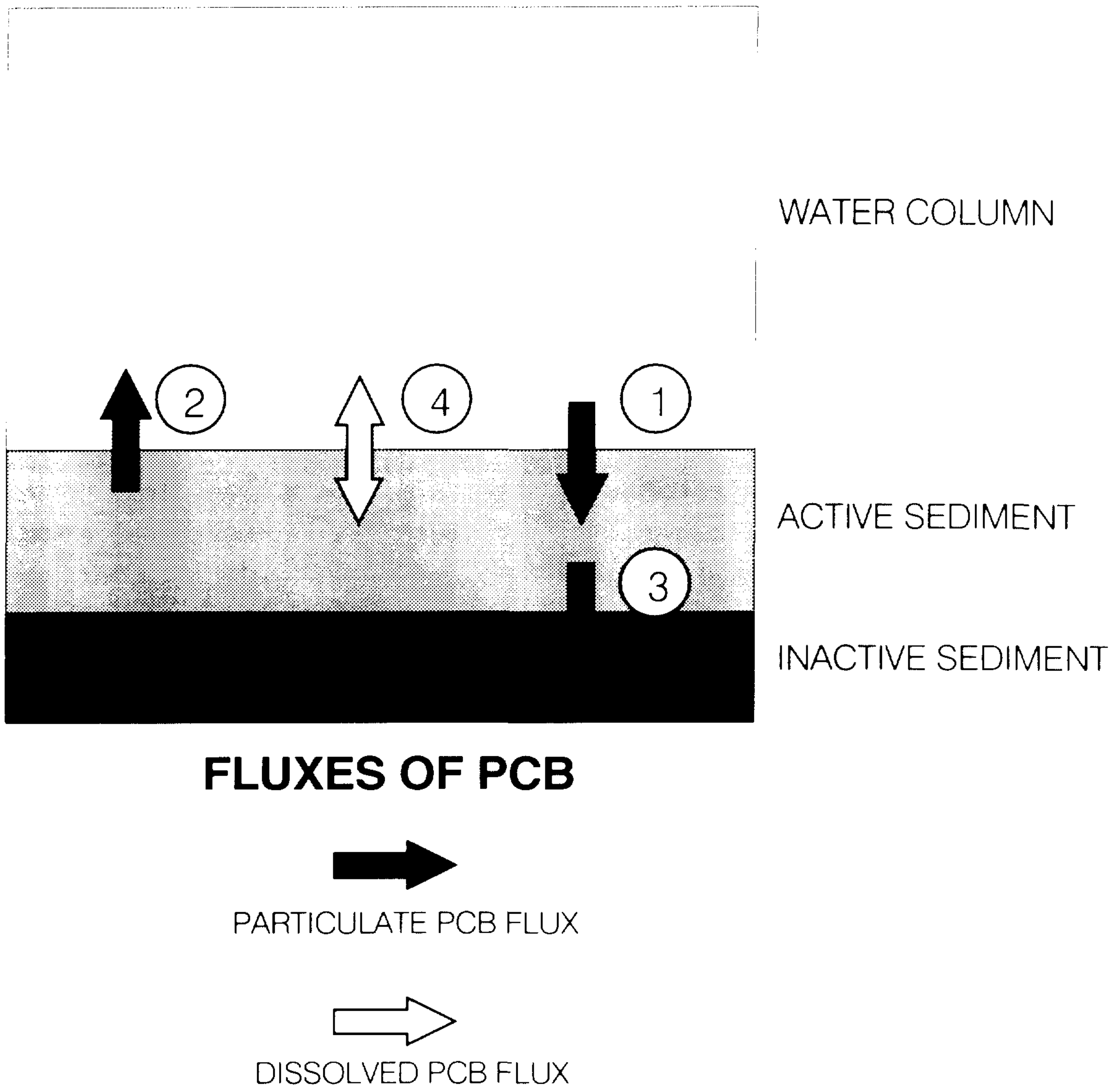
$$0 = \frac{1}{h} (v_s m_w - v_u m_b - v_b m_b) \quad \textbf{(Equation 4-10)}$$

where:

v_b = solids burial rate (L/T)

Assuming the depth of the active sediment layer is constant and the long-term trend is an accretion of bed sediments (at least in the lakes, impoundments, and depositional riverine segments), the solids burial rate may be viewed as the rate at which the sediment water interface moves upward away from a fixed datum such as bedrock. Similarly, for those riverine segments subject to a net solids loss from the bed, the solids scour rate may be viewed as the rate at which the sediment/water interface moves downward.

The fluxes of PCB associated with the active segment are shown schematically in Figure 4-1 and expressed by the equation:



PROCESS	MASS FLUX TERMS
① DEPOSITION OF SOLIDS	$\frac{v_s}{h} f_{p,w} c_{t,w}$
② SCOURING OF SOLIDS	$\frac{v_u}{h} f_{p,b} c_{t,b}$
③ NET SEDIMENTATION OR BURIAL	$\frac{v_b}{h} f_{p,b} c_{t,b}$
④ DIFFUSION OF DISSOLVED CHEMICAL	$\frac{DA}{h}\left[(f_{d,b} + f_{doc,b})c_{t,b} - (f_{d,w} + f_{doc,w})c_{t,w}\right]$

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Fluxes of PCB Associated with the Bed Sediment

Figure 4-1

$$\frac{dc_{t,b}}{dt} = \frac{v_s}{h} f_{p,w}\, c_{t,w} - \frac{(v_u + v_b)}{h} f_{p,b}\, c_{t,b} - \frac{DA}{h}\left[(f_{d,b} + f_{doc,w})c_{t,b} - (f_{d,w} + f_{doc,w})c_{t,w}\right] \qquad \text{(Equation 4-11)}$$

where:

D = diffusion rate coefficient (L^2/T)

4.2 PARAMETER EVALUATION

4.2.1 River Segmentation and Hydrology

HOUSRM extends from the Division Street Bridge in Great Barrington, Massachusetts (MP 106.2) to the Stevenson Dam (MP 19.6). Figure 4-2 shows the water column segmentation of HOUSRM.

The model divides the river into 11 segments, each with similar physical and hydrological characteristics (Table 4-1). The water segments are numbered from 1, for the segment with the Division Street Bridge (Great Barrington) at its upstream end, to 11, for the segment with the Stevenson Dam at its downstream end. Active bed-sediment layer segments below the water segments are numbered from 12, for the bed segment below water segment 1, to 22, for the bed segment below water segment 11. The physical characteristics of the model segments were evaluated based on available data in Frink et al. (1982) and QLM (1971).

Model segment-to-segment and tributary input flows were determined from available U.S. Geological Survey (USGS) monitoring records, where available, or estimated from drainage areas if flows were not available. Table 4-2 shows observed long-term average flows in the study area as well as those estimated by the indicated upstream drainage areas. Figure 4-2 also shows the average flows associated with each segment as well as tributary and additional flows to segments not associated with the named tributaries. Water quality stations are also indicated. Tributary and drainage area flows to the Housatonic River are modeled as inflows to the upstream end of the appropriate segments.

Model input flows are based on the daily flow records at the four USGS gaging stations in the Housatonic River at Great Barrington, Falls Village, Gaylordville, and Stevenson. The

ADDITIONAL FLOW (cfs) TO SEGMENT NOT ASSOCIATED WITH NAMED TRIBUTARY	TRIBUTARY	AVERAGE TRIBUTARY FLOW (cfs)	MP	MP		(Miles)	SEGMENT BOUNDARY NAME AND WATER QUALITY STATION LOCATIONS	AVERAGE MAINSTREAM FLOW (cfs)
				106.2	①	3.7	**Division St. Bridge, Great Barrington***	522
2	Williams R.	68	106.0					
25				102.4	②	3.8	**Christian Hill, Great Barrington**	592
			100.0	98.6	③	6.3	**Sheffield Flats**	617
1	Green R.	79					Kellog Rd. Bridge (mp 97.6)	
							Maple Ave. Bridge (mp 93.5)	
				92.3	④	9.2	**Sheffield Flats**	696
9	Hubbard Br.	40	90.0					
							Andrus Rd. Bridge (mp 86.2)	
173	Blackberry R.	74		83.1	⑤	1.9	**CT-MA State line**	745
				81.2	⑥	5.3	**Falls Village Res.**	992
88.5	Salmon Cr.	4.5	80.0				Canaan (mp 80.0)*	
	Hollenbeck R.	4.0						
				75.9	⑦	18.2	**Falls Village Dam**	1089
							Falls Village Bridge (mp 75.0)*	
191			70.0					
							Cornwall (mp 66.0)*	
							Kent (mp 58.4)*	
75			60.0	57.7	⑧	4.6	**Bulls Bridge Res.**	1280
214	Ten Mile R.	303		53.1	⑨	10.9	**Bulls Bridge Dam**	1355
			50.0				Gaylordsville (mp 50.6)*	
							New Milford (mp 46.0)*	
				42.2	⑩	12.6	**Lake Lillinonah**	1872
161	Still R.	116						
	Shepaug R.	236	40.0					
							Brookfield Center (mp 37.0)*	
				34.2			Rt. 133 Bridge (mp34.2)*	
							Shepaug Dam	2385
63	Pootatuck R.	48	30.0	29.6	⑪	10.0	Lake Zoar	
	Pomeraug R.	128					Glen Rd. Bridge (mp 27.3)*	
							Riverside (mp 25.1)*	
			20.0	19.6			**Stevenson Dam**	2624
			18.0					

* Water quality stations

133/1042modsg pmb

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SCHEMATIC OF MODEL SEGMENTS AND RIVER FLOWS OF HOUSATONIC RIVER

FIGURE 4-2

TABLE 4-1

PHYSICAL CHARACTERISTICS OF MODEL SEGMENTS

SEGMENT No.	MILE POINT (FROM LI SOUND)	LENGTH (ft)	WIDTH (ft)	DEPTH (ft)	SURFACE AREA (ft^2 X 10^6)	X-SECT AREA (ft^2)	VOLUME (ft^3 X 10^6)
1 (water)	106.1-102.4	19536	92	9.0	1.80	828	16.18
12 (bed)				0.083		7.64	0.15
2 (water)	102.4-98.6	20064	93	9.1	1.87	846	16.98
13 (bed)				0.083		7.72	0.15
3 (water)	98.6-92.3	33264	87	12.2	2.89	1061	35.31
14 (bed)				0.083		7.22	0.24
4 (water)	92.3-83.1	48576	113	11.7	5.49	1322	64.22
15 (bed) MA				0.083		9.38	0.46
5 (water) CT	83.1-81.2	10032	230	2.3	2.31	529	5.31
15 (bed)				0.083		19.09	0.19
6 (water)	81.2-75.9	27984	165	10.7	4.62	1766	49.41
17 (bed)				0.092		15.18	0.42
7 (water)	75.9-57.7	96096	242	2.4	23.26	581	55.81
18 (bed)				0.083		20.09	1.93
8 (water)	57.7-53.1	24288	208	15.5	5.05	3224	78.30
19 (bed				0.175		36.40	0.88
9 (water)	53.1-42.2	57552	225	3.9	12.95	878	50.50
20 (bed)				0.083		18.68	1.07
10 (water)	42.2-29.6	66578	1034	38.9	68.79	40223	2675.93
21 (bed)				0.213	58.47	220.24	12.47
11 (water)	29.6-19.6	52800	804	24.6	42.45	19778	982.00
22 (bed)				0.213	31.01	171.25	6.61

TABLE 4-2

DRAINAGE AREAS AND LONG-TERM AVERAGE FLOWS

STATION	MILE POINT	DRAINAGE AREA (Sq. miles)	AVERAGE FLOW (cfs)
Great Barrington, MA*	106.2	280	530
Green River	98.6	51	79
MA-CT state line	83.1	545	910
Blackberry River*	82.0	48	74
Falls Village Res.	81.2	580	990
Salmon Creek*	79.0	29.4	48.5
Hollenbeck River	77.3	24	40
Falls Village Dam*	75.9	635	1087
Bulls Bridge Res.	57.7	745	1278
Bulls Bridge Dam	53.1	791	1353
Ten Mile River*	52.1	203	303
Gaylordsville*	50.6	993	1701
Still River*	40.6	70	116
Lake Lillinonah	40.1	1224	1980
Shepaug River	31.8	133	236
Shepaug Dam	29.6	1392	2380
Pootatuck River*	27.2	24.2	48
Pomperaug River*	26.1	75.1	128
Stevenson Dam	19.5	1544	2620

*USGS flow data available.

WASTOX model allows up to 400 flow values per segment interface to define the flows from segment to segment and tributary to segment (i.e., a WASTOX simulation can have up to 400 changes in flow at variable time steps). HOUSRM is applied to three time periods as follows:

- Calibration refinement - 18-month period from 1 April 1979 to 1 October 1980
- Verification - 13.5-year period from 1 October 1979 to 9 April 1993
- Projection - 50-year period from 1992 to 2042.

Flow, resuspension, and boundary condition model inputs during high-flow events were generally defined using daily time steps, and during low flows time steps were broader (e.g., 15 to 90 days). This method preserves the large variations in these parameters during events; during low-flow conditions, when these parameters do not vary substantially, the model input time steps are appropriately longer.

4.2.2 **Bed Sediment Characteristics**

Model segments 12 through 22 represent the active bed sediment layers beneath the 11 water segments. Segments 12-15 are in Massachusetts and segments 16-22 are in Connecticut. Table 4-3 summarizes the bed fraction of organic carbon (F_{oc}), bulk density, and initial PCB concentrations for the model verification period (1979 to 1993) and the model projection period (1992 to 2040). Note that the F_{oc} and bulk density input to the verification and projections are based on the 1992 LMS survey results. Previously, in LMS (1991), values from Frink (1982) were used. However, those bulk density values were estimated from a simple regression of limited bulk density measurements vs percent sand (see Section 3.2). Thus, as percent sand was measured throughout the study area, it was used previously as an estimator of bulk density. In 1992 bulk density was measured directly in 10 out of the 11 model segments, thereby providing a more dependable source for the bulk density values. Extensive F_{oc} values throughout the study area were available in Frink (1982). However, as discussed in Section 3.3.1, a system-wide decrease in sediment F_{oc} apparently occurred between 1976 and 1992. Water column TOC data suggest that this decrease may have begun in 1979. However, the WASTOX2 model input format for F_{oc} is a constant value for each segment. Thus, it is not possible to vary this parameter with time. Because the model verification time period is from 1979 to 1993 and evidence suggests a late 1979 change in river TOC, the 1992 surficial sediment F_{oc} values are used for model verification.

TABLE 4-3

BED SEDIMENT CHARACTERISTICS OF MODEL SEGMENTS

				BULK DENSITY[a]		INITIAL PCB CONCENTRATION FOR MODEL VERIFICATION[b]			INITIAL PCB CONCENTRATION FOR MODEL PROJECTION[a]		
SEGMENT No.	FRACTION OF ORGANIC CARBON (%)	No. OF SAMPLES[a]	SAND CONTENT[a] (%)	(lb/ft^3)	(g/ml)	(mg/kg)	(mg/l)	No. OF SAMPLES	mg/kg	mg/l	No. OF SAMPLES
12	2.7	2	95.5	60.5	0.969	1.10	1.07	4	0.97	0.94	2
13	2.7	2	49.7	48.4	0.775	1.38	1.07	6	0.88	0.68	2
14	0.3	4	84.8	95.0	1.530	0.57	0.87	6	0.17	0.26	4
15 (MA)	0.7	4	47.6	85.2	1.364	0.72	0.99	20	0.46	0.62	4
16 (CT)	1.0	2	50.1	79.6	1.275	0.70[d]	0.90	-	0.75	0.95	2
17 (Falls village Res.)	1.6	6	30.3	58.9	0.943	0.68	0.62	11	0.31	0.29	6
18	0.8	5	76.0	64.0	1.025	0.15	0.15	4	0.06	0.06	5
19 (Bulls Br. Res)	2.6	5	77.1	88.7	1.421	0.20	0.28	5	0.22	0.31	6
20	1.6	6	-	86.2[c]	1.380[c]	0.22[e]	0.31	-	0.09	0.13	6
21 (Lake Lillinonah)	2.4	8	41.0	52.4	0.839	0.89	0.75	29	0.18	0.15	8
22 (Lake Zoar)	2.3	8	45.9	35.1	0.562	0.70	0.39	25	0.10	0.05	8

[a] Data from LMS surveys in 1992.

[b] Data from Frink et al. (1982) and Stewart Labs (1982) combined.

[c] Bulk density not measured in 1992; used Frink (1982) estimate.

[d] No 1975-1978 PCB data available in this segment; used average of surrounding segments.

[e] No 1975-1978 PCB data available in this segment; used nearest station result in segment 21 (Lake Lillinonah).

Note: Frink samples taken from top 6 in. of bed, Stewart samples from top 6.3 in. of bed, and LMS samples from top 3 in. of bed.

4.2.3 Settling, Resuspension, and Burial

Calibration of the model TSS concentrations was demonstrated in LMS (1991) for monthly-averaged river flow conditions. Because transport of sediment containing sorbed PCB is highly affected by high flow events, the model has been refined to include event-specific (i.e., rainfall-runoff events) flow, resuspension, and TSS and PCB upstream boundary inputs. The change from monthly-averaged to event-specific resuspension input as well as revisions to bulk density and evaluation of resuspension in the Sheffield Flats required some further calibration efforts to evaluate the appropriate resuspension rates that would result in accurate simulations of daily TSS values.

Suspended solids settling rates [v_s(m/d)] are based on the Stokes settling velocity equation as follows:

$$v_s = \frac{g}{18}\left(\frac{\rho_s - \rho}{\mu}\right) d^2 \ x \ 8.64 \ x \ 10^{-6} \qquad \textbf{(Equation 4-12)}$$

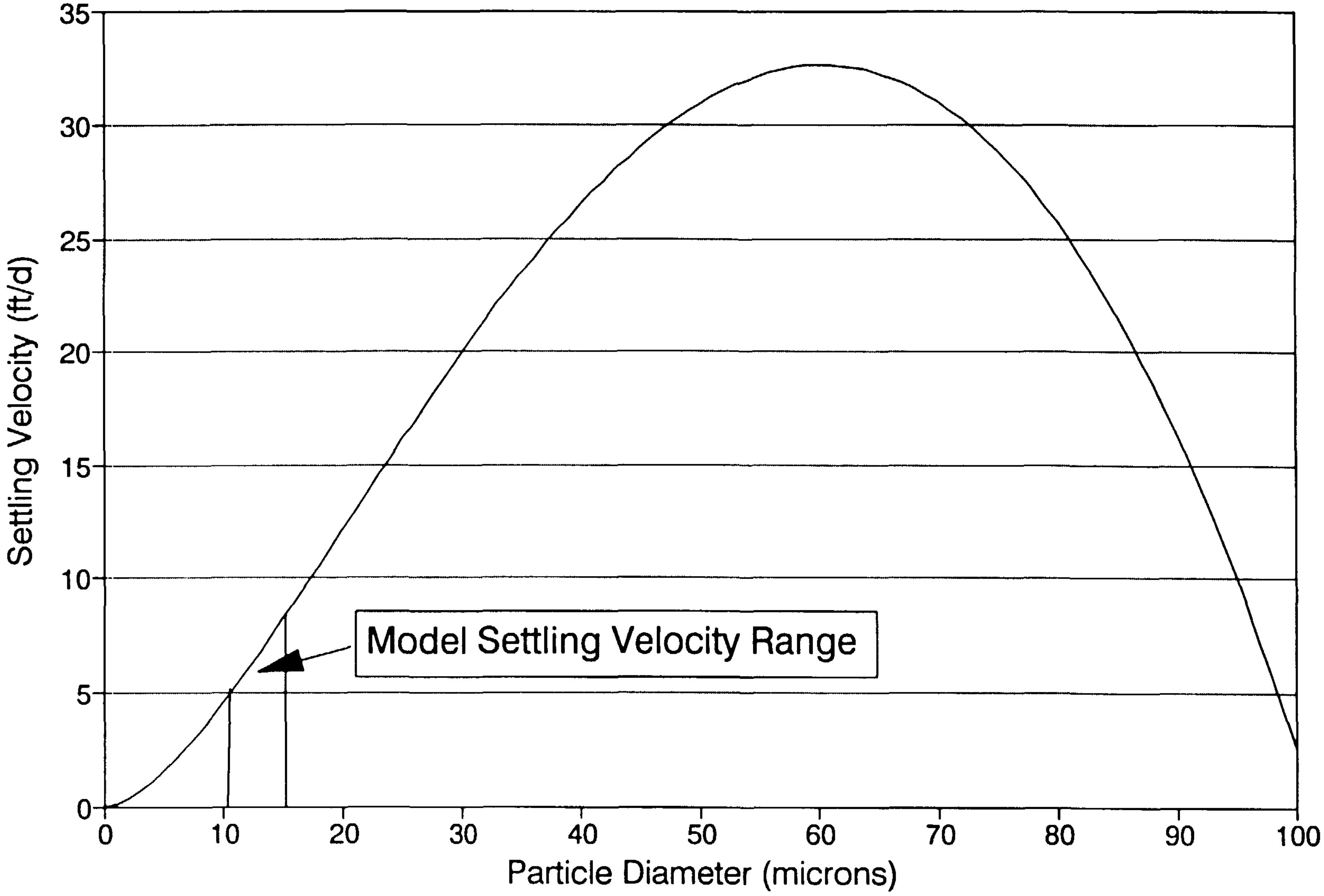
where:

g = acceleration due to gravity (cm/s^2)
ρ_s = particle density (g/cm^3)
ρ = water density (g/cm^3)
μ = dynamic viscosity (g/cm•s)
d = particle diameter (μm)

Clay and silt particles contain the most organic carbon and therefore serve as the predominant binding site for PCBs. These particles range in diameter from 0.2 to 62 μm. We are using a particle diameter range of 10 to 15 μm to estimate the settling velocity. Such diameters represent those particles that Frink (1982) found to be correlated with highest PCB concentrations in the lakes and also result in settling velocities consistent with those used by others as discussed below. DiToro and Nusser (1976) [in Thomman 1987] determined the following empirical relationship to relate particle density to particle diameter:

$$\rho_s = 2.0 \ d^{-0.15} \qquad \textbf{(Equation 4-13)}$$

Application of Equations 4-12 and 4-13 to a range of particle diameters is shown graphically in Figure 4-3. Dynamic viscosity (μ) at 10°C is 0.01307 g/cm•sec, acceleration due to gravity (g) is 981 cm/sec^2, and water density (ρ) is 1 g/cm^3. As indicated, the range of v_s for particles



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Stokes Settling Velocity vs Particle Diameter

Figure 4-3

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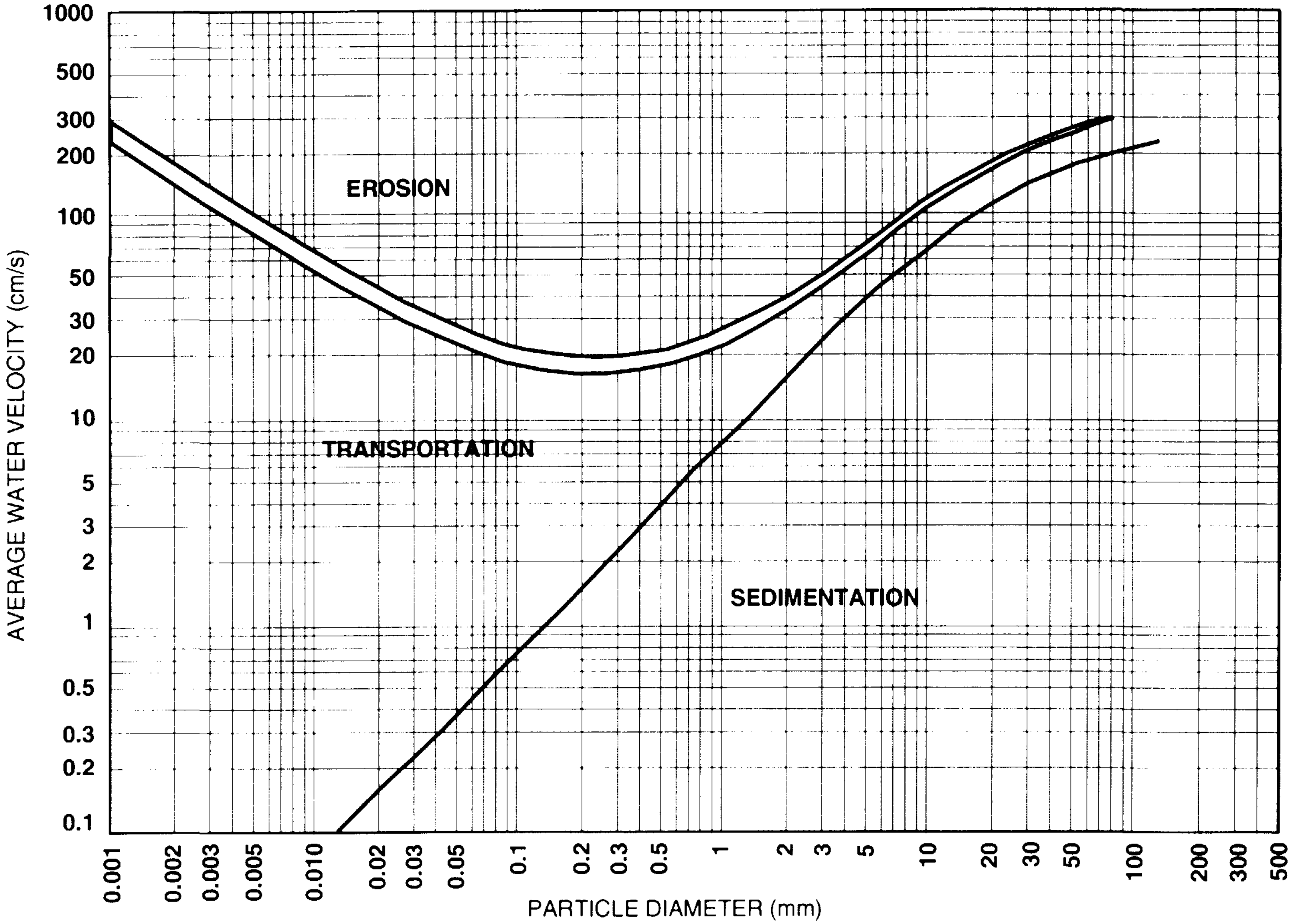
10 to 15μm in diameter and 1.416 to 1.332 g/cm^3 in particle density is 4.5 to 8.3 ft/day. A constant value of 6.35 ft/day is used in all 11 model segments; this is similar to the settling rate of 6 ft/day for riverine segments in the previous model (LMS 1991). Thomann and DiToro (1983) found that a v_s value of 8.2 ft/day was reasonable for the Great Lakes.

Available TSS data were evaluated to develop initial estimates of flow-dependent sediment resuspension relationships for each model segment. These initial estimates were then adjusted in the calibration procedure. The model calibration period is for 18 months from April 1979 to October 1980, when daily TSS measurements were taken at three Housatonic River stations. The results of this calibration effort is provided in Section 4.3. Sediment resuspension occurs when the frictional drag of flow on sediment particles (i.e., shear stress) is sufficient to dislodge particles into the water column (Graf 1971). Shear force is dependent on the velocity and turbulence of water transport, which is dependent on river flow. As river flows increase, velocity increases and sediment resuspends from the bottom and washes into the water from bank erosion. Figure 4-4 (Hjulstrom 1935 [in Graf 1971]) shows regions of sediment erosion, transportation, and sedimentation as a function of average water velocity and particle diameter. For particle diameters of 10-15 μm (i.e., 0.010 to 0.015 mm) velocities of approximately 45 to 55 cm/sec are the threshold values above which sediment erosion and resuspension would be expected to occur.

Table 4-4 shows the average water velocities in each segment and indicates whether scour, transport, or deposition is expected to occur according to the criteria given in Figure 4-4 and the assumption of a 0.015-mm particle diameter. As indicated, the average velocities in segments 5, 7, and 9 are high enough to cause scour. Table 4-4 also indicates that deposition would not occur for a 0.015-mm particle in any of the segments for average velocities. However, grain-size analyses of bed sediment do show a substantial percentage of particles less than 0.015 mm. These particles may settle during low flows, when velocities are less than average.

It is important to note that the use of a 0.015-mm particle in the model is a simplifying assumption, and that there is a wide range of particle diameters. In fact, Table 3-1 indicates that 45 to 60% of particles (averages for all model segments for Frink and LMS, respectively) are above the upper limit of silt size (0.062 mm in diameter). Although WASTOX2 can accommodate up to three different types of solids, sufficient data were not available on particle size distributions of TSS to support a more detailed analysis of particle-specific solids settling rates.



Source: Hjulstrom (1935)

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EROSION-SEDIMENTATION CRITERIA FOR UNIFORM PARTICLES

FIGURE 4-4

TABLE 4-4

SUMMARY OF HJULSTROM'S (1935) SEDIMENT SCOUR AND TRANSPORT FOR THE 15 μm PARTICLE CRITERIA

SEGMENT No.	DESCRIPTION	AVERAGE FLOW (cfs)	AVERAGE VELOCITY (cm/s)	(BASED ON HJULSTROM (1935) CRITERIA)[1] SCOUR	TRANSPORT
1	Great Barrington	592	20		✓
2	Christian Hill	617	22		✓
3	Sheffield Flats	696	19		✓
4	Sheffield Flats	745	17		✓
5	MA/CT Line	992	50	✓	
6	Falls Village Res.	1089	18		✓
7	Kent	1280	62	✓	
8	Bulls Bridge Res.	1355	13		✓
9	Gaylordsville	1872	56	✓	
10	Lake Lillinonah	2385	2		✓
11	Lake Zoar	2624	4		✓

[1] Hjulstrom's study does not support deposition for particles less than 15 μm in any segment (for average flow conditions) but grain size analysis clearly shows deposition of silt and clay sized particles in the lakes and reservoirs. Sediment deposition rates are evaluated using ^{137}Cs data.

Model-predicted sediment burial and scour rates are shown in Sections 4.3 and 4.4 for the calibration and verification time periods, respectively.

Equation 4-10 provides the relationship used by the model to evaluate sediment flux between the bed and water column for riverine and the run-of-river impoundments. Due to the large volumes of Lakes Lillinonah and Zoar, water velocities are substantially diminshed and resuspension is not expected to be significant. Thus, for the two lakes, zero sediment resuspension rates are input to the model. The user inputs settling and resuspension rates and the model calculates the required burial rates (v_b) to maintain a constant solids concentration in the active layer. v_b is positive (i.e., burial) if the flux of solids to the bed exceeds the flux of solids from the bed and v_b is negative (i.e., scour) if the solids flux from the bed to the water column exceeds the flux from the water column to the bed. To evaluate resuspension rates, Equation 4-8 is reexpressed as follows:

$$v_u = \frac{v_s\, m_w}{m_b} - v_b \qquad \textbf{(Equation 4-14)}$$

As discussed previously, v_s is set at 6.35 ft/day; m_b is equivalent to sediment bulk density (see Table 4-3); v_b is based on ^{137}Cs distributions in sediment cores for the Falls Village and Bulls Bridge impoundments and Lakes Lillinonah and Zoar as discussed later in this section. In riverine segments, an initial estimate of $v_b = 0$ is made. The value of m_w (i.e., water column TSS) is evaluated from available data for each of the riverine and run-of-river impoundment segments for the following flow classes (flows are in cfs):

0 - 400
400 - 800
800 - 1200
1200 - 1600
1600 - 3000
3000 - 7000
7000 - 20,000 (if data are available)

Equation 4-14 is then applied to calculate v_u for each flow class. Table 4-5 provides the average m_w values for each flow class based on data presented in Section 3.3.1 for each model segment as well as the values of v_s and m_b and also shows the initial estimate of v_u and the final value based on the model calibration. Figure 4-5 displays v_u as a function of flow for each of the riverine and run-of-river impoundments.

