Section 6

BLASAND, BOUCK & LEE, INC.
engineers & scientists

6. Biota Investigations

6.1 General

This section of the RFI Report characterizes the nature and extent of PCBs and other constituents in biota from both the Massachusetts and Connecticut portions of the Housatonic River. This section provides a summary of the results of the previous biota sampling activities, which include both fish and other organisms (e.g., plants, invertebrates, reptiles and amphibians, birds, small mammals). Where sufficient data are available, temporal and spatial trends are assessed. This section also includes an evaluation of the influence of other factors (e.g., size and/or lipid content of an organism) on observed PCB concentrations.

Since the purpose of this section is to characterize the nature and extent of PCBs and other chemicals in Housatonic River organisms, the results of ecological studies (e.g., population surveys, reproductive studies) or other types of studies (e.g., toxicity testing, in-situ exposure studies) are not discussed here; however, results of chemical analyses conducted as part of those studies are provided where appropriate.

Section 6.2 provides a summary of the biological sampling and analysis activities that have been conducted for fish and other biota. Section 6.3 discusses the data on fish, focusing on the nature and extent of PCBs in fish tissue, including a discussion of the factors that may affect PCB concentrations in fish and analyses of spatial and temporal trends in fish PCB concentrations. Section 6.4 discusses other biota, focusing again on the nature and extent of PCBs in the tissue of those biota. Both of those sections also include brief summary information on other constituents, notably PCDDs/PCDFs. Section 6.5 discusses the current consumption advisories for fish and other biota. Finally, Section 6.6 presents a summary of the conclusions from the biota investigations.

6.2 Summary of Sampling and Analysis Activities

The Housatonic River biota sampling and analysis activities that provided the data considered in this RFI Report are briefly described below. Detailed descriptions of the historical sampling programs are provided in Appendix A, while Table 6-1 lists the fish sampling programs and Table 6-2 lists the sampling programs for other biota. All the PCB data on biota are provided in Appendix B, and summary information on non-PCB constituents in biota is included in Appendix C.

6.2.1 Fish Sampling

Fish sampling and analysis programs conducted on the Housatonic River have targeted a range of species and size classes, and have used several sample preparation methods and analytical procedures. Fish species representing the range of trophic levels have been collected, including top predators (e.g., largemouth bass in Massachusetts, smallmouth bass and brown trout in Connecticut), mid-level predators (e.g., bluegill, pumpkinseed, yellow perch), bottom-feeding species (e.g., brown bullhead, white suckers), and forage fish (e.g., fallfish, golden shiner, bluntnose minnow). Target size classes have included adult fish, juveniles, and fish in their first year of life, known as "young-of-the-year" (YOY). Sample preparation types have included various fillet types (e.g., skin-on or skin-off), offal (i.e., the remaining carcass after the fillet tissue is removed), ovaries, and individual or composite whole body samples. These various species, trophic levels, and tissue preparations reflect diverse intended uses of the data. For example, whole body data from smaller size classes, as well as reconstituted whole body data from matched fillet and offal analyses of larger size classes, for a variety of fish species support an evaluation of ecological risk, while fillet data from larger mid-level and top predatory fish support an evaluation of human health risk. In addition, a variety of analytical methods have been used; analyses for PCBs have included both Aroclor-based and congener-based methods, depending on the particular program.

6.2.1.1 Massachusetts

Among the early studies of chemical constituents in fish collected from the Massachusetts portion of the Housatonic River were those conducted by Stewart in 1980 and 1982 on behalf of GE. Fillets of several sport fish species including trout, bass, yellow perch, and sunfish were collected from multiple locations between Center Pond in Dalton and the Massachusetts/Connecticut border and analyzed for PCBs and lipid content. The 1982 sampling event also included the collection of fish tissue for PCDD/PCDF analyses.

In 1990, to supplement data from the 1980 and 1982 Stewart studies and as part of the MCP Phase II activities, skin-on fillet samples of largemouth bass, yellow perch, and brown trout were collected from Woods Pond and Rising Pond and analyzed for PCBs and lipid content. PCDD/PCDF analyses were also conducted on two samples. Additional fish tissue samples, including whole body and skin-off fillets, were collected in 1998 by BBL on behalf of GE from the River between the Confluence and the Pittsfield WWTP, from Rising Pond, and from a sampling location (HR6) south of Rising Pond and just upstream of the Connecticut border. Species included yellow perch, brown and yellow bullhead, pumpkinseed, bluegill, and bluntnose minnows. These samples were analyzed for PCB congeners and lipid content.

The most comprehensive fish sampling effort within the Massachusetts portion of the River was conducted in 1998 by EPA, with additional sampling in 1999 and 2000, as part of the SI of the Rest of River (see Weston, 2000). More than 1,000 fish samples were collected in 1998; species collected included yellow perch, pumpkinseed, bluegill, largemouth and smallmouth bass, brown and yellow bullhead, and others. Tissue types included skin-off fillet, offal (the tissue remaining after fillet removal), and whole body tissue. Samples were analyzed for PCBs (primarily congeners, with limited analysis for Aroclors in 1999), lipid content, and a number of other constituents, including pesticides, metals, and PCDDs/PCDFs. Sample locations included areas upstream of the Confluence in the East and West Branches, the Confluence to Woods Pond, Woods Pond, and Rising Pond.

Additional adult largemouth bass were collected by GE consultants in 1999 and 2002. In 1999, five largemouth bass were collected from the HR6 location upstream of the Connecticut border. The fish were analyzed as whole body samples for PCB Aroclors and percent lipids. In 2002, 15 largemouth bass were sampled from both Reach 5B and Woods Pond. These samples were separated into skin-off fillets and offal and analyzed for PCB congeners and lipid content.

In addition to the adult fish sampling described above, on behalf of GE, BBL has conducted a biennial YOY fish sampling program since 1994, with the most recent samples collected in 2002. Whole body composite samples of largemouth bass, yellow perch, and bluegill and/or pumpkinseed have been collected and analyzed for PCB Aroclors and lipid content. These samples have been collected at a location (HR2) between the Pittsfield WWTP and Roaring Brook, in Woods Pond, in the Glendale impoundment, and at location HR6 (see Appendix B for sample locations).

6.2.1.2 Connecticut

Fish sampling within the Connecticut portion of the Rest of River for analysis of PCBs and other constituents was primarily conducted under two programs: one by CDEP and the other by the Academy of Natural Sciences of Philadelphia (ANSP) on GE's behalf. These two programs were conducted at many of the same locations, and some of the ANSP fish samples were collected with the assistance of the CDEP Fisheries Division (ANSP, 2003).

From 1977 to 1990, CDEP collected and analyzed fillets from a variety of resident fish species, including brown trout and smallmouth bass, for PCB Aroclors and lipid content. Sample locations were West Cornwall, Bulls Bridge, Lake Lillinonah, and Lake Zoar.

On behalf of GE, ANSP has conducted a biennial fish tissue monitoring program since 1984. This program has primarily targeted the collection of fillet samples of smallmouth bass from the same four locations sampled by CDEP and brown trout fillets from West Cornwall. In addition, in 2000, additional fish samples were collected by ANSP in response to CDEP's request for additional samples for use in reviewing the fish consumption advisory for the Housatonic River (ANSP, 2001). Analyses conducted by ANSP during its program include PCB Aroclors (and since 1992 PCB congeners) and lipid content.

6.2.2 Other Biota

Sampling programs conducted within the Rest of River have also collected data on concentrations of PCBs and other chemicals in the tissues of biological organisms other than fish. Investigations conducted by Stewart on behalf of GE in 1980 included the collection and analysis of aquatic plants such as duck potato, water milfoil, and duckweed. These samples were collected from several areas between Pittsfield and Rising Pond and analyzed for PCB Aroclors. In 1982, a composite sample of bullfrogs and a single snapping turtle, both from Woods Pond, were analyzed for PCB Aroclors and lipid content. Woods Pond bullfrogs were sampled and analyzed again in 1992 by BBL. In 1996, a single algae sample was collected by BBL from the former Housatonic Street Bridge Abutment and analyzed for total PCBs.

The most comprehensive sampling and analysis program to date for non-fish biota was conducted as part of the EPA SI. In this investigation, data for PCBs and other chemical constituents were gathered on a large number of terrestrial and aquatic organisms between 1998 and 2001. Sampling included a number of locations upstream of Woods Pond Dam and from reference areas. Terrestrial vegetation samples included corn, squash, fiddleheads, and grass; aquatic vegetation samples included periphyton, filamentous algae, macrophytes, and detritus. Other organisms included phytoplankton and zooplankton, benthic invertebrates, crayfish, frogs, and worms. Samples of small mammals included tissues from short-tailed shrews and white-footed mice. Tissues from several bird species were collected and analyzed, including: breast and/or liver tissue of mallards and wood ducks; eggs, breast tissue, and stomach contents of tree swallow pippers and nestlings; and house wren and chickadee eggs. In 2000 and 2001, GE's consultants also collected and analyzed PCBs in wood frog larvae and American robin eggs and nestlings.

In Connecticut, the most complete investigation of PCBs in non-fish biota has been the long-term monitoring of aquatic insects conducted by CDEP and ANSP (on behalf of GE). From 1978 through 1990, CDEP collected composite samples of benthic invertebrates at West Cornwall, while ANSP has collected aquatic insect samples from the same general location since 1992. In 1992, ANSP collected two crayfish samples, one comprising a whole-body tissue composite and the second being an egg composite from adult female crayfish at West Cornwall. In addition, in 1999, CDEP and the U.S. Fish and Wildlife Service (USFWS) collected a single mallard from the Housatonic River near Newtown, Connecticut, for PCB analysis.

6.3 Data on Fish

Fish sampling activities have been conducted at the Housatonic River since 1977, and data are available for many species and locations. This section presents the analytical data for fish collected from the Massachusetts and Connecticut portions of the River, focusing on data for PCBs. In general, the data are presented using the same reach and other location descriptors used in previous sections. These reaches are depicted on Figure 2-1 (Massachusetts) and Figure 2-2 (Connecticut). The individual sample locations are also presented on figures included in Appendix B.

The majority of the fish sampling for the Housatonic River has focused on characterizing fish PCB concentrations. The fish PCB data include results for several species of fish collected as early as 1977, and include results for both Massachusetts and Connecticut. Tissue types primarily include skin-on and skin-off fillets, offal, and whole body tissue. Whole body results include actual and calculated values. Actual whole body data are obtained from fish samples in which the laboratory analyzes the entire fish as a single sample. Calculated whole body data are derived on a mass balance basis using separate measurements of fillet and offal samples obtained from the same fish, and enable a comparison of larger adult fish with measured whole body values from smaller size classes of fish.

The individual PCB results for all fish samples are included in Appendix B, along with figures showing sample locations. Summary statistics for the PCB data (on a wet-weight basis) are presented in Table 6-3 (adult fish from Massachusetts), Table 6-4 (YOY fish from Massachusetts), and Table 6-5 (adult fish from Connecticut). Overviews of the Massachusetts and Connecticut fish PCB data (i.e., fillet and whole body results, reported on a wet-weight basis) are presented in Section 6.3.1. Subsequent subsections provide additional analyses of the fish PCB data, including a discussion of factors (e.g., fish size, trophic level, and lipid content) that may affect fish tissue PCB concentrations, spatial and temporal trend analyses, and a characterization of PCB Aroclor and congener composition.

6.3.1 Overview of Fish PCB Data From Massachusetts and Connecticut

6.3.1.1 Massachusetts

The largest and most complete dataset in terms of species, sample locations, fish sizes, tissue preparations (e.g., fillet, offal, whole body), and target analytes was generated from the sampling effort conducted by EPA in 1998. Other Massachusetts fish tissue data are the YOY data (available from biennial collections since 1994), older (1980 and 1982) data from Stewart, and supplemental data that have been collected by GE. A description of the Massachusetts fish sampling activities is provided in Table 6-1, and summary statistics of the data are presented in Table 6-3 (adult fish) and Table 6-4 (YOY fish).

In general, large (edible-size) fish collected by EPA and GE were analyzed as skin-off fillets and offal. Smaller fish were analyzed as individual or composited whole-body preparations. Results presented in this section include total PCBs analyzed as Aroclors or as congeners. Prior to 1998 and in 1999, adult fish collected by GE were analyzed for PCB Aroclors. GE's adult fish samples in 1998 and 2002 were analyzed for PCB congeners. GE's YOY program analyzes samples for PCB Aroclors. Lastly, EPA's

1998-2000 fish samples were analyzed for PCB congeners. This section focuses on wet weight-based PCB concentrations in Massachusetts Rest of River fish, including fillet and whole body (both actual and calculated) data. Fillet data are emphasized because of their importance in evaluating human health risks. In later sections, spatial and/or temporal trends are evaluated using both fillet and reconstructed and measured whole body concentrations. Evaluations of fish size and lipid content are presented in Section 6.3.2.

Adult Fish Tissue Results

Over the past 25 years, many fish species and tissue types have been collected from the Massachusetts portion of the Rest of River. Species collected have included bottom-feeders such as brown bullhead and white sucker, predatory sport fish such as largemouth bass and brown trout, several panfish species including pumpkinseed and bluegill (both of which are species of sunfish), and forage fish such as golden shiner and bluntnose minnow. The species that were collected in the largest numbers and most frequently from each of the Massachusetts River reaches are brown bullhead, largemouth bass, pumpkinseed, and yellow perch. A large number of white sucker, 57 individuals in Reaches 5 and 6 prepared as whole body samples, were collected by EPA in 2000.

The older historical adult fish tissue PCB data for the Housatonic River are the 1980 and 1982 Stewart data (Stewart, 1982). These data consist of the results of a single (composite or individual) fillet sample for a given species and location. These results are included in Table 6-3 and showed the following:

- In Reach 5, PCB concentrations in non-trout species ranged from 2.2 mg/kg in a sunfish to 12 mg/kg in a brown bullhead, with a rainbow trout from Reach 5A at 27 mg/kg and a brown trout from Reach 5B at 260 mg/kg.
- In Reach 6 (Woods Pond), PCB concentrations in non-trout species ranged from 3 mg/kg in a yellow perch (in 1980) to 20 mg/kg in largemouth bass (in 1982), with a trout at 119 mg/kg.
- In Reach 7, PCB concentrations ranged from 2.2 mg/kg in yellow perch (mean of 2 samples in 1980) to 11 mg/kg in a bass and a trout.
- In Reach 8 (Rising Pond), PCB concentrations ranged from 2.6 mg/kg in a bluegill to 7.4 mg/kg in a largemouth bass.

- In Reach 9, PCB concentrations ranged from 2.7 mg/kg in a sunfish to 6.9 mg/kg in a largemouth bass.

The adult fish tissue PCB data collected by BBL in 1990 consisted of fillet samples from brown trout, largemouth bass, and yellow perch from Reach 6 (Woods Pond) and Reach 8 (Rising Pond). Arithmetic mean PCB concentrations from this dataset for the three species (respectively) are 14 mg/kg, 11 mg/kg, and 8.4 mg/kg for Reach 6, and 33 mg/kg, 17 mg/kg, and 6.1 mg/kg for Reach 8. The highest total PCB concentration (39 mg/kg) was detected in a largemouth bass fillet sample from Reach 8.

In 1998, GE collected adult fish tissue PCB data as part of the MCP supplemental Phase II investigations. These data included 62 samples (whole body and fillet) from three areas. The results (Table 6-3) showed the following:

- In Reach 5A, PCB concentrations in single fillet samples of brown bullhead and yellow bullhead showed PCB concentrations of 9.2 mg/kg and 174 mg/kg, respectively.
- In Reach 8 (Rising Pond), arithmetic mean concentrations for fillet samples included 5.8 mg/kg for brown bullhead and 11 mg/kg for yellow perch; and 12 mg/kg for bluntnose minnow whole body samples.
- In Reach 9, arithmetic mean concentrations for whole body samples were 0.4 mg/kg for largemouth bass and 4.9 mg/kg for bluntnose minnow, while fillet samples showed arithmetic mean concentrations of 1.7 mg/kg for brown bullhead, 4.4 mg/kg for yellow perch, and 4.9 mg/kg for largemouth bass.

In 1999 GE/ARCADIS collected five whole body samples of largemouth bass from Reach 9. Total PCB concentrations ranged from 17 to 54 mg/kg, with an arithmetic mean of 26 mg/kg (Table 6-3).

The adult fish data collected by EPA and USFWS in 1998, 1999, and 2000 represent the largest contribution to the overall fish tissue data base. More than 1,000 fish samples from a variety of species and tissue types (including skin-off fillet, offal, and whole body samples) were collected. Sample locations within the Rest of River included Reach 5, Woods Pond (Reach 6), and Rising Pond (Reach 8). The 1998 average fillet PCB concentrations (Table 6-3) were:

- In Reach 5, 5.5 mg/kg (one bluegill fillet), 5.6 mg/kg (brown bullhead), 6.1 mg/kg (pumpkinseed), 9.2 mg/kg (yellow perch), and 23 mg/kg (largemouth bass), with a maximum value of 151 mg/kg in a largemouth bass fillet;
- In Reach 6 (Woods Pond), 3.4 mg/kg (yellow perch), 6.9 mg/kg (largemouth bass), 7.0 mg/kg (pumpkinseed), and 19 mg/kg (brown bullhead), with a maximum value of 90 mg/kg in a brown bullhead fillet; and
- In Reach 8 (Rising Pond), 1.7 mg/kg (brown bullhead), 2.9 mg/kg (pumpkinseed), 3.8 mg/kg (largemouth bass), and 4.9 mg/kg (yellow perch), with a maximum concentration of 13 mg/kg in a yellow perch fillet.

The 1998 EPA/USFWS offal samples (the remaining carcass after removal of the fillet), as expected, have higher PCB concentrations than fillets, as their lipid content was much higher than that of fillets. For example, in pumpkinseed and largemouth bass from Woods Pond, offal lipid content averaged 6.5-fold and 12-fold higher than in fillets, respectively (Table 6-3). PCB concentrations in the 1998 offal samples were almost an order of magnitude higher than the corresponding fillet samples (Table 6-3). For Reach 5, average PCB concentrations in the offal ranged from 47 mg/kg (brown bullhead) to 156 mg/kg (bluegill – one sample) and those from Reach 6 ranged from 43 mg/kg (pumpkinseed) to 149 mg/kg (largemouth bass). Similar to the fillet data, average offal PCB concentrations in Reach 8 were lower than those from upstream reaches, ranging from 6.1 mg/kg to 68 mg/kg. (Offal data are not available from Reach 9.)

Average PCB concentrations in adult whole body samples (calculated from the combined fillet and offal analyses) were higher than in corresponding fillets (Table 6-3). Similar to the fillet data, 1998 whole body samples from Reaches 5 and 6 contained higher average PCB concentrations than whole body samples from Reach 8 (Rising Pond). (Similar whole body data are not available for Reach 9, where only fillet samples were analyzed.) Average wet weight PCB concentrations in calculated whole body samples were:

- In Reach 5, 105 mg/kg for largemouth bass, 41 mg/kg for pumpkinseed, and 96 mg/kg for yellow perch;
- In Reach 6, 107 mg/kg, 32 mg/kg, and 71 mg/kg for these three species, respectively; and
- In Reach 8, 33 mg/kg, 15 mg/kg, and 50 mg/kg for these three species, respectively.

Smaller largemouth bass samples, analyzed as individual whole body preparations, have lower PCB concentrations than the fillet-and-offal combined results for larger fish. For example, in Woods Pond, the arithmetic mean PCB concentration for calculated whole body adult fish was 107 mg/kg, while the mean for smaller whole body fish was only 49 mg/kg (Table 6-3). Body weight-PCB concentration relationships are discussed further in Section 6.3.2. Other arithmetic mean whole body PCB concentrations for Woods Pond included 22 mg/kg for golden shiner (maximum of 26 mg/kg) and 188 mg/kg for goldfish (maximum of 447 mg/kg).

The 1999 EPA/USFWS fish tissue data include results for largemouth bass ovary and offal samples and carp whole body samples from Woods Pond, as well as largemouth bass ovary and offal samples from Rising Pond (Table 6-3). For Woods Pond, the arithmetic mean total PCB concentrations for largemouth bass were 98 mg/kg (ovary) and 48 mg/kg (offal), while that for the whole body carp is 113 mg/kg. The maximum total PCB concentration from Woods Pond was 150 mg/kg for a largemouth bass ovary. For Rising Pond, arithmetic mean PCB concentrations for largemouth bass were 133 mg/kg (ovary) and 42 mg/kg (offal). The maximum total PCB concentration from Rising Pond was 166 mg/kg in an ovary sample.

The 2000 EPA/USFWS fish tissue data consist of results from 11 white sucker whole body samples collected from Woods Pond. The arithmetic mean total PCB concentration in these fish is 71 mg/kg, with a maximum concentration of 199 mg/kg (Table 6-3).

In 2002 GE/BBL collected 15 largemouth bass from each of two locations: a location in Reach 5A and Woods Pond. Fish were analyzed as fillet and offal (remaining carcass) tissues. The arithmetic mean total PCB concentrations for fillet, offal, and calculated whole body tissues (respectively) were: (a) 52 mg/kg, 146 mg/kg, and 129 mg/kg for Reach 5A: and (b) 67 mg/kg, 123 mg/kg, and 113 mg/kg for Woods Pond (Table 6-3). Average fillet concentrations in this 2002 supplemental largemouth bass sampling were higher than those in the 1998 samples collected by BBL and by EPA/USFWS. This difference between the 1998 and 2002 samples is in part attributable to differences in fillet lipid contents; average fillet lipid contents from the 2002 samples were 1.3-fold and 5.1-fold higher than in 1998 in Reaches 5 and 6, respectively (Table 6-3). Average reconstructed whole body values, however, were similar between the 1998 and 2002 samples.

YOY Fish Tissue Results

The YOY fish tissue data for the Housatonic River include the results of GE's biennial monitoring from 1994 to 2002. The GE program targets the young-of-year of three species (largemouth bass, yellow perch, and pumpkinseed or bluegill) from four locations in the Massachusetts portion of the Rest of River region: HR2 (Pittsfield WWTP to Roaring Brook – Reach 5), Woods Pond (Reach 6), Glendale (Reach 7), and HR6 (Rising Pond to Connecticut border – Reach 9) (see Appendix A.1.4 for further details). In addition, EPA collected some YOY fish samples in 1998 from Reaches 5, 6, and 8. YOY tissues samples were prepared as composited whole bodies. The results from the GE and EPA YOY sampling are presented in Table 6-4. A general summary of the PCB data is presented below, and more detailed trend analyses are presented in subsequent sections.

In the GE biennial YOY monitoring program, average YOY PCB concentrations at the four main sampling stations for all years of the program were as follows:

- At HR2 in Reach 5, 17 to 41 mg/kg in largemouth bass, 20 to 37 mg/kg in yellow perch, and 10 to 40 mg/kg in pumpkinseed/bluegill;
- In Woods Pond (Reach 6), 9.0 to 38 mg/kg in largemouth bass, 12 to 58 mg/kg in yellow perch, and 3.3 to 35 mg/kg in pumpkinseed/bluegill;
- At Glendale in Reach 7, 3.2 to 17 mg/kg in largemouth bass, 8.6 to 16 mg/kg in yellow perch, and 0.94 to 19 mg/kg in pumpkinseed/bluegill; and
- At HR9 in Reach 9, 1.8 to 4.8 mg/kg in largemouth bass, 2.2 to 4.6 mg/kg in yellow perch, and 0.90 to 4.7 mg/kg in pumpkinseed/bluegill.

Additional collections of YOY fish by GE and EPA in 1998 yielded average PCB concentrations of 27 to 40 mg/kg for the target species in Reach 5 and 9.6 to 12 mg/kg for the target species in Rising Pond (Reach 8).

As can be seen in the above results, average YOY fish PCB concentrations are generally higher in Reach 5 (location HR2) and Reach 6 (Woods Pond) than in Reach 7 (Glendale) and Reach 9 (location HR6). For example, average YOY largemouth bass PCB concentrations above Woods Pond Dam ranged from

17 to 32 mg/kg, but only from 1.9 to 16 mg/kg from locations below the dam to the Connecticut border (GE data, all years). YOY largemouth bass collected by EPA in 1998 from Reach 5, Woods Pond, and Rising Pond had mean PCB concentrations of 36, 17, and 12 mg/kg, respectively, similar in magnitude to the GE data and illustrating a similar upstream-downstream pattern (Table 6-4).

In addition, average PCB concentrations in YOY fish samples (Table 6-4) are generally lower than in adult whole body samples (Table 6-3). For example, for Woods Pond, the average PCB concentrations in the YOY fish collected by GE in 1998 were 29 mg/kg for yellow perch and 32 mg/kg for largemouth bass (Table 6-4). In comparison, average PCB concentrations for adult reconstructed whole-body fish from Woods Pond in 1998 were 71 mg/kg for yellow perch and 107 mg/kg for largemouth bass (Table 6-3). However, average PCB concentrations do not always increase with size for a given fish species; trends in PCB concentrations with weight, among other factors, are discussed below in Section 6.3.2.

6.3.1.2 Connecticut

The fish data for the Connecticut portion of the River include data collected by CDEP and data collected by ANSP. A description of the Connecticut fish sampling activities is presented in Table 6-1. During the 1980s, fish samples were collected for several years (1982, 1983, 1984, 1985, 1986, and 1988) and from several different locations. The majority of the Connecticut fish data are from samples collected from four areas of the Rest of River: West Cornwall, Bulls Bridge, Lake Lillinonah, and Lake Zoar (Figure 2-2) at a frequency of approximately every 2 years since the late 1970s. Some of the earlier data were collected by CDEP, while the data beginning in 1984 were collected by ANSP. Tissue preparations beginning in 1984 were generally consistent, and included skin-on/scales-on fillet samples for trout and skin-on/scales-off fillet samples for bass and most other species. The primary target species have been brown trout and smallmouth bass; limited data are available for other species. No YOY individuals have been collected from Connecticut. Further details about sampling programs in Connecticut are given in Appendix A.

Prior to 1992, fish PCB concentrations were quantified based on Aroclors. Beginning in 1992, ANSP used both the Aroclor method and an alternate method based on congeners. Studies by ANSP (1997) indicate that the two methods give very similar total PCB concentrations. Because the temporal trend analyses in this RFI Report include data collected prior to 1992, only the Aroclor-based PCB concentrations are included in the tables, figures and analyses in the text of this Report. However, the congener-based PCB concentrations are included in the data presented in Appendix B. Summary statistics of the PCB data are presented in Table 6-5 and are discussed below. Trend analyses for the data are presented in subsequent sections of this RFI Report.

In recent years (1994-2002) in the ANSP biennial monitoring program, arithmetic mean Aroclor-based PCB concentrations in smallmouth bass fillets ranged from 0.77 to 1.6 mg/kg in West Cornwall and Bulls Bridge and between 0.32 and 0.87 mg/kg in Lakes Lillinonah and Zoar further downstream (Table 6-5). Brown trout average fillet PCB concentrations for the same period ranged from 1.5 to 2.7 mg/kg at West Cornwall. There are limited data for forage fish, mid-level predators, and bottom feeders. Average PCB concentrations in fillets from West Cornwall during 1998-2000 ranged from 0.13 to 0.85 mg/kg in sunfish and from 0.18 to 0.34 in yellow perch. A single brown bullhead fillet sampled, in 2000, had a PCB concentration of 0.38 mg/kg (Table 6-4). For comparison, maximum fillet tissue PCB concentrations observed in Woods Pond during 1998 for these same species were 48, 6.4, and 90 mg/kg, respectively (Table 6-3). Spatial and temporal patterns of the PCB concentrations in the target species, smallmouth bass and brown trout, are explored further below in Sections 6.3.3.2 and 6.3.4.2.

6.3.2 Factors Potentially Affecting PCB Concentrations in Fish Tissue

Factors other than the PCB concentrations in the food to which biota are exposed can affect fish tissue PCB concentrations. These factors include species-specific and individual variations in growth rate, lipid content, and feeding and habitat preferences. Because these factors can influence interpretation of spatial gradients and temporal trends, it is important to account for the relationships between these fish characteristics and PCB concentration when interpreting the fish tissue PCB data for patterns in time and space.

The relationships among PCBs, body weight, and lipid content were examined for each of the major fish species and locations in the EPA dataset (fish collected in 1998, except for white sucker, which were collected in 2000), in combination with the 1998 GE YOY data and the data from the GE supplemental adult fish sampling programs (1998 and 2002). (YOY data were limited to 1998 to avoid introducing variability resulting from the impacts of year-to-year differences in water temperature on growth rates and hence on size achieved when these fish are sampled in the fall.) All analyses were performed using reconstituted whole body data (large adult fish) or measured whole body data (all other fish).

Relationships among body weight, percent lipid, and tissue PCB concentration vary by fish species and across the three Massachusetts reaches for which there were sufficient data (Reach 5, Woods Pond, and Rising Pond). Several figures have been prepared to examine, for each such location, the relationships between lipid content and body weight (Figures 6-1a, 6-1b, and 6-1c), between PCB concentration and lipid content (Figures 6-2a, 6-2b, and 6-2c), between PCB concentration and body weight (Figures 6-3a, 6-3b, and 6-3c), and between lipid-based PCB concentration and body weight (Figures 6-4a, 6-4b, and 6-4c) for pumpkinseed, yellow perch, largemouth bass, brown bullhead and white sucker.

Lipid content increases with body weight in white sucker whole body samples in Reaches 5 and 6 ($r^2 > 0.6$ and p-values < 0.01) (Figures 6-1a and 6-1b). There may be a similar trend between lipid and weight in yellow perch, but the strength of the relationship is weaker and, in Woods Pond, not significant (Reach 5 - $r^2 = 0.21$, p-value = <0.01; Woods Pond - $r^2 = 0.034$, p-value = 0.26; Rising Pond - $r^2 = 0.28$, p-value = <0.01) (Figures 6-1a, 6-1b, and 6-1c). For the other species, there is no consistent trend in lipid content with body weight (Figures 6-1a, 6-1b, and 6-1c). In the larger adult fish for which whole-body values were reconstructed from fillet and offal, individual fish lipid contents vary by a factor of 10 or more (Figures 6-1a, 6-1b, and 6-1c). Furthermore, there appear to be some adult fish with extremely low lipid values. Fillet lipid values were often less than about 0.3%, and reconstructed whole body lipids were less than about 1%. This is generally lower than the amounts of structural (membrane) lipid in fillets, suggesting that lipid extraction may have been incomplete in these fish, and therefore that lipid-based PCB levels may not be accurate. This issue is discussed further in Appendix D.2.

Because PCBs strongly sorb to lipids, wet-weight PCB concentrations in fish tissue are often found to increase with lipid content. The strength of this relationship depends on the relative importance of PCB elimination and growth dilution, which in turn depends on the hydrophobicity of the PCBs, the lipid content of the fish, and the growth rate of the fish. In general, the relationship between PCB concentration and lipid content is stronger in larger, slower-growing fish. The relationship is typically weaker in smaller and/or faster-growing individuals and individuals with very high lipid contents. In the datasets examined here, PCB concentration increases with lipid content in some species and locations, particularly largemouth bass, yellow perch, and white sucker (Figures 6-2a, 6-2b, and 6-2c). However, there is considerable variability both within and between reaches for a given species and the relationships are often weak (low r^2).

Wet-weight PCB concentrations increase with weight in largemouth bass and yellow perch in all three reaches ($r^2 = 0.26$ to 0.68 and p-values $\ll 0.01$; Figure 6-3a, 6-3b, and 6-3c), and in white sucker and brown bullhead in Reach 5 (white sucker - $r^2 = 0.13$, p-value = 0.01; brown bullhead - $r^2 = 0.39$, p-value < 0.01; Figure 6-3a). Largemouth bass and yellow perch exhibit similar relationships in the lipid-normalized PCB data (Figures 6-4a, 6-4b, and 6-4c). However, there is no such significant positive trend of lipid-normalized PCB concentration with weight in brown bullhead and white sucker.

In summary, because of the variability in the relationship between PCB concentration and lipid content, spatial gradients and temporal trends are evaluated on both a wet-weight basis and a lipid-normalized basis. Consistency between the two approaches would provide support for spatial or temporal differences in fish tissue PCB concentrations, whereas inconsistency between trends and gradients evaluated in these two ways would limit the reliability of conclusions drawn from the data. Also, because of the evidence for relationships between PCB concentration and weight, the gradients and trends are evaluated independently for fish of three weight classes, based on the classes delineated in the database: large fish (those prepared as fillets), smaller fish prepared as whole bodies, and YOY fish sampled in composites.

6.3.3 Spatial Trends

This section presents spatial trend analyses of the wet-weight and lipid-normalized PCB data for fish from the Massachusetts and Connecticut portions of the Housatonic River. The objective of the trend analyses is to identify differences in fish tissue PCB concentrations among River reaches.

6.3.3.1 Massachusetts

Spatial trends in adult fish PCB concentrations were evaluated in the Massachusetts portion of the Rest of River using data from EPA's 1998 sampling effort. These data include multiple species that were collected from Reach 5 (West Branch Confluence to Woods Pond Headwaters), Reach 6 (Woods Pond), and Reach 8 (Rising Pond). White sucker data (whole-body individuals only) collected by EPA from

Reach 5 and Woods Pond in 2000 were also examined. Spatial information was supplemented with fish data collected by GE in 1998, which provide additional data for Rising Pond and a downstream reach (Reach 9) that was not targeted by EPA. In addition, although limited to only two locations, the 2002 GE largemouth bass data were also evaluated for spatial trends. A summary of the EPA/GE data is presented in Table 6-3.

PCB data from fillets and reconstructed whole body samples (based on matching fillet and offal samples) from the more frequently targeted species (brown bullhead, largemouth bass, pumpkinseed, and yellow perch) are presented on Figures 6-5a and 6-5b, respectively. PCB data for selected smaller fish prepared as whole bodies (goldfish, juvenile largemouth bass, and white sucker) are presented on Figure 6-5c. Aroclor-based PCB data from GE's YOY collection program (including data collected in 1994, 1996, 1998, 2000, and 2002) are shown for largemouth bass, yellow perch, and sunfish (bluegill and pumpkinseed) on Figure 6-6a (wet-weight) and Figure 6-6b (lipid-normalized). (Yellow perch could not be sampled from the Glendale Dam location in 2002.) As indicated above, these preparation types reflect different size and age classes of fish, with potentially different feeding and habitat preferences (e.g., shallow waters versus deeper pools). Furthermore, the YOY data represent, for each collection year, a set of exposure conditions during the fishes' first year of life, whereas fish tissue data from the larger size classes integrate the effects of exposure over several years. Because these factors may result in potential differences in PCB exposure, the data for these preparation/size types are presented separately. All of these fish tissue PCB concentrations are presented as both wet-weight-based and lipid-based values. As discussed previously, gradients are evaluated both ways because relationships between lipid content and PCB concentration were not consistently observed.

In the Rest of River area, average fish tissue PCB concentrations are generally highest in Reaches 5 and 6 (Woods Pond) in all three size classes and on both a wet-weight and a lipid-normalized basis (Figures 6-5a, 6-5b, 6-5c, 6-6a, and 6-6b). Differences in mean concentrations for a given species between these two reaches are small in comparison to the variability; mean values for most species and preparation types in Reaches 5 and 6 fall within two standard errors of each other. Fish fillet tissue PCB concentrations expressed on a wet-weight basis exhibit generally similar mean concentrations (means within two standard errors of each other) across all reaches from Reach 5 to Reach 9, although higher mean values are observed for largemouth bass in Reach 5 and brown bullhead in Woods Pond (Figure 6-5a, upper panel). For all species evaluated except pumpkinseed, average lipid-normalized fillet PCB concentrations are lower downstream of Woods Pond Dam (Figure 6-5a, lower panel). On a whole body basis, mean fish tissue PCB concentrations measured downstream of Woods Pond Dam are generally lower than those measured in Reaches 5 and 6 in both adult and YOY fish (Figures 6-5b, 6-5c, 6-6a, and 6-6b). An exception to this pattern is adult yellow perch, in which highly variable PCB concentrations down to Rising Pond prevent a clear interpretation of declining mean concentrations (Figure 6-5b). Declining mean concentrations downstream of Woods Pond Dam are evident within a given year in the YOY data even though there is year-to-year variability in the overall concentrations (Figures 6-6a and 6-6b). The spatial patterns in fish tissue PCB concentrations are consistent with spatial trends observed in the sediment and water column PCB concentrations presented in Sections 3 and 4 of this RFI Report.

As described above, the lack of consistent, well-defined relationships between PCB concentration and lipid content indicates that within-species, within-location variation in lipid content may hinder detection of exposure-related variations in average fish tissue PCB levels across reaches. Related to this issue is the fact that some of the fish have extremely low fillet lipid contents, defined here as 0.3% or less (the minimum value in the EPA dataset is 0.004%) (see further discussion in Appendix D.2). Due to their very low lipid content, these fish have wet-weight-based PCB concentrations similar to other fish but have elevated lipid-normalized PCB concentrations. To evaluate the impact of this factor on spatial gradients, fillet PCB concentrations were averaged after removal of fish with fillet lipid contents less than or equal 0.3%. The spatial patterns for the remaining adult fish fillets are shown, on wet-weight and lipid-normalized bases, on Figure 6-7.

As can be seen by comparing Figure 6-7 with Figure 6-5a, the removal of the fish with very low lipid levels does not change the large-scale spatial gradients for fillets in that concentrations are still higher in Reaches 5 and 6 than downstream of Woods Pond. Nor does it appreciably change the spatial patterns and inter-species variations in the wet-weight data. However, the removal of these fish does make a significant difference in the lipid-normalized results by reducing considerably both the PCB concentrations and the variability in the data in Reaches 5 and 6 (compare Figure 6-7 with Figure 6-5a).

6.3.3.2 Connecticut

The ANSP data from Connecticut were also used to evaluate spatial trends in fish PCB concentrations. Throughout the ANSP program, smallmouth bass have consistently been collected from the most locations and generally have the largest sample sizes (Table 6-5). Thus, the smallmouth bass data were used to assess spatial trends. In general, arithmetic mean PCB concentrations of the smallmouth bass fillets from all four Connecticut stations are less than the mean concentrations of the fillet samples from top-predator species collected in Massachusetts. To evaluate spatial trends within Connecticut, the fillet data for the most recent years (1994 through 2002) were combined. The combined data for the four major locations (West Cornwall, Bulls Bridge, Lake Lillinonah, and Lake Zoar) are presented on both a wet-weight and lipid-normalized basis on Figure 6-8. Both wet-weight and lipid-normalized PCB concentrations in smallmouth bass fillets decline from upstream to downstream. Average wet-weight PCB concentrations at West Cornwall and Bulls Bridge are similar to each other, as are concentrations from Lake Lillinonah and Lake Zoar, but wet-weight concentrations at the two upstream locations are significantly higher than those further downstream. ANSP (2003), using Analysis of Covariance (with location, year and sex as main effects and age and lipid content as covariates) found that Aroclor-based wet-weight PCB concentrations in smallmouth bass at West Cornwall and Bulls Bridge were not significantly different from one another ($\alpha = 0.05$), but were higher than those at Lake Lillinonah, which in turn were significantly higher than those at Lake Zoar.

6.3.4 Temporal Trends

This section presents temporal trend analyses of the fish PCB data for the Massachusetts and Connecticut portions of the River. The objective of the trend analyses is to evaluate evidence for long-term changes over time in the exposure of Housatonic River fish to PCBs. Similar to the spatial trend analyses, the temporal trend analyses are presented for wet-weight and lipid-normalized PCB concentrations.

6.3.4.1 Massachusetts

For adult fish, the existing fish tissue database for the Massachusetts portion of the Rest of River includes very few instances in which the same species have been collected from the same location in multiple years. Even when such data exist, the sample sizes are frequently too small (e.g., as small as one sample) for analyzing temporal trends, and/or the data are confounded by differences in tissue preparation (i.e., skin-on vs. skin-off fillets). As such, it is not possible to provide a meaningful temporal trend analyses for adult fish from Massachusetts.

The YOY fish data collected by GE biannually provide a database of relatively consistent sampling locations, target species, analytical methods, and moderate sample sizes. The YOY PCB data are summarized in Table 6-4 and presented on Figure 6-6a (wet-weight) and Figure 6-6b (lipid-normalized). Over the period from 1994 to 2002, no overall consistent trends can be discerned in average PCB concentrations in YOY fish from Massachusetts, either on a wet-weight or on a lipid-normalized basis (Figures 6-6a, 6-6b). However, temporal trends are difficult to discern over such relatively short periods due to year-to-year variability in River conditions and changes in specific sampling areas due to the changing availability of fish for collection. Because of the relationships among body size and growth dilution and diet (e.g., diet content shifts as fish grow), year-to-year variation in the body size of the YOY fish may affect PCB concentrations.

6.3.4.2 Connecticut

The most useful data for evaluating temporal trends in the Connecticut portion of the River are the CDEP and ANSP Connecticut fillet data for smallmouth bass and brown trout. These data are available from many years (from 1977 to 2002), and for smallmouth bass, these data include several different locations (West Cornwall, Bulls Bridge, Lake Lillinonah, and Lake Zoar). The PCB data are presented in Table 6-5. The smallmouth bass data are summarized on Figure 6-9a (wet-weight) and Figure 6-9b (lipid-normalized), and the brown trout data are summarized on Figure 6-10 (wet-weight and lipid-normalized).

Average wet-weight PCB concentrations have declined in Connecticut since the late 1970s (Figures 6-9a and 6-10). Lipid data are not available for the pre-1982 samples to evaluate whether the same is true on a lipid-normalized basis. Since 1984, when ANSP began its biennial monitoring program, the data show that concentrations from 1984 through 1992 are generally higher than those from 1994 through 2002. Although there is considerable year-to-year variability, that overall pattern can be seen generally in both the wet-weight and the lipid-normalized data (Figures 6-9a, 6-9b, and 6-10). As stated in the most recent ANSP report (ANSP, 2003), overall PCB concentrations in smallmouth bass and brown trout in 2000 and 2002, in terms of both Aroclor-based and congener-based total PCBs, were similar to each other, similar to or lower than those in 1994-1998, and well below the levels found in 1992 and most prior years. For smallmouth bass, statistical analysis showed that the mean Aroclor-based PCB concentrations in 2000 and 2002 were not significantly different from each other but were significantly lower than those for 1984-1998 in the overall dataset and significantly lower than those for 1984-1992 at every station (ANSP, 2003). For brown trout, statistical analysis showed that the mean Aroclor-based PCB concentrations in 1994-2002 were not significantly different from each other but were significantly lower than those in

1984-1992 (ANSP, 2003). For both species, the congener-based PCB data showed a generally similar pattern of lower mean concentrations in the most recent years (2000-2002) (ANSP, 2003).

6.3.5 Fish PCB Composition

Since the fish collected by EPA in 1998 were analyzed for PCB congeners, they allow a determination of homolog patterns. PCB homolog patterns for several fish species (pumpkinseed, yellow perch, largemouth bass, and brown bullhead) collected by EPA in 1998 from Reach 5 (Confluence to Woods Pond) and Reach 6 (Woods Pond) are presented on Figure 6-11. These data indicate a pattern centered on the dominance of homolog 6 (hexachlorobiphenyl), which is indicative of higher-chlorinated PCB mixtures (i.e., Aroclors 1260 and 1254). Homolog patterns are similar among species and reaches.

The presence of these Aroclors is confirmed by an analysis of Aroclor composition of the PCB data available from GE's YOY fish samples, as presented on Figure 6-12. As shown on that figure, Aroclors 1254 and 1260 were the only quantified Aroclor fractions in these fish samples. In Reaches 5 and 6, Aroclor 1260 is predominant (60% to 70%), and the remainder was quantified as Aroclor 1254

This pattern in fish Aroclor distribution is consistent with the majority of surface water and sediment data for the River. This pattern is also consistent with the ANSP Aroclor-based fish PCB data for Connecticut, which is approximately 70% to 80% Aroclor 1260 (ANSP, 2001).

6.3.6 Other Constituents

Although most of the available fish data for the Housatonic River are for PCBs, data also exist for other chemical constituents (PCDDs/PCDFs, pesticides, and metals) in fish tissue. Tables showing frequencies of detection and summary information on concentrations of these non-PCB constituents in fish tissue are included in Appendix C (Tables C-31 through C-33).

As discussed in Section 2.6, EPA has advised GE that, based on its human health and ecological screening evaluations, the non-PCB constituents, other than potentially PCDDs/PCDFs, are not key constituents of concern in the Rest of River. As a result, this section does not provide a detailed discussion of the extent of these constituents in fish tissue. Rather, it includes a limited discussion of PCDD/PCDF compounds in fish, and also, for completeness, an even more limited discussion of other non-PCB constituents.

PCDD/PCDF data are available from the 1982 Stewart study (four fish from Massachusetts and two fish from Connecticut) and from the EPA 1998 sampling (see Table C-31 for data). For the 1998 dataset, several congeners were detected in the fish tissue samples; the four congeners that were most commonly detected were all furans -- 1,2,3,4,6,7,8-HpCDF, 1,2,3,7,8-PeCDF, 2,3,4,7,8-PeCDF, and 2,3,7,8-TCDF. These congeners were detected in most of the fish tissue samples. In general, the highest PCDF concentrations were detected in offal and whole-body fish samples, with lower concentrations detected in fillet samples. For fillets, yellow perch and brown bullhead frequently exhibited the highest concentrations.

To evaluate these data further, TEQ values were calculated for each of the samples using the PCDD/PCDF mammalian TEFs published by the WHO (van den Berg et al., 1998) and representing non-detected compounds as one-half the analytical detection limit. TEQ values calculated for samples collected by EPA during 1998 and 1999 are summarized in Table 6-6. TEQ concentrations vary by species, sample type, and reach. Arithmetic mean TEQ values are generally highest in samples from Reach 6 (Woods Pond) and decrease in downstream samples.

With respect to other non-PCB constituents, pesticides were detected in some of EPA's 1998 and 1999 fish samples, with the most frequent detections and highest concentrations found for 4,4'-DDE, o,p'-DDD, and o,p'-DDT (Table C-32). Select metals (arsenic, lead, mercury, and nickel) were also analyzed for in a subset of EPA's 1999 largemouth bass samples. Arsenic, lead, and nickel were detected infrequently and at low concentrations, while mercury was detected in all of the samples (Table C-33).

6.4 Data on Other Biota

This section summarizes the analytical data for non-fish biota collected from the Rest of River area, including reptiles and amphibians, aquatic and terrestrial invertebrates, aquatic and terrestrial vegetation, aquatic microorganisms, birds, and small mammals. This section focuses primarily on the PCB data (Aroclors and congeners), but data for other constituents, including PCDDs/PCDFs, pesticides, metals, and polycyclic aromatic hydrocarbons (PAHs), are presented in summary form. Most of the non-fish biota data are from samples collected between the Confluence and Woods Pond, with exceptions including the older data from Stewart and the benthic invertebrate data from Connecticut. Complete listings of analytical data are presented in a series of tables. The non-fish biota PCB data are presented in Tables 6-7 through 6-18, and the non-PCB data for non-fish biota are summarized in Tables C-34 through C-58 included in Appendix C.

6.4.1 Reptiles and Amphibians

Housatonic River PCB data for reptiles and amphibians include data for frogs and snapping turtles. Early frog data include a single 12-frog composite sample collected from Woods Pond in 1982 by Stewart and three 7-frog composite samples collected from Woods Pond in 1992 by BBL on GE's behalf. More recently, EPA collected frogs from Reach 5 (upstream of Woods Pond) and Reach 6 (Woods Pond) in 1998, 1999, and 2000, and GE consultants collected wood frog larvae in 2001. These recent samples consist of whole-body preparations as well as ovary, leg and offal (rest of carcass) preparations. The PCB data for the frog samples are presented in Table 6-7.

PCBs were detected in each of the frog samples. In the earlier datasets from Woods Pond, total PCB concentrations were 4.4 mg/kg in a single whole bullfrog composite sample (1982 Stewart data) and 2.2, 4.4, and 5.3 mg/kg in the three bullfrog leg muscle samples (1992 BBL data). A single bullfrog sampled from Reach 5 in 1998 (EPA) had a whole-body total PCB concentration of 7.7 mg/kg. Whole-body leopard frog composite samples had an arithmetic mean of 2.3 mg/kg and ranged from 0.16 to 5.4 mg/kg, while a single whole body female had a PCB concentration of 1.2 mg/kg in Reach 5 (2000 EPA data). In this same data set, the arithmetic mean PCB concentration in female leopard frog whole bodies with ovaries removed was 0.83 mg/kg, while PCB concentrations in ovary tissue and egg masses averaged 7.8 mg/kg and 0.86 mg/kg, respectively. A single leopard frog tadpole analyzed from Reach 5 had a PCB concentration of 0.68 mg/kg. Bullfrog leg tissue samples in Reaches 5 and 6 (from EPA's 1998 and 1999 collections) had average PCB concentrations ranging from 0.56 mg/kg to 0.87 mg/kg. Bullfrog offal (carcass without the leg muscle) average PCB concentrations ranged from 4.9 to 7.0 mg/kg in Reaches 5 and 6.

Data collected by EPA as part of its 2000 frog reproductive study indicate that PCBs are present in various developmental stages of wood frogs, with arithmetic mean total PCB concentrations ranging up to 2.4 mg/kg (Table 6-7). As part of an ecological study, hatchling and larval wood frogs collected by GE consultants in 2001 from various floodplain ponds between the Confluence and New Lenox Road were composited (by pond) and analyzed for PCBs. The results showed total PCB concentrations in individual samples ranging from 0.27 mg/kg to 11.2 mg/kg, depending on the pond and life stage of the larvae.

A subset of the 1998 and 1999 bullfrog samples was analyzed for PCDDs/PCDFs and pesticides, and a subset of EPA's 2000 wood frog samples was analyzed for PCDDs/PCDFs, pesticides, PAHs, and metals. Only a few PCDD/PCDF congeners were detected in the frog samples (Table C-34). Several pesticides were also detected in the frog tissue samples, with concentrations less than 0.005 mg/kg (Table C-35). Metals (Table C-36) and PAHs (Table C-37) were also detected in each of the frog samples.

The only turtle data available for the Housatonic River are data from a single snapping turtle collected from Woods Pond in 1982. The total PCB concentration in this sample was 2.1 mg/kg (Table 6-7).

6.4.2 Aquatic Invertebrates

Data for aquatic invertebrates include crayfish and benthic macroinvertebrates collected by EPA in Reaches 5 and 6 in 1999 and aquatic insects collected periodically by CDEP and ANSP at West Cornwall, Connecticut from 1978 to 2002. In the EPA program, benthic macroinvertebrates were composited by functional feeding groups (Weston, 2000). In EPA's tissue analytical results database, these are presented as shredders and predators. Predators are represented by various larval insect taxa, while shredders include other detritivorous insects and may include other taxa such as snails (Weston, 2000a). The samples from EPA were analyzed for PCB congeners while a subset was evaluated for pesticides and PCDDs/PCDFs. In the CDEP/ANSP program, caddisfly, stonefly, and hellgrammite (dobsonfly) larvae have been collected; caddisflies are classified as filter feeders while stoneflies and hellgrammites are classified as predators. These samples have been analyzed for PCBs as Aroclors and (beginning in 1994) as congeners; values reported here are Aroclor-based. In addition, in 1992, ANSP collected two crayfish samples from the Housatonic River at West Cornwall, Connecticut (one whole body tissue composite and one egg composite); these were analyzed for total congener PCBs. The results from these programs are summarized below.

A total of 40 crayfish samples were collected from four locations in Reach 5 by EPA in 1999 (see results in Table 6-8). The average total PCB concentration for these crayfish samples is 12 mg/kg. These crayfish samples were also analyzed for pesticides, and a subset of the samples was analyzed for PCDDs/PCDFs. Several PCDD/PCDF congeners were detected in these samples (Table C-38), as were several pesticides (Table C-39).

In 1999, EPA collected eight samples of benthic macroinvertebrates from Reach 5 and one sample from Woods Pond, near its headwaters. These were sorted by taxa into composite functional groups of shredders and predators (Weston, 2000). (One predator sample was lost prior to analysis; Weston 2002.) PCBs were detected in each of the samples, with PCB concentrations ranging from 2.2 mg/kg to 47.6 mg/kg (Table 6-9). Mean total PCB concentrations for the predators and shredders were: a) 19.4 and 13.1 mg/kg, respectively for Reach 5; and b) 14.3 and 2.29 mg/kg for Reach 6, respectively (Table 6-9). Several of the benthic macroinvertebrate samples collected by EPA were also analyzed for pesticides and/or PCDDs/PCDFs. A total of four furan congeners were detected, at concentrations less than 0.06 μg/kg (Table C-40). Twenty two other Appendix IX compounds were also detected at frequencies of 7 to 100% (Table C-41).

The total PCB concentrations found in EPA's samples of aquatic invertebrates in Reaches 5 and 6 are summarized by group (crayfish, predators, and shredders) and approximate River mile in Figure 6-13. These data are summarized on both a wet-weight basis and on a lipid-normalized basis. In these reaches, the aquatic invertebrates generally exhibit higher PCB concentrations, on a wet-weight basis, at and above the WWTP (RM 130) than below RM 130 (Figure 6-13, top panel), with one notable exception – a high wet-weight PCB concentration in the single predator sample at RM 126. The latter may have been determined by its similarly high lipid content (11.7% compared with an average of 0.63% for all other predator samples). The same pattern is observed when PCB concentrations are expressed on a lipid basis, although the upstream/downstream differences are attenuated (Figure 6-13, bottom panel). Again, there is one notable exception – in this case, the exceptionally high lipid-based PCB concentration for the shredder sample at RM 126. The latter may have been determined by the very low lipid value in this sample (0.10% compared with an average of 0.80% for all other shredder samples).

As noted above, aquatic insects [caddisfly, stonefly, and hellgrammite (dobsonfly) larvae] have also been collected from the Connecticut portion of the Housatonic River by CDEP and ANSP. These samples have been collected at West Cornwall since 1978, generally on a biannual basis, and analyzed for PCBs. The results are presented in Table 6-9 and illustrated on Figure 6-14. (Note that in the ANSP program, PCB concentrations for the hellgrammite and stonefly samples are presented separately in recent years and are also averaged together to provide values for predators for comparison to the earlier years in which they were not presented separately.) For most of the Connecticut data, PCB concentrations are highest in hellgrammite samples, followed by caddisfly larvae and stonefly nymphs. For example, in 2002 PCB concentrations were 0.94, 0.58, and 0.46 mg/kg for hellgrammite, caddisfly, and stonefly samples, respectively (Table 6-9). The total PCB concentrations reported for these samples since 1994 are much lower than those detected in upstream samples collected by EPA. For example, PCB concentrations for predatory benthic macroinvertebrates in Reach 5 averaged 19.4 mg/kg and a single sample in Woods Pond had a value of 14.3 mg/kg (EPA 1999 data), compared with concentrations of 1.17 mg/kg in 2001 and 0.82 mg/kg in 2002 at West Cornwall (Table 6-9).

As shown on Figure 6-14, the long-term monitoring of benthic insects at West Cornwall indicates that total PCB concentrations have decreased substantially from 1978 to 2002 for both filter feeders (caddisflies) and predators (hellgrammites and stoneflies). As indicated in the most recent ANSP report (ANSP, 2003), PCB concentrations in both groups of insects in 2001 and 2002 were similar to each other, lower than those in 1994-1998, considerably lower than those from pre-1994 sampling, and among the lowest observed since the monitoring program began.

Finally, it should be noted that the single whole body crayfish sample collected by ANSP in 1992 from West Cornwall had a total PCB concentration of 1.02 mg/kg. This is considerably lower than the average PCB concentration of 12 mg/kg in the crayfish collected by EPA from Reach 5 in 1999.

6.4.3 Terrestrial Invertebrates

In 2000, EPA collected 30 composite earthworm samples from three plots adjacent to and upstream of Woods Pond. The earthworms were analyzed for PCB congeners, select organochlorine pesticides, and PCDDs/PCDFs. PCBs were detected in each of the earthworm samples, with concentrations ranging from 1.1 mg/kg to 26.7 mg/kg (Table 6-10). PCDDs/PCDFs were detected infrequently in earthworms, and the only detected dioxin/furan congener was OCDD (Table C-42). Several pesticides were also detected in the earthworm samples (Table C-43).

In 2000, seven samples of soil litter invertebrates were collected from Reach 5 and analyzed for PCBs. PCBs were detected in each of the samples, and concentrations ranged from 1.4 mg/kg to 4.9 mg/kg (Table 6-10).

6.4.4 Plankton

Plankton (phytoplankton and zooplankton) samples were collected by EPA in 2000 from Reaches 5 and 6 (Table 6-11). Sampling was performed through sequential filtering of pumped water samples. The zooplankton fraction was considered as the material retained on 560-μm and 153-μm mesh nets, while the phytoplankton fraction was that fraction retained on 63-μm and 10-μm mesh nets. For the few samples of each that were collected (four from Reach 5 and one from Reach 6), average total PCB concentrations were higher in the zooplankton samples than in the phytoplankton samples (Table 6-11). For example, average PCB concentrations in Reach 5 were 2.66 mg/kg for phytoplankton and 11.9 mg/kg for zooplankton. Spatially, average total PCB concentrations were higher in Reach 5 than in Reach 6. In addition, PCDDs/PCDFs were detected infrequently in the zooplankton samples from Reach 5 (Table C-44). Pesticides were also detected in the zooplankton samples (Table C-45).

6.4.5 Aquatic Vegetation

Several types of aquatic vegetation have been collected from the Housatonic River, including periphyton, duck potato, water milfoil, lesser duckweed, and algae. Duck potato was collected from Reaches 5, 7, and 9 in 1980. The results are presented in Table 6-12. As shown in that table, the highest total PCB concentration is found in the sample from Reach 5 (0.84 mg/kg). PCB concentrations were lower in samples collected from Reach 7 (0.20 mg/kg and 0.42 mg/kg) and Reach 9 (0.22 mg/kg). Total PCB concentrations for the 10 composite samples of duckweed and water milfoil collected from Reach 6 in 1980 were higher than the duck potato samples, and range from 0.93 mg/kg to 3.9 mg/kg, with an average concentration of 2.3 mg/kg (Table 6-12).

Samples collected by EPA in 2000 included detritus, filamentous algae, macrophytes, and periphyton (filtered and scraped from macrophytes and substrate) (see Table 6-12). Select samples were analyzed for PCB congeners, organochlorine pesticides, and PCDDs/PCDFs. For the few samples that were collected, total PCB concentrations were generally highest in the periphyton samples and lowest in the algae samples. In terms of spatial patterns, total PCB concentrations were generally highest in Reach 6, except for the algae samples, which were highest in Reach 5.

PCDDs/PCDFs were also detected in the aquatic vegetation samples (Table C-46), as were pesticides (Table C-47).

A single algae sample was collected in 1996 from the Housatonic River (near the former Housatonic Street Bridge abutment). The total PCB concentration in this sample was 22.9 mg/kg (Table 6-12).

Finally, periphyton from hard substrate (rock scraping) was also collected in 1978 from the Housatonic River at three locations in Connecticut. Average total PCB concentrations were highest at the upstream location (Sample Station #1 = 0.59 mg/kg) and decreased downstream (Station #2 = 0.36 mg/kg; Station #3 = 0.05 mg/kg) (Table 6-12).

6.4.6 Terrestrial Vegetation

Terrestrial vegetation samples, including corn, squash, fiddleheads, and grass, were collected by EPA from various locations along the Housatonic River in 1998, 1999, and 2001. Summary statistics for total PCB concentrations are presented in Table 6-13. Samples of squash collected from Reach 5A had the highest total PCB concentration (maximum = 1.2 mg/kg). PCBs were not detected in corn ear samples, but were detected in some stalk samples at estimated (J-qualified) concentrations (maximum = 0.024 mg/kg) (Table 6-13). PCBs were not detected in any of the fiddlehead samples. PCBs were detected in each of the grass samples collected from Reach 5B, with a maximum total PCB concentration of 0.13 mg/kg.

The 10 grass samples collected by EPA from Reach 5B were also analyzed for PCDDs/PCDFs. PCDDs/PCDFs were largely non-detect, although a single congener (OCDD) was detected in two of the samples at estimated (J-qualified) concentrations of 0.0023 and 0.0034 µg/kg, respectively (a duplicate of the latter sample, however, was reported as non-detect). The average concentration for OCDD in grass is 0.00243 µg/kg (Table C-48).

6.4.7 Birds

Bird data for the Housatonic River include the results of EPA studies on waterfowl, tree swallows, and house wrens, as well as data collected by GE consultants for American robins. In 1998, waterfowl (mallard and wood ducks) were collected from Reaches 5 and 6 (see Table 6-14). Samples were prepared as breast muscle tissue and liver tissue. The results for the ducks collected from Reaches 5 and 6 are summarized in Table 6-15 (below).

Table 6-15. Summary of EPA 1998 Duck PCB Sample Data

Species and Sample Type	Range and Mean Total PCBs (mg/kg)	
	Reach 5	Reach 6
Mallard		
Breast	(1.59 - 7.80) 4.99	(11.2 - 19.3) 15.3
Liver	(3.56 - 21.9) 13.5	(10.8 - 16.7) 13.7
Wood Duck		
Breast	(4.75 - 12.2) 7.7	(1.06 - 17.9) 6.1
Liver	(5.19 - 38.5) 11.9	(0.34 - 24.0) 8.0

Notes:

1. Additional summary statistics are provided in Table 6-14.
2. Range is provided in parentheses.

Each of the waterfowl samples collected by EPA was also analyzed for PCDDs/PCDFs and pesticides. Several PCDD/PCDF congeners and several pesticides were detected in the waterfowl samples (see Tables C-49 and C-50, respectively).

An additional duck was collected from the Connecticut portion of the Housatonic River by CDEP in 1999. The single mallard was analyzed for PCBs as both a skin-off sample and a skin-on sample. PCB concentrations were 0.27 mg/kg and 2.1 mg/kg, respectively (Table 6-14).

EPA collected tree swallows (specifically pippers and nestlings) from several locations along Reach 5 of the Housatonic River in 1998, 1999, and 2000. Samples included breast tissue, food samples (GI tract), and eggs (Table 6-16 and Figure 6-15). At each location and each sample year, PCB concentrations were highest in eggs, followed by breast tissue and food samples.

Some of the tree swallow samples were also analyzed for PCDDs/PCDFs, pesticides, PAHs, and/or metals. Several PCDDs/PCDFs were detected in the tree swallow samples collected in 1998, 1999, and 2000 (Table C-51), as were several pesticides (Table C-52). In a subset of the tree swallow samples collected in 1998, several metals were detected in the egg samples and breast tissue samples (Table C-53). Finally, PAHs were detected in some of the 2000 tree swallow breast tissue samples (Table B-54).

EPA collected five house wren eggs from Reach 5 in 1999, and samples were analyzed for PCBs and pesticides. Total PCB concentrations in the house wren eggs ranged from 43.3 mg/kg to 149.4 mg/kg, with an average concentration of 71.9 mg/kg (Table 6-17). Several pesticides were also detected in the house wren eggs (Table C-55).

In 1999, EPA collected three composite samples of chickadee eggs from Reach 5 (Confluence to Woods Pond). Samples were analyzed for PCBs and select organochlorine pesticides. PCBs were detected in each of the egg samples, and concentrations ranged from 17.6 mg/kg to 25.0 mg/kg, with an arithmetic mean of 20.3 mg/kg (Table 6-17). A wide variety of pesticides were also detected in the chickadee eggs (Table C-56).

In 2001, GE consultants collected, for use in an ecological study, American robin nestlings and eggs from Reach 5 (Confluence to Woods Pond). These samples were analyzed for PCBs. Total PCB concentrations in fertilized eggs (arithmetic mean = 83.6 mg/kg) were higher than the concentrations detected in nestlings (arithmetic mean = 11 mg/kg) (Table 6-17). Two additional unfertilized eggs had PCB concentrations of 7.38 and 37.5 mg/kg (Table 6-17).

6.4.8 Small Mammals

In 1999, EPA collected white-footed mice and short-tailed shrews from the floodplain in Reach 5 (between the Confluence and Woods Pond) for PCB analysis. The results show a large range of PCB concentrations. Total PCB concentrations were higher for the shrew samples (range of 4.5 mg/kg to 148 mg/kg, with average of 78 mg/kg) than for the mouse samples (range of 0.15 mg/kg to 35 mg/kg, with average of 5.1 mg/kg) (Table 6-18).

Several PCDD/PCDF congeners were also detected in the small mammal samples (Table C-57), as were several pesticides (Table C-58).

6.5 Consumption Advisories for Fish and Other Biota

Biota consumption advisories have been issued for specific reaches of the Housatonic River in Massachusetts and Connecticut. In Massachusetts, the advisory is based on PCBs, and states that the public should not consume any fish, frogs, and turtles from the River between Pittsfield and the Connecticut border (Massachusetts Department of Public Health [MDPH], 2002). The MDPH has also issued a consumption advisory stating that people should refrain from eating mallards and wood ducks from the Housatonic River and its impoundments from Pittsfield south to Rising Pond in Great Barrington (MDPH, 1999).

For Connecticut, the advisory from the Connecticut Department of Public Health (CDPH) are based on PCBs and mercury. The advisory states that for the area above Derby Dam (which includes Lake Zoar, Lake Lillinonah, Bulls Bridge, and West Cornwall) people should not eat trout, catfish, eels, or carp. For other species, the advisory recommends varying restrictions on consumption, depending on whether the consumers fall into a "high risk group" (pregnant women or women planning to be pregnant, and children under 6 years of age) or a "low risk group (other members of the general public) (CDPH, 2002).

The advisories for the Massachusetts and Connecticut portions of the Housatonic River are available from a variety of sources (e.g., on the internet, pamphlets at sporting license sales agents, posted signs along the River).

6.6 Summary

A relatively large body of data exists for chemical concentrations in biota associated with the Housatonic River. The data include a wide variety of aquatic and terrestrial species, including fish, reptiles and amphibians, aquatic and terrestrial invertebrates, plants, birds, and small mammals. Fish tissue samples comprise the largest biota dataset, represented by numerous species, preparation types, locations, and time periods of sampling, beginning as early as 1977. The biota samples have been analyzed for PCBs, and subsets of the data have also been analyzed for metals, pesticides, and/or PCDDs/PCDFs.

PCBs have been detected in biota representing a variety of trophic levels, including primary producers (e.g., plants and algae), lower trophic level species (e.g., benthic macroinvertebrates, earthworms), and mid to upper trophic level species (e.g., fish, frogs, birds and small mammals). PCB concentrations tend to increase with increasing trophic level. In the terrestrial environment, PCB concentrations generally increase as follows: plants < earthworms < birds and small mammals. PCB concentrations in the aquatic environment follow a similar trend: plants, algae and plankton < benthic invertebrates and frogs < fish.

Fish tissue samples comprise a substantial portion of the PCB biota data. The largest fish tissue sampling effort occurred in 1998, when over 1,000 fish samples were collected by EPA and GE in Massachusetts reaches of the River. These and other recent fish data have been evaluated for patterns of PCB concentrations among different species, size and age ranges, and tissue types. Differences in PCB concentrations between species can be attributed to species-specific factors such as variations in growth rate, lipid content, and feeding and habitat preferences. In very general terms, PCB concentrations are lower in sunfish (bluegill, pumpkinseed), and higher in predatory species (trout and bass) and bottom feeders (bullhead, white sucker), although there is substantial variability in the data among years, locations, and species. With respect to size, PCB concentrations (on a whole body basis) generally increase with size (weight) for some species (such as largemouth bass and yellow perch), but not in others (such as pumpkinseed). For example, for largemouth bass, average whole body PCB concentrations from Woods Pond in 1998 are 32 mg/kg in YOY fish, 49 mg/kg in small adult fish, and 107 mg/kg in large adult fish. With respect to tissue type, PCBs are stored in lipid-rich tissues and thus are found in much higher concentrations in offal (rest of carcass) and ovary samples than in fillets. Whole body values reconstructed from offal and fillet results from large adult fish are approximately an order of magnitude greater than those in the fillet tissue alone. For example, the average fillet tissue concentration from adult largemouth bass in Woods Pond in 1998 was 7 mg/kg, 15-fold less than the calculated whole body average (107 mg/kg).

The datasets for fish and benthic invertebrates are sufficient to evaluate spatial patterns of PCBs. In recent (1998-2002) fish samples, average concentrations for a given species are generally highest in either Reach 5 or Reach 6 (Woods Pond), and lower downstream of Woods Pond Dam. For example, based on the data from 1998, average PCB concentrations in largemouth bass fillets are 23 mg/kg for Reach 5, 6.9 mg/kg for Reach 6, 3.8 mg/kg for Reach 8 (Rising Pond), and 4.9 mg/kg for Reach 9 (Rising Pond to the Connecticut border). Similarly, mean whole body PCB concentrations for largemouth bass YOY data from the latest (2002) GE sampling are 21 mg/kg for Reach 5, 17 mg/kg for Reach 6, 3.5 mg/kg for Reach 7, and 1.9 mg/kg for Reach 9. In Connecticut, the data show a declining trend in fish tissue PCB concentrations from the upstream stations (West Cornwall and Bulls Bridge) to the two downstream stations (Lakes Lillinonah and Zoar). For example, the most recent fillet average PCB concentrations (2002 Aroclor-based data) for smallmouth bass are 1.1 mg/kg at West Cornwall, 0.77 mg/kg at Bulls Bridge, 0.36 mg/kg at Lake Lillinonah, and 0.35 mg/kg for Lake Zoar.