TABLE 4-5 (Page 1 of 2)

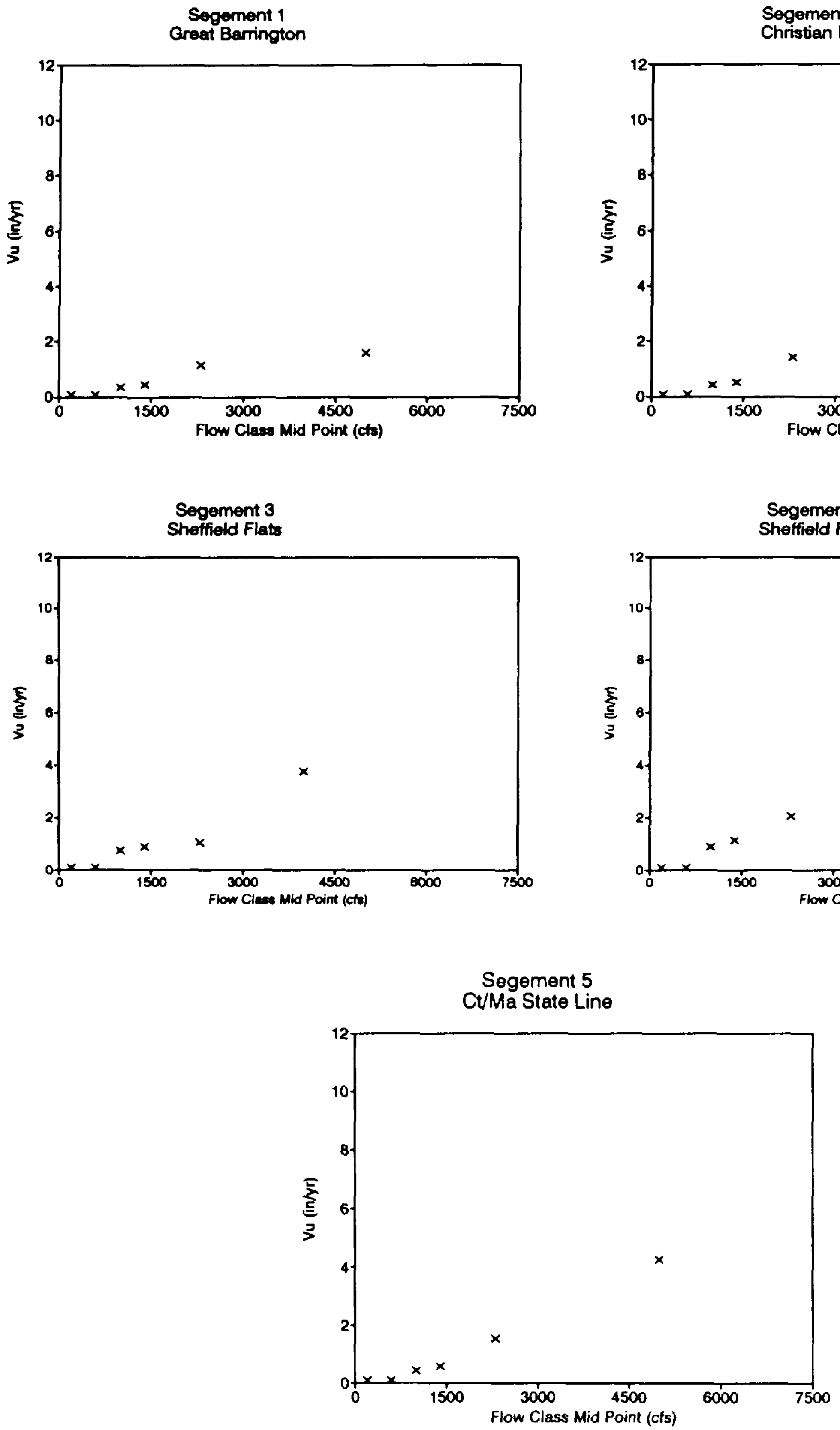
SEGMENT RESUSPENSION CALCULATIONS

FLOW CLASS	SEGMENT No. (Description)	m_w (mg/l)	m_b (mg/l)	PRELIMINARY ESTIMATE OF (in./year)	CALIBRATED VALUE OF v_u (in./year)	COMMENTS
0-400	1	7.4	969,025	0.21	0.075	
400-800	(Great Barrington)	6.5	"	0.19	0.075	
800-1200		11.3	"	0.32	0.32	
1200-1600		14.8	"	0.42	0.42	
1600-3000		39.8	"	1.14	1.14	
3000-7000		55.0	"	1.58	1.58	
0-400	2	7.4	775,200	0.27	0.075	TSS data from Great Barrington used
400-800	(Christian Hill)	6.5		0.23	0.075	
800-1200		11.3		0.41	0.41	
1200-1600		14.8		0.53	0.53	
1600-3000		39.8		1.43	1.43	
3000-7000		55.0		1.97	1.97	
0-400	3	-		0.10	0.075	TSS data are average from MAB and KRB.
400-800	(Sheffield Flats)	14.0	1,522,952	0.26	0.075	
800-1200		39.4	"	0.72	0.72	
1200-1600		47.2	"	0.86	0.86	
1600-3000		56.3	"	1.03	1.03	
3000-5000		68.6	"	1.25	3.76	
0-400	4	-	1,365,847	0.10	0.075	TSS data are average from MAB and KRB
400-800	(Sheffield Flats)	14.0	"	0.29	0.075	
800-1200		42.5	"	0.86	0.86	
1200-1600		55.3	"	1.12	1.12	
1600-3000		100.3	"	2.04	2.04	
3000-5000		86.0	"	1.75	5.25	
0-400	5	13.1	1,274,947	0.29	0.075	Based on TSS measurements at Great Barrington and scaled up by factor of 1.7 to account for increased solids load
400-800	(MA/CT line)	11.5	"	0.25	0.075	
800-1200		20.0	"	0.44	0.44	
1200-1600		26.2	"	0.57	0.57	
1600-3000		70.5	"	1.54	1.54	
3000-7000		97.4	"	2.12	4.25	
0-400	6	12.3	943,398	0.22	0.05	TSS data from Canaan
400-800	(Falls Village Res.)	12.8		0.23	0.05	
800-1200		11.8		0.21	0.05	
1200-1600		14.0		0.27	0.27	
1600-3000		28.6		0.70	0.35	
3000-7000		45.0		1.18	1.18	

TABLE 4-5 (Page 2 of 2)

SEGMENT RESUSPENSION CALCULATIONS

FLOW CLASS	SEGMENT No. (Description)	m_w (mg/l)	m_b (mg/l)	PRELIMINARY ESTIMATE OF (in./year)	CALIBRATED VALUE OF V_u (in./year)	COMMENTS
0-400	7	7.18	1,025,085	0.19	0.075	TSS data from Falls Village Bridge
400-800	(Kent)	11.39	"	0.31	0.075	
800-1200		10.15	"	0.28	0.075	
1200-1600		12.87	"	0.35	0.075	
1600-3000		27.7	"	0.75	0.38	
3000-7000		102.9	"	2.79	9.77	
0-400	8	12.3	1,420,703	-0.02	0.05	No TSS data available in Bulls Bridge Reservoir; Canaan TSS used
400-800	(Bulls Bridge Reservoir)	12.8	"	-0.01	0.05	
800-1200		11.8	"	-0.03	0.05	
1200-1600		14.0	"	0.04	0.05	
1600-3000		28.6	"	0.30	0.15	
3000-7000		45.0	"	0.62	0.62	
0-400	9	5.7	1,380,180	0.11	0.075	TSS data from Gaylordsville
400-800	(New Milford/	8.7	"	0.18	0.075	
800-1200	Gaylordsville)	8.2	"	0.17	0.075	
1200-1600		8.6	"	0.17	0.075	
1600-3000		14.0	"	0.28	0.28	
3000-7000		31.0	"	0.62	0.31	
7000-20,000		132.0	"	2.66	10.64	
Not Applicable	10 (Lake Lillinonah)	16.8	839,288	0.00	0.00	TSS data from Brookfield
Not Applicable	11 (Lake Zoar)	12.0	562,195	0.00	0.00	TSS data from Riverside and Stevenson



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Sediment Resuspension Rates
as a Function of Flow

Figure 4-5
(Page 1 of 2)

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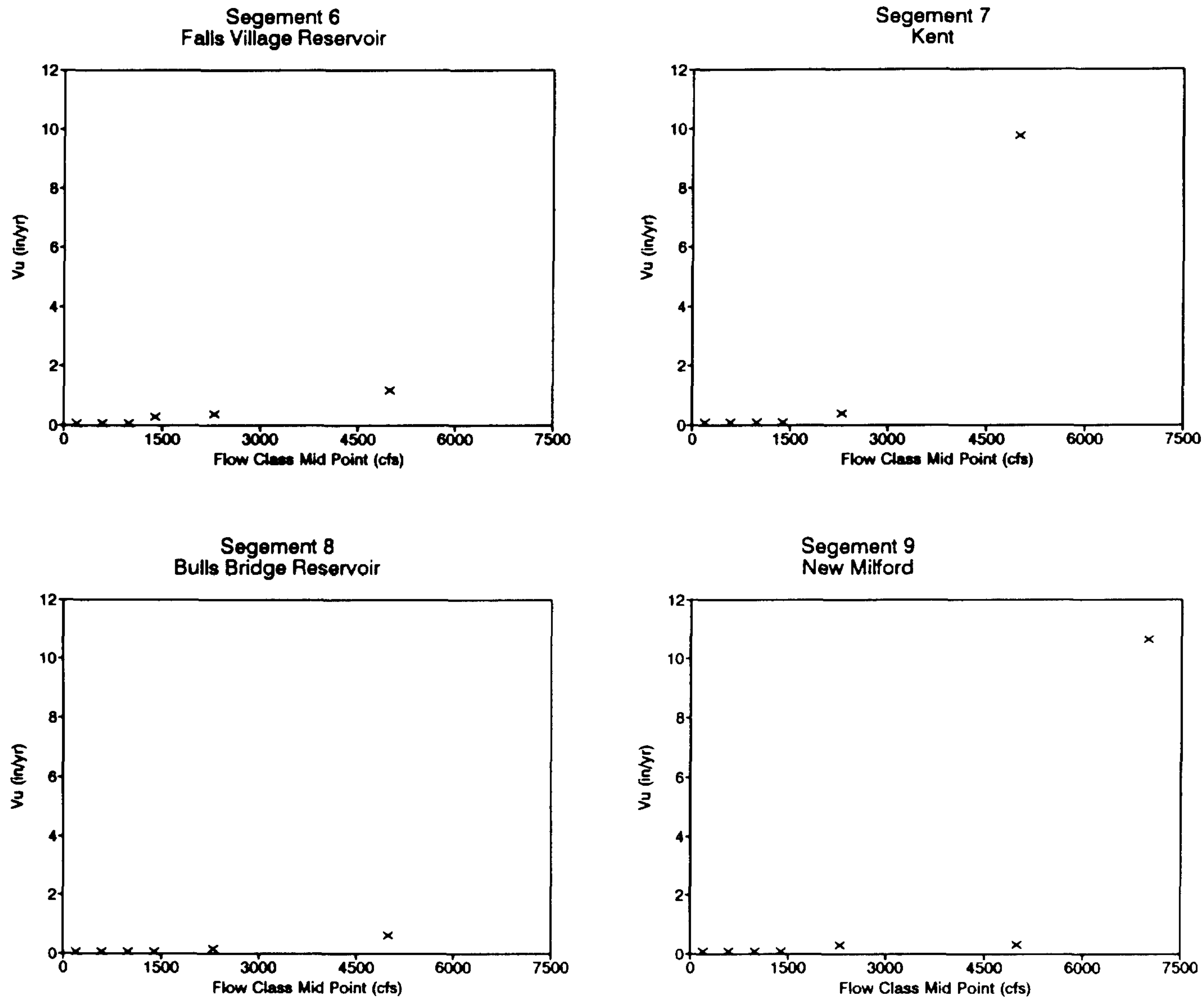

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Sediment Resuspension Rates as a Function of Flow

Figure 4-5
(Page 2 of 2)

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The solids flux relationships have changed from the previous modeling efforts (LMS 1988 and 1991) in the following ways:

1. Previously, solids fluxes for most riverine segments were adjusted to force no net settling or scour. This assumption gave reasonable TSS results for monthly-average conditions. However, in switching to an event-specific model it became evident that certain segments, especially the three segments (5, 7, and 9) indicated in Table 4-4 as subject to scour due to their high water velocities, should generally be in a state of scour to achieve measured TSS concentrations.

2. Revised bulk density values and resuspension relationships in the Sheffield Flats based on 1992/93 surveys also resulted in changes.

As noted in Table 4-5 the general trend of the adjusted resuspension values is to use low resuspensions (0.05 to 0.075 in./year) for lower flows and for Segments 5, 7, and 9 to increase resuspension by factors of 2 to 4 for the highest flow classes.

Sediment burial rates in Lakes Lillinonah and Zoar were originally estimated from ^{137}Cs results in core samples taken in 1986. The method used was to apply a vertical mixing model (Robbins and Edington 1975) to fit the observed data. An iterative least-squares method was used to obtain the best value for the sediment burial rate and the mixing depth. In 1986, ^{137}Cs was analyzed only near the dams of the two lakes. The calculated sedimentation rates at the Shepaug Dam and Stevenson Dam were 0.46 and 0.51 in./year, respectively. To apply these results to the entire lake they were multiplied by factors relating the upstream sediment cross-sectional area to the sediment cross-section area at the dam. These factors as determined from Frink (1982) were estimated at 0.70 for Lake Lillinonah and 0.63 for Lake Zoar. The resulting lake-wide sedimentation estimate for each lake was 0.32 in./year. ^{137}Cs data collected in 1992 at these two dam stations showed ^{137}Cs profiles similar to those found in 1986, so these calculations were not repeated. In 1992, ^{137}Cs was also analyzed at two upstream stations in each of the lakes. The results of these analyses indicated no historical depositional trend at these locations as discernible by ^{137}Cs (see Figure 3-7).

Due to the limited number of core samples (two in each lake) and the large size of the lakes, it is not clear how sedimentation rates very with distance upstream of the dams. Thus, the above lake-wide sedimentation rates are considered reasonable estimates given the limited data but could vary from the indicated values.

Core samples in 1986 were also taken just upstream of the Falls Village and Bulls Bridge Reservoir dams and analyzed for ^{137}Cs. All analyses were below detection due primarily to the lower percentage of clay and organic matter in these sediments, which serve as the primary binding sites for ^{137}Cs. In lieu of ^{137}Cs data in these impoundments, depth profiles of PCBs were used to estimate deposition. The depth of maximum ^{137}Cs concentration was found to be 64% of the depth of maximum PCB concentration in the lakes. This percentage was applied to the depths of maximum PCB concentration in the impoundments to estimate the deposition rate at the core sample locations (near the dams). As the pools from the impoundments are less extensive and shallower than the lakes, the average deposition rate was estimated as 90% of the rates estimated near the dams. The resulting estimated deposition rates are 0.14 in./year for the Falls Village Reservoir and 0.26 in./year for the Bulls Bridge Reservoir.

Table 4-6 summarizes the estimated sediment settling and depositional rates input to the model. Also indicated is the depth of the active sediment layer. Note that previously the depth of active sediment was estimated from the 1986 ^{137}Cs profiles as 4.8 in. in Lake Lillinonah and 3.6 in. in Lake Zoar. The 1992 ^{137}Cs measurements in Lake Lillinonah (MP 29.8) showed less vertical mixing (i.e., a "sharper" peak activity) of ^{137}Cs relative to the 1986 samples (see Figure 3-7). As the degree of vertical mixing is directly related to active layer depth (i.e., the greater the depth, the greater the vertical mixing), a "sharper" peak indicates a shallower active layer. The 1992 ^{137}Cs profile for Lake Zoar (MP 19.7) did not show a definable peak and therefore did not provide further insight into the active layer depth in Lake Zoar. Thomann (1987) indicates that examination of a variety of active sediment depths results in a range of about 0.1 to 10 cm (0.04 to 3.9 in.). Robbins and Edgington (1974) gave a range of 0 to 3.4 cm (0 to 1.3 in.) in Lake Michigan sediments. Given the limited amount of data available and guidance from the literature, a shallower active layer depth of 2.5 in. was assigned to the sediments of both lakes. This depth corresponds to a mixing period of eight years for the indicated deposition rates.

4.2.4 Particulate and Dissolved Organic Carbon

Direct measurements of F_{oc} on suspended solids were not taken in the Housatonic River by LMS or during other previous sampling. Values of F_{oc} can theoretically be calculated from measurements of TOC, DOC, and TSS using the following equation:

$$TOC_{total} = DOC + POC\ (TSS) \qquad \textbf{(Equation 4-17)}$$

where:

TOC_{total} = TOC of the unfiltered water sample (mg/l)

DOC = Dissolved organic carbon of filtered aqueous sample (mg/l)

TABLE 4-6

SOLIDS SETTLING, BURIAL RATES, AND ACTIVE SEDIMENT LAYER DEPTH

SEGMENT No. (Water/Bed)	SURFACE AREA (Acres)	ESTIMATED SETTLING RATE (ft/day)	ESTIMATED BURIAL RATE (in./year)	DEPTH OF ACTIVE BED (in.)
1/12	41	6.35	0	1.0
2/13	43	6.35	0	1.0
3/14	66	6.35	0	1.0
4/15	126	6.35	0	1.0
5/16	53	6.35	< 0	1.0
6/17	106	6.35	0.14	1.1
7/18	534	6.35	< 0	1.0
8/19	116	6.35	0.26	2.1
9/20	297	6.35	< 0	1.0
10/21	1,342	6.35	0.32	2.55
11/22	712	6.35	0.32	2.55

[1] The model calculates burial from the net solids flux to/from the sediment. Therefore, this parameter is not input to the model and the indicated values provide estimates from scour/transport criteria or ^{137}Cs profiles.

POC = Particulate organic carbon on TSS, also called F_{oc} (mg/mg)

TSS = Total suspended solids (mg/l)

However, of 32 samples taken by LMS between 1991 to 1993 that were analyzed for TOC, DOC, and TSS, only three of the reported TOC values were greater than DOC; however, this is required to calculate POC at a positive value. Most of the measurements showed DOC either equal to or slightly greater than TOC.

It was postulated that these discrepancies might be due to contamination during the in-field DOC filtrations. To test this, five field blanks were analyzed for unfiltered TOC and filtered DOC, the results of which follow:

TOC (mg/l)	DOC (mg/l)
0.070	0.071
0.028	0.213
0.041	0.140
0.280	0.184
0.390	0.015

These results did not indicate a systematic biasing of DOC compared to TOC. Therefore, the DOC contamination theory is not supported and the reason for the discrepancy is not known.

The following table summarizes the available usable (i.e., TOC is > DOC) TOC, DOC, TSS data, and calculated F_{oc} values in the Housatonic River from historical sources (USGS surveys):

STATION	DATE	TOC	DOC	TSS	F_{oc}
Hous River @ Stevenson	07/14/81	11	10	1	1.000
Hous River @ Stevenson	03/08/78	5.6	5.2	1	0.400
Hous River @ Stevenson	11/10/77	13	12	4	0.250
Hous River @ Stevenson	09/13/78	6.2	6	1	0.200
Hous River @ Stevenson	05/09/79	5.6	4.4	6	0.200
Hous River @ Stevenson	06/07/78	8.5	8.2	5	0.060
Hous River @ Stevenson	05/14/81	4.2	3.5	16	0.044
Hous River @ Stevenson	01/20/81	3.3	2.9	15	0.027
Hous River @ Stevenson	08/10/79	6	5.7	15	0.020
Hous River @ Stevenson	04/14/80	4.5	4.2	49	0.006
Division Street Bridge	8/20/91	6	5	17	0.059
Division Street Bridge	6/3/92	4	3	132	0.008
Falls Village Bridge	12/17/92	5	3	49	0.041

As indicated, the range of F_{oc} values varies from 0.002 to 1.0. Given the limited number of data points, the wide range of values, and the discrepancies between DOC and TOC, an alternate approach to evaluating F_{oc} was employed.

For most of the 11 model segments in the Housatonic River, surficial bed sediments originate from the settling of water column suspended solids. Thus, the fraction of organic carbon in surficial sediment should be representative of the F_{oc} content in suspended solids. A qualification to this statement is that there be no vegetative growth or significant benthic organisms present in the surficial sediment. Visual inspection of surficial sediment samples did not indicate the presence of vegetative matter or benthic organisms. The following table summarizes the surficial sediment F_{oc} values for each model segment:

WATER COLUMN/SEDIMENT SEGMENT No.	DESCRIPTION	AVERAGE F_{oc} FROM 1992 DATA
1/12	Great Barrington	0.027
2/13	Christian Hill	0.027
3/14	Sheffield Flats	0.003
4/15	Sheffield Flats	0.007
5/16	MA/CT Line	0.010
6/17	Falls Village Reservoir	0.016
7/18	Kent	0.008
8/19	Bulls Bridge Reservoir	0.026
9/20	Gaylordsville/New Milford	0.016
10/21	Lake Lillinonah	0.024
11/22	Lake Zoar	0.023
	Average	0.018
	Number of Obs.	53
	Standard Deviation	0.012

The above F_{oc} values are applied to both the water column suspended solids and the bed sediment. One standard deviation represents 67% of the mean value. The mean +/- one standard deviation will be used to develop sensitivity ranges for this parameter.

Based on available data, DOC concentration in Lakes Lillinonah and Zoar is input to the model at 2.5 mg/l and 3.5 mg/l for the other nine model segments.

4.2.5 Sediment/Water Column and DOC/Water Column Partitioning

Hydrophobic compounds such as PCBs partition to the organic carbon on sediment particles as well as to DOC. Although partitioning of these compounds has been extensively studied, there still remains several unresolved issues as follow:

- Several studies have shown that in the water column partitioning is dependent on suspended solids concentration, as well as K_{ow} and F_{oc}. O'Connor and Connolly (1980) and Di Toro (1983) observed that as solids concentrations decreased, partitioning increased. Di Toro provided a model of this effect which is used in the WASTOX model. The validity of the "solids concentration" effect has been reviewed by others (e.g., McKinley et al. (1991) and continues to be evaluated.

- The assumption of rapid partitioning of chemicals between substrate (i.e., solids and DOC) and water has been used in WASTOX and other generally accepted models. This assumption is generally implemented in fate and transport models by assuming immediate partitioning equilbrium. There is evidence that this equilbrium assumption may not be valid, particularly for receiving water systems subject to rapid changes due to storm flows (personal communications with Dr. R.V. Thomann, Dr. S.W. Karickhoff, and Dr. J.P. Connolly)

- There is a substantial acceptable range of K_{ow} values and a relatively wide range of DOC partition coefficients for the water column and sediment pore water.

- A factor that affects the distribution of PCB between the particulate and dissolved phase is the fraction of PCB that resists desorption (i.e., the resistant fraction). DiToro et al. (1982) provide a method for evaluating the resistant component for clays and natural lake sediment from Saginaw Bay, MI. WASTOX does include the capability to model the resistant component. However, as no data exists concerning the resistant component for sediments of the Housatonic River, which may differ substantially from those of Saginaw Bay, the resistant component was not explicity modeled. As will be discussed further below, the resistant component appears to be an important factor for PCB fate and transport in the Housatonic River and we have employed an empirical relationship to account for it.

Thus, given the uncertainties surrounding partitioning, our approach to evaluating the appropriate level of partitioning in the water column followed a two-step procedure:

(1) Available literature was reviewed to obtain the best estimates of parameters that control partitioning. These parameters include K_{ow} and the DOC partition coefficient ($\P_{doc}$).

(2) All available data for dissolved and particulate PCB was evaluated to determine the actual fraction dissolved (f_d). This data was then used as a guide to select the most appropriate partitioning parameters to fit the available data.

Parameter Values in Literature

Table 4-7 provides a summary of log K_{ow} values from a variety of literature sources. The log K_{ow} values found in the literature for Aroclor 1260 and hexachlorobiphenyl, which constitutes the largest homolog percentage of Aroclor 1260 range from 6.22 to 8.26 for hexachlorobiphenyls and from 6.11 to 7.15 for an Aroclor 1260 mixture. Sensitivity of the model to a range of Log K_{ow} values from 6.11 to 7.41 is evaluated.

The WASTOX model includes provisions for partitioning of compounds to dissolved organic carbon. Partitioning to DOC was not included for previous model applications but was considered for the current application. Several literature sources were reviewed to obtain the most reasonable values of the DOC partition coefficients.

The presence of DOC in the water column or interstitial pore water can increase the solubility of PCBs (Chiou et al. 1986) and can therefore decrease their sorption to sediments. Once PCB partitions to DOC in the water column its fate is similar to that of dissolved PCB except that it does not volatilize. Much of the DOC in natural waters is composed of humic material. Several factors can influence the degree of DOC partitioning (Landrum 1987):

- DOC age
- Structure and composition of DOC molecules, including size
- Degree of aromaticity or hydrophilicity
- pH and hardness

These factors are not considered in the WASTOX model and most of this information (except pH and hardness) is not available for the Housatonic River.

TABLE 4-7

LITERATURE VALUES OF OCTANOL/WATER PARTITION COEFFICIENTS (K_{ow})

CHEMICAL NAME	MOLEC. WEIGHT	LOG K_{ow}	REF.
PCB	372	6.50	LMS (1991)
PCB		6.2-7.1[a]	Thomann (1987)
Aroclor 1260		6.11-7.15	EPA (1987)
Hexa-CB exp		7.284[b]	DeBruijn et al. (1989)
Penta-CB exp		5.81-6.95	Howler et al. (1988)
Hexa-CB		6.22-7.42	"
Hepta-CB		6.69-8.00	"
Octa-CB		7.20-8.00	"
Penta-CB est		6.11	EPA (1983)
Penta-CB		6.24	"
Hexa-CB exp		6.30-6.55	"
Hepta-CB exp		6.68	"
Octa-CB exp		7.11	"
Penta-CB		6.38-7.51	Erickson (1985)
Hexa-CB		7.12-8.26	"
Hepta-CB		7.93	"
Octa-CB		8.42-8.68	"

[a] Range for homologs penta- through hepta-chlorobiphenyls (CB), respectively.
[b] Average for four hexachlorobiphenyls (range is 7.118 to 7.408).

Note: exp - experimental; est - estimated; K_{ow} - octonol/water partition coefficient.

Evans (1988) evaluated $\P_{doc}$ for water column samples from 15 lakes and streams in Ontario. DOC concentrations varied from 2.0 to 26.5 μg/l. The average $\P_{doc}$ for all data collected in the spring, summer, fall, and winter of 1986/1987 was 53,600 l/kg and ranged from 6970 to 170,000 l/kg for PCB153, a Hexa PCB. The lowest value of 6970 l/kg is used in the model, as discussed in the following section.

Observations of f_d and Refinement of Partitioning Parameters

Numerous measurements of dissolved PCB and total PCB have been made in the Housatonic River. Since dissolved concentrations are determined by filtration and since both the free dissolved and DOC partitioned PCB would pass through the filter, the dissolved measurement includes both components (c_d and c_{doc}). The combined fraction dissolved $f_{(d+doc)}$ is therefore equal to the combined dissolved PCB ($c_d + c_{doc}$) divided by the total PCB concentration (c_t). Table 4-8 summarizes the measured $f_{(d+doc)}$ values. Calculations were separated into those that were quantifiable (both dissolved and total PCB were detected) and an estimate which used the detection limit value for non-detected dissolved PCB. Out of 130 pairs of dissolved and total measurements, 33 pairs were quantifiable. The average combined fraction dissolved is 0.37.

The particle interaction model (PIM) [Di Toro 1985], as provided in equation 4-4 was used to calculate the partition coeeficient which is then used to calculate $f_{(d+doc)}$ (sum of equations 4-6 and 4-8) and then compared to observed values. The calculations of $f_{(d+doc)}$ were based on measured TSS corresponding to the samples analyzed for dissolved and total PCB and on the following parameter assumptions:

$\mathrm{Log}K_{ow}$: a range of values between 6.5 to 7.48 l/kg were tested.
$\mathrm{Log}\P_{doc}$: 4.75 l/kg
DOC: 3.5 mg/l
F_{oc}: 0.027

Figure 4-6 shows the results which clearly indicate that by just using PIM, the calculated $f_{(d+doc)}$ is too high. This discrepancy is not unexpected as PIM only accounts for the reversible component of PCB and does not incorporate the resistant component effect. Furthermore, reasonable changes to $\mathrm{Log}\P_{doc}$ and F_{oc} did not substantially lower the calculated $f_{(d+doc)}$.

Thomann (1986) [in Thomann 1987] provides an empirical modification to PIM that accounts for the resistant component effect if it is not modelled directly. An evaluation of data in Di Toro (1985) provided the empirical relation that the overall adsorption partition coefficient ($\P_s$) was roughly equal to 2 times the exchangeable partition coefficient ($\P_s^x$). Thus, the

TABLE 4-8

SUMMARY OF COMBINED FRACTION DISSOLVED $f_{(d+doc)}$ OBSERVATIONS IN THE HOUSATONIC RIVER

SOURCE	DATES	STATION	SOURCE CODE	F_d RANGE	AVERAGE $f_{(d+doc)}$		COMMENTS
					w/o ND[1]	w/ ND[2]	
Frink	10/79-6/80	Division St. Bridge	A	0.25-1.00	0.29 (4)	0.63 (13)	High flow
Kulp	6/84-8/88	Division St. Bridge	B	0.20-2.00	0.20 (1)	0.55 (4)	High flow
Blasland & Bouck	7/89-9/91	Division St. Bridge	C	<0.14-1.00	0.73 (2)	0.60 (9)	Low to moderate flow
LMS	3/91-4/93	Division St. Bridge	D	<0.38-<0.82	---	0.60 (16)	High flow
Stewart	2/82-4/82	Division St. Bridge	E	0.29-<0.75	0.32 (5)	0.48 (8)	Moderate to high flow
Stewart	2/82-4/82	Ashley Falls	P	0.20-<1.36	0.32 (8)	0.58 (14)	Low to high flow
Kulp	1/86-8/88	Ashley Falls	F	<1.0-1.0	---	1.00 (3)	Moderate to high flow
Kulp	1/86-8/88	Falls Village	H	<1.0	---	<1.0 (1)	Moderate to high flow
LMS	3/92-4/93	Falls Village	J	<0.82	---	<0.82 (1)	High flows
Stewart	2/82-4/82	Sweitzer Br.	I	<0.43-<0.75	---	0.64 (10)	Moderate to high flow
Blasland & Bouck	10/90-8/91	Silver Lake	R	<0.28-<0.94	0.67 (4)	0.65 (7)	Low to Moderate flow
Blasland & Bouck	10/90-8/91	Silver Lake Outfall	S	0.29-0.66	0.46 (4)	0.48 (5)	Low to Moderate flow
Blasland & Bouck	10/90-9/91	Dawes Ave Bridge	K	<0.17-<0.79	---	0.52 (3)	Low to Moderate flow
Blasland & Bouck	10/90-9/91	New Lenox Rd Bridge	L	<0.13-<1.41	0.22 (1)	0.53 (9)	Low to Moderate flow
Blasland & Bouck	10/90-9/91	Woods Pond Headwaters	M	<0.22-<0.82	0.33 (2)	0.42 (11)	Low to Moderate flow
Blasland & Bouck	10/90-9/91	Former Hous. St. Br. Abutt.	N	0.11-<0.87	0.20 (1)	0.42 (10)	Low to Moderate flow
Blasland & Bouck	10/90-9/91	Sweitzer Br.	O	<0.15-<0.86	0.35 (1)	0.39 (6)	Low to Moderate flow
				Avg	0.37 (33)	0.56 (130)	

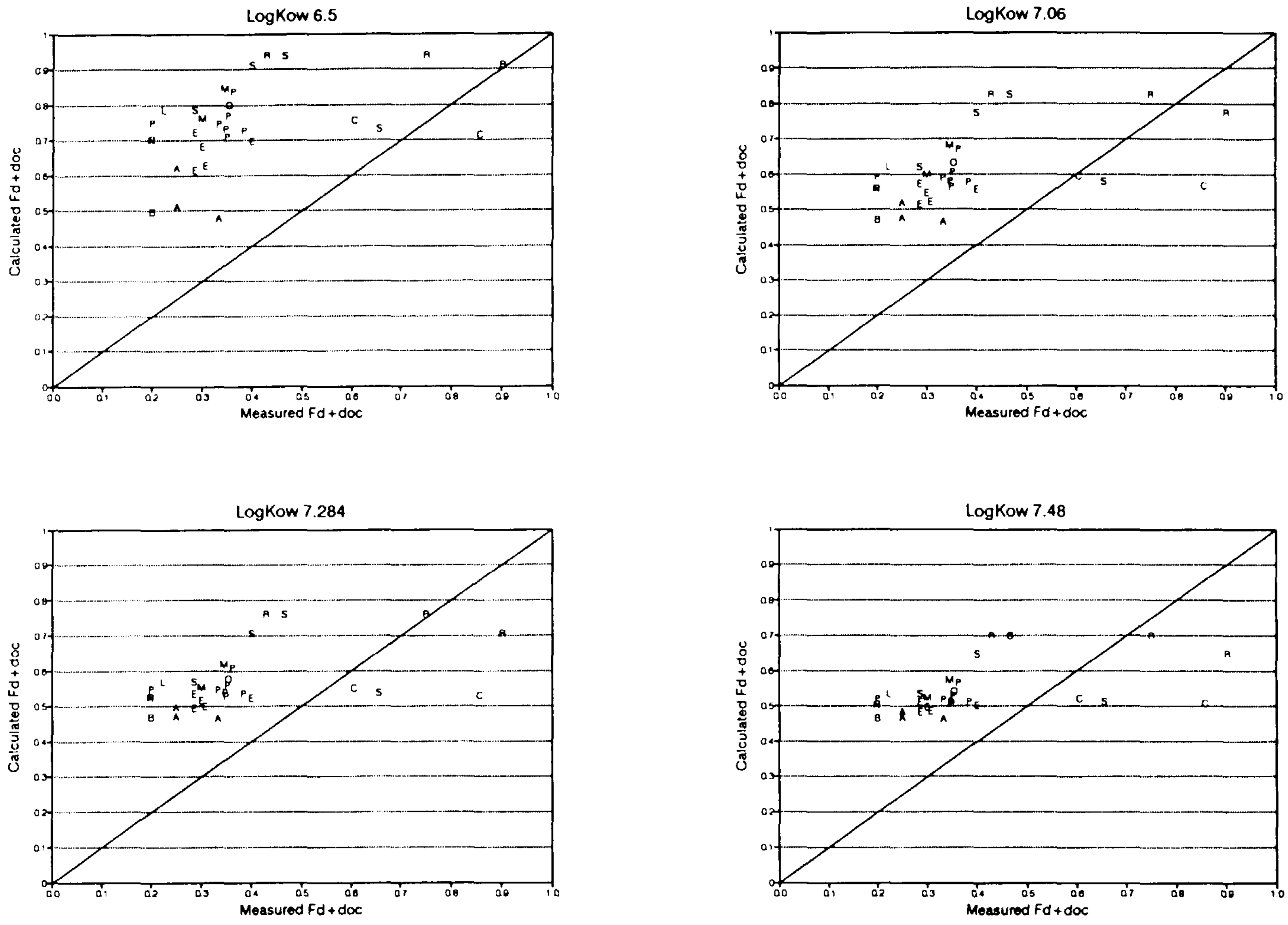
Notes:

Numbers in ( ) are the number of data points.

--- fraction could not be calculated

[1] Does not include f_d values ≥ 1

[2] Reporting limit used for f_d calculation when c_t not detected.



LogPdoc=4.75 l/kg; DOC=3.5 mg/l; Foc=0.027

LogKow 6.5

LogKow 7.06

LogKow 7.284

LogKow 7.48

Notes:

Symbols indicate source of data and are described in Table 4-8

Diagonal line is line of "perfect agreement" between measured and calcualted f(d+doc).