In benthic aquatic invertebrates, PCB concentrations are typically higher in predatory species (e.g., hellgrammites and stonefly nymphs) than in other types of species (e.g., caddisflies), and are considerably higher in Reaches 5 and 6 than in Connecticut. Based on 1999 EPA data, the mean total PCB concentration for benthic predator species in Reach 5 is 19 mg/kg. In general, PCB concentrations in aquatic insects in that reach tend to be higher upstream than downstream of the Pittsfield WWTP. In Connecticut, predatory benthic insect PCB concentrations are up to 20-fold lower than those in Reach 5, with recent values of 1.2 mg/kg in 2001 and 0.8 mg/kg in 2002.

With respect to temporal trends, while the recent fish data collections in Massachusetts reaches have been extensive, prior adult fish tissue datasets are sparse, used different sampling and analytical techniques, and/or had varied or uncertain locations, thus precluding reliable comparisons with the recent fish data. Samples of selected YOY species collected from four Massachusetts reaches since 1994 (5 sampling periods to date) as part of the GE's biennial YOY sampling program show no discernible or consistent temporal trends in PCB concentrations over this period.

In Connecticut, where a consistent biennial sampling program has been conducted by ANSP since 1984, there have been significant temporal declines in fish fillet tissue PCB concentrations. The most recent data (2000-2002) show fish tissue PCB concentrations that are similar to or lower than those from 1994-1998 and well below those found in 1992 and prior years. For example, at West Cornwall, arithmetic mean smallmouth bass PCB concentrations have declined from 3.7 mg/kg in 1992 to 1.1 mg/kg in 2002.

A similar significant decline in PCB concentrations has been observed in the benthic insect sampling program at West Cornwall, which is the only long-term monitoring program for non-fish biota in the Housatonic River. PCB concentrations in benthic insects at this station in 2001 and 2002 are somewhat lower than those from 1994-1998 and considerably lower than those from prior years. For example, in 1978, filter feeder (caddisfly) and predator (hellgrammite and stonefly) benthic insect PCB concentrations were 20 and 23 mg/kg, respectively. In 1992, these concentrations declined to 5 mg/kg in both groups. In 2002, filter feeder and predator PCB concentrations were 0.6 and 0.8 mg/kg, respectively.

With respect to other biota, recent (since 1998) PCB concentrations in plant tissues sampled from areas within Reaches 5 and 6 range from non-detect in corn ears to an average of 0.1 mg/kg in grass and an average of 1.2 mg/kg in aquatic macrophytes. Concentrations in animal tissues include, for example, average breast tissue PCB concentrations of 15 mg/kg in mallards and 6 mg/kg in wood ducks from Woods Pond, 72 mg/kg in house wren eggs, and 78 mg/kg in shrews. A single skin-off mallard tissue sample from the Connecticut portion of the Housatonic River had a PCB concentration of 0.3 mg/kg, approximately 50-fold lower than the average concentration in Woods Pond.

Consumption advisories for eating fish and wildlife (e.g., ducks, frogs) currently exist for the Massachusetts and Connecticut portions of the Housatonic River. In Massachusetts, the PCB-based advisory states that the public should not consume any fish, frogs, or turtles taken from the River between Pittsfield and the border with Connecticut nor should anyone consume ducks taken between Pittsfield and Great Barrington. In Connecticut, advisories state that trout, catfish, eels, and carp should not be consumed; for other game species, restrictions vary depending on the human risk group.

Section 6 Tables

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Table 6-1
Summary of Fish Sampling Activities/Investigations

Study/Investigation Description	Year	Total Number of Samples	Analytical Parameters	Reference
Massachusetts Fish Sample Collection				
Stewart Laboratories - 8 locations along 70-mile stretch from the headwater of Center Pond in Dalton to the Massachusetts/Connecticut state line. Primary species were bass, trout, yellow perch, sunfish, chain pickerel, brown bullhead, crappie, and rock bass.	1980	14 scale-off, skin-on fillet composites	PCB-Aroclors, Percent Lipids, and PCDDs/PCDFs	(Stewart ,1982)
	1982	21 scale-off, skin-on fillet composites; 4 individual scale-off, skin-on fillets		
GE/BBL MCP Phase II Fish Sampling - 2 locations (Woods Pond, Rising Pond), target species were largemouth bass, brown trout, and yellow perch.	1990	28 individual scale-off, skin-on fillets	PCB-Aroclors, Percent Lipids, and PCDDs/PCDFs	(Blasland & Bouck, 1991)
GE/BBL YOY Fish Sampling - 3 to 4 locations (HR2-near New Lenox Road, Woods Pond, Glendale Impoundment, and HR6-near Connecticut border), target species were largemouth bass, yellow perch, bluegill/pumpkinseed.	1994	63 whole body	PCB-Aroclors, Percent Lipids	(BBL, 2000)
	1996	84 whole body		
	1998	90 whole body		
	2000	85 whole body		
	2002	66 whole body		
GE/BBL Tributary Fish Sampling - 3 locations (Green River, Williams River, and Laurel Lake), target species were bass and trout.	1995	13 skin-on/scales-off fillet samples	PCB-Aroclors, Percent Lipids	(BBL, 1996)
MCP Supplemental Phase II Fish Sampling - 3 locations (Rising Pond, HR6-near Connecticut border, and West Branch Confluence to WWTP), target species were bluntnose minnows, brown bullhead, yellow bullhead, yellow perch, pumpkinseed, and largemouth bass.	1998	3 whole-body individuals; 10 whole-body composites; 49 skin-off fillet individuals	PCB-Aroclors, Percent Lipids	(BBL, 1996)
GE/ARCADIS Fish Sampling - 1 location in the Housatonic River and Three Mile Pond. Target species was largemouth bass.	1999	5 whole body	PCB-Aroclors, Percent Lipids	GE Monthly Status Report
EPA/USFWS Fish Sampling - 6 locations (East Branch Upstream of Newell Street, Confluence to Woods Pond, Woods Pond, Woods Pond to Rising Pond, West Branch Housatonic, and Three Mile Pond), target species included bluegill, bluntnose minnow, brown bullhead, common shiner, fallfish, golden shiner, goldfish, largemouth bass, pumpkinseed, smallmouth bass, yellow bullhead, and yellow perch. Samples included skin-off fillets, offal, whole body individuals, and composites.	1998	84 whole-body composites; 282 skin-off fillets; 282 offal samples; 92 whole-body individuals	PCB-Congeners, Pesticides, PCDDs/PCDFs, Metals, Percent Lipids	Weston/EPA November, 2002 database
	1999	3 whole-body composites, 12 ovary; 12 offal samples		
	2000	66 whole-body individual		
GE/BBL Fish Sampling - 2 locations in the Housatonic River (Pittsfield WWTP to Roaring Brook and Woods Pond). Target species was largemouth bass.	2002	30 fish were analyzed as skin-off fillet and offal	PCB-Congeners, Percent Lipids	GE Monthly Status Report

Table 6-1
Summary of Fish Sampling Activities/Investigations

Study/Investigation Description	Year	Total Number of Samples	Analytical Parameters	Reference
Connecticut Fish Sample Collection				
Connecticut Department of Environmental Protection (CDEP) - locations (Falls Village, West Cornwall, Bulls Bridge, Lake Lillinonah, Lake Zoar, Lake Housatonic, and below Derby Dam). Target species varied, and included trout, sunfish, bass, catfish, white perch, yellow perch, black crappie, white sucker, and American eel.	1976	3	PCB-Aroclors, Percent Lipids	CDEP Data Sheets
	1977	63		
	1978	18		
	1979	476		
	1982	4		
	1983	125		
Academy of Natural Sciences Fish Sampling - 4 primary locations (West Cornwall, Bulls Bridge, Lake Lillinonah, and Lake Zoar) and Falls Village. Target species included brown bullhead, sunfish sp., trout sp., carp, largemouth bass, white perch, yellow perch. Samples were processed as skin-on or skin-off fillets for individuals or composites.	1984	283	PCB-Aroclors, PCB-Congeners, Percent Lipids	ANSP Data Sheets
	1985	6		
	1986	152		
	1988	290		
	1990	192		
	1992	146		
	1994	77		
	1996	46		
	1998	78		
	2000	90		
	2002	70		

Table 6-2
Summary of Non-Fish Sampling Activities/Investigations

Year	Species	Description	No. of Samples	Analytical Parameters	Reference
Reptiles/Amphibians					
1982	Turtle	Stewart collected one snapping turtle from Woods Pond.	1 individual	Total PCBs and Percent Lipids	(Stewart, 1982)
1982	Frogs	Stewart collected bullfrogs from Woods Pond.	1 composite of 12 individuals	Total PCBs and Percent Lipids	(Stewart, 1982)
1992	Frogs	BBL collected bullfrogs from Woods Pond.	3 composites of 7 individuals each	Total PCBs and Percent Lipids	(Blasland & Bouck, 1991)
1998	Frogs	EPA collected one bullfrog sample from the Headwaters of Woods Pond.	1 individual whole body	PCB Congeners, Percent Lipids, Select OC Pesticides, and PCDDs/PCDFs	EPA/Weston November, 2002 database
1999	Frogs	EPA collected bullfrogs from between the Confluence to Woods Pond; upstream of Roaring Brook; within the first three major backwater areas upstream of Woods Pond; Woods Pond; a reference area.	28 legs, 30 individual offals	PCB Congeners, Percent Lipids, Select OC Pesticides, and PCDDs/PCDFs	EPA/Weston November, 2002 database
2000	Frogs	EPA collected various developmental stages of wood frogs and leopard frogs from several locations: Confluence to Woods Pond; upstream of Roaring Brook; and a reference area.	40 egg composites, 23 ovaries, 10 composites, 34 whole bodies, 7 offals	PCB Congeners, Percent Lipids, Select OC Pesticides, and PCDDs/PCDFs	EPA/Weston November, 2002 database
2001	Frogs	ARCADIS collected wood frogs from Reach 5 as part of a reproductive study.	9 composite	PCB Congeners and Percent Lipids	GE Monthly Status Report

Table 6-2
Summary of Non-Fish Sampling Activities/Investigations

Year	Species	Description	No. of Samples	Analytical Parameters	Reference
Aquatic Invertebrates					
1978	Benthic Invertebrates	CDEP collected caddisfly and stonefly larvae from various locations (CDEP Sample Stations #1, #2, and #3).	5 composite	Total PCBs	CDEP Data Sheets
1978 - 1990	Benthic Invertebrates	CDEP collected caddisfly larvae, hellgrammite larvae, and stonefly nymphs from West Cornwall, CT.	22 composite	Total PCBs and Aroclors	CDEP Data Sheets
1992 - 2001	Benthic Invertebrates	ANSP collected caddisfly larvae, hellgrammite larvae, and stonefly nymphs from West Cornwall, CT.	28 composite	PCB Congeners	ANSP Data Sheets
1999	Benthic Invertebrates	EPA collected and composited samples of "shredders" and "predators" from the East Branch of the Housatonic River upstream of Newell Street, Reach 5 (Woods Pond headwaters) the West Branch, and a reference area.	21 composite	PCB Congeners, Percent Lipids, Select OC Pesticides, and PCDDs/PCDFs	EPA/Weston November, 2002 database
2000	Benthic Invertebrates	EPA collected caddisfly larvae from the East Branch of the Housatonic River between Lyman and Newell Streets.	2 composite	PCB Congeners, Percent Lipids, and Select OC Pesticides	EPA/Weston November, 2002 database
1992	Crayfish	ANSP collected adult female crayfish from West Cornwall, CT and two tributaries and analyzed whole tissue and eggs separately.	5 composite	Total PCBs	ANSP Data Sheets
1999	Crayfish	EPA collected crayfish from the Housatonic River West Branch, Reach 5, and a reference area.	60 individual whole body	PCB Congeners, Percent Lipids, Select OC Pesticides, and PCDDs/PCDFs	EPA/Weston November, 2002 database
Terrestrial Invertebrates					
2000	Soil Invertebrates	EPA collected soil litter invertebrates from 3 plots from the Confluence to Woods Pond.	7 composite	PCB Congeners, Percent Lipids, and Select OC Pesticides	EPA/Weston November, 2002 database
2000	Earthworms	EPA collected earthworms from 3 plots from the Confluence to Woods Pond.	30 composite	PCB Congeners, Percent Lipids, Select OC Pesticides, and PCDDs/PCDFs	EPA/Weston November, 2002 database

Table 6-2
Summary of Non-Fish Sampling Activities/Investigations

Year	Species	Description	No. of Samples	Analytical Parameters	Reference
Plankton					
2000	Zooplankton and phytoplankton	EPA collected samples from the West Branch, upstream of Woods Pond and Woods Pond.	7 phytoplankton and 6 zooplankton	Total PCBs, PCDDs/PCDFs, and OC pesticides	EPA/Weston November, 2002 database
Aquatic Vegetation					
1978	Periphyton	CDEP collected rock scrapings from various locations along the Housatonic River (CDEP Sample Stations #1, #2, and #3).	3 composite	Total PCBs	CDEP Data Sheets
1980	Aquatic macrophytes	Stewart collected duck potato, water milfoil, and lesser duckweed from numerous areas along the Housatonic River.	15 grab	Total PCBs	(Stewart, 1982)
1996	Algae	BBL collected one algae sample from the Housatonic River, near the former Housatonic Street bridge abutment.	1 composite	Total PCBs	(BBL, 1996)
2000	Periphyton, detritus, macrophytes, algae	EPA collected samples from several areas from Lyman St. Bridge up to and including Woods Pond.	13 periphyton, 8 detritus, 17 macrophyte, 4 algae	Total PCBs, PCDDs/PCDFs, and OC Pesticides	EPA/Weston November, 2002 database
Terrestrial Vegetation					
1998 - 2001	Corn, squash, fiddleheads, grass	EPA collected samples from agricultural fields and other areas along the Housatonic River at the Confluence of the West and East Branches, upstream of the Wastewater Treatment Plant (WWTP), and the East Branch upstream of Newell Street.	53 composite	Total PCBs and Aroclors	EPA/Weston November, 2002 database

Table 6-2
Summary of Non-Fish Sampling Activities/Investigations

Year	Species	Description	No. of Samples	Analytical Parameters	Reference
Birds					
1998	Waterfowl	EPA collected mallards and wood ducks from Woods Pond, the Housatonic River near its Confluence with Woods Pond, and Three Mile Pond, which was used as a reference area. Ducks were processed as breast and liver tissue samples.	90 tissue	PCB Congeners, Percent Lipids, Select OC Pesticides, and PCDDs/PCDFs	EPA/Weston November, 2002 database
1998 - 2000	Tree swallow	EPA collected pippers and nestlings from swallow boxes along the West Branch, near the Confluence with Woods Pond and Three Mile Pond, which was used as a reference area. Swallows were processed as breast tissue and food samples were collected from the swallows' stomachs. Eggs were also collected.	84 breast tissue, 216 eggs, 22 composite food	PCB Congeners, Percent Lipids, Select OC Pesticides, PCDDs/PCDFs, and Metals	EPA/Weston November, 2002 database
1999	House wren	EPA collected eggs from nest boxes along the Housatonic River near its Confluence with Woods Pond.	5 eggs	PCB Congeners, Select OC Pesticides, and Percent Lipids	EPA/Weston November, 2002 database
1999	Mallard	CDEP collected one mallard from the Housatonic River (near Newtown, CT) and analyzed one skin-on breast tissue sample and one skin-off breast tissue sample.	1 individual, 2 samples	Total PCBs and p,p'-DDE	Environmental Research Institute data sheet
1999	Chickadee	EPA collected eggs from the Confluence to Woods Pond.	3 egg samples	PCB Congeners, Select OC Pesticides, and Percent Lipids	EPA/Weston November, 2002 database
2001	American robin	ARCADIS collected eggs and nestlings from the Confluence to Woods Pond and a reference location.	13 eggs and 17 nestlings	PCB Congeners and Percent Lipids	GE Monthly Status Report
Small Mammals					
1999	Small mammals	EPA collected short-tailed shrews and white-footed mice from the Confluence to Woods Pond.	52 mice and 24 shrews	PCB Congeners, Percent Lipids, Select OC Pesticides, PCDDs/PCDFs, and Metals	EPA/Weston November, 2002 database

Table 6-3
Total PCB Data Summary Table for Adult Fish from Massachusetts

Sample Location / Sample Year / Species	Tissue Type[1]	Number of Samples[2]	Average Length[3] (cm)	Average Weight (grams)	Average Lipid (%)	PCB Concentration (mg/kg) Range			Arithmetic Mean	Median	Standard Error
Reach 5 - Housatonic River - Confluence to Woods Pond											
1980[a]											
Yellow perch	Fillet (b)	1	20.8	1147	0.37	--	-	--	3.3	--	--
1982[a]											
Bass	Fillet (b)	1	17.7	125	0.22	--	-	--	4.2	--	--
Brown bullhead	Fillet (b)	1	24.2	195	0.49	--	-	--	12.0	--	--
Chain pickerel	Fillet (b)	1	36.5	377	0.22	--	-	--	3.7	--	--
Sunfish	Fillet (b)	1	13.8	63.4	0.18	--	-	--	2.2	--	--
Yellow perch	Fillet (b)	1	25.9	221	0.26	--	-	--	5.6	--	--
1998[b]											
Bluegill	Fillet (a)	1	16.5	80.0	0.15	--	-	--	5.5	--	--
Bluegill	Offal	1	16.5	80.0	4.3	--	-	--	156	--	--
Bluegill	Whole (calc)	1	16.5	80.0	2.7	--	-	--	99	--	--
Brown bullhead	Fillet (a)	18	26.5	234	0.72	0.41	-	20.3	5.6	3.4	1.19
Brown bullhead	Offal	18	26.5	234	3.5	9.0	-	135	46.6	39.5	7.01
Brown bullhead	Whole (calc)	18	26.5	234	2.7	7.2	-	104	35.7	31.1	5.40
Brown bullhead	Whole	2	19.3	73.3	1.1	20.9	-	22.4	21.7	21.7	0.73
Fallfish	Whole (comp)	5	11.4	54.4*	3.3	42.4	-	54.3	46.9	45.5	2.03
Golden shiner	Whole (comp)	5	10.4	56.6*	2.1	2.6	-	27.6	16.0	19.4	4.62
Goldfish	Whole	18	31.6	688	11.3	38.8	-	412	136	116	21.41
Largemouth bass	Fillet (a)	18	36.1	815	1.6	1.2	-	151	22.9	8.2	8.81
Largemouth bass	Offal	18	36.1	815	4.8	5.1	-	588	141	109	33.41
Largemouth bass	Whole (calc)	18	36.1	815	3.9	10.9	-	424	105	80	23.12
Largemouth bass	Whole	15	23.8	213	3.2	3.0	-	220	62.8	37.6	17.34
Pumpkinseed	Fillet (a)	26	16.9	108	0.74	1.4	-	10.4	6.1	5.5	0.42
Pumpkinseed	Offal	26	16.9	108	3.7	11.4	-	108	55.3	48.5	5.14
Pumpkinseed	Whole (calc)	26	16.9	108	2.8	6.1	-	82	40.9	36.8	3.75
Smallmouth bass	Whole	2	26.9	269	5.5	118	-	194	156	156	38.14
Yellow perch	Fillet (a)	50	26.2	214	0.89	0.79	-	50.3	9.2	6.6	1.28
Yellow perch	Offal	50	26.2	214	6.1	9.1	-	440	138	115	10.00
Yellow perch	Whole (calc)	50	26.2	214	4.4	6.1	-	335	96	82	7.40
2000[b]											
Common carp	Whole	8	65.3	4479	13.2	13.7	-	190	104	114	19.72
Goldfish	Whole	1	22.8	782	7.6	--	-	--	94.7	--	
White sucker	Whole	46	34.6	528	4.8	8.0	-	216	70.6	56.4	7.09

Table 6-3
Total PCB Data Summary Table for Adult Fish from Massachusetts

Sample Location / Sample Year / Species	Tissue Type[1]	Number of Samples[2]	Average Length[3] (cm)	Average Weight (grams)	Average Lipid (%)	PCB Concentration (mg/kg) Range	Arithmetic Mean	Median	Standard Error
Reach 5A - Housatonic River - Confluence to Pittsfield WWTP									
1982[a]									
Rainbow trout	Fillet (b)	1	32.0	326	1.5	-- - --	27.0	--	--
1998[c]									
Brown bullhead	Fillet (a)	1	25.5	220	1.1	-- - --	9.2	--	--
Yellow bullhead	Fillet (a)	1	18.5	70.0	3.3	-- - --	174	--	--
Reach 5B - Housatonic River - Pittsfield WWTP to Roaring Brook									
1982[a]									
Brown trout	Fillet (b)	1	42.0	907	7.6	-- - --	260	--	--
2002[c]									
Largemouth bass	Fillet (a)	15	35.4	812	2.0	14.7 - 138	52	41.8	9.43
Largemouth bass	Offal	15	35.4	812	4.4	36.4 - 640	146	102	39.18
Largemouth bass	Whole (calc)	15	35.4	812	4.0	35 - 546	129	96	33.36
Reach 5C - Housatonic River - Roaring Brook to Woods Pond									
1982[a]									
Brown trout	Fillet (b)	1	38.0	662	7.7	-- - --	192	--	--
Reach 6 - Housatonic River - Woods Pond									
1980[a]									
Bluegill	Fillet (b)	1	17.8	127	0.63	-- - --	4.2	--	--
Yellow perch	Fillet (b)	1	25.1	216	0.24	-- - --	3.0	--	--
1982[a]									
Brown bullhead	Fillet (b)	1	21.5	126	0.50	-- - --	11.0	--	--
Chain pickerel	Fillet (b)	1	33.8	269	0.58	-- - --	13.0	--	--
Crappie	Fillet (b)	1	21.9	141	0.67	-- - --	12.0	--	--
Largemouth bass	Fillet (b)	1	27.4	352	0.77	-- - --	20.0	--	--
Rock bass	Fillet (b)	1	17.6	135	0.46	-- - --	8.1	--	--
Sunfish	Fillet (b)	1	18.4	140	0.34	-- - --	4.7	--	--
Trout	Fillet (b)	1	28.5	330	7.9	-- - --	119	--	--
Yellow perch	Fillet (b)	1	27.3	316	0.39	-- - --	6.1	--	--
1990[c]									
Brown trout	Fillet (b)	2	27.6	205	1.4	0.56 - 27.0	13.8	13.8	13.22
Largemouth bass	Fillet (b)	8	34.9	751	0.93	1.1 - 24.0	10.7	8.6	2.81
Yellow perch	Fillet (b)	8	21.4	113	0.98	5.5 - 14.0	8.4	8.1	0.98
1998[b]									
Brown bullhead	Fillet (a)	25	27.6	274	1.3	5.2 - 90.2	18.6	14.3	3.44
Brown bullhead	Offal	25	27.6	274	4.7	19.0 - 108	45.7	40.5	4.56
Brown bullhead	Whole (calc)	25	27.6	274	3.8	16.5 - 83	38.6	34.4	3.54
Golden shiner	Whole (comp)	5	6.1 - 14.2	43.0*	3.2	19.8 - 26.3	22.4	22.4	1.10

Table 6-3
Total PCB Data Summary Table for Adult Fish from Massachusetts

Sample Location / Sample Year / Species	Tissue Type[1]	Number of Samples[2]	Average Length[3] (cm)	Average Weight (grams)	Average Lipid (%)	PCB Concentration (mg/kg) Range			Arithmetic Mean	Median	Standard Error
Goldfish	Whole	23	31.6	731	12.2	10.8	-	447	188	163	21.20
Largemouth bass	Fillet (a)	14	34.8	691	0.35	2.4	-	11.5	6.9	6.2	0.82
Largemouth bass	Offal	14	34.8	691	4.1	32.1	-	377	149	123	26.91
Largemouth bass	Whole (calc)	14	34.8	691	3.0	23.4	-	281	107	86	19.64
Largemouth bass	Whole	11	19.8	137	2.9	8.3	-	126	49.4	35.4	10.64
Pumpkinseed	Fillet (a)	25	17.4	130	0.83	1.1	-	47.5	7.0	4.8	1.77
Pumpkinseed	Offal	25	17.4	130	5.4	7.3	-	97.7	42.5	41.0	4.54
Pumpkinseed	Whole (calc)	25	17.4	130	4.2	11.2	-	74.0	32.3	32.2	3.18
Yellow perch	Fillet (a)	25	24.4	187	0.64	0.54	-	6.35	3.4	3.6	0.38
Yellow perch	Offal	25	24.4	187	5.0	40.2	-	199	106	102	9.14
Yellow perch	Whole (calc)	25	24.4	187	3.5	17.1	-	134	71	74	6.32
1999[b]											
Largemouth bass	Ovary	6	35.2	698	10.5	53.3	-	150	97.6	99.4	13.58
Largemouth bass	Offal	6	35.2	698	2.1	24.4	-	84.2	47.7	44.2	8.23
Common carp	Whole (comp)	3	NA	NA	12.5	100	-	120	113	120	6.67
2000[b]											
White sucker	Whole	11	36.1	571	2.7	10.0	-	199	70.5	57.8	17.05
2002[c]											
Largemouth bass	Fillet (a)	15	36.2	873	1.8	11.3	-	419	67	26.8	27.61
Largemouth bass	Offal	15	36.2	873	3.8	37.5	-	588	123	82	34.59
Largemouth bass	Whole (calc)	15	36.2	873	3.4	34	-	556	113	72	33.20
Reach 7 - Housatonic River - Woods Pond to Rising Pond											
1980[a]											
Bass	Fillet (b)	1	20.8	208	0.70	--	-	--	11.0	--	--
Bluegill	Fillet (b)	1	17.6	137	0.94	--	-	--	2.9	--	--
Sunfish	Fillet (b)	1	16.1	92.0	0.39	--	-	--	3.0	--	--
Yellow perch	Fillet (b)	2	25.3	244	0.32	1.1	-	3.3	2.2	2.2	1.10
1982[a]											
Bass	Fillet (b)	1	20.2	182	0.69	--	-	--	20.0	--	--
Trout	Fillet (b)	1	28.3	330	10.3	--	-	--	11.0	--	--
Reach 8 - Housatonic River - Rising Pond											
1980[a]											
Bluegill	Fillet (b)	1	17.7	124	0.79	--	-	--	2.6	--	--
Largemouth bass	Fillet (b)	1	29.3	441	0.76	--	-	--	7.4	--	--
Yellow perch	Fillet (b)	1	26.3	265	0.41	--	-	--	3.9	--	--
1982[a]											
Bass	Fillet (b)	1	21.1	216	0.68	--	-	--	7.2	--	--

Table 6-3
Total PCB Data Summary Table for Adult Fish from Massachusetts

Sample Location / Sample Year / Species	Tissue Type[1]	Number of Samples[2]	Average Length[3] (cm)	Average Weight (grams)	Average Lipid (%)	PCB Concentration (mg/kg) Range			Arithmetic Mean	Median	Standard Error
1990[c]											
Brown trout	Fillet (b)	1	33.6	420	3.4	--	-	--	33.0	--	--
Largemouth bass	Fillet (b)	8	28.5	438	1.8	5.5	-	39.0	16.5	13.0	4.27
Yellow perch	Fillet (b)	1	33.0	500	1.4	--	-	--	6.1	--	--
1998[b]											
Brown bullhead	Fillet (a)	7	24.8	194	0.97	0.78	-	4.3	1.7	1.4	0.44
Brown bullhead	Offal	7	24.8	194	3.3	4.2	-	15.7	6.1	4.5	1.61
Brown bullhead	Whole (calc)	7	24.8	194	2.7	3.5	-	12.4	5.0	3.8	1.24
Largemouth bass	Fillet (a)	11	36.0	744	0.35	1.7	-	5.8	3.8	3.6	0.40
Largemouth bass	Offal	11	36.0	744	3.4	1.1	-	81.0	45.0	40.2	7.00
Largemouth bass	Whole (calc)	11	36.0	744	2.5	1.3	-	61.4	33.2	28.0	5.25
Largemouth bass	Whole	14	20.7	127	2.8	12.8	-	41.5	24.2	22.4	2.35
Pumpkinseed	Fillet (a)	13	15.7	84.9	0.46	0.76	-	5.10	2.9	3.3	0.35
Pumpkinseed	Offal	13	15.7	84.9	3.9	8.5	-	38.5	20.8	19.2	1.98
Pumpkinseed	Whole (calc)	13	15.7	84.9	2.7	5.9	-	26.0	14.6	13.7	1.37
Yellow perch	Fillet (a)	6	25.2	200	0.54	1.6	-	13.2	4.9	3.5	1.76
Yellow perch	Offal	6	25.2	200	4.9	19.8	-	207	68.3	44.7	28.41
Yellow perch	Whole (calc)	6	25.2	200	3.5	13.3	-	158	49.8	31.2	22.05
1998[c]											
Bluntnose minnow	Whole (comp)	5	6.99	25.0*	4.2	9.2	-	15.2	11.8	11.2	1.04
Brown bullhead	Fillet (a)	15	25.4	200	1.7	0.66	-	3.3	5.8	4.9	0.71
Yellow perch	Fillet (a)	8	23.3	155	0.84	4.5	-	24.9	10.6	7.0	2.80
1999[b]											
Largemouth bass	Ovary	6	34.0	559	13.1	102	-	166	133	133	8.81
Largemouth bass	Offal	6	34.0	559	2.3	12.1	-	146	41.7	24	21.00
Reach 9 - Housatonic River - Rising Pond to Connecticut Border											
1980[a]											
Bass	Fillet (b)	1	25.8	314	0.63	--	-	--	3.9	--	--
Sunfish	Fillet (b)	1	18.0	149	1.7	--	-	--	2.7	--	--
Yellow perch	Fillet (b)	1	22.7	238	0.46	--	-	--	3.0	--	--
1982[a]											
Brown trout	Fillet (b)	1	37.3	594	7.6	--	-	--	3.3	--	--
Largemouth bass	Fillet (b)	1	30.5	452	0.75	--	-	--	6.9	--	--
1998[c]											
Bluntnose minnow	Whole (comp)	5	7.7	34.9*	4.5	4.0	-	5.4	4.9	5.0	0.23
Brown bullhead	Fillet (a)	2	22.5	135	1.1	1.3	-	2.1	1.7	1.7	0.40
Largemouth bass	Fillet (a)	2	40.1	1230	1.8	2.7	-	7.2	4.9	4.9	2.26
Largemouth bass	Whole	3	25.0	233	1.6	ND	-	0.94	0.40	0.20	0.27
Yellow perch	Fillet (a)	20	28.4	306	1.4	0.92	-	9.6	4.4	3.9	0.59

Table 6-3
Total PCB Data Summary Table for Adult Fish from Massachusetts

Sample Location / Sample Year / Species	Tissue Type[1]	Number of Samples[2]	Average Length[3] (cm)	Average Weight (grams)	Average Lipid (%)	PCB Concentration (mg/kg) Range			Arithmetic Mean	Median	Standard Error
1999[d]											
Largemouth bass	Whole	5	44.5	1551	5.0	16.9	-	53.6	26.3	17.6	7.06
Williams River											
1995[c]											
Smallmouth bass	Fillet (b)	2	28.0	265	1.4	1.1	-	2.5	1.8	1.8	0.70
Brown trout	Fillet (b)	2	28.0	183	3.8	0.81	-	1.0	0.91	0.91	0.092
Green River											
1995[c]											
Rock bass	Fillet (b)	2	21.5	210	1.8	0.16	-	2.3	1.2	1.2	1.06
Brown trout	Fillet (b)	2	35.0	420	3.5	14.0	-	21.0	17.5	17.5	3.46
Laurel Lake											
1995[c]											
Largemouth bass	Fillet (b)	5	30.4	310	0.67	ND	-	0.07	0.03	0.03	0.009

Notes:
1. Tissue Types:
   - Fillet: (a) = skin-off
   - Fillet: (b) = skin-on/scales-off
   - Fillet: (c) = skin-on/scales-on
   - Whole: = whole body
   - Whole: (calc) = whole body calculated from fillet and offal data.
   - Whole: (comp) = whole body composite
2. Samples may be composites of individuals.
3. Average lengths provided when available. Some composite samples had range of individual fish lengths reported.
4. Average weight is indicated per individual (when available); otherwise total weight of composite sample is noted by an asterisk (*).
5. NA = Not Available.
6. -- = No data collected.
7. ND = Not Detected.

* = Average total sample weight

[a]Collected by Stewart
[b]Collected by EPA
[c]Collected by BBL
[d]Collected by JSA Environmental

Table 6-4
Total PCB Data Summary Table for Young-of-Year Fish from Massachusetts

Sample Location / Sample Year / Species	Tissue Type[1]	Number of Samples[2]	Average Length[3] (cm)	Average Weight[4] (grams)	Average Lipid (%)	PCB Concentration (mg/kg) Range			Arithmetic Mean	Median	Standard Error
Reach 5 - Housatonic River - Confluence to Woods Pond											
1998[b]											
Largemouth bass	Whole (comp)	7	NA	39.2	3.4	22.4	-	51.2	36.0	35.9	4.38
Pumpkinseed	Whole (comp)	5	9.5	88.5	2.7	25.6	-	29.9	27.2	26.5	0.75
Yellow perch	Whole (comp)	10	9.8	51.0	2.6	16.5	-	46.9	32.2	31.3	2.97
Reach 5A - Housatonic River - Confluence to Pittsfield WWTP											
1998[c]											
Pumpkinseed	Whole (comp)	2	8.2	49.4	3.1	37.6	-	41.6	39.6	39.6	1.98
Reach 5B - Housatonic River - Pittsfield WWTP to Roaring Brook											
1994[c]											
Largemouth bass	Whole (comp)	7	5.8	25.3	2.8	25.0	-	35.0	31.1	32.0	1.30
Pumpkinseed	Whole (comp)	7	4.8	17.2	3.8	23.0	-	26.0	25.0	26.0	0.53
Yellow perch	Whole (comp)	7	7.8	24.8	2.5	22.0	-	27.0	24.7	25.0	0.61
1996[c]											
Largemouth bass	Whole (comp)	7	6.1	26.6	2.9	21.0	-	36.0	27.6	25.0	2.05
Pumpkinseed	Whole (comp)	7	6.8	31.8	3.5	27.0	-	31.0	29.3	29.0	0.47
Yellow perch	Whole (comp)	7	8.2	53.6	3.2	23.0	-	35.0	27.4	28.0	1.53
1998[c]											
Bluegill	Whole (comp)	6	8.0	48.6	3.2	15.0	-	40.0	21.2	18.0	3.83
Largemouth bass	Whole (comp)	7	6.8	49.6	3.0	17.0	-	20.0	19.3	20.0	0.42
Pumpkinseed	Whole (comp)	1	8.3	61.0	2.8	--	-	--	23.0	--	--
Yellow perch	Whole (comp)	7	9.3	69.5	2.8	20.0	-	33.0	25.7	25.0	1.57
2000[c]											
Bluegill	Whole (comp)	7	7.1	49.0	4.2	28.0	-	39.0	33.0	32.0	1.72
Largemouth bass	Whole (comp)	7	5.5	12.3	3.0	26.0	-	41.0	31.6	28.0	2.36
Yellow perch	Whole (comp)	7	7.5	42.3	2.8	29.0	-	37.0	33.0	33.0	1.18
2002[c]											
Bluegill	Whole (comp)	6	4.6	16.4	2.9	10.0	-	14.0	12.2	12.0	0.54
Largemouth bass	Whole (comp)	7	6.5	40.4	3.6	20.0	-	24.0	21.4	21.0	0.60
Pumpkinseed	Whole (comp)	1	5.2	24.3	3.5	--	-	--	21.0	--	--
Yellow perch	Whole (comp)	4	9.3	38.8	2.3	23.0	-	27.0	25.0	25.0	0.91
Reach 6 - Housatonic River - Woods Pond											
1994[c]											
Bluegill	Whole (comp)	7	< 5.1	16.0	2.8	3.3	-	22.0	17.0	20.0	2.43
Largemouth bass	Whole (comp)	7	7.2	52.3	2.1	17.0	-	37.0	22.9	19.0	3.07
Yellow perch	Whole (comp)	7	8.5	29.7	2.5	32.0	-	58.0	37.6	35.0	3.52

Table 6-4
Total PCB Data Summary Table for Young-of-Year Fish from Massachusetts

Sample Location / Sample Year / Species	Tissue Type[1]	Number of Samples[2]	Average Length[3] (cm)	Average Weight[4] (grams)	Average Lipid (%)	PCB Concentration (mg/kg) Range			Arithmetic Mean	Median	Standard Error
1996[c]											
Bluegill	Whole (comp)	7	4.0	12.7	3.9	19.0	-	26.0	21.9	22.0	0.86
Largemouth bass	Whole (comp)	7	7.3	53.4	3.2	19.0	-	25.0	22.1	22.0	0.77
Yellow perch	Whole (comp)	7	9.3	84.0	4.4	26.0	-	35.0	28.9	29.0	1.18
1998[c]											
Bluegill	Whole (comp)	7	3.4	13.2	2.8	15.0	-	20.0	16.6	16.0	0.78
Largemouth bass	Whole (comp)	7	9.2	115.0	2.5	27.0	-	38.0	32.3	34.0	1.74
Yellow perch	Whole (comp)	7	9.4	54.6	2.4	22.0	-	36.0	28.9	29.0	1.65
1998[b]											
Largemouth bass	Whole (comp)	5	7.0 - 12.9	57.9	1.6	9.0	-	28.1	16.6	12.9	3.67
Pumpkinseed	Whole (comp)	5	8.4 - 11.5	90.1	3.1	8.8	-	35.1	25.9	27.9	4.47
Yellow perch	Whole (comp)	5	8.9 - 10.9	51.7	2.5	27.4	-	32.6	30.0	31.0	1.07
2000[c]											
Bluegill	Whole (comp)	7	5.9	27.7	4.6	25.0	-	33.0	27.9	26.0	1.26
Largemouth bass	Whole (comp)	7	6.8	47.2	2.6	21.0	-	28.0	24.0	23.0	0.93
Yellow perch	Whole (comp)	7	8.0	26.4	3.3	28.0	-	33.0	30.1	30.0	0.74
2002[c]											
Bluegill	Whole (comp)	7	6.7	49.4	4.5	13.0	-	17.0	14.7	15.0	0.60
Largemouth bass	Whole (comp)	7	7.0	49.6	2.7	16.0	-	19.0	17.1	17.0	0.50
Yellow perch	Whole (comp)	2	9.3	49.2	2.3	12.0	-	16.0	14.0	14.0	2.00
Reach 7 - Housatonic River - Woods Pond to Rising Pond											
1996[c]											
Bluegill	Whole (comp)	7	7.4	67.9	4.1	6.7	-	10.0	8.4	8.1	0.47
Largemouth bass	Whole (comp)	7	6.5	37.4	3.0	6.8	-	9.6	7.9	8.0	0.35
Yellow perch	Whole (comp)	7	9.2	74.1	3.4	9.5	-	14.0	11.1	10.0	0.63
1998[c]											
Bluegill	Whole (comp)	5	3.1	5.2	1.9	0.94	-	3.1	2.2	2.3	0.35
Largemouth bass	Whole (comp)	7	7.7	68.9	2.7	3.4	-	7.0	5.2	5.7	0.48
Pumpkinseed	Whole (comp)	3	3.6	10.4	3.7	2.5	-	2.6	2.6	2.6	0.033
Yellow perch	Whole (comp)	7	9.7	107.0	2.8	8.6	-	11.0	10.5	11.0	0.55
2000[c]											
Bluegill	Whole (comp)	7	6.9	55.2	4.9	13.0	-	19.0	15.6	15.0	0.81
Largemouth bass	Whole (comp)	7	7.1	55.2	3.9	14.0	-	17.0	15.6	16.0	0.37
Yellow perch	Whole (comp)	7	8.9	73.2	3.2	13.0	-	16.0	14.7	15.0	0.36
2002[c]											
Bluegill	Whole (comp)	3	5.4	24.9	3.7	2.0	-	2.8	2.5	2.8	0.17
Pumpkinseed	Whole (comp)	4	6.2	39.3	4.0	3.5	-	3.9	3.7	3.7	0.090
Largemouth bass	Whole (comp)	7	7.8	66.0	2.9	3.2	-	4.1	3.5	3.5	0.12

Table 6-4
Total PCB Data Summary Table for Young-of-Year Fish from Massachusetts

Sample Location / Sample Year / Species	Tissue Type[1]	Number of Samples[2]	Average Length[3] (cm)	Average Weight[4] (grams)	Average Lipid (%)	PCB Concentration (mg/kg) Range			Arithmetic Mean	Median	Standard Error
Reach 8 - Housatonic River - Rising Pond											
1998[b]											
Largemouth bass	Whole (comp)	5	7.5 - 12.6	62.8	2.5	10.0	-	15.3	11.9	10.6	0.99
Pumpkinseed	Whole (comp)	5	7.2 - 9.8	50.6	3.0	9.7	-	11.8	10.5	10.4	0.36
Yellow perch	Whole (comp)	5	8.5 - 10.0	36.6	2.0	8.1	-	11.2	9.6	8.9	0.66
Reach 9 - Housatonic River - Rising Pond to Connecticut Border											
1994[c]											
Bluegill	Whole (comp)	7	3.0 - 5.5	15.8	4.2	2.8	-	4.2	3.5	3.5	0.20
Largemouth bass	Whole (comp)	7	6.6	36.0	3.2	3.3	-	4.8	4.3	4.3	0.20
Yellow perch	Whole (comp)	7	7.2	36.6	2.8	4.2	-	4.6	4.5	4.6	0.063
1996[c]											
Bluegill	Whole (comp)	7	4.5	14.4	3.7	0.90	-	2.6	1.5	1.3	0.21
Largemouth bass	Whole (comp)	7	6.4	35.9	3.6	3.0	-	3.7	3.4	3.6	0.11
Yellow perch	Whole (comp)	7	7.5	39.4	2.6	3.0	-	3.7	3.3	3.3	0.086
1998[c]											
Bluegill	Whole (comp)	5	3.6	6.5	3.8	1.0	-	2.7	2.1	2.3	0.30
Pumpkinseed	Whole (comp)	5	8.0	41.2	3.6	0.27	-	2.5	1.2	1.3	0.42
Yellow perch	Whole (comp)	7	9.3	87.4	2.5	2.5	-	4.5	3.2	3.1	0.28
Largemouth bass	Whole (comp)	7	8.8	89.3	3.0	2.1	-	3.4	2.5	2.4	0.17
2000[c]											
Bluegill	Whole (comp)	5	7.0	62.7	3.9	3.1	-	4.5	3.7	3.6	0.28
Largemouth bass	Whole (comp)	7	6.5	30.9	3.2	2.3	-	4.0	3.4	3.4	0.22
Pumpkinseed	Whole (comp)	3	7.1	61.6	3.3	3.5	-	4.7	4.1	4.0	0.35
Yellow perch	Whole (comp)	7	8.4	40.8	2.6	2.8	-	4.6	4.1	4.2	0.23
2002[c]											
Bluegill	Whole (comp)	5	5.3	26.0	3.2	1.6	-	2.3	1.9	2.0	0.12
Largemouth bass	Whole (comp)	7	8.0	67.5	2.9	1.8	-	2.1	1.9	1.8	0.10
Pumpkinseed	Whole (comp)	2	5.3	26.3	2.5	1.7	-	1.9	1.8	1.8	0.10
Yellow perch	Whole (comp)	4	10.4	62.2	2.4	2.2	-	2.6	2.5	2.5	0.10

Notes:

1. Tissue Types:
   Whole: (comp) = whole body composite
2. Samples may be composites of individuals.
3. Average lengths provided when available. Some composite samples had range of individual fish lengths reported.
4. Average weight is indicated per total weight of composite sample.
5. NA = Not Available.
6. -- = Not Applicable.

[b]Collected by EPA

[c]Collected by BBL

Table 6-5
Total PCB Data Summary Table for Fish from Connecticut

Sample Location / Sample Year / Species	Tissue Type[1]	Number of Samples[2]	Average Length[3] (cm)	Average Weight (grams)	Average Lipid (%)	PCB Concentration (mg/kg) Range	Arithmetic Mean	Median	Standard Error
Falls Village, CT									
1977[d]									
Brook trout	Fillet (c)	1	25.4	NA	NA	-- - --	0.30	--	--
Yellow perch	Fillet (a)	1	27.9	NA	NA	-- - --	4.7	--	--
2000[e]									
Bluegill	Fillet (b)	2	NA	NA	1.3	0.29 - 1.1	0.68	0.68	0.40
Brown bullhead	Fillet (a)	1	NA	NA	1.7	-- - --	0.95	--	--
Pumpkinseed	Fillet (b)	1	NA	NA	1.4	-- - --	0.21	--	--
Yellow perch	Fillet (b)	3	NA	NA	1.4	0.33 - 0.38	0.36	0.37	0.015
West Cornwall, CT									
1977[d]									
Brown trout	Fillet (c)	10	NA	NA	NA	9.6 - 43.0	20.8	17.4	3.74
Rainbow trout	Fillet (c)	6	NA	NA	NA	4.6 - 26.0	13.1	11.5	3.01
Smallmouth bass	Fillet (c)	1	NA	NA	NA	-- - --	4.0	--	--
1978[d]									
Brown trout	Fillet (c)	2	NA	NA	NA	-- - --	5.6	--	--
1979[d]									
Brown trout	Fillet (a)	19	28.5	NA	NA	0.91 - 17.0	6.0	4.5	0.98
Brown trout	Fillet (c)	19	28.5	NA	NA	4.1 - 36.6	16.5	16.2	1.64
Rainbow trout	Fillet (a)	20	31.6	NA	NA	1.4 - 11.5	4.8	3.7	0.67
Rainbow trout	Fillet (c)	20	31.6	NA	NA	7.0 - 38.4	16.6	14.7	1.62
1982[d]									
Brown trout	Fillet (c)	3	NA	NA	3.4	2.9 - 6.5	5.1	5.8	1.10
Smallmouth bass	Fillet (b)	1	NA	NA	0.44	NA - NA	1.1	NA	NA
1984[d,e]									
Brown trout	Fillet (a)	6	NA	NA	NA	0.06 - 0.71	0.27	0.23	0.10
Brown trout	Fillet (c)	36	26.0	194	2.9	0.35 - 14.6	3.4	2.1	0.55
Smallmouth bass	Fillet (b)	16	27.7	287	0.64	0.61 - 6.3	2.4	2.2	0.36
1985[e]									
Brown trout	Fillet (c)	6	40.9	786	1.8	0.50 - 4.6	3.1	3.8	0.66
1986[e]									
Brown trout	Fillet (c)	24	29.4	321	3.8	1.9 - 23.6	6.8	5.3	1.04
Smallmouth bass	Fillet (b)	13	26.0	245	1.0	0.62 - 6.0	3.2	2.9	0.52
1988[e]									
Brown trout	Fillet (c)	36	27.5	297	2.9	2.6 - 16.7	5.7	4.8	0.51
Rainbow trout	Fillet (c)	9	19.9	84.3	0.95	2.3 - 4.3	3.2	3.0	0.23
Smallmouth bass	Fillet (b)	13	29.1	373	1.6	1.6 - 13.6	4.8	2.8	1.02
1990[d,e]									
Brown trout	Fillet (c)	36	25.1	171	1.3	2.9 - 9.3	5.6	5.4	0.30
Smallmouth bass	Fillet (b)	12	28.0	298	0.57	1.2 - 6.5	3.5	3.1	0.47

Table 6-5
Total PCB Data Summary Table for Fish from Connecticut

Sample Location / Sample Year / Species	Tissue Type[1]	Number of Samples[2]	Average Length[3] (cm)	Average Weight (grams)	Average Lipid (%)	PCB Concentration (mg/kg) Range	Arithmetic Mean	Median	Standard Error
1992[e]									
Brown trout	Fillet (c)	44	25.8	227	4.0	2.5 - 29.4	9.3	8.4	0.78
Smallmouth bass	Fillet (b)	14	29.2	351	1.3	1.1 - 6.6	3.7	3.8	0.43
1994[e]									
Brown trout	Fillet (c)	36	23.7	170	2.5	0.42 - 9.4	1.5	1.2	0.26
Smallmouth bass	Fillet (b)	13	29.9	405	2.3	0.67 - 2.6	1.6	1.6	0.19
1996[e]									
Brown trout	Fillet (c)	20	30.8	348	1.6	0.09 - 9.7	2.7	1.8	0.59
Smallmouth bass	Fillet (a)	5	31.0	477	0.68	0.68 - 1.5	1.1	1.2	0.18
Smallmouth bass	Fillet (b)	3	29.9	426	0.51	0.77 - 2.0	1.5	1.4	0.36
1998[e]									
Brown trout	Fillet (c)	30	30.8	368	2.5	1.0 - 11.2	2.3	1.6	0.36
Smallmouth bass	Fillet (b)	10	31.3	436	0.76	0.35 - 1.9	0.97	0.82	0.17
2000[e]									
Brown trout	Fillet (c)	36	NA	NA	3.6	0.70 - 3.6	1.5	1.5	0.11
Smallmouth bass	Fillet (b)	10	31.9	440	1.4	0.26 - 1.6	1.0	0.95	0.16
2002[e]									
Brown trout	Fillet (c)	30	34.6	524	4.5	0.67 - 4.8	1.7	1.4	0.16
Smallmouth bass	Fillet (b)	10	31.2	436	1.8	0.45 - 1.6	1.1	1.03	0.11
Bulls Bridge, CT									
1979[d]									
Black crappie	Fillet (a)	3	23.1	198	NA	2.0 - 2.3	2.1	2.0	0.11
Brown bullhead	Fillet (a)	10	25.1	187	NA	1.3 - 6.5	2.5	2.2	0.48
Common carp	Fillet (a)	7	54.8	2386	NA	0.81 - 13.7	4.8	4.1	1.60
Chain pickerel	Fillet (a)	9	36.2	359	NA	0.60 - 4.5	1.9	1.4	0.49
Chain pickerel	Fillet (c)	1	29.2	113	NA	-- - --	4.3	--	--
Largemouth bass	Fillet (a)	10	29.7	431	NA	1.3 - 4.5	2.3	1.9	0.35
Smallmouth bass	Fillet (a)	10	26.5	230	NA	1.7 - 25.3	8.2	6.3	2.22
Smallmouth bass	Fillet (c)	12	24.0	175	NA	6.0 - 29.7	11.9	10.1	1.97
Sunfish	Fillet (c)	10	17.6	136	NA	0.37 - 1.3	0.75	0.73	0.082
White sucker	Fillet (a)	9	38.3	551	NA	0.87 - 28.2	8.2	4.6	2.98
Yellow perch	Fillet (a)	10	26.3	215	NA	0.68 - 2.0	1.3	1.2	0.15
1983[f]									
Bluegill	Unknown	5	18.6	164	0.58	0.10 - 0.88	0.42	0.38	0.13
Brown bullhead	Unknown	6	28.0	340	0.53	0.46 - 3.9	1.6	1.29	0.51
Brown trout	Unknown	2	26.8	236	2.2	1.50 - 2.40	2.0	1.95	0.45
Chain pickerel	Unknown	1	23.5	77.2	0.30	-- - --	0.94	--	--
Largemouth bass	Unknown	6	25.8	435	0.22	0.30 - 0.49	0.38	0.37	0.029
Pumpkinseed	Unknown	1	17.6	155	0.39	-- - --	0.22	--	--
Rainbow trout	Unknown	1	39.5	500	3.1	-- - --	2.4	NA	NA
Rock bass	Unknown	6	20.7	202	0.14	0.10 - 0.56	0.35	0.43	0.083
Smallmouth bass	Unknown	6	23.1	162	0.50	0.18 - 1.80	0.51	0.26	0.26
White crappie	Unknown	1	22.4	188	0.59	-- - --	0.43	--	--

Table 6-5
Total PCB Data Summary Table for Fish from Connecticut

Sample Location / Sample Year / Species	Tissue Type[1]	Number of Samples[2]	Average Length[3] (cm)	Average Weight (grams)	Average Lipid (%)	PCB Concentration (mg/kg) Range			Arithmetic Mean	Median	Standard Error
Yellow perch	Unknown	5	23.2	177	0.31	0.22	-	1.30	0.71	0.49	0.22
1984[e]											
Brown bullhead	Fillet (a)	12	25.7	241	0.66	0.38	-	1.4	0.80	0.82	0.093
Bluegill	Fillet (b)	2	18.8	147	1.4	0.60	-	1.2	0.88	0.88	0.28
Common carp	Fillet (b)	1	35.9	759	1.5	--	-	--	1.1	--	--
Largemouth bass	Fillet (b)	24	31.3	548	0.80	0.34	-	2.8	1.4	1.0	0.17
Redbreast Sunfish	Fillet (b)	2	18.6	141	0.73	1.5	-	1.6	1.5	1.5	0.070
Smallmouth bass	Fillet (b)	12	28.9	346	0.92	0.89	-	2.9	1.9	1.9	0.18
Yellow perch	Fillet (b)	23	24.9	208	0.83	0.46	-	6.3	1.3	1.0	0.28
1986[e]											
Brown bullhead	Fillet (a)	6	30.2	427	1.1	0.84	-	3.1	1.8	1.6	0.40
Smallmouth bass	Fillet (b)	12	29.2	369	1.3	0.73	-	2.8	1.6	1.3	0.22
Yellow perch	Fillet (b)	25	26.7	307	1.0	0.20	-	2.1	0.82	0.62	0.10
1988[e]											
Brown bullhead	Fillet (a)	14	28.7	320	1.0	0.39	-	6.4	2.0	1.5	0.43
Bluegill	Fillet (b)	3	20.1	265	2.2	1.1	-	4.4	2.2	1.2	1.07
Common carp	Fillet (b)	3	54.3	2959	10.5	2.4	-	9.9	6.7	7.7	2.24
Largemouth bass	Fillet (b)	11	34.2	790	1.4	0.52	-	8.8	2.6	1.9	0.71
Pumpkinseed	Fillet (b)	2	16.4	90.9	0.79	0.03	-	0.55	0.29	0.29	0.26
Redbreast sunfish	Fillet (b)	2	18.5	141	1.2	1.4	-	2.6	2.0	2.0	0.60
Smallmouth bass	Fillet (b)	14	32.1	521	1.5	1.0	-	5.7	2.8	2.6	0.32
Yellow perch	Fillet (b)	23	26.7	256	0.81	0.40	-	1.9	0.99	0.79	0.10
1990[e]											
Smallmouth bass	Fillet (b)	6	30.1	385	0.74	0.87	-	3.8	2.5	2.6	0.40
Yellow perch	Fillet (b)	18	24.8	201	0.66	0.16	-	1.9	0.95	0.75	0.12
1992[e]											
Smallmouth bass	Fillet (b)	8	29.9	388	1.2	1.0	-	2.7	1.8	1.8	0.21
Yellow perch	Fillet (b)	12	24.2	207	1.2	0.39	-	1.3	0.69	0.62	0.079
1994[e]											
Smallmouth bass	Fillet (b)	8	30.5	405	2.2	0.77	-	1.8	1.4	1.4	0.13
1996[e]											
Smallmouth bass	Fillet (a)	5	28.7	370	0.73	0.95	-	1.3	1.1	1.1	0.062
Smallmouth bass	Fillet (b)	3	28.3	347	1.01	1.15	-	1.3	1.3	1.3	0.057
1998[e]											
Redbreast sunfish	Whole	2	24.8	227	1.7	0.42	-	0.50	0.46	0.46	0.039
Smallmouth bass	Fillet (b)	10	29.9	397	1.5	0.36	-	1.4	0.93	0.99	0.10
Yellow perch	Whole	2	17.8	124	0.62	0.46	-	0.55	0.50	0.50	0.048
2000[e]											
Bluegill	Fillet (b)	2	NA	NA	1.4	0.13	-	0.85	0.49	0.49	0.36
Brown bullhead	Fillet (a)	1	NA	NA	1.0	--	-	--	0.38	--	--
Pumpkinseed	Fillet (b)	1	NA	NA	1.5	--	-	--	0.73	--	--
Smallmouth bass	Fillet (b)	10	31.9	466	1.9	0.60	-	2.0	0.98	0.78	0.14
Yellow perch	Fillet (b)	3	NA	NA	0.98	0.18	-	0.34	0.27	0.28	0.047

Table 6-5
Total PCB Data Summary Table for Fish from Connecticut

Sample Location / Sample Year / Species	Tissue Type[1]	Number of Samples[2]	Average Length[3] (cm)	Average Weight (grams)	Average Lipid (%)	PCB Concentration (mg/kg) Range			Arithmetic Mean	Median	Standard Error
2002[e]											
Smallmouth bass	Fillet (b)	10	35.32	637.72	1.6	0.33	-	1.45	0.77	0.70	0.11
Lake Lillinonah, CT											
1976[d]											
Common sucker	Whole (comp)	2	NA	NA	NA	5.6	-	38.0	21.8	21.8	16.20
Yellow perch	Unknown	1	NA	NA	NA	NA	-	NA	2.0	NA	NA
1977[d]											
Largemouth bass	Fillet (c)	2	NA	NA	NA	4.7	-	5.2	5.0	5.0	0.25
Smallmouth bass	Fillet (c)	5	NA	NA	NA	2.7	-	9.8	5.1	4.1	1.30
White catfish	Fillet (a)	1	33.0	227	NA	--	-	--	11.0	--	--
White catfish	Fillet (b)	3	36.4	529	NA	4.3	-	8.6	7.0	8.0	1.34
White perch	Fillet (c)	3	NA	NA	NA	3.7	-	10.0	6.6	6.2	1.83
Yellow perch	Unknown	1	20.3	150	NA	--	-	--	0.30	--	--
1979[d]											
Brown bullhead	Fillet (a)	10	28.1	241	NA	1.0	-	11.6	5.4	4.8	1.18
Black crappie	Fillet (a)	10	22.7	203	NA	0.25	-	0.69	0.50	0.55	0.052
Common carp	Fillet (a)	10	47.6	1667	NA	0.47	-	27.6	5.8	3.3	2.58
Largemouth bass	Fillet (a)	10	34.3	627	NA	0.43	-	3.8	1.2	0.89	0.33
Smallmouth bass	Fillet (a)	10	34.0	428	NA	1.3	-	5.3	3.3	3.0	0.45
Sunfish sp.	Fillet (c)	10	19.1	125	NA	0.28	-	2.2	1.2	1.1	0.24
White catfish	Fillet (a)	10	33.7	456	NA	8.0	-	20.5	12.8	13.4	1.25
White perch	Fillet (a)	10	28.4	289	NA	2.2	-	13.3	5.8	4.7	1.07
White sucker	Fillet (a)	10	34.8	465	NA	0.22	-	2.7	0.94	0.84	0.22
Yellow perch	Fillet (a)	10	25.3	170	NA	0.33	-	2.5	1.0	0.87	0.24
1983[f]											
Brown bullhead	Unknown	4	24.1	229	0.89	0.13	-	1.30	0.70	0.68	0.27
Black crappie	Unknown	6	22.8	210	0.84	0.32	-	0.65	0.45	0.46	0.05
Bluegill	Unknown	1	20.1	204	0.31	--	-	--	0.19	--	--
Largemouth bass	Unknown	1	33.4	656	0.32	--	-	--	0.30	--	--
Rock bass	Unknown	6	18.1	125	0.22	0.05	-	0.25	0.15	0.16	0.032
Redbreast sunfish	Unknown	5	17.8	128	0.30	0.07	-	0.47	0.24	0.13	0.090
Smallmouth bass	Unknown	2	27.8	296	0.64	0.49	-	1.70	1.1	1.10	0.61
White catfish	Unknown	6	26.5	259	2.9	0.43	-	2.60	1.5	1.30	0.33
White perch	Unknown	6	22.5	212	3.4	0.56	-	2.10	1.5	1.80	0.27
Yellow bullhead	Unknown	1	20.5	111	0.53	--	-	--	0.27	--	--
Yellow perch	Unknown	6	23.2	154	0.35	0.08	-	0.65	0.28	0.23	0.088
1984[e]											
Brown bullhead	Fillet (a)	3	30.5	395	1.5	2.2	-	2.6	2.4	2.3	0.11
Bluegill	Fillet (b)	2	20.0	181	1.1	0.52	-	0.53	0.53	0.53	0.0050
Common carp	Fillet (b)	1	59.6	3700	10.5	--	-	--	2.2	--	--
Largemouth bass	Fillet (b)	6	37.5	855	0.93	0.84	-	2.7	1.3	1.1	0.28
Redbreast sunfish	Fillet (b)	2	18.7	128	0.56	1.1	-	1.9	1.5	1.5	0.40
Smallmouth bass	Fillet (b)	25	29.8	351	1.2	0.44	-	2.8	1.2	1.1	0.11
White catfish	Fillet (a)	12	33.6	649	3.2	0.80	-	55.1	6.5	1.5	4.43

Table 6-5
Total PCB Data Summary Table for Fish from Connecticut

Sample Location / Sample Year / Species	Tissue Type[1]	Number of Samples[2]	Average Length[3] (cm)	Average Weight (grams)	Average Lipid (%)	PCB Concentration (mg/kg) Range			Arithmetic Mean	Median	Standard Error
White perch	Fillet (b)	24	22.5	176	3.3	0.86	-	5.3	2.3	2.0	0.23
Yellow perch	Fillet (b)	3	25.5	171	0.69	0.33	-	1.2	0.64	0.44	0.26
1986[e]											
Smallmouth bass	Fillet (b)	26	32.5	507	0.86	0.36	-	7.28	1.6	0.85	0.33
White catfish	Fillet (a)	15	38.4	898	3.0	1.1	-	36.5	8.4	2.9	2.67
White perch	Fillet (b)	15	22.9	194	5.2	0.86	-	5.2	2.2	1.9	0.33
1988[e]											
Brown bullhead	Fillet (a)	5	32.0	443	0.50	0.55	-	4.1	1.7	0.81	0.69
Bluegill	Fillet (b)	3	18.2	152	1.1	0.32	-	0.90	0.52	0.33	0.19
Common carp	Fillet (b)	3	55.1	2493	3.4	0.77	-	17.3	7.4	4.2	5.02
Largemouth bass	Fillet (b)	7	34.8	724	0.75	0.03	-	4.8	1.4	0.97	0.62
Pumpkinseed	Fillet (b)	1	17.0	108	0.94	--	-	--	0.03	--	--
Pumpkinseed (hybrid)	Fillet (b)	1	18.8	149	0.80	--	-	--	0.3	--	--
Redbreast sunfish	Fillet (b)	1	16.4	83.7	1.0	--	-	--	0.03	--	--
Smallmouth bass	Fillet (b)	25	33.0	476	0.79	0.46	-	3.7	1.4	1.1	0.18
White catfish	Fillet (a)	16	38.4	822	2.2	1.0	-	24.7	5.6	2.5	1.82
White perch	Fillet (b)	11	21.5	155	5.2	0.79	-	2.8	1.8	2.0	0.21
Yellow perch	Fillet (b)	6	21.9	125	0.88	0.03	-	0.62	0.23	0.14	0.10
1990[e]											
Bluegill	Fillet (b)	6	18.2	136	0.87	0.25	-	1.0	0.51	0.43	0.11
Pumpkinseed	Fillet (b)	6	16.3	83.7	0.44	0.11	-	0.37	0.21	0.19	0.045
Redbreast sunfish	Fillet (b)	6	17.3	98.1	0.57	0.11	-	0.64	0.40	0.41	0.088
Smallmouth bass	Fillet (b)	6	33.9	558	0.91	0.69	-	1.8	1.1	0.96	0.17
Yellow perch	Fillet (b)	18	20.9	107	0.51	0.15	-	0.76	0.38	0.39	0.042
1992[e]											
Bluegill	Fillet (b)	4	18.3	122	0.83	0.11	-	1.8	0.62	0.30	0.39
Pumpkinseed	Fillet (b)	2	14.2	61.3	0.93	0.10	-	0.30	0.20	0.20	0.10
Redbreast sunfish	Fillet (b)	3	18.7	130	0.95	0.43	-	0.73	0.61	0.68	0.095
Smallmouth bass	Fillet (b)	8	34.5	500	0.97	0.73	-	5.9	1.9	1.1	0.60
Yellow perch	Fillet (b)	8	22.6	118	0.86	0.12	-	0.62	0.41	0.42	0.055
1994[e]											
Smallmouth bass	Fillet (b)	9	31.1	353	1.0	0.16	-	1.6	0.56	0.39	0.15
1996[e]											
Smallmouth bass	Fillet (a)	5	29.4	309	0.53	0.23	-	0.56	0.33	0.28	0.059
1998[e]											
Redbreast sunfish	Whole	2	26.5	220	0.49	0.11	-	0.12	0.11	0.11	0.0063
Smallmouth bass	Fillet (b)	10	30.8	398	1.2	0.24	-	1.3	0.80	0.86	0.084
Yellow perch	Fillet (b)	1	17.9	117	0.60	--	-	--	0.08	--	--
2000[e]											
Smallmouth bass	Fillet (b)	10	33.7	481	1.7	0.23	-	1.2	0.51	0.40	0.089
2002[e]											
Smallmouth bass	Fillet (b)	10	33.4	476	1.7	0.12		0.9	0.36	0.28	0.071

Table 6-5
Total PCB Data Summary Table for Fish from Connecticut

Sample Location / Sample Year / Species	Tissue Type[1]	Number of Samples[2]	Average Length[3] (cm)	Average Weight (grams)	Average Lipid (%)	PCB Concentration (mg/kg) Range			Arithmetic Mean	Median	Standard Error
Lake Zoar, CT											
1977[d]											
Black crappie	Fillet (b)	1	NA	NA	NA	NA	-	NA	0.66	NA	NA
Common carp	Fillet (b)	1	NA	NA	NA	--	-	--	10.4	--	--
Largemouth bass	Fillet (b)	5	NA	NA	NA	1.2	-	3.3	2.3	2.4	0.36
Smallmouth bass	Fillet (b)	2	NA	NA	NA				2.0		
White catfish	Fillet (b)	5	NA	NA	NA	4.4	-	26.0	9.0	4.7	4.25
White perch	Fillet (b)	5	NA	NA	NA	3.6	-	8.2	5.9	1.9	2.86
Yellow perch	Fillet (b)	3	NA	NA	NA	0.40	-	2.6	1.3	0.90	0.67
1978[d]											
Black crappie	Fillet (b)	1	15.2	142	NA	--	-	--	0.20	--	--
Common carp	Fillet (b)	2	64.2	5443	NA	1.0	-	7.0	4.0	4.0	3.00
Smallmouth bass	Fillet (b)	1	27.9	113	NA	--	-	--	1.2	--	--
1979[d]											
Brown bullhead	Fillet (a)	10	29.8	352	NA	0.65	-	6.4	2.4	1.9	0.50
Black crappie	Fillet (a)	10	22.9	142	NA	0.33	-	3.9	1.0	0.74	0.33
Common carp	Fillet (a)	10	49.4	2183	NA	0.24	-	10.2	2.5	1.0	1.13
American eel	Fillet (a)	3	61.9	413	23.7	0.25	-	1.8	1.2	1.55	0.48
Largemouth bass	Fillet (a)	10	36.4	635	NA	0.32	-	1.8	0.78	0.70	0.13
Smallmouth bass	Fillet (a)	10	36.2	505	NA	0.93	-	4.6	2.5	2.4	0.37
Sunfish sp.	Fillet (a)	10	19.7	161	NA	0.14	-	0.90	0.49	0.45	0.092
White catfish	Fillet (a)	10	33.2	468	NA	5.1	-	12.3	8.8	8.0	0.75
White perch	Fillet (a)	10	23.1	142	NA	2.4	-	7.6	4.1	3.3	0.57
White sucker	Fillet (a)	10	40.3	734	NA	0.02	-	1.9	0.86	0.83	0.21
Yellow perch	Fillet (a)	10	22.5	133	NA	0.28	-	5.5	1.5	0.97	0.49
1983[f]											
Brown bullhead	Unknown	1	30.4	383	1.8	--	-	--	0.97	--	--
Black crappie	Unknown	2	22.8	190	0.35	0.04	-	0.28	0.16	0.16	0.12
Bluegill	Unknown	2	20.4	183	0.10	0.02	-	0.03	0.03	0.03	0.0050
Brown trout	Unknown	1	31.3	315	2.4	--	-	--	1.6	--	--
American eel	Unknown	4	55.1	382	10.4	0.95	-	7.10	3.1	2.08	1.45
Largemouth bass	Unknown	4	35.3	736	0.31	0.09	-	0.26	0.19	0.21	0.040
Rock bass	Unknown	6	19.0	140	0.13	0.02	-	0.14	0.07	0.07	0.017
Redbreast sunfish	Unknown	4	17.8	115	0.18	0.06	-	0.13	0.09	0.09	0.015
Smallmouth bass	Unknown	1	27.5	273	0.56	--	-	--	0.16	--	--
White catfish	Unknown	4	23.9	180	1.8	0.40	-	1.30	0.87	0.88	0.19
White perch	Unknown	6	21.6	165	1.5	0.39	-	1.80	0.81	0.69	0.20
Yellow perch	Unknown	6	23.8	166	0.36	0.07	-	0.18	0.11	0.11	0.02
1984[e]											
Brown bullhead	Fillet (a)	2	26.4	267	0.72	0.30	-	0.52	0.41	0.41	0.11
Bluegill	Fillet (b)	2	19.2	137	0.90	0.78	-	1.3	1.0	1.0	0.24
Common carp	Fillet (b)	1	58.5	2529	6.8	--	-	--	4.9	--	--
Largemouth bass	Fillet (b)	2	28.2	330	0.67	0.42	-	0.43	0.42	0.42	0.0050
Redbreast Sunfish	Fillet (b)	2	17.2	92.2	0.62	0.07	-	0.11	0.09	0.09	0.020

Table 6-5
Total PCB Data Summary Table for Fish from Connecticut

Sample Location / Sample Year / Species	Tissue Type[1]	Number of Samples[2]	Average Length[3] (cm)	Average Weight (grams)	Average Lipid (%)	PCB Concentration (mg/kg) Range			Arithmetic Mean	Median	Standard Error
Smallmouth bass	Fillet (b)	24	27.9	279	0.86	0.01	-	1.1	0.50	0.45	0.056
White catfish	Fillet (a)	12	35.5	719	2.3	0.97	-	8.6	2.7	2.4	0.60
White perch	Fillet (b)	24	19.6	115	3.4	0.55	-	2.0	0.95	0.89	0.076
Yellow perch	Fillet (b)	2	18.9	78.6	0.46	0.06	-	0.07	0.07	0.07	0.0050
1986[e]											
White catfish	Fillet (a)	16	38.5	864	3.0	0.79	-	9.2	3.1	2.6	0.59
1988[e]											
Brown bullhead	Fillet (a)	6	31.4	437	1.1	0.37	-	0.94	0.68	0.65	0.082
Bluegill	Fillet (b)	2	20.3	264	0.58	0.03	-	0.38	0.20	0.20	0.17
Common carp	Fillet (b)	3	65.5	4144	7.2	2.9	-	25.7	16.5	21.0	6.94
American eel	Fillet (a)	3	61.9	413	23.7	0.25	-	1.8	1.2	1.6	0.48
Largemouth bass	Fillet (b)	7	35.7	913	1.4	0.24	-	4.4	1.4	0.90	0.55
Pumpkinseed	Fillet (b)	2	16.5	98.5	0.85	0.03	-	0.19	0.11	0.11	0.080
Redbreast sunfish	Fillet (b)	2	18.0	117	1.2	0.03	-	0.27	0.15	0.15	0.12
Smallmouth bass	Fillet (b)	16	33.0	543	1.3	0.14	-	2.1	0.97	0.69	0.17
White catfish	Fillet (a)	21	39.4	919	2.0	0.86	-	18.1	4.3	3.3	0.80
White perch	Fillet (b)	12	20.8	140	4.0	0.03	-	3.9	1.5	1.2	0.37
Yellow perch	Fillet (b)	7	22.3	128	0.72	0.03	-	0.37	0.22	0.28	0.057
1990[e]											
Bluegill	Fillet (b)	6	17.6	126	0.57	0.03	-	0.22	0.13	0.15	0.031
American eel	Fillet (a)	18	58.7	527	9.4	0.34	-	9.0	2.9	1.9	0.55
Pumpkinseed	Fillet (b)	6	16.2	95.1	0.40	0.07	-	0.29	0.17	0.16	0.031
Redbreast sunfish	Fillet (b)	6	17.6	105	0.46	0.08	-	0.43	0.21	0.19	0.054
Smallmouth bass	Fillet (b)	6	31.2	265	0.41	0.27	-	1.0	0.65	0.65	0.12
White perch	Fillet (b)	18	20.9	129	2.0	0.18	-	3.6	1.0	0.82	0.19
Yellow perch	Fillet (b)	18	20.8	107	0.39	0.10	-	0.65	0.25	0.22	0.03
1992[e]											
Bluegill	Fillet (b)	3	19.2	141	0.68	0.05	-	0.50	0.32	0.40	0.14
American eel	Fillet (a)	5	65.7	542	18.8	1.7	-	28.1	8.8	3.9	4.98
Pumpkinseed	Fillet (b)	3	16.3	83.5	0.63	0.05	-	0.51	0.29	0.32	0.14
Redbreast sunfish	Fillet (b)	3	18.0	109	0.70	0.08	-	0.61	0.31	0.23	0.16
Smallmouth bass	Fillet (b)	7	33.7	602	1.5	0.65	-	3.3	1.4	0.90	0.44
White perch	Fillet (b)	14	20.6	112	1.2	0.14	-	7.1	1.3	0.70	0.48
Yellow perch	Fillet (b)	8	22.5	122	0.80	0.12	-	0.99	0.35	0.24	0.10
1994[e]											
Largemouth bass	Fillet (b)	1	36.2	753	0.97	--	-	--	0.26	--	--
Smallmouth bass	Fillet (b)	10	32.1	444	1.3	0.10	-	1.1	0.45	0.43	0.09
1996[e]											
Smallmouth bass	Fillet (a)	5	32.0	455	0.61	0.37	-	0.81	0.51	0.45	0.08
1998[e]											
Smallmouth bass	Fillet (b)	10	31.4	493	1.2	0.28	-	2.9	0.87	0.66	0.24
Yellow perch	Whole	1	18.6	111	0.48	--	-	--	0.73	--	--
2000[e]											
Smallmouth bass	Fillet (b)	10	30.2	342	1.2	0.11	-	0.74	0.32	0.23	0.06
2002[e]											
Smallmouth bass	Fillet (b)	10	30.8	399	1.4	0.13		0.89	0.35	0.35	0.07

Table 6-5
Total PCB Data Summary Table for Fish from Connecticut

Sample Location / Sample Year / Species	Tissue Type[1]	Number of Samples[2]	Average Length[3] (cm)	Average Weight (grams)	Average Lipid (%)	PCB Concentration (mg/kg) Range	Arithmetic Mean	Median	Standard Error
Lake Housatonic, CT									
1977[d]									
White catfish	Unknown	3	NA	239	NA	2.7 - 4.7	3.5	3.0	0.76
White perch	Unknown	3	NA	113	NA	1.1 - 2.7	2.0	2.2	0.47
Yellow perch	Unknown	1	228.6	226.8	NA	-- - --	0.04	--	--
1978[d]									
Black crappie	Unknown	1	21.6	NA	NA	-- - --	0.18	--	--
Largemouth bass	Unknown	1	22.9	NA	NA	-- - --	0.60	--	--
Smallmouth bass	Unknown	1	27.9	NA	NA	-- - --	1.1	--	--
White catfish	Unknown	2	34.3	NA	NA	1.9 - 6.7	4.3	4.3	2.40
White perch	Unknown	2	NA	NA	NA	1.1 - 2.5	1.8	1.8	0.70
Yellow perch	Unknown	4	NA	NA	NA	0.06 - 0.30	0.15	0.12	0.053
1979[d]									
American eel	Fillet (a)	10	61.6	524	NA	2.3 - 29.4	13.26	11.89	2.39
Brown bullhead	Fillet (a)	10	29.9	357	NA	0.78 - 1.5	0.97	0.87	0.074
Black crappie	Fillet (b)	10	19.3	133	NA	0.24 - 1.7	0.71	0.63	0.15
Common carp	Fillet (a)	10	63.3	3362	NA	0.61 - 17.5	5.1	3.4	1.62
Largemouth bass	Fillet (a)	10	34.0	632	NA	0.36 - 1.2	0.61	0.60	0.076
Smallmouth bass	Fillet (a)	4	34.0	397	NA	0.33 - 9.3	3.5	2.2	2.04
Sunfish sp.	Fillet (a)	10	18.3	122	NA	0.19 - 1.2	0.61	0.65	0.10
White catfish	Fillet (a)	10	32.2	411	NA	0.89 - 6.8	3.7	4.3	0.64
White perch	Fillet (a)	10	23.7	180	NA	1.4 - 5.1	3.3	3.2	0.35
White sucker	Fillet (a)	10	44.9	1072	NA	0.31 - 2.2	1.3	1.1	0.22
Yellow perch	Fillet (a)	10	22.9	136	NA	0.24 - 1.8	0.79	0.54	0.17
Below Derby Dam									
1978[d]									
Brown trout	Fillet (c)	1	40.6	NA	NA	-- - --	6.3	--	--

Notes:

1. Tissue Types:
   Fillet: (a) = skin-off
   Fillet: (b) = skin-on/scales-off
   Fillet: (c) = skin-on/scales-on
   Whole: = whole body
   Whole (comp): = whole body composite
2. Samples may be composites of individuals.
3. Average lengths provided when available. Some composite samples had range of individual fish lengths reported.
4. Average weight is indicated per individual (when available); otherwise total weight of composite sample is noted by an asterisk (*).
5. NA = Not Available.
6. -- = Not Applicable.
7. Unknown = samples are fillets, but the specific sample preparation method is not known.

* = Average total sample weight.
[d]Collected by CDEP.
[e]Collected by ANSP.
[f]Collected by Stewart.

Table 6-6
PCDD/PCDF TEQ Data Summary Table for Fish Collected by EPA 1998/1999

Species/Reach	Skin-off Fillet Samples			Whole Body Samples			Whole Body Composite Samples		
	Number of Samples	Range	Arithmetic Mean	Number of Samples	Range	Arithmetic Mean	Number of Samples	Range	Arithmetic Mean
Brown Bullhead									
Reach 5 (1998)	16	8.1E-06 - 3.4E-05	1.4E-05	1	-- - --	3.0E-05	--	-- - --	--
Reach 6 (1998)	15	1.4E-05 - 5.5E-05	2.3E-05	--	-- - --	--	--	-- - --	--
Reach 7 (1998)	7	6.3E-06 - 2.4E-05	1.0E-05	--	-- - --	--	--	-- - --	--
Largemouth Bass									
Reach 5 (1998)	13	4.7E-06 - 3.3E-05	1.0E-05	10	6.6E-06 - 4.3E-05	1.6E-05	7	1.4E-05 - 2.8E-05	2.2E-05
Reach 6 (1998)	10	4.5E-06 - 1.9E-05	8.3E-06	5	5.2E-06 - 2.2E-05	1.6E-05	5	1.0E-05 - 2.5E-05	1.6E-05
Reach 6 (1999)	--	-- - --	--	--	-- - --	--	--	-- - --	--
Reach 7 (1998)	10	5.3E-06 - 1.8E-05	7.9E-06	5	1.4E-05 - 5.0E-05	2.9E-05	5	6.9E-06 - 1.7E-05	1.3E-05
Reach 7 (1999)	--	-- - --	--	--	-- - --	--	--	-- - --	--
Yellow Perch									
Reach 5 (1998)	31	5.0E-06 - 2.6E-05	8.7E-06	--	-- - --	--	10	1.3E-05 - 3.4E-05	2.3E-05
Reach 6 (1998)	15	6.4E-06 - 2.8E-05	1.9E-05	--	-- - --	--	5	2.4E-05 - 3.1E-05	2.8E-05
Reach 7 (1998)	6	8.6E-06 - 2.4E-05	1.5E-05	--	-- - --	--	5	1.6E-05 - 2.6E-05	2.0E-05
Goldfish									
Reach 5 (1998)	--	-- - --	--	15	2.3E-05 - 1.1E-04	5.6E-05	--	-- - --	--
Reach 6 (1998)	--	-- - --	--	14	1.4E-05 - 1.0E-04	6.1E-05	--	-- - --	--
Pumpkinseed									
Reach 5 (1998)	16	5.2E-06 - 2.2E-05	8.9E-06	--	-- - --	--	5	9.9E-06 - 1.9E-05	1.6E-05
Reach 6 (1998)	15	6.8E-06 - 4.3E-05	1.5E-05	--	-- - --	--	5	1.3E-05 - 2.5E-05	2.0E-05
Reach 7 (1998)	13	7.0E-06 - 1.4E-05	1.1E-05	--	-- - --	--	5	1.2E-05 - 1.8E-05	1.4E-05
Bluegill									
Reach 5 (1998)	1	-- - --	6.3E-06	--	-- - --	--	--	-- - --	--
Golden Shiner									
Reach 5 (1998)	--	-- - --	--	--	-- - --	--	5	9.2E-06 - 6.9E-05	2.7E-05
Reach 6 (1998)	--	-- - --	--	--	-- - --	--	5	1.8E-05 - 7.5E-05	4.6E-05
Fallfish									
Reach 5 (1998)	--	-- - --	--	--	-- - --	--	5	9.3E-06 - 3.1E-05	1.8E-05
Smallmouth Bass									
Reach 5 (1998)	--	-- - --	--	2	3.2E-05 - 4.1E-05	3.6E-05	--	-- - --	--

Notes:
1. All concentrations in mg/kg.
2. -- = Not Applicable.
3. TEQs calculated using the PCDD/PCDF mammalian TEFs published by the WHO. Non-detected compounds represented as one-half the analytical detection limit.
4. Ovary samples from largemouth bass collected from Reaches 6 and 7 in 1999 were also analyzed for PCDDs/PCDFs. Results are summarized in Appendix C.

Table 6-7
Total PCB Data Summary Table for Frogs and Turtles

Sample Location / Sample Year / Species	No. of Samples	Average Lipid (%)[2]	Frequency of Detection	PCB Concentration (mg/kg)[1] Range			Median	Arithmetic Mean[2]	Standard Error
Reach 5 - Housatonic River - Confluence to Woods Pond									
1998[c]									
Bullfrog (whole body)	1	2.30	100%	--	-	--	--	7.73	--
1999[c]									
Bullfrog (leg)	3	0.23	100%	0.40	-	0.86	0.60	0.62	0.13
Bullfrog (offal)	3	1.50	100%	4.22	-	8.90	6.35	6.49	1.35
2000[c]									
Leopard frog (composite whole body)	7	1.31	100%	0.163	-	5.39	2.114	2.35	0.70
Leopard frog (whole body female)	1	0.55	100%	--	-	--	--	1.23	--
Leopard frog (whole body w/o ovary)	7	0.75	100%	0.025	-	2.56	0.390	0.83	0.35
Leopard frog (ovary)	7	12.75	100%	0.240	-	45.09	1.630	11.81	6.53
Leopard frog (tadpole)	1	0.10	100%	--	-	--	--	0.68	--
Leopard frog (egg mass)	3	0.63	100%	0.049	-	1.43	1.105	0.83	0.42
Wood frog (ovary)	8	0.76	100%	0.011	-	2.10	0.068	0.59	0.28
Wood frog (phase I)	9	1.84	100%	0.059	-	6.61	0.87	2.42	0.89
Wood frog (phase I - egg comp.)	2	2.20	100%	0.053	-	0.11	0.081	0.081	0.03
Wood frog (phase II)	14	1.05	100%	0.092	-	10.40	0.55	1.62	0.74
Wood frog (phase III -comp.)	7	1.74	100%	0.13	-	5.34	1.22	1.42	0.70
2001[d]									
Wood frog (hatchling)	5	3.65	100%	0.27	-	11.20	3.28	4.84	2.16
Wood frog (larval)	4	0.93	100%	1.42	-	6.14	1.51	2.65	1.17
Reach 5C - Housatonic River - Roaring Brook to Woods Pond									
1999[c]									
Bullfrog (leg)	6	0.23	100%	0.48	-	1.67	0.59	0.87	0.21
Bullfrog (whole body w/out legs)	6	1.10	100%	2.83	-	10.73	6.88	6.91	1.13
Reach 5D - Housatonic River - Backwaters Upstream of Woods Pond									
1999[c]									
Bullfrog (leg)	1	0.25	100%	--	-	--	--	0.62	--
Bullfrog (whole body w/out legs)	1	1.10	100%	--	-	--	--	4.58	--

Table 6-7
Total PCB Data Summary Table for Frogs and Turtles

Sample Location / Sample Year / Species	No. of Samples	Average Lipid (%)[2]	Frequency of Detection	PCB Concentration (mg/kg)[1] Range			Median	Arithmetic Mean[2]	Standard Error
Reach 6 - Housatonic River - Woods Pond									
1982[a]									
Bullfrog	1	0.23	100%	--	-	--	--	4.40	--
Snapping turtle	1	0.18	100%	--	-	--	--	2.10	--
1992[b]									
Bullfrog (leg)	3	0.37	100%	2.20	-	5.30	4.40	3.97	0.92
1999[c]									
Bullfrog (leg)	6	0.25	100%	0.25	-	1.21	0.72	0.72	0.16
Bullfrog (whole body w/out legs)	6	1.02	100%	3.30	-	6.63	4.78	4.88	0.55
Reach 6A - Housatonic River - Woods Pond (West Half)									
1999[c]									
Bullfrog (leg)	3	0.20	100%	0.26	-	1.01	0.42	0.56	0.23
Bullfrog (whole body w/out legs)	3	1.83	100%	1.77	-	6.45	5.23	4.48	1.40
Reach 6B - Housatonic River - Woods Pond (East Half)									
1999[c]									
Bullfrog (leg)	1	0.20	100%	--	-	--	--	0.63	--
Bullfrog (whole body w/out legs)	1	0.80	100%	--	-	--	--	7.01	--

Notes:

1. For 1982 and 1992 bullfrog samples, total PCB concentration represents total Aroclors.
   For 1998, 1999, 2000, and 2001 bullfrog samples, total PCB concentration represents total congeners.
2. For sampling years with only one sample, the datum represents the concentration of that individual sample.
3. For 1992 bullfrog sample, leg is prepared skinless and boneless.

[a] Collected by Stewart.
[b] Collected by BBL.
[c] Collected by EPA.
[d] Collected by ARCADIS.
NA = Not Available.
-- = Not Applicable.

Table 6-8
Total PCB Data Summary Table for Crayfish

Sample Location / Sample Year / Species	No. of Samples	Average Lipid (%)	Frequency of Detection	PCB Concentration (mg/kg)[1] Range	Median	Arithmetic Mean	Standard Error
Reach 5 - Housatonic River - Confluence to Woods Pond							
1999[a]							
Crayfish	40	1.00	100%	2.59 - 52.14	8.15	12.24	1.61
West Cornwall, CT							
1992[b]							
Crayfish (tissue)	1	NA	100%	-- - --	--	1.02	
Crayfish (eggs)	1	NA	100%	-- - --	--	3.53	

Notes:
1. Total PCB concentrations represent total PCB congeners.
[a] Collected by EPA.
[b] Collected by ANSP.

Table 6-9
Total PCB Data Summary Table for Benthic Invertebrates

Sample Location / Sample Year	Species	No. of Samples[2]	Average Lipid (%)[3]	Frequency of Detection	PCB Concentration (mg/kg)[1] Range	Median	Arithmetic Mean[3]	Standard Error
Massachusetts								
Reach 5 - Housatonic River - Confluence to Woods Pond								
1999[b]								
	Predators	6	0.60[4]	100%	4.87 - 47.59	13.09	19.40	7.09
	Shredders	7	0.90	100%	2.23 - 28.61	13.06	13.09	3.18
Reach 6 - Housatonic River - Woods Pond								
1999[b]								
	Predators	1	0.90	100%	-- - --	--	14.31	
	Shredders	1	0.20	100%	-- - --	--	2.29	
Connecticut								
Sample Station #1								
1978[a]								
	Caddisfly larvae	1	NA	100%	-- - --	--	18.6	
	Stonefly larvae	1	NA	100%	-- - --	--	29.5	
Sample Station #2								
1978[a]								
	Caddisfly larvae	1	NA	100%	-- - --	--	18.1	
	Stonefly larvae	1	NA	100%	-- - --	--	16.4	
Sample Station #3								
1978[a]								
	Stonefly larvae	1	NA	100%	-- - --	--	0.21	

See Notes on Page 5.

Table 6-9
Total PCB Data Summary Table for Benthic Invertebrates

Sample Location	Sample Year	Species	No. of Samples[2]	Average Lipid (%)[3]	Frequency of Detection	PCB Concentration (mg/kg)[1] Range	Median	Arithmetic Mean[3]	Standard Error
Connecticut (cont'd)									
West Cornwall, CT									
	1978[a]								
		Caddisfly larvae	1	NA	100%	-- - --	--	18.9	
		Hellgrammite larvae and stonefly nymphs	1	NA	100%	-- - --	--	22.9	
	1979[a]								
		Caddisfly larvae	1	NA	100%	-- - --	--	8.2	
		Hellgrammite larvae and stonefly nymphs	1	NA	100%	-- - --	--	5.6	
	1980[a]								
		Caddisfly larvae	1	NA	100%	-- - --	--	9.2	
		Hellgrammite larvae and stonefly nymphs	1	NA	100%	-- - --	--	6.6	
	1981[a]								
		Caddisfly larvae	1	NA	100%	-- - --	--	6.2	
		Hellgrammite larvae and stonefly nymphs	1	NA	100%	-- - --	--	4.6	
	1984[a]								
		Caddisfly larvae	1	NA	100%	-- - --	--	3.7	
		Hellgrammite larvae and stonefly nymphs	1	NA	100%	-- - --	--	2.9	
	1985[a]								
		Caddisfly larvae	1	NA	100%	-- - --	--	0.5	
		Hellgrammite larvae and stonefly nymphs	1	NA	100%	-- - --	--	0.8	
	1986[a]								
		Caddisfly larvae	1	NA	100%	-- - --	--	2.8	
		Hellgrammite larvae and stonefly nymphs	1	NA	100%	-- - --	--	2.8	

See Notes on Page 5.

Table 6-9
Total PCB Data Summary Table for Benthic Invertebrates

Sample Location / Sample Year	Species	No. of Samples[2]	Average Lipid (%)[3]	Frequency of Detection	PCB Concentration (mg/kg)[1] Range	Median	Arithmetic Mean[3]	Standard Error
Connecticut (cont'd)								
West Cornwall, CT (cont'd)								
1987[a]								
	Caddisfly larvae	1	NA	100%	-- - --	--	7.9	
	Hellgrammite larvae and stonefly nymphs	1	NA	100%	-- - --	--	5.2	
1988[a]								
	Caddisfly larvae	1	NA	100%	-- - --	--	4.2	
	Hellgrammite larvae and stonefly nymphs	1	NA	100%	-- - --	--	2.3	
1989[a]								
	Caddisfly larvae	1	NA	100%	-- - --	--	5.6	
	Hellgrammite larvae and stonefly nymphs	1	NA	100%	-- - --	--	4.6	
1990[a]								
	Caddisfly larvae	1	NA	100%	-- - --	--	1.2	
	Hellgrammite larvae and stonefly nymphs	1	NA	100%	-- - --	--	1.9	
1992[a]								
	Caddisfly larvae	2	NA	100%	1.91 - 8.14	5.03	5.03	3.12
	Hellgrammite larvae	1	NA	100%	-- - --	--	7.45	
	Stonefly nymphs	2	NA	100%	3.38 - 4.07	3.75	3.75	0.35
	Hellgrammite larvae and stonefly nymphs[d]	3	NA	100%	3.38 - 7.45	4.07	4.97	1.26

See Notes on Page 5.

Table 6-9
Total PCB Data Summary Table for Benthic Invertebrates

Sample Location / Sample Year	Species	No. of Samples[2]	Average Lipid (%)[3]	Frequency of Detection	PCB Concentration (mg/kg)[1] Range	Median	Arithmetic Mean[3]	Standard Error
Connecticut (cont'd)								
West Cornwall, CT (cont'd)								
1994[a]								
	Caddisfly larvae	3	NA	100%	1.42 - 2.42	2.07	1.97	0.29
	Hellgrammite larvae	2	NA	100%	2.24 - 3.83	3.03	3.03	0.79
	Stonefly nymphs	1	NA	100%	-- - --	--	1.09	
	Hellgrammite larvae and stonefly nymphs[d]	3	NA	100%	1.09 - 3.83	2.24	2.39	0.80
1996[a]								
	Caddisfly larvae	2	NA	100%	1.89 - 3.84	2.87	2.87	0.98
	Hellgrammite larvae	2	NA	100%	2.78 - 3.53	3.16	3.16	0.37
	Stonefly nymphs	1	NA	100%	-- - --	--	2.43	
	Hellgrammite larvae and stonefly nymphs[d]	3	NA	100%	2.43 - 3.53	2.78	2.91	0.32
1998[a]								
	Caddisfly larvae	1	0.38	100%	-- - --	--	1.05	
	Hellgrammite larvae	1	6.22	100%	-- - --	--	3.94	
	Stonefly nymphs	1	1.18	100%	-- - --	--	0.54	
	Hellgrammite larvae and stonefly nymphs[d]	2	3.7	100%	0.54 - 3.94	2.24	2.24	1.70
2001[a]								
	Caddisfly larvae	1	6.0	100%	-- - --	--	0.9	
	Hellgrammite larvae	1	10.0	100%	-- - --	--	1.81	
	Stonefly nymphs	1	1.0	100%	-- - --	--	0.53	
	Hellgrammite larvae and stonefly nymphs[d]	2	5.5	100%	0.53 - 1.81	1.17	1.17	0.64
2002[a]								
	Caddisfly larvae	3	1.6	100%	0.55 - 0.62	0.57	0.58	0.02
	Hellgrammite larvae	3	3.6	100%	0.83 - 1.08	0.93	0.94	0.07
	Stonefly nymphs	1	1.7	100%	-- - --	--	0.46	
	Hellgrammite larvae and stonefly nymphs[d]	4	3.1	100%	0.46 - 1.08	0.88	0.82	0.13

See Notes on Page 5.

Table 6-9
Total PCB Data Summary Table for Benthic Invertebrates

Notes:

1. Total PCB concentrations for benthic invertebrate samples collected by CDEP/ANSP from 1978 to 2002 represent total PCBs Aroclors.
   Total PCB concentrations for benthic invertebrate samples collected by EPA in 1999 represent total PCB congeners.
2. Samples were composites.
3. For sampling years with only one sample, the data represent the concentration of that individual sample.
4. One outlier value of 11.7 not included in average.
5. NA = Not Available.
6. -- = Not Applicable.

[a] Collected by CDEP/ANSP.

[b] Collected by EPA.

[c] Includes one duplicate sample.

[d] Data for individual hellgrammite larvae and stonefly nymph samples were combined for summary statistics so comparisons could be made between other years for which individual data are not presented.

Table 6-10

Total PCB Data Summary Table for Soil Invertebrates (Litter Invertebrates and Earthworms)

Sample Location / Sample Year / Species	No. of Samples[1]	Average Lipid (%)	Frequency of Detection	PCB Concentration (mg/kg)[2] Range	Median	Arithmetic Mean	Standard Error
Reach 5 - Housatonic River - Confluence to Woods Pond							
2000[a]							
Earthworm	30	3.92	100%	1.10 - 26.71	15.84	13.08	1.66
2000[a]							
Soil Litter Invertebrates	7	1.19	100%	1.39 - 4.86	3.58	3.37	0.44

Notes:

1. Samples are composite.
2. Total PCB concentration represents total congeners.
3. NA = Not Available.

[a] Collected by EPA.

Table 6-11
Total PCB Data Summary Table for Plankton

Sample Location / Sample Year / Species	No. of Samples	Frequency of Detection	PCB Concentration (ug/L)[1]			
			Range	Median	Arithmetic Mean[2]	Standard Error
Reach 5 - Housatonic River - Confluence to Woods Pond						
2000[a]						
Phytoplankton	4	100%	1.40 - 4.40	2.41	2.66	0.63
Zooplankton	4	100%	4.68 - 27.70	7.69	11.94	5.30
Reach 6 - Housatonic River - Woods Pond						
2000[a]						
Phytoplankton	1	100%	-- - --	--	1.43	--
Zooplankton	1	100%	-- - --	--	3.93	--

Notes:
1. Total PCB concentration represents total congeners from filtered composite samples.
2. For sampling years with only one sample, the datum represents the concentration of that individual sample.
3. -- = Not Applicable.
[a] Collected by EPA.

Table 6-12
Total PCB Data Summary Table for Aquatic Vegetation (Periphyton, Algae, and Aquatic Macrophytes)

Sample Location	Sample Year	Species	No. of Samples	Frequency of Detection	PCB Concentration (mg/kg)[1]			
					Range	Median	Arithmetic Mean[2]	Standard Error
Massachusetts								
Reach 5 - Housatonic River - Confluence to Woods Pond								
	1980[b]							
		Duck potato	1	100%	-- - --	--	0.84	--
	2000[d]							
		Filamentous algae	3	100%	0.48 - 2.24	0.82	1.18	0.54
		Macrophyte	4	100%	1.01 - 1.85	1.26	1.35	0.18
		Periphyton (from macrophyte)	3	100%	8.56 - 22.09	10.96	13.87	4.17
		Periphyton (filtered (ug/L))	1	100%	-- - --	--	79.90	--
		Periphyton (substrate)	4	100%	9.91 - 20.97	14.92	15.18	3.00
Reach 5A - Housatonic River - Confluence to Pittsfield WWTP								
	2000[d]							
		Detritus (filtered (ug/L))	1	100%	-- - --	-	0.058	--
Reach 5B - Housatonic River - Pittsfield WWTP to Roaring Brook								
	2000[d]							
		Detritus (filtered (ug/L))	2	100%	0 - 0.74	0.58	0.58	0.16
Reach 6 - Housatonic River - Woods Pond								
	1980[b]							
		Water milfoil and duckweed	10	100%	0.93 - 3.91	2.09	2.27	0.30
	2000[d]							
		Detritus (filtered (ug/L))	2	100%	0.93 - 1.48	1.20	1.20	0.27
		Filamentous algae	1	100%	-- - --	--	0.41	--
		Macrophyte	1	100%	-- - --	--	2.70	--
		Periphyton (from macrophyte)	1	100%	-- - --	--	41.02	--
		Periphyton (substrate)	1	100%	-- - --	--	27.16	--

Table 6-12
Total PCB Data Summary Table for Aquatic Vegetation (Periphyton, Algae, and Aquatic Macrophytes)

Sample Location / Sample Year / Species	No. of Samples	Frequency of Detection	PCB Concentration (mg/kg)[1] Range	Median	Arithmetic Mean[2]	Standard Error
Reach 7 - Housatonic River - Woods Pond to Rising Pond						
1980[b]						
Duck potato	2	100%	0.20 - 0.42	0.31	0.31	0.11
Reach 9 - Housatonic River - Rising Pond to Connecticut Border						
1980[b]						
Duck potato	1	100%	-- - --	--	0.22	--
Housatonic River near former Housatonic St. abutment						
1996[c]						
Algae	1	100%	-- - --	--	22.90	--
Connecticut						
Sample Station #1						
1978[a]						
Periphyton (rock scrapings)	1	100%	-- - --	--	0.59	--
Sample Station #2						
1978[a]						
Periphyton (rock scrapings)	1	100%	-- - --	--	0.36	--
Sample Station #3						
1978[a]						
Periphyton (rock scrapings)	1	100%	-- - --	--	0.05	--

Notes:

1. Total PCB concentration represents total Aroclors for all non-EPA data. EPA data is sum of congeners. Units are in mg/kg unless noted.
2. For sampling years with only one sample, the datum represents the concentration of that individual sample.
3. -- = Not Applicable.

[a] Grab samples collected by CDEP.
[b] Grab samples collected by Stewart.
[c] Grab sample collected by BBL.
[d] Grab samples collected by EPA.

Table 6-13
Total PCB Data Summary Table for Terrestrial Vegetation (Corn, Squash, Fiddleheads, and Grass)

Sample Location / Sample Year / Species	No. of Samples	Frequency of Detection	PCB Concentration (mg/kg)[1] Range			Median	Arithmetic Mean[2,3]	Standard Error
Reach 5A - Housatonic River - Confluence to Pittsfield WWTP								
1998[a]								
Corn	9	0%	ND (0.023)	-	ND (0.03)	NA	ND	0.00034
1999[a]								
Corn (Ear)	6	0%	ND (0.057)	-	ND (0.057)	NA	ND	NA
Corn (Stalk)	6	67%	ND (0.067)	-	0.024	0.017	0.022	0.0039
Squash	4[b]	100%	0.98	-	1.20	1.10	1.09	0.055
Squash (Flesh)	4[b]	67%	ND (0.17)	-	0.74	0.65	0.46	0.17
Squash (Pulp and Seeds)	1	100%	--	-	--	--	0.74	--
Fiddlehead	2[c]	NA	NA	-	NA	NA	NA	NA
Reach 5B - Housatonic River - Pittsfield WWTP to Roaring Brook								
1999[a]								
Corn (Ear)	4	0%	ND (0.057)	-	ND (0.057)	NA	ND	NA
Corn (Stalk)	4	25%	ND (0.067)	-	0.010	NA	0.028	
Fiddlehead	1[c]	NA	--	-	--	--	NA	--
2001[a]								
Grass	10	100%	0.0439	-	0.13	0.11	0.0976	0.0092

Table 6-13
Total PCB Data Summary Table for Terrestrial Vegetation (Corn, Squash, Fiddleheads, and Grass)

Notes:

1. Total PCB concentrations for corn, squash, and fiddleheads from 1998 and 1999 sampling represents total PCB Aroclors.
   Total PCB concentrations for 2000 fiddleheads and 2001 grass represent total PCB congeners.
2. For sampling years with only one sample, the data presented is the concentration of that individual sample.
3. Arithmetic mean and standard deviation were calculated using one-half the laboratory detection limit for all non-detects.
4. NA = Not Available.
5. ND = Not Detected. Concentration in parentheses is the laboratory detection limit.
6. -- = Not Applicable.

[a] Collected by EPA.

[b] The analytical results for one of the four samples were rejected. Summary statistics are based on three remaining samples.

[c] All analytical results were rejected.

Table 6-14
Total PCB Data Summary Table for Waterfowl

Sample Location / Sample Year / Species		No. of Samples[1]	Average Lipid (%)	Frequency of Detection	PCB Concentration (mg/kg)[2]					
					Range			Median	Arithmetic Mean	Standard Error
Reach 5 - Housatonic River - Confluence to Woods Pond										
1998[a]										
	Mallard Breast	3	0.77	100%	1.59	-	7.80	5.57	4.99	1.82
	Mallard Liver	3	4.07	100%	3.56	-	21.90	15.15	13.54	5.35
	Wood Duck Breast	9[3]	1.68	100%	4.75	-	12.20	6.84	7.70	0.98
	Wood Duck Liver	8	4.75	100%	5.19	-	38.49	7.16	11.90	4.04
Reach 6 - Housatonic River - Woods Pond										
1998[a]										
	Mallard Breast	2	3.85	100%	11.20	-	19.34	15.27	15.27	4.07
	Mallard Liver	2	4.50	100%	10.79	-	16.66	13.72	13.72	2.93
	Wood Duck Breast	14[4]	6.23	100%	1.06	-	17.85	5.26	6.13	1.12
	Wood Duck Liver	12	4.77	100%	0.34	-	23.99	4.45	8.02	2.56
Housatonic River (Newtown, CT)										
1999[b]										
	Mallard Breast (skin-off)	1	6.58	100%	--	-	--	--	0.27	--
	Mallard Breast (skin-on)	1	14.40	100%	--	-	--	--	2.05	--

Notes:

1. Samples are individual.
2. Total PCB concentration represents total congeners.
3. Includes one duplicate breast sample.
4. Includes two duplicate breast samples.

[a] Collected by EPA.

[b] Collected by CDEP.

Table 6-16
Total PCB Data Summary Table for Tree Swallows

Sample Location / Sample Year / Species	No. of Samples	Average Lipid (%)[2]	Frequency of Detection	PCB Concentration (mg/kg)[1] Range			Median	Arithmetic Mean[2]	Standard Error
Reach 5 - Housatonic River - Confluence to Woods Pond									
1998[a]									
Tree Swallow (Breast)	15	7.41	100%	14.31	-	60.18	39.54	37.97	3.63
Tree Swallow (Egg)	37	2.33	100%	3.05	-	134.10	50.83	52.31	3.43
Tree Swallow (GI Tract)	3	1.80	100%	1.89	-	18.52	15.27	11.89	5.09
1999[a]									
Tree Swallow (Breast)	15	8.00	100%	27.43	-	50.67	33.34	34.95	1.75
Tree Swallow (Egg)	55	4.22	100%	29.24	-	189.56	74.85	84.78	5.25
Tree Swallow (GI Tract)	6	2.20	100%	1.54	-	31.89	8.17	10.48	4.51
2000[a]									
Tree Swallow (Breast)	20	7.31	100%	10.79	-	34.23	21.14	21.14	1.29
Tree Swallow (Egg)	40	3.46	100%	12.16	-	107.26	49.51	53.64	3.93
Tree Swallow (GI Tract)	3	1.80	100%	3.70	-	7.13	5.64	5.49	0.99

Notes:
1. Total PCB concentration represents total congeners.
2. -- = Not Applicable.
[a] Collected by EPA.

Table 6-17
Total PCB Data Summary Table for House Wrens, Chickadee, and American Robins

Sample Location / Sample Year	Species	No. of Samples	Average Lipid (%)	Frequency of Detection	PCB Concentration (mg/kg)[1] Range			Median	Arithmetic Mean [2]	Standard Error
Reach 5 - Housatonic River - Confluence to Woods Pond										
1999[a]										
	House Wren, Avian Egg	5	7.82	100%	43.30	-	149.44	57.57	71.88	19.73
	Chickadee, Avian Egg	3	7.13	100%	17.58	-	24.98	18.18	20.25	2.37
2001[b]										
	Robin, Avian Egg	9	4.23	100%	5.04	-	170.00	86.30	83.60	22.30
	Robin, Avian Egg (unfertilized)	2	5.10	100%	7.38	-	37.50	22.40	22.40	15.10
	Robin, Nestling	11	2.53	100%	0.09	-	43.70	7.29	11.90	15.06

Notes:

1. Total PCB concentrations in House Wren and Chickadee represent total congeners; PCB concentrations in Robin represent total aroclors.
2. The arithmetic mean and standard deviation were calculated using one-half the laboratory detection limit for all non-detects.

[a] Collected by EPA.

[b] Collected by ARCADIS.

Table 6-18
Total PCB Data Summary Table for Small Mammals

Sample Location / Sample Year / Species		No. of Samples	Average Lipid (%)	Frequency of Detection	PCB Concentration (mg/kg)[1]			
					Range	Median	Arithmetic Mean	Standard Error
Reach 5 - Housatonic River - Confluence to Woods Pond								
1999[a]								
	Short tailed shrew	24	2.8	100%	4.5 - 148	86	78	9.76
	White footed mouse	52	4.3	100%	0.15 - 35	2.4	5.1	0.98

Notes:
1. Total PCB concentration represents total congeners.
[a] Collected by EPA.

Section 6 Figures

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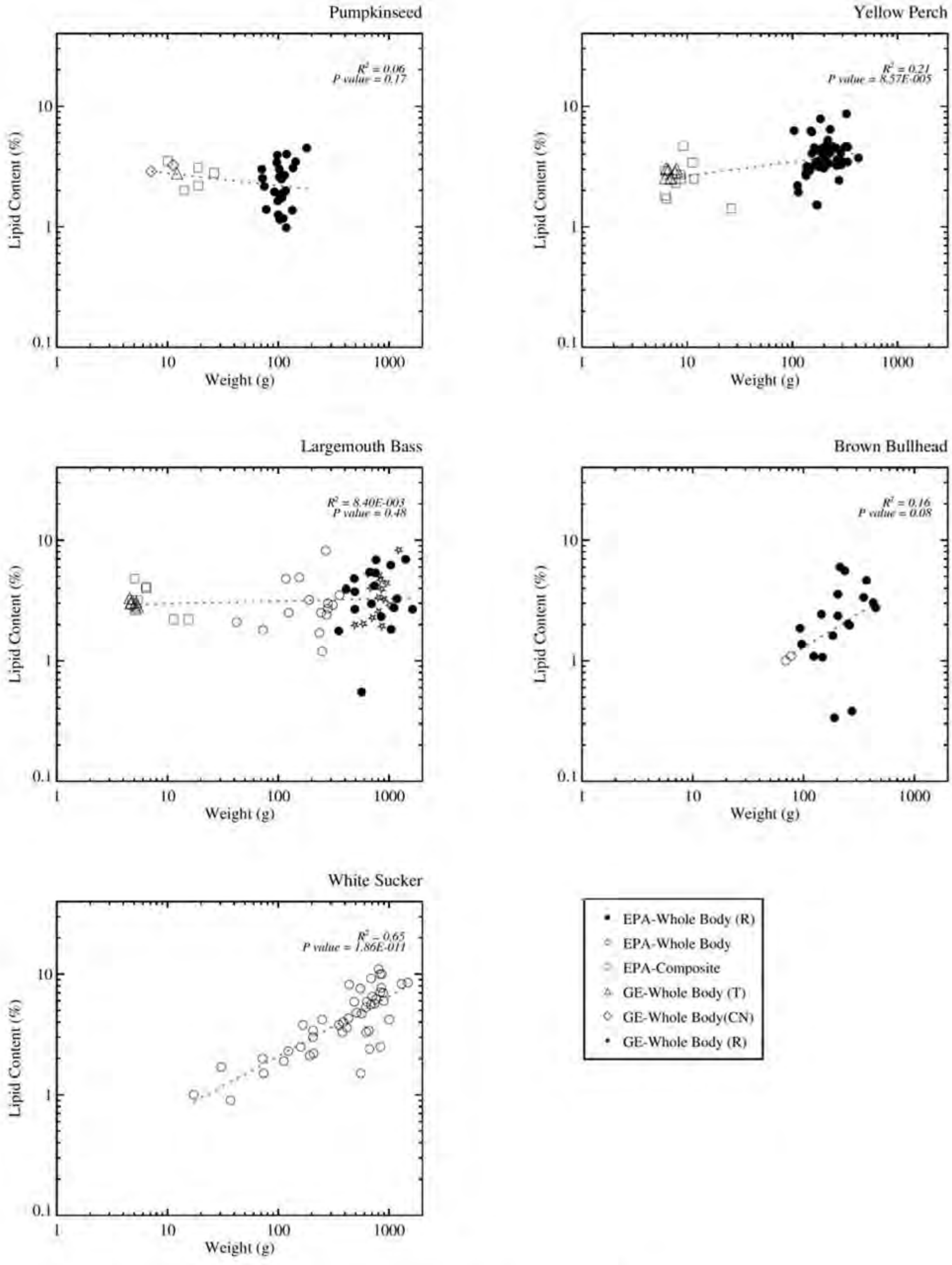

Figure 6-1a. Relationship between percent lipid and wet weight (Confluence to Woods Pond Headwaters).

Data: EPA (Released: November, 2002), and GE (Released: January, 2002)

Note: EPA data from 1998, except White Sucker (2000). GE adult fish from 1998 and 2002 (largemouth bass).
T or CN: samples for which PCB concentrations is reported on Aroclor-based and congener-based, respectively.
R: whole body reconstructed from fillet and offal. Split samples were not included.

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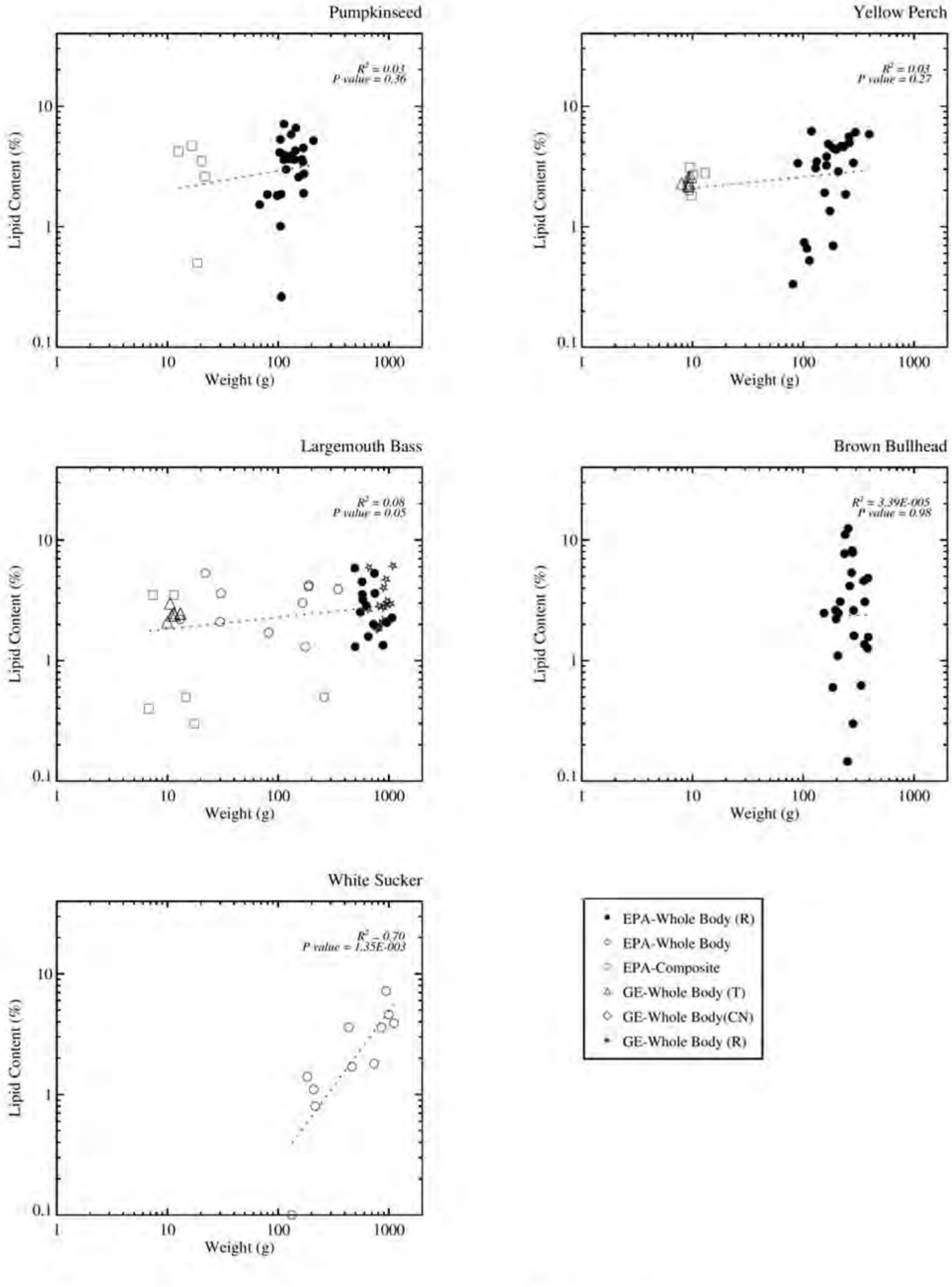

Figure 6-1b. Relationship between percent lipid and wet weight (Woods Pond).

Data: EPA (Released: November, 2002), and GE (Released: January, 2002)

Note: EPA data from 1998, except White Sucker (2000). GE adult fish from 1998 and 2002 (largemouth bass).
T or CN: samples for which PCB concentrations is reported on Aroclor-based and congener-based, respectively.
R: whole body reconstructed from fillet and offal. Split samples were not included.

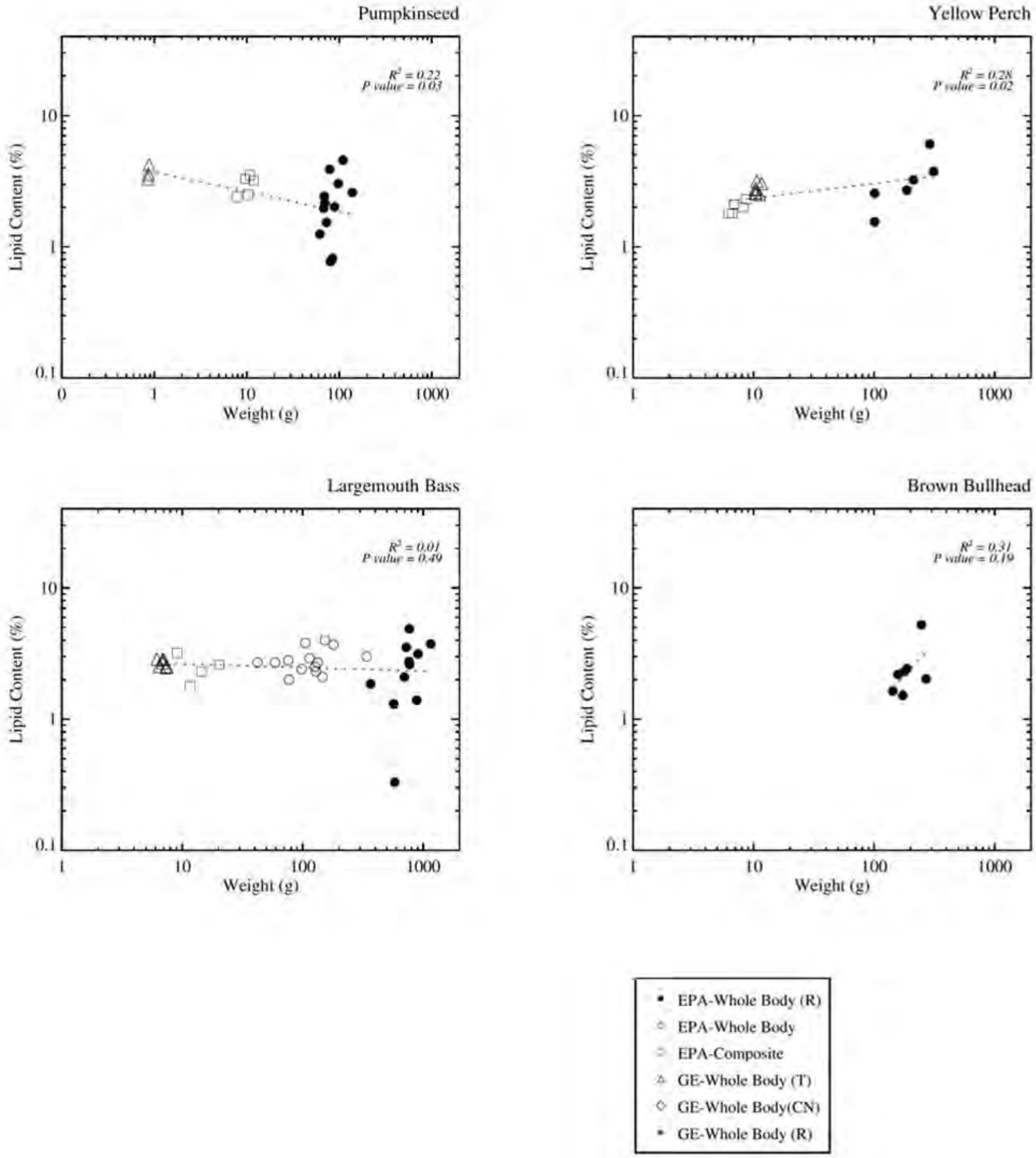

Figure 6-1c. Relationship between percent lipid and wet weight (Rising Pond).

Data: EPA (Released: November, 2002), and GE (Released: January, 2002)

Note: EPA data from 1998, except White Sucker (2000). GE adult fish from 1998 and 2002 (largemouth bass).
T or CN: samples for which PCB concentrations is reported on Aroclor-based and congener-based, respectively.
R: whole body reconstructed from fillet and offal. Split samples were not included.

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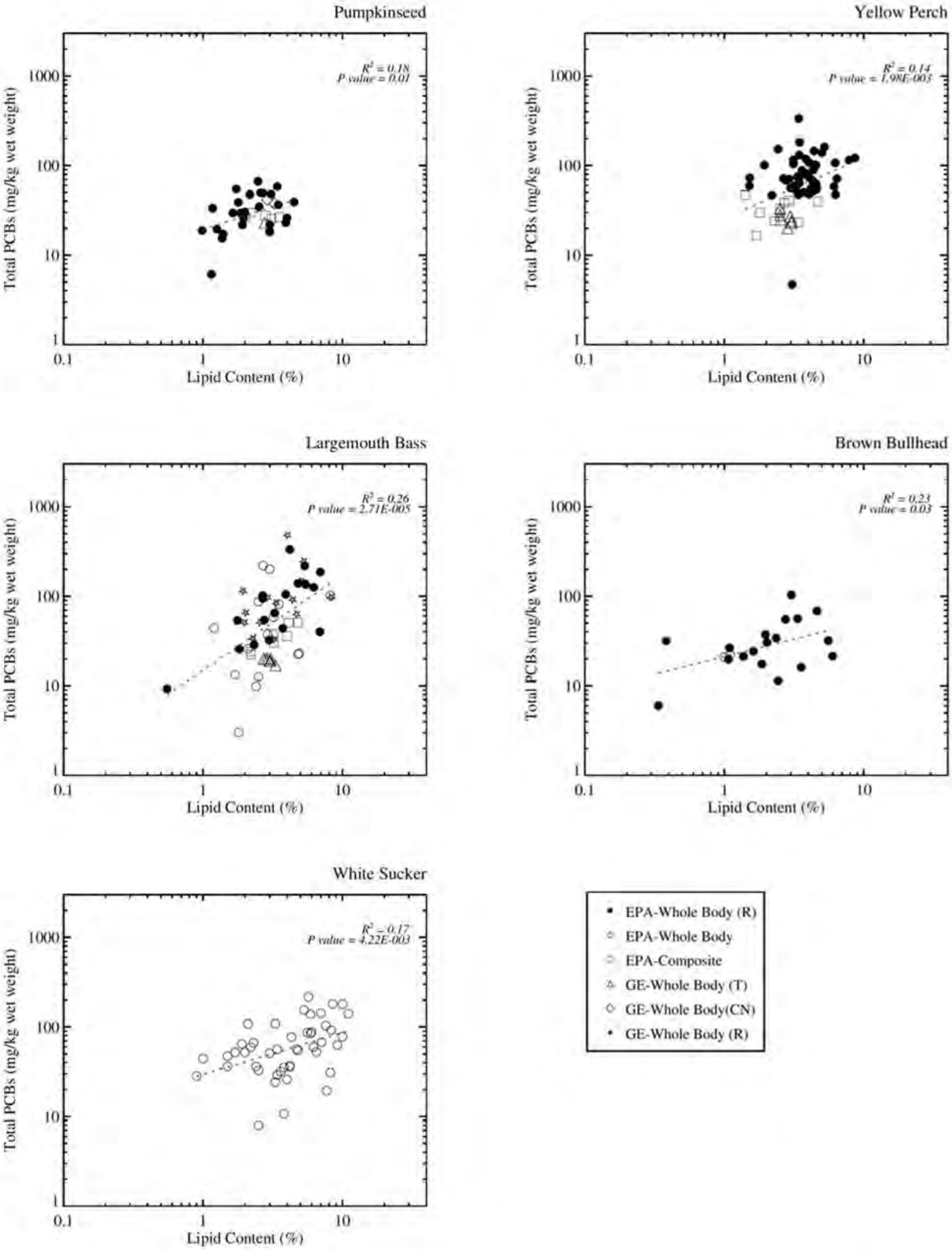

Figure 6-2a. Relationship between wet weight PCB concentrations and percent lipid (Confluence to Woods Pond Headwaters).

Data: EPA (Released: November, 2002), and GE (Released: January, 2002)

Note: *EPA data from 1998, except White Sucker (2000). GE adult fish from 1998 and 2002 (largemouth bass).*
T or CN: samples for which PCB concentrations is reported on Aroclor-based and congener-based, respectively.
R: whole body reconstructed from fillet and offal. Split samples were not included.

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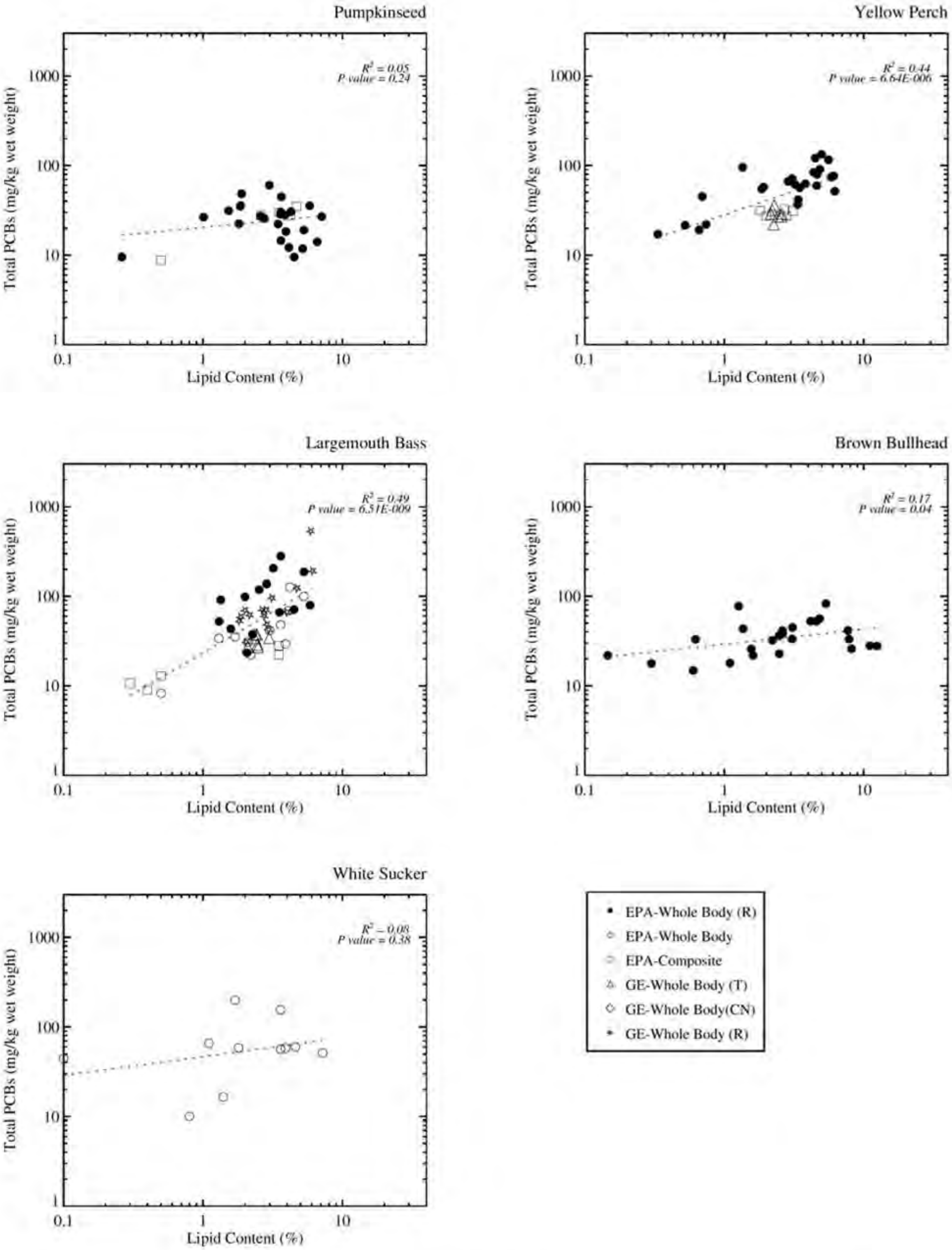

Figure 6-2b. Relationship between wet weight PCB concentrations and percent lipid (Woods Pond).

Data: EPA (Released: November, 2002), and GE (Released: January, 2002)

Note: EPA data from 1998, except White Sucker (2000). GE adult fish from 1998 and 2002 (largemouth bass).
T or CN: samples for which PCB concentrations is reported on Aroclor-based and congener-based, respectively.
R: whole body reconstructed from fillet and offal. Split samples were not included.

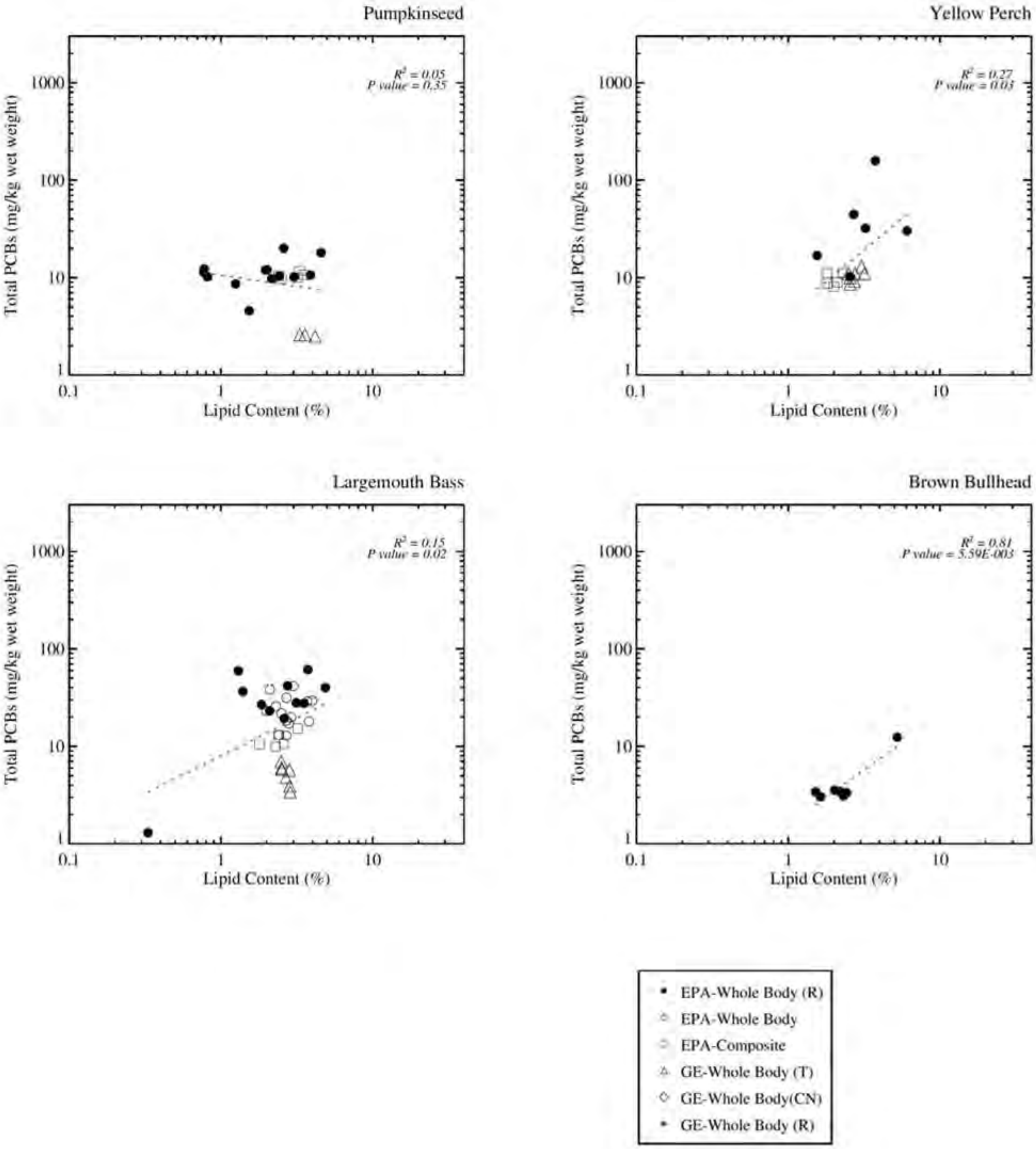

Figure 6-2c. Relationship between wet weight PCB concentrations and percent lipid (Rising Pond).

Data: EPA (Released: November, 2002), and GE (Released: January, 2002)

Note: *EPA data from 1998, except White Sucker (2000). GE adult fish from 1998 and 2002 (largemouth bass).*
T or CN: samples for which PCB concentrations is reported on Aroclor-based and congener-based, respectively.
R: whole body reconstructed from fillet and offal. Split samples were not included.

DR - \\Poseidon\E_Drive\GENhou\Analysis\Biota\RFI_Specific\raw_data_combined_fig_rfi_PCBlipvwgt_calc_wbr_062403.pro
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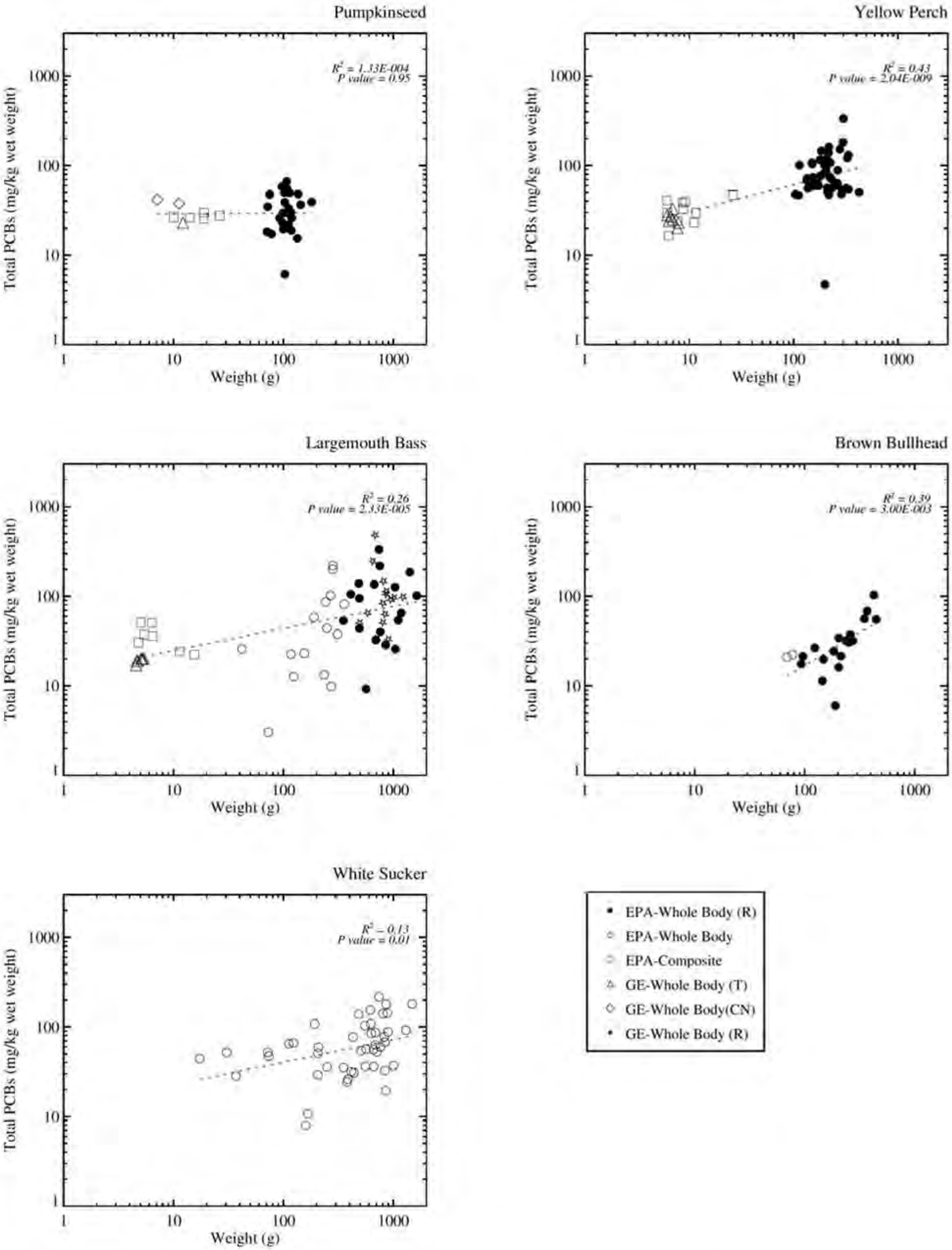

Figure 6-3a. Relationship between wet weight PCB concentrations and wet weight (Confluence to Woods Pond Headwaters).

Data: EPA (Released: November, 2002), and GE (Released: January, 2002)

Note: EPA data from 1998, except White Sucker (2000). GE adult fish from 1998 and 2002 (largemouth bass).
T or CN: samples for which PCB concentrations is reported on Aroclor-based and congener-based, respectively.
R: whole body reconstructed from fillet and offal. Split samples were not included.