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Measured and Calculated F (d+doc) (Particle Interaction Model)

Figure 4-6

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following empirically derived equation is thought to provide reasonable estimates of partitioning when the resistant component is important (personal communication with Dr. R.V. Thomann):

$$\P_s = \frac{2(F_{oc}K_{ow})}{1 + m(F_{oc}K_{ow})/1.4}$$

(Equation 4-16)

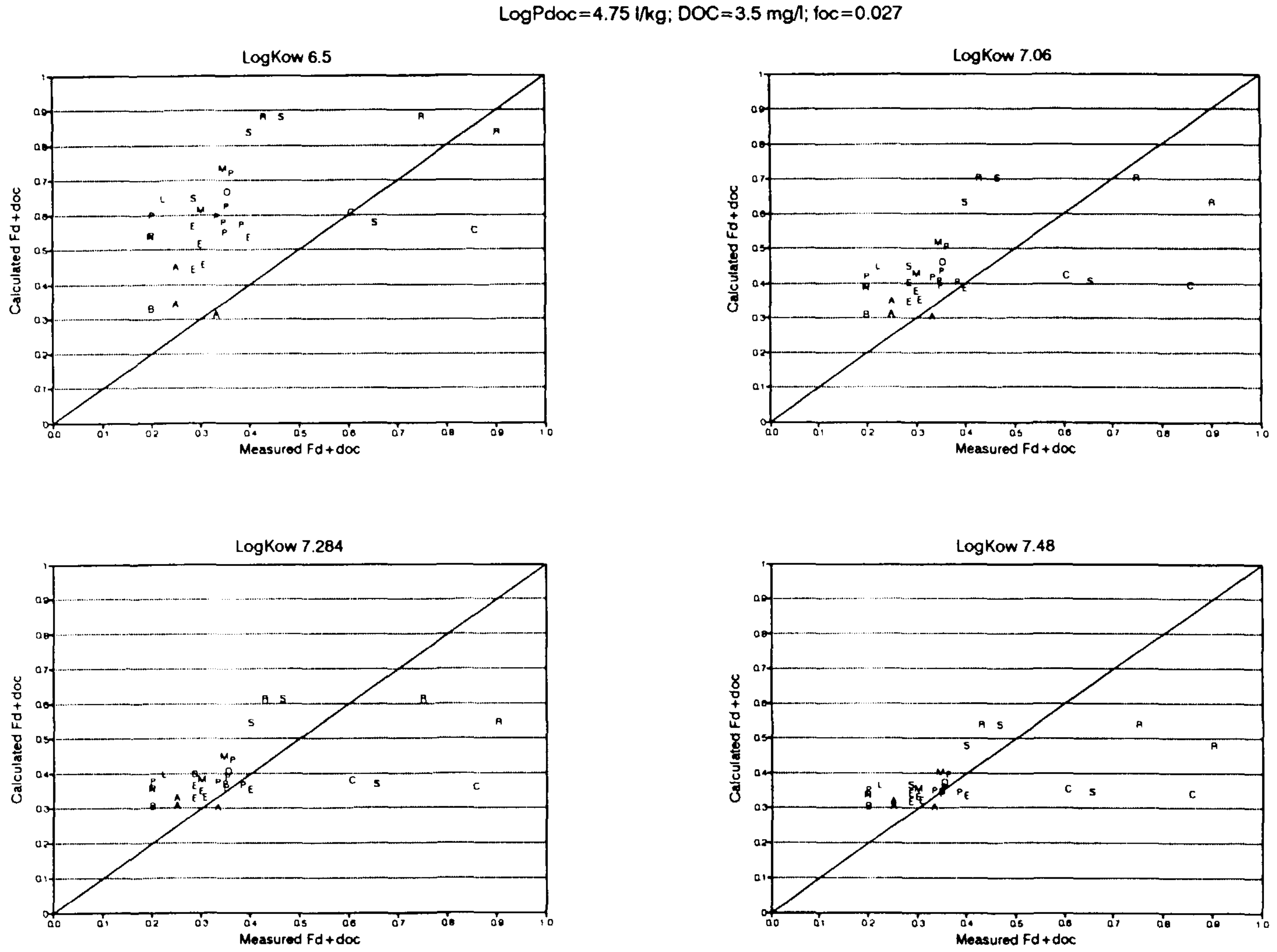
Figure 4-7 shows the $f_{(d+doc)}$ values resulting from the application of equation 4-16 as compared to the observed fractions. Reasonable agreement between the calculated and observed combined fractions is seen for the LogK_{ow} values of 7.284 and 7.48. The calculated values generally appear slightly higher than those observed. Figure 4-8 shows the comparisons using a lower Log $\P_{doc}$ value of 3.843 which correspond to the lowest value of the previously referenced range. Some decrease in the calculated $f_{(d+doc)}$ is observed.

Based on this analysis we have concluded that it is reasonable to apply equation 4-16 in WASTOX with a LogK_{ow} of 7.284 l/kg and a Log $\P_{doc}$ of 3.843 l/kg. This required a simple modification to the WASTOX code. The LogK_{ow} value of 7.284 is the average value reported by De Bruijn (1989) for four hexachlorobiphenyls. Importantly, Dr. S. Karickhhoff of EPA, a key figure in partitioning research, considers De Bruijn's results to be reliable (personal communication, 1994). For TSS values ranging from 1 to 50 mg/l and F_{oc} of 2%, the solids-dependent partition coefficient (equation 4-16) ranges from 6.0×10^6 to 5.2×10^5 l/kg, respectively.

As mentioned previously, water column DOC concentration is input to the model at 2.5 mg/l in the lakes and 3.5 mg/l elsewhere. At these low DOC concentrations, partitioning to DOC is not an important mechanism affecting the fate and transport of PCB. The $\P_{doc}$ to K_{ow} ratio in the water column is approximately 0.00036, and the DOC to POC x TSS ratio is roughly 10. Thus, the effect of DOC partitioning in the water column is 0.0036 (0.00036 x 10) of the effect of partitioning to solids, which is about two orders of magnitude smaller.

4.2.6 **Bed Sediment Partitioning**

At the present time there is no general theory or empirical relationships available to estimate stationary bed sediment solids-dependent partition coefficients at solids concentrations >100,000 mg/l (Thomann 1987). Thus, the WASTOX2 model uses a constant partition coefficent for bed sediment equal to the product of K_{ow} F_{oc}.



Notes:

Symbols indicate source of data and are described in Table 4-8

Diagonol line is line of "perfect agreement" between measured and calculated f(d+doc)

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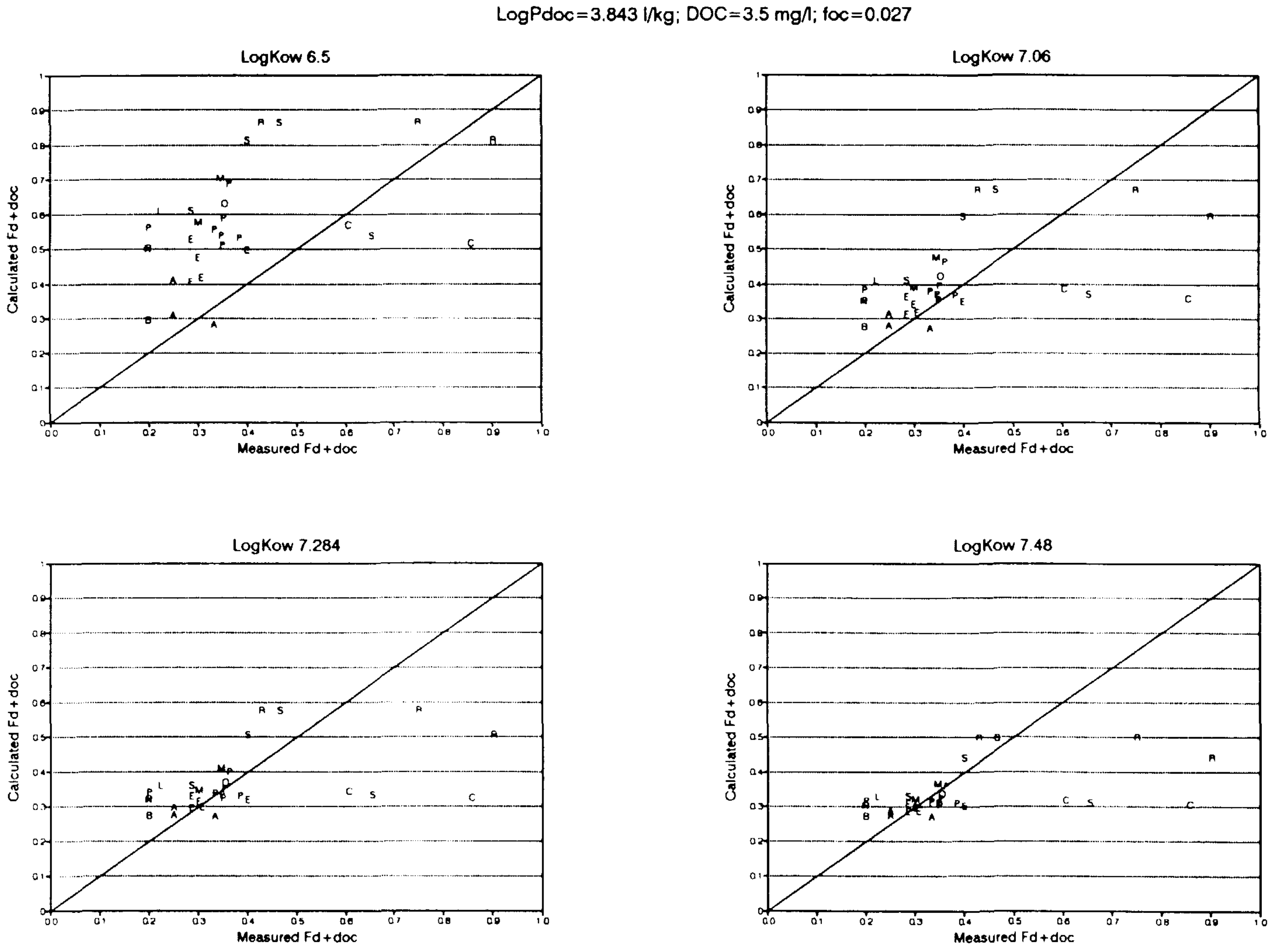
Measured and Calculated F (d+doc) (Empirically Adjusted Particle Interaction Model)

Figure 4-7

\337\042TBLK ds4
disk HS4300 file [illegible] wq1



Notes:
Symbols indicate source of data and are described in Table 4-8
Diagonol line is line of "perfect agreement" between measured and calculated f(d+doc)

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Measured and Calculated F (d+doc) (Adjusted Particle Interaction Model) with reduction to ¶$_{\mathrm{doc(wc)}}$

Figure 4-8

\337\042TBLK ds4
disk HS4300 file stokes wq1

However, this formulation assumes that K_{ow} is about equal to K_{oc} (i.e., classical partitioning theory is $\P_s = K_{oc} F_{oc}$), which is somewhat inaccurate. K_{ow} and K_{oc} are related by the following empirical equation which is determined by Di Toro (1985) for 129 data points representing various insecticides and hexachlorobiphenyls:

$$\mathrm{Log}K_{oc} = 0.924\ \mathrm{Log}K_{ow} + 0.178 \qquad \textbf{(Equation 4-17)}$$

As WASTOX only allows a single $\mathrm{Log}K_{ow}$ value for both the water column and sediment, $\mathrm{Log}K_{oc}$ can not be simply substituted for $\mathrm{Log}K_{ow}$. However, as WASTOX allows segment specific input for F_{oc}, this parameter can be multiplied by the ratio of K_{oc}/K_{ow} to effect the same result as substituting $\mathrm{Log}K_{oc}$ for $\mathrm{Log}K_{ow}$. Using a $\mathrm{Log}K_{ow}$ of 7.284, the application of equation 4-17 results in $\mathrm{Log}K_{oc}$ of 6.908. Therefore, the ratio of K_{oc} to K_{ow} is 0.421 and this factor was multiplied by the F_{oc} values in the bed sediment as discussed in Section 4.2.4. The resulting bed partition coefficients for the F_{oc} values ranging between 0.3 and 2.7% is 2.4×10^4 to 2.2×10^5 l/kg, respectively.

Available literature for $\P_{doc}$ in interstitial waters of riverbeds is summarized in the following table:

PCB CONGENERS	$\P_{doc}$ (l/kg)	SOURCE
PCB 153 (Hexa)	3.6×10^7	Karickoff et al. (1979)
PCB 141 (Hexa)	7.9×10^5	
PCB 170 (Hepta)	5.8×10^6	
PCB 153 (Hexa)	1.2×10^6	Schwarzenbach and Westall (1981)
PCB 141 (Hexa)	2.6×10^4	
PCB 170 (Hepta)	2.5×10^5	

Landrum (1987) developed the following regression equation of $\P_{doc}$ vs K_{ow} data using four organic compounds, including tetra PCB but not including hexa PCB, the most dominant isomer in the Housatonic River ($r^2 = 0.70$, $n = 22$):

$$Log\ \P_{doc} = 0.87 + 0.72\ \log K_{ow} \qquad \textbf{(Equation 4-18)}$$

We are using a $\P_{doc}$ value of 3.55×10^5 l/kg, which is within the range of available data. This value is consistent with guidance provided by the author of the WASTOX model (Dr. John

Connolly, personal communication) that $\P_{doc}$ is generally in the range of 1 to 10% of K_{ow}. Sensitivities are performed for a range of interstitial pore water $\P_{doc}$ values, from 2.6 x 10^4 l/kg to 3.5 x 10^7 l/kg.

Note that $\P_{doc}$ in sediment pore water is about 50-times greater than $\P_{doc}$ in the water column. Such a difference in the literature sources may be due to structure, composition, or age differences of the DOC molecules or differences in pore vs water column chemistry.

No data are available on interstitial water DOC. Literature sources indicate a reasonable range of from 3 to 100 mg/l. A value of 10 mg/l is chosen and model sensitivity is tested for the indicated range. $\P_{doc}$ in interstitial water is expected to have a substantial effect on the distribution of PCBs in the bed sediment. Partitioning to pore water DOC causes PCBs to move from the solids to the pore water, where it can diffuse into the water column.

4.2.7 **Bed Sediment-Water Column Diffusion**

The diffusion of dissolved PCBs between the bed sediment and water column depends on the molecular diffusion coefficient of PCBs in water and the porosity of the bed sediment.

According to Chapra and Reckhow (1983), the diffusion coefficient (the parameter D in Equation 4-11) for PCBs in the Housatonic River is estimated at 6 x 10^{-6} cm^2/sec. It was determined in LMS (1991) that the diffusive flux of PCB from the bed to water column was small and sensitivity to this parameter is not repeated.

4.2.8 **Volatilization**

The WASTOX model contains several options for calculating volatilization rates and an option to input the segment-specific volatilization rates directly. There has been a substantial amount of recent research on volatilization for the Great Lakes that has not been incorporated into WASTOX. Therefore, the approach used herein was to review this literature, evaluate segment-specific volatilization rates, and input these directly to HOUSRM.

Current research is consistent with WASTOX's use of the two-phase resistance theory, which describes volatilization as a function of the gas-film resistance and the liquid-film resistance. Mass transfer is governed by molecular diffusion through a stagnant liquid and gas film. Mass of chemical moves from areas of high concentration to areas of low concentration. The film resistance depends on diffusion and mixing and the volatilization characteristics of the chemical are defined by Henry's constant (H), which is the ratio of the chemical's vapor pressure to its solubility. The application of the two-phase resistance theory results in an overall volatilization transfer coefficient K_{OL} being given as:

$$\frac{1}{K_{OL}} = \frac{1}{k_w} + \frac{RT}{k_a H}$$ **(Equation 4-19)**

where:

k_w = water-side mass-transfer coefficient (m/day)

k_a = Air-side mass-transfer coefficient (m/day)

H = Henry's constant (atm.m^3/mole)

R = universal gas constant = 8.206 x 10-5 atm.m^3/°K mole

T = temperature (°K)

The following table from Burkhard (1985) provides Henry's constant values for PCB Aroclor 1260 for a range of air temperatures:

AIR TEMPERATURE °C	**H (atm.m^3) mole**
5	4.35×10^{-5}
10	7.54×10^{-5}
15	1.27×10^{-4}
20	2.10×10^{-4}

The rate of PCB exchange between the water column and atmosphere is controlled mainly by the liquid-film, but at the above Henry's constants the gas-film also exhibits some resistance. The mass rate of exchange or flux (mole/m^2.day) is a function of K_{OL} and the concentration gradient between water and air and is expressed by the following equation:

$$Flux = K_{OL}\,(c_d - c_{air})$$ **(Equation 4-20)**

Where:

c_d = dissolved chemical concentration (mole/m^3)

c_{air} = concentration of chemical in air (mole/m^3)

Water-Side Mass-Transfer Coefficient

The evaluation of the water-side mass-transfer coefficient (k_w) is performed differently for riverine and lake model segments. In riverine segments the water velocity is the primary factor influencing mixing. Segments 1, 5, 7, 9, and 10 are riverine. The run-of-river impoundments (Falls Village Reservoir [Segment 6] and Bulls Bridge Reservoir [Segment 8]) have both riverine and lake characteristics. For purposes of volatilization calculations these impoundments, which do not have large surface areas compared to the lakes, are considered to be riverine (i.e., water velocity controls mixing). For these segments the O'Connor-Dobbins formula is used to determine k_w:

$$k_w = \left(\frac{D_w \ x \ U}{Depth} \right)^{0.5} \qquad \textbf{(Equation 4-21)}$$

where

D_w = diffusivity of chemical in water (m^2/sec)

u = Water velocity (m/sec)

This equation is considered applicable for velocities in the range of those existing in the "riverine" segments. Achman et al. (1993) reports a D_w value for hexachlorinated PCBs of 4.1×10^{-10} m^2/sec. Velocity is computed as the long-term average flow divided by the cross-sectional area.

For open bodies of water such as Lake Lillinonah (Segment 10) and Lake Zoar (Segment 11) the water-side transfer coefficient is controlled by wind-induced mixing as velocity due to flow is minimal. Liss and Merlivat (1986 [in Achman 1993]) summarized the transfer coefficient as a function of wind speed based on wind tunnel experiments. For wind speeds at 10 m above the water surface (U_{10}) between 0-17 m/sec they identified the following three regimes where different physical processes control gas exchange:

1. ***Smooth surface (wave-free)*** $U_{10} < 3.6$ m/sec

2. ***Capillary wave formation*** - $3.6 < U_{10} < 13$ m/sec - transfer coefficient increases considerably

3. ***Bubble formation by breaking waves*** - $U_{10} > 13$ m/sec - transfer coefficient increases further due to bubble formation

The following equations show values of k_w normalized to CO_2 (i.e., $k_{w\,(CO2)}$) for these three regimes:

1. $k_{w\,(CO2)} = 0.17\, U_{10}$ for $U_{10} < 3.6$ m/sec **(Equation 4-22)**

2. $k_{w\,(CO2)} = 2.85\, U_{10} - 9.65$ for $3.6 > U_{10} < 13$ m/sec **(Equation 4-23)**

3. $k_{w\,(CO2)} = 5.9\, U_{10} - 49.3$ for $U_{10} >$ 13 m/sec **(Equation 4-24)**

The following equation is used to adjust $k_{w\,(CO2)}$ to $k_{w\,(PCB)}$:

$$k_{w(CO2)}/k_{w(PCB)} = Sc^{n}_{(CO2)} / Sc^{n}_{(PCB)} \qquad \textbf{(Equation 4-25)}$$

where:

Sc = Schmidt number (kinematic viscosity of the medium (water) divided by the compound's diffusivity through the medium)

n = -0.67 for $U_{10} < 3.6$ m/sec

n = -0.5 for $U_{10} > 3.6$ m/sec

Sc for hexachlorinated PCB in water at 20°C is 2780, and Sc for CO_2 in water at 20°C is 600 (Achman 1993). The ratio of $k_{w\,(CO2)}/k_{w(PCB)}$ at 29°C for wind speeds less than 3.6 m/sec is 2.79, and 2.15 for wind speeds greater than 3.6 m/sec.

Air-Side Mass-Transfer Coefficient

The air-side mass-transfer coefficient is a function of wind speed and the diffusivity of the chemical in water. Schwarzenbach et al. (1992 [in Achman et al. 1993]) used results from several studies on exchange of water across the gas-film to develop a relationship of $k_{a(H20)}$ as a function of wind and then related this function to other compounds by their diffusivities. An approximation of $k_{a(H20)}$ as a function of wind speed is:

$$k_{a(H_20)} = 0.2\ U_{10} + 0.3 \qquad \textbf{(Equation 4-26)}$$

where

$k_{a(H20)}$ is the exchange coefficient of water through air (cm^2/sec).

$k_{a(H20)}$ is related to organic chemical transfer by the following equation:

$$k_{a(org.chem)} = k_{a(H_20)}\ [D_{a(org.chem)}/D_{a(H_20)}]^n \qquad \textbf{(Equation 4-27)}$$

where:

D_a is the molecular diffusivity in air (cm^2/sec)

n is between 0.5 and 1. Smith et al. (1980 [in Achman 1993]) estimated n = 0.61, and this value is used herein.

D_a of hexa PCB in air is given as 0.052 cm^2/sec and D_a of H_2O is 0.239 cm^2/sec.

Evaluation of Overall Volatilization Transfer Coefficient

Using the above equations the overall volatilization transfer coefficients (K_{OL}) were evaluated for each segment. Long-term air temperature records at the Hartford Airport for 38 years indicate a mean temperature of 49.8°F. Thus, a temperature of 50°F, or 283°K, is used. An estimate for wind speed for segments 1 to 9 was made based on recent wind speed measurements at GE Pittsfield (Zorex 1992). For Lakes Lillinonah and Zoar, wind speeds are based on 23 years of data obtained from the Bridgeport Airport. The average wind speed at that location is 5.4 m/sec. Bridgeport is located on the coast, which is generally windier than inland locations. Thus, some reduction of the Bridgeport wind speed was appropriate and a value of 4.5 m/sec was chosen to apply to the two lakes.

Table 4-9 shows the resulting K_{OL} values for each segment and also shows the velocity, k_w, and k_a values. The calculated K_{OL} values, which vary from 0.22 to 0.56 m/day, are consistent with ranges reported in Achman et al. (1993) and others.

TABLE 4-9

VOLATILIZATION RATE COEFFICIENTS

SEG. No.	DESCRIPTION	U_{water} (m/sec)	U_{wind} @ 10 m (m/sec)	DEPTH (m)	$k_{w(CO2)}$ (cm/hr)	$k_{w(PCB)}$ (m/day)	$k_{a(H2O)}$ (cm/sec)	$k_{a(PCB)}$ (m/day)	$1/k_{w(PCB)}$ (day/m)	$RT/Hk_{a(PCB)}$ (day/m)	K_{OL} (m/day)
1	Great Barrington	0.2	2.4	2.74		0.47	0.78	265.80	2.12	1.16	0.31
2	Christian Hill	0.22	2.4	2.77		0.49	0.78	265.80	2.03	1.16	0.31
3	Sheffield Flats	0.19	2.4	3.72		0.40	0.78	265.80	2.53	1.16	0.27
4	Sheffield Flats	0.17	2.4	3.57		0.38	0.78	265.80	2.62	1.16	0.26
5	MA/CT line	0.5	2.4	0.7		1.48	0.78	265.80	0.68	1.16	0.54
6	Falls Village Reservoir	0.18	2.4	3.26		0.41	0.78	265.80	2.43	1.16	0.28
7	Kent	0.62	2.4	0.73		1.61	0.78	265.80	0.62	1.16	0.56
8	Bulls Bridge Reservoir	0.13	2.4	4.73		0.29	0.78	265.80	3.45	1.16	0.22
9	New Milford	0.56	2.4	1.19		1.20	0.78	265.80	0.83	1.16	0.50
10	Lake Lillinonah	0.02	4.5	11.86	3.175	0.35	1.20	408.92	2.82	0.75	0.28
11	Lake Zoar	0.04	4.5	7.5	3.175	0.35	1.20	408.92	2.82	0.75	0.28

A value for the concentration of PCBs in air is required in order to evaluate the exchange of PCBs across the air/water interface as indicated in Equation 4-20. Data on air concentrations were available from a station located approximately 3.5 miles west of GE Pittsfield (Zorex 1992) at the Berkshire Community College. As winds predominantly move from west to east at this location, it is considered a good background station. Thirty-eight air samples were analyzed for PCBs between August 1991 and August 1993 (Zorex 1992, 1993). The mean value, assuming that those values below detection (0.5 ng/m^3) are at half the detection limit, is 0.57 ng/m^3. The following table summarizes available data on background air concentrations:

LOCATION	PCB CONCENTRATION (ng/m^3)	SOURCE
Berkshire Community College	0.57	Zorex (1992, 1993)
Lake Michigan	0.25	Achman et al. (1993)
Green Bay	0.33	Hornbuckle et al. (1993)
Foyette State Park near Lake Michigan	0.085	Sweet et al. (1993)

The value of 0.57 ng/m^3 at Berkshire Community College is consistent with other background sources and is therefore considered reasonable. As shown in Section 4.5, Model Sensitivity, the range of air concentrations indicated do not play an important role in the flux of PCBs due to volatilization.

Achman et al. (1993) point out that it is intuitive that volatilization is an important phenomenon controlling the fate of many low-boiling (i.e., semivolatile) compounds, but that volatilization may also be important for high-boiling chemicals with low aqueous solubilities and vapor pressures such as PCBs. Flux calculations provided in Sections 4.4 and 4.6 for model verification and projections indicate the relative importance of volatilization in the Housatonic River compared to other processes.

4.2.9 Upstream and Tributary Boundary Conditions for TSS and PCB

In Section 3.3.2 available TSS and PCB data were analyzed to develop statistically valid relationships of TSS as a function of river flow and season and a relationship of PCB as a function of TSS. In Section 3.3.3 surficial sediment, invertebrate, and water column data were evaluated to estimate the rate at which PCBs in the water column are diminishing with time. Because many of the sampling efforts in the Housatonic River have resulted in PCB analyses being less than the detection limit, it has not been possible to confidently determine the PCB reduction rate from water column data directly. However, all of the available data (i.e., surficial sediment, invertebrate, and water column) consistently indicate the rate to be about 5% per year.

As indicated in Section 3.3.2, a statistically valid relationship was found between PCBs and TSS but only for flows greater than 750 cfs. For flows less than 750 cfs the data suggest that PCB concentrations are genearally below detection. Thus, as a value needs to be assigned to this condition, the PCB concentration at flows less than 750 cfs was estimated from available surficial sediment data. A value was estimated for the beginning of the model verification time period (1979) using Equation 4-2, which states that the total PCB concentration (c_t) is equal to the dissolved (c_d) plus particulate concentration (c_p) [c_{doc} was not included because it is not important in the water column] as well as available water column PCB data.

Substituting c_d with f_d c_t in Equation 4-2 yields the following equation:

$$c_t = \frac{m\ c_p}{1 - f_d} \qquad \textbf{(Equation 4-28)}$$

where:

m = TSS concentration (mg/l)
f_d = Fraction dissolved as computed with equation 4-6 assuming $\P_{doc}=0$)

If one assumes that c_p in the water column is about equal to the particulate concentration in the surficial sediment just above Great Barrington and f_d is calculated from the octanol water partition coefficient (K_{ow}) of 1.92×10^7 l/kg, F_{oc} of approximately 0.027, and average low flow (<750 cfs) TSS (m) at Great Barrington of about 7.2 mg/l, c_t can be calculated.

Available surficial sediment PCB data from Stewart (1982) just above Great Barrington (MP 106.2) are used to estimate c_p:

MILE POINT	C_p (mg/kg)	SOURCE
106.64	2.30	Stewart
107.19	3.79	Mean conc. from 20 Stewart samples in Rising Pond Dam as reported in Blasland and Bouke (1992)
Average	3.05	

Applying these values to Equation 4-28 results in $c_t = 0.033\ \mu g/l$.

Furthermore, limited low-flow water column measurements (n=4) were made by Stewart during March of 1982. Flows were between 686 to 967 cfs and all PCB measurements of filtered water were undetected (<0.03 μg/l) and those of filtered residue were also not detected (<2 μg/g). Using the measured TSS, which was between 5.1 to 6.2 mg/l, the total PCB concentration was less than about 0.04 μg/l. Thus, based on the available surficial sediment and water column data, we have chosen a low flow upstream boundary condition of 0.03 μg/l in 1980. There is some degree of uncertainty in this value due to the limited amount of data available. Nevertheless, it represents a reasonable value supported by available data.

Applying the exponential reduction rate of 5% per year to this value as well as to Equation 3-5 results in the following expression, which describes the upstream PCB boundary condition for the verification time period:

For Q < 750 cfs

$$c_t = 0.03e^{-0.000137(t)} \qquad \textit{(Equation 4-29)}$$

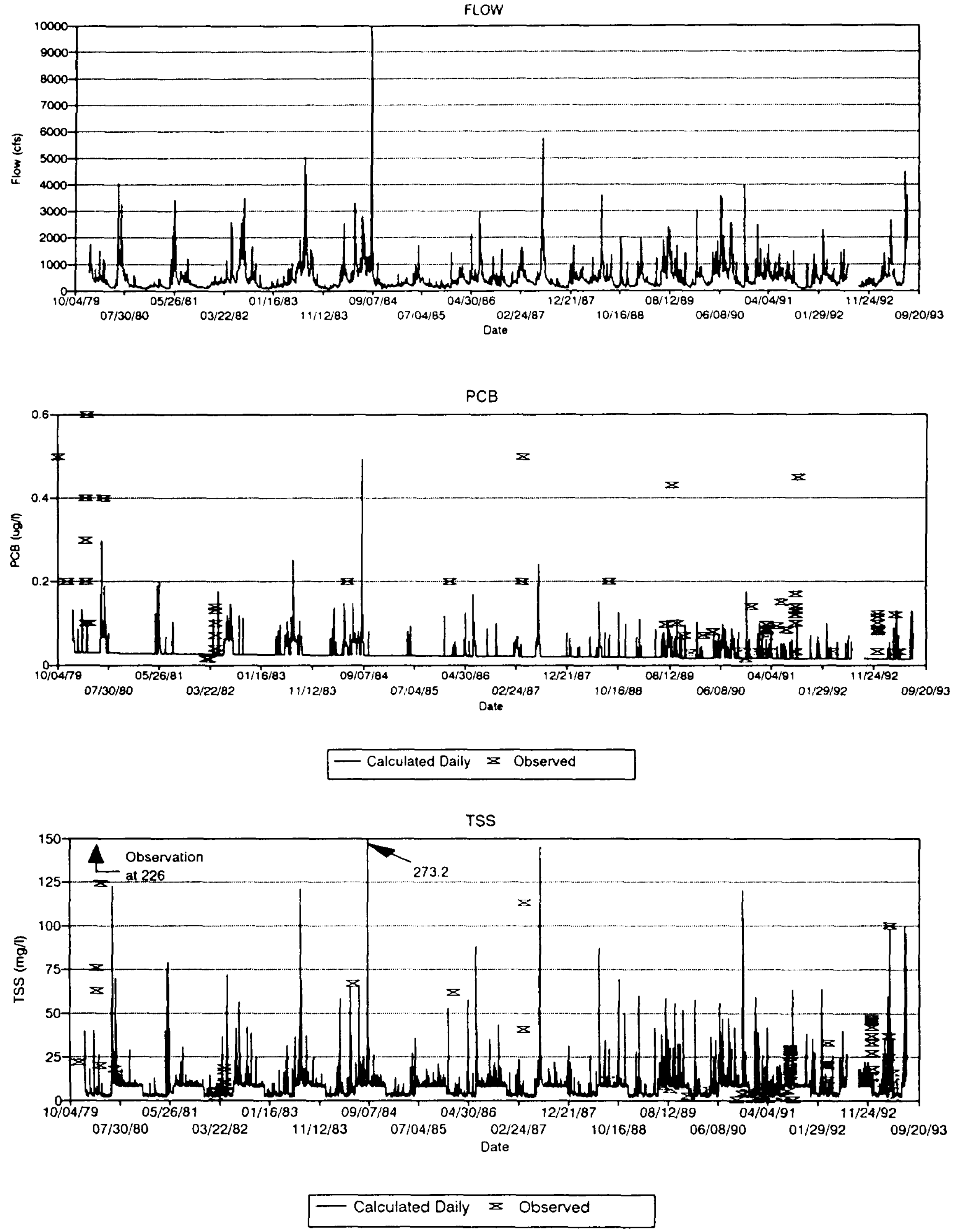
For Q > 750 cfs

$$c_t = (0.048 + 0.0021 \times TSS)e^{-0.000137(t)} \qquad \textit{(Equation 4-30)}$$

where

t = time (days from t = 0)

Applying the measured daily flow values at Great Barrington for the time period from 1 October 1979 to 9 April 1993 (13.5 years) to the above expression results in the upstream PCB boundary condition. For the upstream TSS boundary condition, Equations 3-3 and 3-4 are applied to the same time period. Figure 4-9 shows the daily flows, the calculated as well as observed PCB concentrations, and the calculated and observed TSS concentrations for the verification time period. There are 4944 daily flow values within the verification time period. As previously discussed, the WASTOX model allows up to 400 boundary condition step function inputs. Therefore, the flow, PCB, and TSS results in Figure 4-6 had to be simplified to fit the model input format. Figure 4-10 shows the resulting PCB and TSS step functions that serve as the actual model input.