DR - \\Poseidon\E_Drive\GENhou\Analysis\Biota\RFI_Specific\raw_data_combined_fig_rfi_PCBlipvwgt_calc_wbr_062403.pro
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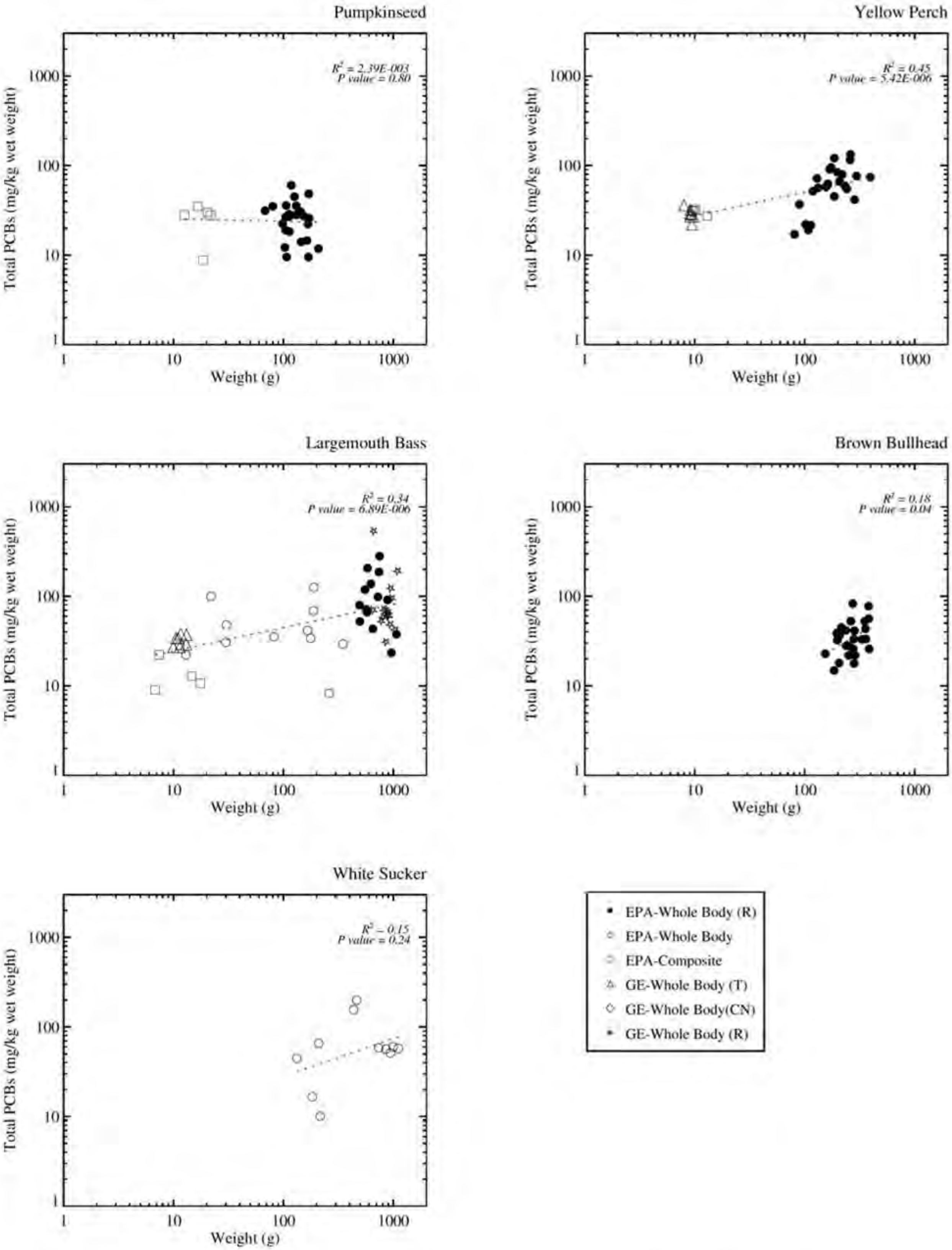

Figure 6-3b. Relationship between wet weight PCB concentrations and wet weight (Woods Pond).

Data: EPA (Released: November, 2002), and GE (Released: January, 2002)

Note: EPA data from 1998, except White Sucker (2000). GE adult fish from 1998 and 2002 (largemouth bass).
T or CN: samples for which PCB concentrations is reported on Aroclor-based and congener-based, respectively.
R: whole body reconstructed from fillet and offal. Split samples were not included.

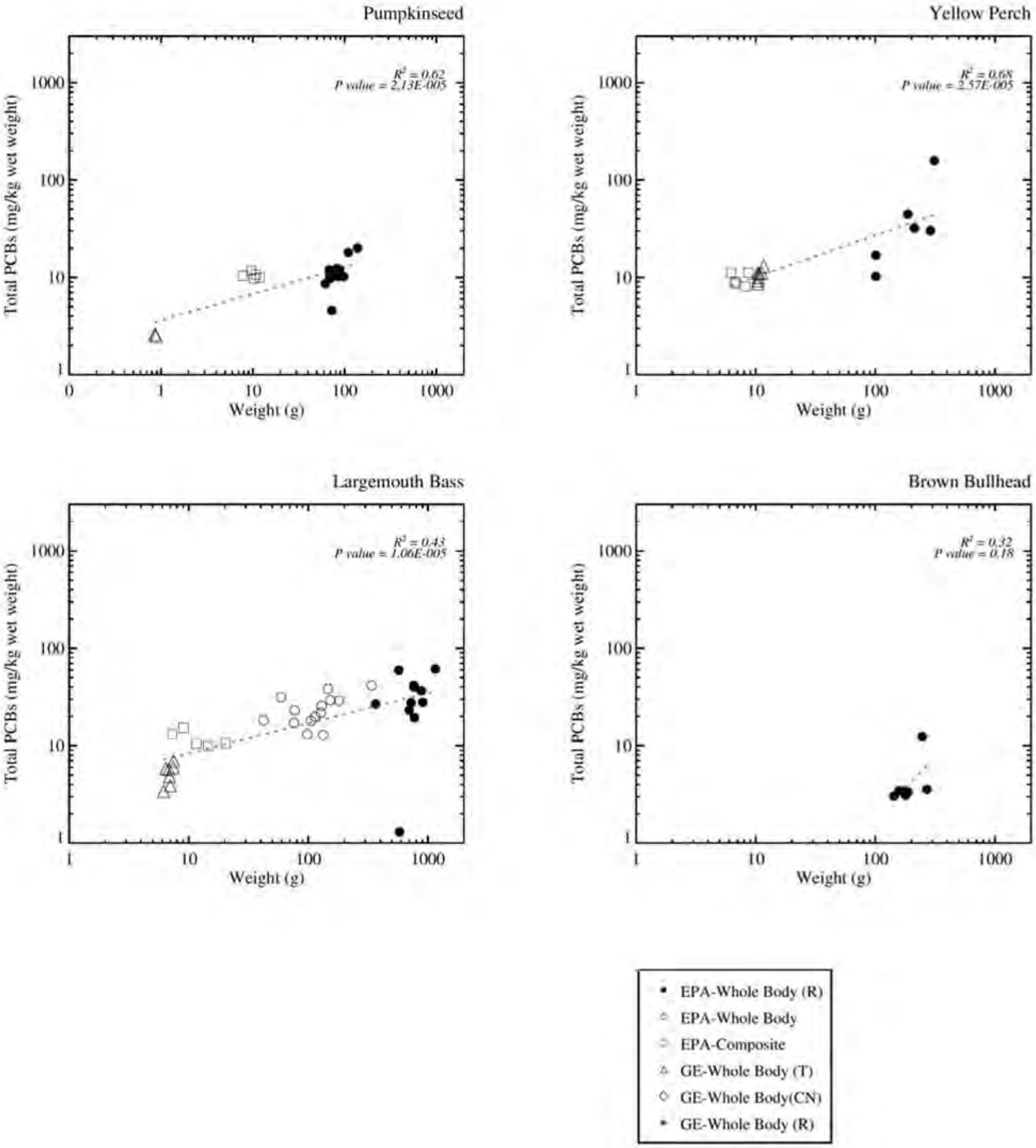

Figure 6-3c. Relationship between wet weight PCB concentrations and wet weight (Rising Pond).

Data: EPA (Released: November, 2002), and GE (Released: January, 2002)

Note: EPA data from 1998, except White Sucker (2000). GE adult fish from 1998 and 2002 (largemouth bass).
T or CN: samples for which PCB concentrations is reported on Aroclor-based and congener-based, respectively.
R: whole body reconstructed from fillet and offal. Split samples were not included.

DR - \\Poseidon\E_Drive\GENhou\Analysis\Biota\RFI_Specific\raw_data_combined_fig_rfi_PCBlipvwgt_calc_wbr_062403.pro
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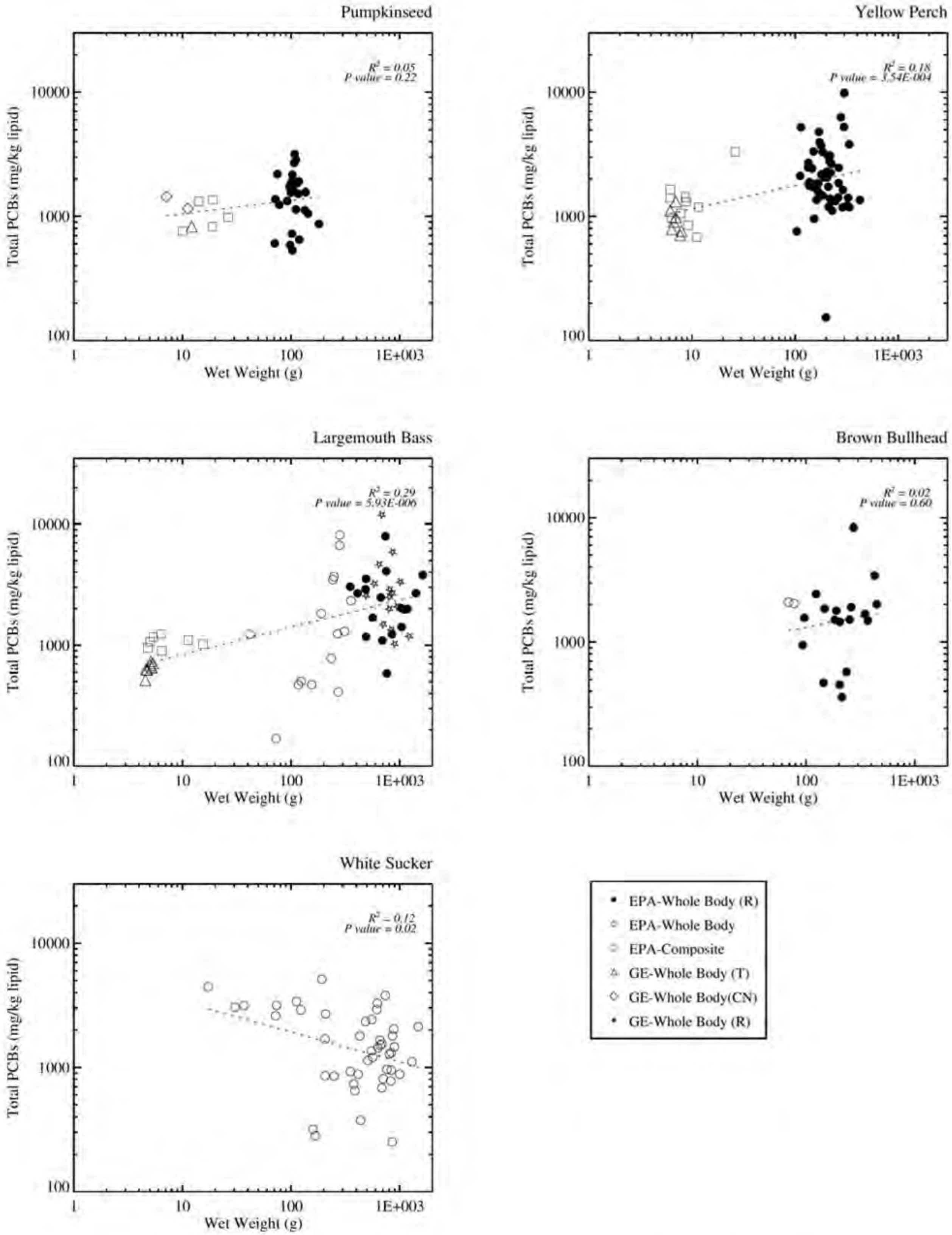

Figure 6-4a. Relationship between lipid-based PCB concentrations and wet weight (Confluence to Woods Pond Headwaters).

Data: EPA (Released: November, 2002), and GE (Released: January, 2002)

Note: EPA data from 1998, except White Sucker (2000). GE adult fish from 1998 and 2002 (largemouth bass).
T or CN: samples for which PCB concentrations is reported on Aroclor-based and congener-based, respectively.
R: whole body reconstructed from fillet and offal. Split samples were not included.

DR - \\Poseidon\E_Drive\GENhou\Analysis\Biota\RFI_Specific\raw_data_combined_fig_rfi_PCBlipvwgt_calc_wbr_062403.pro
Tue Jul 01 12:22:00 2003

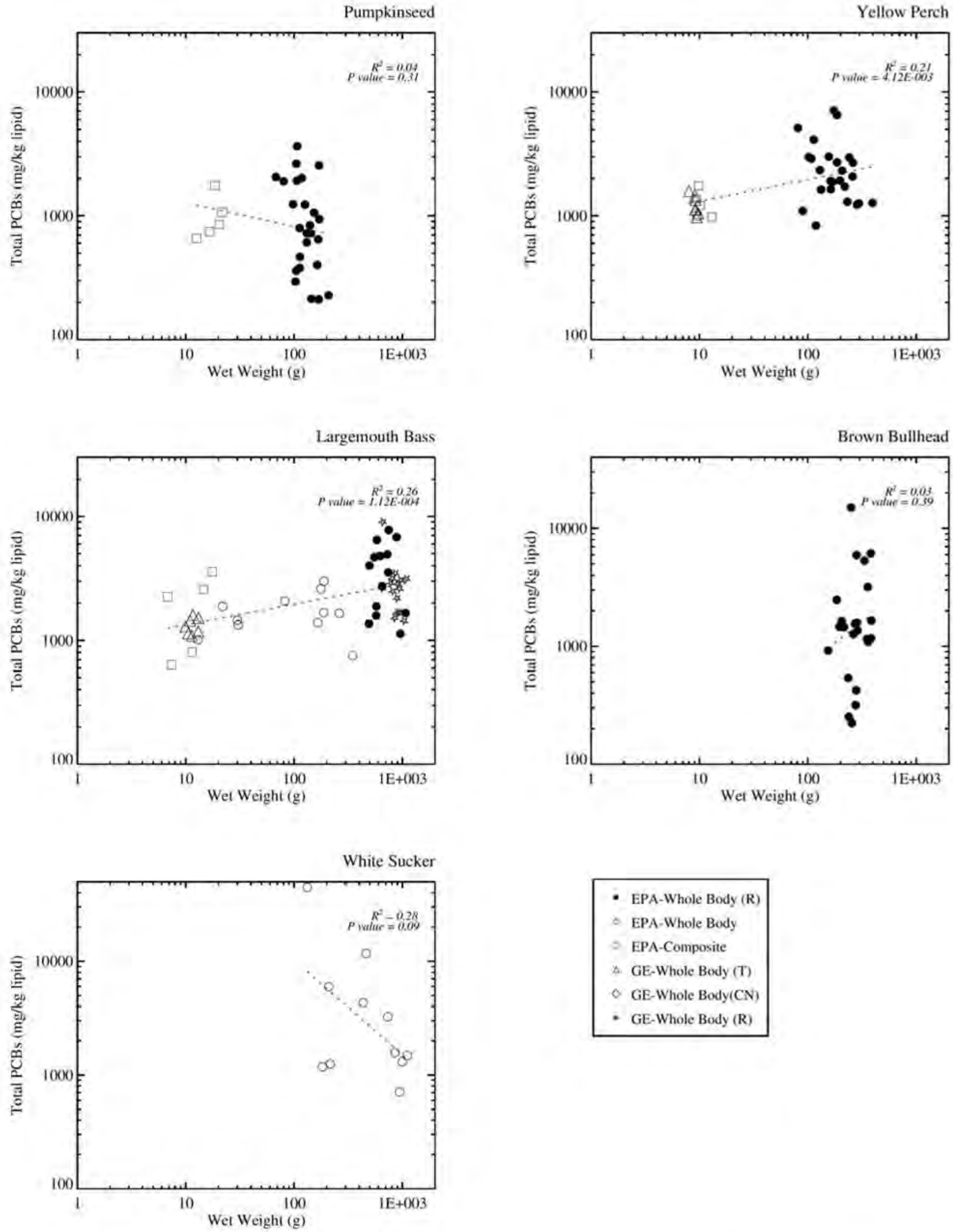

Figure 6-4b. Relationship between lipid-based PCB concentrations and wet weight (Woods Pond).

Data: EPA (Released: November, 2002), and GE (Released: January, 2002)

Note: EPA data from 1998, except White Sucker (2000). GE adult fish from 1998 and 2002 (largemouth bass).
T or CN: samples for which PCB concentrations is reported on Aroclor-based and congener-based, respectively.
R: whole body reconstructed from fillet and offal. Split samples were not included.

DR - \\Poseidon\E_Drive\GENhou\Analysis\Biota\RFI_Specific\raw_data_combined_fig_rfi_PCBlipvwgt_calc_wbr_062403.pro
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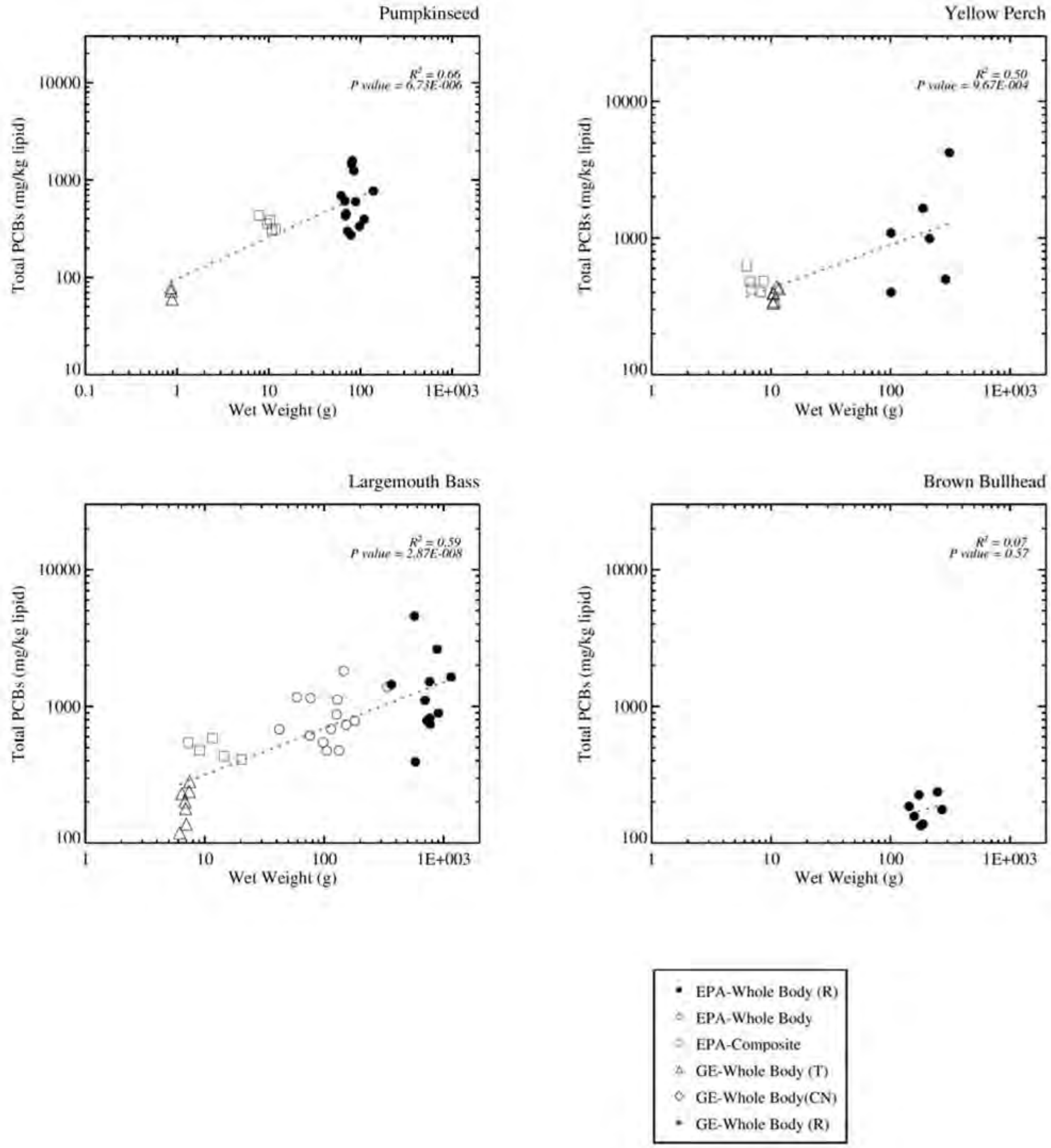

Figure 6-4c. Relationship between lipid-based PCB concentrations and wet weight (Rising Pond).

Data: EPA (Released: November, 2002), and GE (Released: January, 2002)

Note: EPA data from 1998, except White Sucker (2000). GE adult fish from 1998 and 2002 (largemouth bass).
T or CN: samples for which PCB concentrations is reported on Aroclor-based and congener-based, respectively.
R: whole body reconstructed from fillet and offal. Split samples were not included.

DR - \\Poseidon\E_Drive\GENhou\Analysis\Biota\RFI_Specific\raw_data_combined_fig_rfi_PCBlipvwgt_calc_wbr_062403.pro
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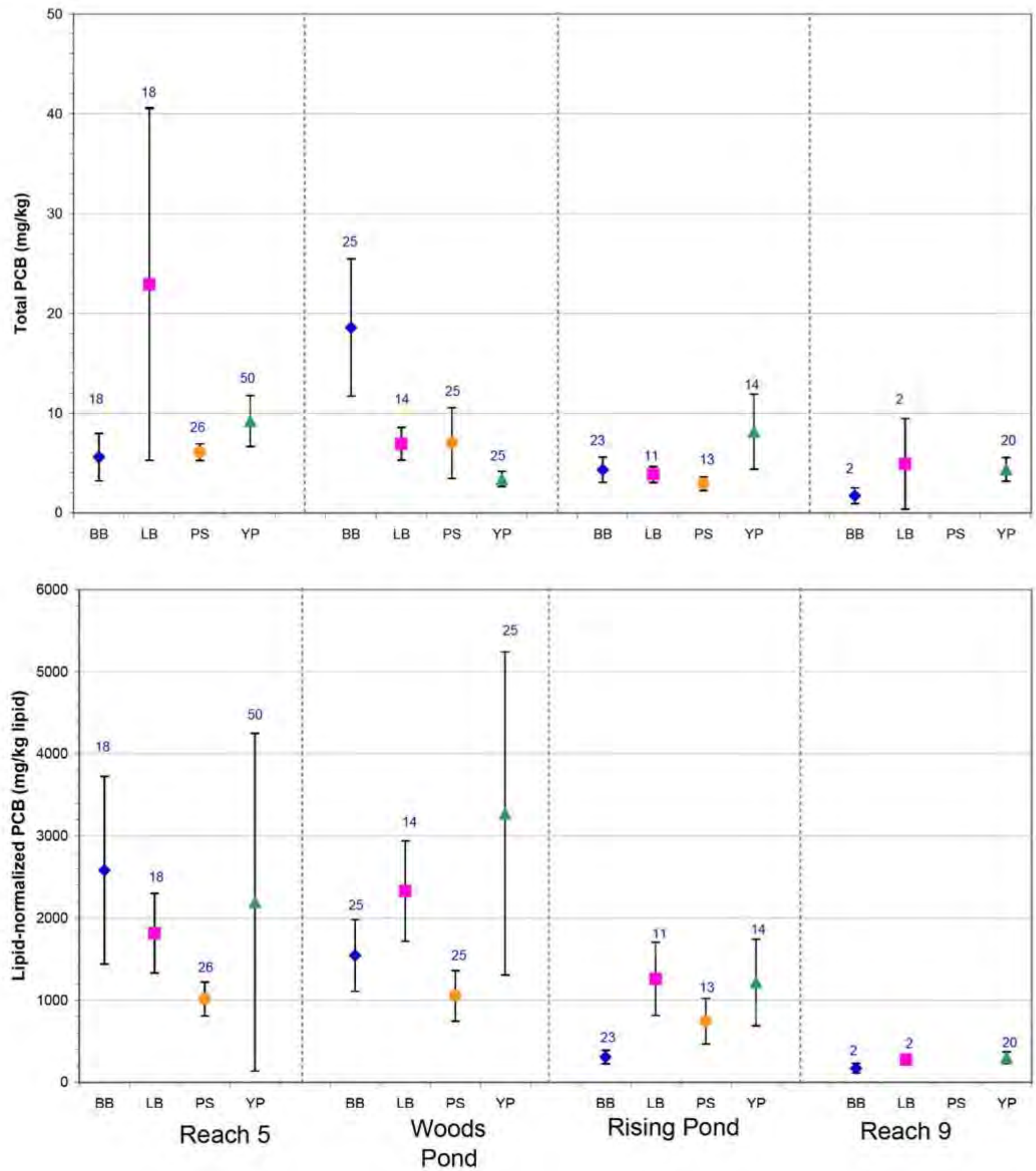


Notes:

1. BB - Brown Bullhead
2. LB - Largemouth Bass
3. PS - Pumpkinseed
4. YP - Yellow Perch
5. PCB - polychlorinated biphenyl
6. mg/kg = milligram/kilogram
7. mg/kg-lipid = milligram/kilogram-lipid
8. Presents data collected by the EPA in 1998 with 1998 GE data for Reach 9. In Rising Pond, EPA and GE fillet data were combined
9. Arithmetic means. Error bars represent +/- 2 standard errors. Number of observations is indicated.
10. Lipid-normalized mean concentration determined by dividing the total PCB concentration (in mg/kg) for each sample in the data set by the sample's associated lipid content (kg lipid / kg wet-weight), and calculating arithmetic mean of those values.

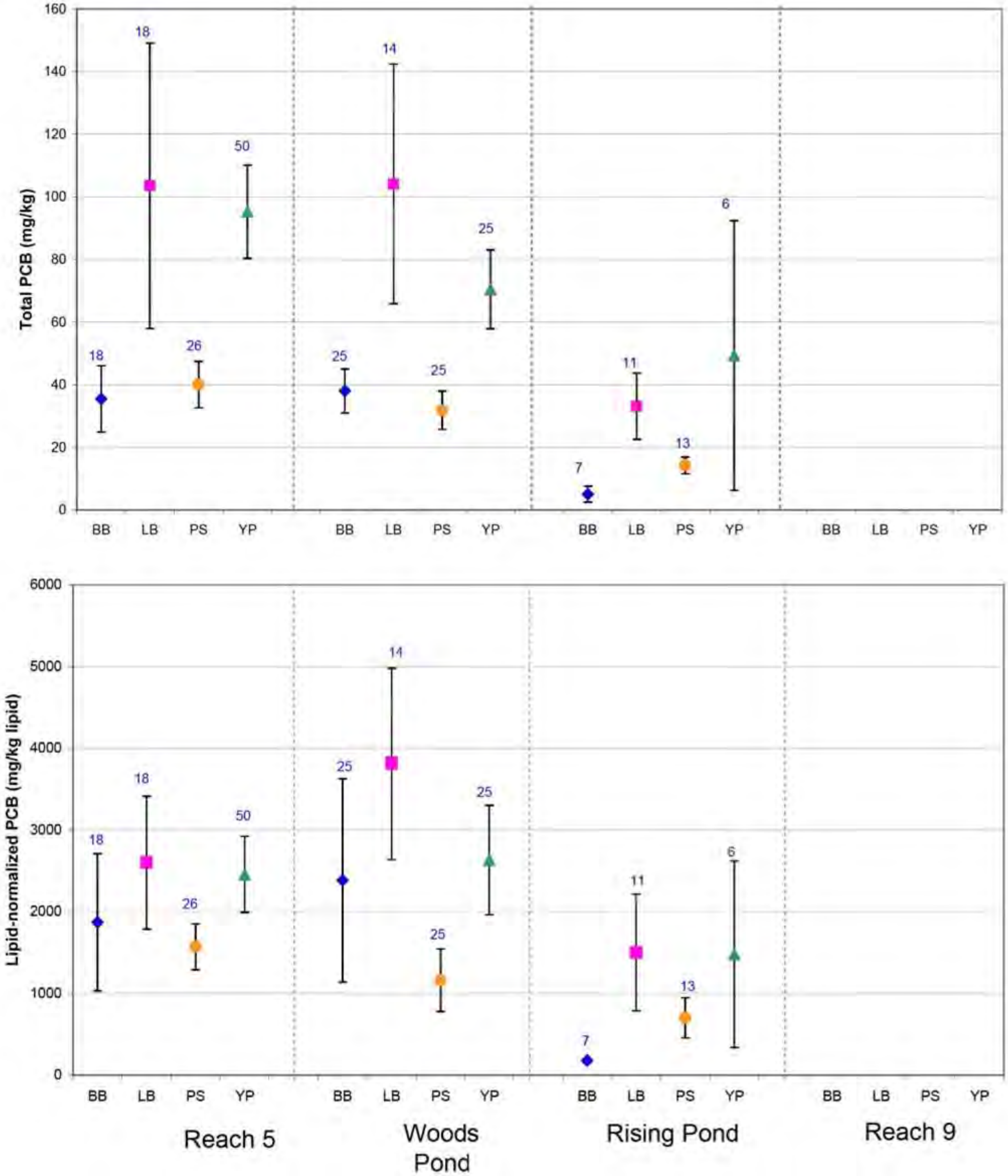
General Electric Company
Housatonic River - Rest of River
RFI Report

SPATIAL DISTRIBUTION OF PCB LEVELS IN LARGE FISH (FILLET)

QEA Quantitative Environmental Analysis, LLC

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 6-5a



Notes:
1. BB - Brown Bullhead
2. LB - Largemouth Bass
3. PS - Pumpkinseed
4. YP - Yellow Perch
5. PCB - polychlorinated biphenyl
6. mg/kg = milligram/kilogram
7. mg/kg-lipid = milligram/kilogram-lipid
8. Presents data collected by the EPA in 1998.
9. Arithmetic means. Error bars represent +/- 2 standard errors. Number of observations is indicated.
10. Lipid-normalized mean concentration determined by dividing the total PCB concentration (in mg/kg) for each sample in the data set by the sample's associated lipid content (kg lipid / kg wet-weight), and calculating arithmetic mean of those values.

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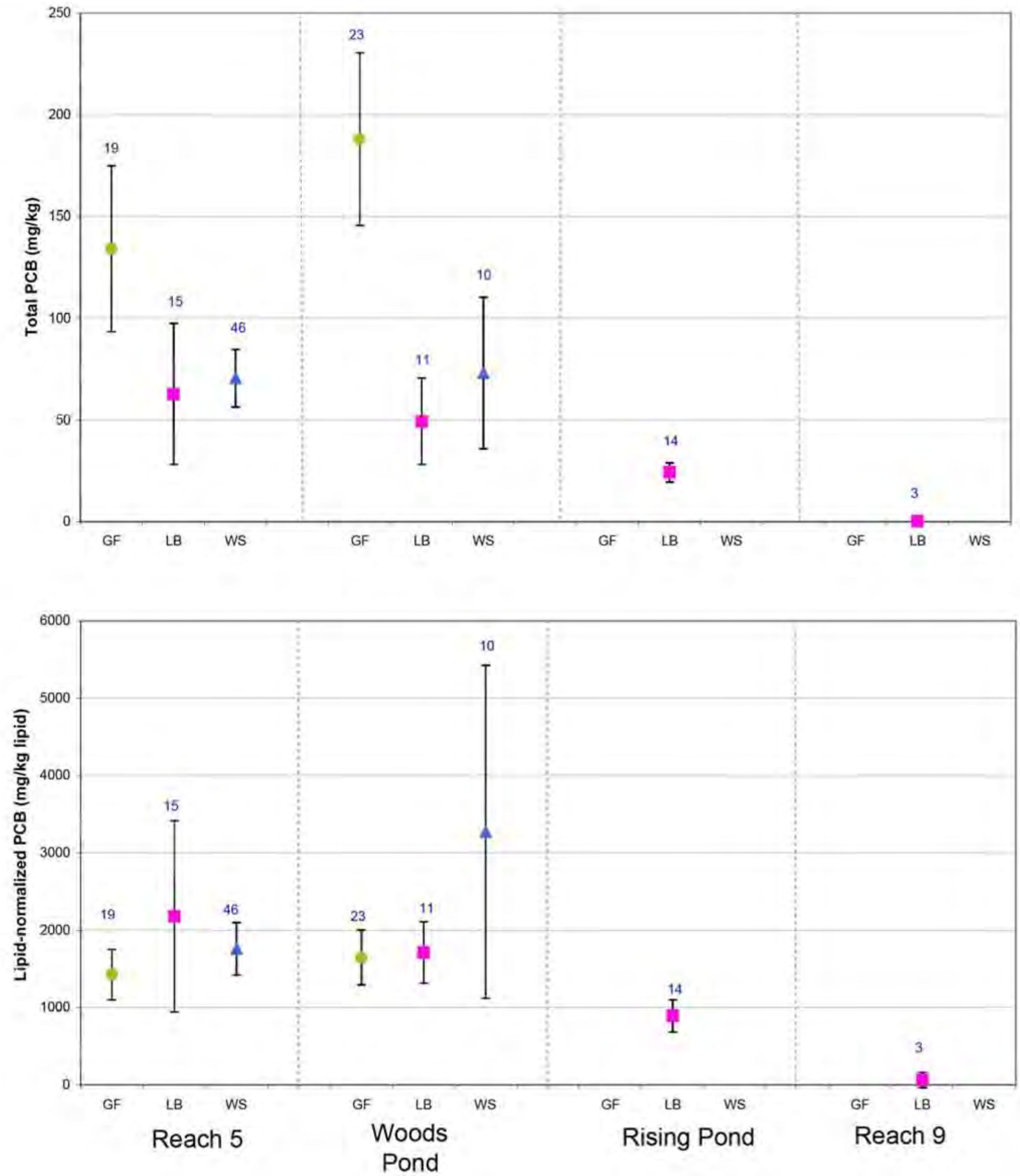
SPATIAL DISTRIBUTION OF PCB LEVELS IN LARGE FISH (RECONSTRUCTED WHOLE BODY)

QEA Quantitative Environmental Analysis, LLC

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 6-5b



Notes:
1. GF - Goldfish
2. LB - Largemouth Bass
3. WS - White Sucker
4. PCB - polychlorinated biphenyl
5. mg/kg - milligram/kilogram
6. mg/kg-lipid = milligram/kilogram-lipid
7. Presents data collected by the EPA in 1998 and 2000, and 1998 GE data for Reach 9.
8. Arithmetic means. Error bars represent +/- 2 standard errors. Number of observations is indicated.
9. Lipid-normalized mean concentration determined by dividing the total PCB concentration (in mg/kg) for each sample in the data set by the sample's associated lipid content (kg lipid / kg wet-weight), and calculating arithmetic mean of those values.
10. One outlier (low lipid value) for WS in Woods Pond was removed; total PCB = 44.7 mg/kg wet weight, lipid = 0.1%; lipid-based PCB = 44,700 mg/kg lipid.

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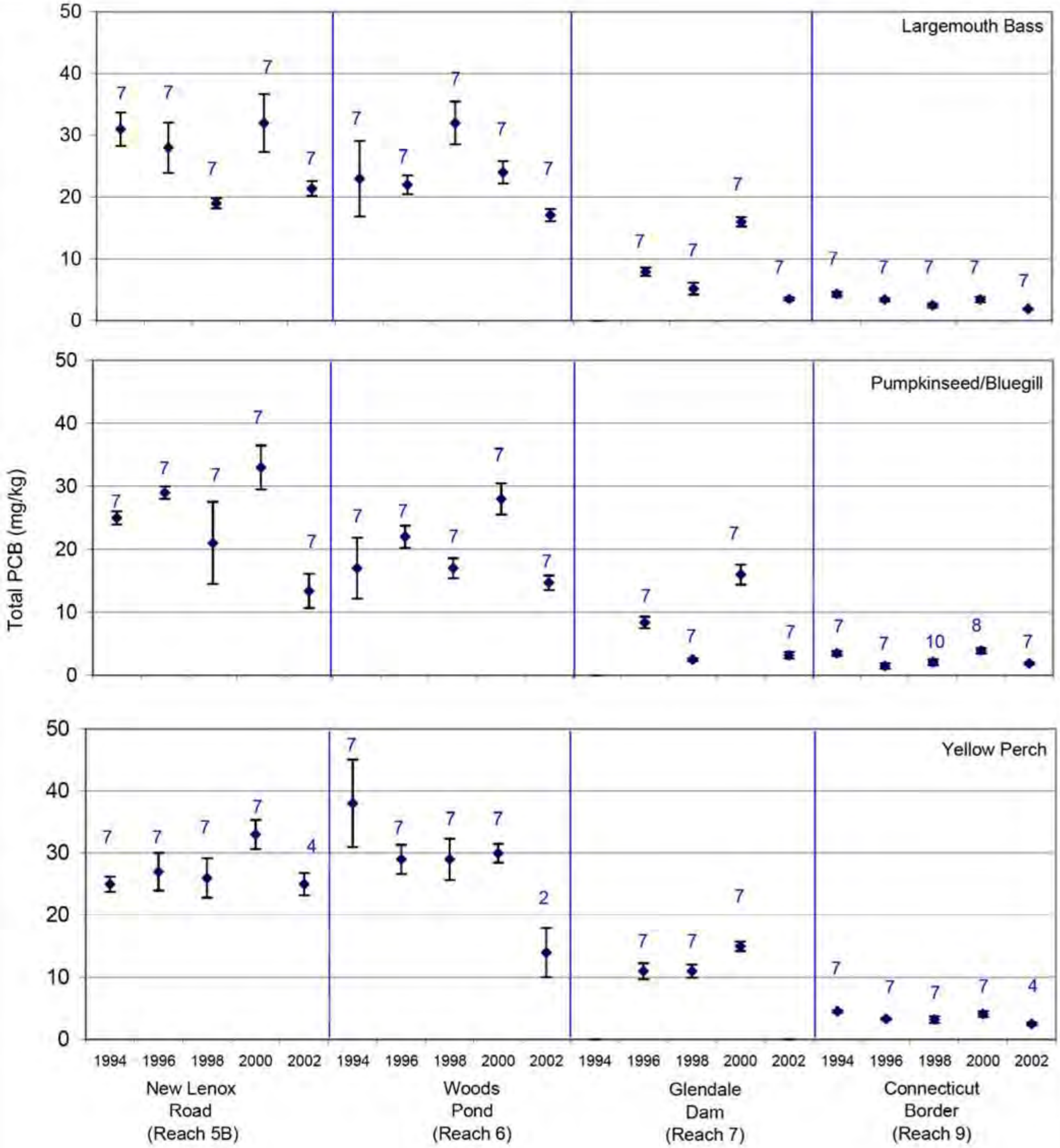
RFI Report

SPATIAL DISTRIBUTION OF PCB LEVELS IN INTERMEDIATE-SIZED FISH (WHOLE BODY)

QEA Quantitative Environmental Analysis, LLC

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 6-5c



Notes:
1. PCB - polychlorinated biphenyl
2. mg/kg = milligram/kilogram
3. Presents all young-of-year data collected by BBL in 1994, 1996, 1998, 2000, and 2002.
4. Arithmetic means. Error bars represent +/- 2 standard errors. Number of observations is indicated.

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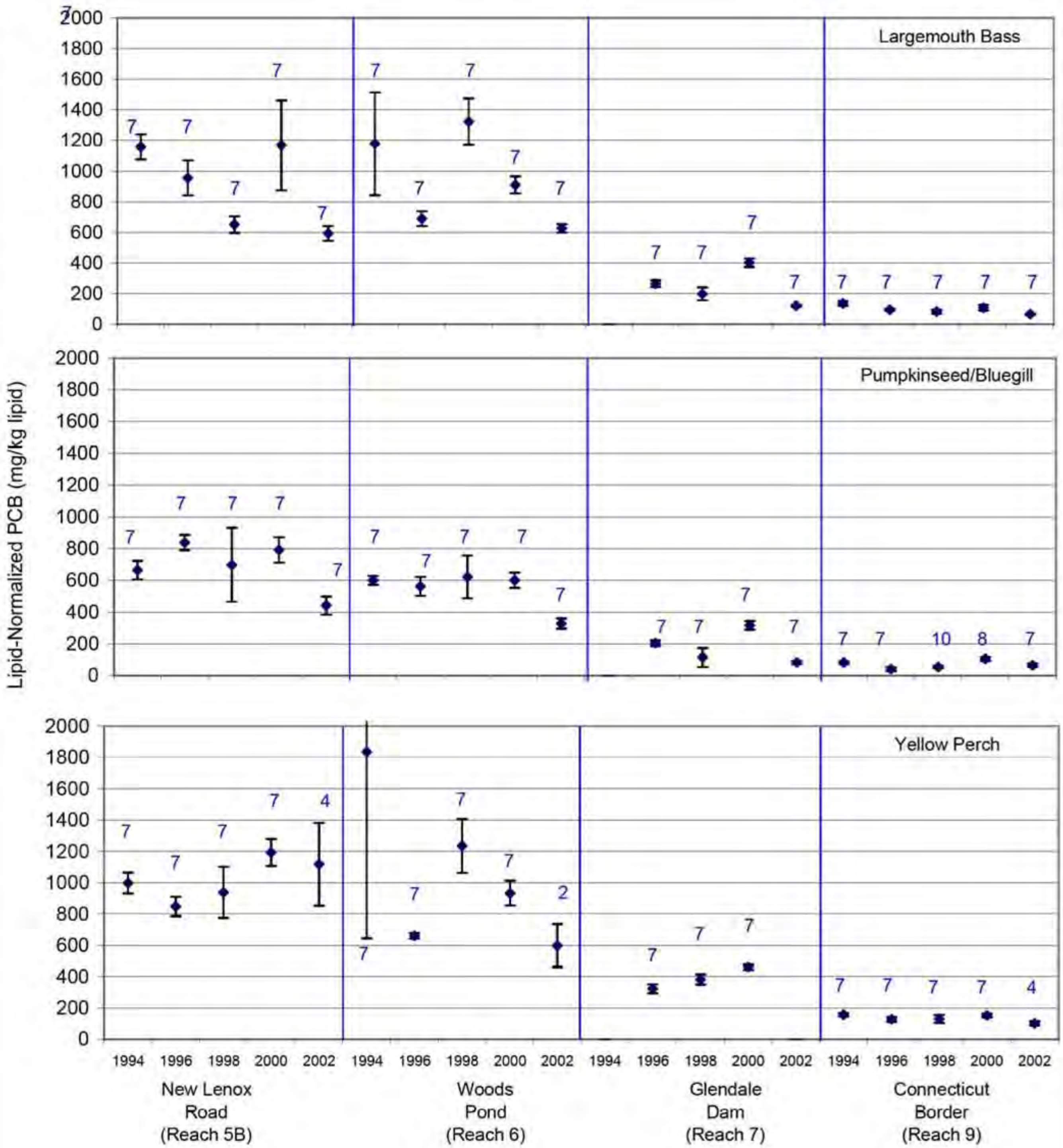
RFI Report

TEMPORAL AND SPATIAL DISTRIBUTION OF PCB LEVELS IN YOUNG-OF-YEAR FISH TISSUE (WET-WEIGHT)

QEA Quantitative Environmental Analysis, LLC

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 6-6a



Notes:
1. PCB - polychlorinated biphenyl
2. mg/kg-lipid = milligram/kilogram-lipid
3. Presents all young-of-year data collected by BBL in 1994, 1996, 1998, 2000, and 2002.
4. Arithmetic means. Error bars represent +/- 2 standard errors. Number of observations is indicated.
5. Lipid-normalized mean concentration determined by dividing the total PCB concentration (in mg/kg) for each sample in the data set by the sample's associated lipid content (in kg/lipid/kg wet-weight), and calculating the arithmetic mean of those values.

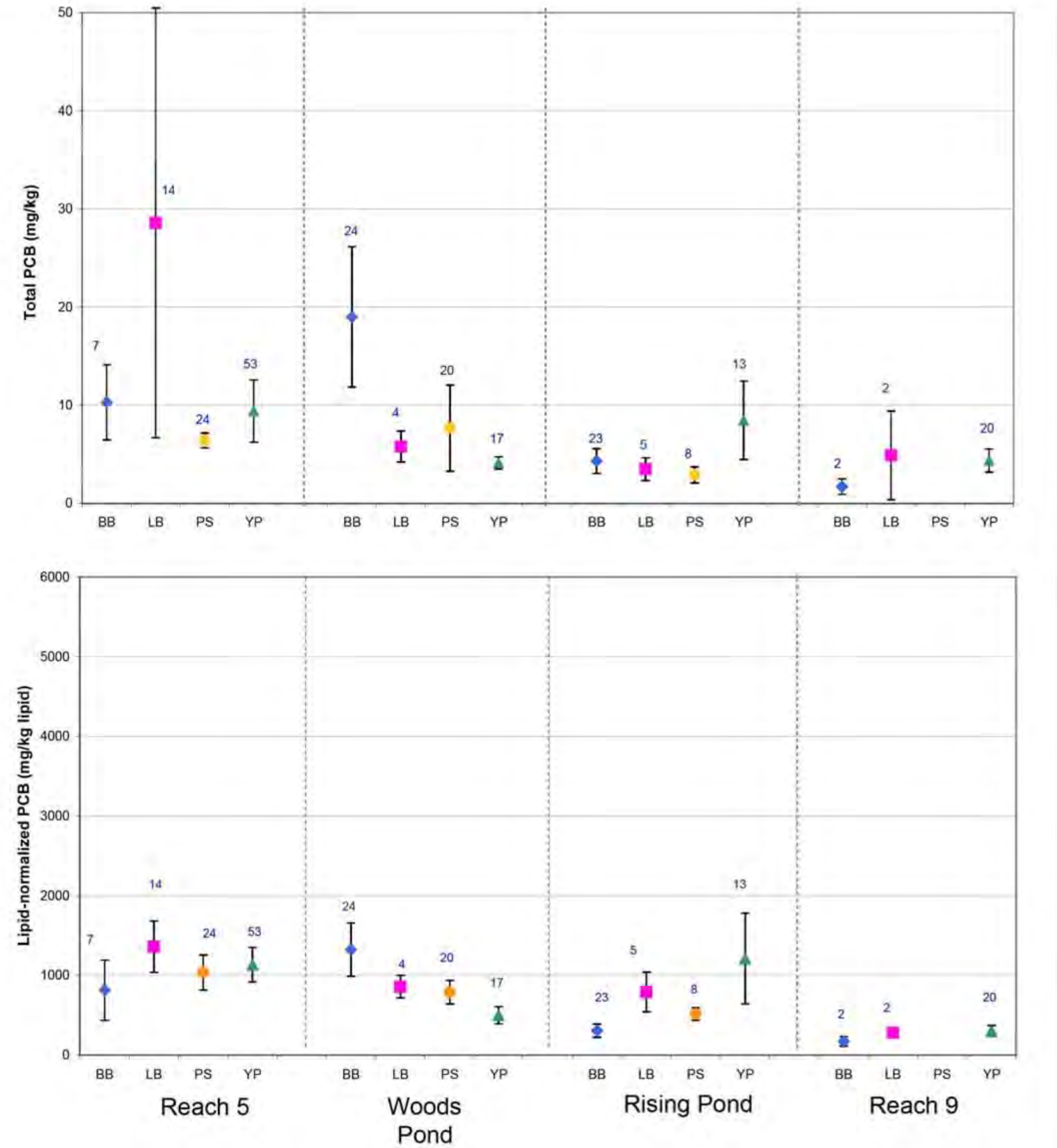
General Electric Company
Housatonic River - Rest of River
RFI Report

TEMPORAL AND SPATIAL DISTRIBUTION OF PCB LEVELS IN YOUNG-OF-YEAR FISH TISSUE (LIPID-NORMALIZED)

QEA Quantitative Environmental Analysis, LLC

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 6-6b



Notes:
1. LB - Largemouth Bass
2. YP - Yellow Perch
3. PS - Pumpkinseed
4. BB - Brown Bullhead
5. PCB - polychlorinated biphenyl
6. mg/kg = milligram/kilogram
7. mg/kg-lipid = milligram/kilogram-lipid
8. Presents data collected by the EPA in 1998 with 1998 GE data for Reach 9. In Rising Pond, EPA and GE data were combined.
9. Arithmetic means. Error bars represent +/- 2 standard errors. Number of observations is indicated.
10. Lipid-normalized mean concentration determined by dividing the total PCB concentration (in mg/kg) for each sample in the data set by the sample's associated lipid content (kg lipid / kg wet-weight), and calculating the arithmetic mean of those values.

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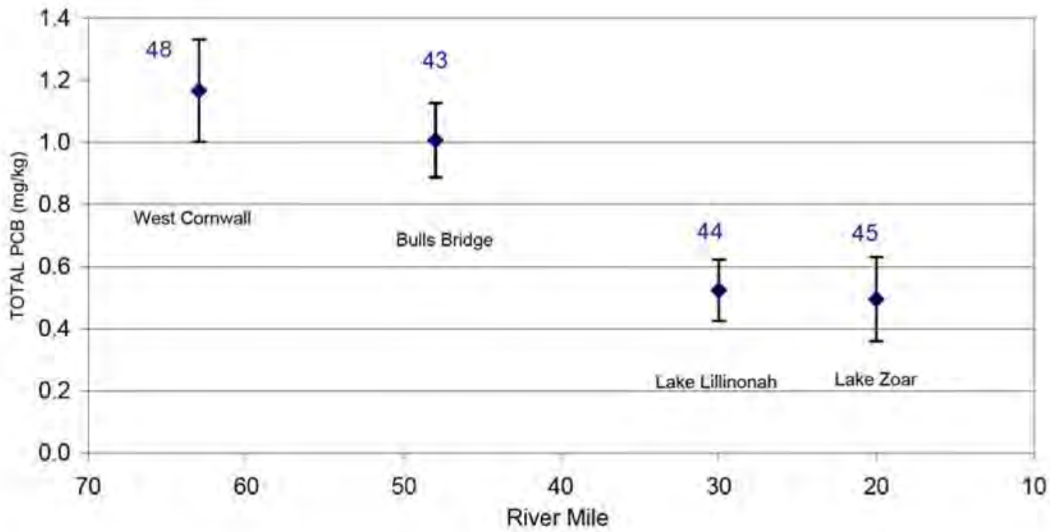
Housatonic River - Rest of River
RFI Report

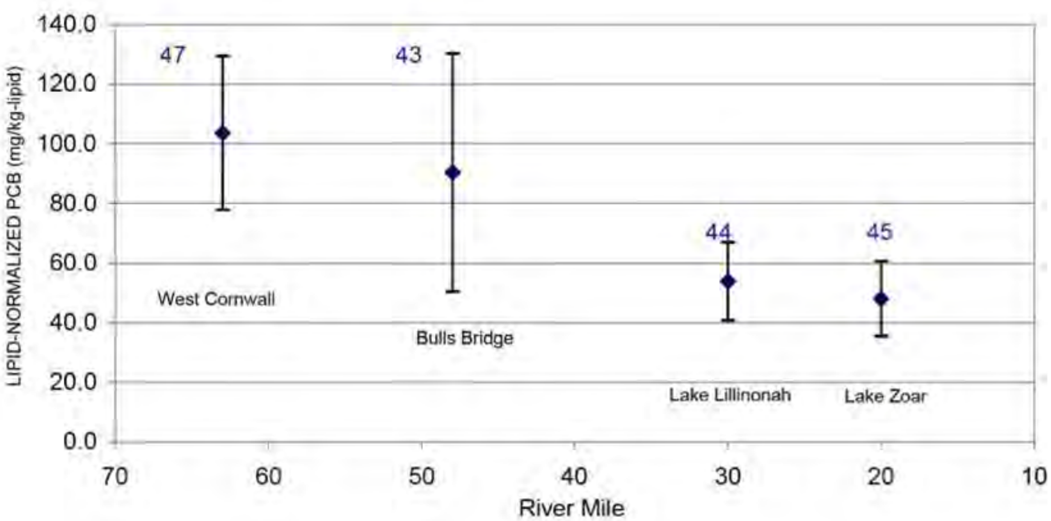
SPATIAL DISTRIBUTION OF PCB LEVELS IN LARGE FISH (FILLET) WHERE FILLET LIPID > 0.3%

QEA Quantitative Environmental Analysis, LLC

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 6-7





Notes:
1. Data include the combined smallmouth bass fillet samples from 1994 through 2002.
2. Source of Data: ANSP fish tissue data sheets.
3. PCB - polychlorinated biphenyl.
4. mg/kg - milligram/kilogram.
5. mg/kg-lipid - milligram/kilogram-lipid.
6. Lipid-normalized mean concentrations determined by dividing the total PCB concentration (in mg/kg) for each sample by the sample's associated lipid content (kg lipid/kg wet-weight, and calculating the arithmetic mean of those values.
7. Arithmetic means. Error bars represent +/- 2 standard errors.

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Housatonic River - Rest of River
RFI Report

WET WEIGHT AND LIPID-NORMALIZED PCB LEVELS IN SMALLMOUTH BASS TISSUE COLLECTED FROM THE CONNECTICUT SECTION OF THE HOUSATONIC RIVER

QEA Quantitative Environmental Analysis, LLC

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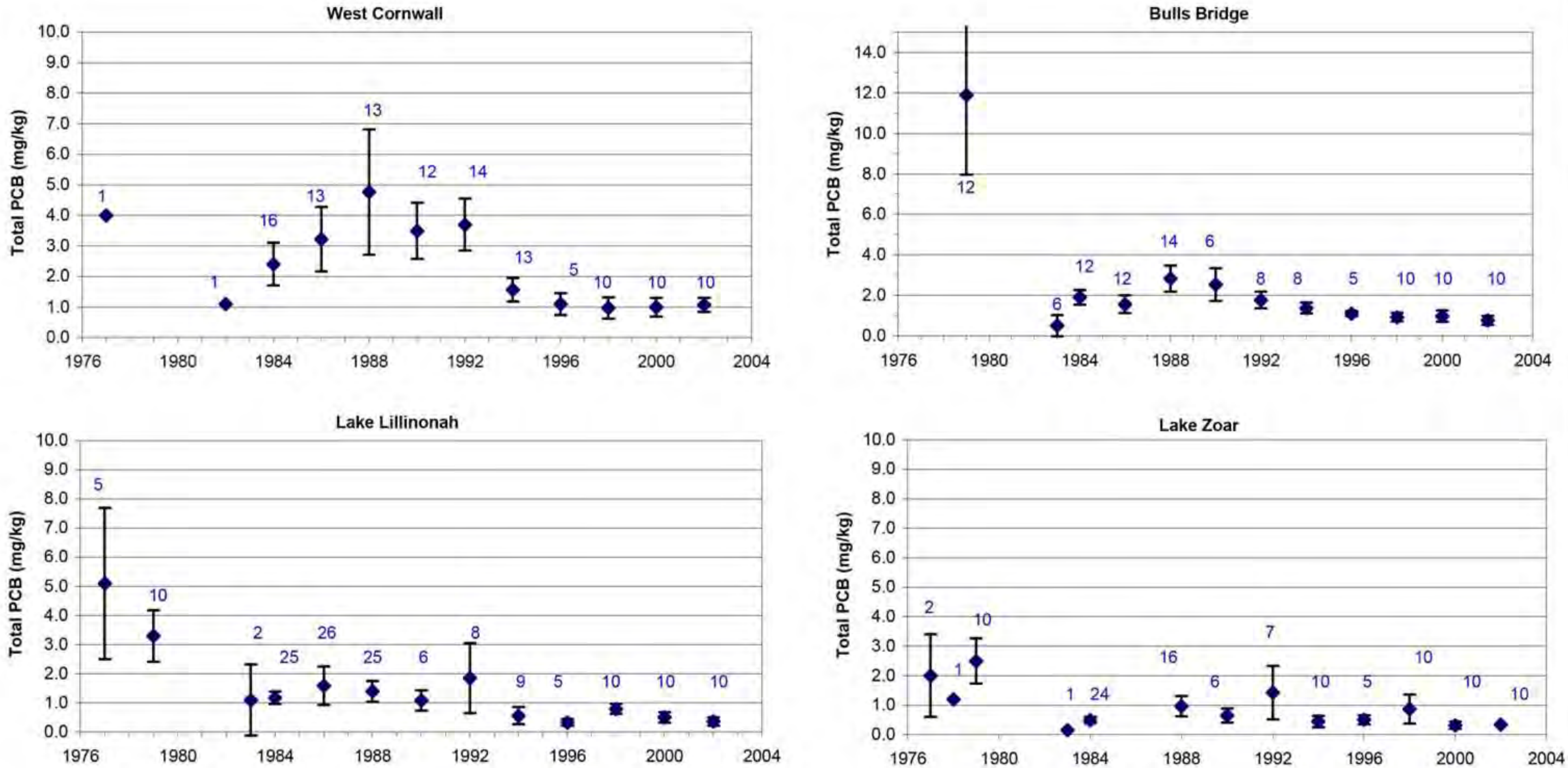
FIGURE 6-8



Notes:

1. Source of data: ANSP and CDEP fish tissue data summary sheets.
2. PCB - polychlorinated biphenyl
3. mg/kg - milligram/kilogram
4. Arithmetic means. Error bars represent +/- 2 standard errors.
5. Data are Aroclor-based total PCBs.

General Electric Company
Housatonic River - Rest of River
RFI Report

WET-WEIGHT PCBs IN SMALLMOUTH BASS TISSUE COLLECTED FROM THE CONNECTICUT SECTION OF THE HOUSATONIC RIVER

QEA Quantitative Environmental Analysis, LLC

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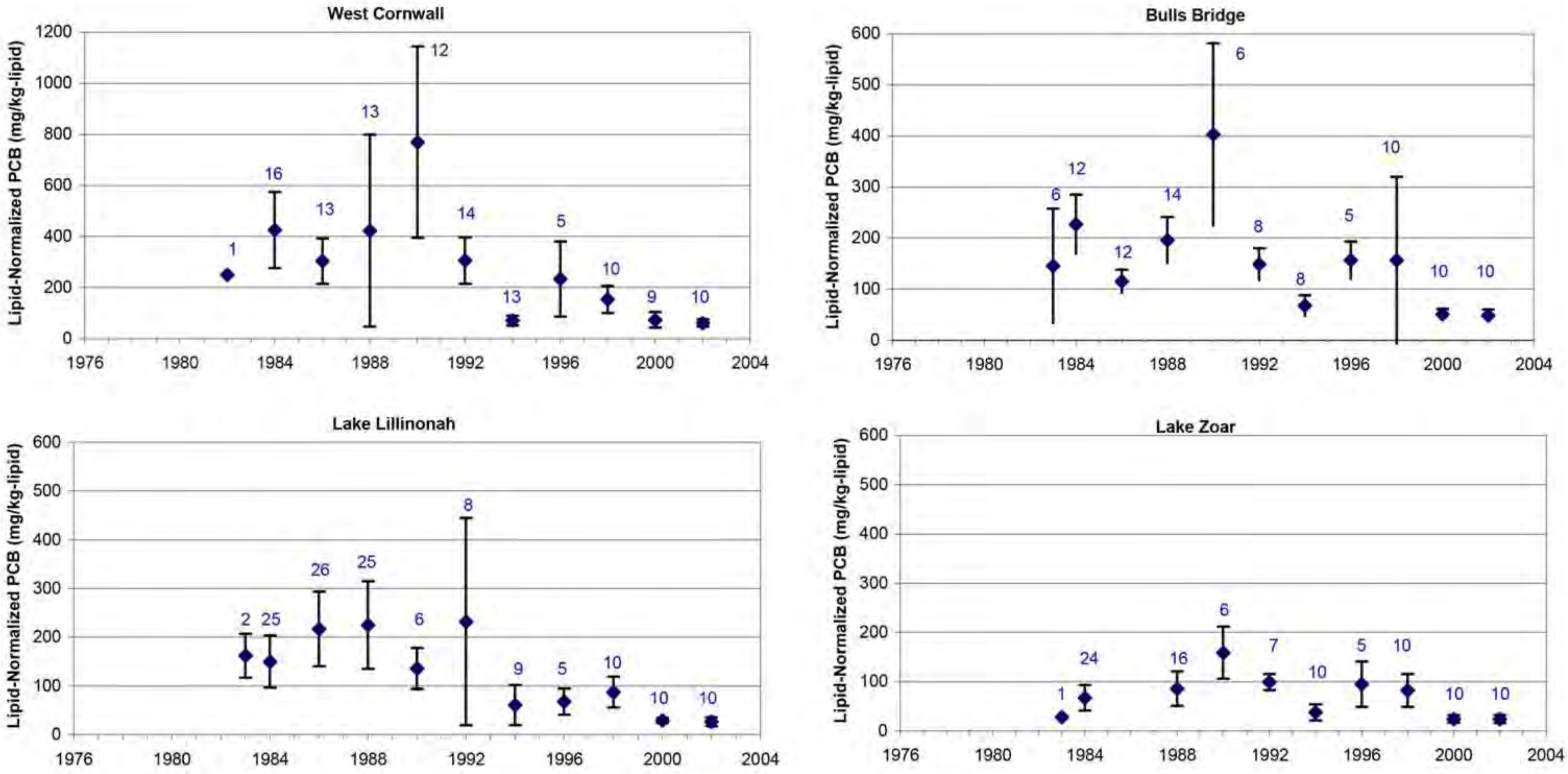
FIGURE 6-9a



Notes:
1. Source of data: ANSP and CDEP fish tissue data summary sheets.
2. PCB - polychlorinated biphenyl
3. mg/kg-lipid - milligram/kilogram-lipid
4. Lipid-normalized mean concentrations determined by dividing the total PCB concentration (in mg/kg) for each sample by the sample's associated lipid content (kg lipid/kg wet-weight), and calculating the arithmetic mean of those values.
5. The pronounced peak in lipid-normalized total PCB in 1990 is due to unusually low lipid levels rather than high total PCB levels.
6. Lipid data are not available for samples collected in the 1970s.
7. Arithmetic means. Error bars represent +/-2 standard errors.
8. Data are Aroclor-based total PCBs.

General Electric Company
Housatonic River - Rest of River
RFI Report

LIPID-NORMALIZED PCBs IN SMALLMOUTH BASS TISSUE COLLECTED FROM THE CONNECTICUT SECTION OF THE HOUSATONIC RIVER

QEA Quantitative Environmental Analysis, LLC

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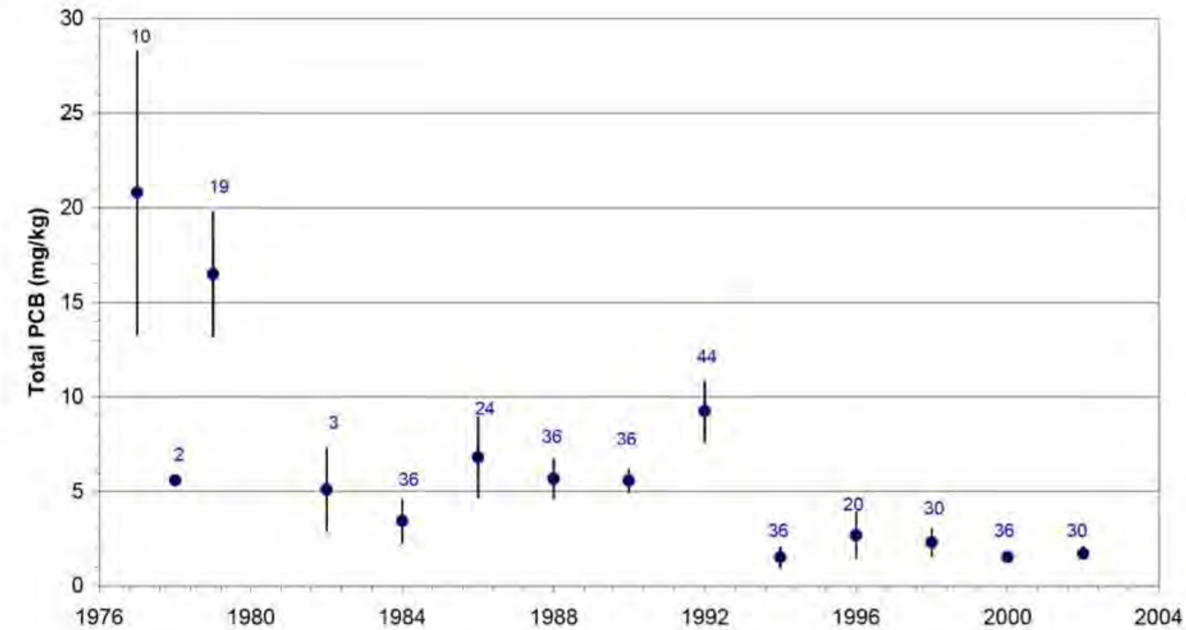
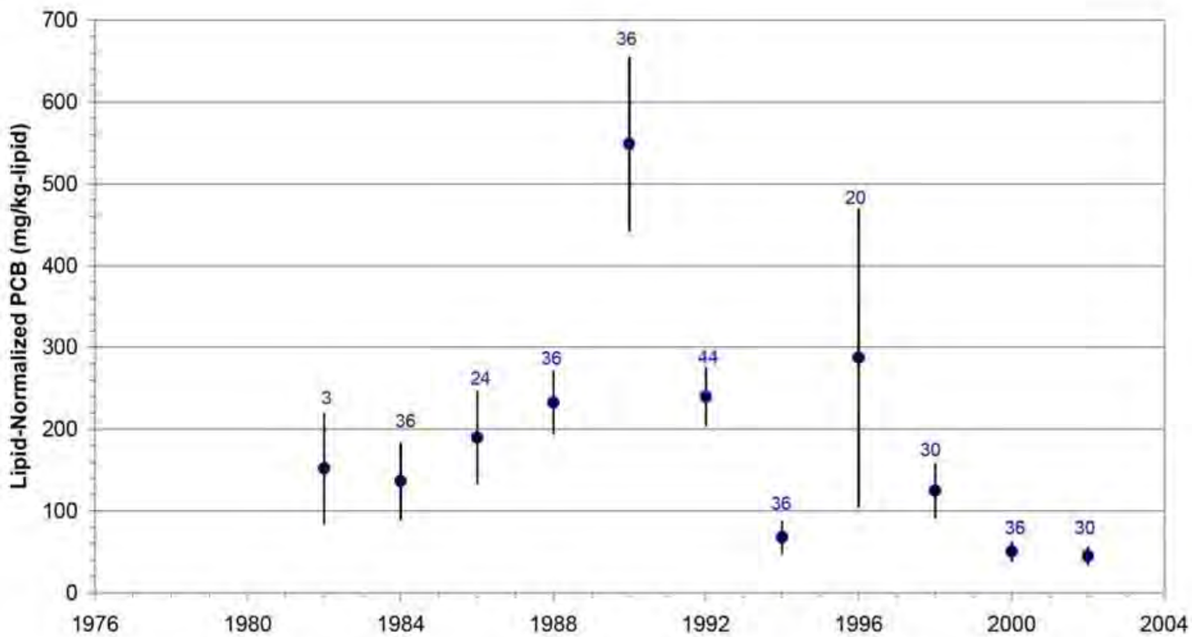
FIGURE 6-9b





Notes:
1. Source of data: CDEP and ANSP fish tissue data summary sheets.
2. PCB - polychlorinated biphenyl
3. mg/kg - milligram/kilogram
4. mg/kg-lipid - milligram/kilogram-lipid
5. Lipid-normalized mean concentration determined by dividing the total PCB concentration (in mg/kg) for each sample in the data set by the sample's associated lipid content (kg lipid/kg wet-weight), and calculating the arithmetic mean of those values.
6. The pronounced peak in lipid-normalized PCB in 1990 is due to unusually low lipid values rather than high total PCB levels.
7. Arithmetic means of skin-on/scales-on fillets. Error bars represent +/- 2 standard errors. Number of observations is indicated.
8. Data are Aroclor-based total PCBs.