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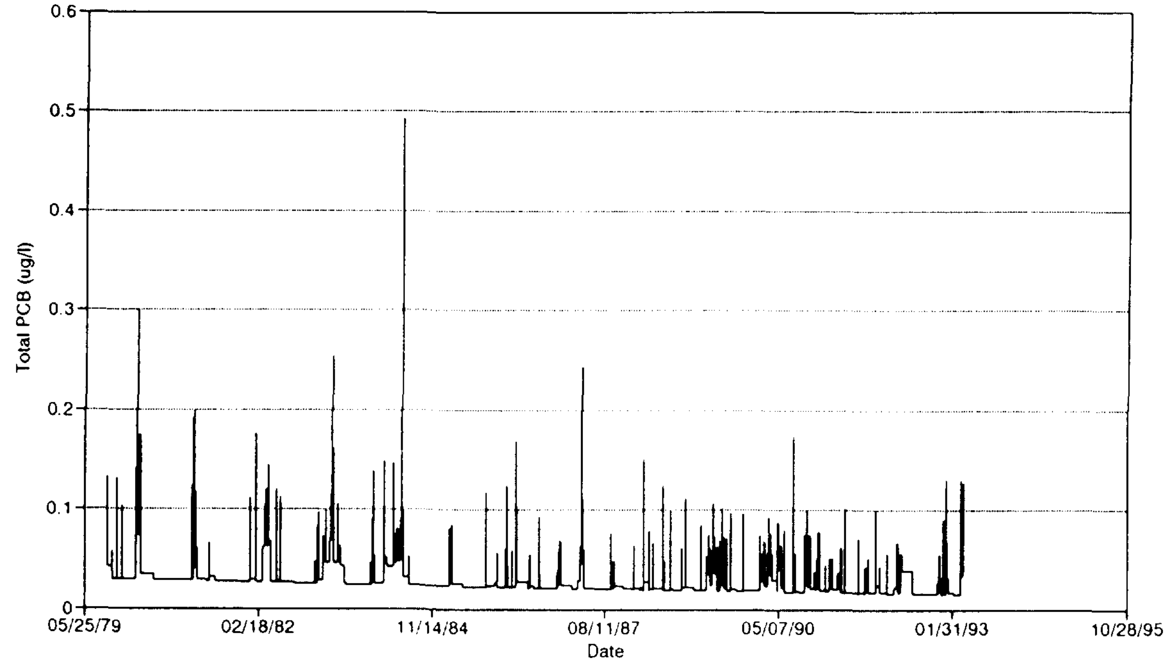
Model Verification Upstream Boundary Basis - Daily Flow, PCB, and TSS

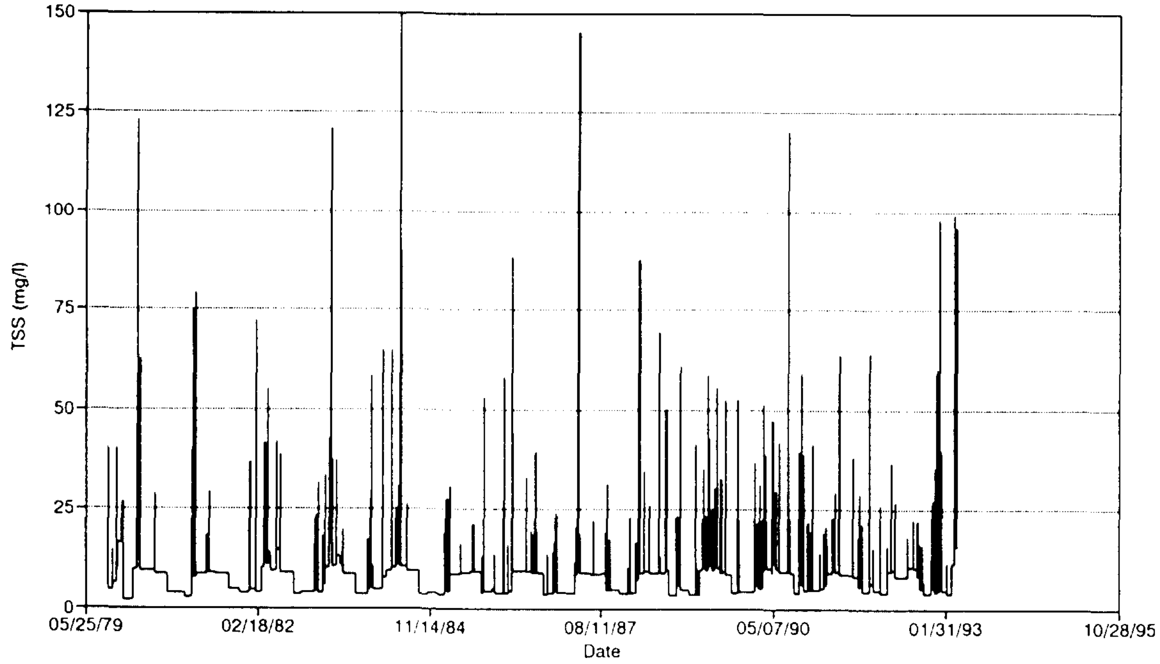
Figure 4-9

337\042TBLK ds4
disk HS4300 file Fig4-9 wq1

PCB Step Function



TSS Step Function



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Model Verification Upstream Boundary - Model Step Function Inputs for PCB and TSS

Figure 4-10

337.042TBLK ds4
disk HS3656 file Fig4-10.wq1

The projection period is from 1992 to 2042 (50 years). The daily flow record from 1942 to 1992 was used to generate the daily PCB and TSS values. The initial PCB concentration in 1992 for low flow conditions at Great Barrington was set at 0.02 μg/l. Surficial sediment PCB concentrations upstream from Great Barrington in 1992 are available only in Rising Pond. The mean of 17 surficial sediment PCB samples is 2.7 mg/kg (Blasland and Bouck 1992). Using equation 4-28 and the same parameters previously used for 1980, an estimate of $c_t = 0.029$ μg/l is made. However, as there is no data between Rising Pond and Great Barrington, this value assumes that Rising Pond is the only source of particulates at Great Barrington. Thus, since PCB concentrations are higher in Rising Pond sediments as compared to the downstream riverine sediment segments above Great Barrington and since the source of suspended particulates at Great Barrington is likely both areas as well any tributary inflows, this estimate of c_t may be high.

Low flow water column data were collected by Blasland and Bouck in 1989 to 1991, and measured for total PCB. Six data points were representative of low flow conditions. Five data points were below detection (detection limits varied between 0.03 to 0.07 mg/l). As several of the detection limits are between 0.06 to 0.07 and the high estimate of c_t is approximately 0.03, this low flow data is of limited usefulness. Applying the 5% per year "decay" rate to the value of 0.03 μg/l in 1980 yield 0.016 μg/l in 1992. Based on the above information c_t is estimated as 0.02 μg/l in 1992 for flows less than 750 cfs.

Another factor necessary to consider for the projection time period, however, is the future lower concentration limit. Applying the 5%/year decay rate to an initial PCB concentration of 0.02 μg/l results in a concentration of 0.0016 μg/l in the year 2042. This value is slightly higher than concentrations from background sites in the following lakes:

LOCATION	TOTAL PCB (μg/l)	SOURCE
Lake Superior	0.0003	Rowan and Rasmussen (1992)
Lake Michigan	0.00035	Achman et al. (1993)
Lake Ontario	0.0014	Stevens and Nielsen (1989)

Additionally, 0.005 to 0.008 μg/l of total PCB have been found in rainfall in the Great Lakes basin (Chan and Perkins 1989). Given this information, it would appear that a lower concentration limit of 0.0016 μg/l may be too low for an impacted site. We have chosen a lower limit of 0.005 μg/l, which is consistent with the previously referenced rainfall PCB concentrations and with the lower limit used in LMS (1991). Importantly, this is an assumed value and could differ substantially from future concentrations. Thus, the projection period PCB boundary condition can be expressed as follows:

For $Q < 750$ *cfs*

$$c_t = 0.020e^{-0.000137(t)} \quad [c \geq 0.005\ \mu g/l] \qquad \text{(Equation 4-31)}$$

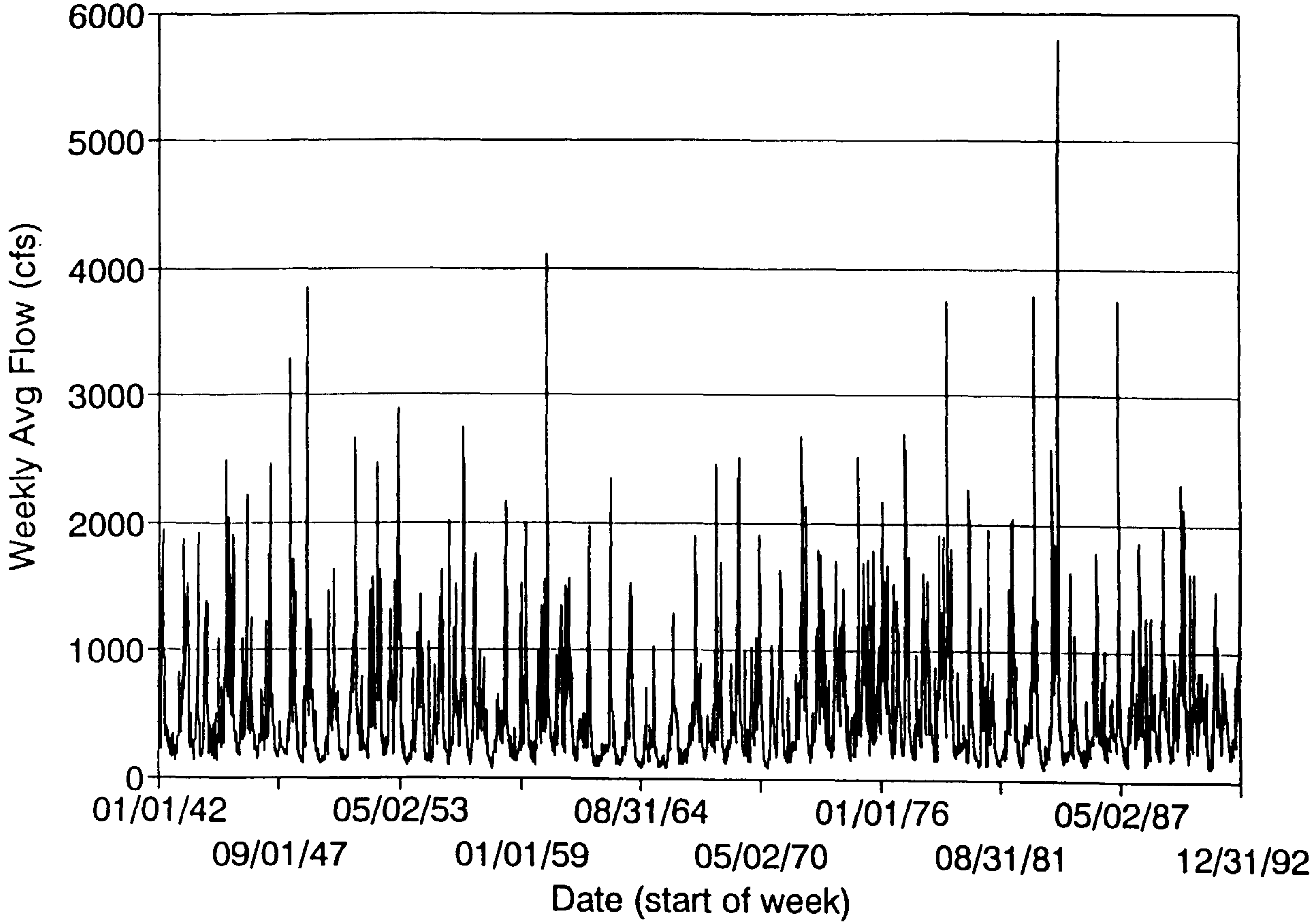
For $Q > 750$ *cfs*

$$c_t = (0.026 + 0.0021 \times TSS)e^{-0.000137(t)} \quad [c \geq 0.005\ \mu g/l] \qquad \text{(Equation 4-32)}$$

The constant value of 0.026 μg/l in equation 4-32 is the result of applying the 5% per year "decay" rate from 1980 to 1992 to the value of 0.048 used for 1980 (see equation 4-30).

The upstream TSS concentrations are determined from Equations 3-3 and 3-4. Figure 4-11 shows the weekly averaged flows for the 50-year period from 1942 to 1992. (As the daily flow plot consists of 18,250 data points, the graph is too compressed to show any detail.) The daily flows from 1942 to 1992 are used to develop the step function flow input for the 1992 to 2042 projection period. Figure 4-12 shows the calculated step function input for water column PCB and TSS derived from the previously discussed relationships between flow, TSS and PCB.

PCB and TSS boundary conditions are also required for tributary inputs to the Housatonic River. Very limited data are available for tributary PCBs. From sediment sample results reported in Frink (1982) it is known that the Still River is a source of PCB. Frink (1982) indicates that PCB concentrations in Still River sediments consist primarily of Aroclor 1248. Total surficial sediment PCB concentration in the mid 1970s at numerous stations in Still River ranged from 0 to 2.4 mg/kg (Frink 1982). Furthermore, PCB concentrations in crayfish from the Still River were found at approximately 30% of crayfish concentrations in the Housatonic River (ANSP 1992). ANSP also concluded that the Still River may be a substantial source of Aroclor 1242 to the Housatonic River. As GE primarily released Aroclors 1254 and 1260 into the Housatonic River, it is evident that there is or has been a source of PCB to the Housatonic River other than the facility GE in Pittsfield. The source of the Aroclor 1248 and/or 1242 has not been identified. Water column PCB results are not available for the Still River. Sporadic PCB measurements have been made in other tributaries. Five measurements have been made in the Pomperaug River over the period 1978-1979 and six measurements were made in Wangum Lake Brook near South Canaan. All measurements were less than the detection limit of 0.1 μg/l.



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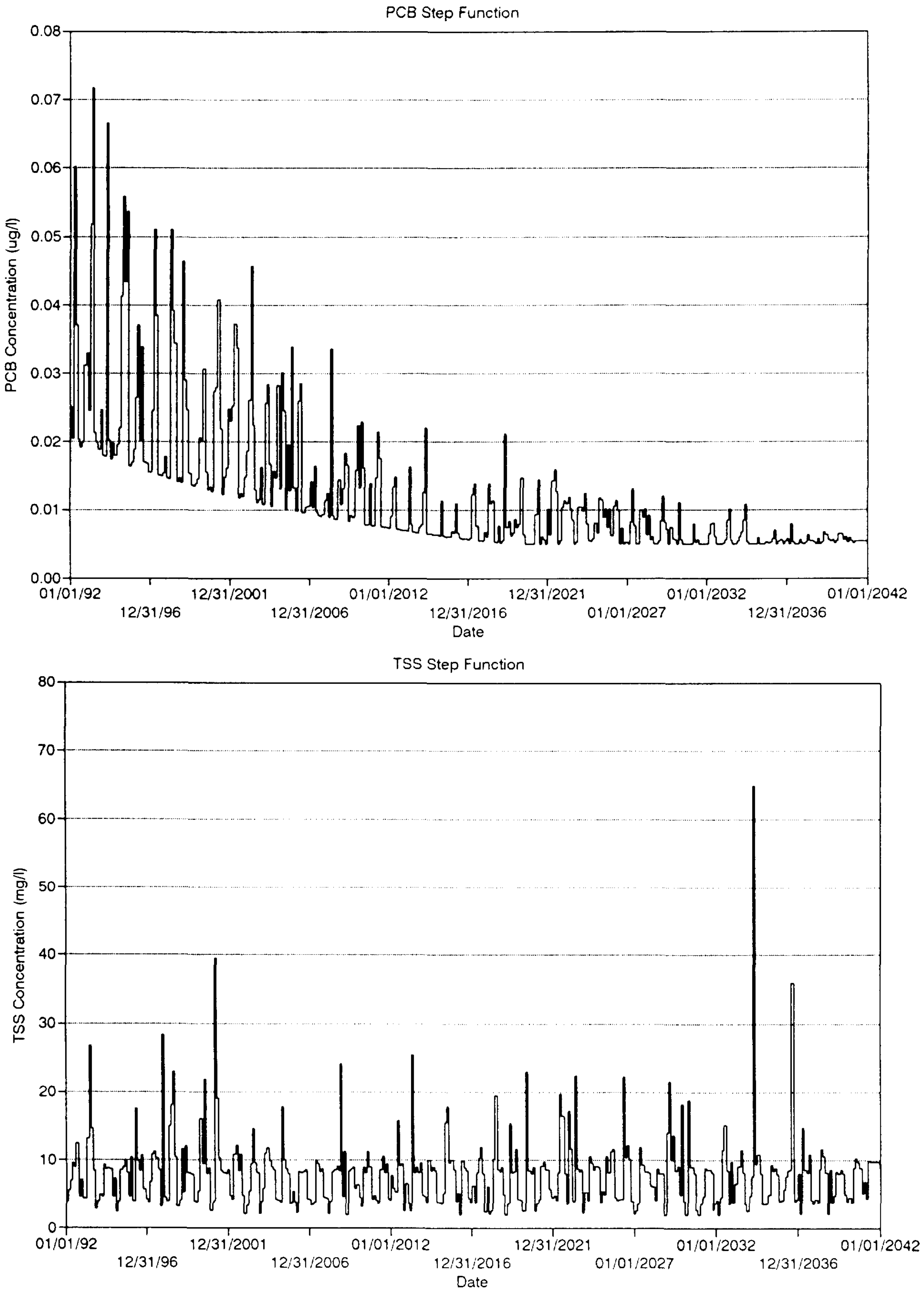
Daily Flow at Great Barrington
(1942-1992)

Figure 4-11

1337\0427BLK ds4
disk HS4300 file [illegible]kes wq1



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Model Projection Upstream Boundary -
Model Step Function Inputs for PCB and TSS

Figure 4-12

337-042TBLK ds4
disk HS4300 file final wc1

Given the lack of water column data, boundary conditions are estimated in the same manner as the upstream boundary was estimated for flows less than 750 cfs, as described by Equation 4-28. Surficial sediment PCB samples were taken from five stations in the late 1970s in the Still River between Danbury and the confluence with the Housatonic River (Frink 1982) as follows:

SITE No. (Frink 1982)	c_p (mg/kg)*
142	0.28
143	0.13
144	0.30
145	0.07
146	0.38
Average	0.232

*Includes only those results for which a sample location was shown on the sampling map.

Two surficial sediment samples were also taken in the Ten Mile River, but PCBs were reported by Frink (1982) as 0.00 mg/kg (i.e., below detection, but the limit was not provided). No other surficial sediment samples of Housatonic River tributaries have been taken. Frink (1982) reported, however, that during 1973-1977 the USGS collected and analyzed 79 sediment samples from the Connecticut and Thames River sediments (no samples from impoundments) and found that concentrations ranged from 0 to 1.0 mg/kg, with a mean of 0.043 mg/kg. It was decided to use the mean value of 0.043 mg/kg as an estimate of c_p in all other tributaries to the Housatonic River Study area except the Still River, for which c_p is 0.232 mg/kg as indicated above. TSS data were taken from available records as indicated in Table 3-3. The following table summarizes the data used in applying Equation 4-28.

TRIBUTARY	c_p (mg/kg)	TSS (mg/l)	$LogK_{ow}$ (l/kg)	F_{oc}	CALCULATED c_t (μg/l)
Still River	0.232	25	7.284	0.01	0.0085
Other Tributaries	0.043	18	7.284	0.01	0.0012

As the Still River and Shepaug River are combined in HOUSRM, the PCB concentration assigned to the combined flow was computed as 0.0038 μg/l by mass balance as summarized below:

TRIBUTARY	AVG FLOW (cfs)	c_t (μg/l)
Still River	131	0.0085
Shepaug River	233	0.0012
Combined for Model Input	364	0.0038

The reduction rate of 5% per year is applied to the combined Still and Shepaug Rivers with a lower limit of 0.0012 μg/l. All other tributaries are assigned the value of 0.0012 μg/l as a background concentration, which is not subject to decay. This value is similar to the range of background concentrations in the Great Lakes and in rainfall as discussed previously. Figure 4-13 shows the tributary PCB boundary conditions for the verification and projection time periods.

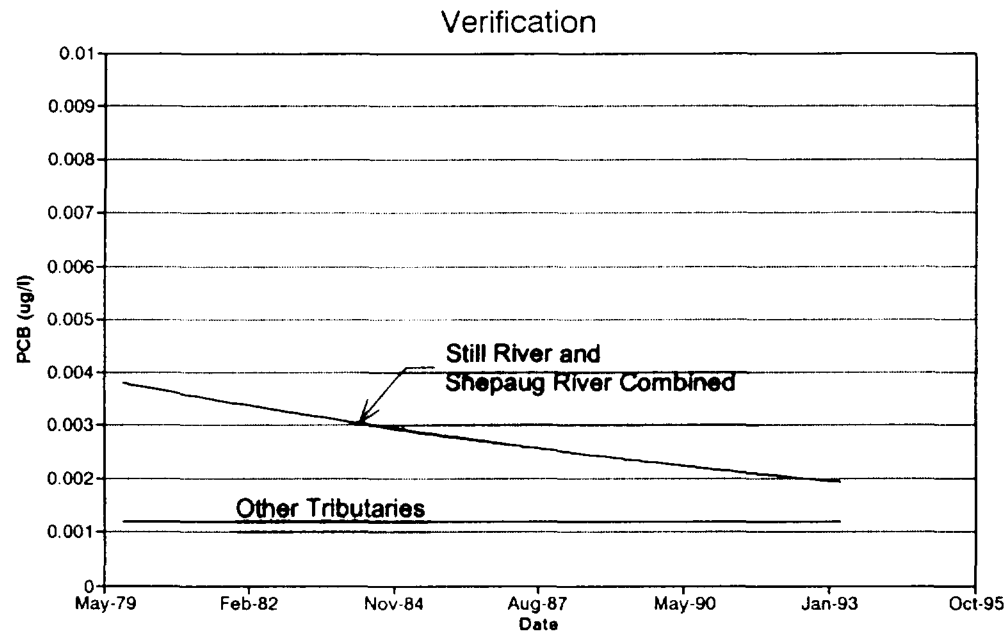
Based on available data, tributary TSS concentrations were input as follows:

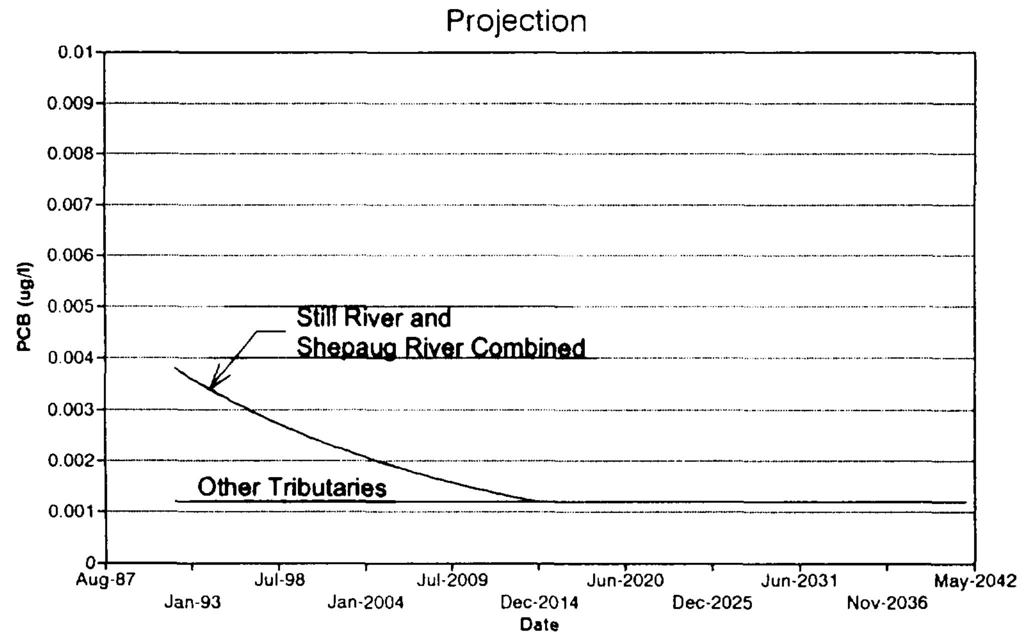
TRIBUTARY INPUTS MODEL SEGMENTS	TSS (mg/l)
1-9	17.8
10	23.8
11	21.6

4.3 MODEL CALIBRATION REFINEMENT FOR TSS

As discussed previously, it was necessary to make some refinements to the previous model calibration (LMS 1991) to accommodate the change from monthly-averaged conditions to event-specific conditions. The 1991 model calibration focused on an 18-month period from April 1979 to October 1980, when daily TSS measurements were made at three Housatonic River USGS gaging stations (Great Barrington [MP 106.2], Falls Village Bridge [MP 75.0], and Gaylordsville [MP 50.6]). The TSS upstream boundary condition consisted of monthly-averaged values, hydrodynamic flow was monthly-averaged, and flow-dependent resuspension was based on the monthly-averaged flows. The calibration process focused only on obtaining agreement between observed and modeled TSS as water column PCB data, which are quantifiable concentrations (≥ detection limit), are scarce.

In the study herein, the upstream TSS and PCB boundary conditions were further evaluated to develop relationships to describe these parameters as a function of daily flow. The results of this evaluation are presented in Section 3.3.2. This task was performed to improve the model's





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Tributary PCB Boundary Conditions for Verification and Projection Periods

Figure 4-13

1337\042TBLK ds4
disk HS4300 file fig4-10 wq1

simulation capabilities during high-flow events, which have a significant effect on the fate and transport of PCBs. Again, calibration efforts focused on TSS. To be consistent with an event-specific upstream boundary, it was also necessary to use event-specific hydrodynamic flows and sediment resuspension values.

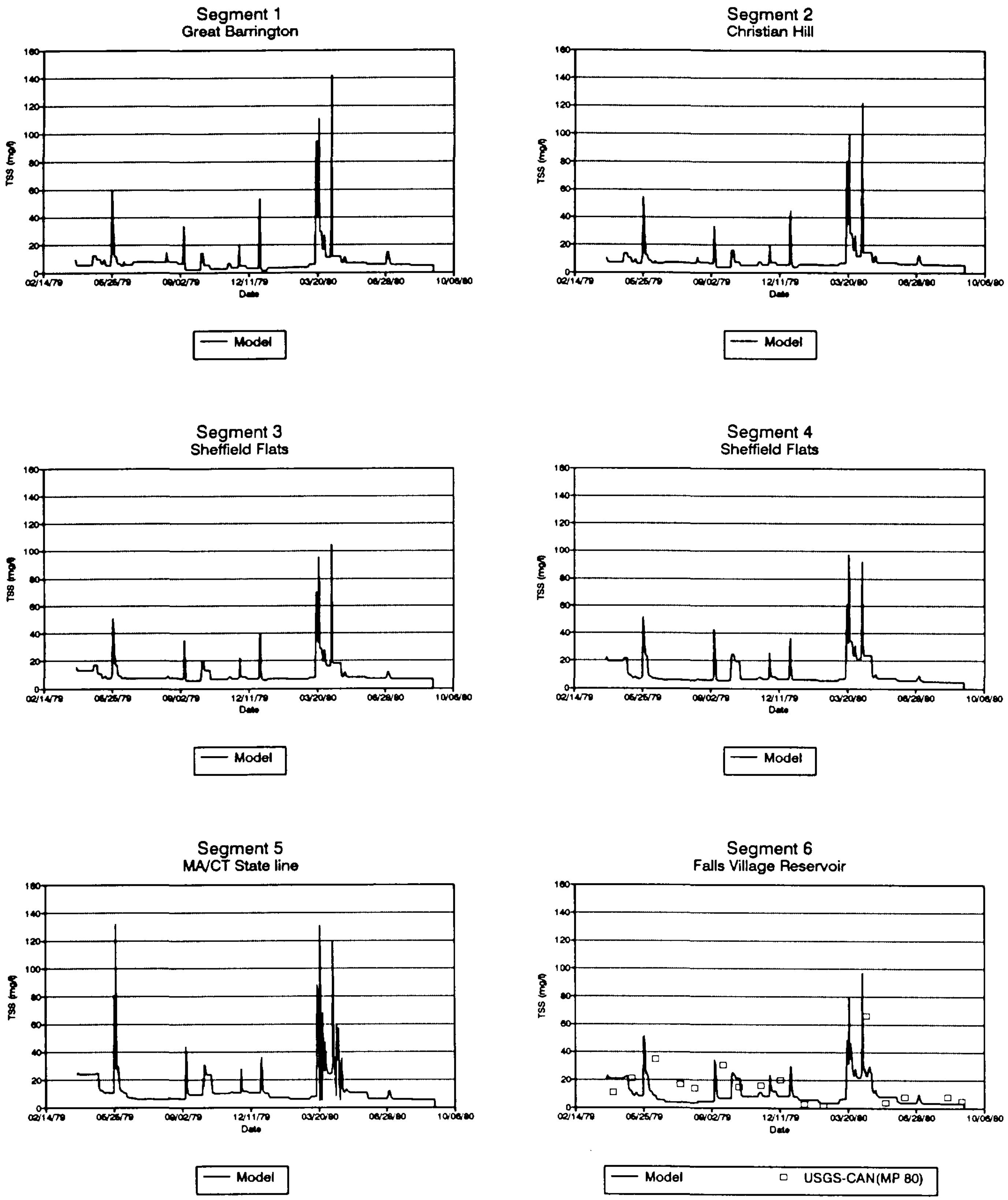
The upstream flow and TSS data used to develop the model's upstream boundary for the calibration period are shown in Figure 3-13. The model uses 58 flow, resuspension, and TSS upstream boundary step-functions to define the model input.

Figure 4-14 shows the results of the model calibration to TSS for each of the 11 model segments. The daily TSS measurements are shown at the downstream locations (segments 7 and 9 and other available data is also shown). As shown, the model reasonably simulates most of the daily variations in TSS in segments 7 and 9. When comparing the modeled and measured TSS, it is important to consider that TSS measurements are mostly from daily grab samples. As the model is based on daily average flow, we expect some differences in the measured and simulated TSS.

In addition to the daily TSS measurements there were various intermittent measurements of TSS and indirect measurements of TSS (i.e., total solids [TS] minus total dissolved solids [TDS]) in segments 6 (Falls Village Reservoir), 10 (Lake Lillinonah), and 11 (Lake Zoar). The indirect measurements of TSS were made at the following stations:

SEGMENT	STATION	MP
6	Canaan	80
9	New Milford	46.0
10	Brookfield	37
11	Riverside	25.1

We are distinguishing between the direct and indirect TSS measurements because at low TSS values, the indirect measurements may not be completely reliable. In calculating TSS from TS and TDS it was found that numerous results were negative, implying that TDS was greater than TS, a result that is not theoretically possible. This problem was most evident at low concentrations of TS and TDS, indicating a lack of accuracy at such concentrations. As these data are 15 years old, it was not possible to evaluate QA/QC aspects.



Segment 1
Great Barrington

Segment 2
Christian Hill

Segment 3
Sheffield Flats

Segment 4
Sheffield Flats

Segment 5
MA/CT State line

Segment 6
Falls Village Reservoir

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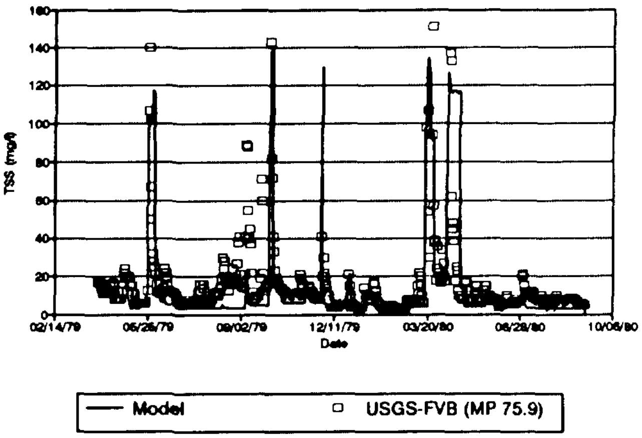
Model Calibration Results for TSS

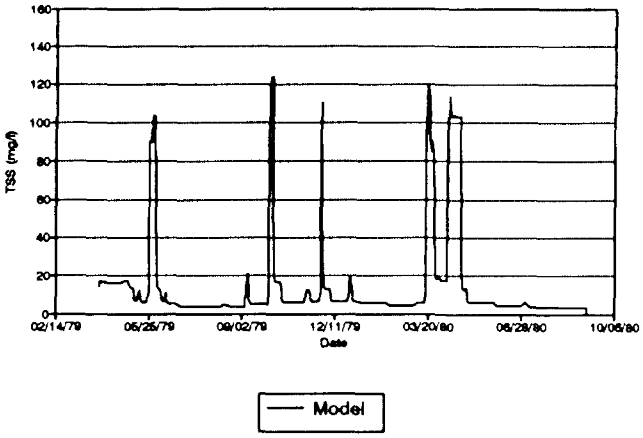
Figure 4-14
(1 of 2)

337 042TBLK ds4
Disk HS4306 File 16MTest2 wq*

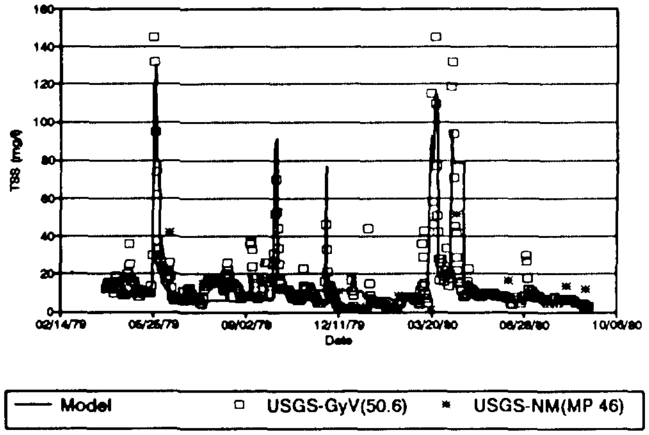
Segment 7
Kent



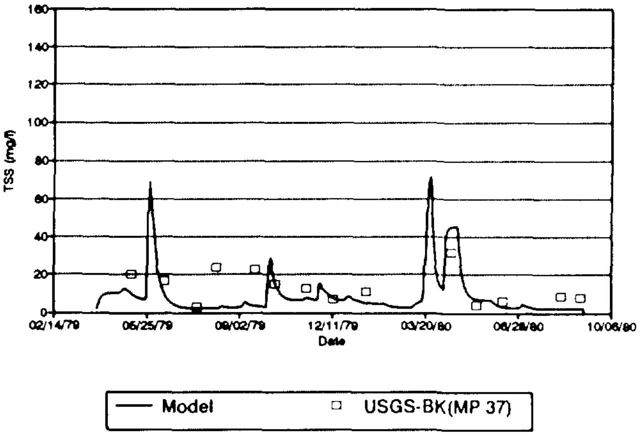
Segment 8
Bulls Bridge Reservoir



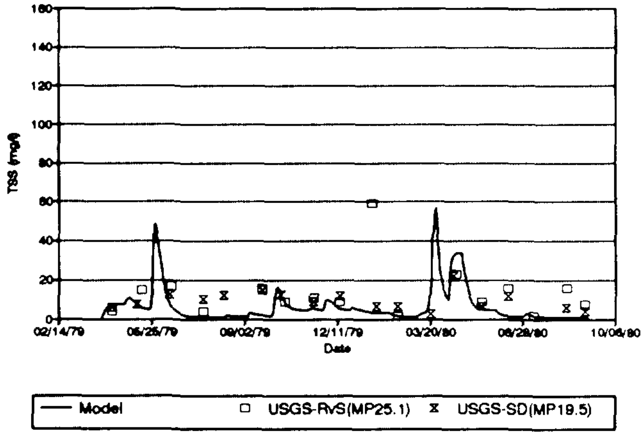
Segment 9
Gaylordsville



Segment 10
Lake Lillinonah



Segment 11
Lake Zoar



Note: Observation legends show "organization that collected data - station abbreviation (milepoint)."

Descriptions of Station Abbrevations:

DSB = Division Street Bridge - Great Barrington
CAN = Canaan
FVB = Falls Village Bridge
GyV = Gaylordsville
NM = New Milford
BK = Brookfield
RvS = Riverside

Model Calibration Results for TSS

Figure 4-14
(2 of 2)

Nevertheless, all available TSS data are plotted in Figure 4-14 and demonstrate that the model provides reasonable TSS simulations. Another factor in considering how accurately the model simulates TSS is its simulation of sediment burial and scour. The following table shows the model's average burial and scour values for the 18-month simulation and also shows the estimated burial values (from ^{137}Cs and PCB profiles [see Section 4.2.3]) in the two run-of-river impoundments and two lakes and, for comparison, shows whether deposition, scour, or transport is estimated based on average river velocity and criteria provided by Hjulstrom (1935):

		SEDIMENT BURIAL RATES (in/yr) [NEGATIVE VALUE INDICATES SCOUR]	
SEGMENT No.	TYPE	MODEL	ESTIMATED
1	Riverine	0.08	~ 0
2	Riverine	0.08	~ 0
3	Riverine	-0.03	~ 0
4	Riverine	-0.06	~ 0
5	Riverine	-0.27	< 0
6	Falls Village Reservoir	0.15	0.14
7	Riverine	-0.39	< 0
8	Bulls Bridge Reservoir	0.16	0.26
9	Riverine	-0.07	< 0
10	Lake Lillinonah	0.23	0.32
11	Lake Zoar	0.25	0.32

The model sediment burial results are generally consistent with those estimated. The model simulates sediment burial rates in the impoundments and lakes similar to those estimated from ^{137}Cs and PCB profiles (see Section 4.2.3). The model predicts scour in segments 5 and 7 and to a lesser degree in segment 9. This is consistent with anticipated results from comparing average water velocities with Hjulstrom's criteria (see Table 4-4). The other segments show low values of scour or burial, indicating that the bed is not substantially eroding or accumulating, a result consistent with the conclusion, based on average river velocity and Hjulstrom's criteria, that these segments primarily support sediment transport.

In conclusion, as the model appears to provide reasonable simulations of daily TSS and solids flux across the bed-water interface, the controlling parameters of resuspension, settling, upstream and tributary TSS boundaries, and the concentration of solids in the sediment (i.e., bulk density), are set at reasonable values. The next step in model acceptance is to verify that it reasonably simulates TSS and sediment flux for another time period and to also show that it provides reasonable simulations of water column and sediment PCB, as discussed in the following section.

4.4 MODEL VERIFICATION

The model verification time period extends from 1 October 1979 to 9 April 1993 (13.5 years). Calibration of HOUSRM for TSS was demonstrated in Section 4.3. The model verification effort focuses primarily on sediment PCB, as much of the water column PCB data are below the detection limit. However, comparisons between the model simulations of water column PCB as well as TSS with all available data are also shown.

Table 4-10 summarizes the segment-specific model input parameters. Pertinent model constants (i.e., those that WASTOX allows only one value throughout all segments) are as follows:

Henry's constant (Pa -m^3/mole)	7.64
PCB conc. in air (ng/m^3)	0.57
Air temp (°C)	10.0
Log K_{ow} (l/kg)	7.284
Solids density (g/ml)	2.0

Figure 4-15 shows the model-predicted and observed TSS concentrations in all segments. As indicated, the model seems, in general, to reasonably simulate TSS trends in the Housatonic River. The model reasonably simulates many of the peak TSS concentrations as well as normal flow concentrations. Some peak TSS concentrations were not simulated; this may be due to several factors:

- The verification time period is 4944 days and model input allows 400 inputs. Thus, it was necessary to average some of the TSS, flow, and resuspension model input so as not to exceed the model dimensions.

- As continuous measurements of TSS at the upstream boundary were not taken, the boundary was developed using Equations 3-3 and 3-4. This equation estimates TSS as a function of flow and season and is based on the 18-month period of TSS measurements. As explained further in Section 3.3.2, such a time period may not fully reflect seasonal effects or other unknown effects on TSS.

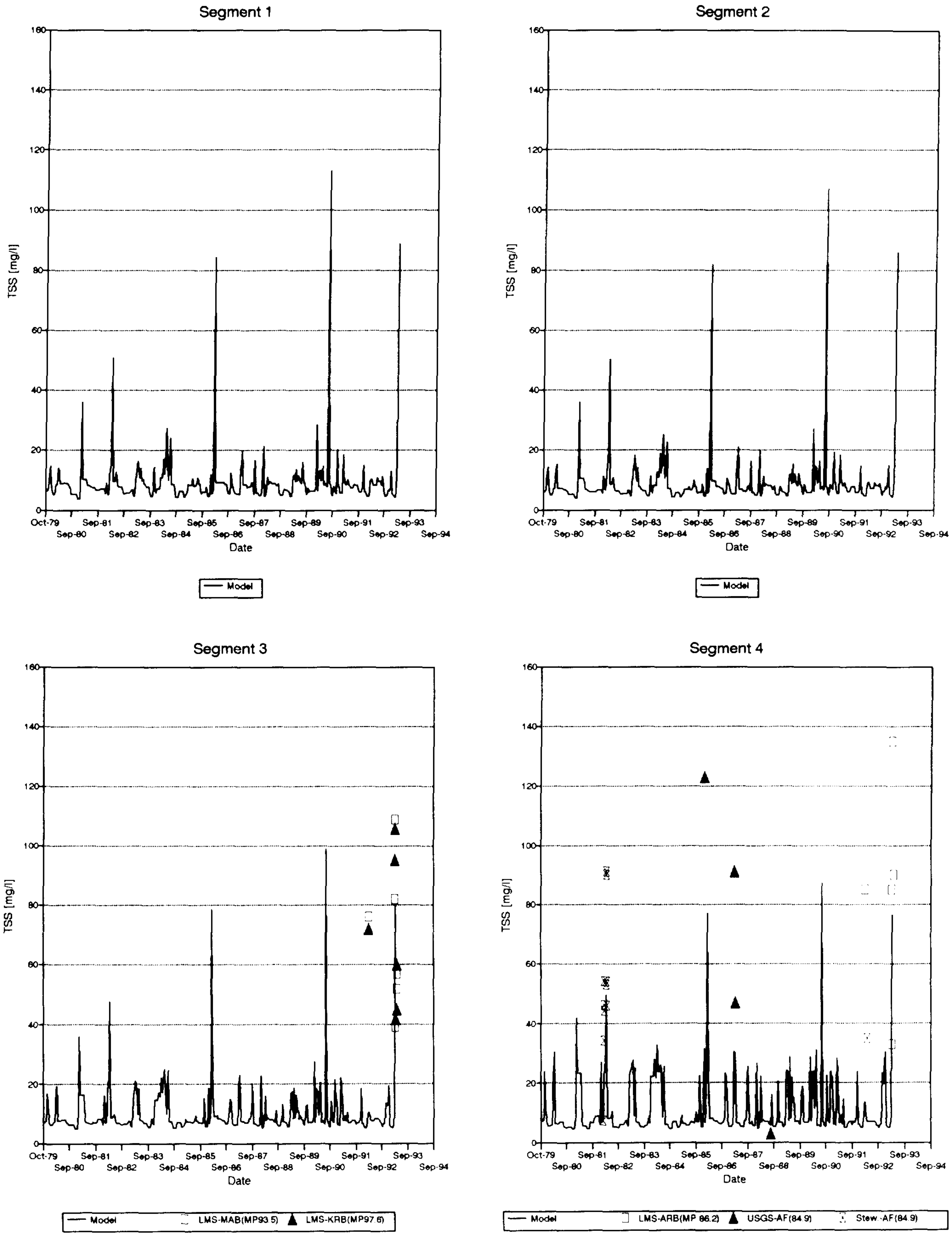
- Most of the TSS concentrations are taken from grab samples whereas the model is based on daily average flows.

TABLE 4-10

MODEL INPUT PARAMETERS

MODEL PARAMETER NAME	UNITS	DESCRIPTION	MODEL SEGMENT DESCRIPTION AND NUMBER										
			GREAT BARRINGTON 1	CHRISTIAN HILL 2	SHEFFIELD FLATS 3	SHEFFIELD FLATS 4	CT/MA LINE 5	FALL VILLAGE RESERVOIR 6	KENT 7	BULLS BRIDGE RESERVOIR 8	GAYLORDSVILLE NEW MILFORD 9	LAKE LILLINONAH 10	LAKE ZOAR 11
			Water Column Segments										
DEPTH	m	Depth of segment	2.74	2.77	3.72	3.57	0.7	3.26	0.73	4.73	1.19	11.86	7.5
AREA	ft^2	Surface area	1.80E+06	1.87+0.6	2.89E+06	5.49E+06	2.31E+06	4.62E+06	2.33E+07	5.05E+06	1.03E+07	6.88E+07	4.25E+07
VELOC	m/sec	Water velocity	0.2	0.22	0.19	0.17	0.5	0.18	0.62	0.13	0.56	0.02	0.04
TEMP	°C	Water temperature	11	11	11	11	11	11	11	11	11	11	11
WVEL	m/sec	Wind velocity	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4	4.5	4.5
DOC	mg/l	Dissolved organic carbon	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	3.5	2.5	2.5
PIDOC	l/kg	Partition coefficient to DOC	6966	6966	6966	6966	966	6966	6966	6966	6966	6966	6966
KL	m/day	Volatilization rate	0.31	0.31	0.27	0.26	0.54	0.28	0.56	0.22	0.5	0.28	0.28
FOC		Fraction of organic carbon	0.027	0.027	0.003	0.007	0.01	0.016	0.008	0.026	0.016	0.024	0.023

PARAMETER	UNITS		12	13	14	15	16	17	18	19	20	21	22
			Sediment Segments										
DEPTH	m	Depth of segment	0.025	0.025	0.025	0.025	0.025	0.028	0.025	0.053	0.025	0.065	0.065
AREA	ft^2	Surface area	1.80E+06	1.87E+0.6	2.89E+06	5.49E+06	2.31E+06	4.26E+06	2.33E+07	5.05E+06	1.30E+07	5.85E+07	3.10E+07
DOC	mg/l	Dissolved organic carbon	10	10	10	10	10	10	10	10	10	10	10
PIDOC	l/kg	Partition coefficient to DOC	3.55E+05	3.55E+05	3.55E+05	3.55E+05	3.55E+05	3.55E+05	3.55E+05	3.55E+05	3.55E+05	3.55E+05	3.55+05
FOC		Fraction of organic carbon	0.027	0.027	0.003	0.007	0.01	0.016	0.008	0.026	0.016	0.024	0.023



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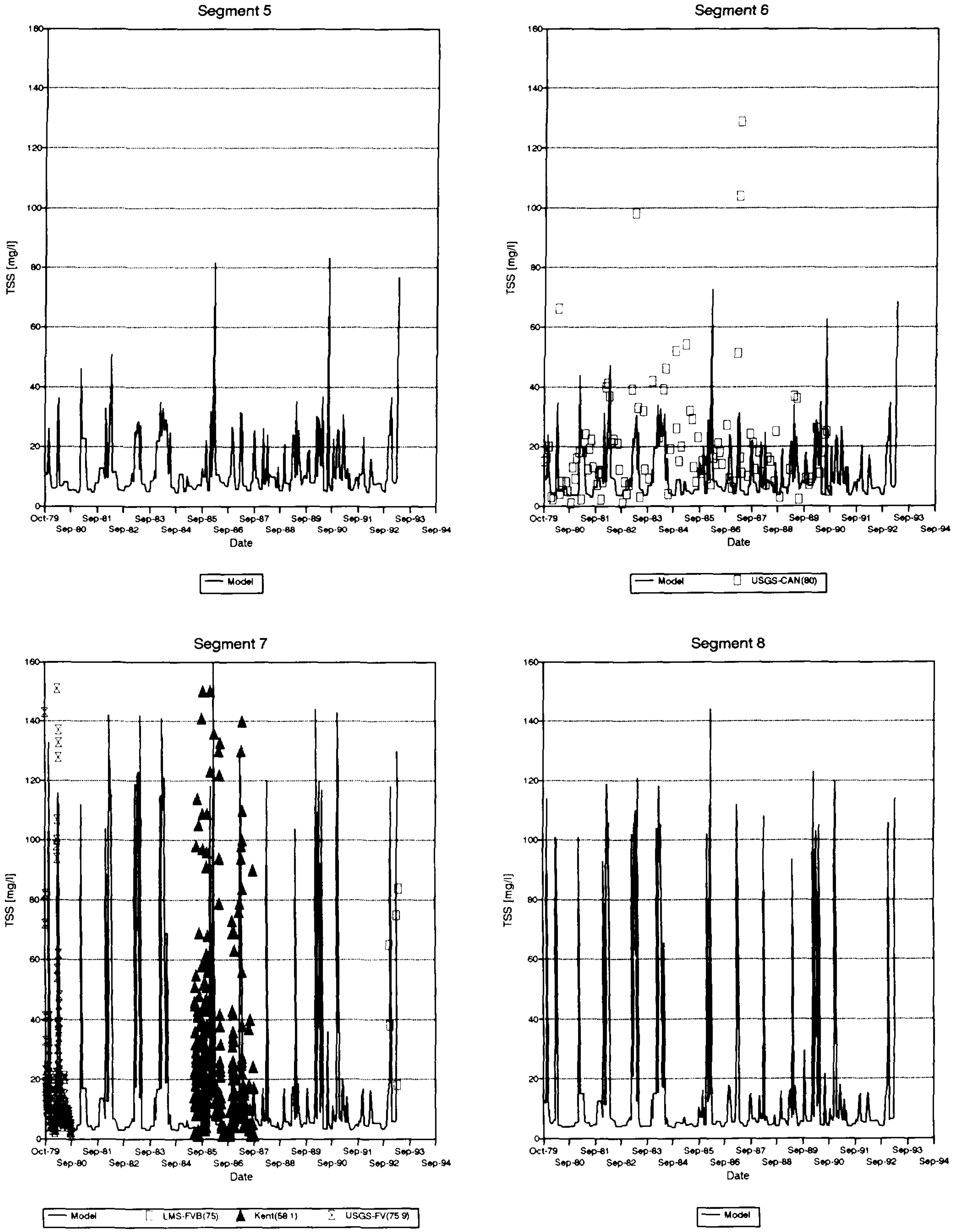
Model Verification Results for TSS

Figure 4-15
(1 of 3)

337-042TBLK ds4
TSSVER wq1 HS4352



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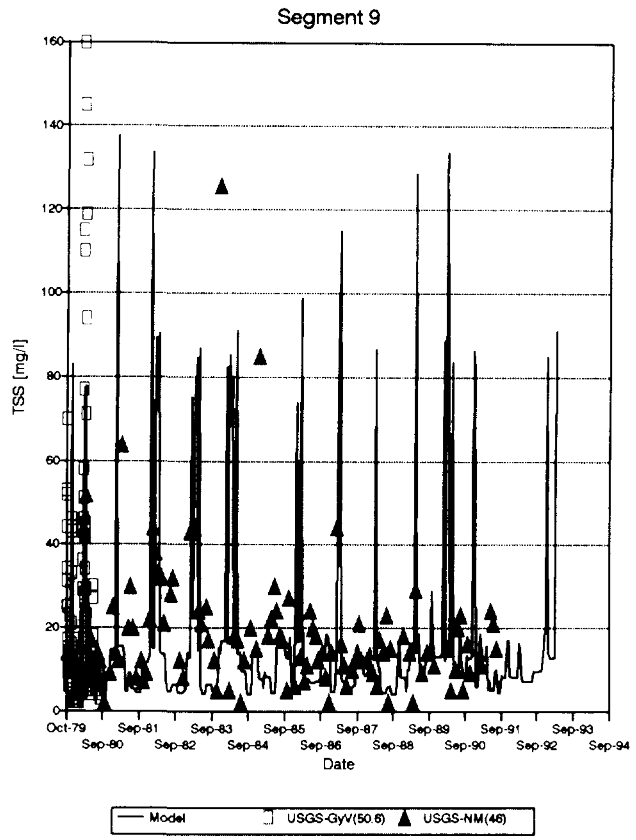
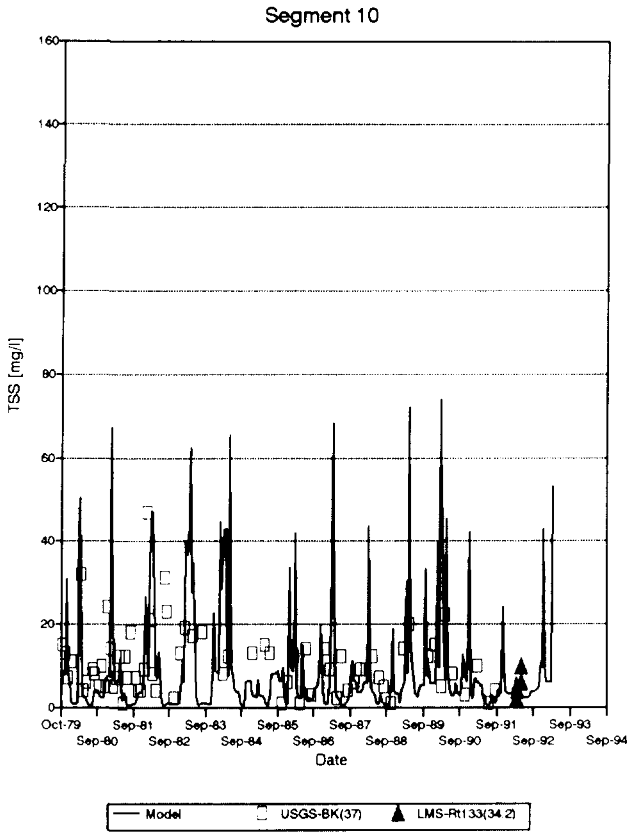
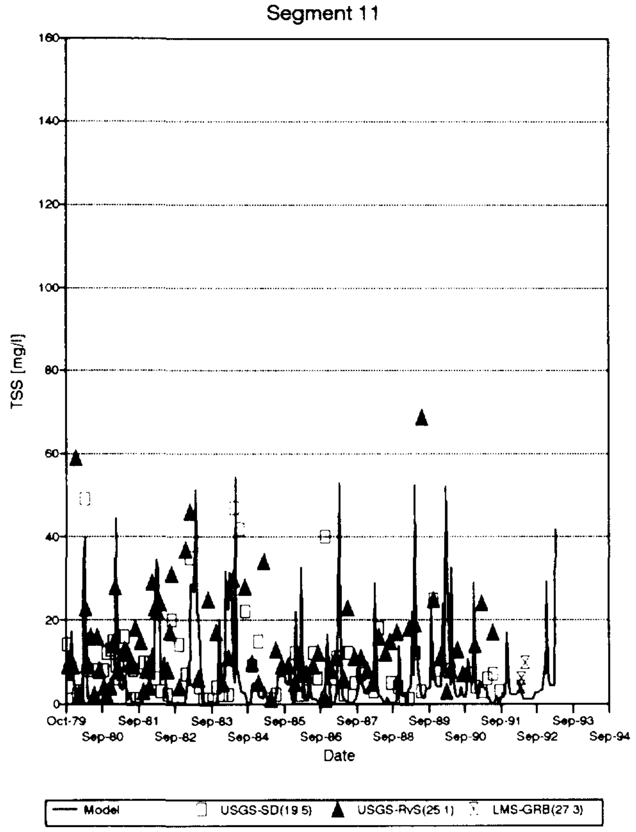
Model Verification Results for TSS

Figure 4-15
(2 of 3)

337\042TBLK ds4
TSSVER.wq1 HS4352







Note: Observation legends show "organization that collected data - station abbreviation (milepoint)."
Discriptions of Station Abbrevations:
DSB = Division Street Bridge - Great Barrington
MAB = Maple Avenue Bridge
KRB = Kellogs Road Bridge
ARB = Andrus Road Bridge
AF = Ashley Falls
CAN = Canaan
FVB = Falls Village Bridge
GyV = Gaylordsville
NM = New Milford
BK = Brookfield
Rt133 = Route 133 Bridge
SD = Stevenson Dam
RvS = Riverside
GRB = Glen Road Bridge

Model Verification Results for TSS

Figure 4-15
(3 of 3)

337-042TBLK ds4
TSSVER wq1 HS4352

- The model does not simulate localized events that may affect TSS concentrations. These include and land disturbances (i.e., construction or agricultural activities) and severe bank erosion (i.e., sediment sloughing).

Given the above limitations, the model provides reasonable TSS simulations.

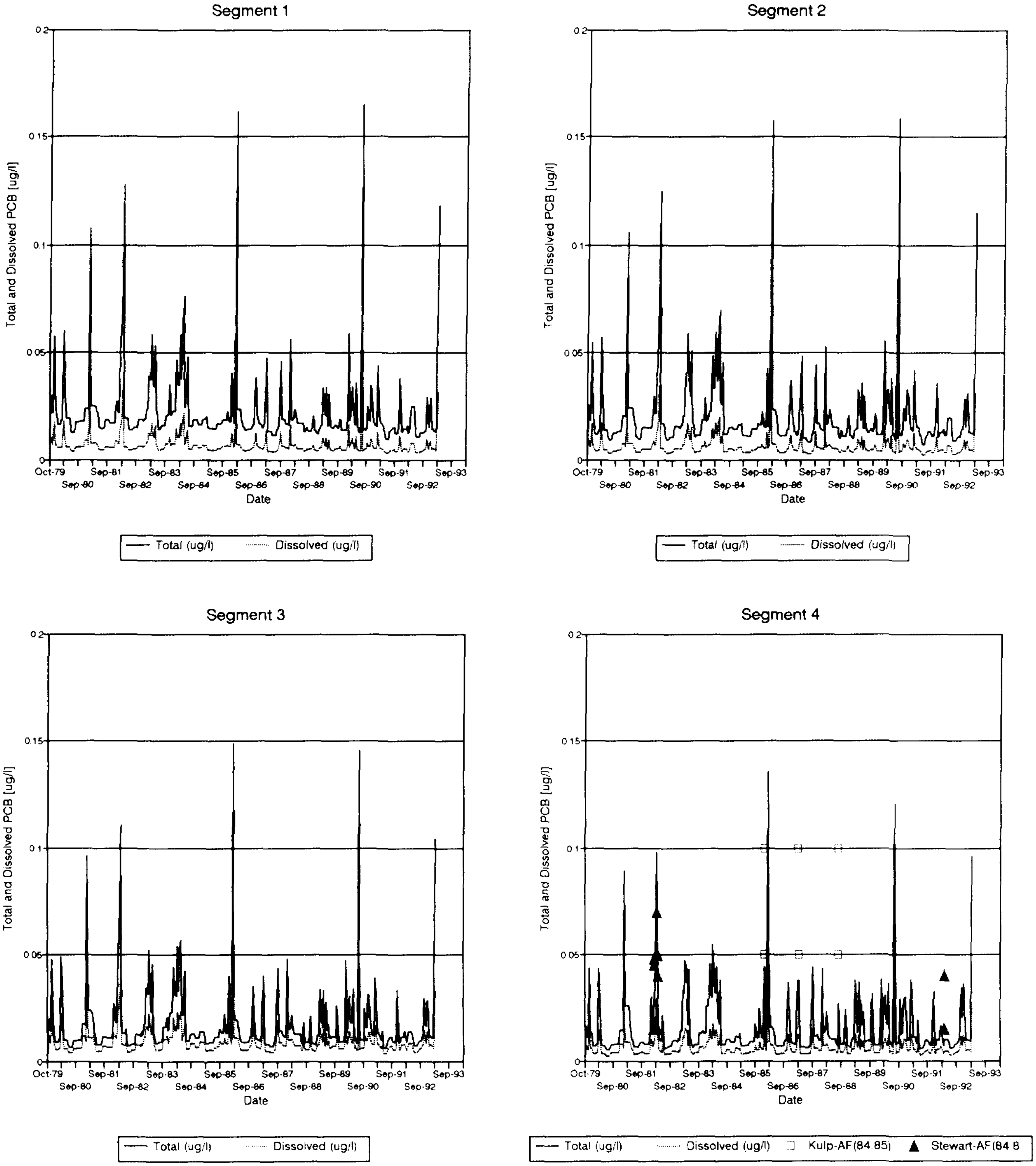
The model's calculations of sediment burial or scour for the verification period is shown below:

SEGMENT No.	MODEL-CALCULATED BURIAL RATES[1] (in./year)
1	0.07
2	0.07
3	-0.08
4	-0.13
5	-0.27
6	0.15
7	-0.66
8	0.24
9	-0.04
10	0.30
11	0.31

[1] Negative values indicate scour.

These results are consistent with those presented for the calibration period. Burial rates in the impoundments and lakes agree well with the estimated values based on ^{137}Cs and PCB sediment profiles. However, average velocity in segment 9 supports the scour classification. As resuspension rates are set high in segment 9, the model's simulation of essentially no net scour or burial is due to the large influx of solids from the upstream segment. As there are no TSS data available for segment 8, however, the segment 8 solids load cannot be confirmed and further evaluations of sediment flux cannot be made at this time.

Figure 4-16 shows the model-simulated total and dissolved PCB concentrations as well as available total PCB observations. As mentioned previously, detectable water column PCB concentrations are very limited for stations downstream of Great Barrington. Note that only PCB concentrations reported as greater than or equal to the detection limit are plotted. The available data indicate that the model's simulation of total PCB is generally reasonable. The following table summarizes water column PCB averages and fraction dissolved for each model segment for the verification period:



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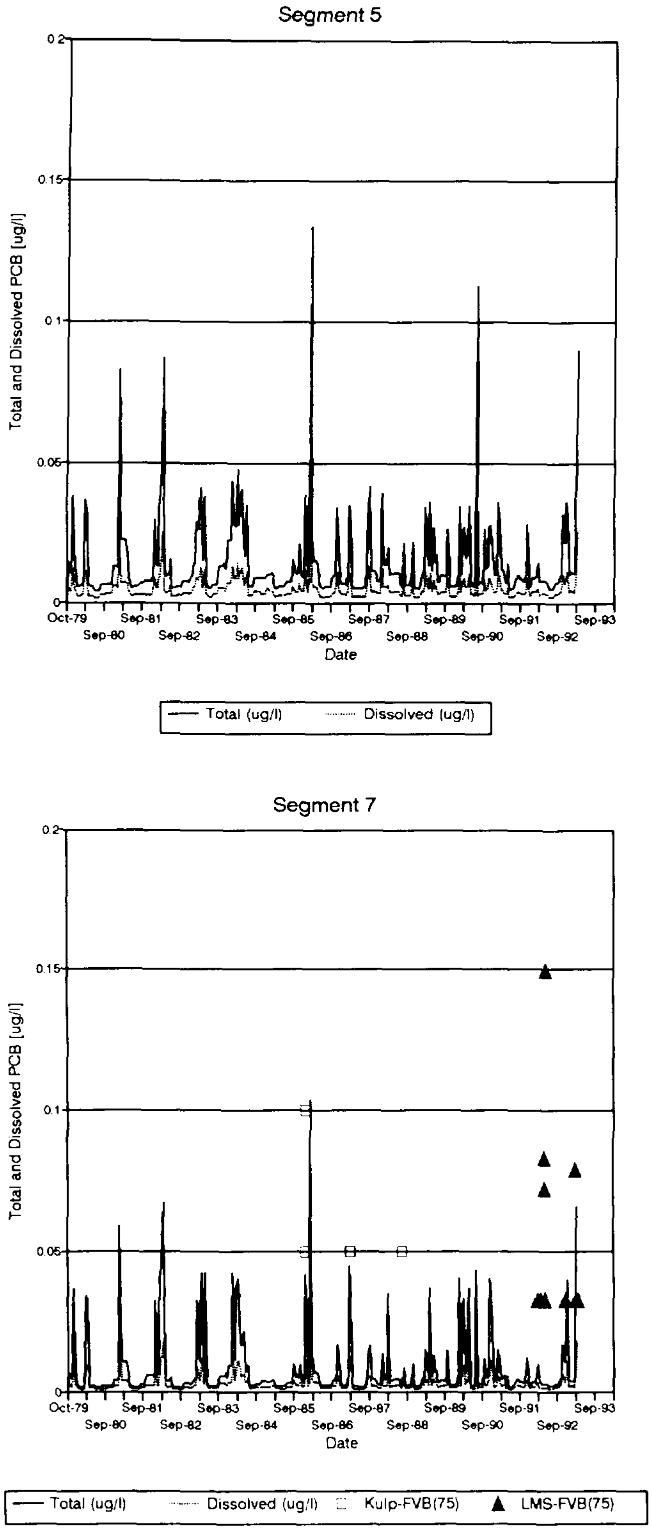
Model Verification Results for Total and Dissolved PCB

Figure 4-16
(1 of 3)

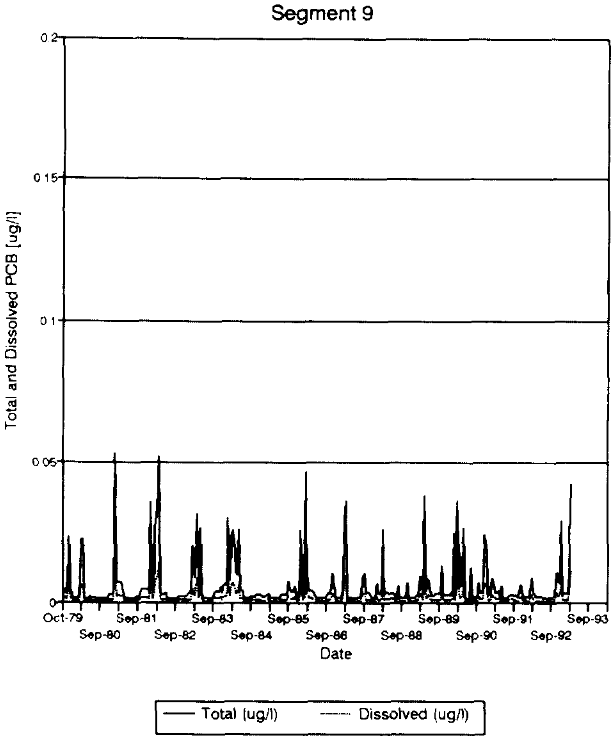
337.042TBLK ds4
HRM18

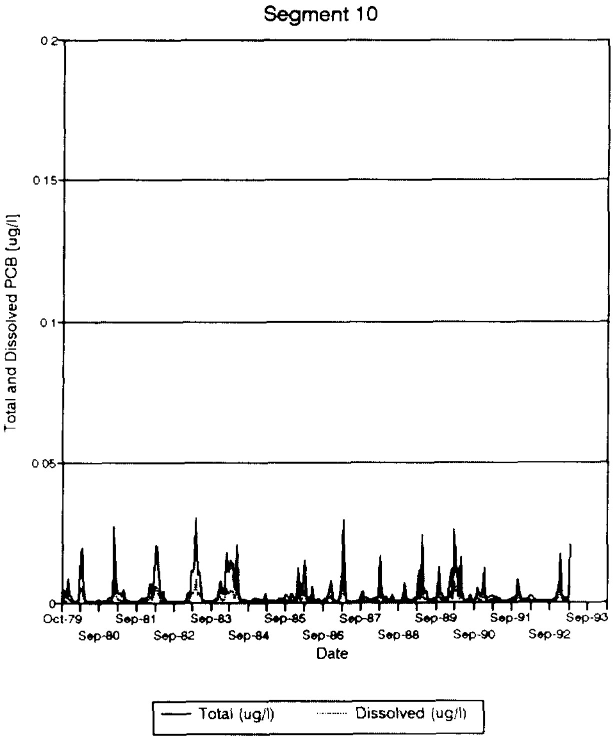


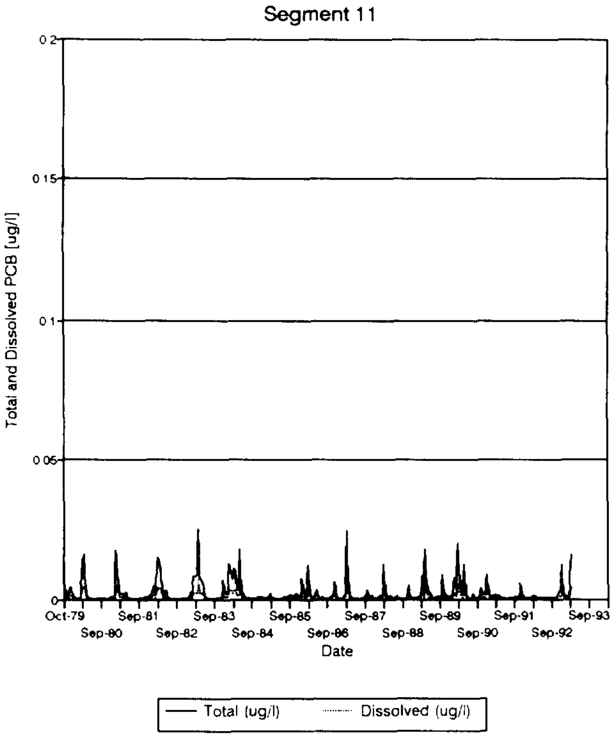
Model Verification Results for Total and Dissolved PCB

Figure 4-16
(2 of 3)

1337\042TBLK ds4
HRM18







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NM = New Milford
BK = Brookfield
Rt133 = Route 133 Bridge
SD = Stevenson Dam
RvS = Riverside
GRB = Glen Road Bridge

Model Verification Results for Total and Dissolved PCB

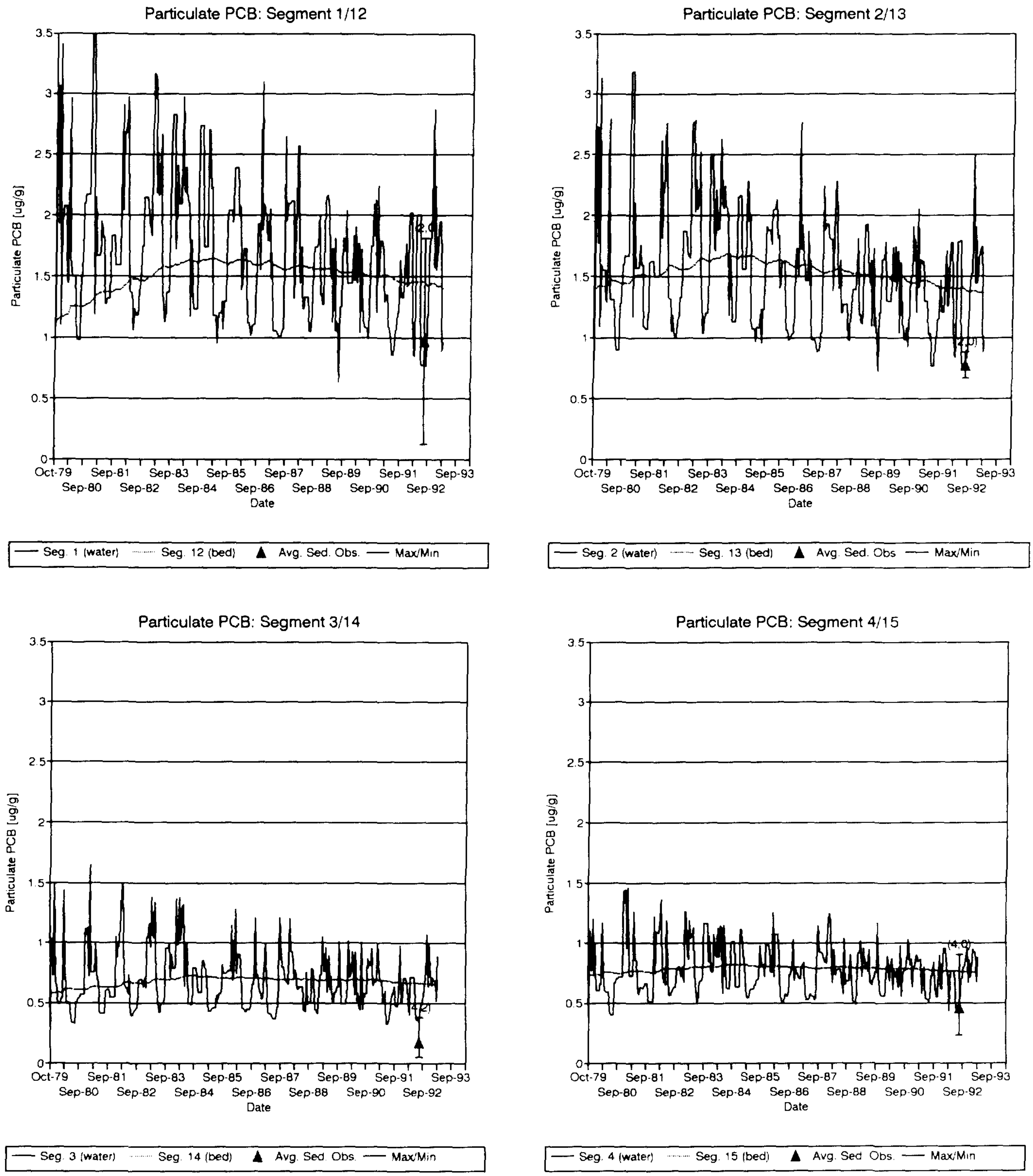
Figure 4-16
(3 of 3)

337'042 TBLK ds4
HRM18

SEGMENT	c_t (μg/l)	c_d (μg/l)	f_d
1	0.022	0.007	0.33
2	0.020	0.006	0.34
3	0.017	0.009	0.59
4	0.015	0.006	0.46
5	0.014	0.005	0.40
6	0.012	0.004	0.38
7	0.008	0.003	0.48
8	0.007	0.002	0.35
9	0.006	0.002	0.36
10	0.003	0.001	0.43
11	0.002	0.001	0.51

Figure 4-17 shows the model simulated bed sediment and suspended sediment PCB concentrations and for comparison the results of surficial (top 3 in.) bed sediment PCB samples collected by LMS in 1986 and 1992. The initial sediment PCB concentrations used in the model for the beginning of the verification period (1979) were determined from data reported in Frink et al. (1982) and Stewart Labs (1982). These data are not presented in Figure 4-17 since they are, by definition, equivalent to the initial sediment PCB concentrations in the model. As indicated, HOUSRM reasonably simulates the change in bed sediment PCB concentration from 1979 to 1992. In Lakes Lillinonah and Zoar (segments 10 and 11, respectively), the surficial sediment data collected in 1986 had an average PCB concentration higher than that in 1979. Given the limited number of samples collected in 1986 (two cores in each lake and one each in the run-of-river impoundments), it is not possible to confirm whether this apparent increasing trend is real. As the greater number of surficial sediment samples collected in 1992 provides more thorough segment-averaged PCB concentrations, comparisons with the model are better made with 1992 data.