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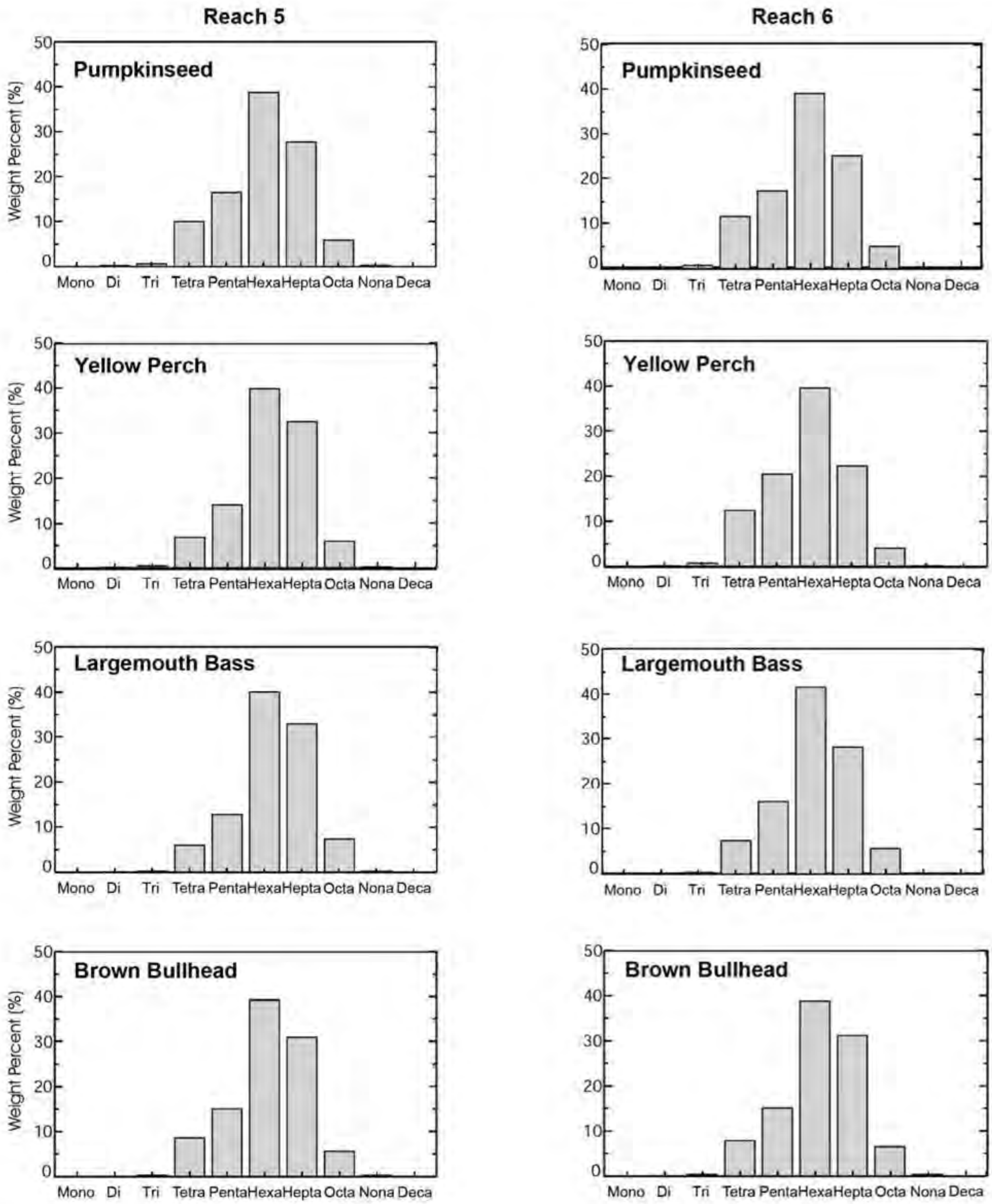
Housatonic River - Rest of River
RFI Report

PCBs IN BROWN TROUT FILLETS COLLECTED FROM HOUSATONIC RIVER AT WEST CORNWALL, CT

QEA
BBL
BLASLAND, BOUCK & LEE, INC.
engineers & scientists

FIGURE 6-10



NOTES:

1. Data sets included in the average are from the November 2002 EPA/Weston data release.
2. Fillet samples only.

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HOUSATONIC RIVER - REST OF RIVER

RFI REPORT

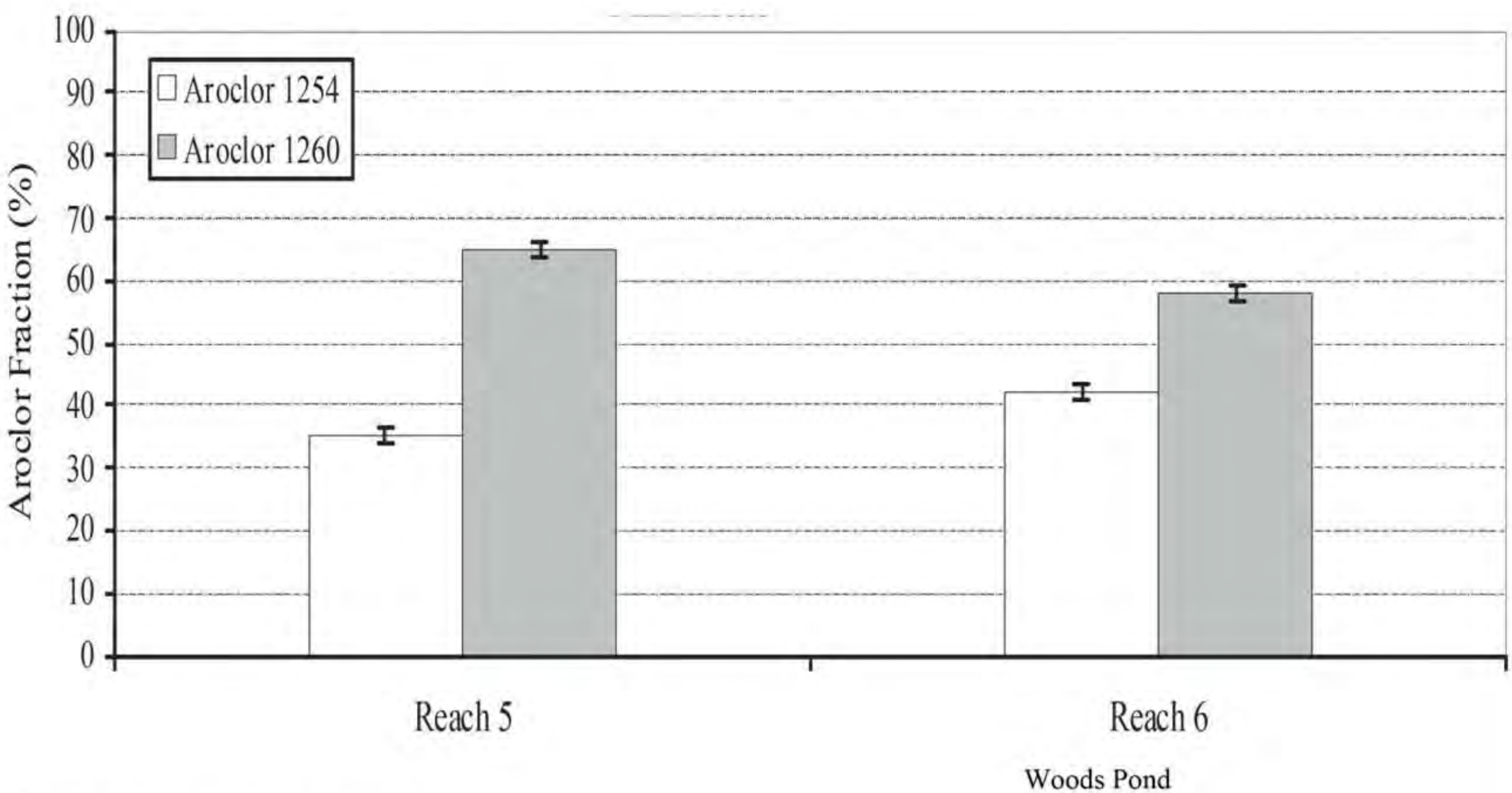
AVERAGE FISH TISSUE PCB HOMOLOG DISTRIBUTIONS

BLASLAND, BOUCK & LEE, INC.
engineers & scientists

Quantitative Environmental Analysis, LLC

FIGURE 6-11

12/20/02 SYR-D54-DJH LAS
C:/20199072/20199g16.cdr



Notes
1. Includes the combined data from 1994 to 2000, all species
2. Arithmetic means. Error bars represent +/- 2 standard errors.

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Housatonic River - Rest of River
RFI Report

AVERAGE AROCLOR COMPOSITION IN YOUNG-OF-YEAR FISH TISSUE SAMPLES FROM THE HOUSATONIC RIVER

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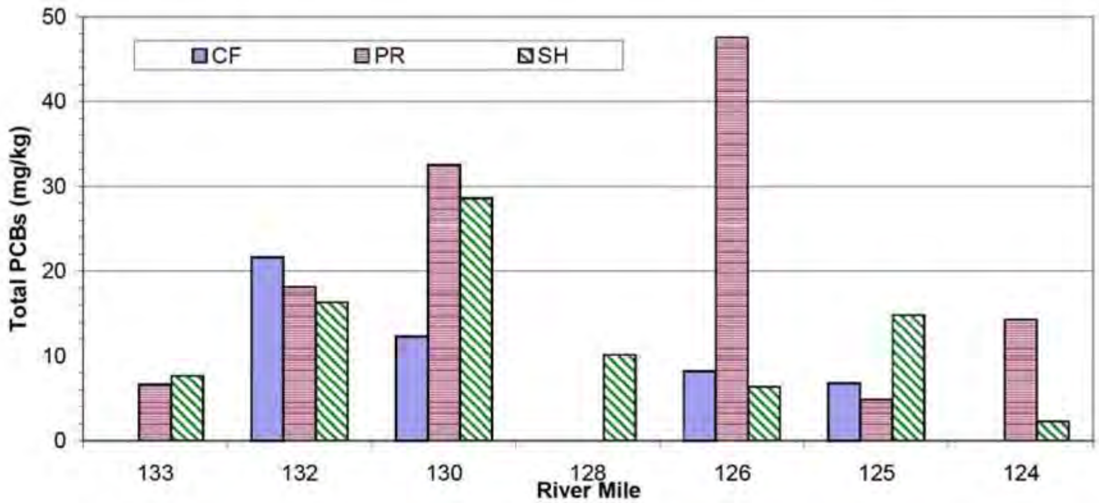
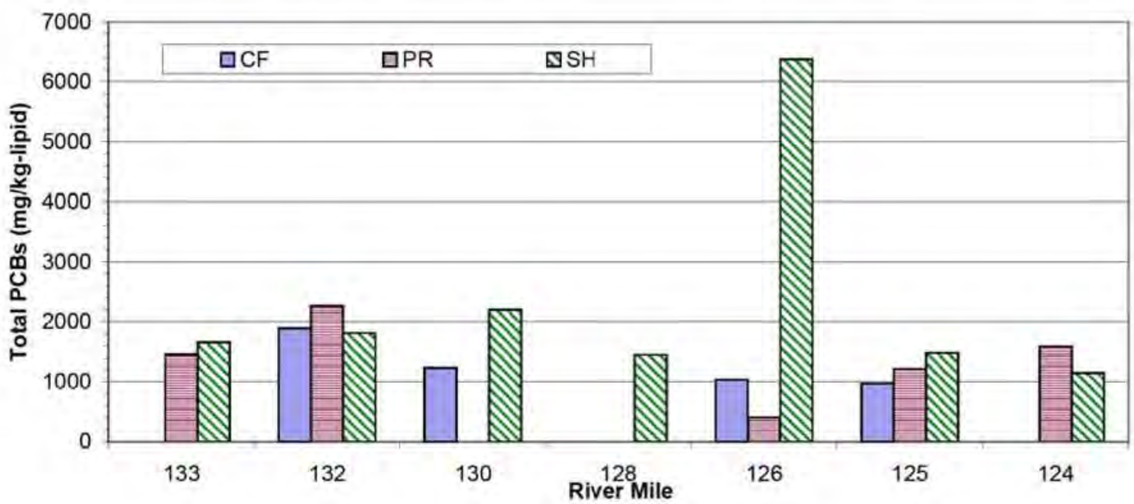
FIGURE 6-12

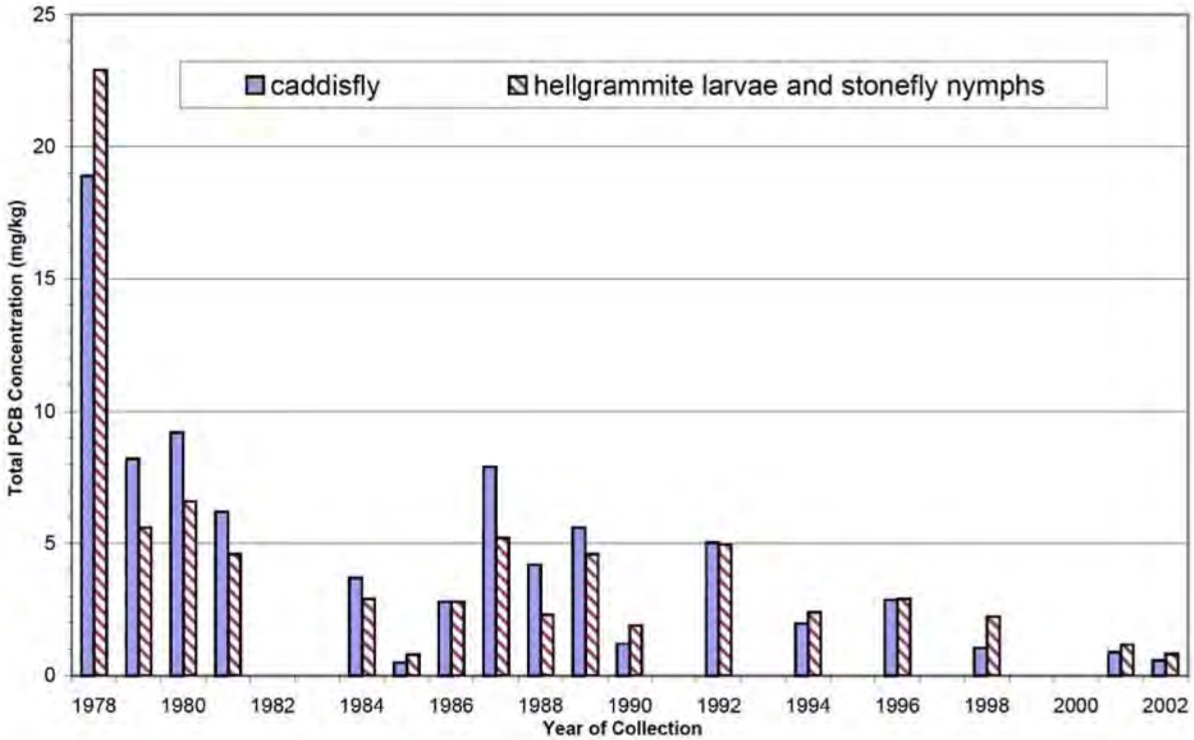
Figure 6-13. Total PCB Concentration in Benthic Macroinvertebrates from Reaches 5 and 6





Notes:

PCBs = polychlorinated biphenyls, measured as PCB congeners
EPA data collected in 1999.
CF = crayfish; PR = predators (insects); SH = shredders (primarily insects).
River miles are approximate.
Two samples each for PR and SH between river miles 134 and 133 were averaged for the value reported at 133.
No lipid data available for PR at RM 130.
At RM 126, PR lipid = 11.7% versus average of 0.63% for all other PR samples.
At RM 126, SH lipid = 0.10% versus average of 0.80% for all other SH samples.



Notes:

1. Source of data: ANSP and CDEP tissue data summary sheets.
2. PCB - polychlorinated biphenyl
3. mg/kg - milligram/kilogram

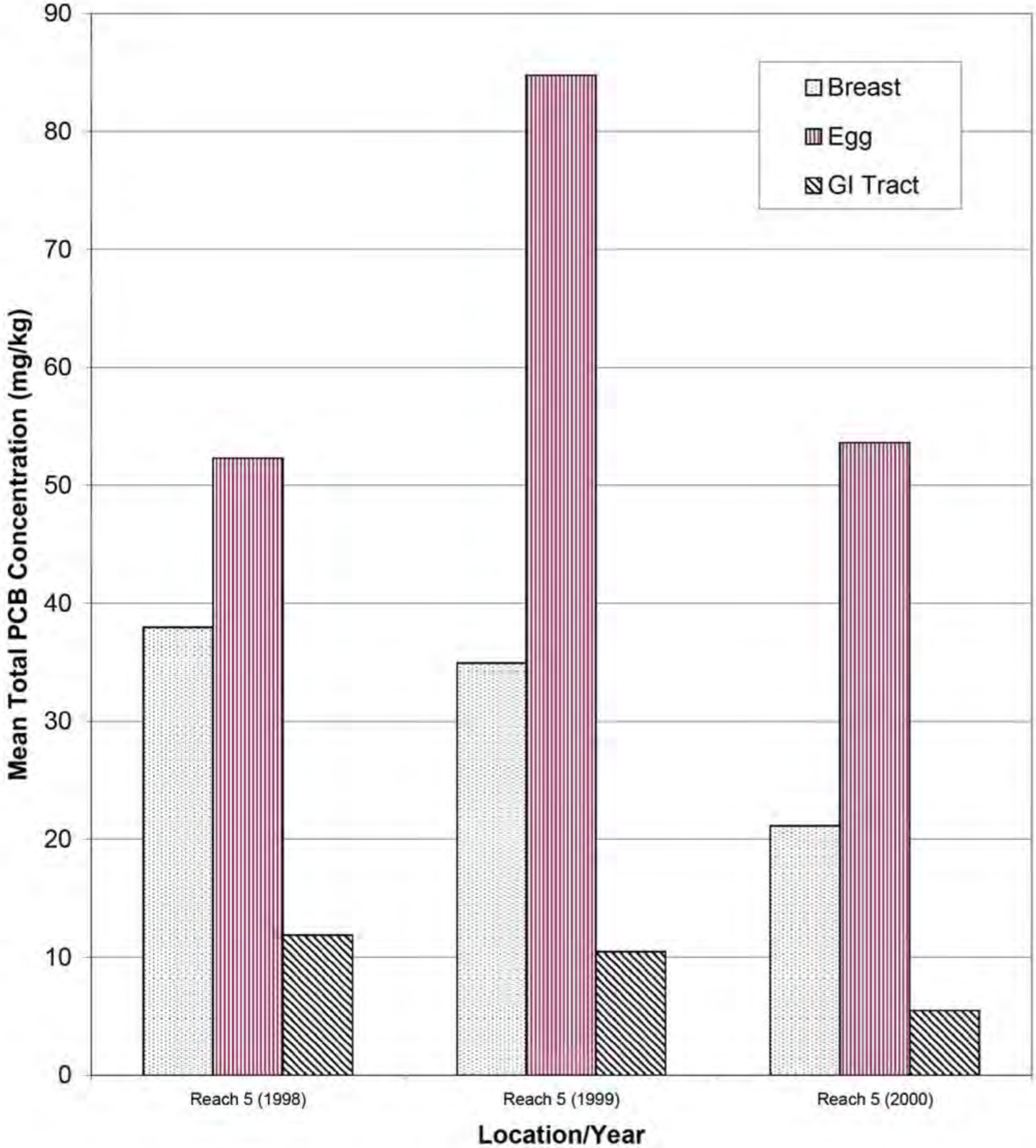
General Electric Company
Housatonic River - Rest of River
RFI Report

TEMPORAL DISTRIBUTION OF PCB LEVELS IN BENTHIC MACROINVERTEBRATES COLLECTED FROM WEST CORNWALL, CONNECTICUT

QEA Quantitative Environmental Analysis, LLC

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 6-14



Notes:
1. Data are from the EPA/Weston November 2002 Database release.
2. PCB - polychlorinated biphenyl
3. mg/kg - milligram/kilogram
4. GI - gastro-intestinal
5. Mean total PCB concentrations represent arithmetic means.

General Electric Company
Housatonic River - Rest of River
RFI Report

PCB LEVELS IN TREE SWALLOWS COLLECTED FROM THE HOUSATONIC RIVER

QEA Quantitative Environmental Analysis, LLC

BBL BLASLAND, BOUCK & LEE, INC. engineers & scientists

FIGURE 6-15

Section 7

7. Air Monitoring Investigations

7.1 General

Beginning in 1991, a number of studies have been conducted within the Housatonic River environs to characterize ambient air PCB concentrations. The purpose of this section is to summarize the sampling and analysis activities and results regarding airborne PCB concentrations in and around the Housatonic River, with particular emphasis on the area between the Confluence and Woods Pond.

7.2 Supplemental Phase II/RFI Air Monitoring Activities (1995)

Ambient air monitoring for PCBs was conducted as part of the Supplemental Phase II/RFI activities from May to August 1995, resulting in eight sampling events. The air sampling was conducted as part of ongoing investigations of the Housatonic River and Silver Lake pursuant to the 1990 ACO (executed by GE and MDEP) and GE's prior RCRA Permit (under the supervision of MDEP and EPA). The objectives of the 1995 ambient air monitoring program were: 1) to obtain valid and representative ambient air levels of PCBs at locations near Silver Lake, Woods Pond, and the Housatonic riverbank between the GE facility and the Confluence; and 2) to evaluate the validity of low-volume sampling methods and their comparability to high-volume sampling methods (Zorex Environmental Engineers and Berkshire Environmental Consultants, 1996). These air monitoring activities were conducted at the station on the eastern shore of Silver Lake, two locations on the Housatonic River -- one upstream of the Confluence (Fred Garner Park) and one at Woods Pond -- and a background station (Berkshire Community College).

During the 1995 ambient air monitoring program, high-volume samplers established at the breathing zone (high elevation) were employed at all stations, while low-volume samplers at both high and low elevation were also used at the Silver Lake station. The sampling program consisted of eight high-volume sampling events and three low-volume sampling events. A total of 32 discrete high-volume samples (not including co-located or duplicate samples) and six discrete low-volume samples were collected. The details of this air monitoring program and a presentation and evaluation of the results were provided in a report prepared by Zorex Environmental Engineers and Berkshire Environmental Consultants (1996) titled *Ambient Air Monitoring for PCB: May 10, 1995 through August 24, 1995*. The conclusions of that report relevant to the Rest of River area are as follows:

- The mean high-volume spring/summer PCB concentrations along the Housatonic River at Fred Garner Park and Woods Pond measured 0.0055 $\mu g/m^3$ and 0.0033 $\mu g/m^3$, respectively.
- The mean ambient PCB concentration at the background location (Berkshire Community College) was 0.0012 $\mu g/m^3$.
- Temperature appears to have some impact on the variation in ambient PCB concentrations. Ambient PCB concentrations generally increase with increasing temperature above approximately 50°F to 60°F.
- The detection limits for the low-volume sampling methods were too high to provide definitive data.

7.3 EPA Supplemental Investigation Air Monitoring Activities (1999)

EPA conducted ambient air sampling downstream of the Confluence as part of its investigations. Two locations were selected for air sampling: one location across from the Decker Canoe Launch on the DeVos property (H3-AR000003) and the other at an access area off October Mountain Road upstream of Woods Pond (H3-AR000004). The two air sampling locations are shown on Figure 7-1. The original goals of the program, as described in the SI Work Plan (Weston, 2000), were to collect 40 air samples for analysis of both particulate and volatile PCB Aroclors over four seasons (two locations sampled on five consecutive days over four seasons, i.e., spring, summer, fall, and winter). The SI Work Plan proposed that the data collected during the first two seasons of the field program (spring and summer) be evaluated and used to determine whether or not to modify or terminate the remaining two seasons of the sample collection program.

Two air sampling events were conducted, one in April 1999 and another in July 1999, resulting in the collection of a total of 30 PCB Aroclor samples. Sixteen air samples were collected from the Decker Canoe Launch station in Reach 5B (location H3-AR000003 on Figure 7-1), and 14 samples were collected from the air sampling station upstream of Woods Pond in Reach 5C (location H3-AR000004 on Figure 7-1). The 30 air samples were analyzed for individual PCB Aroclors. PCBs were not measured in any of the 30 samples above the quantitation limit for the individual PCB Aroclors (approximately 3 $\mu g/m^3$). As noted in EPA's SI Data Report (Weston 2002), EPA terminated the air monitoring investigation early due to the absence of PCBs in the samples.

The results of this program confirm that, due to their low volatility, PCB concentrations in the ambient air are not a significant concern in the Rest of River area.

Section 7 Figure

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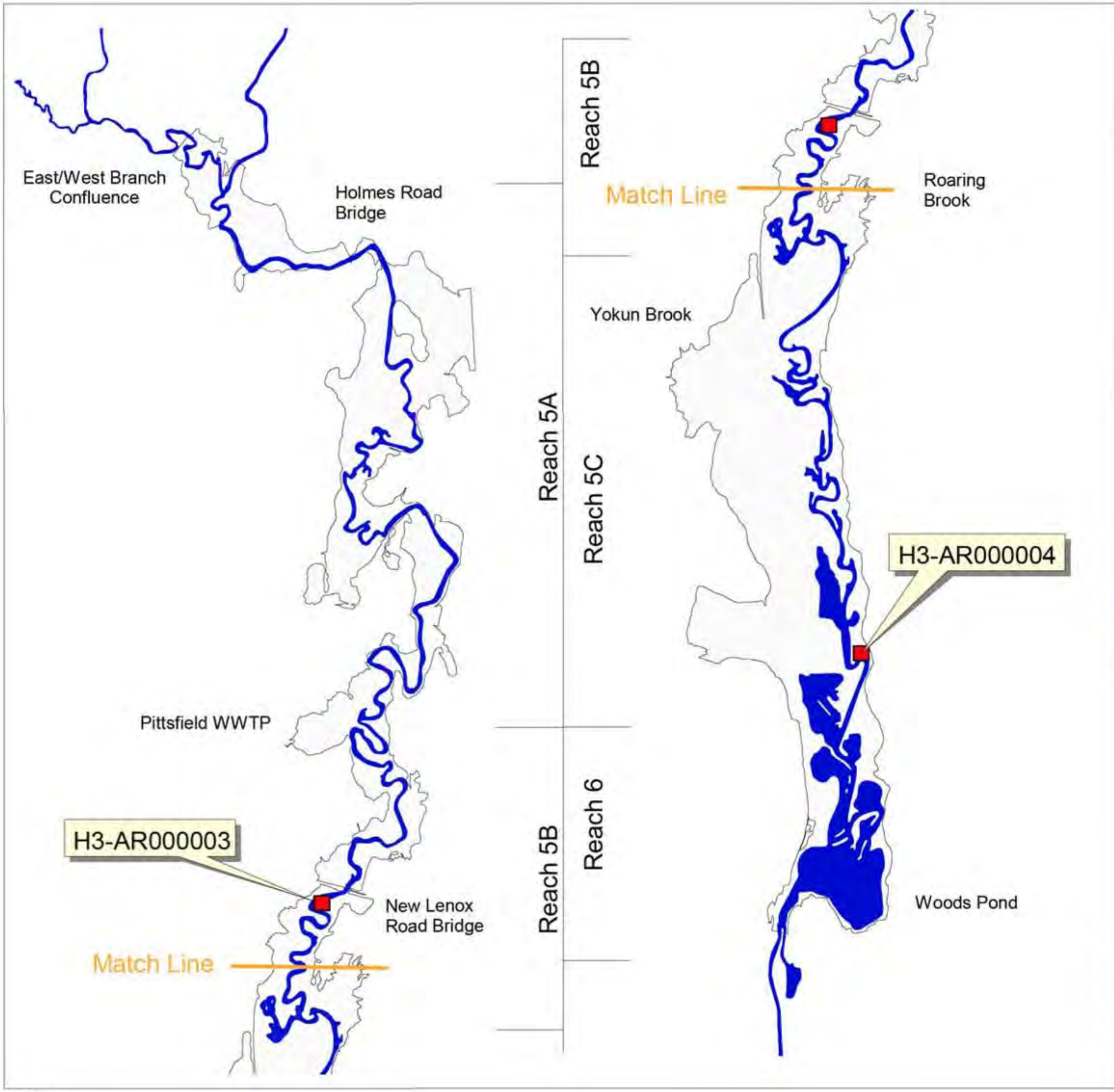

Figure 7-1.

EPA Air Sampling Locations

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QEA Quantitative Environmental Analysis, LLC

September 2002

Air Locations

Section 8

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8. Fate and Transport of Constituents

8.1 General

This section addresses the sources, fate, transport, and bioaccumulation of the constituents of concern for the Rest of River, focusing mainly on PCBs and, to a lesser extent, PCDDs/PCDFs. It includes discussion of the processes that affect the fate and transport of these constituents, potential sources of the constituents, and significant mechanisms that govern the fate and transport of the constituents within the Housatonic River. Numerous physical, chemical and biological processes affect chemical fate and transport. However, not all of the processes are of major importance; some fate and transport processes control the dynamics observed in the system, while others have minimal or negligible impacts. Identifying this hierarchy of processes is fundamental to understanding the distribution and fate of PCBs.

The remainder of this section is presented in the following major subsections: Section 8.2 contains a brief description of sampling activities specific to evaluating fate and transport. Sections 8.3 through 8.5 address the physical, chemical, and biological characteristics of the system that affect chemical fate and transport. Section 8.6 presents information on potential sources of PCBs and PCDDs/PCDFs to the system. Section 8.7 discusses the composition of PCBs in the system. Finally, Section 8.8 provides information on mechanisms that affect the fate, transport, and bioaccumulation of PCBs in the Rest of River, while Section 8.9 presents a brief discussion of mechanisms affecting the fate and transport of PCDDs/PCDFs. The next section of this RFI Report (Section 9) presents a conceptual model of the Housatonic River that integrates the major mechanisms that control fate and transport of PCBs and PCDDs/PCDFs in the Rest of River.

8.2 Description of Sampling Activities

In addition to the various media-specific sampling activities described in Sections 3 through 7, a number of sampling programs were conducted specifically to evaluate fate and transport characteristics of sediments and PCBs within the Rest of River. These programs include the following (along with cross-references that identify the subsections where the results are discussed):

- 1997 GE Study of Cohesive Sediment Erosion Properties. Erosion properties of cohesive sediments were measured in cores collected from various impoundments along the Rest of River (Section 8.8.1.5).

- 1999-2002 EPA Cross-Section Surveys. Periodic river channel cross-sectional surveys were conducted at a number of locations to evaluate bed elevation changes (Section 8.3.5.6).

- 2000-2002 EPA Toe Pin Measurements. Elevation readings at toe pins installed in 2000 were taken periodically to evaluate bank erosion rates (Section 8.8.1.9).

- 2001-2002 GE/EPA Partitioning Study. A sampling program was conducted to evaluate PCB partitioning characteristics in sediments and surface water (Section 8.8.1.2).

- 2001-2002 EPA River Meander Study. Field surveys were conducted along various bends in the River to evaluate short-term channel movement, while digital shorelines were developed from historic aerial photography to facilitate a long-term assessment of River meandering (Section 8.8.1.10).

- 2002-2003 EPA Bed Load Sampling. Sediment bed load (i.e., coarse-grained sediment being transported by the River current near the sediment-water interface) was sampled during storm events in May 2002 and March 2003 (Section 8.8.1.8).

8.3 Physical Characteristics of the System that Affect Fate and Transport

The physical characteristics of the Housatonic River significantly affect chemical fate and transport; these include:

- Watershed characteristics;
- Hydrologic and hydraulic characteristics; and
- Sediment transport characteristics.

8.3.1 Watershed Characteristics

Watershed characteristics largely control the Housatonic River's hydrologic response to precipitation intercepted by the watershed. Tributaries determine the spatial distribution of water and solids loading to the River and can be important determinants of chemical fate and transport. Tributaries deliver water, which acts to dilute waterborne chemicals, and solids that settle within the impoundments and backwaters.

Land use is the principal determinant of how a tributary network functions, in terms of both the hydrologic response to precipitation and the sediment loading delivered to a river. Agricultural lands generally produce higher sediment yields than forested areas and urbanized areas. The high percentage of impervious cover in urban and suburban areas produces a sharper hydrologic response to a given precipitation event than that from other land-use types. As discussed in Section 2, the Housatonic River watershed upstream of Great Barrington is mostly forested (71%) with urban, agricultural, and wetland areas ranging from 4% to 10 % of the watershed (Figure 2-14).

8.3.2 Groundwater Interactions

Groundwater has the potential to impact fate and transport within a watershed, both through discharge and recharge. Discharge of groundwater containing contaminants at high concentrations can cause accumulation of those constituents in the local sediments and a net flux to a river system. One potential interaction associated with groundwater is the impact of upward advective flux through contaminated sediments (i.e., groundwater seepage). This process can cause chemical constituents dissolved in interstitial waters to be transported to the overlying water column at a rate that is accelerated relative to diffusion. The rate of groundwater seepage is a function of the local hydraulic gradient and the hydraulic conductivity of the bed materials. Groundwater seepage within the Housatonic River is likely influenced by a number of factors, including sediment type, local topography and groundwater elevations, and the local effects of dams and their associated backwaters. No data are available to directly assess the seepage flux within the Rest of River area. However, because the hydraulic conductivity of the soils within the region is typically low (10^{-6} cm/sec; EPA 2000a) , the extent to which seepage flux causes accelerated transport of constituents dissolved in sediment pore waters is not expected to be significant.

8.3.3 Hydrology and Hydraulics

The timing and annual extent of precipitation, as both rain and snow, influence chemical fate and transport. Precipitation contributes both water and sediment, via soil erosion, to the River. The spring thaw, occurring between March and May, generates significant runoff from the watershed, with the largest floods of the year usually occurring during this period. The magnitude and duration of the spring floods depend on a number of factors, including areal extent and depth of the snowpack, soil and groundwater conditions, meteorological conditions, and amount of rainfall. Flow in the River is impacted by rainfall in various ways, with River flow depending on: spatial distribution, duration and intensity of rainfall; vegetative cover in the watershed; soil conditions; and groundwater conditions. Rare, intense storms (e.g., thunderstorms and tropical storms that have made landfall) produce large amounts of rain that can cause major high-flow events in the River during the summer and fall.

The geometry of a river channel and its slope affect fate and transport characteristics. As discussed in Section 2, between the Confluence and the WWTP (Reach 5A), the River is relatively shallow and fast-flowing, due in large part to the relatively steep slope of the channel. This flow regime results in a high energy environment and a coarse sediment bed, both of which affect transport of constituents that are bound to particulate matter. Downstream of the WWTP, the River slope decreases, producing a deeper and wider channel. This section is characterized by a broad floodplain and large areas of shallow backwater regions associated with Woods Pond Dam. These characteristics affect chemical fate and transport differently than does the steeper channel upstream, as the lower energy environment promotes deposition and accumulation of fine sediments as well as biological growth. Within Reach 7, the channel gradient is much steeper, resulting in large stretches where the River is shallow and fast flowing and sediments are characterized mainly by gravels and coarse sands. The River does become locally more quiescent in the relatively small backwaters associated with the three dams in Reach 7. At Rising Pond (Reach 8), the presence of the dam causes the River to become much deeper and wider, with lower current velocities. This flow regime promotes fine sediment accumulation, which affects the fate and transport characteristics of the system in this reach.

Water velocities in a river control the energy exerted at the sediment-water interface and, consequently, is the driving force for sediment resuspension, bank erosion, and channel meandering. The hydrologic characteristics of the Housatonic River Basin that affect velocities and sediment transport were described in Section 2. These include basin geometry and bathymetry (including bed elevation gradients), water flow, stage height, and bank elevation, as well as vegetation (both submerged macrophytes in the main channel and backwaters and emergent vegetation in the floodplain).

8.3.4 Water Temperature

Several physicochemical processes are affected by temperature, including diffusion, volatilization, and desorption from sediments. Temperature also affects a number of biological processes, which indirectly influence fate, transport, and bioaccumulation of constituents. These include phytoplankton dynamics, bioturbation, and the growth and metabolism of fish and other biota.

The water temperature measured during water column sampling efforts (discussed in Section 3) is summarized in Figure 8-1 for the major sampling stations along the Rest of River. The data exhibit no clear differences among the locations within Reaches 5 through 8 (panel a) and show slight year-to-year variations (e.g., 1998 appears to have been a warmer water year than 1999). Further, high frequency data (e.g., every 15 minutes) collected by R2 in 2001 and EPA between October 2001 and June 2002 (shown together in panel c of Figure 8-1) indicate moderate variability on daily and weekly time scales and further demonstrate the year-to-year differences. However, the predominant trend in the River's water temperature is the seasonal pattern, characterized by temperatures in the 0-5° C range in winter and early spring, followed by an increase to 20° C to 25° C during the summer, and a subsequent decline in the autumn months.

Based on this seasonal trend, it would be expected that the rates of kinetic processes such as diffusion, volatilization, and the extent to which hydrophobic chemicals desorb from sediments would all be greater in the summer than in the winter (Chapra, 1997). Furthermore, the year-to-year variations in water temperature have the potential to impact metabolic rates of fish, resulting in differences in chemical uptake during the growing season. Temperature also affects the onset of spawning and has a significant effect on larval development and YOY growth rates. For example, in largemouth bass (a warm-water species), adults are active at temperatures above 10° C and YOY fish do not feed below a temperature of 15 °C (R2, 2002).

8.3.5 Solids in the Sediment Bed

Due to their hydrophobicity, PCBs and other chlorinated organics preferentially partition onto solids. Consequently, the fate and transport of these chemicals are directly linked to the fate and transport of solids within the system. Sources of solids include both those generated outside the system (allochthonous) and those generated within the system (autochthonous). Sediments and associated PCBs and other chemical constituents are eroded from the channel and banks and transported downstream or onto floodplains under elevated flow conditions. Deposition of solids and associated chemicals occurs as river current velocities slow within the channel or floodplain due to changes in river flow, channel morphology, or the density of vegetation.

8.3.5.1 Allochthonous Sources

Erosional processes in the surrounding watershed generate sediment loads to the tributaries and main channel of a river. The magnitude of the annual sediment load to the River is affected by many watershed characteristics, including land use, vegetation type and density, soil properties, and the intensity and duration of precipitation. Loading of sediments to a river and its tributaries from watershed erosion is a nonlinear and episodic process, with the majority of the annual load typically occurring during a relatively small number of storm events each year.

Sediment loads to a river can be estimated using different methods, including: soil erosion equations; data-based methods using suspended sediment rating curves; and application of a watershed model. These provide a quantitative means of evaluating the magnitude of solids sources along the system; estimates are provided in Section 8.3.5.3.

8.3.5.2 Autochthonous Sources

Autochthonous solids, sometimes termed biotic solids, are those solids that originate within a system from primary production. Biotic solids are characterized by a variable percentage of organic matter in the form of lipids that serve as a reservoir for the partitioning of hydrophobic organic chemicals such as PCBs (Stange and Swackhamer, 1994). The most common autochthonous source of biotic solids in the water column is phytoplankton growth, which is promoted by high concentrations of nutrients and light. As phytoplankton grow, PCBs are scavenged from the dissolved phase and become associated with these solids. Subsequent settling of these solids serves to remove PCBs from the water column. Ultimately, the growth and settling of phytoplankton serve as a mechanism to convey PCBs from the water column to the sediments. Observations within the system suggest that significant primary production of phytoplankton occurs within Woods Pond. Therefore, biotic solids may play a role in the fate and transport of PCBs and other constituents in this area of the River. The dynamics of phytoplankton growth in the Housatonic River are discussed further in Section 8.5.2.

8.3.5.3 Suspended Sediment and Solids Loadings

Suspended sediment loadings were evaluated using data collected by GE and EPA from eight locations during 1989-2002[2]: East Branch at Hubbard Avenue Bridge (Coltsville), Dawes/Pomeroy Avenue Bridge, West Branch, Holmes Road Bridge, Sackett Brook, New Lenox Road Bridge, Woods Pond Headwaters, and Woods Pond Dam. These locations are representative of tributary sediment loading to the River from the Confluence to Woods Pond Dam, as well as sediment loads in the main channel. These data were used to develop sediment rating curves, which are mathematical equations that describe the relationship between TSS concentrations and flow rate. These curves are plotted on Figure 8-2. (Appendix E.2 provides a description of how the rating curves were developed.)

Annual sediment loads for these locations were estimated by using daily average flow rates from the period 1980-1999 and the sediment rating curves (i.e., Figure 8-2). The mean annual sediment loads that resulted from this analysis are presented in Table 8-1. It should be noted that there is a degree of uncertainty associated with the absolute loading values because there is variability contained in the data that the rating curves do not account for. An interesting spatial pattern in annual sediment load is seen between the Confluence and Woods Pond Dam. The sediment load increases by over 30% between Holmes Road Bridge and New Lenox Road Bridge. This increase could be due to several factors, including tributary loading, bed erosion, and bank erosion. From New Lenox Road Bridge to Woods Pond Dam, the annual sediment load decreases by more than a factor of two, with about half this decrease

[2] Data collected before 1996 were used in the solids loading analyses to provide a more robust dataset. TSS concentrations are not affected by the changes in sampling and analytical methods that were a factor in deciding not to use the pre-1996 PCB data for the spatial trend analyses in Section 3.

occurring in Woods Pond. This decline in sediment loading suggests that significant deposition occurs over this reach.

Table 8-1. Solids Loads and Sediment Yield within and Upstream of Reaches 5 and 6

Location	Drainage Area (mi^2)	Mean Annual Load (MT/yr)	Mean Annual Sediment Yield (MT/mi^2-yr)
East Branch at USGS Gage in Coltsville	58	786	14
East Branch at Dawes/Pomeroy Avenue	69	2180	32
West Branch	61	1,520	25
Holmes Road Bridge	132	3,160	24
Sackett Brook	11	280	26
New Lenox Road Bridge	147	4,170	28
Woods Pond Headwaters	169	2,890	17
Woods Pond Dam	169	1,700	10

Note:
MT/yr = metric tons per year

Net erosion processes in the drainage areas of the three tributaries (i.e., the East Branch, West Branch, and Sackett Brook) can be quantified by calculating the sediment yield, which is the annual sediment load per unit area (Table 8-1). The sediment yields for the three tributaries are similar, varying by less than 30%. This result indicates that the net erosional processes in these three drainage areas are similar, which is consistent with their similarities in watershed land use and topography.

The USGS conducted a sediment loading study between Great Barrington and Ashley Falls from March 1994 through September 1995 (USGS, 2000). The annualized sediment load at Great Barrington was 3,800 metric tons per year (MT/yr), which corresponds to a yield of 14 MT/mi^2-yr (drainage area of 280 mi^2). The USGS study also estimated loads for the Green River, which is a tributary to the Housatonic River between Great Barrington and Ashley Falls, with a drainage area of 51 mi^2. The annualized load for the 18-month study period on the Green River was 1,570 MT/yr. This load corresponds to a sediment yield of 31 MT/mi^2-yr, which is within a factor of two of the three tributaries in Reach 5. These values indicate that the sediment yields within Reaches 7 through 9 are similar to those in Reaches 5 and 6, which is expected given the similarities in land use.

8.3.5.4 Physical Properties of Sediments

Sediment bed grain size decreases significantly from the Confluence to Woods Pond, which is consistent with the decreasing channel gradient across this reach (see Section 2). As channel gradient decreases, current velocities (and associated bottom shear stresses) generally decrease and the sediment bed becomes dominated by finer materials. As described above in Section 4, the sediment bed in Reaches 5A and 5B is primarily composed of non-cohesive (sandy) sediment, while most of the bed in Reach 5C and Woods Pond is composed of cohesive (muddy) materials. Backwater sediments are generally characterized by cohesive sediments colonized by aquatic vegetation. These regions with finer sediment deposits are associated with relatively high PCB concentrations, as discussed in Section 4.5.3.2. The River's sediments are much coarser within Reach 7 due to the relatively high current velocities, and become finer again within Rising Pond.

8.3.5.5 Floodplain Soils

In the proximal and distal floodplains, the presence of widespread vegetation generally minimizes erosion of soils during overbank flows. The stems of vegetation reduce bottom shear stresses while their roots inhibit erosion. Vegetation stems and leaves also act as filters for suspended sediment, thereby trapping fine-grained suspended solids during overbank flow periods. Therefore, PCBs and other hydrophobic constituents associated with suspended sediments entering the floodplain regions of the River will likely be deposited there.

8.3.5.6 Sediment Transport

Sediment transport between the Confluence and Woods Pond Dam is primarily affected by the following processes: resuspension, deposition, bed load, bank erosion, and watershed sediment loads. Resuspension and deposition processes impact suspended load transport in the River, with biotic solids, clay, silt, fine sand and medium sand being transported as suspended load; sediment particles with diameters less than 500 μm are generally found in the water column. Resuspension, or erosion, of bed sediment is controlled by bottom shear stress, sediment type (cohesive or non-cohesive), and various bed properties, including grain size distribution, dry density, state of consolidation, gas content, and mineralogy. Sediment deposition rate at a particular location is determined by local bottom shear stress, settling speed of depositing particles, and particle size distribution of suspended sediments. Bed load transport primarily affects coarser sediment (i.e., medium sand, coarse sand and gravel). Sediments moved by bed load typically roll or "saltate" along the bed in a thin layer that is typically about 10 particle diameters thick (van Rijn, 1984). Bank erosion acts as an additional sediment source to the River that generally occurs episodically during high-flow events. Sediment loads from tributaries and upstream sources are important because the magnitude and composition of these loads have a major impact on sediment transport processes in the River. Watershed sediment loads impact sedimentation rates in the River, which often have a primary effect on burial rates of PCBs from the bioavailable layer of the bed.

The impacts of these sediment transport processes on bed morphology in Reaches 5A and 5B were examined using channel cross-section data obtained by EPA between 1999 and 2002. Bed elevation and channel geometry data were collected along nine transects (i.e., channel cross-sections) located between the Confluence and New Lenox Road Bridge, as shown on Figure 8-3. Bed elevation at various points across the channel was measured at each transect location, at four different times: 1999, September 2001, April 2002, and June 2002.

These data are useful for evaluating changes in bed morphology at the nine transect locations between 1999 and 2002. Figure 8-4 shows changes in bed elevations during the nine-month period from September 2001 to June 2002. Net changes in bed morphology for the different transects and observation periods were quantified by calculating the average variation in bed elevation over the entire transect for a particular period (Table 8-2). The 1999 to June 2002 comparisons were only made for five transects; the 1999 data at the other four transects (49, 61, 192, and 198) could not be lined up with the more recent data with sufficient accuracy to provide meaningful results.

Table 8-2. Average Change in Bed Elevation at Nine Transects in Reaches 5A and 5B

Reach	Transect	Sept 2001 to April 2002 Change (ft)	April 2002 to June 2002 Change (ft)	Sept 2001 to June 2002 Change (ft)	1999 to June 2002 Change (ft)
5A	49	0.08	0.05	0.12	NA
	61	0.16	0.40	0.56	NA
	89	-0.27	-.024	-0.51	0.13
	133	-0.03	-0.18	-0.21	0.10
	153	0.75	0.33	0.42	-0.57
5B	198	0.40	-0.09	0.31	NA
	194	0.37	-0.16	0.22	-0.28
	192	0.16	-0.24	-0.07	NA
	182	0.01	-0.16	-0.15	2.67

Notes:

1. Positive change = net bed aggradation; negative change = net bed degradation.
2. NA = no analysis completed because 1999 transect could not be properly referenced.
3. Transects are listed in order moving from upstream to downstream.

Several observations concerning bed morphology in Reaches 5A and 5B may be made from the above analyses. First, significant bed aggradation or degradation (i.e., 1-2 feet) may occur at different locations along a particular transect during periods ranging from two months to nearly two years. Second, bed movement appears to generally be higher at the locations surveyed in Reach 5A (Figure 8-4a) than for those in Reach 5B (Figure 8-4b). Third, seven transects of the nine experienced net aggradation between September 2001 and April 2002, which was a period during which the peak daily average flow rate at the USGS Coltsville gage was 321 cfs. Net degradation occurred at six of the nine transects for the April 2002 to June 2002 period, when the peak flow was 618 cfs. Thus, increased bed degradation was observed during the higher-flow period (i.e., April to June), which would be expected. These results suggest that bed load may have a significant impact on bed morphology in Reaches 5A and 5B because the relatively large magnitudes of aggradation and degradation at some locations are unlikely to be caused solely by deposition or resuspension of suspended sediment.

8.4 Chemical Characteristics of the System that Affect Chemical Fate and Transport

Of the numerous system characteristics that affect chemical fate and transport, organic carbon is the most important for hydrophobic organic chemicals such as PCBs.

8.4.1 Impacts of Organic Carbon on Fate and Transport

Due to their low aqueous solubility and elevated octanol-water partition coefficients, PCBs and other hydrophobic organic compounds preferentially partition to organic carbon within natural aquatic systems. Therefore, to understand the fate of PCBs, it is first necessary to characterize the distribution of organic carbon in the system. Organic carbon appears both in particulate form (e.g., a portion of suspended matter) and in "dissolved" form (e.g., organic molecules such as humic acids), in both the water column and sediment bed. Particulate-phase sediment PCB concentrations are generally positively correlated to organic carbon concentration (i.e., higher PCB concentrations are generally observed in areas having fine-grained, high organic carbon sediments). Consequently, the fate of PCBs and other hydrophobic organic chemicals is bound to the fate of organic solids.

Dissolved forms of organic carbon can elevate the dissolved-phase concentrations of PCBs and other hydrophobic compounds. In sediments, these elevated concentrations produce elevated pore water chemical concentrations, which in turn promote higher dissolved chemical fluxes between sediments and overlying waters. Autochthonous generation of water column organic solids such as phytoplankton impacts hydrophobic organic chemical dynamics. Dissolved-phase chemicals partition onto organic solid particles. Chemical fate is then coupled with the fate of water column organics and subject to downstream transport processes, bioaccumulation within the food chain, and settling to the sediment bed.

8.4.2 Water Column Organic Carbon

The amount of PCBs that sorb to water column particulates is proportional to the particulates' organic matter content, which is quantified as the fraction of organic carbon (f_{oc}). Figure 8-5 contains a temporal profile of water column f_{oc} at five locations within Reaches 5, 6, and 8: 1) Dawes/Pomeroy Avenue; 2) New Lenox Road; 3) Woods Pond Headwaters; 4) Schweitzer/Lenoxdale Bridge; and 5) Division Street.

Figure 8-5 illustrates that measured f_{oc} ranges between approximately 1% and 30% at each location, with year-to-year variability, but generally no distinct patterns. A seasonal trend characterized by higher f_{oc} in the summer would be expected in regions where algae represent a significant fraction of the particulate organic carbon suspended in the water column. As shown on Figure 8-5, the data exhibit some evidence of such seasonality for a few years/locations (e.g., Woods Pond Headwaters in 1997), but this pattern is not consistent. It would be expected that a higher fraction of PCBs would be sorbed to water column suspended matter at the locations and times when the f_{oc} is high.

As stated above, in addition to being bound to sediment particles, organic carbon is also present in the water column in dissolved form. Figure 8-6 shows temporal and spatial profiles of 1998-1999 EPA water column data on DOC collected between Dawes/Pomeroy Avenue and Schweitzer/Lenoxdale Bridge. The average DOC concentration is approximately 5 mg/L; the data exhibit no clear spatial trend. Assessment of temporal trends is difficult given the limited dataset (i.e., a single year). These DOC concentrations are consistent with those observed in other similar systems (e.g., Wetzel, 2001), and are indicative of refractory (i.e., slowly degraded) carbon moving through the system. Because of the relatively low DOC concentration and the higher affinity of PCBs for POC (e.g., Evans, 1988), the fraction sorbed to DOC in the water column is likely low in comparison to that sorbed to POC.

8.4.3 Sediment Organic Carbon

Organic carbon is the primary sorption site for PCBs in the sediments; the mass of PCBs sorbed is generally dependent on the amount of organic carbon. As discussed in Section 4.4.1, average surface sediment f_{oc} in Reaches 5 and 6 increases with distance downstream, from approximately 1.5% in Reaches 5A and 5B to 2.6% in Reach 5C, and then increases substantially to approximately 9-10% in the backwaters upstream of Woods Pond and in Woods Pond (Figure 4-3). This spatial pattern in sediment organic carbon is consistent with the observed increase in biological productivity (e.g., algae, submerged aquatic vegetation, and macrophytes) primarily in the backwaters and Woods Pond, which is linked to the nutrient inputs from the WWTP, as well as the decreased gradient in these areas (Section 2). Annual decay of this material is a continuous source of organic carbon to surface sediments. In several areas of the river that are highly depositional (e.g., Reach 5C, backwaters, Woods Pond), sediment f_{oc} is generally higher in surface sediments (top 6 inches) as compared to deeper sediments (e.g., Figure 4-10). This difference may be explained by deposition of organic matter to the surface sediments (e.g., dead algae), followed by subsequent decomposition that occurs at depth in the bed. Downstream of Woods Pond Dam, f_{oc} is generally lower in the free-flowing portions of the River (i.e., Reaches 7 and 9), and is higher on average within the impoundments, particularly behind Glendale Dam and within Rising Pond (e.g., Figure 4-2). These differences in organic carbon distribution appear to affect, in part, the distribution of PCBs (see Section 4.5.3.1).

DOC in sediment pore water can be a significant sorbant of chemicals that are highly hydrophobic, thereby increasing the fraction of PCBs that can be transported to the surface water in the dissolved phase. As part of the 2001 EPA/GE partitioning study, DOC was measured in sediment pore water. Figure 8-7 depicts the spatial profile of pore water DOC between the Confluence and Woods Pond. Based on this plot, there is no apparent spatial trend in the data, with an average pore water DOC concentration for Reaches 5 and 6 of approximately 16 mg/L. This concentration is about three times higher than that observed in the water column. Consequently, sorption of PCBs to pore water DOC may be important.

8.5 Biological Characteristics of the System that Affect Chemical Fate, Transport, and Bioaccumulation

The pathways by which PCBs are transferred through the aquatic food web are controlled by fish movement patterns and the structure of the food web.

8.5.1 Movement Patterns/Exposure Areas

Understanding the regions of the River over which individual fish are exposed to PCBs is an important part of assessing PCB bioaccumulation patterns. As described in Section 2, the character of the River changes dramatically near the WWTP outfall. Above the WWTP, the River is relatively shallow, fast-flowing, and characterized by coarser sediments and no significant backwaters. In addition, algal biomass and invertebrate abundances are lower upstream of the WWTP. Downstream from this point, the River changes, being characterized by deeper water, finer sediments, and by the increasing area of shallow backwater habitats towards Woods Pond.

These changes in river character have consequences for the biology of the system. Increasing habitat diversity, finer organic-rich sediments, and greater algal and plant biomass in Reaches 5B, 5C, and 6 affect sources of food to the fish and possibly contaminant exposure routes. With respect to the fish fauna, the cyprinids, such as the dace, darters, and minnows, are common in the East and West Branches and in the upstream portion of Reach 5, above New Lenox Road Bridge, but become less common downstream in Reach 5C and Woods Pond (Chadwick and Associates, 1994; R2, 2002). The cyprinids are also common in the brooks (Moorewood, Sackett, Mill, Felton, and Roaring Brooks) that are tributaries to Reach 5, as is brown trout (R2, 2002). The centrachids (e.g., the sunfish and largemouth bass), yellow perch, white sucker and brown bullhead are more abundant in the slower, deeper sections, Reaches 5C and Woods Pond (Chadwick and Associates, 1994; R2, 2002).

PCB concentrations in the media to which fish are exposed vary over the reach from the Confluence to Woods Pond Dam (Reaches 5 and 6). Organic carbon-normalized PCB concentrations in the surface sediments (which represent the sediment-based portion of food-web exposures for fish) decline at least 10-fold from the Confluence to the WWTP, and then exhibit no consistent trend to Woods Pond Dam (e.g., Figure 4-12). In contrast, average water column PCB concentrations increase approximately 40% over Reach 5A, are similar in Reaches 5B and 5C, and then decline over Reach 6 (Woods Pond) by less than a factor of two (e.g., Figure 3-7). Where PCB concentration gradients exist, the extent to which fish move across those gradients or remain in a small home range may be reflected in the spatial trends in fish tissue PCB concentration for a given species. Hence, spatial gradients in fish PCB concentrations that mimic gradients in sediment or water provide evidence of limited movement through the River reach.

For comparison with water column and sediment PCB gradients, spatial patterns in adult fish from the 1998 and 2000 EPA collections were examined on whole body basis (because this metric is the most meaningful for understanding fish exposures). Reconstructed whole body fish tissue PCB concentrations remain relatively constant across the shallow portion (5A) and deep portions (5B, 5C) of Reach 5 and into Woods Pond (Figure 8-8) for both wet-weight and lipid-normalized PCBs (see Section 6.3.3). Fish tissue PCB concentrations between the shallow reach (5A) and the deeper reaches (5B, 5C) do not appear to be consistent with either water column or sediment PCB gradients because average water column concentrations increase across Reach 5, while average organic-carbon normalized sediment concentrations decrease over this reach.

There are several potential explanations for this lack of consistent gradients in Reach 5. First, the fish may move extensively over this region of the River such that their exposure is not tied directly to local surface sediment or water column concentrations. Second, variability in the data may mask spatial gradients. Very few fish were collected in Reach 5A, and in general in the Housatonic River dataset, variability is relatively large (see, e.g., Figure 8-8). However, this is at best a partial explanation, since the variations in fish PCB concentrations are considerably less than the 10-fold decline in surface sediment organic carbon-normalized PCB concentrations. Third, diets may change over this reach of the River. Shifts in exposure resulting from shifts in the relative importance of sediment- and water column-based sources of food are explored in Section 8.8.4. EPA has suggested a fourth potential explanation: that a change in bioavailability of PCBs may be responsible for the lack of consistent gradients within Reach 5.

8.5.2 Food Web Structure

Understanding the fate of PCBs in fish requires an understanding of the various exposure routes and pathways through the riverine food web. The PCBs accumulated by fish come from both the water column and the sediment. The relative importance of these two PCB sources depends upon their relative PCB concentrations and also upon the structure of the food web itself.

A simplified food web of the Housatonic River, which contains primary producers, invertebrates, and fish, is presented on Figure 8-9.

Primary Producers

Phytoplankton, periphyton, and macrophytes form the base of the aquatic food web. These autochthonous sources of organic matter are supplemented by allochthonous organic matter derived from terrestrial plants that enters the River through run-off from the surrounding watershed. Water column dissolved PCBs sorb to organic matter contributed by both of these sources. Plant production, senescence, and settling provide a sink for water column PCBs and a source of PCBs to the sediments. The importance of this mechanism is directly related to the growth and settling rates of phytoplankton. Water column and benthic invertebrates consume both living and non-living organic matter, and thus are the first step in the bioaccumulation of PCBs within the aquatic food web. The relative importance of plant production to PCB fate, transport, and bioaccumulation can be assessed by examining patterns in organic matter, nutrient, and phytoplankton (as indicated by chlorophyll-*a*) concentrations measured in surface water samples.

The most common limitation to algal growth within a river is the availability of nutrients, with phosphorus almost always being the limiting nutrient element, although light can be a limiting factor under some conditions. Nutrient limitations to phytoplankton growth occur at about 5 to 25 μgP/L (measured as orthophosphate or soluble reactive phosphorus [SRP]) and 25 to 100 μgN/L (measured as the sum of ammonia and nitrate) (Chapra, 1997). Based on the 1998-1999 EPA routine monthly water column sampling data, the primary limiting factor to growth between the Confluence and the Pittsfield WWTP appears to be nutrients, as indicated by the nitrogen and phosphorus data plotted on Figure 8-10. Because the measured SRP in Reach 5A is below these limiting values, phytoplankton growth is likely to be phosphorus-limited. Chlorophyll-*a* concentrations of about 2 μg/L indicate that phytoplankton biomass in Reach 5A is relatively low (Figure 8-10). The nutrient levels in Reach 5A do, however, support a well-defined community of periphyton (Weston, 2002). At the location of the WWTP discharge, the data indicate a significant increase in nutrient concentrations, which promotes increased phytoplankton growth (Figure 8-10). Nutrient inputs from the WWTP result in increased concentrations in the river, especially at lower river flows, because the average flow of the WWTP, approximately 12 MGD or 8 cfs (EPA 2003), is significant when compared to typical summer low flows in the river (Figure 2-17). Chlorophyll-*a* concentrations, however, typically remain low in Reaches 5B and 5C, with mean values of 2 μg/L to 3 μg/L, due to the relatively short residence time in this flowing system. At Woods Pond, the residence times increase and phytoplankton concentrations concomitantly increase, as evidenced by the increase in chlorophyll-*a* concentrations (Figure 8-10). The increased hydraulic residence time and productivity in Woods Pond allow for increased settling of phytoplankton. Hence, it is in Woods Pond that the most significant impact of phytoplankton on PCB transport is expected to occur. The average 1998-1999 chlorophyll-*a* concentrations in Woods Pond (i.e., 5-10 μg/L) are not at levels that are typically associated with a highly productive system. However, visual observations at this location during summer months have indicated the presence of significant populations of macrophyte beds and standing mats of algae, both of which would affect PCB transport as described above, but would not be captured by a grab sample of water flowing past the Woods Pond outlet because water column sampling has not been performed within the Pond itself. Temporal trends in chlorophyll-*a* from the Woods Pond region also exhibit seasonal trends indicative of algal growth within the Pond (Figure 8-11).

The relative importance of phytoplankton carbon as a factor influencing PCB dynamics can be further evaluated by comparing the estimated phytoplankton carbon standing crop with total organic carbon in the River. Based on the data plotted on Figure 8-10, phytoplankton biomass above the WWTP is approximately 0.08 mgC/L (assuming a carbon to chlorophyll ratio of 40) (Chapra, 1997). This estimate is consistent with POC concentrations measured in phytoplankton samples collected during EPA's phytoplankton biomass study (Weston 2002). Average POC concentrations in this portion of the River are approximately 0.5 mgC/L. Thus, phytoplankton biomass likely represents less than 20% of the POC in Reach 5A. Phytoplankton production, therefore, is not likely to be a significant factor in the dynamics of PCBs in Reach 5A. Using a similar calculation, phytoplankton carbon concentrations downstream of the WWTP of approximately 0.1 mg/L represent 20% to 40% of the total POC in Reaches 5B and 5C. In Woods Pond, phytoplankton biomass is approximately 0.2 mgC/L to 0.4 mgC/L. Although they may not be representative of the more stagnant portions of the Pond, POC values from Schweitzer Bridge average 0.4 mgC/L. Based on these data, phytoplankton may represent a significant fraction of the total POC, and therefore may contribute significantly to the PCB dynamics within Woods Pond.

Further indication of the degree of primary production within Reach 5C and Woods Pond is provided by the macrophyte biomass survey performed by EPA in September 2000 (Weston 2002). Within each subreach between the Confluence and Woods Pond Dam, three plots were harvested for macrophyte tissue; the average dry weight tissue density is listed in Table 8-3 (below).

Table 8-3. Macrophyte Density and Areal Coverage

Reach	Average Macrophyte Density (g/m^2)	Percent Surface Area Containing Macrophytes (including backwater regions)
5A	24	1%
5B	186	25%
5C	334	57%
6	140	55%

Note:
g/m^2 = grams per square meter

Similar to the spatial trend in phytoplankton, the values in this table indicate an increase in macrophyte density downstream of the WWTP (i.e., below Reach 5A). The average densities in Reach 5C and Woods Pond and its backwaters (i.e., 200 grams per square meter [g/m^2] to 300 g/m^2) are considered moderate to high for a riverine system (Wetzel, 2001; Stevenson, 1988), and further illustrate the high productivity in this reach. Estimates of areal macrophyte coverage reported by EPA (Weston, 2002) were normalized by the reach-wide total surface area and are listed in Table 8-3. These values demonstrate the relatively large areal extent of macrophyte populations in Reach 5C and Woods Pond.

Macrophytes also provide surface area for the growth of periphyton, which accumulate PCBs from the water column and serve as food for invertebrates. Measurements of periphyton biomass made on EPA's behalf indicated that periphyton attached to macrophytes were much more abundant in Reaches 5C and Woods Pond than in Reaches 5A and 5B (Weston, 2002). Furthermore, macrophytes themselves sorb PCBs and their senescence provides another route for PCB transfer to the sediment bed. As the plant material decomposes and is consumed by benthic invertebrates, PCBs originally sorbed from the water column can enter the food web.

Invertebrates

Components of the invertebrate fauna significant to the trophic transfer of PCBs to fish include zooplankton, insect larvae, worms, and crayfish. Sampling conducted by EPA within Reach 5 indicate that the abundance of benthic invertebrates increases towards Woods Pond (Figure 8-12), which is consistent with the change in River bed characteristics over this reach. Finer sediments accumulate in the bottom in this area (i.e., Reaches 5C and 6), as the River deepens and slows. The higher organic carbon content of these sediments serves as a food supply for the invertebrates

Fish

Forty-one species of fish have been documented from the Massachusetts reaches of the Housatonic River and adjacent ponds (Chadwick and Associates, 1994; R2, 2002). These are shown on Figure 8-13 by their trophic level (TL) positions, depending on whether they prefer water-column invertebrate prey, benthic prey (i.e., they feed along the bottom and/or in the bottom sediments), or are predatory on other fish species. In a September 1993 survey, white sucker, sunfish (pumpkinseed and bluegill), yellow perch, brown bullhead, and largemouth bass were the most abundant species between the Confluence and Woods Pond Dam (Chadwick and Associates, 1994). In recent surveys conducted in 2000 and 2001 upstream of Woods Pond Dam, 26 of the species listed on Figure 8-13 were found (R2, 2002). The top five most abundant species caught during an October 2001 survey in the main channel of the River were yellow perch, largemouth bass, sunfish (including pumpkinseed, bluegill, and juvenile sunfish), black crappie, and rock bass (R2, 2002).

8.6 Sources of PCBs and PCDDs/PCDFs to the System

Assessment of chemical fate and transport necessitates the quantification of contemporary sources to the system. For the purposes of this discussion, the Rest of River system is defined as the water and sediments within the main channel, backwater regions, and floodplains, as well as the biota living in or feeding from these areas. External sources would therefore consist of inputs from tributaries, groundwater, manmade discharges, and the atmosphere (via non-point sources such as direct runoff).

This discussion of sources, as well as the subsequent discussions of fate and transport mechanisms, focuses on PCBs and, to a lesser extent, PCDDs/PCDFs (see Section 2.6).

8.6.1 PCBs

8.6.1.1 Upstream of Confluence

As discussed in Section 2, the Consent Decree defines the upstream boundary of the Rest of River as the Confluence of the East and West Branches. The PCB load entering the Rest of River at this point represents the most significant external source of PCBs to the system; PCB sources associated with the two branches are discussed separately below.

<u>East Branch</u>

Historically, the vast majority of the PCBs entering the Rest of River system has originated from the East Branch. PCB loadings transported to the system in the East Branch originated from the GE Pittsfield Plant area via a number of sources, including:

- Surface water runoff and discharges, including Unkamet Brook and Silver Lake;
- Groundwater flow, including migration of PCBs in LNAPL and DNAPL forms to some extent; and

- Transport of PCBs from the sediments, and potentially bank soils to some extent, within the reach above the Confluence via diffusion, erosion, and bed load transport.

The external sources to the East Branch of the River (e.g., groundwater and NAPL) have been controlled by on-site mitigation measures, as discussed in Section 1.4.1. Further, the water column PCB mass transport in the East Branch at Dawes/Pomeroy Avenue over the last several years is consistent with that which would be expected based on the sediment PCB concentrations measured upstream of the Confluence in recent years. Therefore, the PCB-containing sediments have likely been the most significant contributor to PCB loads upstream of the Confluence in recent years. At the writing of this report, remediation activities to address the sediments in these areas have been completed in the Upper ½-Mile Reach and are underway in the 1½-Mile Reach.

Data from the Dawes/Pomeroy Avenue monitoring stations were used to represent PCB loads entering the Rest of River system from the East Branch. As discussed in Section 3, PCB concentrations within the system differ significantly between flows above and below 100 cfs (at Coltsville), due primarily to increased transport of sediments and associated PCBs during higher flows. Based on the 1996-2002 data, the average water column PCB concentrations at the Dawes/Pomeroy locations are approximately 0.06 μg/L at the lower flows and 0.08 μg/L at the higher flows, with fairly large year-to-year differences (see Section 3, esp. Figure 3-10). For the 1997-2002 period (see Section 8.8.1.1), the average PCB loading at this location was calculated to be approximately 7 grams per day (g/d) at the lower flows and 81 g/d at the higher flows. Integrating these loadings on an annual average basis through flow-weighted averaging yields a mean PCB loading at this location of approximately 28 g/day, or 10 kilograms per year (kg/yr). It is anticipated that this load will decrease due the effects of the sediment remediation in the Upper ½-Mile and 1½-Mile Reaches. Water column PCB loads in the system are discussed in more detail in Section 8.8.1.

<u>West Branch</u>

As discussed in Section 3, water column sampling from the West Branch has not been conducted routinely. However, the limited data from samples collected just above the Confluence indicate that PCBs are present at this location. The source of these PCBs is likely sediments within the West Branch, which contain PCBs in some isolated regions (e.g., PCBs were detected in about half of the 36 surface sediment samples collected by EPA in 1999 from the West Branch within 1 kilometer [km] of the Confluence, with all but two detected concentrations being near or below 1 mg/kg).

Since 1998, 40% of the water column samples collected from the West Branch have yielded detectable PCBs; concentrations are typically much lower than those in the East Branch. Depending on the assumptions made for non-detect samples, average water column PCB concentrations in the West Branch range from approximately 0.015 μg/L to 0.025 μg/L (Figure 8-14), which is at the lower end of the typical detectable range. Although the data are not sufficient to support an accurate calculation of PCB loading, a gross estimate can be obtained by multiplying the concentrations by daily average flow rates estimated from measured flow at Coltsville and drainage area proration (Appendix E.1). This approach yields a low-flow average load from the West Branch of about 2 g/d and a high-flow mean of 10 g/d to 16 g/d, producing a flow-weighted average of about 4 g/d to 6 g/d, or 2 kg/yr.

Thus, the current primary source of PCBs entering the Rest of River system from upstream is the East Branch, with inputs from the West Branch being measurable but much less significant. The PCB loadings discussed above will be compared against estimates of PCB loads associated with various fate and transport mechanisms within the system in Section 8.8.

8.6.1.2 Tributaries Downstream of the Confluence

As discussed in Section 2, there are a few small tributaries in Reach 5 (Sackett Brook, Roaring Brook, and Yokun Brook). The tributaries to Reaches 7 through 9 are larger and include Hop Brook and the Williams, Green, and Konkapot Rivers, plus those in the Connecticut portion of the River. There are no recent sampling data to assess inputs of PCBs from these tributaries. Based on review of spatial trends in water column and sediment PCB data, primarily within Reaches 5 through 8, there are no data that would suggest that PCBs are entering the system from tributaries. Therefore, tributaries do not likely represent a significant contemporary source of PCBs to the system. One exception may be the Still River, Connecticut, where previous studies have documented some evidence of PCBs in the sediments and biota (e.g., Frink et al., 1982; BBL, 1996). However, the data in this portion of the Housatonic River are insufficient to assess the current impacts of this potential source.

8.6.1.3 Point Sources

A number of permitted discharges within the Rest of River system could be classified as potential point sources. These include the discharge from the Pittsfield WWTP in Reach 5, paper mills in Lee and South Lee, and municipal wastewater treatment plants in Lee and Great Barrington, all of which discharge to the River in Reach 7 (EPA, 2002). There are also several municipal and some industrial discharges within the Connecticut portion of the River. The flow inputs from most of these facilities are relatively small compared to the flow within the River, and PCBs are not measured in their effluent. Further, based on review of spatial trends in water column and sediment PCB data, primarily within Reaches 5-8, there are no data that would suggest that PCBs are entering the system from these discharges. Therefore, point source discharges within the Rest of River are likely not a significant contemporary source of PCBs to the system.

8.6.1.4 Groundwater

Previous studies of groundwater within the Housatonic River and its surrounding area were mainly focused on the GE Pittsfield Plant area, where PCB contamination in local groundwater has been identified and control measures have been implemented in some areas (e.g., BBL, 2000a). Little data exist to evaluate groundwater interactions with the River downstream of the Confluence. Previous studies have indicated that the River serves as a net discharge zone for regional overburden groundwater, with the exception of areas near the dams, where the River loses water to the subsurface (BBL, 1996; ChemRisk, 1996). As discussed in Section 2, however, the River is predominately fed by precipitation runoff; flow from groundwater is a very minor component of the system water budget. Impacts on the River from PCBs in groundwater in the GE Plant reach have been documented in the past, but these were impacted by local LNAPL and DNAPL plumes (BBL, 2000a). There are no data or information that indicate PCB contamination of groundwater within the Rest of River reach. Further, review of spatial trends in water column and sediment PCB data does not suggest the presence of any regions in the Rest of River in which PCBs are entering the system from groundwater. Therefore, groundwater is likely not a significant contemporary source of PCBs to the Rest of River system.

8.6.1.5 Atmospheric Deposition

Due to their wide-scale use in the past and their high affinity for particulate matter, PCBs have been found to be ubiquitous within the environment. Therefore, atmospheric sources can result in a net flux of PCBs to a watershed through both dry deposition processes and precipitation. Atmospheric sources of PCBs, however, are usually only significant to water bodies with large watersheds and large surface areas. There have been no studies that have attempted to directly measure atmospheric fluxes of PCBs in the Housatonic River watershed. Results reported by the Integrated Atmospheric Deposition Network (IADN) indicate that the maximum atmospheric deposition measured at various stations in the Great Lakes during 1997-1998 was 0.011 $\mu g/m^2/day$ (IADN, 1998). Applying this flux to the surface area of the River within Reaches 5 and 6, including backwaters, translates into an annual PCB load of less than 0.01 kg/yr, which is less than 0.1% of the mass entering the Rest of River from the East Branch. This calculation suggests that atmospheric deposition is not a significant source of PCBs to the Rest of River system.

8.6.2 Sources of PCDDs/PCDFs

Since summary information on PCDDs/PCDFs is included in the discussions of the various media in this RFI Report (for the reasons given in Section 2.6), a brief discussion of potential sources of these compounds is presented here. Due to the hydrophobic nature of PCDDs/PCDFs, sediments provide a record of past source activity. While such records are modified by fate and transport processes, they are the most reliable data upon which to infer source activity. Therefore, the discussion of PCDD/PCDF sources in this section focuses on sediment data. Water column monitoring for PCDDs/PCDFs at the site was not sufficient to permit credible estimates of sources and associated loadings.

8.6.2.1 Spatial Patterns and Potential Sources

As discussed in prior reports (e.g., BBL, 1996; Eitzer, 1993) and shown by the PCDD/PCDF data included in the GE and EPA databases (Appendix F), PCDDs/PCDFs have been detected in sediment samples collected both adjacent to the GE facility and upstream of Pittsfield. These data indicate that the East Branch is a source of PCDDs/PCDFs to the Rest of River. The fact that PCDDs/PCDFs were detected in sediments both upstream and adjacent to the GE facility implies that PCDDs/PCDFs entering the Rest of River and measured in downstream sediments may originate from multiple sources upstream of the Confluence.

Sediment PCDD/PCDF data from all depths collected in Reaches 5 through 8 are plotted spatially on Figure 8-15. The analytical method used to measure PCDDs/PCDFs quantifies the concentration of seventeen congeners and eight homolog groups. The various congeners and homologs exhibited similar trends; therefore data from only one representative PCDD and PCDF congener and homolog group each are plotted on Figure 8-15.

Despite significant variability (e.g., concentrations often range over two or more orders of magnitude over short distances), the spatial trends in the PCDD/PCDF data contain several features. These features are most clearly observable when the concentrations are plotted on a reach-averaged basis (Figure 8-16). For the purposes of this analysis, the data were averaged by reach (Reaches 5A, 5B, 5C, 6, and 8) based upon the location of potential sources, spatial differences in River channel and sediment characteristics, patterns of historical sediment PCB concentrations, and data coverage.

In general, PCDD/PCDF concentrations increase over the reach between the Confluence and Woods Pond (Figures 8-15 and 8-16). The patterns evident on Figure 8-16 indicate that concentrations of some PCDD/PCDF congeners and homologs are lower in Reach 5B than in Reach 5A, and then increase in Reach 5C, which is likely due to the higher concentration of organic carbon contained in the sediments; this trend was also observed in the PCB data (Section 4.5). Higher concentrations of both PCDDs and PCDFs are observed in Woods Pond (Reach 6) and Rising Pond (Reach 8). These results are consistent with known sediment deposition patterns within the system (i.e., low-energy environment within the impoundments), as inputs of hydrophobic constituents from sources located upstream tend to accumulate with the fine, high organic content sediments in these downstream impoundments. However, the PCB data presented in Section 4 indicate that PCB concentrations in Rising Pond are much lower than those in Woods Pond (due to a reduction in PCB transport and dilution from clean solids that enter the River over the 20-mile reach between these impoundments), whereas the PCDD/PCDF data indicate the opposite (Figures 8-15 and 8-16). The presence of higher PCDD/PCDF concentrations in Rising Pond sediments relative to Woods Pond may suggest additional sources within this reach of the River.

8.6.2.2 Composition Trends

Observed changes in composition across the four reaches were used to further evaluate potential sources of PCDDs/PCDFs to the River. Reach-averaged PCDD/PCDF homolog weight percents are plotted on Figure 8-17. As stated above, average PCDD/PCDF concentrations generally increase with distance downstream across the reaches between the Confluence and Woods Pond Dam (Figure 8-16). This increase is likely a result of the increased accumulation of fine-grained, organic-rich sediments (to which hydrophobic organic chemicals preferentially sorb). However, composition in these reaches is relatively similar, characterized primarily by a significant fraction of OCDD (D8) (approximately 37% to 43%; Figure 8-17). The patterns on Figure 8-17 indicate that a shift in the average homolog composition is observed in Rising Pond (Reach 8). In this reach, not only are average PCDD/PCDF concentrations higher than in Woods Pond but the composition contains a higher proportion of the heptachlorodibenzo-p-dioxin (HPCDD) and OCDD compounds, which again may suggest additional PCDD sources between Woods Pond and Rising Pond. The presence of paper mills at Columbia Mill and Willow Mill Dams and the strong D7-D8 signal in the Rising Pond composition are consistent with this suggestion.

8.6.2.3 PCDD/PCDF TEQs

As discussed in Section 4.9, another method of assessing PCDD/PCDF sources is by calculating the total TEQ concentrations for the PCDD/PCDF compounds in the samples. These TEQ values are plotted in the top panel of Figure 8-18. The spatial pattern in this plot generally follows that of the individual congeners and homologs discussed above. TEQs calculated for samples collected in Reach 5 exhibit a large amount of variability, but are generally within the 10-100 pg/g range. Relatively higher TEQs occur in the Woods Pond and Rising Pond sediment data, due to the higher PCDD/PCDF concentrations associated with the high inventory of organic carbon in these impoundments.

The calculated TEQs were averaged for the same four reaches described above, and are plotted in the bottom panel of Figure 8-18. Since the data analyses described above suggest there may be additional sources of PCDDs between Reaches 6 and 8, the reach-average TEQs were proportioned among the PCDD and PCDF compounds in this plot. Differences in this proportion among the reaches may be indicative of different sources. Reach-average TEQ concentrations range from approximately 40 pg/g in

Reach 5A to approximately 200 pg/g in Reach 6 (Woods Pond). However the PCDD fraction of the TEQ is relatively constant, at approximately 20%. Conversely, nearly 30% of the 175 pg/g average TEQ in Rising Pond is associated with PCDDs. This shift further implies that there may be an additional source of PCDDs downstream of Woods Pond, which is consistent with the observed patters in PCDD/PCDF concentrations and composition discussed above.

8.7 PCB Composition in the System

The fate of PCBs in the system is affected by PCB composition. A number of physicochemical and biochemical processes ultimately depend on PCB composition (e.g., partitioning, volatilization, and bioaccumulation). As discussed in Sections 3 and 4, the majority of PCBs detected in the Housatonic River water column and sediment were quantified as Aroclor 1260 and, to a lesser extent, Aroclor 1254. These quantifications are consistent with the source Aroclors used at the GE Pittsfield facility. These compounds are towards the heavier end of the PCB spectrum, with the majority of the PCB congeners having between five and seven CL/BP. Higher chlorinated congeners are generally less soluble in water and tend to bioaccumulate more readily as they have a higher affinity for lipids. Also, the extent to which PCBs sorb to organic matter generally increases with increasing number of CL/BP. Therefore, an understanding of PCB composition, and how such composition changes in the system, is important in the evaluation of PCB fate and transport. The majority of Housatonic River water column, sediment, and fish data collected since 1980 have been quantified as Aroclor PCBs. However, more recent data collection efforts by EPA have also quantified PCBs at the congener-specific level; these congener-specific data were used to evaluate PCB homolog composition in Sections 3 through 6.

The homolog distributions are generally consistent with the Aroclor quantifications (i.e., predominance of Aroclor 1260, with a lesser amount of Aroclor 1254). However, they do show some slight differences among media and reaches. As discussed in Section 4.8, PCBs in the sediments consist predominantly of congeners with six (hexa) or seven (hepta) CL/BP. A slight increase in less chlorinated congeners occurs near Woods Pond, which may be the result of modest dechlorination processes (see Section 8.8.1.11). In general, the water column PCB composition has a greater percentage of lower chlorinated congeners than is observed in the sediment (e.g., Figure 3-20). This same shift in composition between the water column and sediment data is consistent with the observed shift in the average Aroclor 1254 and 1260 quantitation shown in Tables 3-12 and 4-11. Further, the PCB composition observed in dissolved water column samples (Figure 3-20) is consistent with that expected from diffusion of lighter chlorinated PCBs from sediment pore water during low-flow conditions (Figure 4-28). The propensity for desorption of lower chlorinated PCBs from sediments may be the cause of this shift in composition. In general, fish tissue homolog patterns are consistent with those observed in the water column and sediment data (e.g., Figure 6-11).

8.8 Mechanisms of PCB Fate, Transport, and Bioaccumulation

In this section, various mechanisms of PCB fate, transport, and bioaccumulation are discussed. Because of differences for some fate and transport mechanisms, the three hydrologic regimes in the system – main channel, backwaters, and floodplains – are discussed separately. For each regime, the important mechanisms are discussed, and to the extent possible, data analyses and calculations are presented to evaluate their relative importance. This section focuses on reaches of the river where the preponderance of the data has been collected: Reaches 5 and 6. Some discussion of further downstream reaches is also provided where the available data are adequate to do so.

8.8.1 Main Channel

The major processes potentially affecting fate and transport of PCBs within the water column and sediments of the main channel in the system include:

- Water column transport (i.e., advection and dispersion);
- Partitioning of PCBs between particulate and dissolved phases;
- Diffusive exchange at the sediment-water interface;
- Deposition and resuspension, which contribute to sedimentation;
- Transport with bed load at the sediment-water interface;
- Exchange at the air-water interface (i.e., volatilization); and
- Transformations within the bed from reductive dechlorination.

8.8.1.1 Advection/Dispersion

Mass transport of constituents suspended and/or dissolved in the water column (e.g., solids and PCBs) is controlled by advective and dispersive processes in a river. Advection of water column constituents is caused by moving water, which is quantified by current velocity and flow rate. Current velocity is spatially and temporally variable; velocity at a particular location in a river depends upon different factors including channel gradient, bathymetry and channel geometry, bed roughness, vegetation, and flow rate. Dispersion in a river refers to mixing processes caused by turbulent fluctuations of the currents. Similar to other rivers, vertical turbulent mixing in the Housatonic River is in most places large enough to keep the water column well mixed under most conditions. Horizontal turbulent mixing processes vary in space and time, with horizontal dispersion generally increasing as flow rate increases in a river.

Mass transport of PCBs and other water column constituents can be separated into two broad categories: 1) in-channel flow conditions; and 2) overbank flow conditions. Flow in the River is confined within the main channel for in-channel conditions. The primary advective process is typically transport by currents along the longitudinal axis of the River channel. Lateral current velocities are generally significantly smaller than longitudinal velocities; lateral currents, however, make important contributions to horizontal mixing. Within the Rest of River system, mass transport between the main channel and adjoining backwaters is usually relatively small for in-channel flow conditions. Overbank flow allows PCBs and other constituents to be transported to the floodplain and backwaters during high-flow events. The magnitudes of advective and dispersive mass transport to the floodplain are spatially and temporally variable between the Confluence and Woods Pond. Local bathymetry and geometry conditions, along with the magnitude of the flood and position on the flood hydrograph, affect mass transport processes among the main channel, backwaters and the floodplain during overbank flow.

To evaluate PCB mass transport within the system, spatial patterns of in-River PCB loadings have been evaluated. These loadings quantify advective PCB transport; the spatial trends can be used to evaluate contributing mechanisms. Spatial profiles of average water column PCB loadings are shown on Figure 8-19 for each individual year from 1996 to 2002. Based on the observed dependence of PCB concentrations on flow (see Section 3), average loadings were separated into low flow and higher flow (i.e., below and above 100 cfs at Coltsville) in this plot. These plots indicate year-to-year differences in PCB loadings. Some of the variability in higher-flow loadings is related to flow. For example, the elevated loadings observed in 1999 can be explained by higher average flows during the days of sampling for that year (Figure 8-19b). The spatial trend and magnitude of the PCB loading during lower flows is generally consistent between 1997 and 2002, but the calculated low-flow loadings for 1996 are substantially higher. For example, at the first water column sampling location in Reach 5A (Holmes Road), the 1996 low-flow PCB loading is higher than the other years' averages at any of the remaining locations between 1997 and 2002. Further, there is much greater variability in the low-flow averages for the downstream sampling locations in 1996 (i.e., New Lenox Road, Woods Pond Headwaters). One possible explanation for the observed differences in PCB loading during 1996 may be due to changes in sampling and analytical methods that were implemented beginning in 1997. Consistent sampling and analytical techniques have been used by GE since 1997 which may explain the similarity in the data collected since that time. For these reasons, the analysis of spatial patterns in water column PCB loads presented in the remainder of this section focus primarily on the 1997-2002 GE dataset. For completeness, these GE data were supplemented with the 1998-1999 EPA routine water column monitoring data.

Based on these data, average spatial profiles of advective PCB loads between the Dawes/Pomeroy Avenue and the Schweitzer/Lenoxdale Bridge, for flows both less than and greater than 100 cfs at Coltsville, are plotted on Figure 8-20. Under low-flow conditions (flows less than 100 cfs at Coltsville), there is a consistent increase in the average water column PCB load from approximately 7 g/d at Dawes/Pomeroy Avenue to approximately 22 g/d at Woods Pond Headwaters. The PCB load is transported downstream via advection, where it then decreases to approximately 18 g/d across Woods Pond. This decrease in loading is likely due to sorption of PCBs to abundant biotic solids present in Woods Pond that subsequently settle out of the water column (discussed further in Section 8.8.1.7). Low-flow PCB loadings downstream of Reach 8 (Rising Pond) measured at Division Street (not plotted) are lower, averaging 14 g/d; this decrease indicates PCB loss processes (e.g., volatilization and/or deposition) are occurring over this 20-mile stretch of the River. As indicated in Section 3, data were not available to develop comparable loading calculations for the Connecticut portion of the River.

Under higher-flow conditions (greater than 100 cfs at Coltsville), there is a notable difference in the spatial profile of water column loading (Figure 8-20). In general, PCB loadings under these flow conditions are nearly an order of magnitude higher than low-flow loadings, due to additional inputs to the water column associated with erosion of sediments and bank soils (to some extent). On average, PCB loadings increase to a maximum of approximately 320 g/d at New Lenox Road, and then decrease by approximately a factor of two between New Lenox Road and Woods Pond Dam (Figure 8-20). The reason for this decrease is likely settling of PCBs sorbed to solids, which is caused by lower current velocities in this region of the River. Also, during higher-flow periods when the River is overbank, the observed spatial pattern in water column loading is likely impacted by interactions with the floodplains and backwater regions downstream of New Lenox Road. Based on data collected at Division Street Bridge, high flow PCB loads further decrease to an average of under 100 g/d (not plotted), suggesting PCBs transported over Woods Pond Dam are deposited within Reaches 7 and/or 8 under these conditions.

Table 8-4 contains a summary of annual average advective loadings passing five locations that have been routinely monitored by GE between 1997 and 2002. Annual loadings were calculated based on daily average loading estimates weighted according to the percentage of days the River was at low and higher flows (as defined above) from 1997 to 2001 (approximately 70% low flow, 30% higher flow, using 100 cfs at Coltsville as a cutoff). The estimated PCB load entering the Rest of River reach at Dawes/Pomeroy Avenue is approximately 10 kg/yr. This annual average loading increases by approximately 25 kg/yr over Reach 5A and the upper portion of Reach 5B, and then declines by nearly 20 kg/yr downstream of Woods Pond.

Table 8-4. 1997-2002 Annual Average PCB Loadings in the Housatonic River

Location	Annual PCB Load (kg/yr)
Dawes/Pomeroy Avenue	10
Holmes Road	21
New Lenox Road	36
Woods Pond Headwaters	35
Schweitzer/Lenoxdale Bridge	21
Division Street Bridge	14

The remainder of this section will address the various mechanisms contributing to the observed gains and losses of PCBs transported in the water column.

8.8.1.2 Partitioning to Organic Matter

As discussed in Section 8.4, PCBs partition onto organic carbon in both dissolved and particulate forms. This process is an important determinant in the fate, transport, and bioaccumulation of PCBs. For example, partitioning within sediments determines the concentrations in pore water, which govern diffusive flux to the water column. Similarly, partitioning in the surface water during elevated flows determines how much of the PCBs are transported with the water and how much will settle with solids in quiescent areas.

Typically, partitioning of PCBs is described by an organic carbon-referenced sorption partition coefficient (K_{oc}), which describes the equilibrium ratio of sorbed chemical concentration to dissolved chemical concentration. When PCBs partition to dissolved and colloidal organic matter, the distribution of PCBs between the dissolved and particulate phases is affected. Sorption of PCBs within the dissolved phase reduces bioavailability because only freely dissolved chemical can be taken up through the respiratory surfaces of aquatic animals (Landrum et al., 1985, 1987). The partition coefficient describing the equilibrium sorption of PCBs to dissolved/colloidal organic matter is typically expressed on an organic carbon basis and is termed K_{doc}. The value of K_{doc} is typically less than that of K_{oc} (e.g., Evans, 1988). Equations defining partitioning coefficients are presented in Appendix E.3.

PCB sorption in the Housatonic River was investigated through a joint EPA/GE field sampling and analysis program conducted during the fall of 2001 and spring of 2002 (Appendix A). This program consisted of sampling and analysis to evaluate the PCB and organic carbon phase distribution in surface sediments (and associated pore water) and surface water (including direct analysis of suspended matter)[3].

Surface sediment PCB and TOC concentrations from the partitioning study are plotted spatially on Figure 8-21. These results are generally consistent with the data from the larger EPA 1998-2002 program, with the exception of samples collected from Reach 5A, in which locations with higher PCBs and lower TOC were selectively sampled (to facilitate an evaluation of partitioning in coarser sediments). Indeed, the

[3] As discussed in Appendix A, PCBs have been measured in paired filtered and unfiltered water column samples in various sampling programs, including EPA's 1999 data. Although these data provide a means for evaluating PCB phase distribution (e.g., particulate and dissolved fractions), considerable uncertainty would be introduced if these data were used to evaluate water column partitioning because it is necessary to calculate particulate PCBs by subtraction of whole water and filtered sample results. Therefore, water column partitioning was evaluated based on the data from the 2001-2002 EPA/GE study (Appendix A).

median organic carbon-normalized PCB concentration from the 2001 samples in Reach 5A appears to be substantially greater than that of the entire dataset (Figure 8-21).

These data were used in conjunction with the pore water PCB and TOC data to estimate site-specific partitioning coefficients using the equations discussed in Appendix E.3. The calculated K_{oc} values from this analysis are plotted spatially on Figure 8-22. Included for comparison in this plot is a range of published K_{oc} values for Aroclor 1260 (MacKay et al., 1992a). Calculated K_{oc} values for a majority of the samples, except for several from Reach 5A, fall within this range, which is also consistent with K_{oc} values for the hexa and hepta congeners reported in other studies (e.g., MacKay et al., 1992a). The samples in Reach 5A with K_{oc} values exceeding this range are characterized by extremely low TOC concentrations, which produce very high organic carbon-normalized sediment PCB concentrations. The pore water PCB concentrations in these samples, however, are not elevated as would be expected. Possible explanations for this difference are that the PCBs are resistantly bound to the particles or that that the nature of the organic carbon differs from the remainder of the system in these regions. However, flux calculations (discussed in the following subsection) indicate that this group of samples is likely not representative of the Reach as a whole. Downstream of Reach 5A, there is no clear spatial trend in calculated K_{oc} for these samples, although some values near Woods Pond are higher than those from Reaches 5B and 5C. This increase may be explained by a difference in the nature of the organic matter (i.e., decaying algal matter in the surface sediments is more prevalent in this highly productive impoundment). In general, apart from the elevated and non-representative K_{oc} values in Reach 5A (discussed above), the K_{oc} values calculated from these data are consistent with expected values, indicating that PCBs in the Housatonic River sediments partition to particulate and dissolved organic carbon in the expected proportions.

Surface water sampling in the partitioning study was conducted for three different events covering low-, moderate-, and high-flow conditions. The daily average flows measured at the Coltsville gage for these events were 25, 230, and 330 cfs, respectively, with respective peak flows of approximately 300 and 440 cfs during the moderate and high-flow events. A spatial profile of dissolved and particulate-phase PCB concentrations measured during the three events is plotted on Figure 8-23. The observed spatial pattern and magnitude of PCB concentrations in this plot are similar to those discussed in Section 8.8.1.1. This plot also demonstrates that there is a shift in the fraction of PCBs bound to water column particulate matter across these events. The particulate and dissolved PCB concentrations were similar during the low-flow event, indicating that approximately half the PCBs were partitioned onto suspended matter.

However, higher values of the particulate fractions were observed at Woods Pond during the low-flow event due to a higher f_{oc} (likely associated with phytoplankton). The fraction of PCBs in the particulate phase increased to approximately 80% for the moderate-flow event and to 90% for the high-flow event, as evidenced by the large difference in particulate and dissolved PCB concentrations (Figure 8-23). This observed increase in the particulate fraction is consistent with resuspension of PCB-containing sediments during higher flows. In both these events, the relative amount of particulate-phase PCB decreased at the Woods Pond station, which is indicative of solids settling.

Similar to the analysis presented above for sediment/pore water partitioning, 3-phase K_{oc} values were calculated for the surface water samples according to the equations in Appendix E.3. Calculated surface water K_{oc} values are plotted spatially on Figure 8-24. For comparison, the calculated sediment/pore water K_{oc} values are also included in this plot. In general, surface water K_{oc} values are within the range of those calculated for sediment/pore water (and are also consistent with the range of values reported for Aroclor 1260). This plot also indicates a small increase in calculated K_{oc} with increasing flow, which may suggest that water column PCBs in the particulate and dissolved phases were not fully at equilibrium at the time the high-flow samples were filtered. This is not unexpected, as PCBs sorbed to sediments will desorb once suspended into the water column due to the difference in overall fraction of PCBs in the dissolved phase (i.e., dissolved PCBs in the bed typically represent less than 1% of the total mass per unit volume); this process occurs over time scales of several hours.

Overall, based on the data and analyses presented in this section, it appears that PCBs in the Housatonic River partition to particulate and dissolved organic carbon in the expected proportions in both the sediments and water column. The relative amount of PCBs sorbed to suspended matter in the water column changes significantly with River flow due to the large changes in suspended sediment concentrations.

8.8.1.3 Diffusive Flux from Sediments

During low-flow conditions, a significant internal source of PCBs to the water column is diffusion of PCB-containing pore water from sediments. Estimates of sediment diffusive flux have been developed based upon equilibrium partitioning of PCBs between sediments and pore water and the interaction between the sediments and water column as represented by a mass transfer coefficient. The primary objective of the diffusive flux calculation is to evaluate the extent to which sediment PCB sources can account for the observed advective PCB loading between the Confluence and Woods Pond during low-flow conditions (< 100 cfs at Coltsville), as discussed in Section 8.8.1.1; a detailed description of the equations is presented in Appendix E.4.

The cumulative diffusive PCB loading calculated for one-mile subreaches between the Confluence and Woods Pond Headwaters is plotted on Figure 8-25 against the average observed low-flow water column PCB loading. Based on this plot, it is reasonable to conclude that the majority of the observed low-flow water column load gain across Reach 5 can be attributed to sediment diffusive flux during low-flow conditions. Based on the values plotted in Figure 8-24, a K_{oc} of $10^{6.4}$ was used to describe partitioning to organic carbon in this analysis. Preliminary calculations using K_{oc} values of 10^7 and greater in Reach 5A resulted in calculated PCB loads that were more than a factor of 2 lower than the data, indicating that the sediment/pore water samples in Reach 5A that had calculated K_{oc} values greater than 10^7 are not representative of the reach as a whole. The greatest uncertainty in this calculation is the estimated sediment/water exchange coefficient; however, the value selected is within the range of those calculated for other riverine systems (e.g., QEA, 1999). Another source of uncertainty is the extent to which the backwaters contribute to the loading observed in the main channel of the River during low flow, particularly downstream of New Lenox Road. It is possible that lateral dispersive exchange of PCBs occurs between the backwaters and main channel, thereby contributing to the flux measured in the main channel. This mechanism is discussed further in Section 8.8.2.

8.8.1.4 Volatilization

Volatilization is the process by which PCBs are transported across the air-water interface. A chemical's tendency to volatilize is determined by its Henry's constant, which equals the vapor pressure divided by its solubility in water and can be calculated from the equilibrium ratio of gas phase and water phase concentrations in a laboratory experiment. A high Henry's constant is indicative of a volatile chemical that preferentially accumulates in the air phase. A low Henry's constant is indicative of a non-volatile chemical that preferentially accumulates in the water phase. Values of Henry's constant for Aroclors 1254 and 1260 are relatively low (MacKay et al., 1992a), but are of sufficient magnitude to warrant consideration of volatilization, particularly in regions with large surface areas and long residence times (such as Woods Pond and the backwater regions).

The importance of volatilization within the main channel was evaluated using an upper-bound calculation for Woods Pond, as presented in Appendix E.5. This calculation suggests that volatilization would cause water column dissolved PCB concentrations to decrease across Woods Pond by approximately 5% under typical low-flow conditions. At higher flows, volatilization would be lower because the hydraulic residence time is much shorter (although the rate of mass transfer would increase to some extent because of increased current velocities). Therefore, PCB volatilization from the main channel can be considered a minor PCB loss mechanism for the system between the Confluence and Woods Pond Dam.

Volatilization may be more important for the remainder of the system (i.e., Reaches 7 through 9 and the Connecticut portion of the River), as the travel time through these reaches is much longer, and current velocities and turbulence are greater through the freely flowing portions. Further, volatilization across the dams, which occurs due to increased efficiency of gas transfer in the high-energy environment at the base of the dams, would cause the total flux in these reaches to be enhanced to some extent. However, the concentrations are considerably lower in these downstream reaches due to the dilution effects of tributary hydrologic loadings, thereby reducing the driving force for volatilization.

8.8.1.5 Deposition/Resuspension

Sediment resuspension depends on bottom shear stress and various bed properties. Bottom shear stress is generated by water flowing over the sediment bed and is affected by the shape of the bed. Sediment properties that affect erosion include grain size distribution, dry density, organic matter content, gas content, and mineralogy. The erosion properties of cohesive and non-cohesive beds are different. Erosion from a cohesive (muddy) sediment bed at a particular shear stress is generally limited to a finite depth due to bed armoring processes. By contrast, a non-cohesive (sandy) bed with an approximately uniform grain size distribution will erode, once a critical shear stress has been exceeded, until the bed is depleted of material. In the Housatonic River, however, non-cohesive bed areas generally have a sufficiently wide range of particle sizes to ensure that bed armoring processes limit scour depths during floods.

Temporal profiles of TSS and PCB data collected during storm events sampled by EPA were presented in Section 3 (Figure 3-14). During two of these events, GE collected split samples at one location that were analyzed for PCBs and TSS during every hour of sampling (Figures 3-14a and 3-14f). For each event, TSS concentration increased in a manner similar to that of the hydrograph. While some of the observed increase in solids may be attributed to tributary inputs (as discussed in Section 3), a portion of this solids increase is due to resuspension of bed sediments and potentially bank erosion upstream of the sampling locations. This is supported by the observed increase in PCB concentrations in the water column, which is consistent with resuspension of PCB-containing sediments in the main channel of the River and bank erosion, and not inputs of relatively clean solids from upstream tributaries. Once suspended in the water column, PCBs sorbed to sediment particles are transported downstream via advection, and may be deposited in a lower-energy environment.

A field study was conducted by GE during June 1997 to measure the resuspension properties of cohesive sediments in the Housatonic River. A portable resuspension device, commonly referred to as a shaker, was used to measure the erosion properties of surficial sediment cores collected from the Woods Pond, Columbia Mill, Willow Mill, Glendale, Rising Pond, Falls Village and Bulls Bridge Dam impoundments. The objective of the field study was to obtain site-specific measurements of the erodibility of cohesive sediments (see Appendix E.7 for details). Based on analyses presented in Appendix E.7, the resuspension parameters of cohesive sediments in the Housatonic River are similar to those measured in other systems. For example, based on the resuspension parameters measured for Woods Pond, the depth of erosion that would occur for sediments with a bulk density of 0.4 g/cm^3 under a current velocity of 2 ft/s is approximately 2.0 mm, which is similar to results for cohesive sediments from the Upper Hudson River (1.8 mm), the Lower Fox River (8.0 mm), the Saginaw River (1.6 mm), and the Buffalo River (0.8 mm) (see Appendix E.7).

8.8.1.6 Sedimentation

When annual deposition exceeds erosion, significant sediment accumulation can occur over large time scales. Sedimentation includes the combined effects of settling of both allochthonous and autochthonous solids. As discussed in Section 4.5.4, sedimentation rates in the River have been estimated based on analysis of Cs-137 profiles in finely segmented sediment cores. Since 1995, 32 of these finely segmented sediment cores have been collected, but only 75% of these cores had Cs-137 depth profiles that are sufficient to estimate deposition rates (see Section 4.5.4 and Figures 4-21c and 4-22). Based on such cores collected in Woods Pond, typical sedimentation rates generally range from about 0.14 to 0.91 cm/yr (Section 4.5.4). The corresponding PCB data further support the conclusion that this region of the River is net depositional, as the higher concentrations are buried at depth in a number of cores, which indicates the decrease in contemporary PCB loadings relative to those during active discharges several decades ago.

Data from cores with interpretable profiles (i.e., a prominent peak in Cs-137 concentration) collected from Rising Pond and Bulls Bridge indicate deposition rates in the range of 0.5 cm/yr to 1.3 cm/yr (see Section 4.5.4). The PCB data from these impoundments also indicate that the highest concentrations are beneath the surface (see Sections 4.5.2.4 and 4.5.2.6), consistent with the significant decreases in PCB transport over the last few decades. These vertical patterns in PCB concentrations indicate that historically discharged PCBs have been sequestered within the sediments accumulated behind these dams.

8.8.1.7 Interactions with Biological Solids

As discussed in Section 8.5.2.1, data and visual observations of Woods Pond indicate that this area of the system is highly productive (i.e., large populations of macrophytes and standing algal mats), particularly during summer months. This increase in productivity, along with an increased PCB residence time in Woods Pond, allows for potentially significant sorption of dissolved PCBs from the water column. PCBs will sorb to this organic material and subsequently settle out of the water column. The settling of biotic solids likely accounts for a significant fraction of the total sedimentation rate in Woods Pond. These observations are supported by the observed decrease in the water column PCB loading across Woods Pond discussed in Section 8.8.1.1.

If PCB removal from the water column via partitioning to biotic solids is significant, a seasonal component to the decrease in PCB loading across Woods Pond would be expected. To assess this seasonality, the difference in water column loading between Woods Pond Headwaters and Schweitzer/Lenoxdale Bridge was calculated using the 1997-2002 GE/EPA data and plotted, by month, on Figure 8-26. To isolate any seasonality, only sampling events having a decrease in PCB load across Woods Pond were considered in the analysis and the magnitude of the decrease was scaled equally in the analysis by normalizing each event to the largest observed decrease between 1997 and 2002. This plot demonstrates that there is a seasonal component to the PCB loss across Woods Pond, as indicated by the increase in PCB loss between February and May (Figure 8-26), likely due to an increase in PCB uptake during initial biotic growth in spring. Later in the year, in the fall, there is a second, smaller increase in the PCB loss across the Pond. This may be associated with a large flux of organic matter due to die-off of algae and macrophytes in the fall. Although there is a fair amount of variability in these data, the seasonal pattern does suggest that deposition of PCBs within Woods Pond is affected by biological activity.

8.8.1.8 Bed Load

Bed load transport involves the movement of coarse sediment in a thin layer near the sediment-water interface. Coarse sand and gravel (i.e., sediment particles with diameters greater than 500 μm) are transported as bed load. Fine and medium sand (i.e., particle diameters between 62 and 500 μm) may be transported as either bed load or suspended load, depending upon the local bottom shear stress, with bed load transitioning to suspended load as shear stress increases (van Rijn, 1984a). Initiation of bed load transport occurs when the bottom shear stress exceeds a certain critical value. The coarse sediment particles roll or bounce (saltate) along the sediment bed in a thin layer (bed load layer) that is typically two to 10 times the median particle diameter (D-50) of the bed material (van Rijn, 1984a). The bed load transport rate depends upon bottom shear stress and size of bed load material.

An important aspect of Housatonic River bed load transport is the load entering from the East Branch at the upstream boundary of the Rest of River. During a storm event in May 2002 (peak 15-minute flow at the USGS gage in Coltsville of 750 cfs), EPA conducted a study to measure bed load transport rates at three locations: Pomeroy Avenue Bridge, adjacent to the EPRI facility (approximate RM 130), and New Lenox Road Bridge. Temporal profiles of data collected at Pomeroy Avenue during this sampling event are plotted on Figure 8-27. The significant increase in TSS observed during the rising limb of the hydrograph (Figure 8-33, panel b) is consistent with other sampling conducted at this location during high-flow events (e.g., Figure 3-14). The D-50 of the bed load solids that were collected ranged from 600 to 1200 μm (i.e., coarse sands), which is consistent with the expected grain size of materials that are transported as bed load. Panels (d) and (e) on Figure 8-27 contain temporal profiles of suspended and bed sediment loading rates, respectively (details on the method for computing loads are provided in Appendix E.8). Integrating these observed rates over the approximate two and a half day duration of this sampling event results in a total suspended load of approximately 400 MT and a total bed load of approximately 16 MT at Pomeroy Avenue. Based on these values, approximately 4% of the total sediment load during this event was transported as bed load, suggesting this mechanism serves as a source of solids to the Rest of River under higher flows.

No bed load transport was observed at the downstream locations (i.e., near the EPRI facility and at New Lenox Road Bridge) at the flows encountered during EPA's May 2002 study. These observations suggest that, at the flows sampled, most of the bed load entering Reach 5A at Pomeroy Avenue remains within that reach. The observed decrease in bed load transport across Reach 5A is consistent with the declines in D-50 and channel gradient, which result in lower velocities and shear stresses for a given flow rate.

To the extent that PCBs are partitioned to the coarse-grained sediments that are transported as bed load, this mechanism can be important for PCB transport as well. During the EPA May 2002 study, PCBs were measured in both the water column and on bed load solids samples (Figure 8-27, panels g and h). Similar to previous monitoring (e.g., Figure 3-14), water column PCBs during this event increased to over 1 μg/L, with one sample at 13 μg/L (Figure 8-27, panel g). PCB concentrations on the bed load solids ranged from 2 mg/kg to 40 mg/kg, with an average of 16 mg/kg (Figure 8-27, panel h); these values are within the range of sediment concentrations measured within the East Branch upstream of the Confluence. Similar to the solids analysis presented above, integration of the PCB loading rates (see Appendix E.8) over the duration of this sampling event resulted in a water column PCB load of approximately 8 kg and a PCB bed load of 0.15 kg for this event. The magnitude of this water column PCB load is influenced by the one uncharacteristically high PCB concentration of 13 μg/L; removing this value from the analysis results in a water column PCB load of approximately 2.4 kg for this event. Based on this value, approximately 6% of the PCB mass entering the Rest of River during this event was associated with bed load. Comparing the observed PCB bed load computed for this single sampling event (i.e., 0.15 kg) to the annual average water column PCB loading at Dawes/Pomeroy Avenue (10 kg/yr -- Table 8-4, above) indicates that bed load transport of PCB may account for a percentage of the PCBs entering the system from upstream.

Bed load transport within Reach 5A likely acts as a mechanism to redistribute the PCBs associated with coarse grained surface sediments. However, for flow regimes similar to or lower than those observed during the May 2002 storm event, this mechanism appears to be limited primarily to Reach 5A, and decreases with downstream distance as the River's gradient, current velocities, and sediment character change at Reach 5B. This statement is further supported by the absence of bed load at the Reach 5B monitoring locations during the EPA May 2002 storm event.

EPA conducted additional bed load sampling at New Lenox Road during a March 2003 storm event (peak 15-minute flow at the USGS gage in Coltsville of 2,100 cfs). This sampling event was limited compared to the May 2002 event in that only a single bed load sample was taken and no water column samples were collected. In contrast to the May 2002 event, bed load transport was observed at New Lenox Road, indicating that, at the much higher flows experienced during this event, bed load transport extends beyond this location. As expected, the materials sampled during the March 2003 event were coarse sediments, with a D-50 of approximately 700 μm. If the bed load rate measured by the single sample (~17 MT/d – see Appendix E.8 for calculation method) is representative of the average during the 2-day elevated flow event, the estimated sediment bed load sums to about 33 MT. This value is difficult to put into perspective because sampling was not conducted in the water column or at the upstream stations during this event. However, it should be noted that this value represents less than one percent of the 4,170 MT annual average suspended sediment load passing this location (Table 8-1). The measured PCB concentration on this sediment bed load sample was 2.4 mg/kg, which is consistent with that of coarse grained sediments from Reach 5B (e.g., Figure 4-16).

8.8.1.9 Bank Erosion

Bank erosion is primarily caused by two processes: fluvial entrainment and subaerial/subaqueous weakening and weathering. Bank retreat occurs as a result of entrainment of material directly from bank scour. Bank failure is caused by weakening and weathering processes that decrease bank stability. The rate of bank erosion at a particular location depends on the forces acting on the bank (e.g., applied shear stress from moving water), the bank properties (e.g., type of sediment, grain size distribution, stratigraphy, type, and density of vegetation), as well as the slope of the bank.

To evaluate bank erosion, EPA installed groups of toe pins on October 5, 2000 in the bank at five locations along an approximately 2,000-foot-long reach of the River near RM 130. The toe pins were used to measure bank elevations at four different times over an approximately 20-month period, with the last data collected on June 21, 2002. For the 20-month period from October 2000 to June 2002, average bank erosion rates for the five groups of toe pins ranged from about -0.3 foot per year (ft/yr) to -0.8 ft/yr, with an overall average rate of -0.7 ft/yr (15 observations). It should be noted that the overall average rate for the reach would be lower because these measurements were taken in areas that were visually identified to be undergoing active bank erosion.

In addition, EPA conducted a study to evaluate the migration of riverbanks at 15 locations in Reaches 5A and 5B, shown on Figure 8-28. Bank location data (i.e., top- and bottom-of-bank) were collected along 15 riverbank stretches that ranged in length from approximately 140 feet to 525 feet. The bank location data were obtained at two different times: November 5, 2001 and June 17, 2002. The top- and bottom-of-bank locations were analyzed to determine average changes in bank location during this seven-month period. Average bank erosion occurred for 10 of the 15 bank sections, with mean erosion rates for individual sections ranging from -0.03 ft/yr to -3.0 ft/yr (Figure 8-28). The overall average erosion rate for these 10 eroding bank sections was -0.7 ft/yr, which is the same average erosion rate determined from the toe pin data. The remaining five bank sections experienced net accretion, on average, with accretion rates of 0.07 ft/yr to 2.9 ft/yr and an overall average accretion rate of 1.0 ft/yr. For all 15 bank sections, average erosion occurred during this seven-month period, at a mean rate of -0.3 ft/yr, which is about a factor of two lower than the average of the toe pin erosion rate data. Again, these values are not necessarily representative of Reaches 5A and 5B as a whole because specific bends where bank erosion is more likely to occur were targeted in these surveys.

Based on previous qualitative observations of the riverbank, EPA produced maps in 1998 depicting approximate locations and extent of active bank erosion along the River channel in Reach 5. These maps were used to develop an estimate of the length of bank that is experiencing active bank erosion between the Confluence and New Lenox Road Bridge, which totaled approximately 13,400 feet. This information was used to estimate the annual sediment mass load to the River from bank erosion based on the equation presented in Appendix E.6. The result of this estimate is a range of about 1,400 MT/yr to 3,200 MT/yr of sediment load to the River from bank erosion.

These approximate bank erosion load estimates, when compared to the estimated sediment loadings entering at the Confluence (~1,500 MT/yr for the West Branch and 2,200 MT/yr in the East Branch – see Table 8.1) and at New Lenox Road Bridge (~4,200 MT/yr), suggest that bank erosion may be a significant source of sediment to the River on an annual basis. Comparison of the suspended load values with the bank erosion load estimates suggests that the average bank erosion rate between the Confluence and New Lenox Road Bridge is likely not consistent with the upper end of the average range measured by

EPA (i.e., 0.7 ft/yr), but could be near the lower end (i.e., 0.3 ft/yr). It should be noted, however, that not all material eroded from the banks will be transported as suspended load, as some portion will remain near where it slumped or eroded into the river. To the extent that this occurs, the range of load estimates discussed above (i.e., 1,400 to 3,200 MT/yr) would be lower.

8.8.1.10 River Meanders

Meandering is caused by bank erosion on the outside of a river bend, where current velocities are relatively high, and deposition on the inside of the bend, where velocities are relatively low. Generally, the extent, rate and type of meandering depend on channel gradient, flow rates in a river, channel bed properties, and soil properties of the bank and floodplain. When viewed on a reach scale, meandering is a stochastic process, with the channel moving within the meander belt between the edges of the floodplain. In many rivers, the cross-sectional area of the River will remain approximately constant at a particular location even though the channel is moving laterally as it meanders. In addition, the lateral migration of the channel is typically a major component of the floodplain aggradation process, with deposition during overbank floods being a minor component of that process.

The River channel between the Confluence and Woods Pond headwaters tends to meander, with the extent of meandering and width of the meander belt being spatially variable between these locations. Past meandering is evident from the existence of abandoned oxbows, connected and disconnected backwaters, and cutoffs in the proximal and distal floodplain. Evaluation of channel width:depth ratios (Section 2) indicates that Reach 5A channel is classified as sinuous (between straight and minimally meandering), Reach 5B is minimally meandering, and Reach 5C has a moderately meandering channel.

As part of a river meandering study, EPA generated digital shorelines from aerial photography in 1952, 1978, and 2000 to supplement aerial photographs generated by GE in 1990. Qualitative comparison of changes in channel location in the study area between 1990 and 2000 suggests that channel migration during this 10-year period was not extensive, with a relatively stable channel existing in most locations. A small number of meanders and channel sections, however, did experience significant movement during this 10-year period. On a longer time scale, a qualitative evaluation of shoreline location change over the 48-year period between 1952 and 2000 is consistent with the 1990-2000 assessment, as shown on Figure 8-29. Overall, it appears that the River channel has been relatively stable during the past 50 years, with significant channel migration (e.g., meander cutoffs) occurring only at a few locations (e.g., see inset map in Figure 8-29). Based on these observations, there has been no large-scale migration of the River channel over the last 50 years.

The process of meandering results in the movement of solids and PCBs within the system. Although a significant portion of meandering occurs during high-flow events, the process occurs over large spatial and temporal scales. As discussed above, during high-flow events, bank materials are eroded and deposited as the meanders are incrementally formed. During these conditions, PCBs present in bank materials are likely released to the River water column to some extent, and are transported and deposited with solids, as well as transported in the dissolved phase to downstream portions of the River. Because meandering is a process that occurs over large time scales (i.e., decadal or more), the PCB transport associated with this mechanism difficult to quantify on a yearly basis. However, the erosion of bank soils that occurs during high-flow events within a given year is a primary cause of river meandering. The PCB transport associated with this process was described in the previous section.

8.8.1.11 Dechlorination

Microbially mediated reductive dechlorination has the potential to significantly affect the fate and transport of PCBs within the Housatonic River. Dechlorination reduces the total number of chlorine atoms per PCB molecule and alters basic chemical properties (e.g., solubility, K_{ow}), which, in turn, alters a number of fate and bioaccumulation mechanisms (e.g., diffusion, gill uptake by fish).

Numerous studies, conducted both in the laboratory and the field, have documented anaerobic PCB dechlorination as an important biotransformation process (see Bedard and Quensen, 1995, for a review). The rate and extent of biotransformation depend on the PCB chlorine substitution pattern and a myriad of environmental factors. In general, only chlorines in the meta and para position on the PCB molecule are subject to anaerobic dechlorination; their removal depends on the total number and position of the remaining chorines on the molecule (Brown et al., 1987a, 1987b; Sokol et al., 1998).

The rate and extent of PCB dechlorination within the Housatonic River have been extensively studied (Bedard et al., 1996, 1997; van Dort et al., 1997; Bedard and May, 1996; Wu et al., 1997). Bedard and May (1996) applied high-resolution gas chromatographic (GC) techniques to 90 samples collected from Woods Pond and quantified PCBs on a congener basis. The sediments contained between 30 and 150 mg/kg total PCBs. Although sediment PCB congener distributions indicated that the original PCB contaminant was predominately Aroclor 1260, there was clear evidence that the PCBs had lost para-substituted chlorines through dechlorination (Bedard and May, 1996). Relative to Aroclor 1260, sediment PCBs exhibited losses in the major hexa- and heptachlorobiphenyls and gains in select tri-, tetra, and pentachlorinated biphenyls. Specific tetrachlorinated biphenyls not found in Aroclor 1260 were present in the sediments. Their existence provided evidence of some PCB dechlorination within the Housatonic River. However, the extent of PCB dechlorination in the Housatonic River was modest relative to that observed in other systems (e.g., the Upper Hudson River, New York; QEA 1999). Indeed, Housatonic River sediment PCBs exhibited only a 13% loss of the meta and para chlorines (Bedard and May, 1996).

The 1998-2002 sediment PCB data collected by EPA and GE support the observations of Bedard and May (1996) of limited natural PCB dechlorination within the Housatonic River. As discussed in Sections 4 and 8.7, sediment PCB composition from these data is dominated by hexa- and heptachlorinated biphenyls (Figure 4-27). The total number of chlorines per biphenyl as well as the total meta + para substituted chlorines per biphenyl are consistent with that of the source Aroclors (predominately Aroclors 1260 and 1254) between the Confluence and Roaring Brook (Figure 8-30). Downstream of Roaring Brook, the meta + para chlorines per biphenyl decline by 0.2, from approximately 3.9 to approximately 3.7 while the total chlorines per biphenyl decline from approximately 6.3 to 6.1 (Figure 8-30). This modest drop in meta + para chorines is consistent with other field observations of Woods Pond sediment PCB dechlorination (Bedard and May, 1996).

While PCB dechlorination has been observed in Housatonic River sediments, the rate and extent of dechlorination do not appear to be of significance in the analysis of PCB fate and transport within the system.

8.8.2 Backwaters

Two types of backwaters exist in the Rest of River area: 1) backwaters hydraulically connected to the main channel; and 2) backwaters disconnected from the main channel (including vernal pools; see Section 5). With regard to PCB fate and transport, many of the mechanisms discussed above are much less significant in both types of backwater areas. For example, sediment resuspension is likely not important in backwaters because of relatively low current velocities in these areas. However, some of the mechanisms discussed for the main channel, such as PCB partitioning, occur similarly in the backwater regions. Of all the mechanisms discussed above, the most important mechanisms affecting PCB fate and transport in backwaters are advection between backwaters and the main channel (flushing), diffusive flux of PCBs from sediments to the water column, deposition, and volatilization. Each of these mechanisms is discussed in the following sub-sections in the context of their relative importance in backwater areas.

8.8.2.1 Advection/Dispersion

During low to moderate flow conditions when the River flow remains within the main channel, mass transport between the channel and the connected backwaters is relatively low. The interface providing a hydraulic connection between most of the backwaters (primarily backwaters located upstream of Woods Pond Headwaters) and the main channel consists of a narrow, shallow ledge that prevents significant advection and dispersion of constituents. For example, while typical water depths within the main channel of Reach 5C are several feet (e.g., Figure 2-8), the depth at the interface with a backwater region is often less than one foot. During high-flow conditions when the River goes overbank, a significant amount of suspended constituents may be transported into or out of both connected and disconnected backwaters as those areas become inundated with floodwaters. Overbank flow is the only condition that transports material into the disconnected backwaters.

8.8.2.2 Diffusive Sediment Flux

Within backwaters (both connected and disconnected), diffusive flux from sediments is likely the primary source of PCBs to the overlying water column. As discussed above, there is likely little advective exchange between backwaters and the main channel under low to moderate flow conditions. Surface sediment data indicate typical PCB concentrations of 10 mg/kg to 100 mg/kg in many of the backwater regions (see Figure 4-20). Therefore, under these conditions, it is expected that water contained in backwater areas will have a relatively long residence time, causing PCBs in sediment pore water to diffuse to the overlying water until a state of equilibrium is reached (volatilization would alter this equilibrium to some extent).

If diffusion from sediment pore water is the primary source of PCBs to the water column in backwater regions given the conditions described above (i.e., little advective exchange and long residence time), it is expected that a positive relationship would exist between the observed water column and sediment concentrations. One way to evaluate this relationship is by comparing average water column and organic carbon-normalized surface sediment concentrations in the backwater regions for which PCBs were measured in both media; these are limited to a small number of vernal pools sampled by EPA. This comparison, presented on Figure 8-31, indicates that a positive relationship appears to exist between water column and sediment concentrations in the select pools sampled by EPA.

This mechanism has some implications with regard to PCB fate in the system. During low-flow conditions when the River is within bank, water contained in backwater areas has the potential to accumulate PCBs that are diffusing from sediments. This could be important in some of the larger backwater areas that have relatively high surface sediment concentrations. For example, surface sediment PCBs in excess of 50 mg/kg were observed in a number of the backwater areas (see Figure 4-20). As PCBs from sediment pore water diffuse within these backwaters, water column concentrations in these areas may be relatively high during low-flow conditions, which will affect exposure to the aquatic food web. During high-flow periods when the River is overbank, some of these backwater areas are inundated with floodwaters and are consequently "flushed," as they undergo advective exchange with the main channel. The total PCB mass transported to the main channel under such events, however, would likely be much less than that associated with PCB advection in the main channel (e.g., as a result of erosion from upstream channel sediments) because of the large difference in total volume transported. Further, the PCB loading to the system associated with diffusion from backwater sediments likely accounts for a small portion of the overall system mass balance.

8.8.2.3 Volatilization

Volatilization is one PCB loss mechanism that is potentially more significant in backwaters than in the main channel. Specifically, backwaters have a relatively large surface area and a much larger hydraulic residence time than the main channel; this would tend to increase the relative importance of volatilization flux from the system. However, because there is little flow in these water bodies, volatilization is limited by the rate of gas film transport at the air-water interface. Although little data are available to assess volatilization in backwaters, the range of water concentrations measured in some of the small vernal pools is within that expected based on equilibrium conditions between sediment pore water diffusion and volatilization. However, while volatilization may potentially be much greater in backwater areas, the total mass volatilized is likely a small fraction of the overall system mass balance.

8.8.2.4 Deposition/Resuspension

The primary sediment transport process occurring in backwaters is deposition during overbank flow conditions. As discussed in Section 8.8.2.1, significant transport of sediment to backwaters only occurs during high-flow events when the River is overbank. Most backwaters will experience deposition during these overbank floods because of reduced bottom shear stresses in these areas due to the increased water depth relative to the surrounding floodplain. In addition, extensive vegetation in the backwaters enhances deposition. Resuspension in backwaters is likely minimal because of reduced bottom shear stresses and vegetation. Deposition during high-flow events, therefore, serves as a PCB source for backwater regions; this is consistent with the similarity between PCB data from these regions and the main channel (Section 4.5.3.2). As a result of net decomposition in the backwater regions, sedimentation is expected to be an important process in these areas.

8.8.3 Floodplains

As discussed in Sections 4 and 5, the physical and chemical properties of constituents (e.g., organic carbon content, grain size, and PCB composition) within the floodplains are generally similar to those in the main channel and backwater regions. For this reason, PCB fate and transport in the floodplains differ from that in the main channel and backwaters due only to the different nature of their hydrologic regime (i.e., occasional inundation, followed by long periods in which these regions are considered "dry").

The proximal floodplains within the system become inundated during high-flow events, during which the River flow goes overbank; this occurs to some extent nearly every year. As a result of these processes, PCBs can be transported to and deposited in the floodplain regions during such conditions. Following high-flow events, floodplain regions become dry as a result of infiltration, evaporation, and transpiration processes. When the floodplain regions are dry, significant PCB mass transport and exchange do not occur (i.e., there is no diffusion to surface water and limited volatilization). Therefore, the exchange processes during high flow (i.e., advection and deposition) are the most significant PCB fate and transport mechanisms in floodplain regions.

8.8.3.1 Advection/Dispersion

Transport of suspended constituents to the floodplains only occurs during overbank floods. The extent of floodplain inundation varies with the magnitude of the flood, with the proximal floodplain being flooded more frequently than the distal portions of the floodplain, as discussed in Section 5. Current velocities and advective mass fluxes in the floodplain tend to decrease with distance from the main channel. In addition, vegetation impacts water movement in the floodplain by increasing drag on flowing water and decreasing the current velocity.

8.8.3.2 Deposition/Resuspension

Floodplains are generally depositional during high-flow events that go overbank, primarily because the floodplain is vegetated. Vegetation enhances deposition of suspended sediment in floodplain areas by two means: reduction in bottom shear stresses and filtration of suspended sediment. Vegetation also minimizes erosion of floodplain soils during overbank floods due to reductions in bottom shear stresses and stabilization of soils by their root systems.

Evidence that the Housatonic River floodplain is depositional can be seen by examining floodplain soil PCB data (discussed in Section 5). Figure 8-32 contains a spatial profile of floodplain soil concentrations between the Confluence and Woods Pond, compared to the sediment data. The floodplain soil data plotted in this figure do not differentiate samples collected in the proximal and distal floodplains; concentration differences between the two are discussed in Section 5. In general, floodplain soil PCB concentrations are within the range of concentrations observed in in-River sediments, suggesting that depositional processes that distributed PCBs within the River sediments over time were also occurring within the floodplains.

Consistent with the processes of PCB deposition in the floodplain and minimization of erosion from the floodplain back to the river due to vegetation, PCBs in floodplain soils appear to have low potential for remobilization to downstream areas.

8.8.4 PCB Bioaccumulation

PCBs are transferred from the sediments and waters of the Housatonic River through the aquatic food web to fish. This section describes the significant mechanisms by which PCBs are accumulated within the aquatic food web, including invertebrates and fish.

Uptake of PCBs by fish occurs via their diet and directly from the water across their gill surface (Figure 8-33). Loss mechanisms are diffusion across the gill surface back into the water, metabolism (that is, transformation of the PCBs within the fish body), and excretion across the gut surface into the feces. Growth of the fish itself lowers PCB concentrations in the body through dilution of the body burden. Exposure sources (i.e., diet and food web structure) and exposure locations (movement patterns) were discussed in Section 8.4.

8.8.4.1 PCB Uptake Mechanisms

Contaminant mass transfer at the gut wall is determined by the amount of food consumed and the chemical assimilation efficiency. The amount of food consumed is determined by the energetic needs of the fish for respiration and movement, and is influenced by the availability of food. Food consumed in excess of basic requirements is used for growth. Organisms can take up, or assimilate, a significant fraction of the PCBs present in the food.

PCBs dissolved in the water and in the blood diffuse across the gill surface. If the concentration of PCBs in the blood is greater than in the surrounding waters, the gill provides a means for elimination of PCBs. If the concentration in the blood is lower, there is a net uptake of PCBs across the gill into the fish. PCBs taken up across the gill move via the blood throughout the body and are stored in its tissues. PCBs are primarily stored in lipids, or fats, wherever they occur in the body (e.g., fat that occurs within muscle tissue, or fat stores in other parts of the body). Elimination is the opposite process: PCBs are released from the fatty storage tissues, are transported via the blood to the gill, and diffuse into the environment.

8.8.4.2 PCB Loss Mechanisms

PCBs are eliminated across the gut wall (Gobas et al., 1989; Connolly et al., 1992). Elimination across the gut is relatively more important for the more hydrophobic congeners. Elimination can be very slow in chronically exposed fish (de Boer et al., 1994; Lieb et al., 1974;, Sijm et al., 1992). This is because lipid is a "deep" compartment, that is, one which holds on tightly to the PCBs. Elimination is controlled in large part by the fat content of the organism: with more fat, the organism can more easily store PCBs. The consequence of this is that wet-weight-based fish PCB concentrations will often vary with the lipid content of the fish – i.e., the concentrations will be lower in fish with low lipid levels and higher in fish with high lipid levels. However, other mechanisms (e.g., growth dilution, as discussed below) can confound this relationship. As discussed in Section 6.3.2 for the datasets of interest here, fish tissue PCB concentrations correlated with lipid content for some species, size ranges, and locations and not for others.

Fish metabolize PCBs, but such metabolism is generally limited to certain congeners and may not be of great importance on a total PCB basis (Stapleton et al., 2001).

Growth leads to dilution of PCB concentrations in the body through the accumulation of body mass. In rapidly growing fish, growth dilution can outpace elimination; in these cases, there is little or no relationship expected between PCB concentration and lipid content (e.g., pumpkinseed; Figures 6-2a and 6-2b). For slower-growing individuals or species, the PCB body burden is more dependent upon elimination across the gill. In these fish, PCB concentration tends to be correlated with lipid content (e.g., largemouth bass and yellow perch; Figures 6-2a and 6-2b).

8.8.4.3 Routes of PCB Bioaccumulation

A better understanding of PCB bioaccumulation can be gained by quantifying the relative contributions of local sediments and the water column to PCB concentrations in invertebrates and fish of the River. This section includes an analysis of the PCB data for the sediments, water and biota, designed to provide evidence concerning the sources of PCBs to the aquatic food web. One approach to evaluating the potential routes of exposure is to examine the relationships between contaminant concentrations measured in organisms and contaminant concentrations measured in the surrounding water and in the sediment. Two metrics are useful in this evaluation – the biota-sediment accumulation factor (BSAF), expressed as the ratio of an organism's lipid-normalized chemical concentration to that of the sediment on an organic carbon basis (kg organic carbon/kg lipid), and the bioaccumulation factor (BAF), expressed as the ratio of an organism's lipid-normalized chemical concentration to of the chemical's dissolved concentration in water (L/kg lipid).

With respect to spatial gradients, if the water column is the sole source of PCBs to the food web, then PCB concentrations in the biota should track PCB concentrations in the water. This means that the BAF value for a given species should be relatively constant, even if water column PCB concentrations vary. Similarly, if the sediment is the sole source, then the BSAF should be relatively constant.

As described in Sections 3 and 4, PCB concentrations in the sediments and water both change with distance downstream from the Confluence to Woods Pond. Water column PCB concentrations increase by more than two-fold from the Confluence to Reach 5C and then decline by about 40% towards Woods Pond Dam. Organic-carbon normalized PCB concentrations in channel sediments are highest in Reach 5A and then decrease approximately 10-fold from the Confluence to Woods Pond Dam. These gradients provide an opportunity to use BAFs and BSAFs to evaluate the relative importance of the sediments and the water column as PCB sources to the fish.

To investigate the importance of surficial sediments and the water column as PCB sources, invertebrate and fish contaminant levels were paired with locally averaged PCB concentrations in the water column or in the surface sediments (0 to 6 inches, organic carbon-normalized), and BAFs and BSAFs were calculated.[4] For invertebrates, data are available for crayfish and for aquatic insects composited as either shredders or predators; BSAFs and BAFs for these invertebrates are shown on Figure 8-34. For fish, sufficient data are available for largemouth bass, brown bullhead, pumpkinseed, and white sucker. Largemouth bass and brown bullhead were analyzed as reconstructed whole body values based on

[4] Because dissolved-phase concentrations are normally used when calculating BAFs, water column PCB concentrations were multiplied by a representative dissolved fraction of 0.3 based on results of the 2001-2002 surface water partitioning study (Figure 8-29). This does not affect spatial gradients.

combining the fillet and offal data from large adults. Pumpkinseed were analyzed based on composite whole body data, reflective of smaller individuals (prey for larger fish). For white sucker, individual whole body preparations were used in this evaluation. BSAFs and BAFs for these species and preparation types are presented on Figure 8-35.

In general, BSAFs are lower at and upstream of the WWTP (RM 130) than downstream, while BAFs exhibit the opposite pattern, with higher values upstream of the WWTP than downstream. These results are consistent with the outcome from a mixed diet of sediment and water-based food sources, since neither the BSAF nor the BAF for a given species is constant over the entire extent of Reaches 5 and 6.

Downstream of Woods Pond Dam, additional concurrent sediment, water, and fish PCB data are available in Rising Pond. Between Woods Pond and Rising Pond Dams, sediment PCBs (organic carbon-normalized) decline by approximately five-fold, while water column PCBs decline by three-fold, based on the recent GE and EPA datasets. Median BAF values for largemouth bass and yellow perch in Rising Pond are 72×10^6 and 74×10^6, respectively. These values are within the expected range for these fish (Thomann, 1989; HydroQual, 1995). Both largemouth bass and yellow perch had BSAF values in Rising Pond of 13, higher than expected based on the literature (Tracey and Hansen, 1996; QEA, 1999; Wong et al., 2001). This suggests that the food web in Rising Pond may be tied more to dietary PCB sources based in the water column than to those based in the sediments.

The relative importance of water column-based or sediment-based dietary sources of PCBs to the fish depends not only on the relative PCB concentrations in sediment and water, but on the structure of the food web as well. For sediments to be an important source of energy to the food web, energy must be delivered to the sediment, typically by way of the deposition of organic matter. The organic matter content in the sediments is lower upstream of the WWTP and higher downstream: concentrations rise from 1 to 2% of dry matter in Reach 5A to 8 to 10% in Woods Pond (see Section 4). This means that in Reach 5A, sediments are a relatively poorer food source but have higher carbon-based PCB concentrations. Downstream of the WWTP, sediments are a relatively richer food source, but exhibit lower carbon-based PCB concentrations. Because of the complexity of the relationships between food web structure and PCB concentrations, the relative importance of sediments and water as sources of PCBs in Reaches 5 and 6 cannot be quantified solely on the basis of these data.

8.9 Mechanisms Affecting Fate and Transport of PCDDs/PCDFs

A discussion of potential PCDD/PCDF sources to the Housatonic River has been presented in Section 8.5.2. This section discusses the major mechanisms controlling the fate and transport of PCDDs/PCDFs within the River.

PCDDs/PCDFs share many of the general physical-chemical properties of PCBs. Similar to PCBs, PCDDs/PCDFs are hydrophobic organic compounds characterized by low aqueous solubilities, low vapor pressures, and high octonal-water partition coefficients (Table 8-5), and are not readily degraded in the environment. However, PCDDs/PCDFs are considerably more hydrophobic than PCBs (Table 8-5). Consequently, PCDDs/PCDFs are highly particle reactive and accumulate within the sediments of receiving waters. Due to their generally similar physical/chemical traits, PCBs and PCDDs/PCDFs are generally found in the same types of areas within the Housatonic River. That is, these compounds are found within impoundments where sediments accumulate, as well as in bank and floodplain soils.

Table 8-5. Physical-Chemical Properties of Selected PCBs, PCDDs, and PCDFs

Physical-Chemical Property[1]	PCB Aroclors		PCDDs[2]		PCDFs[3]	
	1254	1260	D7	D8	F5	F7
Solubility (g/m^3)	0.05	0.02	2.4E-6	7.4E-8	2.4E-4	1.E-6
Vapor Pressure (Pa @ 25 C)	0.01	0.0035	7.5E-10	1.1E-10	3.6E-7	5.0E-10
Log Octonal-Water Partition Coefficient	6.2	6.5	8.0	8.2	6.4	7.4

Notes:
[1] Parameter values taken from Mackay et al. (1992a and 1992b).
[2] D7 and D8 refer to hepta- and octachlorinated dioxins, respectively, which are the predominate PCDD homologs detected in the Housatonic River.
[3] F5 and F7 refer to penta- and heptachlorinated dibenzofurans, respectively, which represent the range of PCDF homolog composition in the Housatonic River.

Therefore, some of the major mechanisms that govern the fate and transport of PCBs (as discussed in Section 8.8) also govern the fate and transport of PCDDs/PCDFs. These include:

- Exchange processes at the sediment-water interface (i.e., primarily sediment deposition and resuspension); and
- Transport with bed load at the sediment-water interface.

Section 8 Figures

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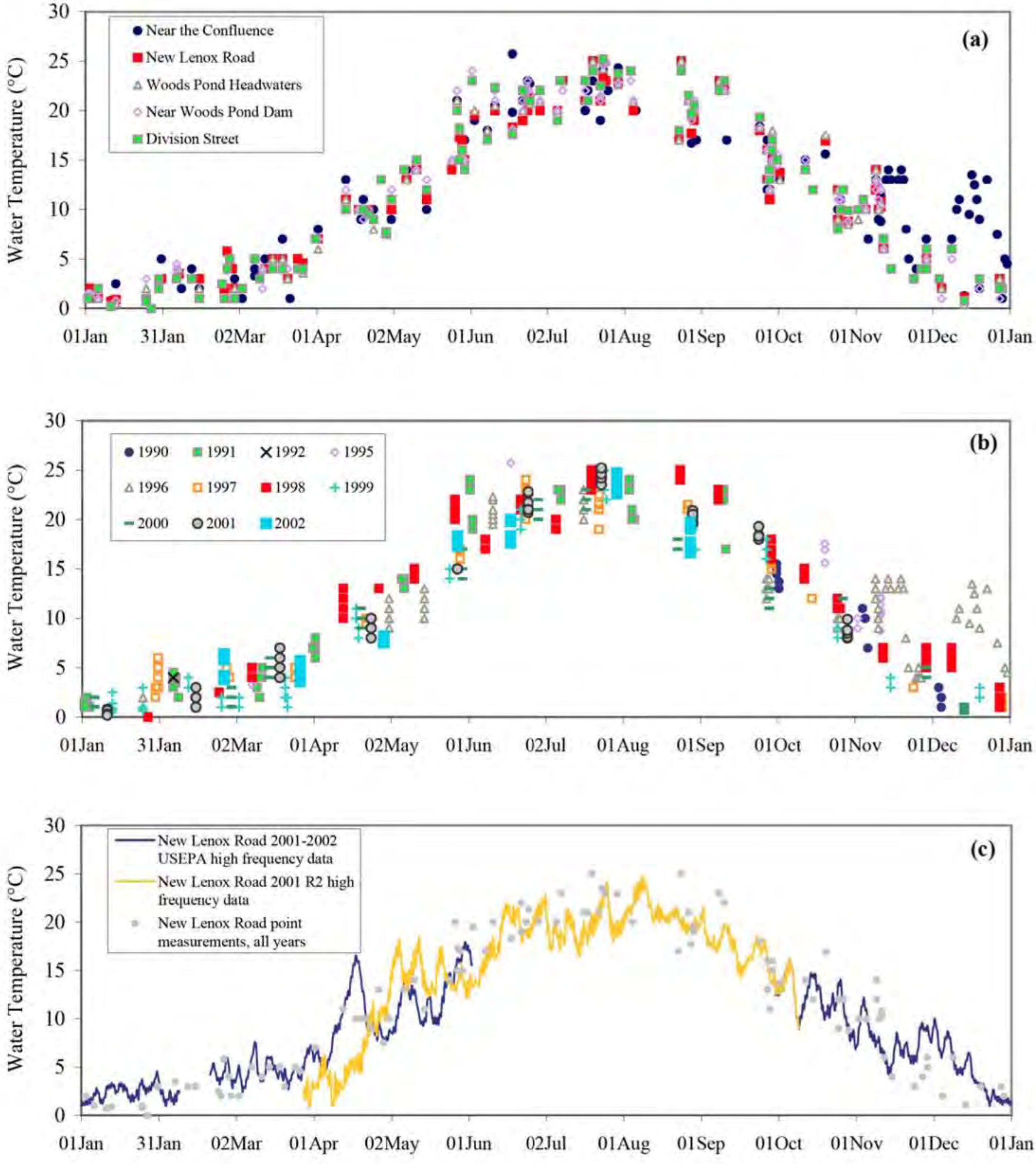

Figure 8-1. Seasonal trend in Housatonic River water temperature data: (a) all years, by major sampling stations; (b) all stations near and downstream of the Confluence, by year; and (c) high frequency measurements at New Lenox Road.