A mass balance of PCBs for the verification time period was also performed to identify the relative importance of PCB sources and sinks. The following table shows the mass of PCB sources and sinks for the entire study area:



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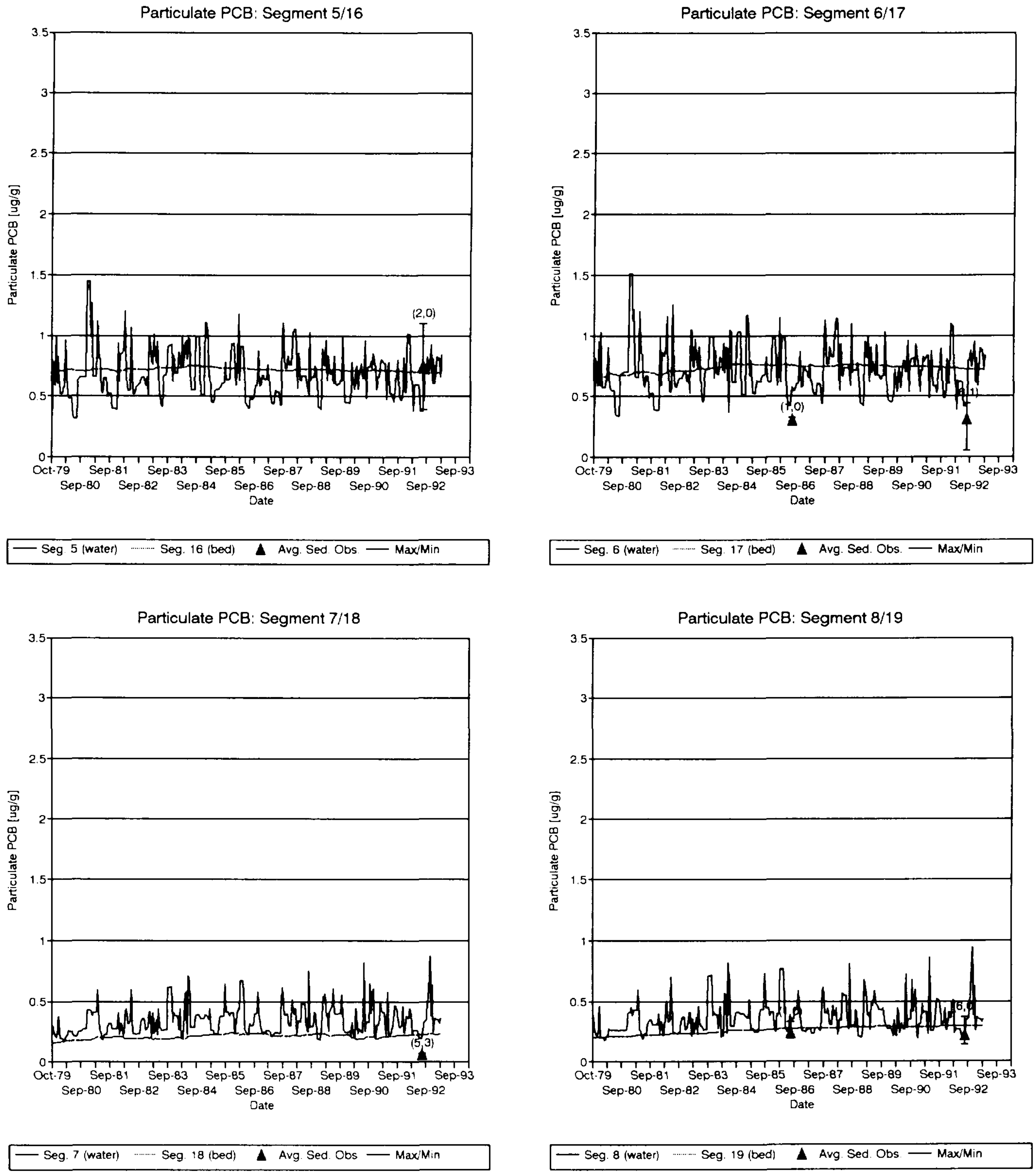
Model Verification Results for Particulate PCB

Figure 4-17
(1 of 3)

337'042 TBLK ds4
PTOX wq1 HS4352



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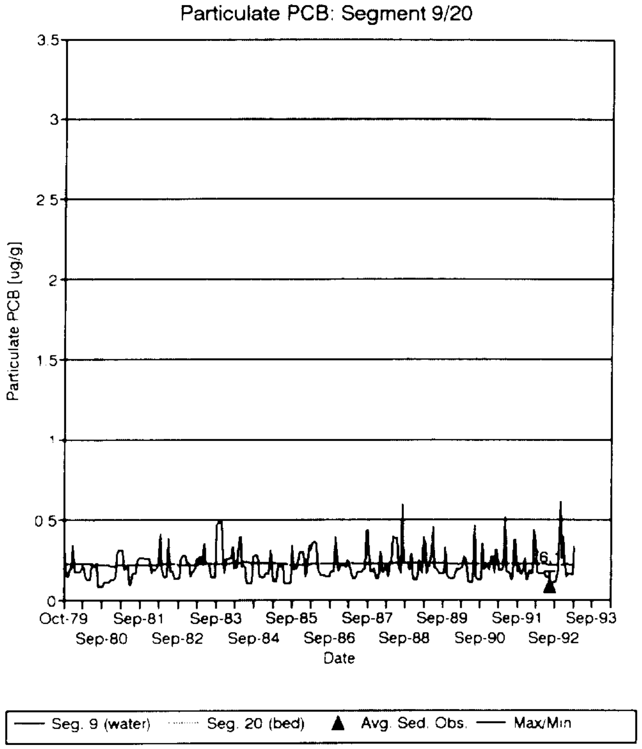
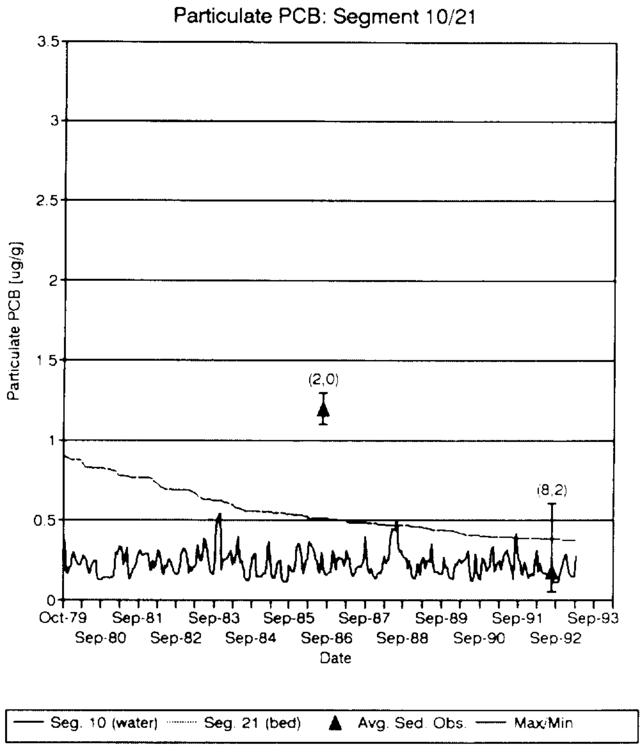
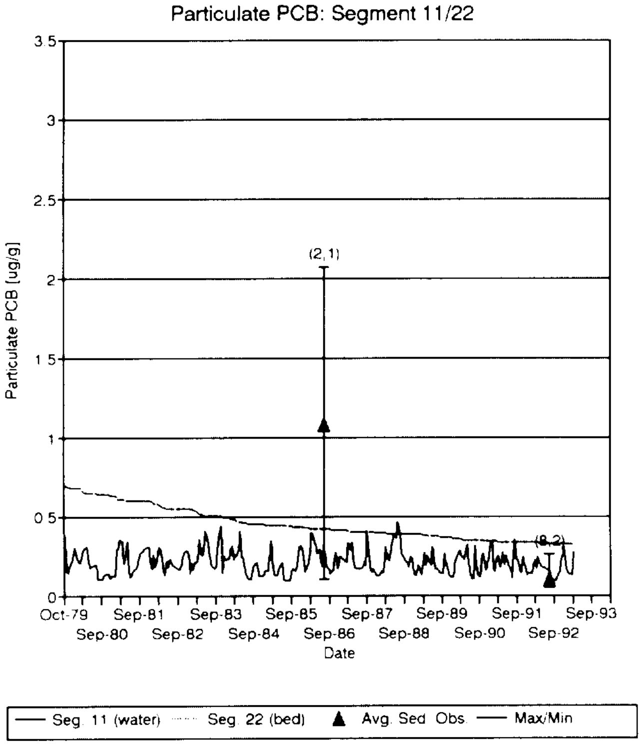
Model Verification Results for Particulate PCB

Figure 4-17
(2 of 3)

337\042TBLK ds4
PTOX wq1 HS4352







Note: Numbers in ( ) above data indicate the number of samples that make up average, followed by the number of those samples that were below detection limit. The average includes the detection limit value.

Model Verification Results for Particulate PCB

Figure 4-17
(3 of 3)

CONTRIBUTING COMPONENT	AVERAGE YEARLY PCB TRANSPORT (1979-1993) (lb/year)
Sources	
Inflow at Great Barrington	37
Tributaries	10
Total Input:	47
Sinks	
Outflow at Stevenson Dam	20
Volatilization	9
Sedimentation and burial	18
Total Output	47

The model indicates that the calculated annual average loss of 9 lb/yr due to volatilization is about 50% of the loss due to sedimentation. The predicted mass of PCB that leaves the study area with water flowing over the Stevenson Dam (20 lb/yr) is about equal to the loss due to sedimentation.

In conclusion, the model provides reasonable comparisons with available TSS, water column PCB, and bed sediment PCB. The application of HOUSRM to the 1979-1993 time period confirms the reasonable accuracy of the model and provides a basis for performing future projections as provided in Section 4.6.

4.5 MODEL SENSITIVITY

The sensitivity of HOUSRM to possible parameter ranges is performed to identify those parameters of key importance. The key parameter ranges are then tested in the model projections to evaluate their effect. The initial screening of several parameters was performed using the 18-month calibration version of HOUSRM. Table 4-11 shows the low and high parameter ranges relative to the "baseline" values for those parameters selected for an initial sensitivity analysis and also shows the source of the information. Table 4-12 shows the percent difference results for total PCB (c_t), dissolved PCB (c_d), particulate PCB (c_p), and PCB partitioned to DOC (c_{doc}) for both the water column and sediment segments. The results are averaged to include the full 18-month model run for all 11 water column and sediment segments. Based on these model runs four parameters are identified as substantially affecting the total PCB in the water column and sediment:

TABLE 4-11

MODEL PARAMETER SENSITIVITY RANGES

	UNITS	RANGE OF VALUES			SOURCE
		LOW	MIDDLE	HIGH	
Model Parameters					
DOC Partition Coeff (water) [$PIDOC_{(wc)}$]	l/kg	6918*	55,976	169,824	(Evans 1988), (Landrum 1987)
DOC Partition Coeff (pore) [$PIDOC_{(pore)}$]	l/kg	2.6×10^4	3.55×10^5*	3.6×10^7	(Capel and Eisenrach 1990), (Landrum 1987)
$DOC_{(pore)}$	mg/l	3	10*	100	Estimated
Fraction of Org. Carbon ($Foc_{(wc)}$)		0.001-0.009	0.003-0.027*	0.006-0.045	Estimated from avail. data
Log Kow for solids depend. Partitioning	l/kg	6.11	7.284*	7.408	(EPA 1987), (De Bruijn 1989)
Log Kow for constant partitioning	l/kg		7.284		(De Bruijn 1989)
PCB (air)	μg/l	0.085×10^{-6}	0.57×10^{-6}	3.5×10^{-6}	Low = (Sweet 1993), Baseline and High = (Zorex 1992)
Volatilization					
• Henry's Constant (H)	atm m^3/mole [Pa m^3/mole]	0.435×10^{-4} [4.41] (T = 5°C)	0.754×10^{-4}* [7.64] (T = 10°C)	0.210×10^{-3} [21.3] (T = 20°C)	(Burkhard 1985)
• Wind speed (U_{wind})	m/s				
Segs 1 to 9		1.2	2.4*	3.6	Baseline = 2 yr avg at GE
Segs 10 to 11		2.3	4.5*	6.8	Baseline = 20% lower than 9-yr avg at Bridgeport to adjust for inland locations of segments

* Parameter values used in baseline model run.

Table 4-12

Average PCB % Differences for All Segments

Parameter	Value	Water Column % Differences from baseline				Sediment % Differences from baseline			
		c_t	c_d	c_p	c_{doc}	c_t	c_d	c_p	c_{doc}
pdoc-wc(l/kg)	6918								
	55976	2.7	-3.3	-3.2	682.1	-1.2	-1.3	-1.2	-1.3
	169824	8.4	-10.1	-9.7	2104.1	-3.7	-3.8	-3.6	-3.8
pdoc-pore(l/kg)	26000	-0.1	-0.1	-0.1	-0.1	0.0	0.1	0.0	-92.7
	355000								
	36000000	8.2	9.6	9.5	9.6	-3.1	-5.6	-2.8	9473.6
DOCpore (mg/l)	3	-0.1	-0.1	-0.1	-0.1	0.0	0.0	0.0	-70.0
	10								
	100	0.8	0.9	0.9	0.9	-0.3	-0.5	-0.3	894.6
FOCwc (g oc/g sol)	0.001-0.009	6.6	41.9	-15.4	41.8	-4.9	-6.5	-4.5	-6.4
	0.003-0.027								
	0.006-0.045	-1.9	-11.8	4.4	-11.8	1.3	2.1	1.1	2.2
Solids Dependent partitioning (Log-kow values [l/kg])	6.11	23.2	144.8	-50.2	144.1	-17.8	1092.6	-17.1	1092.7
	7.284								
	7.408	-1.1	-6.4	2.4	-6.4	0.8	-24.0	0.7	-24.0
Solids Independent (1) partitioning (Log-kow values [l/kg])	7.284	-3.6	-29.1	8.8	-29.0	4.2	2.1	4.6	2.1
PCBair (ng/m^3)	0.085	-0.1	-0.1	-0.1	-0.1	-0.0	-0.0	-0.0	-0.0
	0.57								
	3.5	0.5	0.5	0.6	0.5	0.1	0.1	0.1	0.1
Henry (Pa m^3/mole)	4.41	1.3	1.4	1.3	1.4	0.4	0.4	0.4	0.4
	7.64								
	21.28	-2.1	-2.1	-2.0	-2.1	-0.6	-0.7	-0.6	-0.7
Wind (m/s)	1.2 to 2.3	1.0	1.0	1.0	1.0	0.3	0.3	0.3	0.3
	2.4 to 4.5								
	3.6 to 6.8	-0.7	-0.8	-0.8	-0.7	-0.2	-0.2	-0.2	-0.2
No Volatilization	0	6.3	6.9	6.5	6.8	1.8	2.0	1.7	2.0

Note: shaded values are those used in "baseline" 18-month model run

(1) Percent difference for solids independent partitioning is relative to solids dependent partitioning

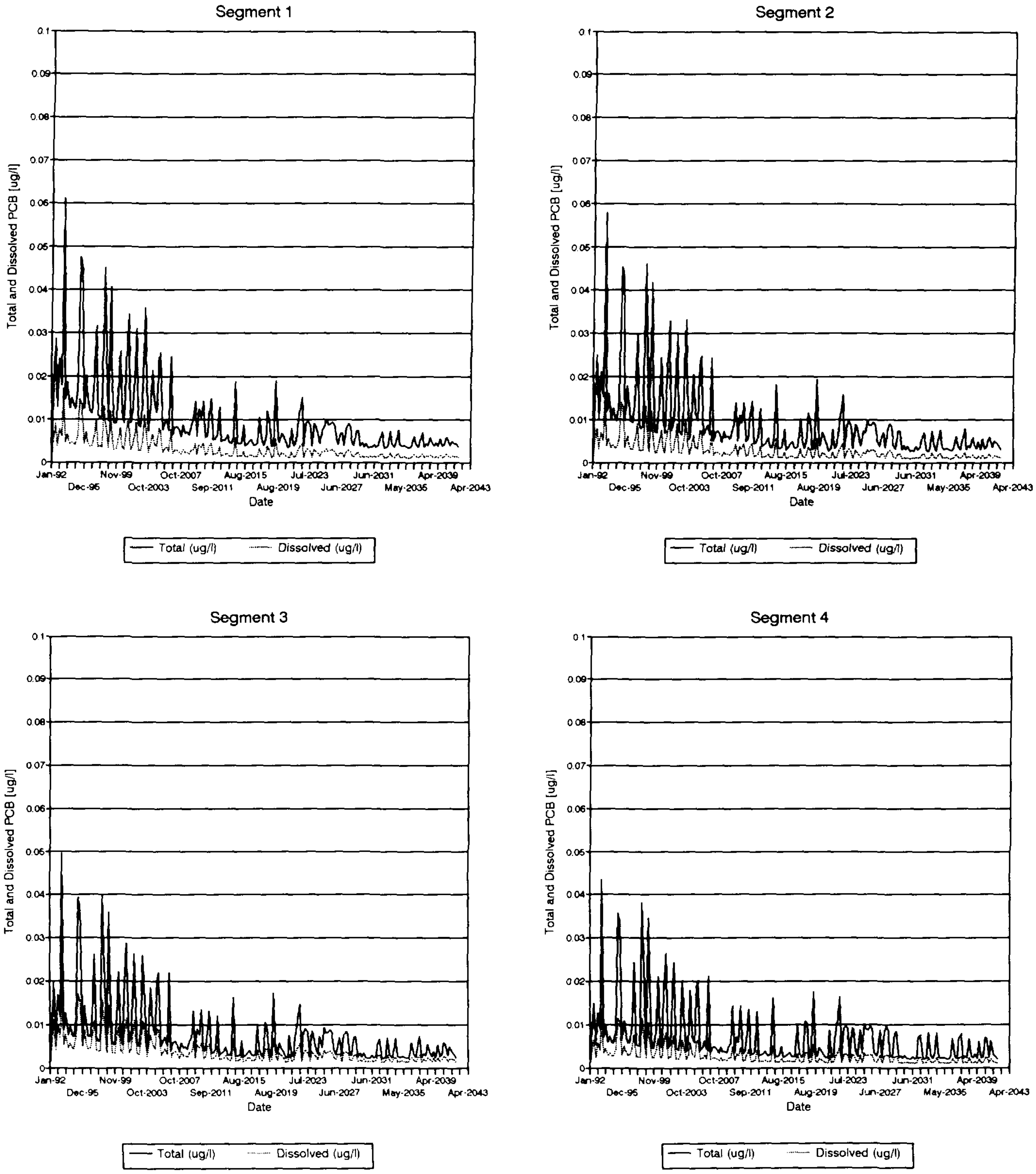
¶$_{doc\text{-}wc}$ - partition coefficient to DOC in the Water Column
¶$_{doc\text{-}pore}$ - partition coefficient to DOC in pore water
$F_{oc\text{-}wc}$ - fraction of organic carbon in the water column
$\mathrm{Log}k_{ow}$ - the ocatanol/water partition coefficient

Therefore, the effect of these parameter ranges on model projection results will also be considered in the following section on model projection results.

4.6 MODEL PROJECTIONS

Model projections were performed for a 50-year period from 1992 to 2042. Hydrodynamic flow inputs were based on the previous 50 years of daily flow records from 1942 to 1992. Section 4.2.9 describes the upstream and tributary PCB and TSS boundary conditions. Model inputs for flow, and upstream TSS and PCB were based on 50 years of daily observations for flow and 50 years of daily predictions for TSS and PCB. These 18,250 daily values were then simplified to approximately 400 step function inputs to meet the model's dimensional limits. Given the limited number of model inputs with which to describe the 50 years of values, the focus was to "capture" the large events and take broad averages over periods of no or small events. Flow-dependent resuspension values are based on the approximately 400 step function flow inputs. As discussed in Section 4.2.9, the model's upstream PCB boundary diminishes by 5% per year from an average value of 0.02 μg/l in 1992 to a limiting value of 0.005 μg/l.

Figure 4-18 shows the model's projection of total and dissolved PCB in the water column. Figure 4-19 shows the projection of particulate PCB in the water column and bed. Note that in the upstream segments 1 and 2 the model projects significant reductions in surficial bed sediment concentrations throughout the projection period, from about 1.0 to 1.5 μg/g at present to about 0.5 μg/g in the year 2030 to lower levels in subsequent years. In the lakes, however, only slight reductions are seen, indicating that the current bed concentrations are essentially in a state of equilibrium with the water column. The following table summarizes the average PCB concentrations during the projection period:



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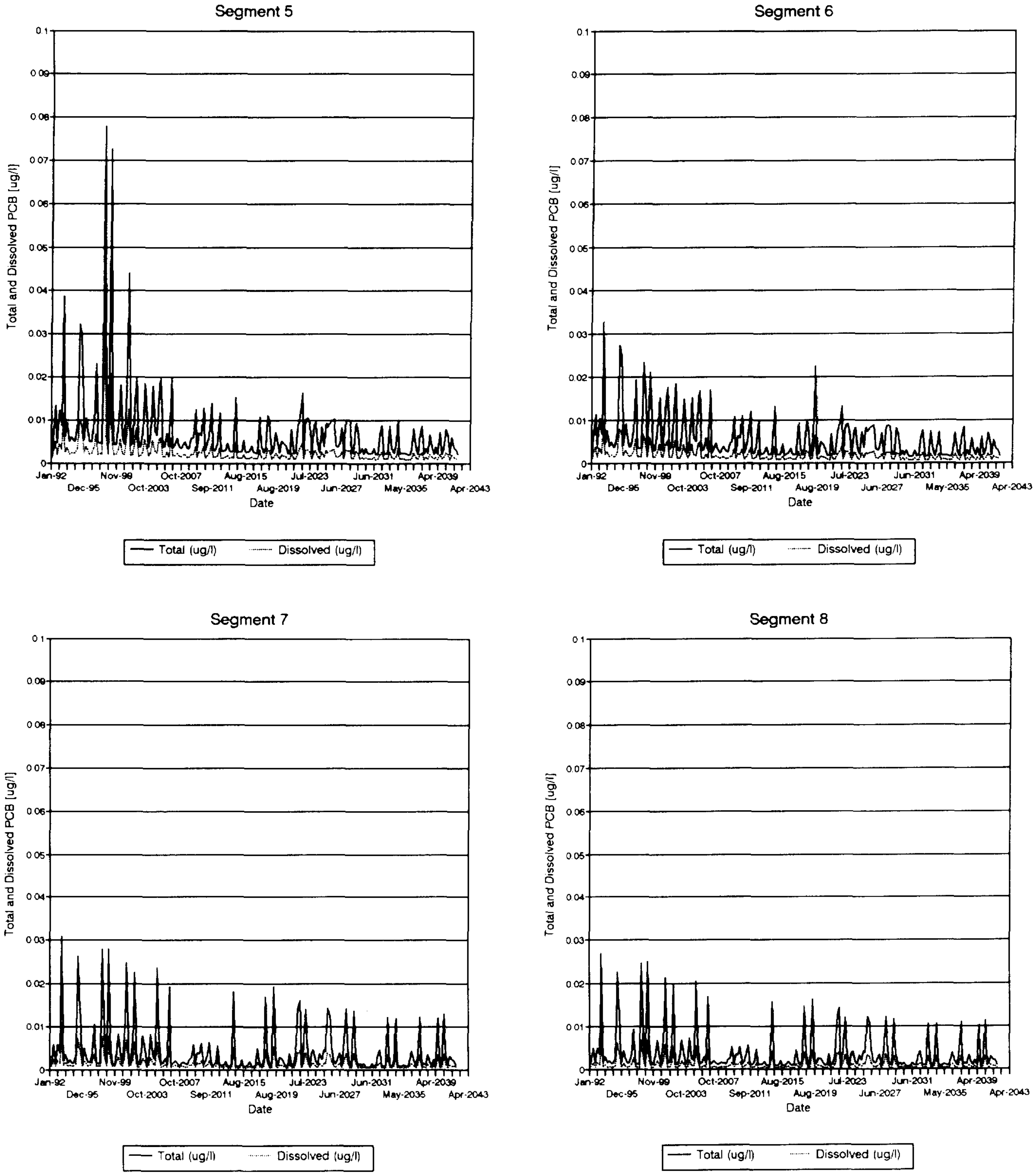
Model Projection Results for Total and Dissolved PCB in the Water Column

Figure 4-18
(1 of 3)

.337'042TBLK ds4
PROJ-01D



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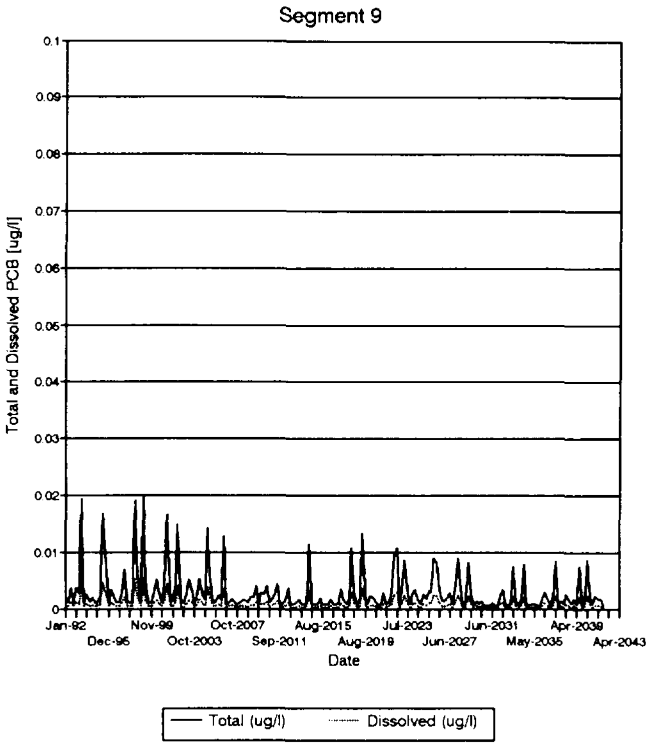
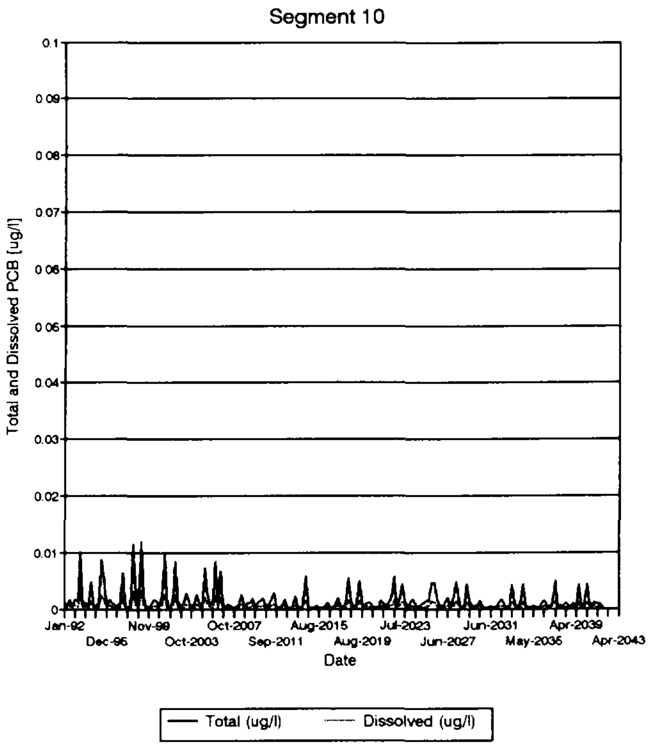
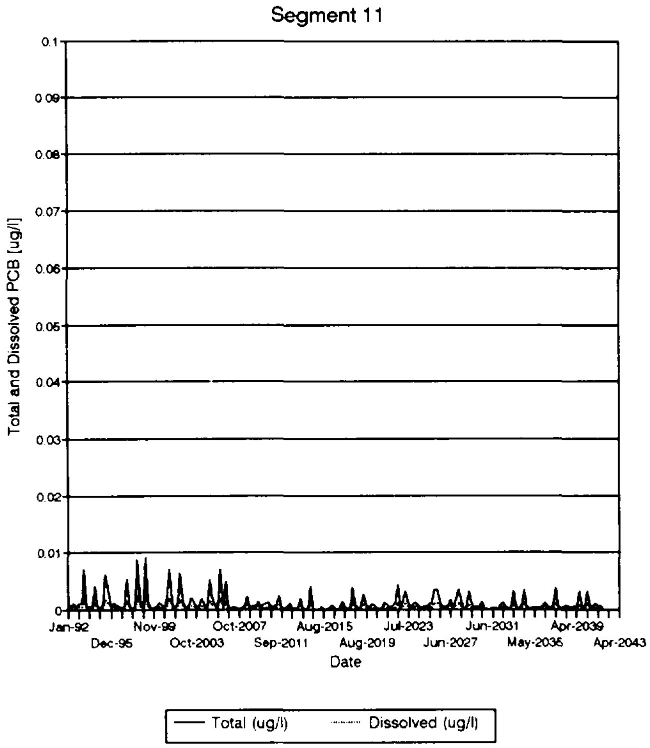
Model Projection Results for Total and Dissolved PCB in the Water Column

Figure 4-18
(2 of 3)