Note: Data sets shown: 1990-2002 GE routine monitoring, 2001-2002 EPA high frequency monitoring, and 2001 R2 high frequency monitoring data.

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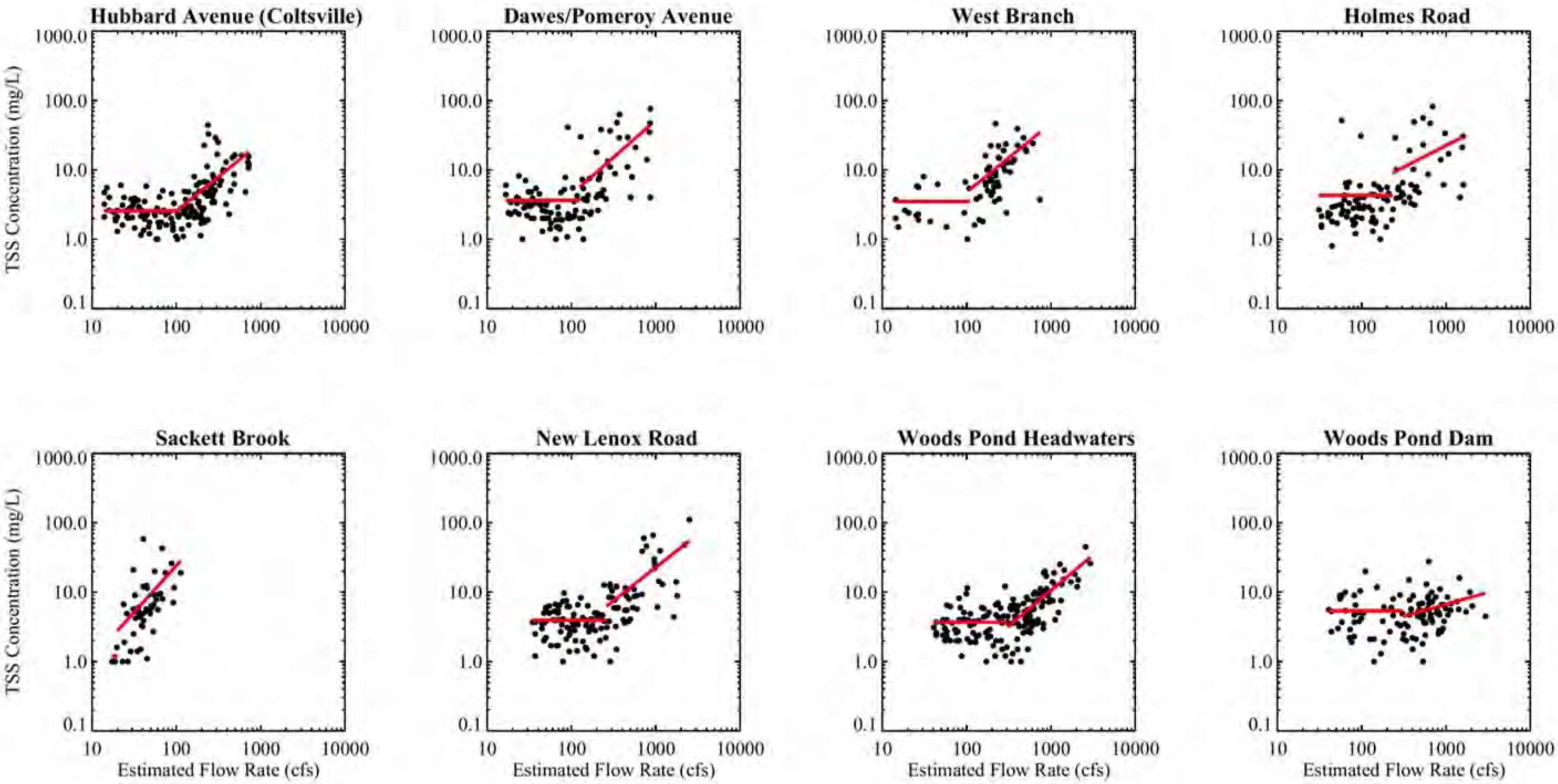

Figure 8-2. Sediment rating curves.

Notes: Solid dots are data and lines are rating curves. Data shown are 1989-2002 GE and 1998-1999 EPA TSS data.

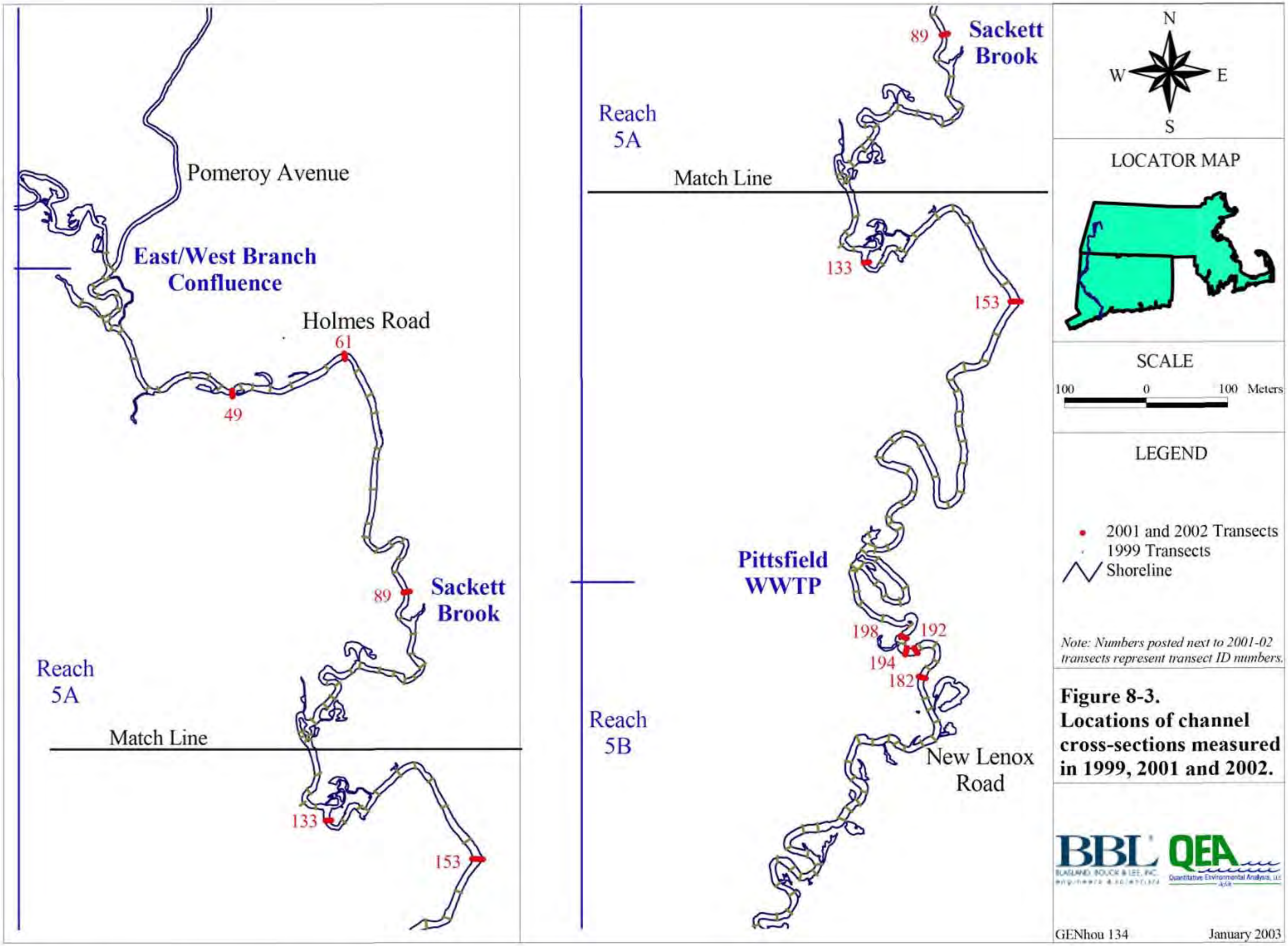

Figure 8-3. Locations of channel cross-sections measured in 1999, 2001 and 2002.

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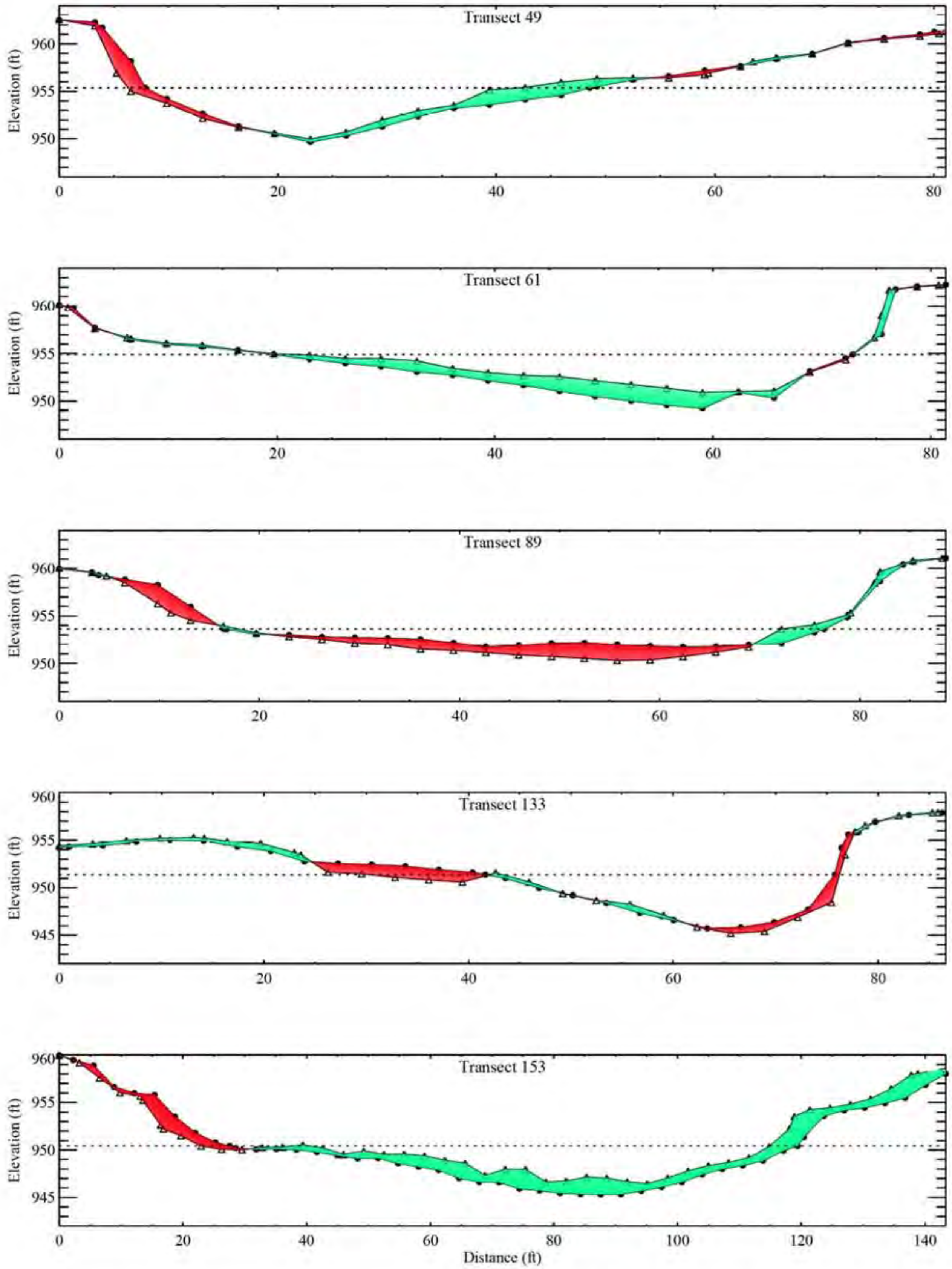

Figure 8-4a. Bed elevation changes between September 2001 and June 2002 at EPA transects within Reach 5A (49, 61, 89, 133 and 153).

Note: Transect orientation is looking upstream.

- Bed Aggradation
- Bed Degradation
- September 2001 Water Level
- September 2001 Measurements
- June 2002 Measurements

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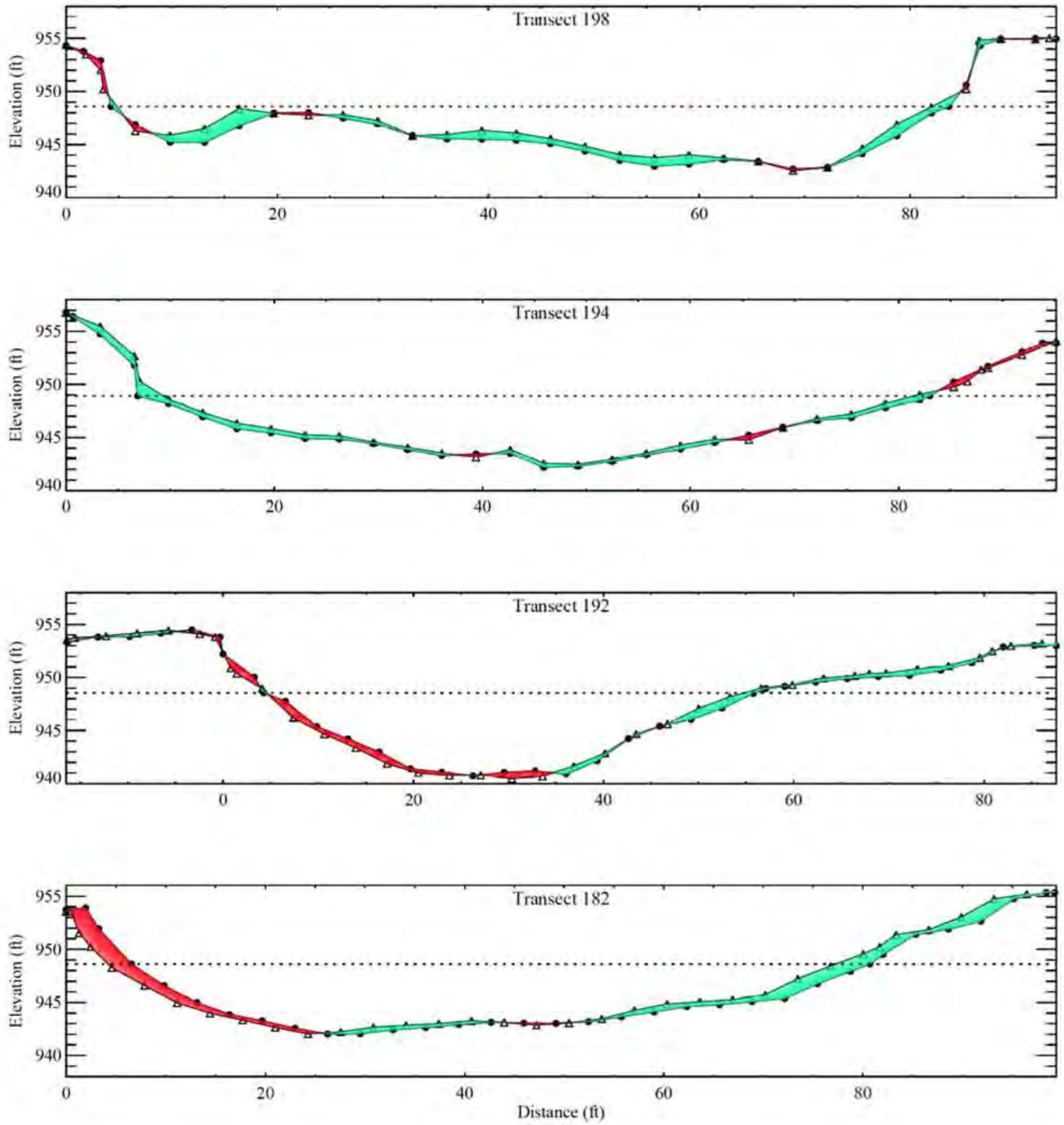

Figure 8-4b. Bed elevation changes between September 2001 and June 2002 at EPA transects within Reach 5B (198, 194, 192 and 182).

Note: Transect orientation is looking upstream.

Bed Aggradation
Bed Degradation
September 2001 Water Level
September 2001 Measurements
June 2002 Measurements

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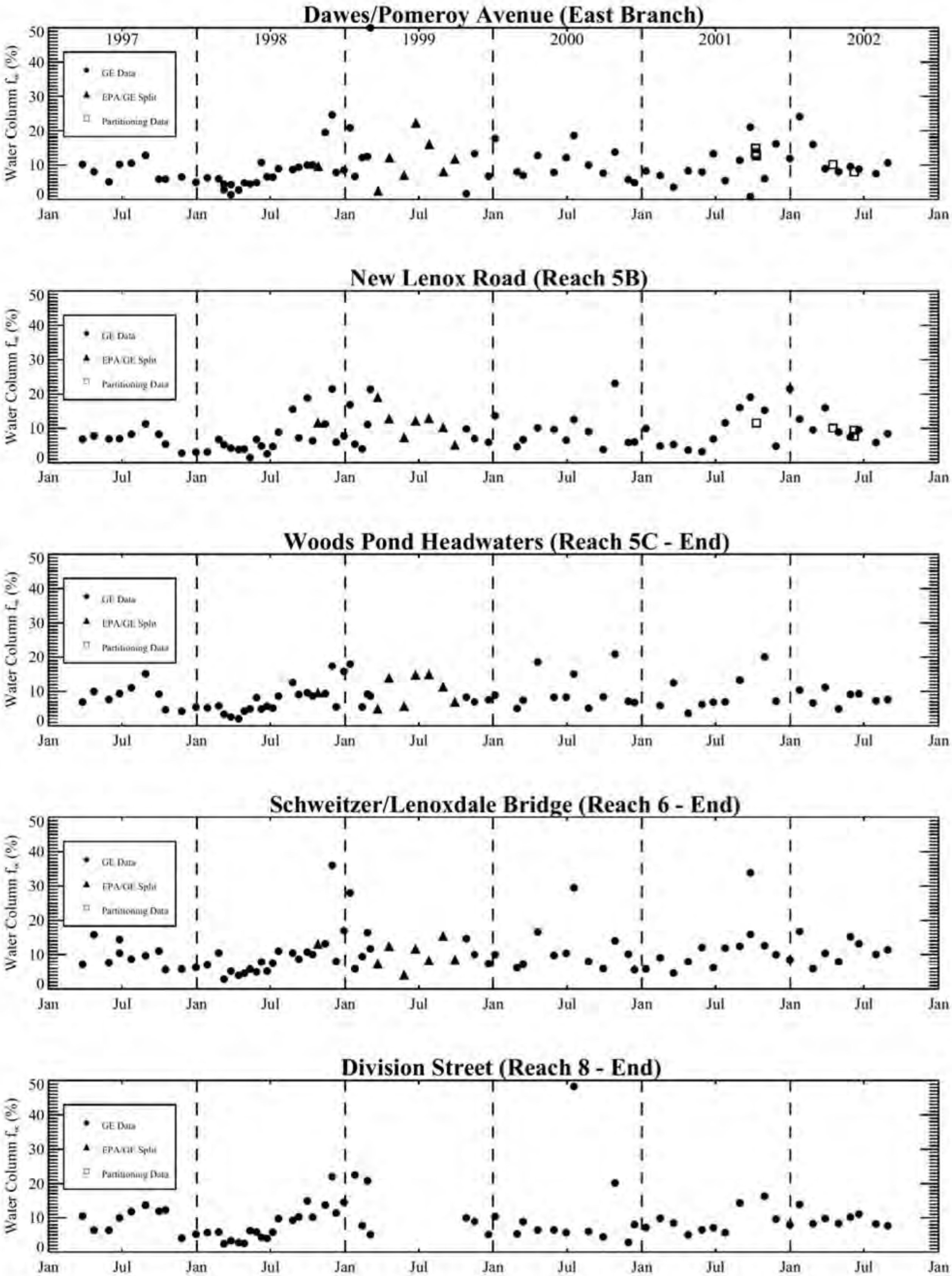

Figure 8-5. Temporal profiles of water column organic carbon fractions.

Note: Data shown are 1997-2002 GE, EPA/GE splits, and 2001-2002 EPA/GE partitioning data.

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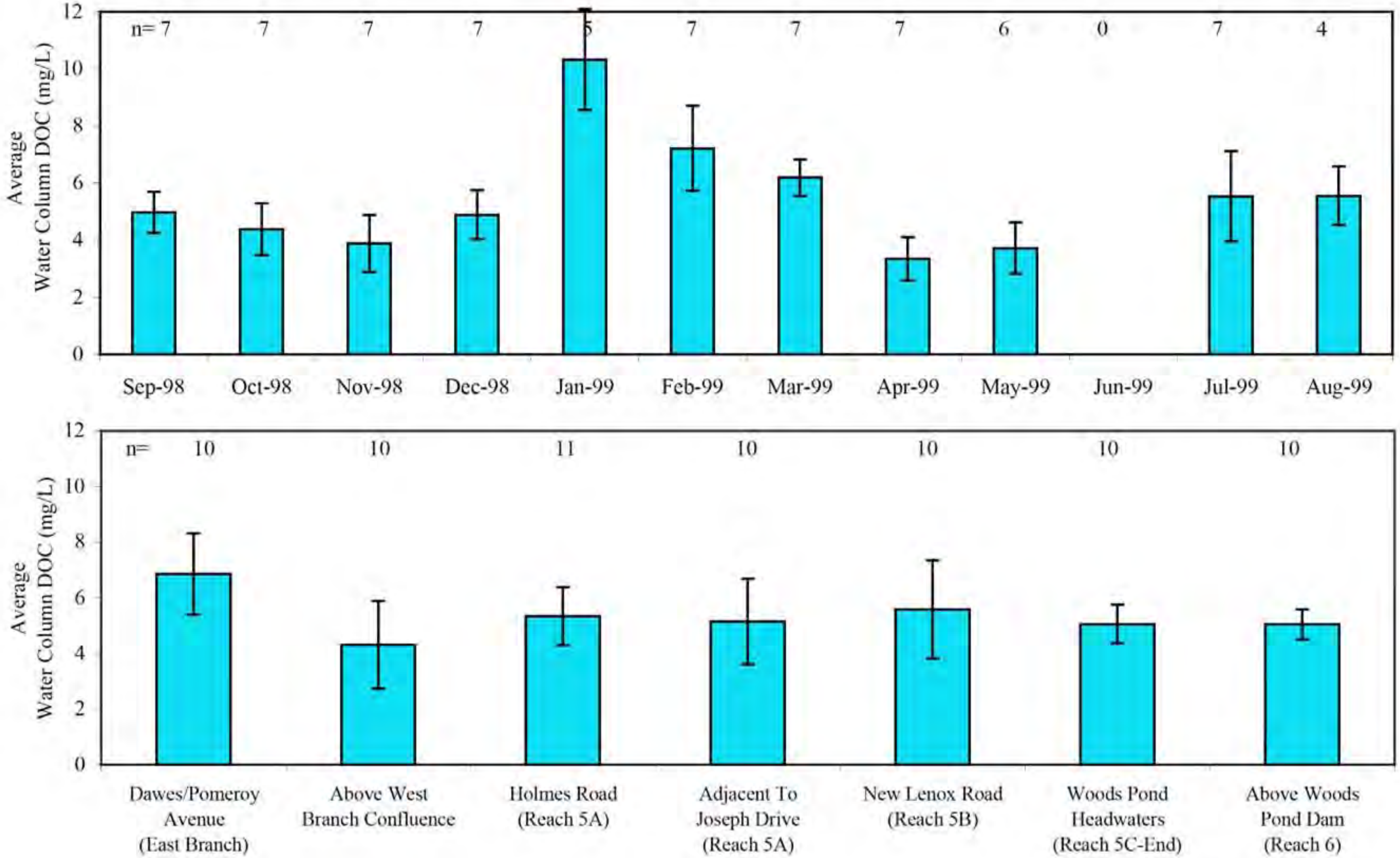

Figure 8-6. Spatial and temporal profiles of EPA average water column DOC data.

Notes: Error bars represent 2 standard errors of the mean. Duplicate and estimated results omitted. Includes routine (non-storm event) monitoring data only.

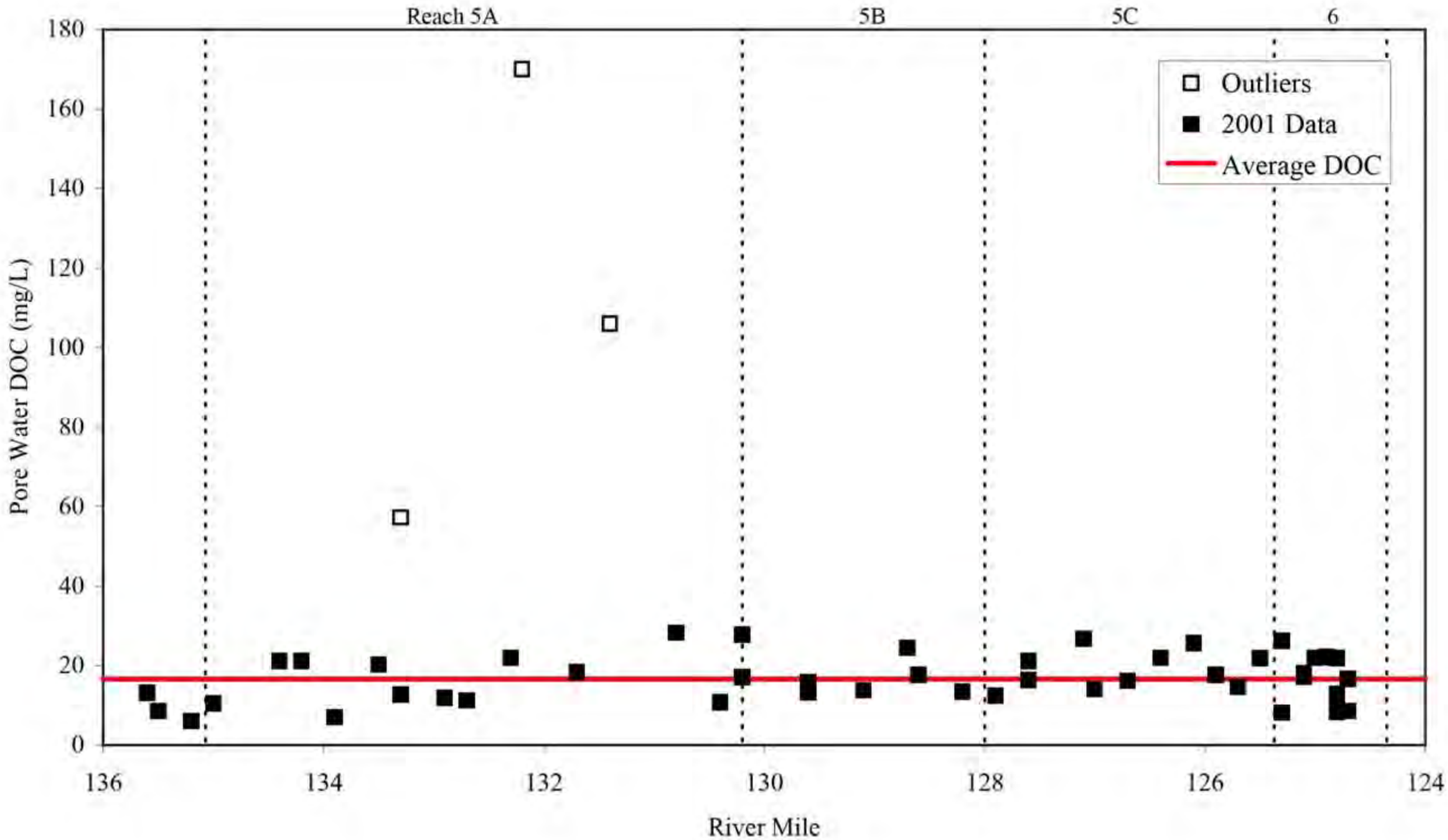

Figure 8-7. Spatial profile of 2001 EPA/GE sediment pore water DOC data.

Note: Open squares represent outliers based on outlier test utilizing "studentized deviation" at a 1% level of significance.

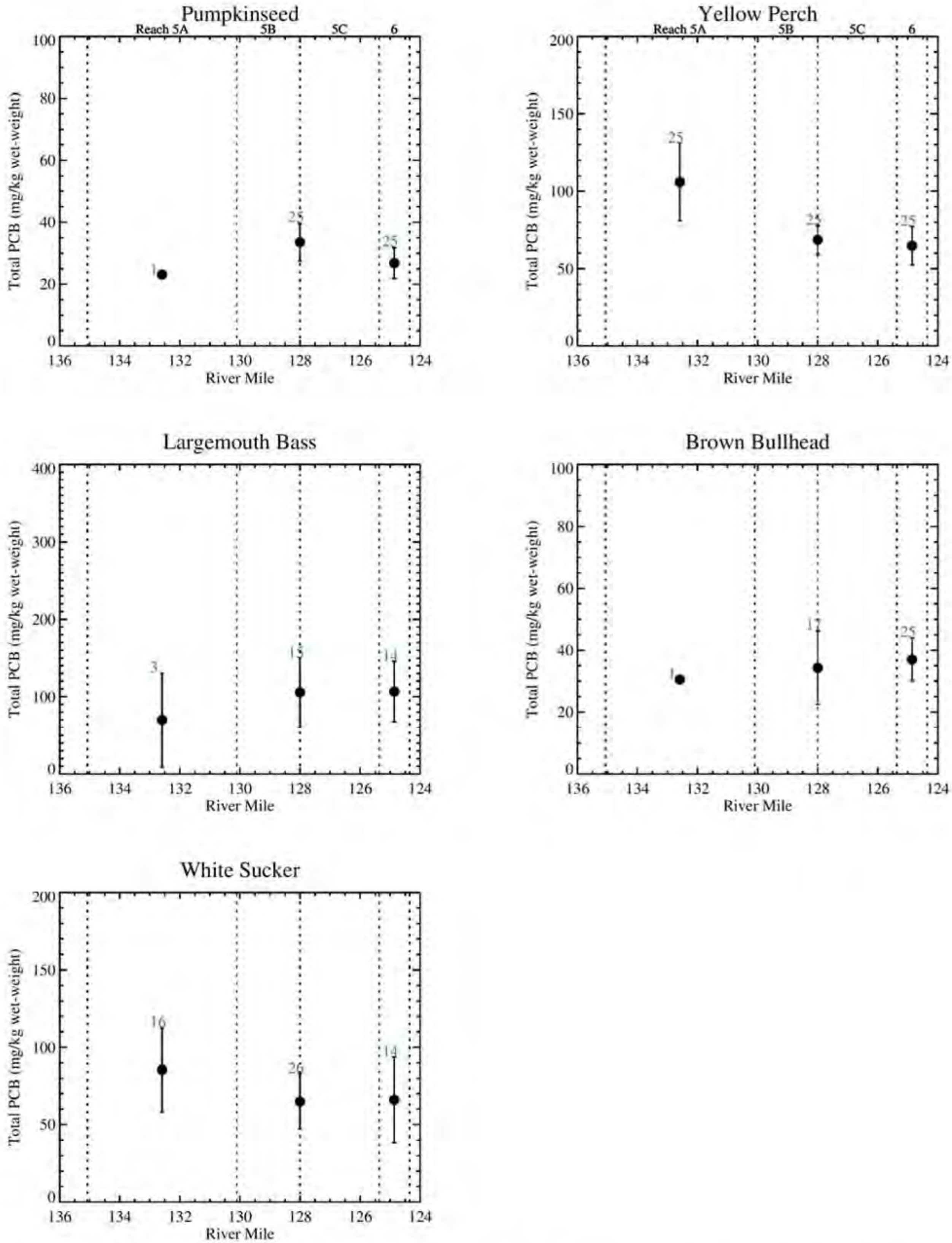

Figure 8-8. Spatial distribution of wet-weight PCB levels in large fish collected in Reaches 5 and 6 of the Housatonic River.

Data: EPA(Released: November, 2002). Whole body samples for white sucker, reconstructed whole body samples for all other species.
One outlier (low lipid value) for White Sucker in Woods Pond was removed; total PCB=44.7 mg/kg wet-weight, lipid = 0.1%.
Values are Mean +/-2*StdErr with number of observations indicated. All fish were collected in 1998 except White Sucker collected in 2000.
Split samples were not included.

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Tue Jun 24 17:58:38 2003

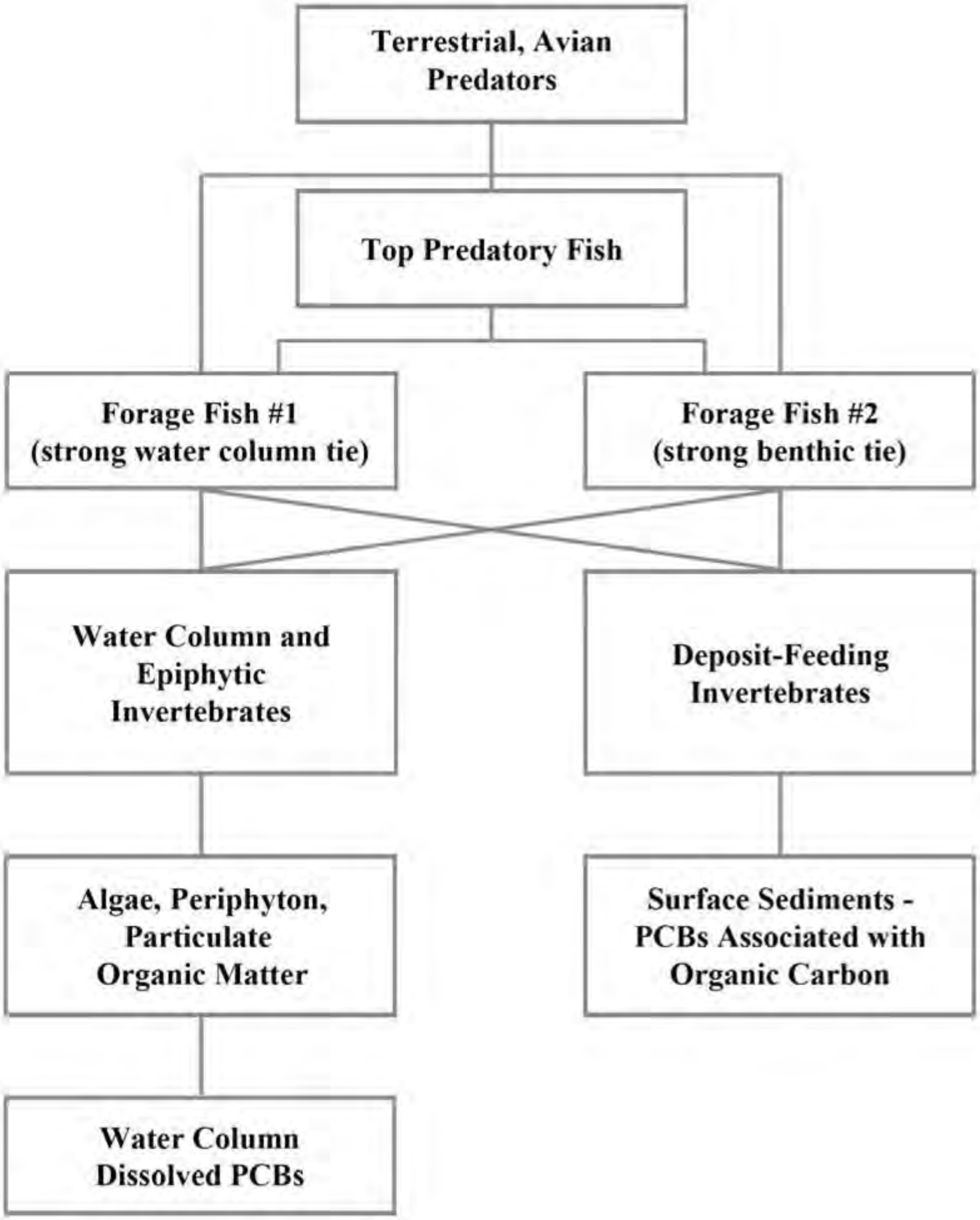

Figure 8-9. Schematic of a riverine food web determining the fate of PCBs in various organisms.

Note: At the forage fish level, diets are mixed, with differing relative proportions of water column or benthic prey.

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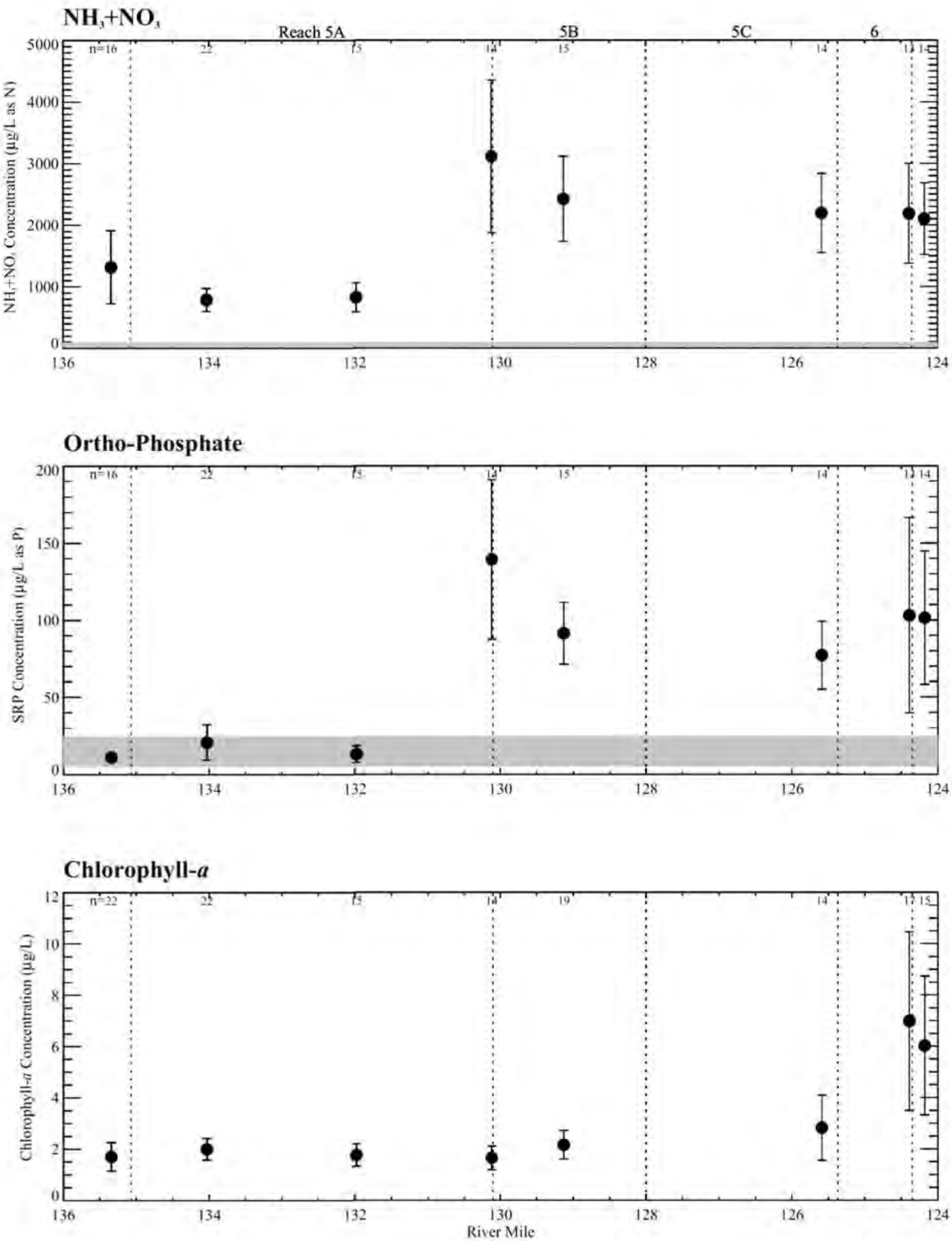

Figure 8-10. Spatial profiles of average nitrogen, phosphorus, and chlorophyll-*a* concentrations.

Data set shown: 1998-1999 EPA routine water column samples.

Note: Shaded area represents range of concentrations that are limiting to algal growth (Chapra 1997). Error bars represent 2 standard errors of the mean. One outlier sample with non-detect SRP reported at 200 µg/L *omitted.*

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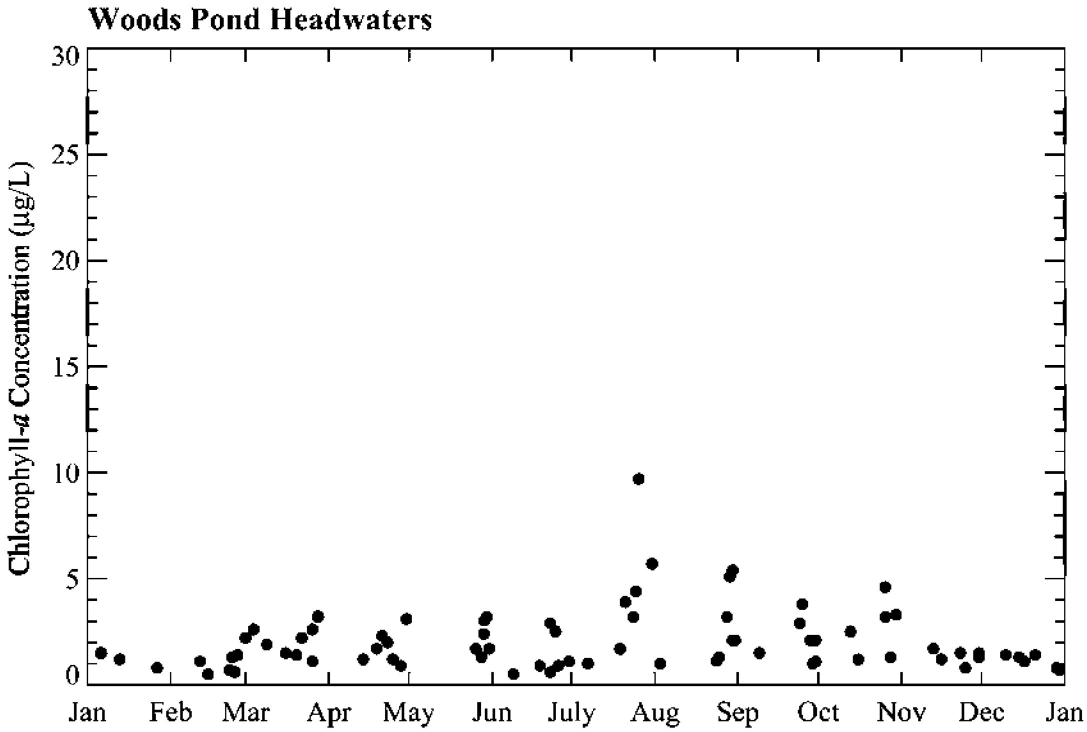

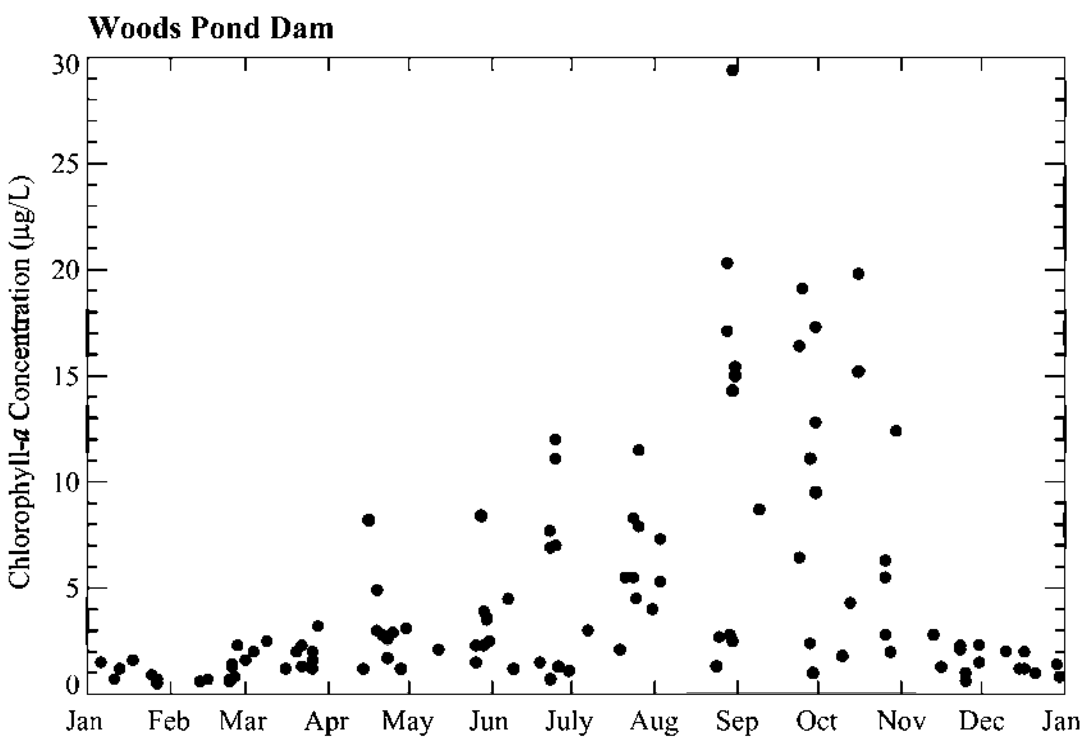

Figure 8-11. Temporal overlay of chlorophyll-*a* concentrations.

Data sets included: 1997-2002 GE/EPA routine water column samples.

Note: Woods Pond Dam plot contains samples collected at the Woods Pond Footbridge, and Schweitzer/ Lenoxdale Bridge.

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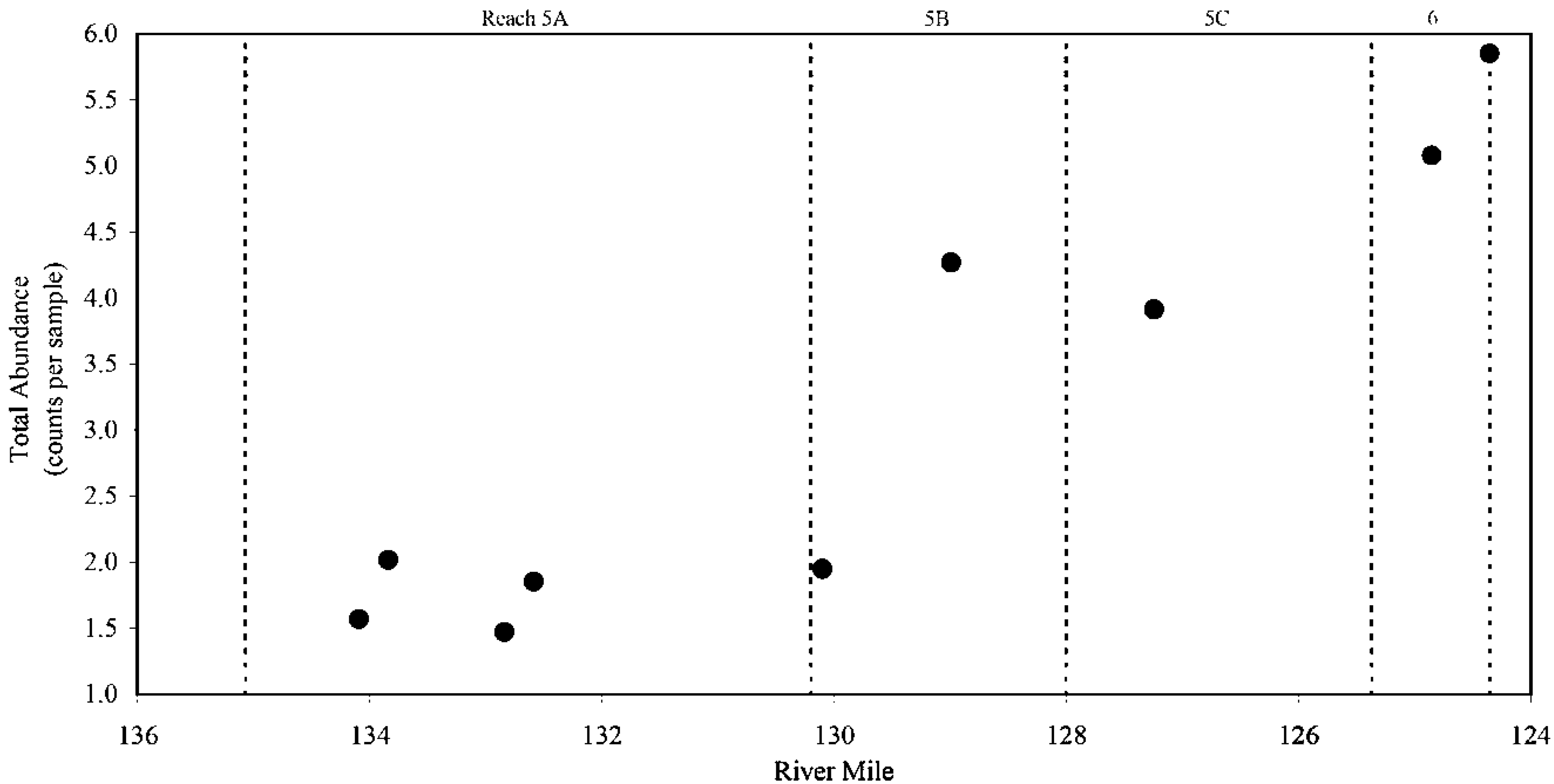

Figure 8-12. Spatial distribution of the abundance of invertebrates in Reaches 5 and 6.

Notes: Data shown are 1999-2000 EPA data set. Samples were taken with a 6" square Ponar grab.

Predators (Trophic Level 3)	**Invertebrate-Feeders** (Trophic Level 2)	**Bottom-Feeders** (Trophic Level 2)
Largemouth bass	Pumpkinseed	Brown bullhead
Brown trout	Yellow perch	White sucker
Smallmouth bass	Bluegill	Common carp
Rock bass	Goldfish	Yellow bullhead
Chain pickerel	Bluntnose minnow	Longnose sucker
Rainbow trout	Fallfish	Creek chubsucker
Northern pike	Golden shiner	Redhorse sucker
Grass pickerel	Redbreasted sunfish	Slimy sculpin
Brook trout	Green sunfish	
Black crappie	Redear sunfish	
White crappie	Tessellated darter	
Muskellunge	Trout perch	
	Blacknose dace	
	Bridle shiner	
	Common shiner	
	Creek chub	
	Fathead minnow	
	Longnose dace	
	Spottail shiner	
	Killifish	
	Banded killifish	

Figure 8-13. Fish species reported in the Massachusetts reaches of the Housatonic River.

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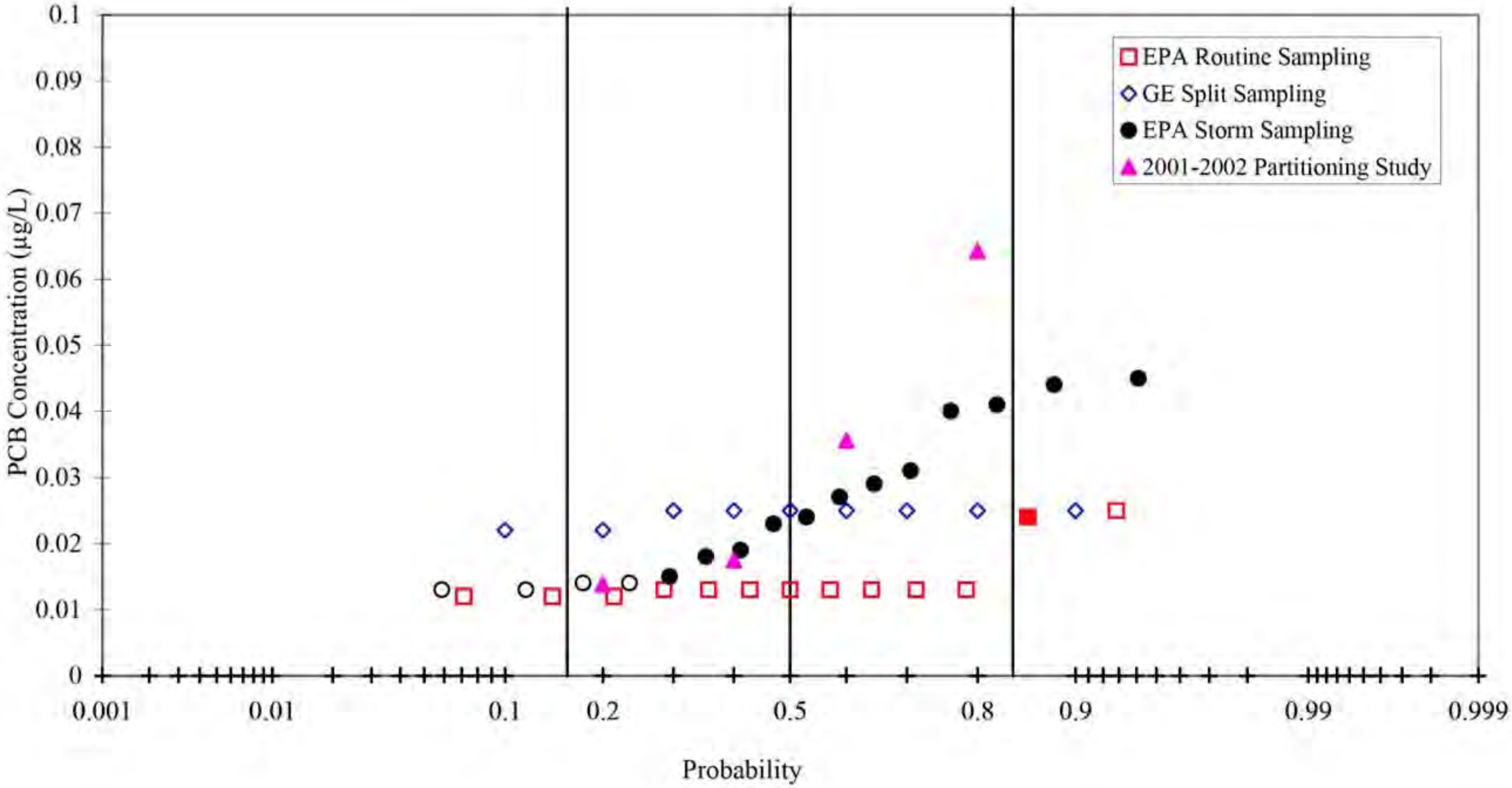

Figure 8-14. Probability plot of water column PCB concentrations in the West Branch Housatonic River since 1998.

Note: Filled symbols represent detected PCBs, non-detects are plotted as open symbols at the detection limit.

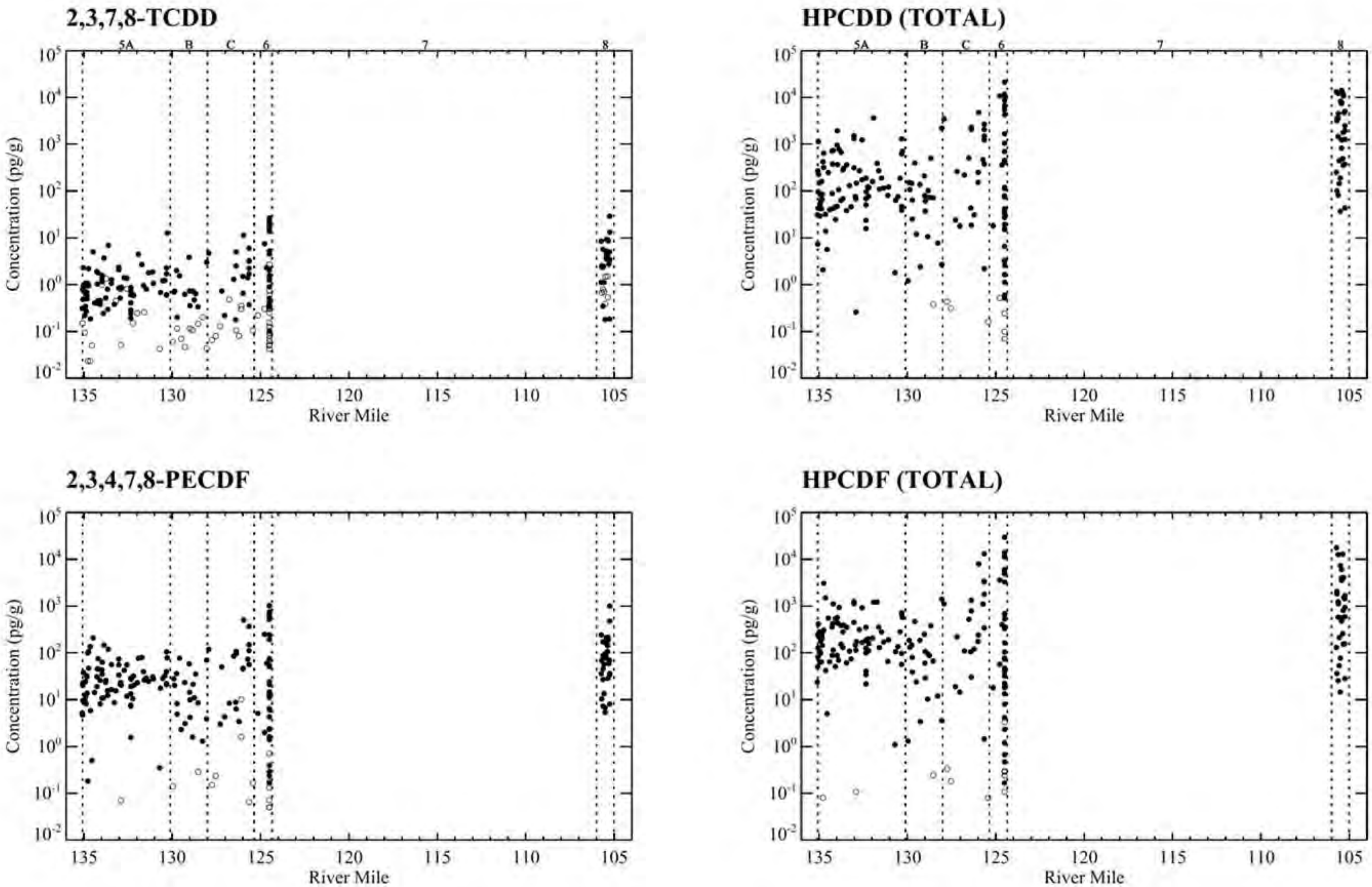

Figure 8-15. Spatial profiles of sediment PCDD and PCDF data.

Note: Non-detect samples plotted at 1/2 MDL. Plot shows 1998-2002 EPA data from all depths.

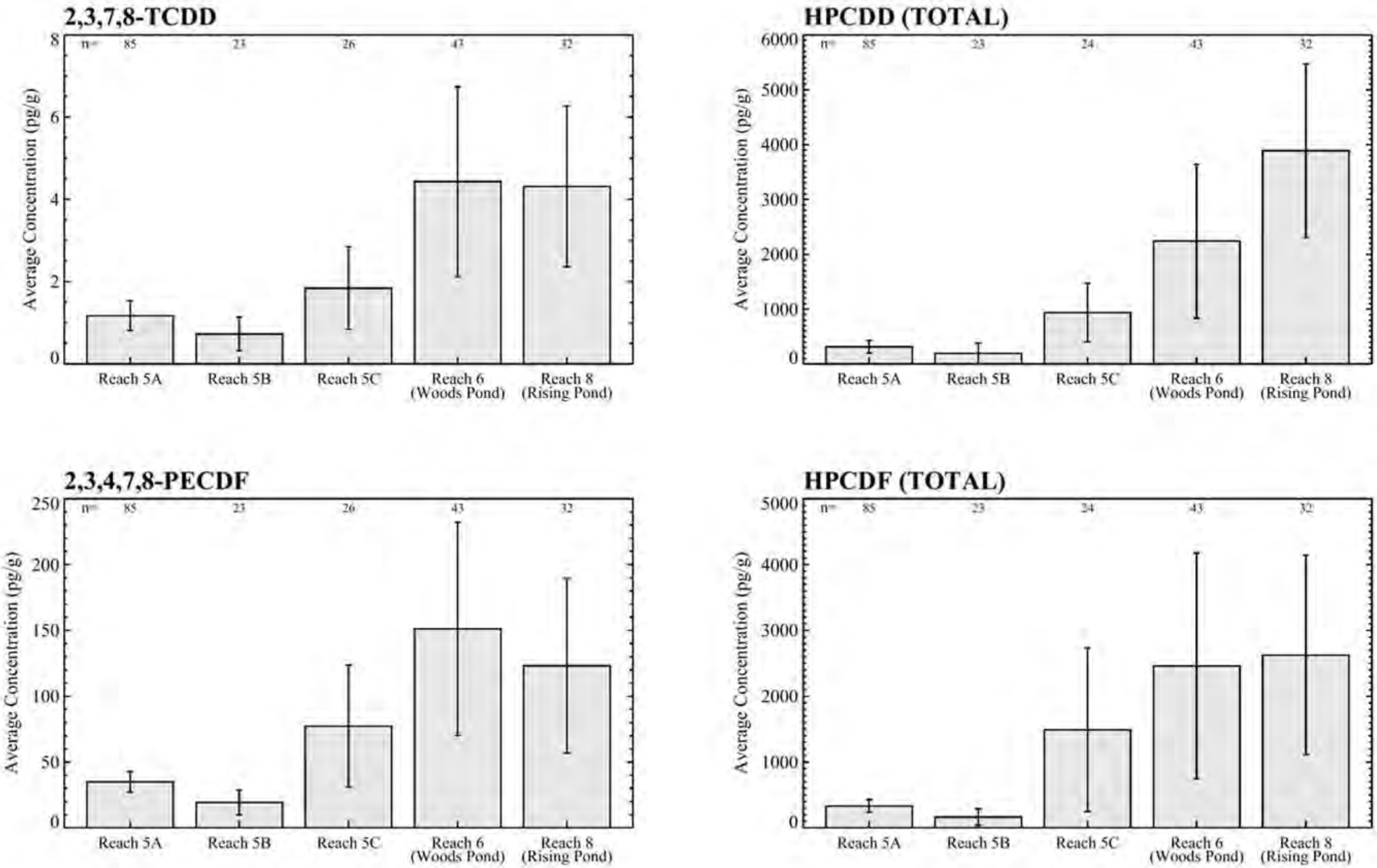

Figure 8-16. Average sediment PCDD and PCDF data by reach.

Note: Non-detect samples included at 1/2 MDL. Plot shows 1998-2002 EPA data from all depths. Error bars represent 2 standard errors of the mean.

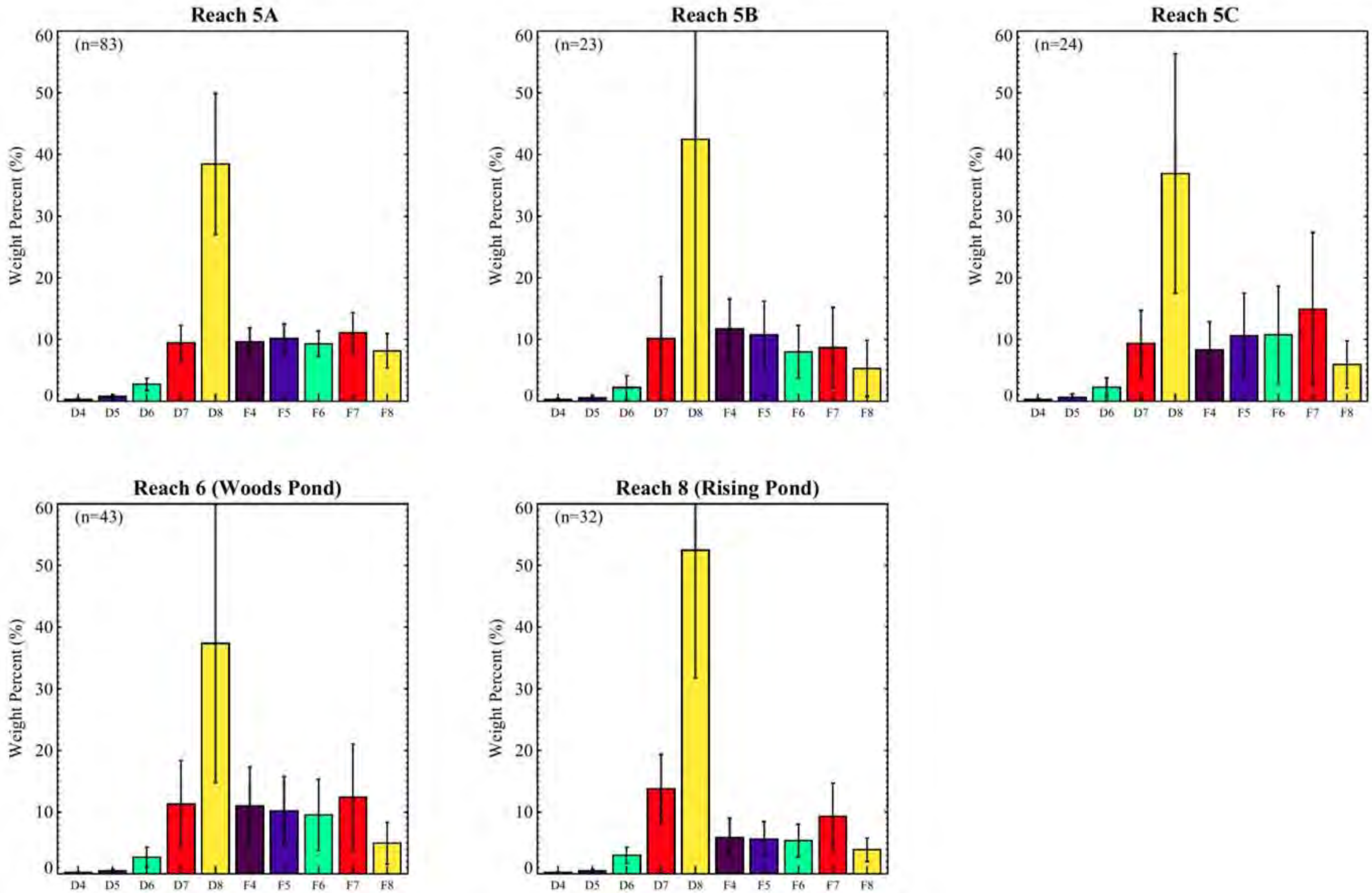

Figure 8-17. Average sediment PCDD/PCDF homolog weight percents by reach.

Notes: Non-detect samples included at 1/2 MDL. Plot shows EPA data from all depths. Number of samples in each reach included on plots. Error bars represent 2 standard errors of the mean.

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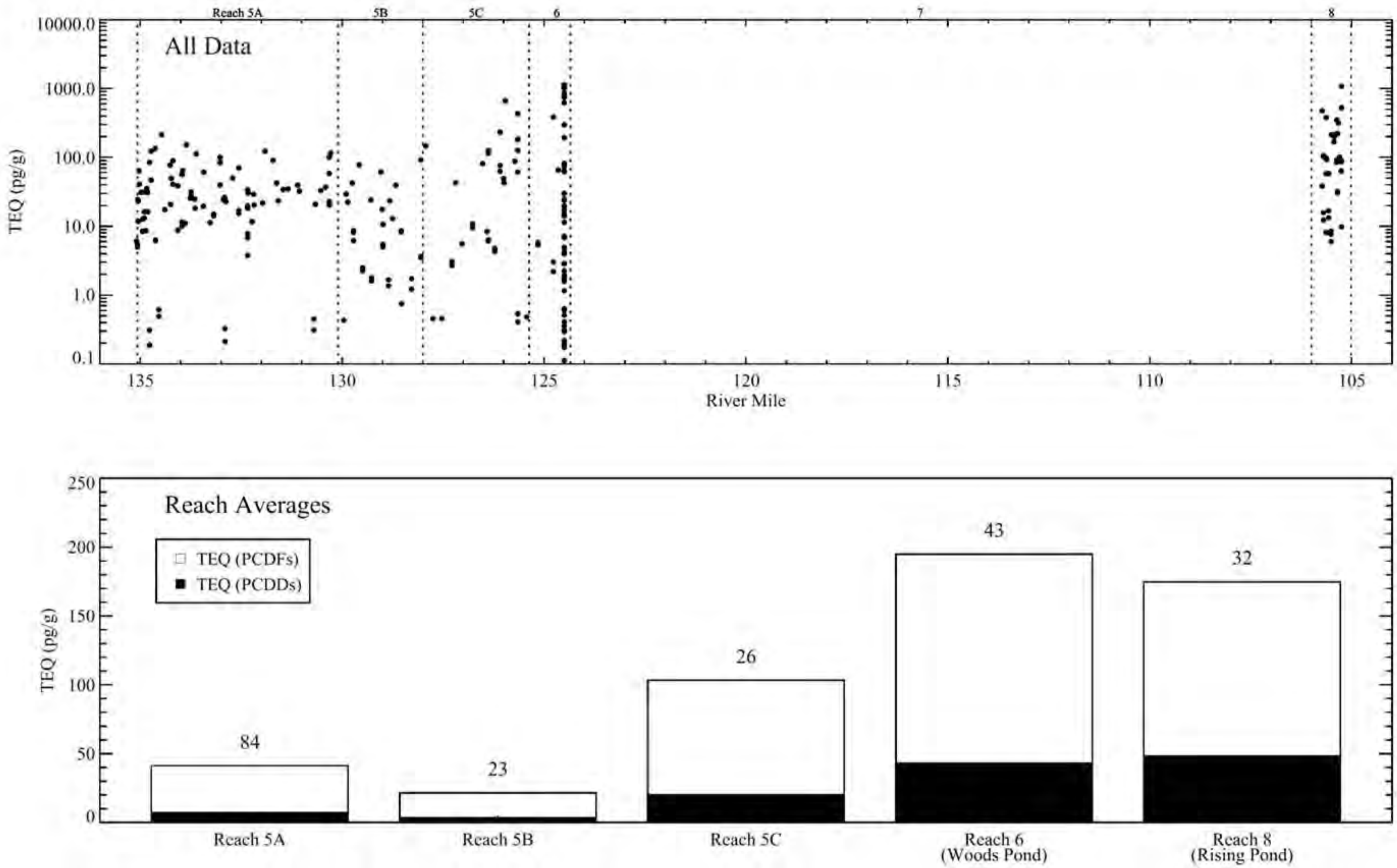

Figure 8-18. Spatial profiles of TEQ calculated from Housatonic River sediment PCDD/PCDF data.