337/042TBLK ds4
PROJ-01D







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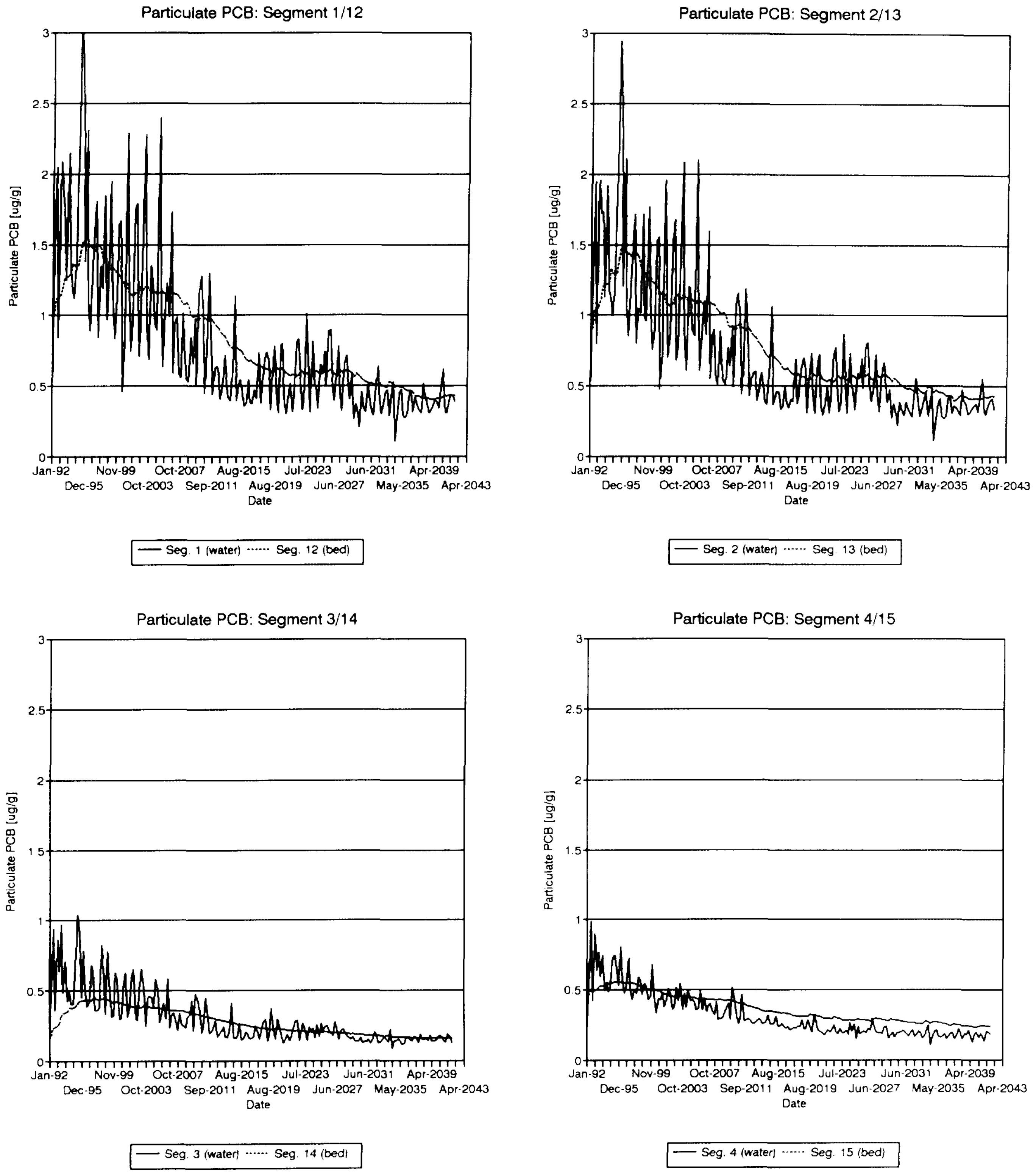
Model Projection Results
for Total and Dissolved PCB in the Water Column

Figure 4-18
(3 of 3)

337.042TBLK ds4
PROJ-010



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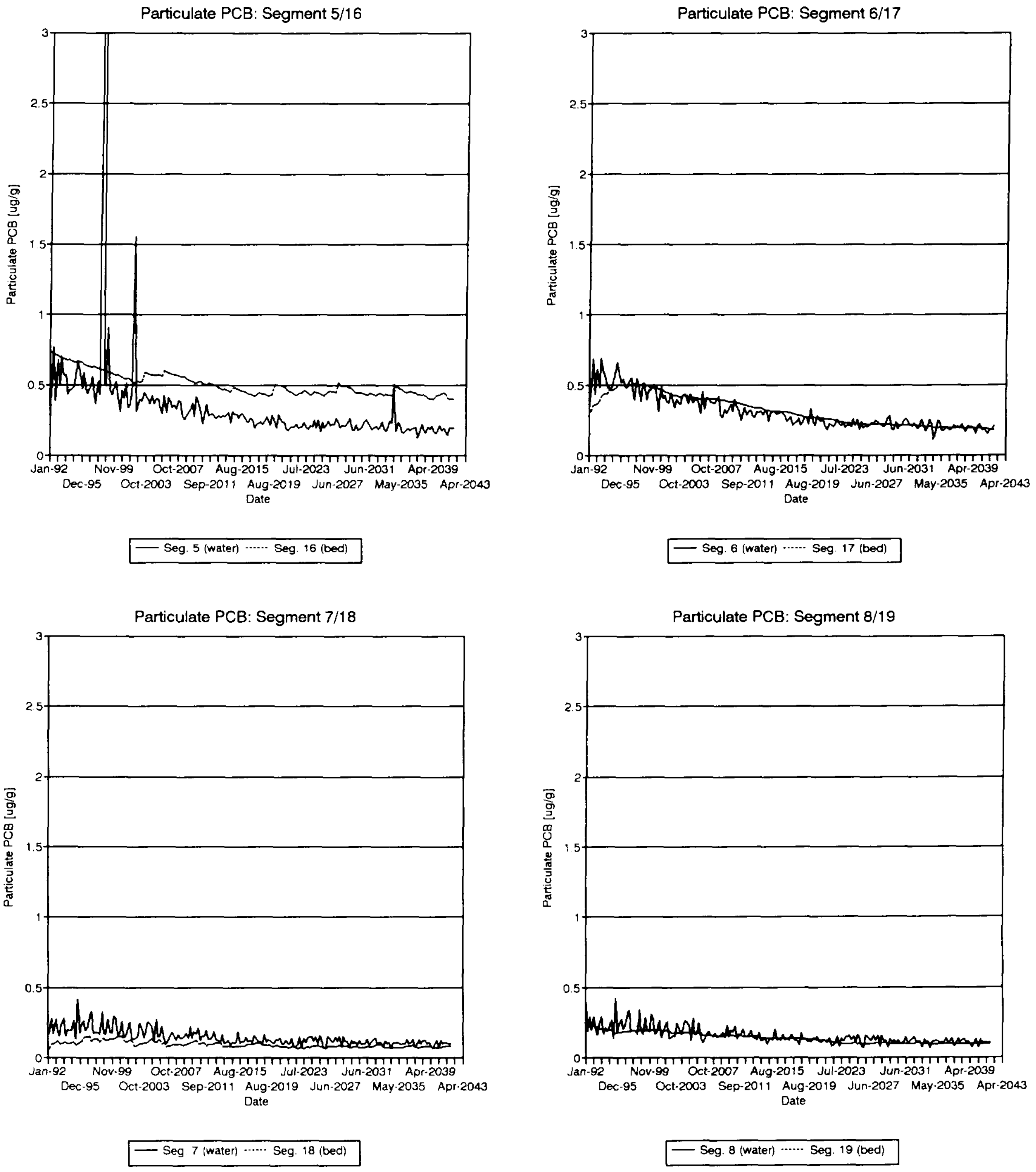
Model Projection Results for Particulate PCB

Figure 4-19
(1 of 3)

337-042TBLK ds4



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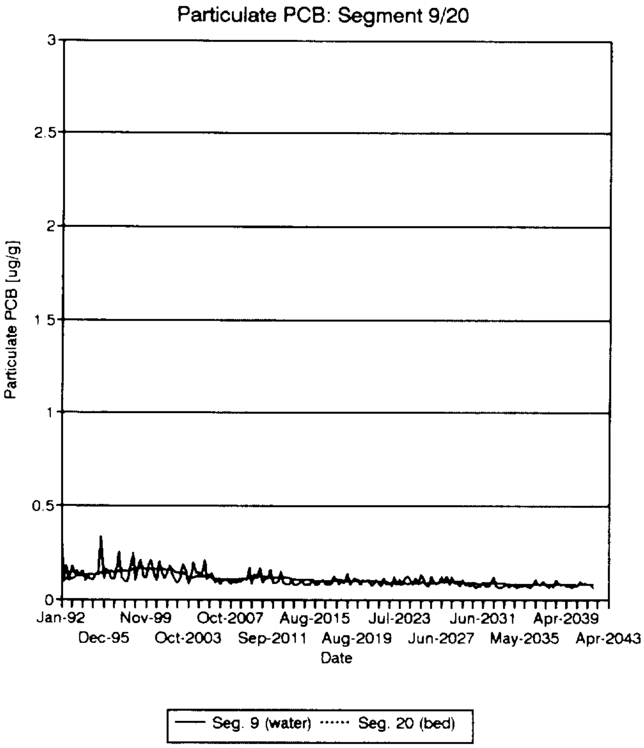
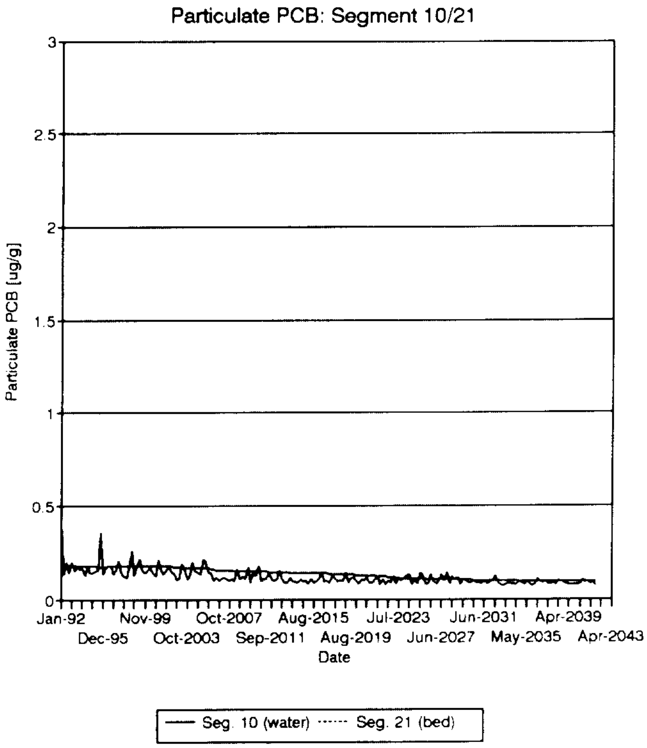
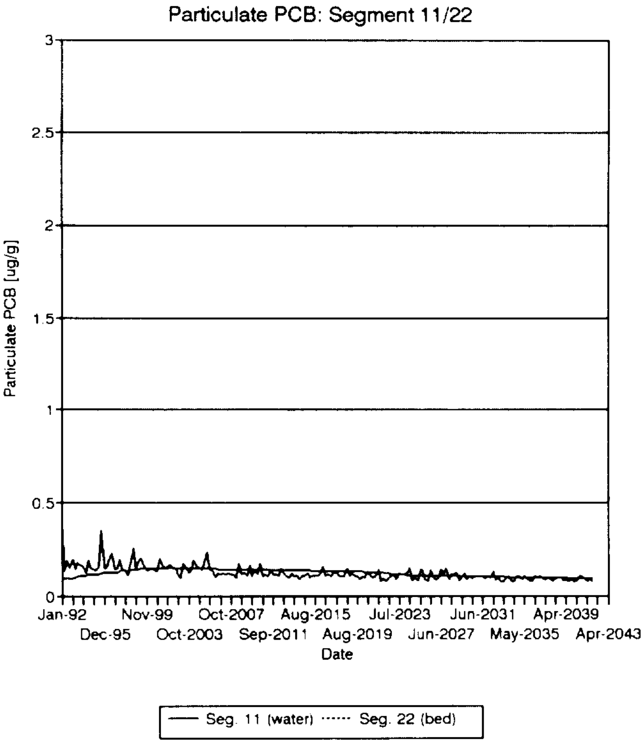
Model Projection Results for Particulate PCB

Figure 4-19
(2 of 3)
337042TBLK ds4







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Model Projection Results for Particulate PCB

Figure 4-19
(3 of 3)

337 042 "BLK os4

SEGMENT No.	c_t (μg/l)	c_d (μg/l)	c_p (bed) (μg/g)
1	0.010	0.003	0.827
2	0.009	0.003	0.779
3	0.008	0.004	0.269
4	0.007	0.003	0.363
5	0.007	0.003	0.506
6	0.006	0.002	0.315
7	0.004	0.002	0.091
8	0.004	0.001	0.139
9	0.003	0.001	0.105
10	0.002	0.001	0.133
11	0.001	<0.001	0.121

As discussed in the previous section, model sensitivity analyses using the 18-month calibration model were performed to identify those parameters having a significant effect on PCB concentration. This analysis identified four parameters: the DOC partition coefficient in the water column ($\P_{doc(wc)}$), the DOC partition coefficient in sediment pore water ($\P_{doc(pore)}$), the solids partition coefficient ($\P_s$) evaluated with K_{ow} ranges, and the fraction of organic carbon on TSS (F_{oc}). The parameter ranges of $\P_{doc(pore)}$, $\P_{doc(wc)}$ and Log K_{ow} are as provided in Table 4-11. For $F_{oc,}$ parameter ranges are segment/specific as shown below:

	F_{oc} ON TSS[1]	
SEGMENT	LOW	HIGH
1	0.009	0.045
2	0.009	0.045
3	0.001	0.006
4	0.002	0.012
5	0.003	0.017
6	0.005	0.027
7	0.002	0.013
8	0.008	0.043
9	0.005	0.026
10	0.008	0.040
11	0.008	0.039

[1] F_{oc} ranges are +/- 67% of the best estimate values provided in Table 4-8. 67% is the percentage of 1 standard deviation to the mean for all sediment F_{oc} measurements made in 1992.

The following table shows the percent difference for the overall change in model computed PCB concentration from the baseline parameter values given in Table 4-11, which are our best estimates.

PARAMETER	VALUE	PERCENT DIFFERENCE FROM BEST ESTIMATE (%)	
		TOTAL PCB WATER COLUMN	PARTICULATE PCB SEDIMENT
¶ $_{doc(pore)}$ (l/kg)	2.6 x 10^4	< 1.00	0.45
	3.6 x 10^7	9.10	-13.30
LogK_{OW} (l/kg)[1]	6.11	9.10	-37.36
	7.408	< 1.00	2.02
¶$_{doc(wc)}$ (l/kg)	5.6 x 10^4	1.82	-2.65
	1.7 x 10^5	5.45	-8.62
F_{oc} on TSS	0.001-0.009	3.64	-10.46
	0.006-0.045	< 1.00	3.33

[1] for Solids dependent partitioning

As indicated, the model results for total PCB in the water column are most sensitive to a low LogK_{ow} value and a high ¶$_{doc(pore)}$ value. However, sensitivity of the average model total water column PCB results to the various parameter ranges is less than 10%. Particulate PCB in the sediment is most sensitive to the low value of LogK_{ow}. A low LogK_{ow} value decreases partitioning to solids resulting in less flux of PCB to the bed.

These sensitivity evaluations demonstrate the relative importance of these four parameters in simulating the long-term fate of PCBs on a system-wide basis. In the water column, total PCB concentrations do not vary by more than 10% compared to the "baseline" model run. In the bed sediment, the low LogK_{ow} value causes a 37% decrease in bed sediment PCB compared to the baseline.

The final evaluation of the model projections is a source/sink mass balance to demonstrate the relative importance of the various input and output pathways. The following table summarizes the mass balance results for the projection period:

CONTRIBUTING COMPONENT	AVERAGE YEARLY PCB TRANSPORT (1992-2042) (lb/year)
Sources	
Inflow at Great Barrington	15
Tributaries	5
Total Input:	20
Sinks	
Outflow at Stevenson Dam	6
Volatilization	4
Sedimentation and burial	10
Total Output	20

The results of this analysis are similar to those presented previously for the verification time period. The model projects that sedimentation and burial is the largest sink of PCB (10 lb/yr) and that the yearly loss of PCB over the Stevenson Dam (6 lb/yr) is similar to the loss by volatilization (4 lb/yr).

In conclusion, the model projections provide a potentially useful tool to assist in assessing future concentrations of PCBs in the water column and sediment. However, it is important that the uncertainty in these model results be considered in any potential applications. The various uncertainties are discussed throughout this report and in the following section. Assumptions regarding upstream and tributary PCB concentrations are of particular importance to the model results. Although estimates are based on reasonable interpretations, the preponderance of undetected PCB at Great Barrington and the lack of PCB data for tributary water limit the model accuracy.

4.7 MODEL LIMITATIONS

Any model makes simplifying assumptions to be consistent with current knowledge regarding natural systems and to keep within the realistic bounds as defined by available data. The process of model verification provides a degree of confirmation to these assumptions. Following are the primary model limitations for this application.

- PCB boundary conditions - the selection of PCB upstream and tributary boundary conditions for a 50-yr projection plays a very important role in model results. In the Housatonic River the upstream boundary is at Great Barrington. Although numerous measurements of PCB have been made over the years at this and other locations, most of these samples had undetected concentrations. The result of this data limitation is that PCB concentrations during high flows could be predicted as a function of TSS concentration with statistical confidence, but that for low flows estimates were necessary. Thus, it is difficult to evaluate an upstream PCB boundary with a high degree of confidence.

Tributary PCB concentrations are also an important factor but to a lesser degree than the upstream boundary. No detectable water column PCB concentration data are available for tributaries. Therefore, these concentrations were estimated as well.

- Lack of Detectable Water Column PCB Observations - As most of HOUSRM's simulations of water column PCB are below the current detection limit of 0.065 μg/l, as are much of the data, verification of the model's accuracy to simulate water column PCB is not completely possible. However, sufficient data did exist to confirm that the model's simulation of bed sediment PCB is reasonably accurate. As the water column and bed exchange PCB via solids settling and resuspension as well as diffusion, it can be inferred that water column PCB simulations do provide reasonable estimates.

- Model Parameters - Extensive literature searches were performed to evaluate model input parameters for the key model transfer mechanisms of volatilization and partitioning. There are a range of acceptable parameter values for these mechanisms. We generally chose average values and checked the model's sensitivity to reasonable ranges of these parameters. As parameter estimates for the Housatonic River specifically do not exist, the model sensitivity results indicate the potential range of model results.

Thus, these primary model limitations need be considered in applying HOUSRM results. Although the verification results do show that HOUSRM provides reasonable results, there is a degree of uncertainty in applying this model for 50 years into the future.

CHAPTER 5

CONCLUSIONS

This report addresses Task IV.B. (Additional Monitoring and Model Verification) as required by the Housatonic River Cooperative Agreement. The conclusions contained in this report are summarized below.

1. On 5 and 6 August 1992 a total of six deep core sediment samples were collected from Lakes Lillinonah and Zoar and the Falls Village and Bulls Bridge impoundments. Numerous 1-in. increments of these samples were analyzed for PCBs, TOC, and ^{137}Cs. PCB concentrations were lower in the 1992 deep sediment samples than those in samples taken in 1986. ^{137}Cs profiles were similar to those found in 1986, indicating that sediment deposition rates were similar and that the bed sediment had not been disturbed. The lower PCB concentrations of subsurface sediments found in 1992 were not expected as PCB is a relatively stable compound. This is particularly true of the primary Aroclor found in the Housatonic River, Aroclor 1260. As different laboratories analyzed the samples in 1986 (York Labs) and 1992 (ITAS Labs), an investigation was performed to determine whether concentration differences were due to laboratory procedural differences. Based on the information available from the laboratories, each generally followed acceptable sample handling and analytical protocols.

   Given the limited number of deep core sampling locations, comparative analyses between the 1986 and 1992 data are not considered conclusive. A review of other historical investigations of the river indicates that a substantial amount of variation in observed deep sediment PCB concentrations has been found for samples taken in close proximity to each other during the 1975 to 1978 surveys performed by CDEP and USGS. Thus, a possible explanation for the concentration differences between the 1986 and 1992 samples may be spatial variability.

2. Between 25 August and 4 September 1992, 49 surficial sediment samples were collected between Great Barrington, Massachusetts (MP 106.2), and the Stevenson Dam (MP 19.5). Samples were analyzed for PCBs, TOC, bulk density, and particle size. Relative to surficial sediment PCB concentrations measured in 1975 to 1978, the 1992 PCB concentrations were lower, especially in the two lakes where sediment deposition is greatest. The 1992 TOC concentrations were also substantially lower than those taken in 1975 to 1978. This indicates a change in water column TOC, which was confirmed by evaluating historical water column TOC at several Housatonic River stations. It is concluded that PCB concentrations in surficial sediment have diminished, in part, due to a reduction of PCB and TOC in the water column. However, the magnitude of the decrease in surficial sediment TOC is greater than that explained by the decrease in water column TOC. Therefore, the reasons for the

surficial sediment TOC decrease have not been completely explained. As PCB partitioning to sediment is dependent on particulate TOC content (i.e., F_{oc}), diminished TOC would cause a reduction in the flux of PCBs to the bed sediment for those segments subject to sediment deposition.

3. Task IV.B. water column surveys were performed during high river flow events between March 1992 and April 1993. Samples of PCB, TOC, DOC, and TSS were collected from stations at Great Barrington, Massachusetts (MP 106.2), and Falls Village, Connecticut (MP 75.0). A special study of TSS concentrations as a function of river flow was performed in the Sheffield Flats region of the Housatonic River in Massachusetts (MP 98.6 to 83.1) to evaluate sediment resuspension rates. Limited samples of TOC, DOC, and TSS were collected from stations in Lakes Lillinonah and Zoar. Two high-flow surveys were performed while Dam maintenance construction activities were being performed at the Rising Pond Dam (MP 107) in spring 1992. These construction activities resulted in higher TSS and PCB concentrations at Great Barrington. Sampling after the construction was complete demonstrated a return to normal river conditions for PCBs and TSS. Four surveys were performed when construction activities were not being performed, and these are representative of normal conditions. Of 21 samples taken at Great Barrington, 14 were below detection and the others had a range of 0.079 to 0.122 μg/l of PCBs. At the Falls Village station PCBs were not detected in 17 out of 18 samples. The single detectable concentration was 0.079 μg/l. This is consistent with prior studies which indicated that water column PCB levels decrease downstream and are generally below the detection level in Connecticut. Survey flows varied between 200 to 4500 cfs.

4. A statistical analysis of TSS and PCB trends was performed at Great Barrington. Using the 18 months of TSS and flow data collected by USGS in 1978 to 1980, a statistically valid relationship was developed that relates daily TSS to daily flow and season. For flows greater than 750 cfs, a statistically significant relationship between PCB and TSS was also found. For flows less than 750 cfs it is concluded that PCB concentrations are mostly nondetected (i.e., less than 0.065 μg/l). For modeling purposes, rather than assume a PCB concentration below the detection limit, the concentration is estimated using surficial sediment PCB concentrations. In 1979 the average PCB concentration at flows less than 750 cfs is estimated as 0.03 μg/l and in 1992 it is estimated as 0.02 μg/l. The above relationships are used to develop HOUSRM's upstream boundary conditions for TSS and PCB for the model verification and projection time periods.

5. Comparative PCB levels in sediment and biota suggest that the water column PCB concentrations are diminishing with time. Despite this, statistical analyses of available water column PCB data do not indicate a statistically significant relationship between PCB concentration and time. These analyses are limited by the fact that most of the PCB sample results are below the detection limit. Reduction rates are estimated using historical and current surficial sediment PCB concentrations, invertebrate (caddisfly) PCB concentrations from 1978 to 1993,

and the statistically nonsignificant relationship of PCB concentration in the water column as a function of time. All data support a reduction rate of approximately 5% per year, which is consistent with the rate used in LMS (1991). This decay rate is applied to the model's upstream PCB boundary condition. However, the estimated lower limit during the model projection period is 0.005 μg/l, which is the assumed future background level.

6. The WASTOX model is used to develop the Housatonic River Model (HOUSRM). The model has been changed from using monthly-averaged inputs, as was done in LMS (1991) to event-specific inputs. Thus, the upstream TSS and PCB boundary conditions, time-variable flow inputs, and sediment resuspension rates all reflect daily variations in these parameters. This change is an improvement to the previous approach as it allows the effects of high-flow events to be simulated with HOUSRM. These events are thought to play an important role in the fate and transport of PCBs in rivers.

   Several literature sources were reviewed to evaluate appropriate model input parameters. A change to the WASTOX model's solids dependent partition coefficient calculation was made to empirically include the effect of the fraction of PCB on suspended solids that is resistant to desorption. This change was based on numerous direct observations of the ratio of dissolved to total PCBs (i.e., fraction dissolved) which can be used to evaluate an appropriate partition coefficient.

   Volatilization rates were revised based on current literature that was not available at the completion of the previous report (LMS 1991). Partitioning to DOC in the water column and interstitial pore water has also been added to HOUSRM. Literature was also reviewed to determine appropriate background PCB concentrations for tributary inputs and to estimate the lower PCB concentration limit for the upstream boundary condition. Tributary inputs are set at 0.0012 μg/l, except for the combined Still and Shepaug rivers, which are currently estimated at approximately 0.0038 μg/l. A reduction rate of 5% per year is applied to this concentration but it does not go below the background estimate of 0.0012 μg/l. The estimated lower limit for PCB at the upstream boundary is 0.005 μg/l, which is consistent with LMS (1991).

7. Refinements to the 18-month TSS calibration were performed to accommodate the event-specific approach. Initial estimates of sediment resuspension rates were adjusted to obtain the observed TSS concentrations. Adjustments to these values resulted in reasonable simulations of daily TSS variations as well as agreement with estimated sediment deposition rates.

   Verification of the model was tested for a 13.5-year period from October 1979 to April 1993. The results indicate that the model provides generally reasonable simulations of TSS. As detectable water column PCB data are scarce at stations downstream of the model's upstream boundary, it is not possible to verify that the model accurately simulates total PCB in river water. Comparisons with limited data do suggest that the model simulations are reasonable. Sufficient data are available to verify that the model provides reasonable simulations of bed sediment PCB for the 13.5-year verification time period. An evaluation of PCB flux indicates that tributary inputs account for about 20% of the total PCB input to the river and the remainder comes from the upstream boundary. HOUSRM indicates that on a system-wide basis annual PCB losses due to sedimentation and burial (18 lb/yr) are about equal to losses over the Stevenson Dam (20 lb/yr). The model also predicts that volatilization accounts for an appreciable loss of PCB (9 lb/yr), which is half the PCB loss due to sedimentation and burial.

8. Model projections are performed for a 50-year period from 1992 to 2042. Results of this projection indicate that surficial bed sediment PCB concentrations in the upper model segments in Massachusetts (segments 1 and 2) will continue to decrease over the projection period, from about 1.0 to 1.5 μg/g at present to about 0.5 μg/g in the year 2030 to lower levels in subsequent years. In the lakes, only slight reductions beyond the current levels are anticipated as the model indicates that bed sediment PCB concentrations have effectively "leveled off." During the projection time period, the average total PCB concentrations in Lakes Lillinonah and Zoar are simulated to be 0.002 and 0.001 μg/l, respectively. A mass balance of PCB sources and sinks, expressed as an annual average for the 50-yr period, indicates that the upstream boundary will add 15 lb/yr into the study area and that tributary inputs will account for 5 lb/yr. Sedimentation and burial will account for the greatest loss of PCB (10 lb/yr). The projected loss of PCB over the Stevenson Dam is projected at 6 lb/yr and loss due to volatilization is estimated at 4 lb/yr. The annual projected inflow of PCBs of 20 lb/yr is about 40% of the estimate made in LMS (1991). This difference is primarily due to a revision (i.e., decrease) in the upstream and tributary PCB boundary conditions, which is based on further evaluations of available data, as discussed herein. Thus, the projected mass of PCB lost to the various sinks (sedimentation and burial, overflow and volatilization) is also lower than estimated previously.

   Although the model projections do provide a reasonable and potentially useful method to assist in assessing future concentrations of PCBs in the water column and sediment, it is important to recognize the model's limitations in any potential applications. The various uncertainties are identified in this report, with the most important ones discussed in Section 4.7. In particular, due to the importance of the assumptions regarding upstream and tributary PCB contributions in the model projections, the large number of non-detect PCB results at Great Barrington and the lack of detected PCB data for the tributaries, the model's accuracy is limited.

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APPENDIX A

POTENTIAL METHODS TO DETERMINE AMBIENT PCB CONCENTRATIONS IN HOUSATONIC RIVER TRIBUTARIES

STATE OF CONNECTICUT
DEPARTMENT OF ENVIRONMENTAL PROTECTION

RECEIVED
JUL 20 1992
ENVIRONMENTAL PROGRAMS

July 15, 1992

John D. Ciampa
Environmental Quality Engineer
Area Environmental and Facilities Programs
General Electric Company
100 Woodlawn Avenue
Pittsfield, MA 01201

Dear Mr. Ciampa:

The Connecticut DEP has reviewed the information on potential methods for monitoring ambient PCB levels in tributaries, submitted by General Electric Company by letter dated July 6, 1992. We concur that water column sampling methods are not yet sufficiently developed for utilization in our Housatonic River monitoring. We are therefore not requesting any additional water column sampling for development of the PCB fate and transport model at this time.

Sincerely yours,

Charles Fredette

Charles G. Fredette
Supervising Sanitary Engineer

CGF:job

(Printed on Recycled Paper)
165 Capitol Avenue • Hartford, CT 06106
An Equal Opportunity Employer

Area Environmental & Facility Programs
General Electric Company
100 Woodlawn Avenue, Pittsfield, MA 01201

July 6, 1992

Mr. Charles G. Fredette
Connecticut Department of Environmental Protection
165 Capitol Avenue
Hartford, CT 06106

Re: PCB Analysis in Housatonic River Tributaries

Dear Mr. Fredette:

GE has been evaluating potential methods to determine ambient levels of PCB in tributaries to the Housatonic River. As you know, this evaluation stems from your request to further assess these levels since they are input values to the Housatonic River fate and transport model which has been developed by LMS Engineers. As presented in their September 1991 report, "Ambient Trend Monitoring and PCB Fate and Transport Model," LMS utilized a PCB concentration of .008 ug/l for the inflowing tributaries. Since this concentration is significantly lower than the detection limit for PCB analyses in water, it is very difficult to directly determine how accurate this input value actually is.

In my previous correspondences to you of February 20 and March 31, 1992, a threefold approach to assess these background values was presented. These were: an evaluation of the feasibility to utilize alternative methods to collect and analyze low level PCB concentrations in water; sampling of crayfish to indirectly assess the presence of PCB in two of the tributaries; and an update of the literature review performed for the Chapter 6 report to determine background levels in the Northeast, in particular, Connecticut.

Enclosed is a letter report by LMS Engineers that assesses the feasibility of several special sampling and/or analytical techniques which have the potential to quantify low background PCB levels. This review included large volume field extraction methods, modifications to currently accepted analytical techniques (USEPA Method 8080), passive membrane in-situ collection, and continuous flow centrifuging. The review indicates that all of these techniques at this time are of limited utility. In general, the methods appear to be research oriented and have not yet been proven to be reliable.

Based upon this review, GE proposes not to implement any of these techniques at this time to determine tributary water column PCB levels. We will, however, continue the proposed sampling and analysis of crayfish in the Housatonic, Still and Shepaug Rivers. If PCBs are present in the tributaries, they may be detected in the crayfish because of bioaccumulation. After the PCB analyses are completed on the crayfish, GE will reevaluate whether an attempt to further quantify PCB levels in select tributaries is warranted.

Additionally, as you requested, I am also enclosing a recent publication concerning GE's research findings on PCB biodegradation in the Hudson River. Regarding the tour of the BETS facility in Woods Pond, Steve Moore has informed me that he has been in contact with Ms. Lynn Werner of the Housatonic Valley Association and that she is attempting to identify a mutually convenient time for interested parties to make the visit. A tentative time frame for the end of July had been discussed, however, I suggest that you contact her for the latest information.

Please let me know if you have any questions on this or other matters.

Yours truly,

John D Ciampa

John D. Ciampa
Environmental Quality Engineer

/ljr

cc: G.G. Bowman
    R.F. Desgroseilliers
    J. Bieke, Shea & Gardner
    D. Distante, LMS Engineers
    J. McNair, Academy of Natural Sciences of Philadelphia

Lawler,
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THOMAS E. PEASE, P. E.

7 July 1992
File No. 337-042 (0040)

Mr. John Ciampa
General Electric Company
Building 11-250
100 Woodlawn Avenue
Pittsfield, MA 01201

Re: Recommendations on quantifying low background PCB levels

Dear Mr. Ciampa:

As stated in the 20 February 1992 letter to Mr. Charles Fredette, LMS has evaluated the feasibility of special sampling and/or analytical techniques to quantify low background PCB levels. Following are brief discussions and recommendations for each of the four proposed methods:

Large Volume Field Extraction Method (Green Bay Mass Balance Study)

The Green Bay/Fox River Mass Balance (GBMB) project is a test of the mass balance approach for control to toxic substances in the Great Lakes. As part of this study extensive monitoring of the inputs to Green Bay and the Lower Fox River were initiated in 1988 and completed in the spring of 1990. As the organochlorine contaminants (PCBs and Dieldrin) are present in these waters at very low levels, a special sample collection method was devised that allows increased detectability of these compounds. This method involves the filtration of a large volume of sample (60 to 100 liters) to collect particulate organochlorines and then in-situ extraction of the filtrate to collect the dissolved component. Collection of dissolved organochlorines is accomplished by passing the large volume sample through an XAD-2 resin[1] column, which extracts the hydrophobic organic compounds (HOC). As the filtrate passes through the column, the dissolved HOCs are concentrated on the resin. After sampling is completed, the HOCs are extracted from the resin. Both the particulate and dissolved components are analyzed separately.

Attached are the following unpublished procedures which explain the field sampling and analytical protocols:

---

[1] XAD-2 resin is a polymeric adsorbent that adsorbs and releases ionic species based on hydrophobic or hydrophilic interactions.

- Standard Operating Procedure for the Sampling of Hydrophobic Organic Compounds in the Water Column
- XAD-2 Resin - Preparation and Extraction Procedures
- Quality Assurance Plan - Green Bay Mass Balance Study - I. PCBs and Dieldrin

While this large volume method offers significant potential for quantifying low level PCB concentrations, no results or peer reviews have been formally published. The final report on the Green Bay/Fox River Mass Balance Project is anticipated in October 1992. Thus, while LMS intends to follow the progress of this study and evaluate the methodology, use of this procedure is not recommended until it is thoroughly peer reviewed and officially approved by EPA.

Modifications to USEPA Method 8080

The current USEPA-approved technique for PCB analysis is SW-846 (second edition) method 8080. According to this EPA publication, the method detection limit (MDL) for Aroclor 1242 following these procedures is 0.065 μg/l. This detection limit was based upon a one liter sample of water which was concentrated to 10 ml. Based on theoretical considerations alone, it is possible to lower this detection limit by either increasing the original sample volume and/or decreasing the volume of sample extract. However, the actual method detection limit which can be achieved on an environmental sample depends upon the sample matrix and associated interferences.

In an effort to lower the detection limits for Housatonic River analyses, IT Corporation has already slightly modified method 8080 by concentrating the sample extract to 5 ml rather than 10 ml. Theoretically, this has reduced the MDL to one half of that of the published methodology. IT has determined that with this modification, the smallest concentration which can be detected above the background noise of the instruments is 0.018 μg/l for Aroclor 1242. It should be pointed out that IT's actual reporting detection limit for Aroclor 1242 (0.030 μg/l) is higher than this to allow for quantification uncertainty associated with the matrix effects of actual environmental samples. Although the lab reduces matrix interferences with acid, Florisil and mercury cleanup techniques, there are interferences associated with Housatonic water samples which are unaffected by these procedures.

As previously mentioned, it is theoretically possible to further reduce detection limits by increasing the original sample volume above 1 liter. However, because of the interferences associated with Housatonic samples, IT is concerned that the increased volume may magnify the interferences and actually do more harm than good. Additional studies would be necessary to assess the actual impact of increasing the original sample volume. Furthermore, since the actual detection levels are dependent upon the specific matrix, a similar evaluation would be necessary for the water samples from the Still and Shepaug Rivers.

For another GE project on a New York State lake, the impact that modifying method 8080 had on PCB detection limits was studied in detail. Changes to the standard method included the use of a two liter sample volume which was concentrated to a 0.5 ml final extract volume. The matrix-specific MDL with these modifications was determined to be 0.022 μg/l. Given this and the above considerations, it is doubtful that similar analytical modifications could achieve a detection limit sufficient to quantify PCBs in water at the concentrations anticipated for the tributaries.

Passive Membrane In-situ Sample Collection

The New York State Department of Conservation (NYSDEC) is currently using an in-situ sampling device to collect PCB samples. This device, called PISCES (Passive In-Situ Chemical Sampler) is an experimental means for concentrating hydrophobic substances over time in an organic solvent. The device is suspended in the water column and sampling occurs by molecular diffusion of organic contaminants from the water through the semi-permeable membrane into solvent (hexane) held within the device. In order to concentrate quantifiable masses of PCB, PISCES are deployed for several weeks. Thus, this method provides for a time-averaged concentration of PCB and would not be appropriate to quantify PCB levels during short-term high flow events. Some significant disadvantages of this sampling technique are summarized as follows:

- Only the dissolved PCB component diffuses through the PISCES membrane
- At high suspended solids concentrations, PISCES underestimates dissolved PCB concentration
- Accuracy of PCB concentrations measured with this device have not been provided.

Because of these limitations, particularly that measurements pertain only to the dissolved phase, this method does not appear applicable. A copy of a draft manuscript which discusses the PISCES methods and results is attached.

Continuous Flow Centrifuging

The purpose of this proposed option was to provide a method to collect sufficient suspended sediment material to quantify low PCB levels in the particulate phase. Since proposing this option on 20 February 1992, alternate filtration methods which require much simpler equipment have come to our attention. In fact, such filtration methods are used as part of the large volume sampling performed during the Green Bay/Fox River Mass Balance Study.

While filtration is certainly a valid technique to obtain particulate PCB concentrations, it does not provide for the analysis of the dissolved component. As both components are important to the fate and transport of PCB in the Housatonic River, filtration is not recommended for further evaluation.

Please call me or Guy Apicella if you have any questions.

Sincerely,

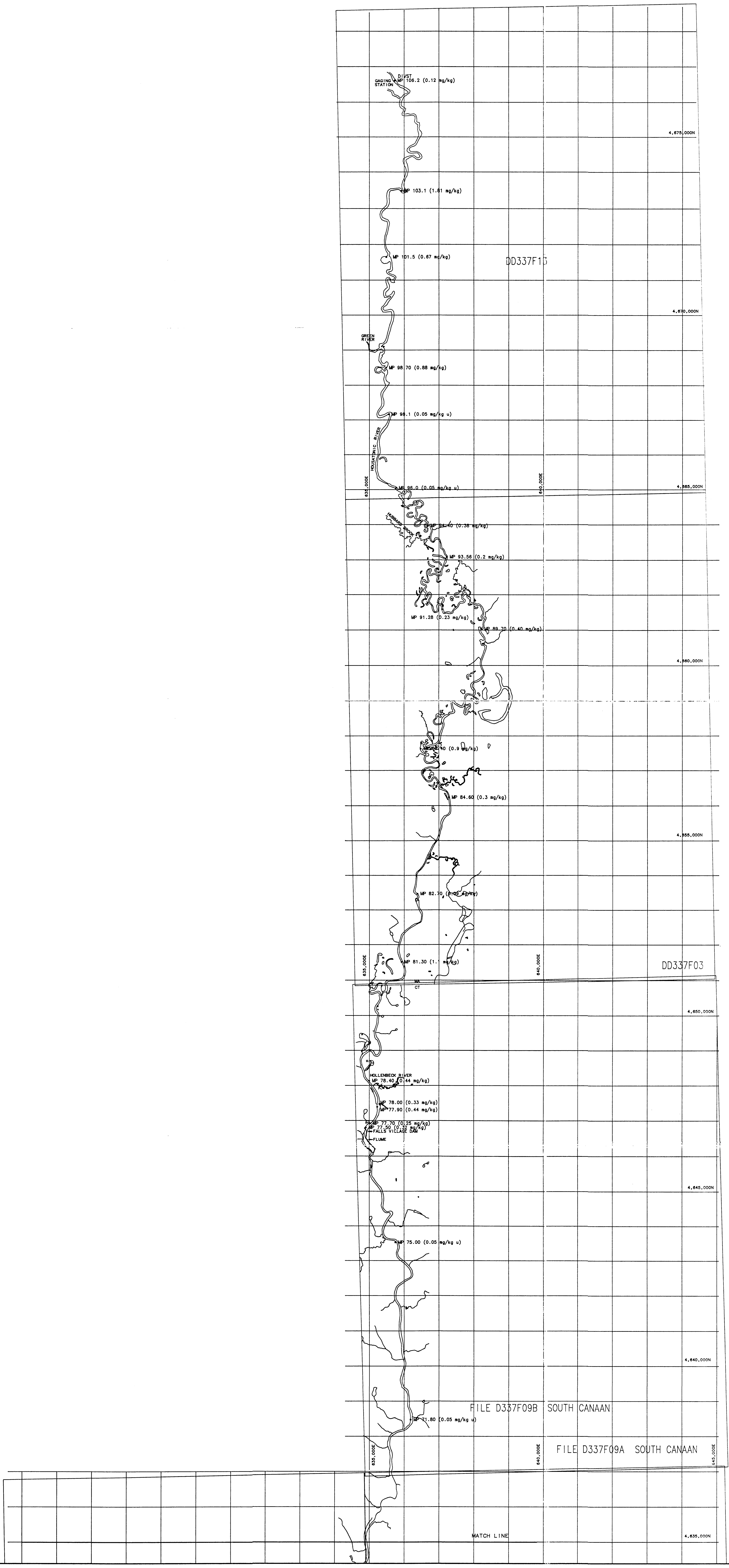
Donald Distante

Donald Distante, P.E.
Project Manager

Enclosures

APPENDIX B

OVERSIZED MAPS SHOWING 1992
SURFICIAL SEDIMENT MONITORING RESULTS



Lawler,
Matusky &
Skelly Engineers

Environmental Science & Engineering Consultants
One Blue Hill Plaza Pearl River, New York 10965

APPENDIX B - 1992 SURFICIAL SEDIMENT MONOTORING RESULTS (MILEPOINT 106 TO 72)

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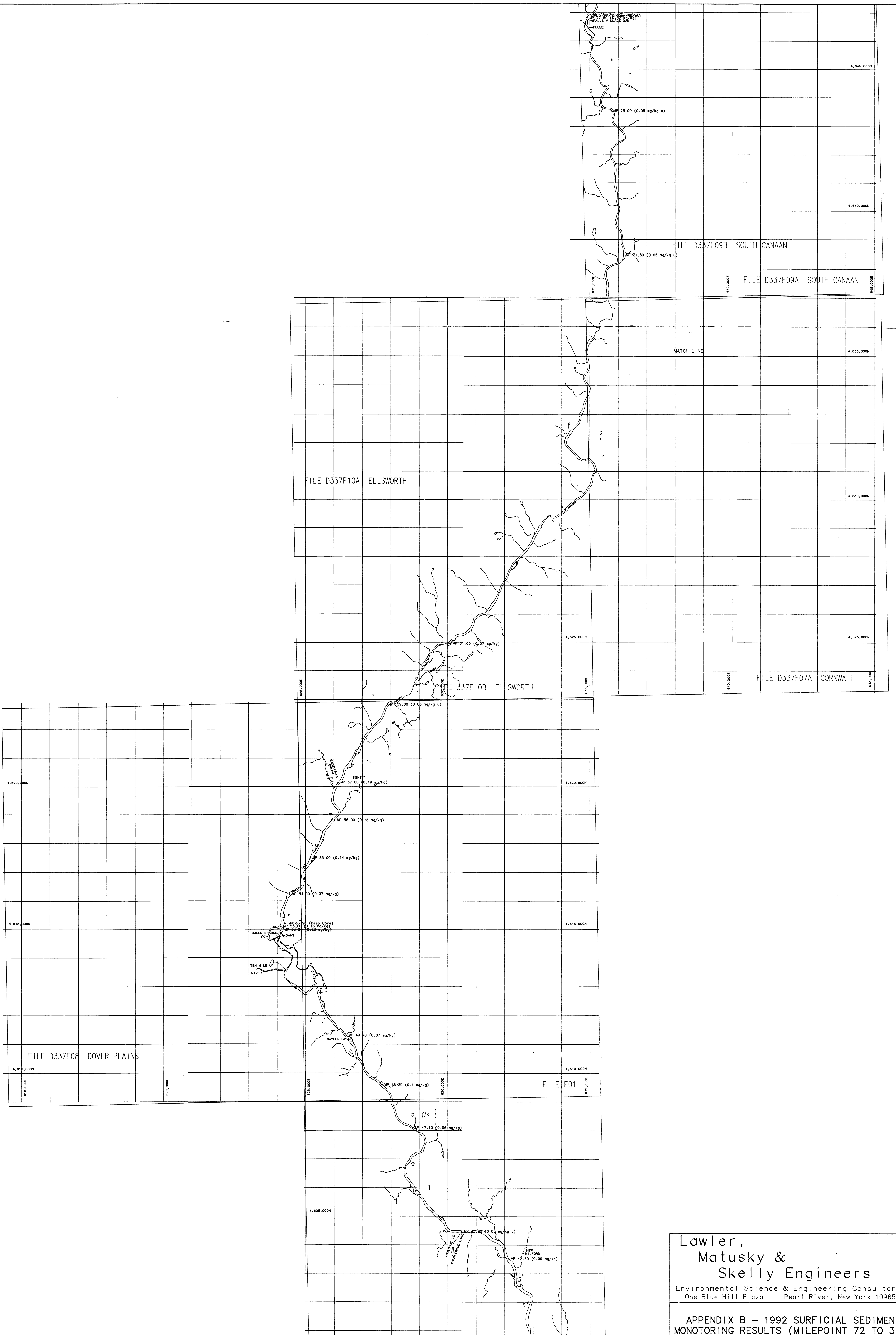

Lawler,
Matusky &
Skelly Engineers

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One Blue Hill Plaza Pearl River, New York 10965

APPENDIX B – 1992 SURFICIAL SEDIMENT MONOTORING RESULTS (MILEPOINT 72 TO 32)

SCALE:
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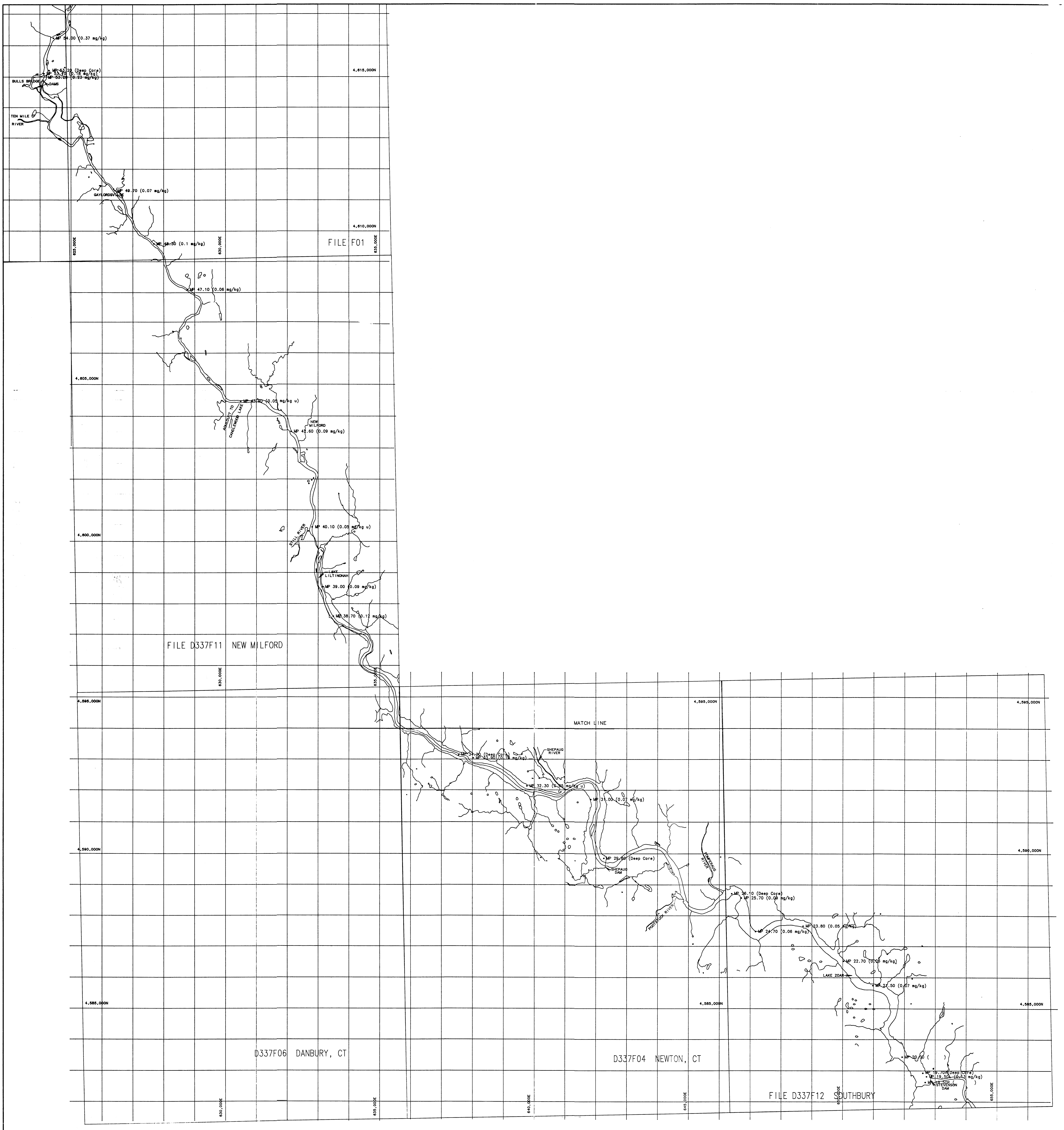
DATE:
NOV. 16, 1994

FL NAME: 1–9&1113
DISK # 17533 – 4

SHEET 2 OF 3



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Matusky &
Skelly Engineers
Environmental Science & Engineering Consultants
One Blue Hill Plaza Pearl River, New York 10965

APPENDIX B – 1992 SURFICIAL SEDIMENT MONOTORING RESULTS (MILEPOINT 32 TO 19)

SCALE: 1200 0 1200ft SCALE IN FT	DATE: NOV. 16, 1994	FL NAME: 1-9&1113 DISK # 17533 - 4 SHEET 3 OF 3

APPENDIX C

PCB DATA REVIEW FOR 1986 AND 1992 HOUSATONIC RIVER DEEP SEDIMENT CORES

APPENDIX C
PCB DATA REVIEW FOR 1986 AND 1992 HOUSATONIC RIVER DEEP SEDIMENT CORES

BACKGROUND

As part of the work performed by Lawler, Matusky & Skelly Engineers (LMS) on the Housatonic River, sediment samples were collected and analyzed for PCBs and total organic carbon (TOC). Approximately 200 deep core sediment samples were collected from six locations in the Housatonic River in 1986 and 1992 (100 for each of the two years). The samples collected in 1986 were sent to Industrial & Environmental Analysts, Inc. (formerly York Labs) and the samples collected in 1992 were sent to I.T. Analytical Services (ITAS) for chemical analysis. The results of the analyses show that nearly all of the samples collected in 1992 had lower concentrations of total PCBs than did the 1986 samples. At the request of General Electric (GE), LMS investigated the possibility that the difference in the PCB concentrations from 1986 to 1992 may have occurred as a result of laboratory analyses.

The investigation conducted by LMS focused on a possible systematic difference in how the laboratories were processing the samples, including how the laboratories prepared, analyzed and quantified PCBs in the two data sets. A critical review of the data packages submitted by York Labs and ITAS was conducted by LMS and a subcontracted data validator (Data Validation Services). A copy of the review prepared by Data Validation Services is presented in Appendix A.

REVIEW

Differences in the laboratories' methods and procedures for processing sediment samples for PCB analyses were reviewed. Areas where systematic variances could occur include: sample preparation and analysis, and calculation algorithms and standard dilution calculations used to calculate sample results.

Information on sample preparation was reviewed including; drying, weighing, extraction, and cleanup. Sample analysis documentation was reviewed including information concerning GC calibration; preparation of calibration standards, source of standards, age of standards, and standard concentrations used to calibrate the instruments. Lastly, quality assurance data submitted by each of the laboratories was reviewed. This included information concerning matrix spikes, matrix spike duplicates, surrogate recoveries and blank analyses.

RESULTS

The methods used by each of the laboratories to analyze the samples for PCBs were derived from different established protocols: York Labs used EPA Method 608, and ITAS used EPA SW-846 Method 8080. Method 608 was originally developed for the analysis of organochlorine pesticides and PCBs in water to facilitate the implementation of the Clean Water Act. However, until the promulgation of the Third Edition of EPA SW-846 (1986) commercial laboratories routinely used Method 608 to analyze soil and sediment samples for PCBs. With the promulgation of the Third Edition of EPA SW-846 (1986) Method 8080 was available for use by commercial laboratories. Method 8080 was developed to analyze soil, sediment, and waste samples in addition to water samples for organochlorine pesticides and PCBs. Each of these methods are similar in performance and do not provide substantially different results. These methods also provide the analyst with some flexibility in the extraction methods, cleanup procedures, and the identification and quantification technique used. The results of the review indicate that each of the laboratories followed the protocols referenced without modification or major deviation.

A significant difference was noted in the procedures used by the laboratories to prepare the samples for analysis. York Labs air-dried the samples prior to extraction for PCB analyses, whereas ITAS only decanted the samples prior to extraction. These differences in sample preparation resulted in differing percent moisture on samples extracted and analyzed for PCBs (see Table 1). In general, the percent moisture of samples analyzed by ITAS were higher than those analyzed by York Labs.

The weight of sample extracted and the volume of the final extract were similar (10 grams and 10 ml, respectively) for each of the laboratories. Each of the laboratories performed florisil cleanups as recommended by both Methods 608 and 8080. In addition to the florisil cleanups ITAS also performed mercury cleanups to remove any sulfur compounds that would potentially interfere with PCB quantitation. This procedure is optional and only recommended if sulfur compounds are suspected of being present in the sample.

Separation and detection of PCBs was performed through the use of packed glass columns and electron capture detectors (ECDs). Packed glass columns are recommended for the separation of PCB congeners in sediment extracts when identifying specific Aroclors. Quantification of PCB concentrations in sediment samples by each of the laboratories was based on the comparison of Aroclor standard responses (peaks) to the resulting response of the sediment samples. When using an ECD the analyst must rely on the appearance of a detector signal (peak) at the appropriate retention time to identify a sample component. The retention time is determined by analyzing a standard of an Aroclor under the same GC conditions used to analyze the sediment samples. Since Aroclor standards used for identification are never identical to the sediment samples, another sample component to which the ECD responds might have the same retention time as the PCB of interest. Therefore, interpretation of resulting chromatograms by the analyst is a very important aspect of PCB identification. Each of the laboratories quantified the levels of PCBs detected by comparing the GC peak areas (or heights) produced by the sediment samples to those produced by the Aroclor standards.

Each of the laboratories properly calibrated the integrators used to quantify the concentrations of PCBs using external standard calibration procedures. External standards were used to calibrate each instrument to known standards of specific Aroclors (1221, 1232, 1242, 1248, 1254, and 1260). The resulting peak areas or heights on the chromatograms for each sediment sample were compared to the known standard responses. York Labs used peak areas and ITAS used peak heights to quantify PCB concentrations; either of these approaches are acceptable. Multiple peak responses (i.e., 7 to 11 peaks) to quantify Aroclor concentrations were used by both laboratories. The use of multiple peak responses reduces the effect that degradation of individual sample peaks, with respect to standard peak responses, will have on the final Aroclor concentration. Each of the laboratories correctly calculated the concentrations of PCBs using multiple peak responses. Also, both laboratories correctly incorporated percent solids and dilution factors during computation of final concentrations. The equation used to calculate the final concentrations of PCBs is:

$$\frac{\begin{array}{c}\textit{Height/Area of Peaks}\\ \textit{of Unknown Sample}^{*}\end{array}}{\begin{array}{c}\textit{Height/Area of Peaks}\\ \textit{of Known Standard}\end{array}} \text{ x } \textit{Concentration of Standard} \text{ x } \textit{Volume of Extract}$$

$$\text{x } \frac{1}{\begin{array}{c}\textit{weight of}\\ \textit{sample extract}\end{array}} \text{ x } \frac{1}{\%\ \textit{Solids}} = \textit{Sample Concentration}$$

* If a dilution is performed the dilution factor is multiplied by the resulting peak area.

Each of the analytical methods (608 and 8080) recommend the use of surrogates, i.e., compounds added to every sample to evaluate analytical efficiency by measuring their recovery. ITAS did not spike surrogates into any of the samples they analyzed, a deviation from the cited protocol. York Labs spiked dybutylchlorendate (DBC) into each of the samples, however they did not calculate any surrogate recoveries. Without surrogate recovery information it is not possible to evaluate target compound recovery with any confidence.

Both laboratories performed matrix spikes, i.e., known quantities of specific compounds that are subject to the entire analytical procedure to evaluate the appropriateness of the method for the matrix by measuring recovery. Both laboratories reported good recoveries (see Table 2). However, due to lack of sample availability, the matrix spike performed by York Labs was performed on a laboratory blank sample and, therefore, the results of this analysis does not reflect any matrix interferences that might be present in river sediments.

An examination of the chromatograms produced by ITAS and York Labs suggest that interferences were present in sediment samples analyzed for PCBs. Each of the laboratories performed florisil cleanups (ITAS also performed mercury cleanups) and used multiple peak responses to calculate the final concentrations, thereby reducing any effect matrix interferences may have had on PCB quantitation.

CONCLUSIONS

Both methods used by the laboratories to analyze for PCBs (Method 608 and 8080) are approved EPA methods for the determination of PCBs in aqueous and solid matrices and generally provide comparable results. Each of the laboratories complied with method requirements with the exception of a small deviation by ITAS, i.e., ITAS did not spike surrogates into any of the sediment samples analyzed for PCBs.

There is no indication that the decline in PCB concentrations from 1986 to 1992 was the result of improper sample analysis. The results of the review show no indication of systematic laboratory errors that would have resulted in the decrease in PCB concentration from 1986 to 1992. Information reported within the data packages substantiate that the laboratories were detecting and quantifying PCBs with acceptable precision and accuracy despite the lack of surrogate recoveries by either laboratory and the use of a laboratory blank for a matrix spike by York Labs.

The difference in sample preparation resulted in consistent differences in the percent moisture reported by each of the laboratories. York Labs routinely had lower percent moisture (i.e., higher percent solids) than ITAS because, as mentioned previously, York Labs air dried the samples prior to analysis. The differences in percent moisture were taken into account by both laboratories during the quantitation of final PCB concentrations and does not appear to be the source of any systematic error. As mentioned by Dr. Fessler of GE, the presence of moisture in soil and sediment samples had been known to reduce the efficiency of the PCB extraction procedure. To evaluate whether moisture affects PCB extraction efficiency, it would be necessary to analyze sediment aliquots with different percent moisture contents but from the same sample (i.e., same PCB concentration as well as other sediment characteristics). As these analyses were not performed by either laboratory in 1986 or 1992, such an evaluation could not be made. If GE has information indicating that the magnitude of sediment moisture differences between the two laboratories (Table 1) could lead to the observed differences in PCB concentration, then additional sampling to quantify this effect may be advisable. If, however, evidence suggests that the effect of moisture on PCB extraction is relatively small as compared to the observed PCB differences, then additional sampling would not be recommended.

Both of the laboratories performed florisil cleanups on all the sediment samples to remove any compounds that might interfere with the detection of PCBs; however, ITAS also performed mercury cleanups to remove elemental sulfur. As with the differences in moisture content, there is no evidence that the use of mercury cleanup is the source of the difference in the two data sets.

Based on the information provided by each of the laboratories, it is not possible to confirm whether the source of the difference in the two data sets is the result of sample handling and/or analyses.

TABLE 1 (Page 1 of 4)

PERCENT MOISTURE
GE - Housatonic River
Sediment Survey

LAKE LILLINONAH			
RIVER MILE	CORE DEPTH (in)	PERCENT MOISTURE*	
		(ITAS)	(YORK)
29.8	0 - 1	86.86	12.00
29.8	1 - 2	78.16	44.56
29.8	2 - 3	78.52	1.06
29.8	3 - 4	-	34.96
29.8	4 - 5	75.68	4.00
29.8	5 - 6	-	17.50
29.8	6 - 7	78.72	48.36
29.8	7 - 8	-	18.37
29.8	8 - 9	74.18	16.00
29.8	9 - 10	-	30.59
29.8	10 - 11	72.11	32.87
29.8	11 - 12	-	10.68
29.8	12 - 13	78.99	35.58
29.8	13 - 14	21.65	5.89
29.8	14 - 15	24.43	6.56
29.8	15 - 16	82.47	14.04
29.8	16 - 17	79.68	9.41
29.8	17 - 18	50.25	5.36
29.8	18 - 19	42.21	4.91
29.8	19 - 20	24.65	38.50
29.8	20 - 21	25.32	9.00
29.8	22 - 23	20.26	-
29.8	24 - 25	21.88	-
29.8	26 - 27	27.24	-
34.2	0 - 1	72.89	44.34
34.2	1 - 2	69.89	20.10
34.2	2 - 3	70.95	19.57
34.2	3 - 4	-	33.02
34.2	4 - 5	68.86	57.72
34.2	5 - 6	66.34	16.67
34.2	6 - 7	69.62	50.36
34.2	7 - 8	-	57.98
34.2	8 - 9	62.26	57.18
34.2	9 - 10	-	61.34
34.2	10 - 11	66.16	57.43
34.2	11 - 12	-	43.84
34.2	12 - 13	62.14	56.00
34.2	13 - 14	64.96	51.66
34.2	14 - 15	64.47	55.18
34.2	15 - 16	28.13	29.23
34.2	16 - 17	62.01	51.36
34.2	17 - 18	62.00	54.43
34.2	18 - 19	62.18	21.85
34.2	19 - 20	63.00	-
34.2	20 - 21	62.55	-
34.2	22 - 23	46.00	-
34.2	24 - 25	61.18	-

* - Percent Moisture = (wet wt. - dry wt.)/wet wt. X 100.

TABLE 1 (Page 2 of 4)

PERCENT MOISTURE
GE - Housatonic River
Sediment Survey

LAKE ZOAR			
RIVER MILE	CORE DEPTH (in)	PERCENT MOISTURE*	
		(ITAS)	(YORK)
19.7	0 - 1	69.73	6.16
19.7	1 - 2	68.78	34.91
19.7	2 - 3	70.18	47.27
19.7	3 - 4	69.62	56.90
19.7	4 - 5	69.87	29.29
19.7	5 - 6	70.58	28.78
19.7	6 - 7	70.28	49.84
19.7	7 - 8	68.52	4.30
19.7	8 - 9	72.54	35.91
19.7	9 - 10	-	11.78
19.7	10 - 11	56.86	6.62
19.7	11 - 12	-	31.21
19.7	12 - 13	71.71	15.62
19.7	13 - 14	66.21	45.29
19.7	14 - 15	62.09	53.97
19.7	15 - 16	63.94	8.04
19.7	16 - 17	50.00	54.89
19.7	17 - 18	64.65	9.68
19.7	18 - 19	64.91	8.58
19.7	19 - 20	25.95	49.53
19.7	20 - 21	55.96	54.24
19.7	21 - 22	55.00	54.92
19.7	22 - 23	46.99	41.69
19.7	23 - 24	-	11.12
19.7	24 - 25	-	55.10
19.7	25 - 26	-	32.24
19.7	26 - 27	-	53.42
19.7	27 - 28	-	41.06
19.7	28 - 29	-	31.41
19.7	29 - 30	-	38.28
19.7	30 - 31	-	38.05
26.1	0 - 1	23.60	16.89
26.1	1 - 2	21.34	17.39
26.1	2 - 3	20.58	17.28
26.1	3 - 4	-	16.75
26.1	4 - 5	8.12	18.97
26.1	5 - 6	-	15.87
26.1	6 - 7	23.43	14.57
26.1	7 - 8	24.36	-
26.1	8 - 9	25.58	-
26.1	9 - 10	25.67	-
26.1	10 - 11	25.38	-
26.1	11 - 12	25.98	-
26.1	12 - 13	27.31	-
26.1	13 - 14	28.02	-

* - Percent Moisture = (wet wt. - dry wt.)/wet wt. X 100.

TABLE 1 (Page 3 of 4)

PERCENT MOISTURE
GE - Housatonic River
Sediment Survey

FALLS VILLAGE APEX			
RIVER MILE	CORE DEPTH (in)	PERCENT MOISTURE* (ITAS)	(YORK)
77.7	0 - 1	20.13	0.80
77.7	1 - 2	22.73	6.09
77.7	2 - 3	24.60	21.31
77.7	3 - 4	-	9.51
77.7	4 - 5	17.99	24.58
77.7	5 - 6	-	11.58
77.7	6 - 7	-	8.52
77.7	7 - 8	19.96	-
77.7	8 - 9	19.80	-
77.7	9 - 10	18.71	-
77.7	10 - 11	19.77	-
77.7	11 - 12	19.81	-
77.7	12 - 13	17.79	-
77.7	13 - 14	17.79	-
77.7	14 - 15	19.40	-
77.7	15 - 16	20.81	-
77.7	17 - 18	20.62	-
77.7	19 - 20	20.70	-
77.7	21 - 22	19.71	-
77.7	23 - 24	18.66	-
77.7	25 - 26	19.98	-

* - Percent Moisture = (wet wt. - dry wt.)/wet wt. X 100.

TABLE 1 (Page 4 of 4)

PERCENT MOISTURE
GE - Housatonic River
Sediment Survey

BULLS BRIDGE			
RIVER MILE	CORE DEPTH (in)	PERCENT MOISTURE*	
		(ITAS)	(YORK)
53.2	0 - 1	69.72	0.00
53.2	1 - 2	59.60	0.50
53.2	2 - 3	59.93	0.00
53.2	3 - 4	-	0.30
53.2	4 - 5	61.77	0.20
53.2	5 - 6	-	0.10
53.2	6 - 7	-	0.50
53.2	7 - 8	49.42	5.73
53.2	8 - 9	-	9.70
53.2	9 - 10	35.76	11.14
53.2	10 - 11	-	1.11
53.2	11 - 12	25.61	1.49
53.2	12 - 13	24.67	13.62
53.2	13 - 14	25.19	19.00
53.2	14 - 15	36.81	-
53.2	15 - 16	50.84	-
53.2	16 - 17	43.62	-
53.2	17 - 18	41.47	-
53.2	18 - 19	31.85	-
53.2	19 - 20	30.13	-
53.2	20 - 21	34.26	-

* - Percent Moisture = (wet wt. - dry wt.)/wet wt. X 100.

TABLE 2

QUALITY ASSURANCE/QUALITY CONTROL SUMMARY

GE - Housatonic River
Sediment Survey

PCBs	MATRIX SPIKE/MATRIX SPIKE DUPLICATE % RECOVERY		RPD
	MS	MSD	
ITAS (AROCHLOR 1242)			
	90	85	6
	85	92	8
	76	94	21
	81	83	2
	88	82	7
	91	86	6
YORK (AROCHLOR 1260)			
	85	95	11
	75	85	13
	95	95	0
	90	90	0
	79	79	0
	120	90	29

MS - Matrix spike.
MSD - Matrix spike duplicate.
RPD - Relative percent difference.

Appendix A

Data Validation Services Review

Data Validation Services
Cobble Creek Road P. O. Box 208
North Creek, N. Y. 12853
Phone 518-251-4429

RECEIVED
FEB 09 1993
LMS ENGINEERS

TO: Lawler, Matusky & Skelly Engineers

FROM: Judy Harry, Data Validation Services J. Harry

DATE: 02-06-93

RE: Summary of review of General Electric -Housatonic River PCB data

The data provided for the 1986 and 1992 PCB analyses on Housatonic River samples has been reviewed as described below. The documentation of the data packages does not allow for complete validation of the data, and verification of all sample reported results was not attempted. Parameters relating to systematic variances, such as calculation orithms used for sample results, standard dilution calculations, and Aroclor entifications in the two sets of analyses, were evaluated (as permitted by the deliverable limitations). TOC data was not evaluated; no raw data was provided.

Certain inconsistencies were present between the two methods. Although the specific EPA methodologies utilized by the labs vary somewhat, those differences would not account for the overall variances in sample reported results. Pre-extraction sample treatment was quite different. The York Lab PCB analyses (1986) involved air-drying of samples prior to extraction, whereas the IT Lab PCB extractions involved decanting of the samples. The York sample results may then include contribution from aqueous supernatant liquids not used for the IT analyses. It is not known whether the TOC results were derived from air-dried and decanted samples, or from the original samples as delivered to the labs.

Surrogate recovery is one of the primary criterion used for evaluation of the accuracy of sample reported results. York Labs spiked surrogate into samples, but the recoveries were not calculated or summarized; the presence of the surrogate can be observed on the York chromatograms. IT Labs has apparently not added surrogate to the samples, and evaluation of target compound recovery from a given sample cannot be made with confidence. However, matrix spikes were performed by IT Labs on samples, with good recoveries. The "matrix" spikes performed by York Labs, which also produced good recoveries, were done on lab blank soils (due to lack of sample availability), and do not reflect matrix effects.

Delays in holding times from sampling to delivery to the lab were present in each sampling group, but were much more significant for the 1986 group, and therefore do not account for the higher reported values for those samples.

In summary, no systematic errors have been observed in the determinations of PCB ported values for either of the two sampling events, and the method variances are likely to have resulted in the variance in sample reported results.