Notes: Includes data from all depth intervals. Number of observations in each reach is posted above the bars. Non-detects plotted at 1/2 MDL. Error bars not shown for averages.

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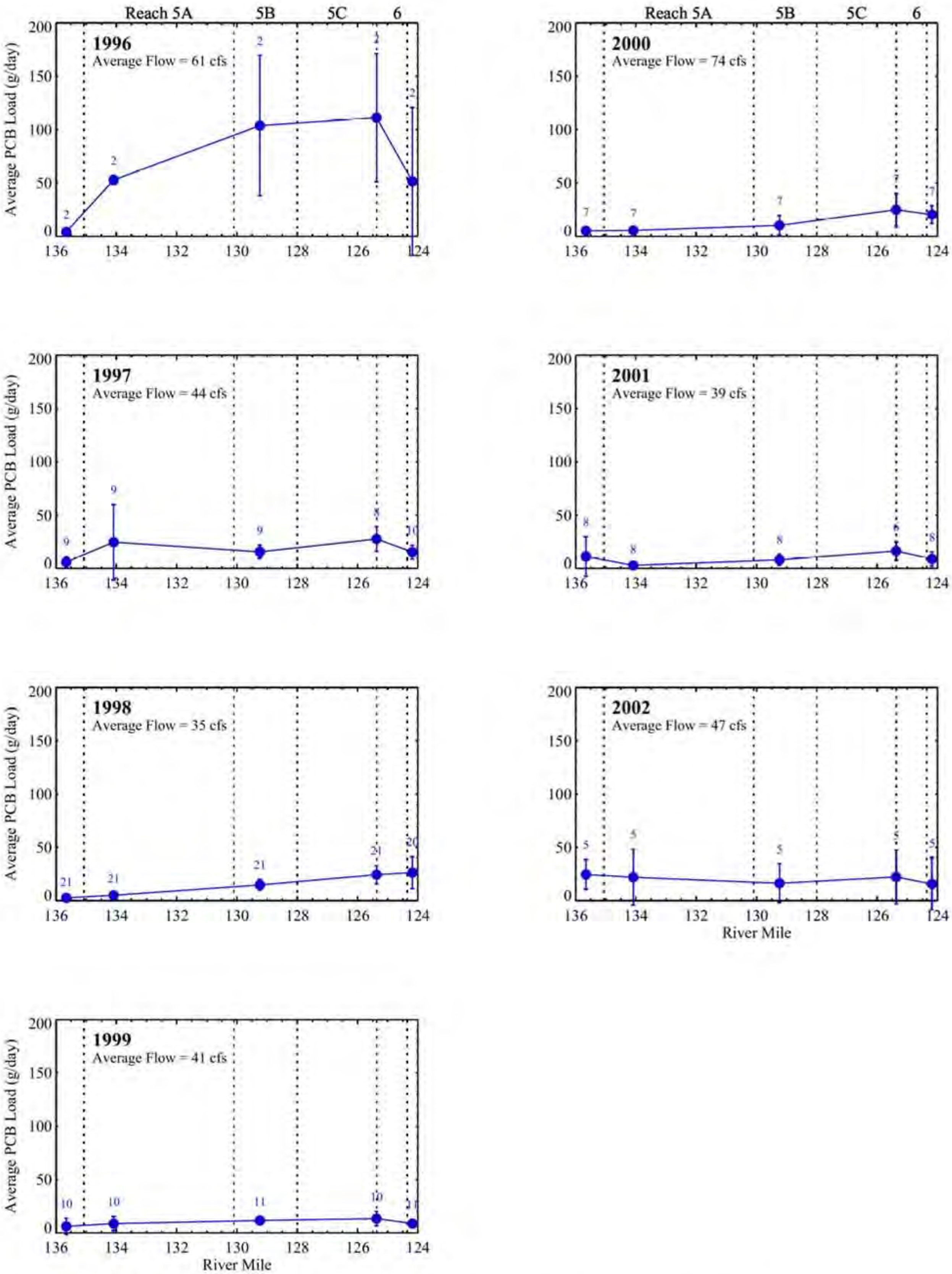

Figure 8-19a. Annual average spatial profiles of PCB loading for low flow (< 100 cfs at Coltsville) GE/EPA monthly water column monitoring data.

Notes: Error bars represent 2 standard errors of the mean. Flows for loading calculations prorated based on drainage basin proration values computed for each sampling station. Outlier collected on 3/26/98 at Holmes Road removed. Numbers posted above points indicate number of samples in averages.

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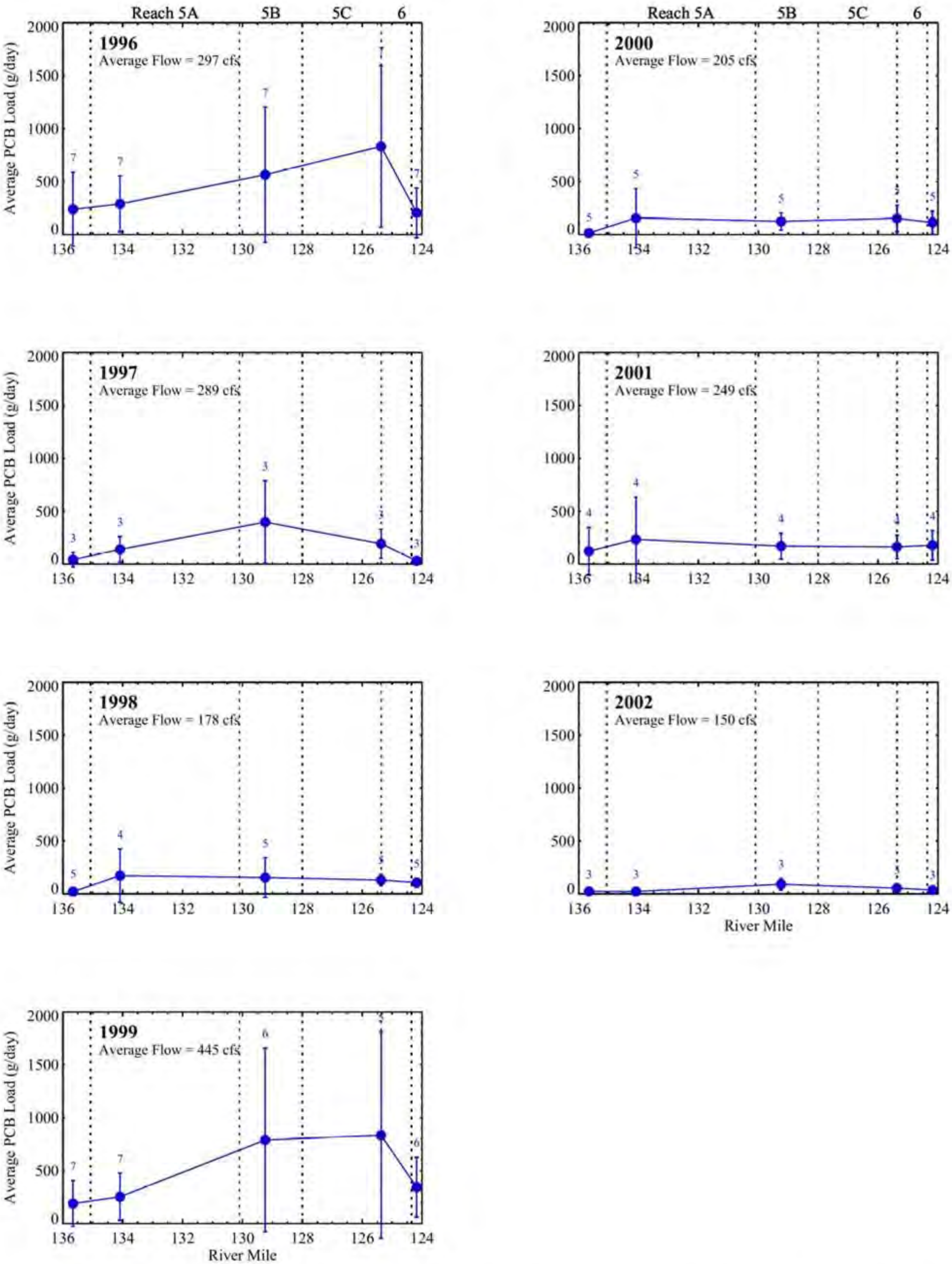

Figure 8-19b. Annual average spatial profiles of PCB loading for higher flow (> 100 cfs at Coltsville) GE/EPA monthly water column monitoring data.

Notes: Error bars represent 2 standard errors of the mean. Flows for loading calculations prorated based on drainage basin proration values computed for each sampling station. Outlier collected on 3/26/98 at Holmes Road removed. Numbers posted above points indicate number of samples in averages.

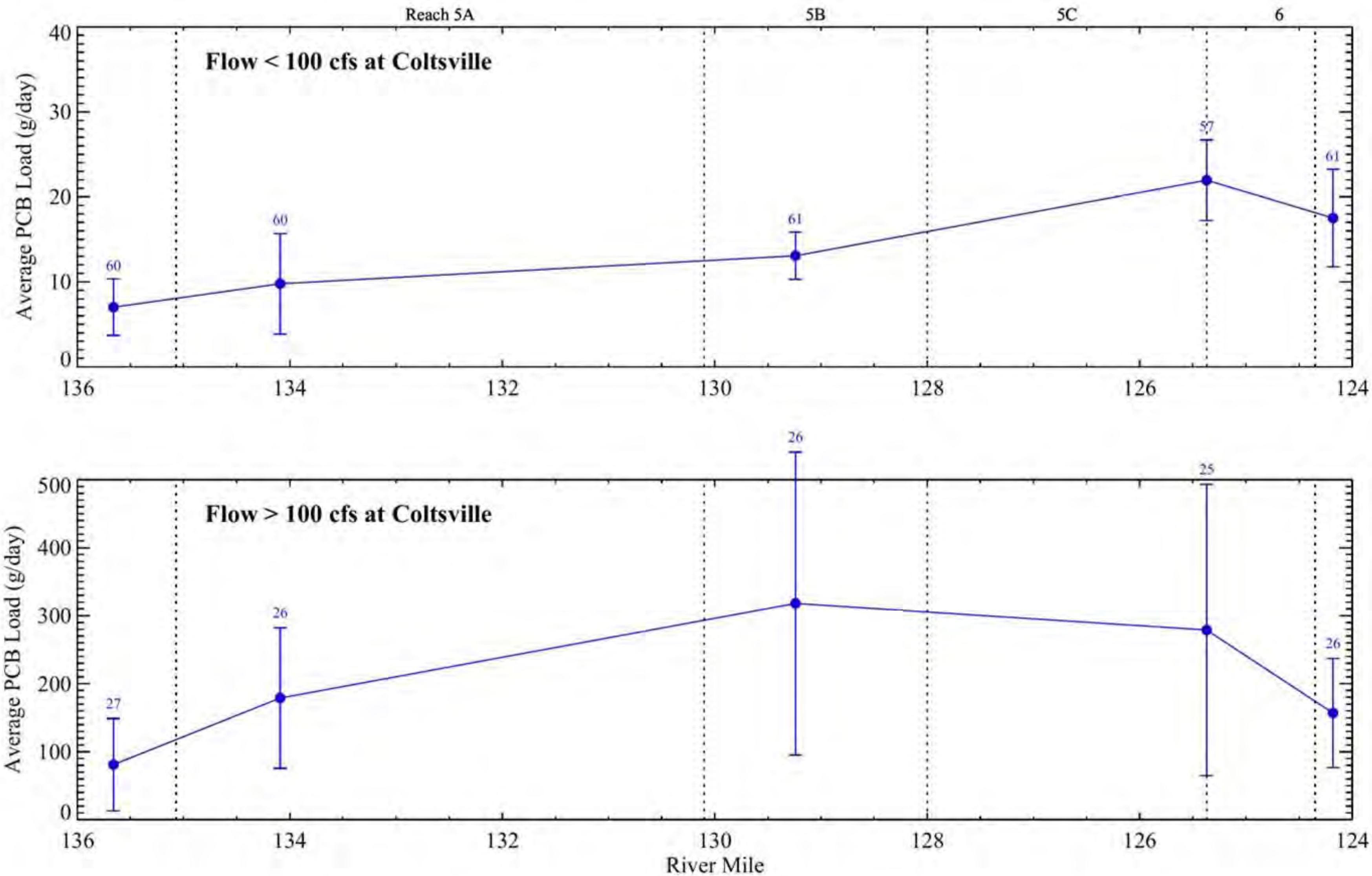

Figure 8-20. Spatial profiles of PCB loadings for 1997-2002 GE/EPA monthly water column monitoring data.

Notes: Flows for loading calculations prorated based on drainage basin proration values computed for each sampling station. Error bars represent 2 standard errors of the mean. Outlier collected on 3/26/98 at Holmes Road removed. Numbers posted above points indicate number of samples in averages.

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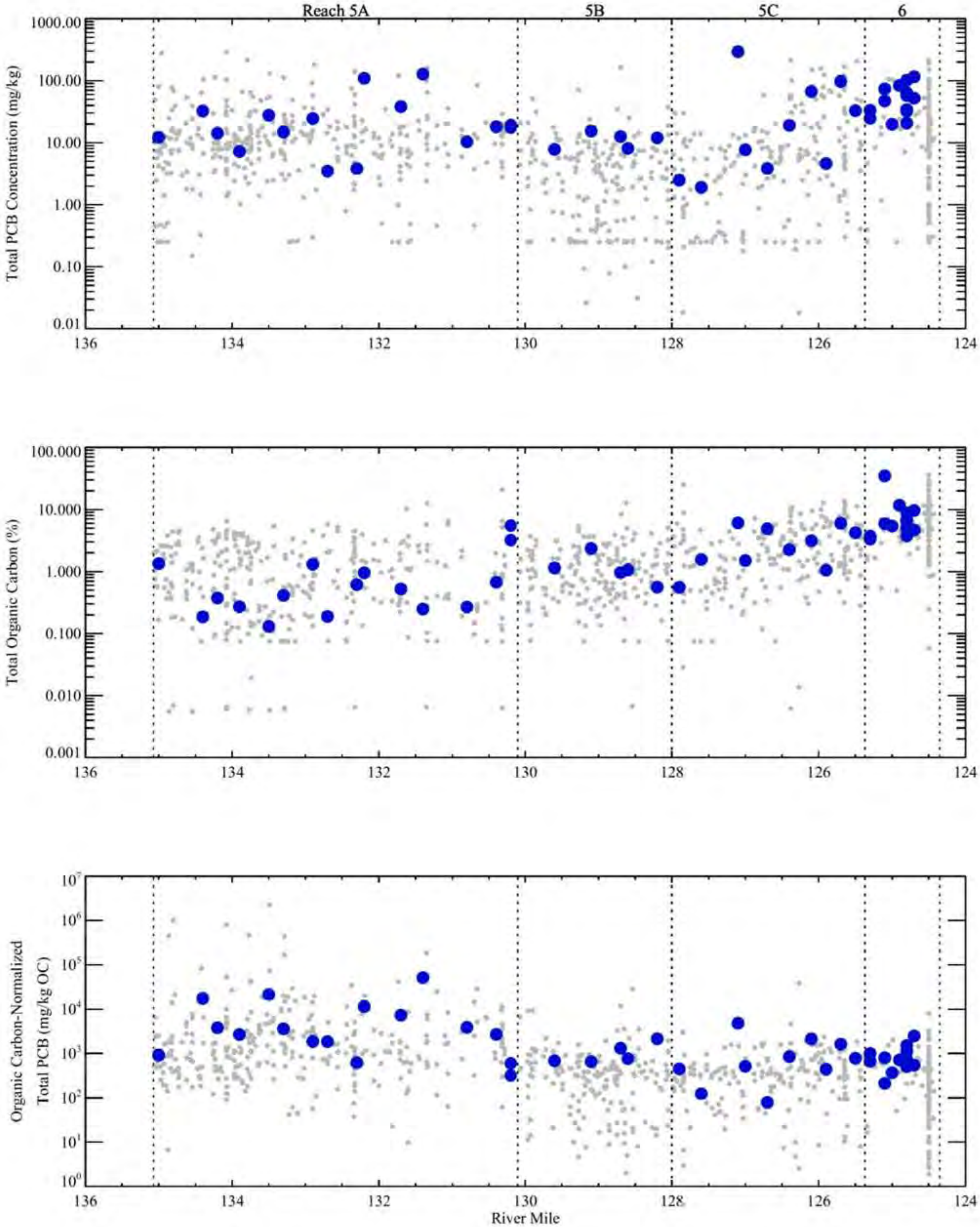

Figure 8-21. Spatial profiles of surface sediment (0-6") data collected as part of the 1998-2002 EPA and 2001 EPA/GE partitioning studies.

- 1998-2002 EPA Data
- 2001 Partitioning Data

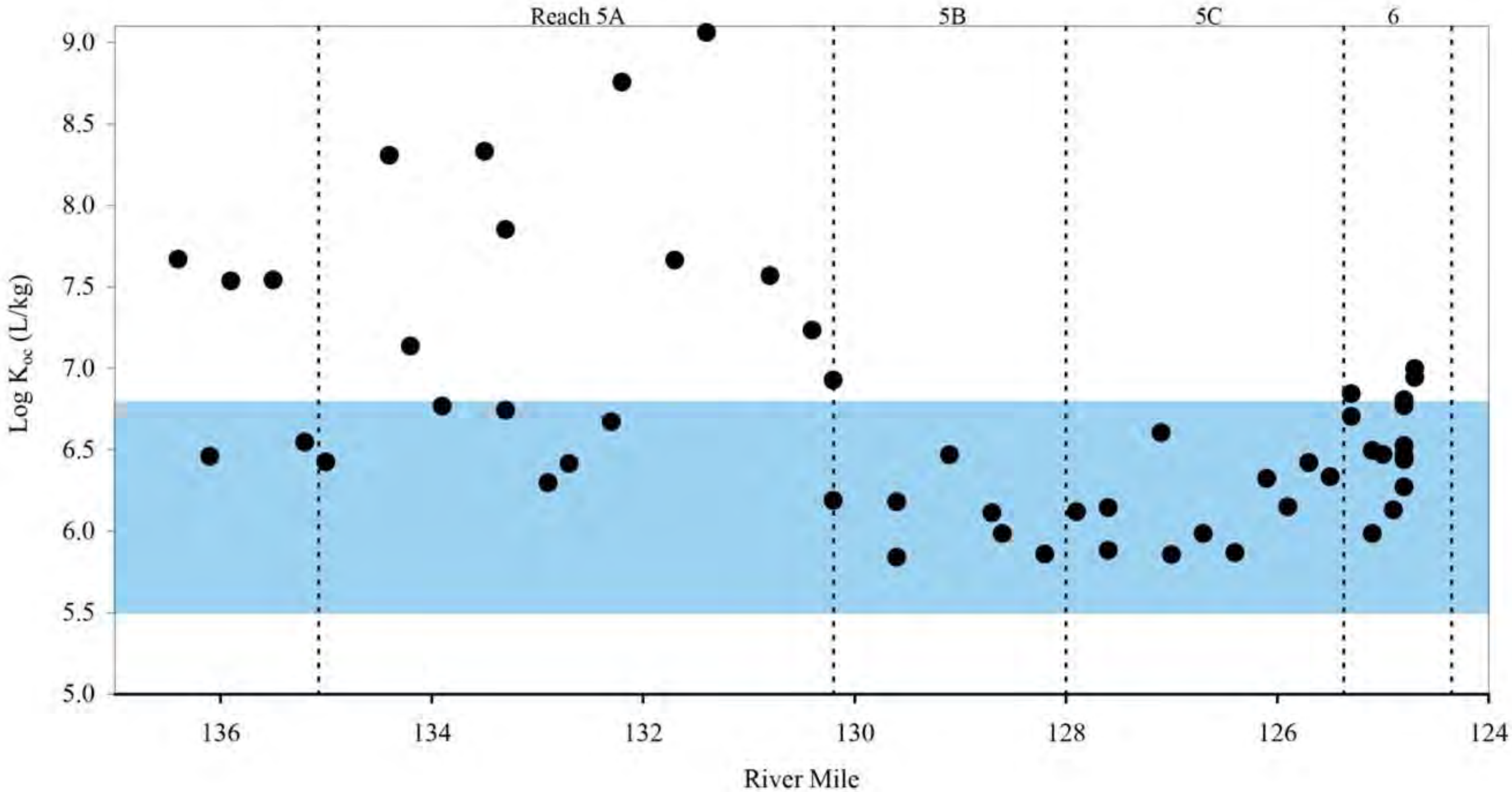

Figure 8-22. Spatial profile of sediment 3-phase partition coefficients calculated from 2001-2002 EPA/GE partitioning study data.

Note: Shaded area represents the range (5.5-6.8) of published Aroclor 1260 K $_{oc}$ values (Mackay, 1992).

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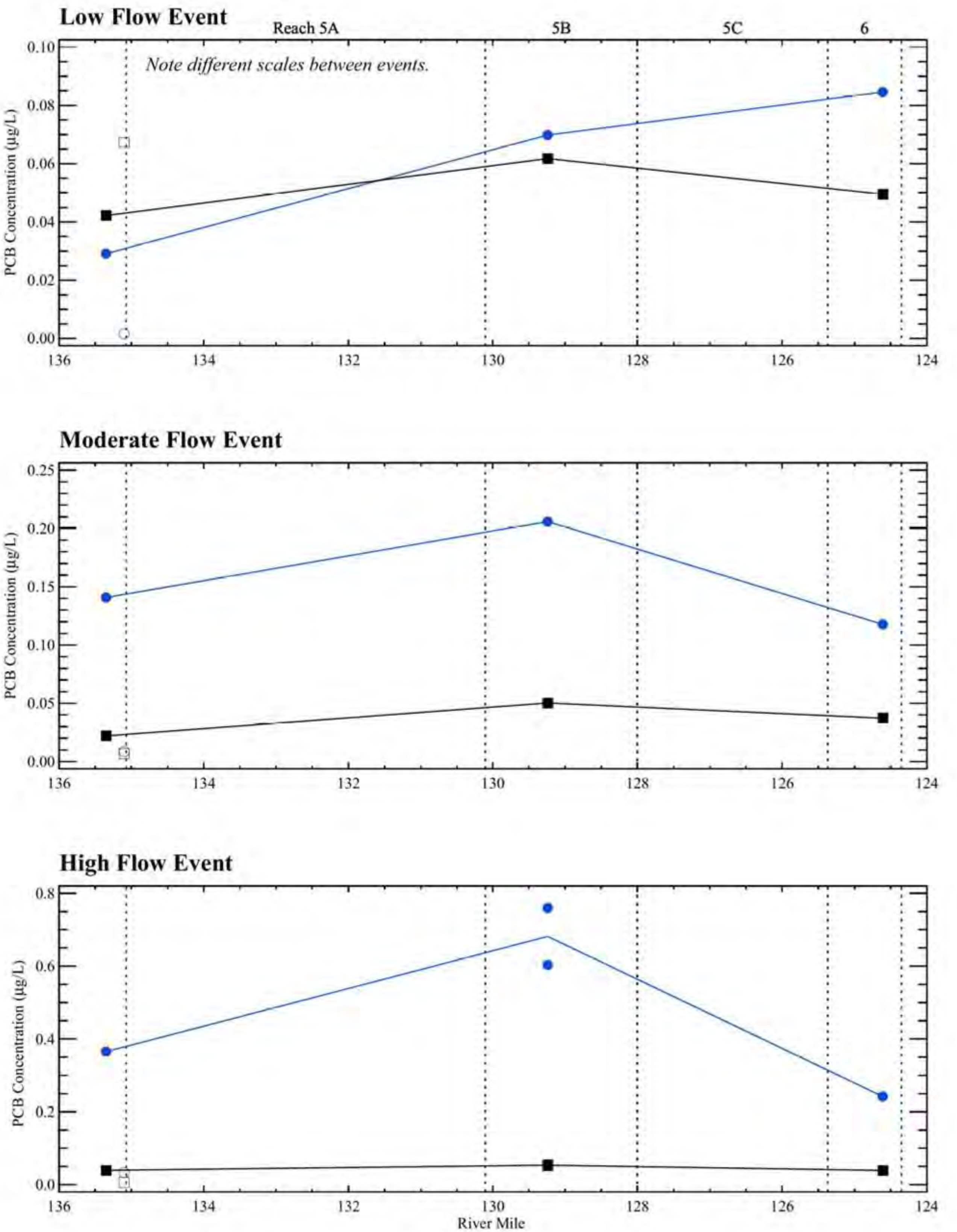

Figure 8-23. Spatial profiles of water column particulate- and dissolved-phase PCBs during low, moderate, and high flow events.

Data set shown: 2001-2002 EPA/GE partitioning data.

Note: Open symbols denote samples collected in the West Branch.

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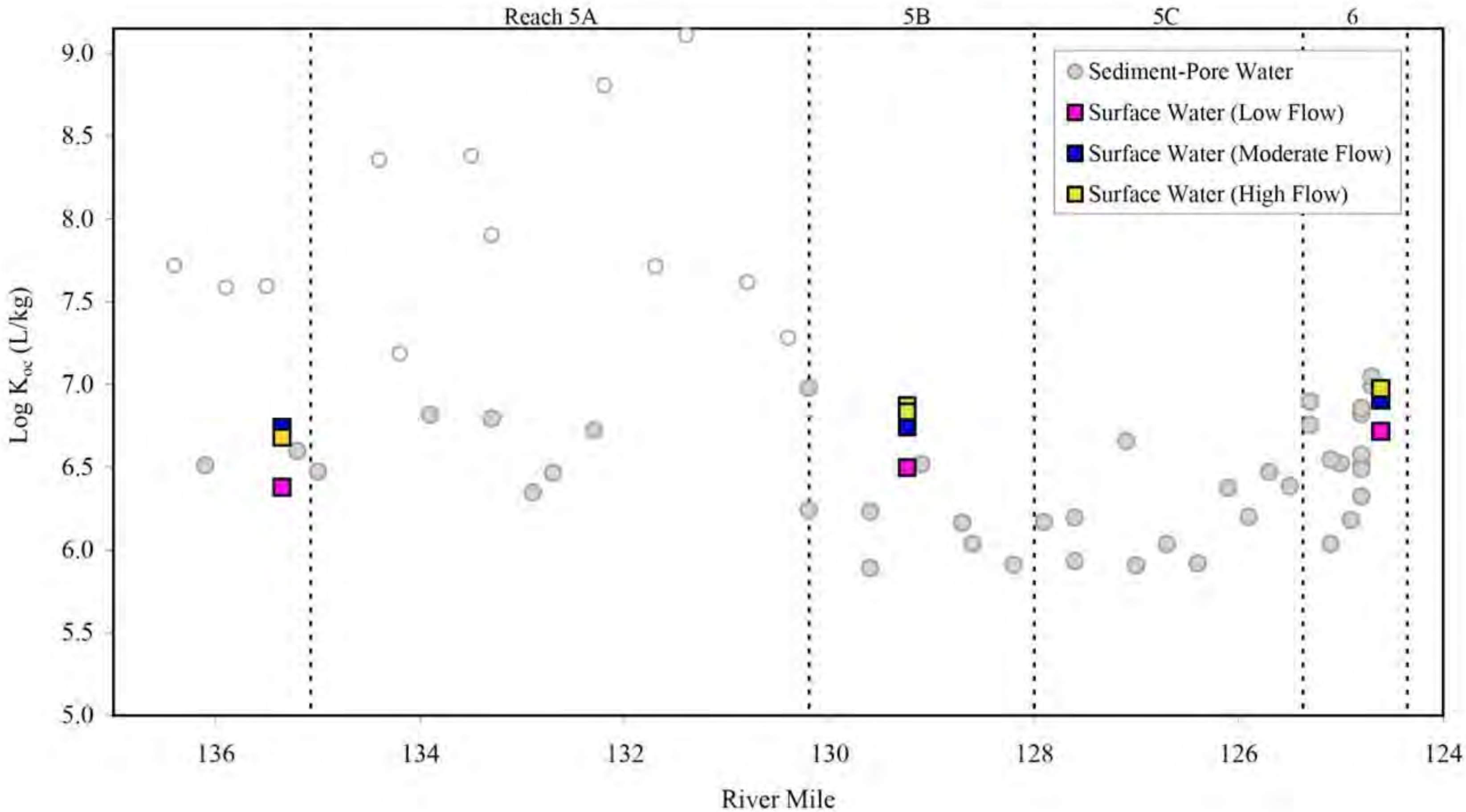

Figure 8-24. Spatial profile of sediment and surface water 3-phase partition coefficients calculated from 2001-2002 EPA/GE partitioning study data.

Note: Empty symbols represent samples having calculated log K_{oc} values greater than 7.0 and are considered generally unrepresentative of the system.

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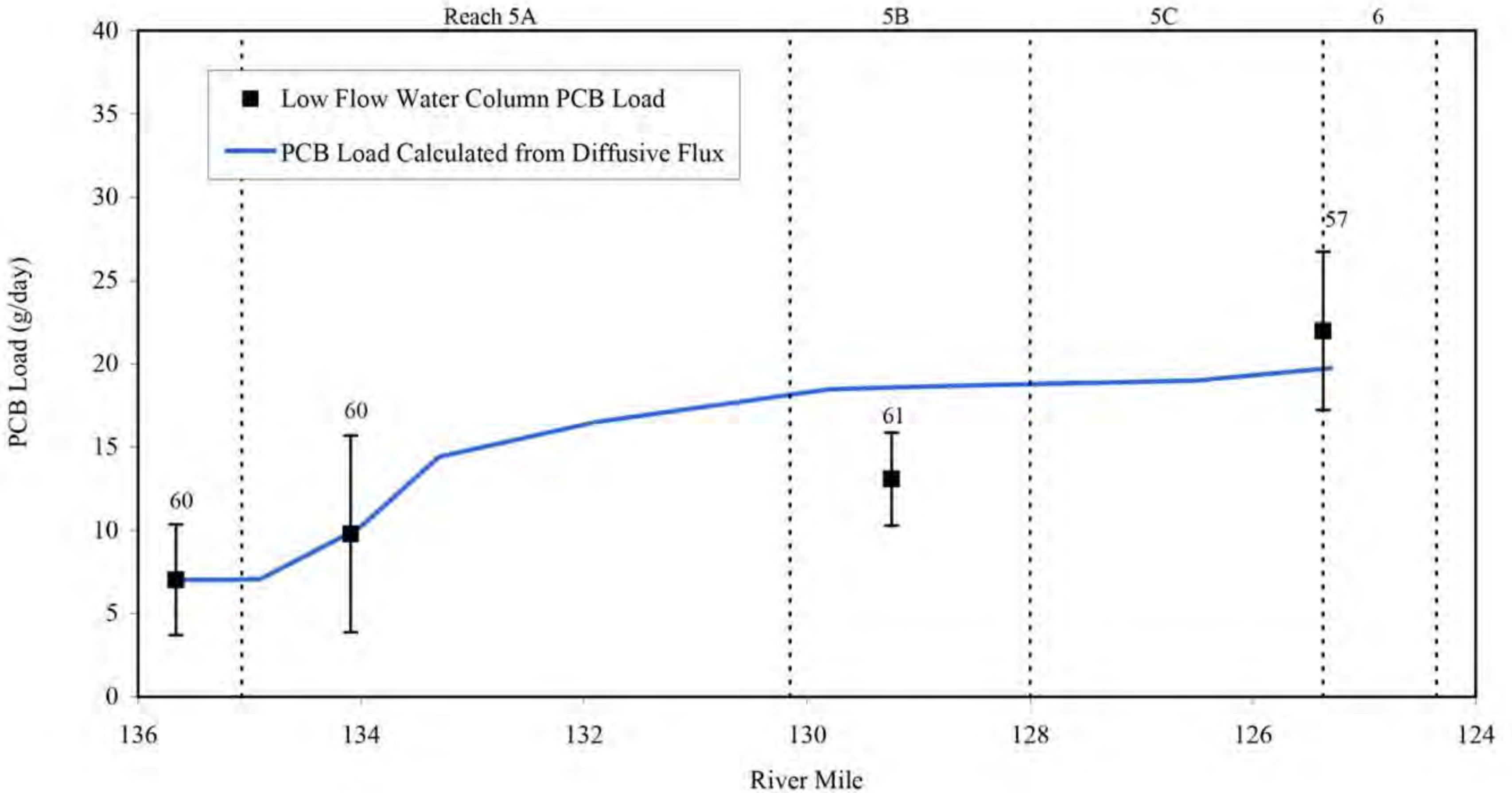

Figure 8-25. Comparison between low flow (< 100 cfs at Coltsville) water column PCB loadings calculated based on a diffusional sediment source and observed 1997-2002 GE/EPA water column loadings.

Notes: Non-detect samples set to 1/2 MDL. Error bars represent 2 standard errors of the mean. Numbers posted above points indicate number of samples in averages.

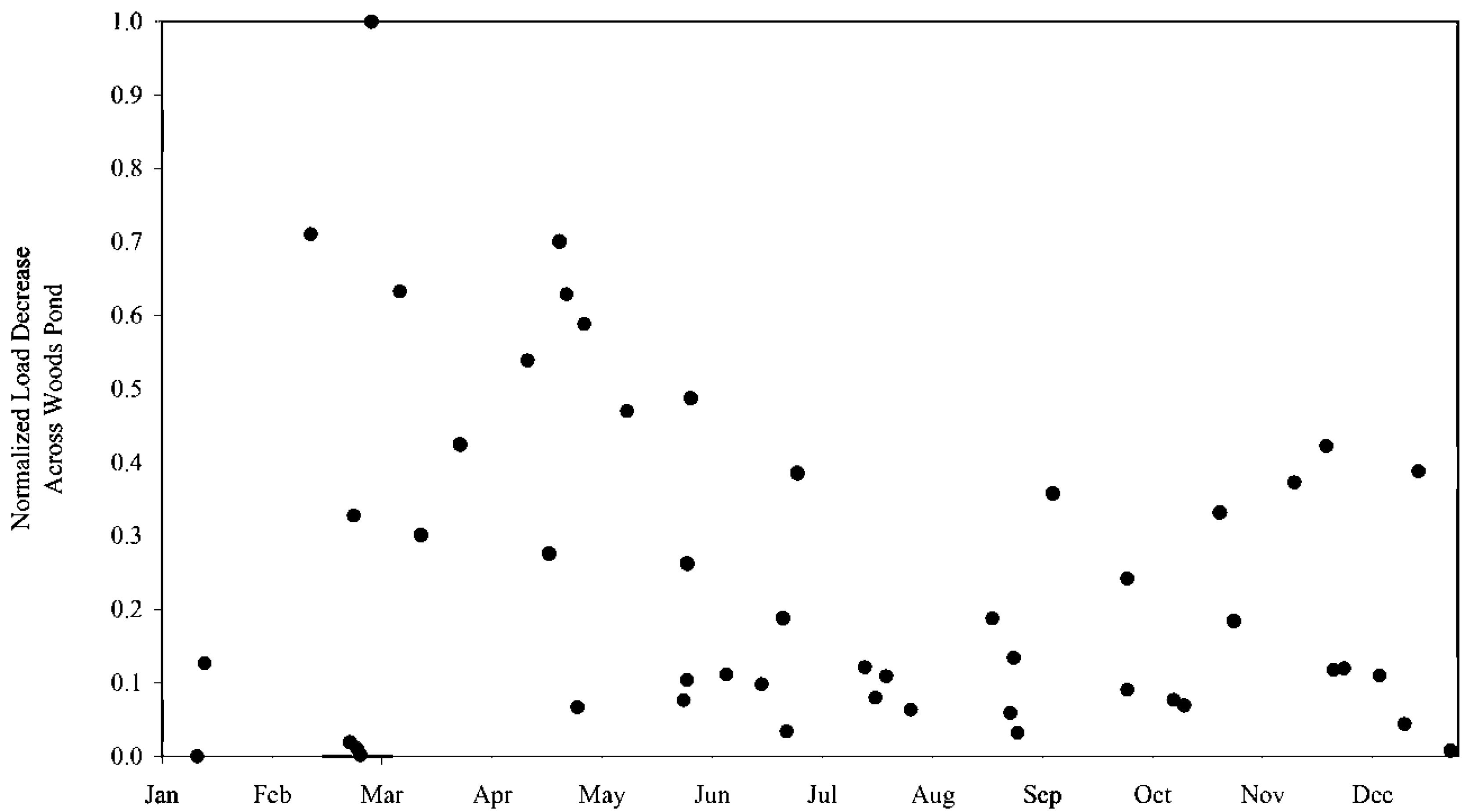

Figure 8-26. Temporal profile of the observed PCB load decrease across Woods Pond attributed to biotic solids.

Notes: Chart only includes sampling events in which a decrease in PCB loading was observed across Woods Pond. Load decrease normalized to largest observed decrease between 1997 and 2002. 3 outliers were removed.

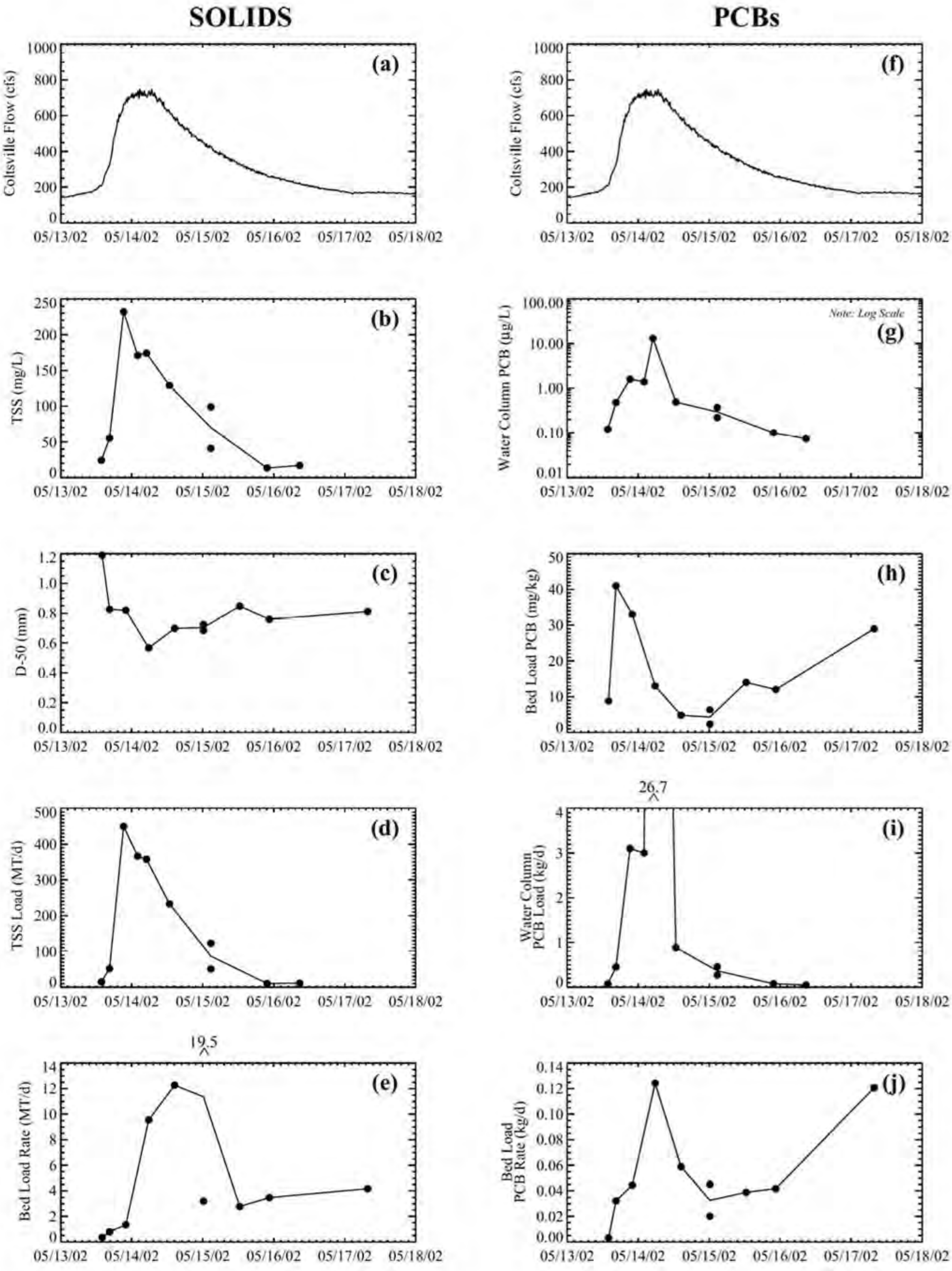

Figure 8-27. Bed load data collected by EPA at Pomeroy Avenue during May 2002.

Notes: Solid line represents the average for duplicate samples. Flows for loading calculations prorated based on drainage basin proration.

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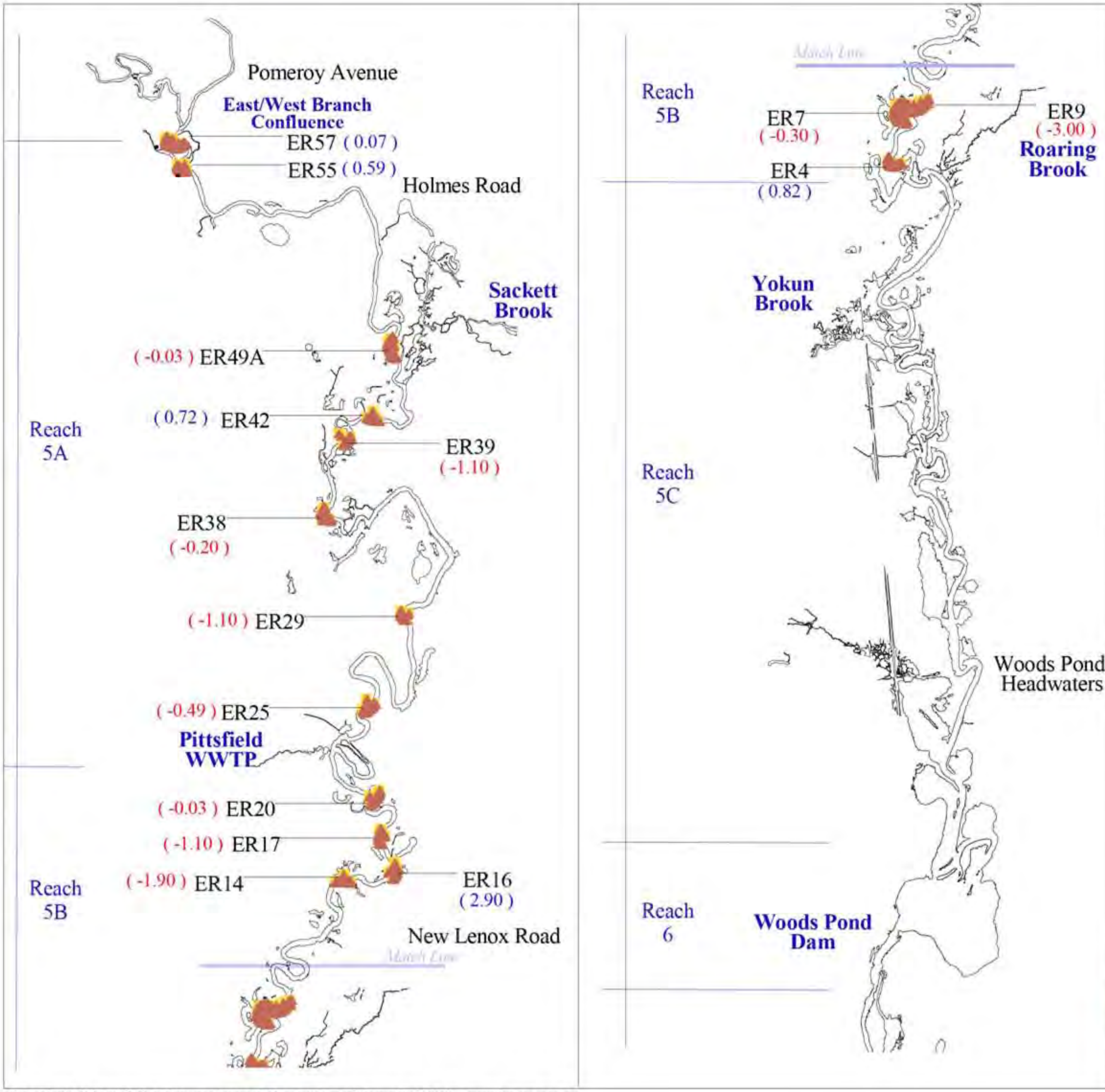

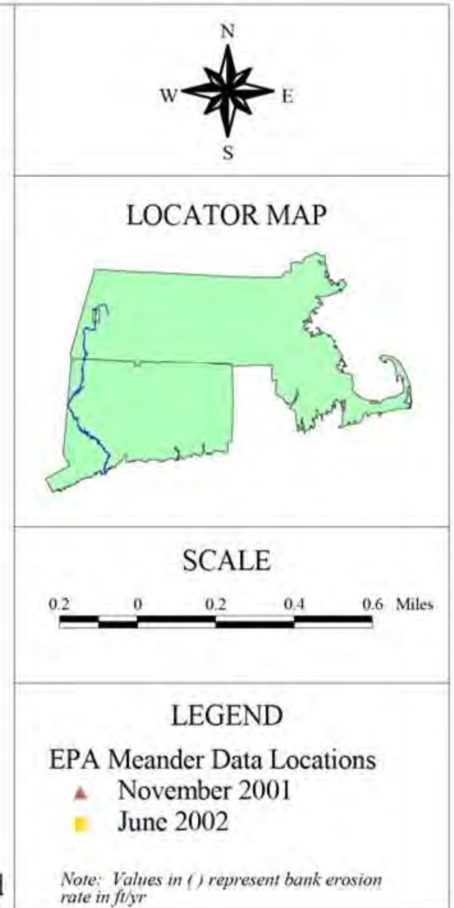

Figure 8-28. Riverbank survey locations and average accretion/erosion rates for 2001-2002 EPA meandering study

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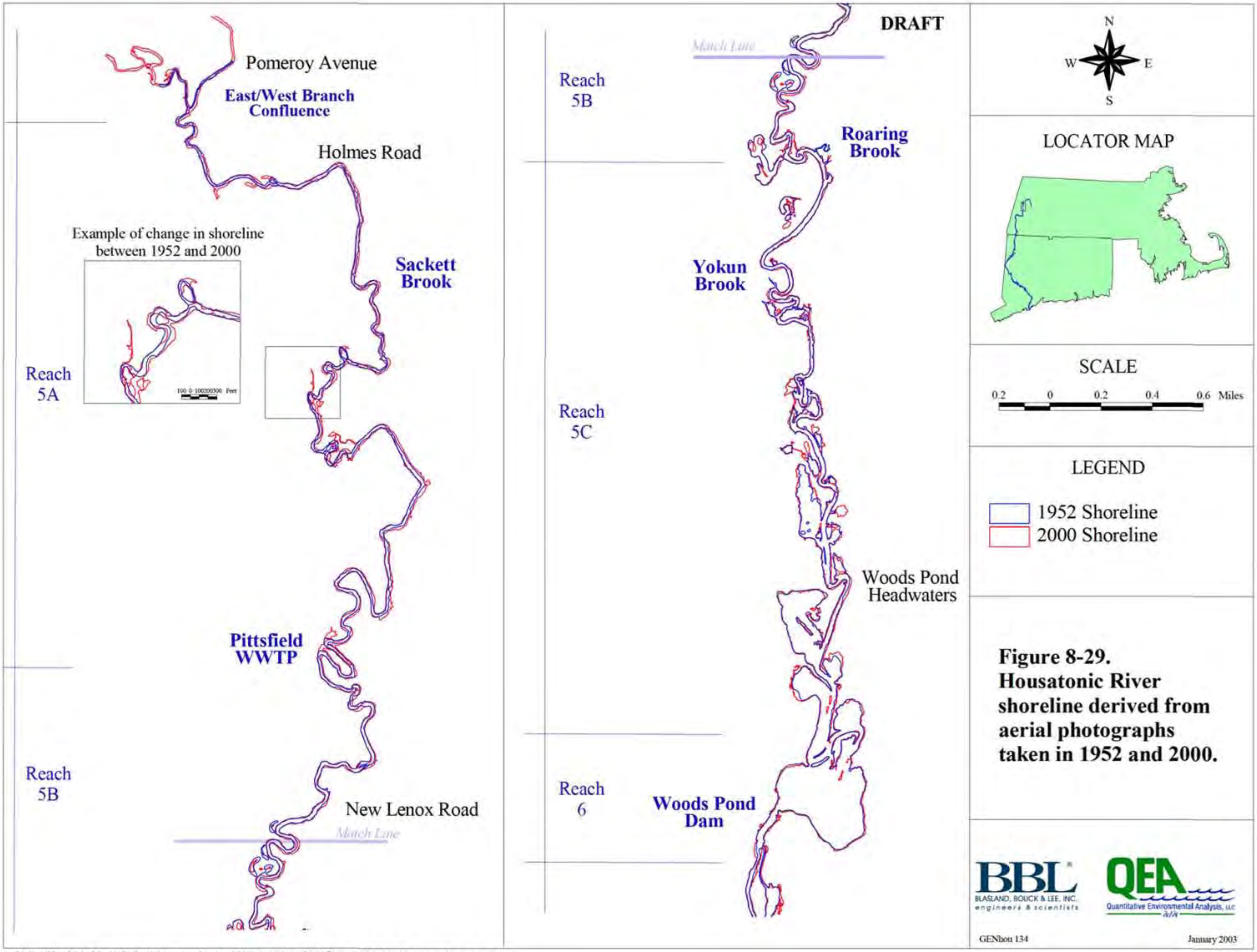

Figure 8-29. Housatonic River shoreline derived from aerial photographs taken in 1952 and 2000.

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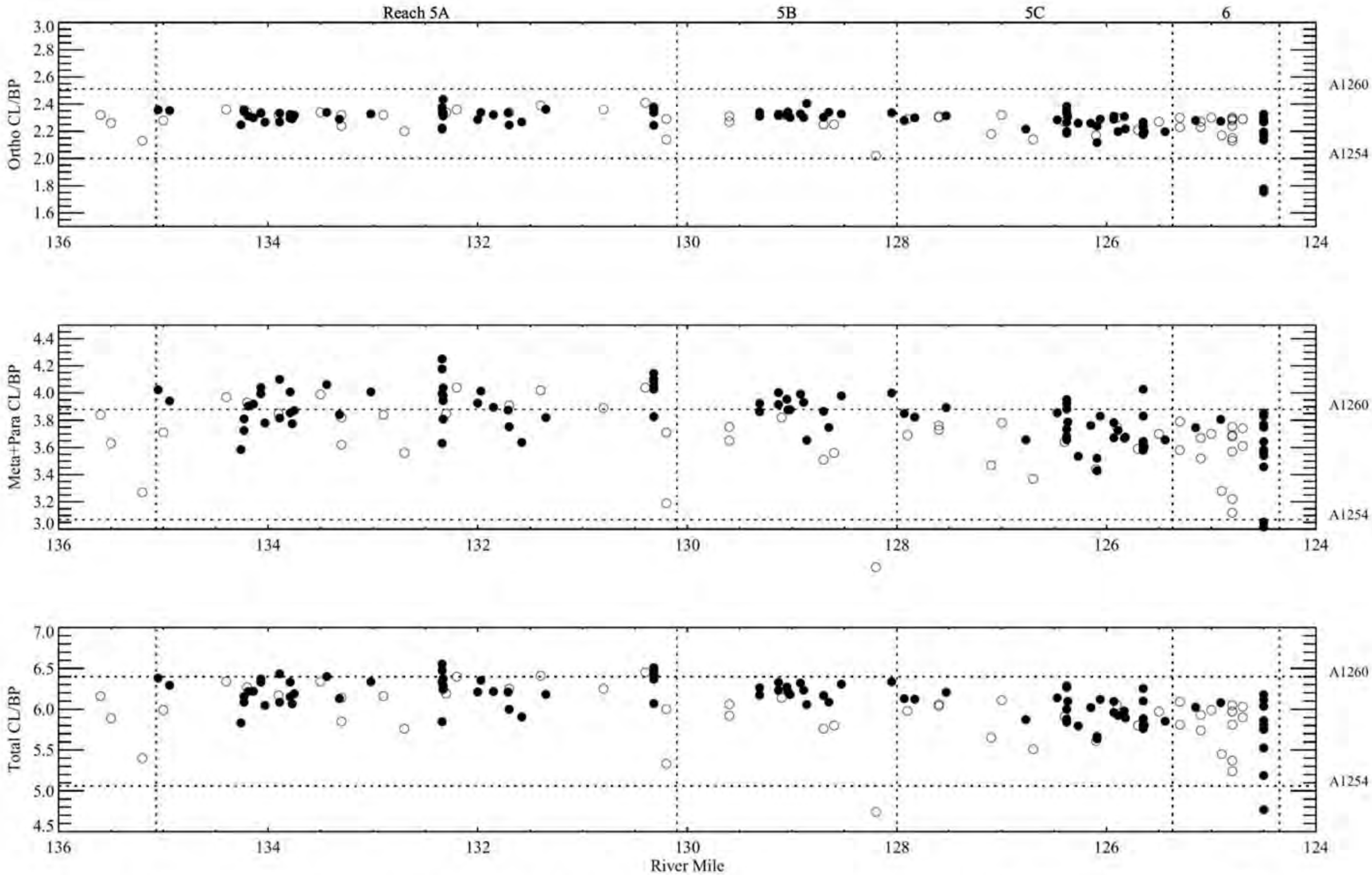

Figure 8-30. Spatial profiles of surface sediment PCB CL/BP.

Data sets shown: 1998-2002 EPA and 2001 EPA/GE partitioning data.

Notes: Non-detect PCB congeners were set to 0. Horizontal dotted lines represent CL/BP in Aroclor 1254 and 1260 standards (Frame, 1996).

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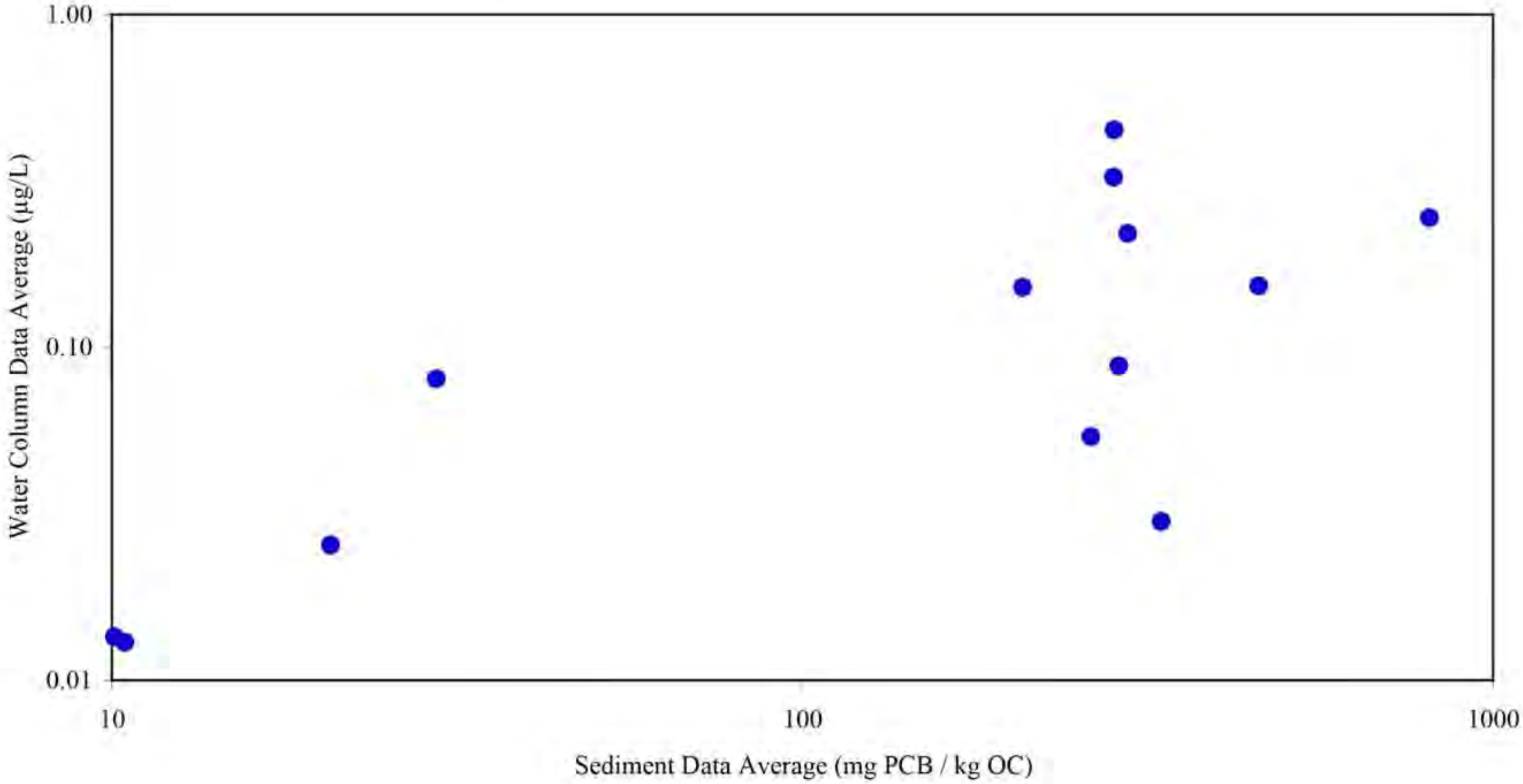

Figure 8-31. Comparison between average 1998-2002 EPA water column and sediment PCB concentrations measured in vernal pool areas.

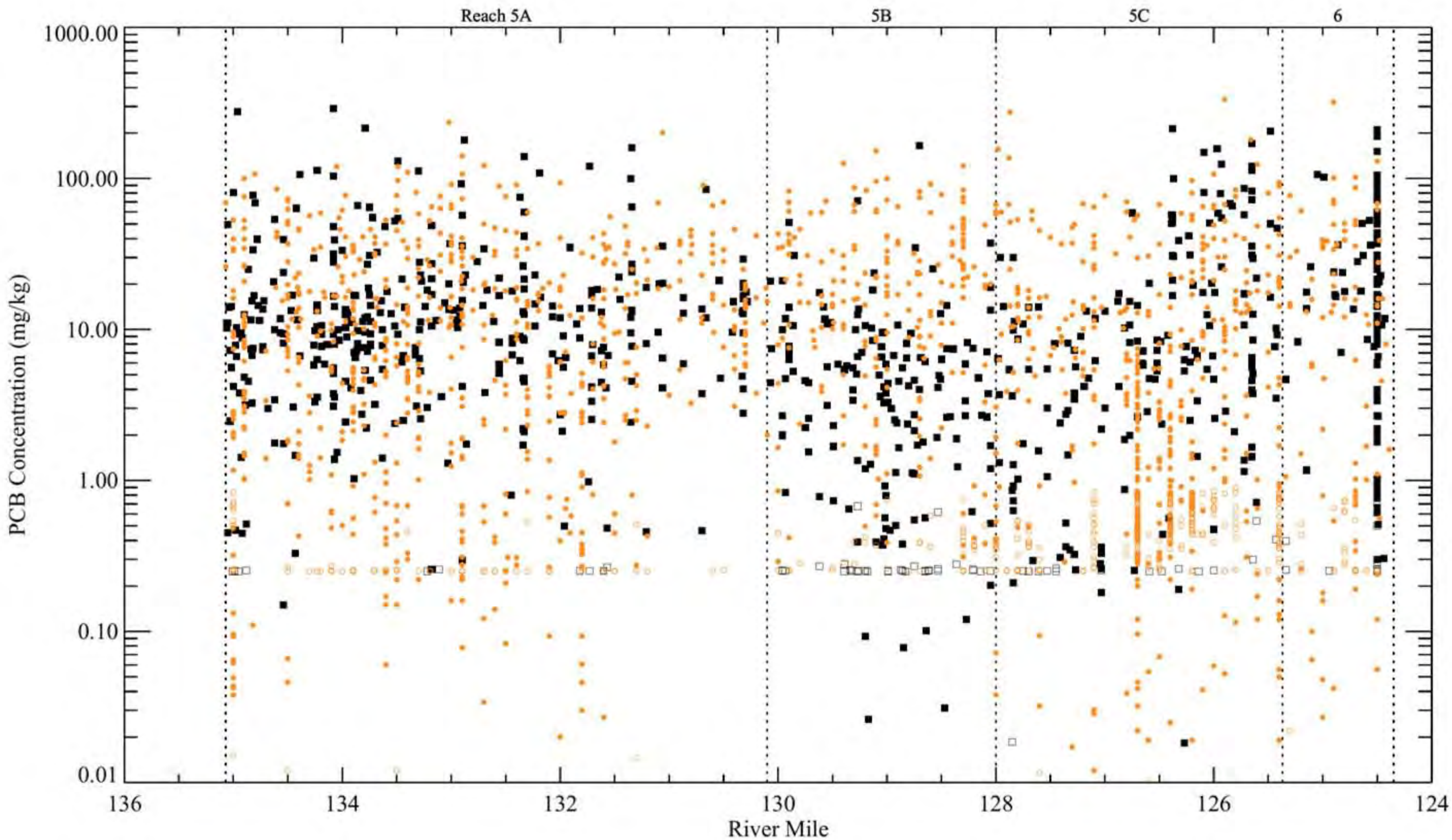

Figure 8-32. Spatial profile of PCBs in surface (0-6") floodplain soil and sediment.

Notes: Data shown are 1998-2002 EPA and 2001 EPA/GE partitioning data. Non-detects plotted as open symbols at 1/2 MDL.

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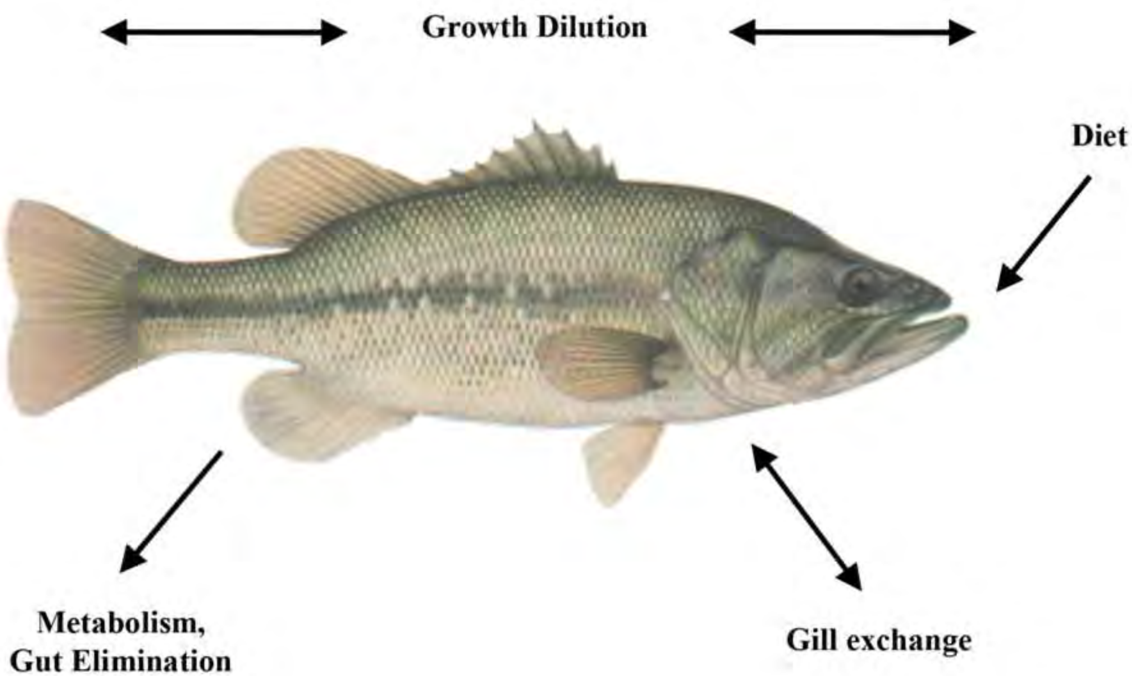

Figure 8-33. The mechanisms of bioaccumulation in an aquatic organism.

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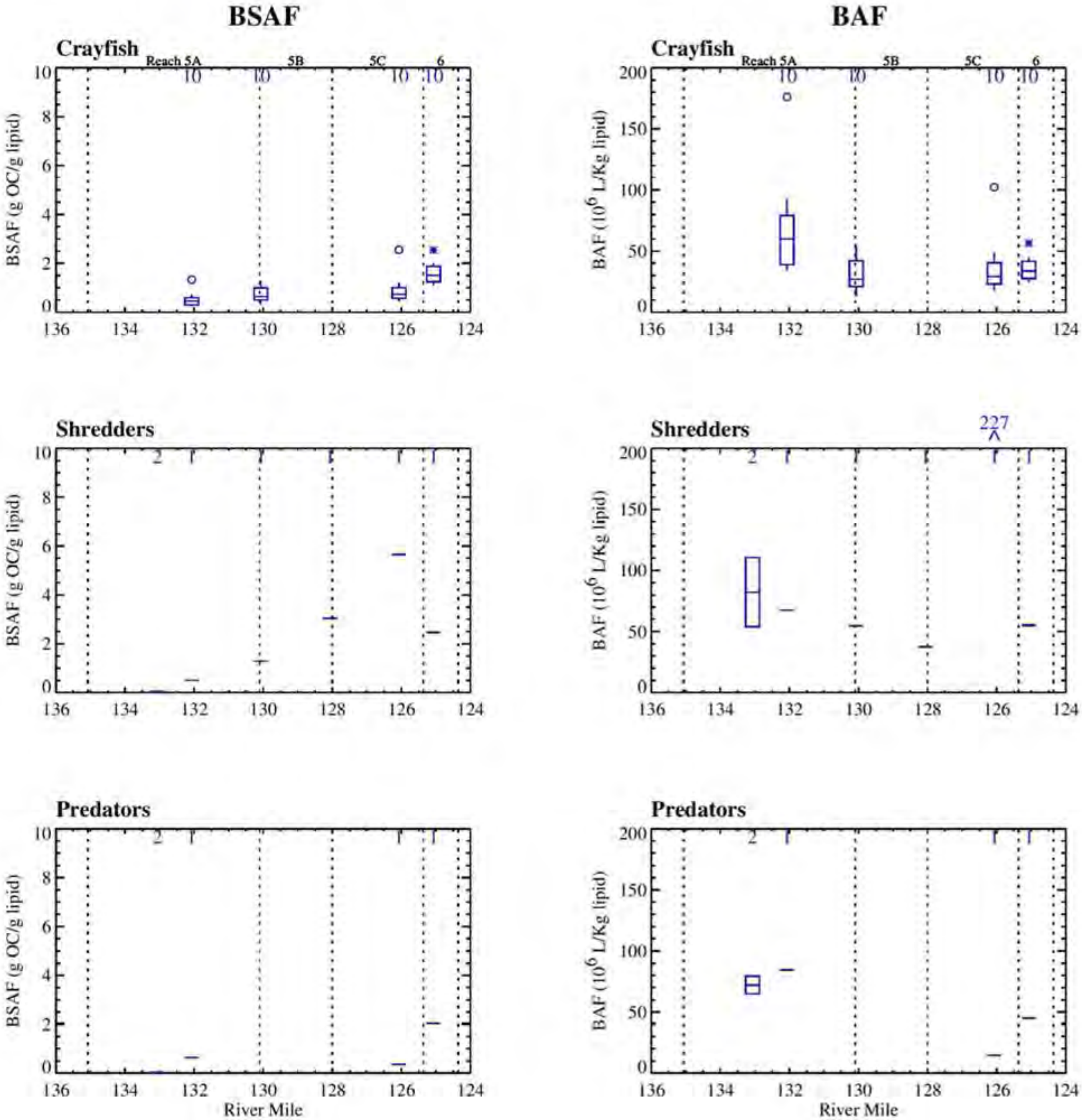

Figure 8-34. PCB BSAFs and BAFs for benthic invertebrates.

Data set shown: 1999 EPA data.

BSAFs calculated using reach averages of 1998-2001 sediment concentrations; BAFs calculated using May-October averaged water column concentrations for the year in which the invertebrates were caught.
Data are presented as standard Tukey box plots by location.

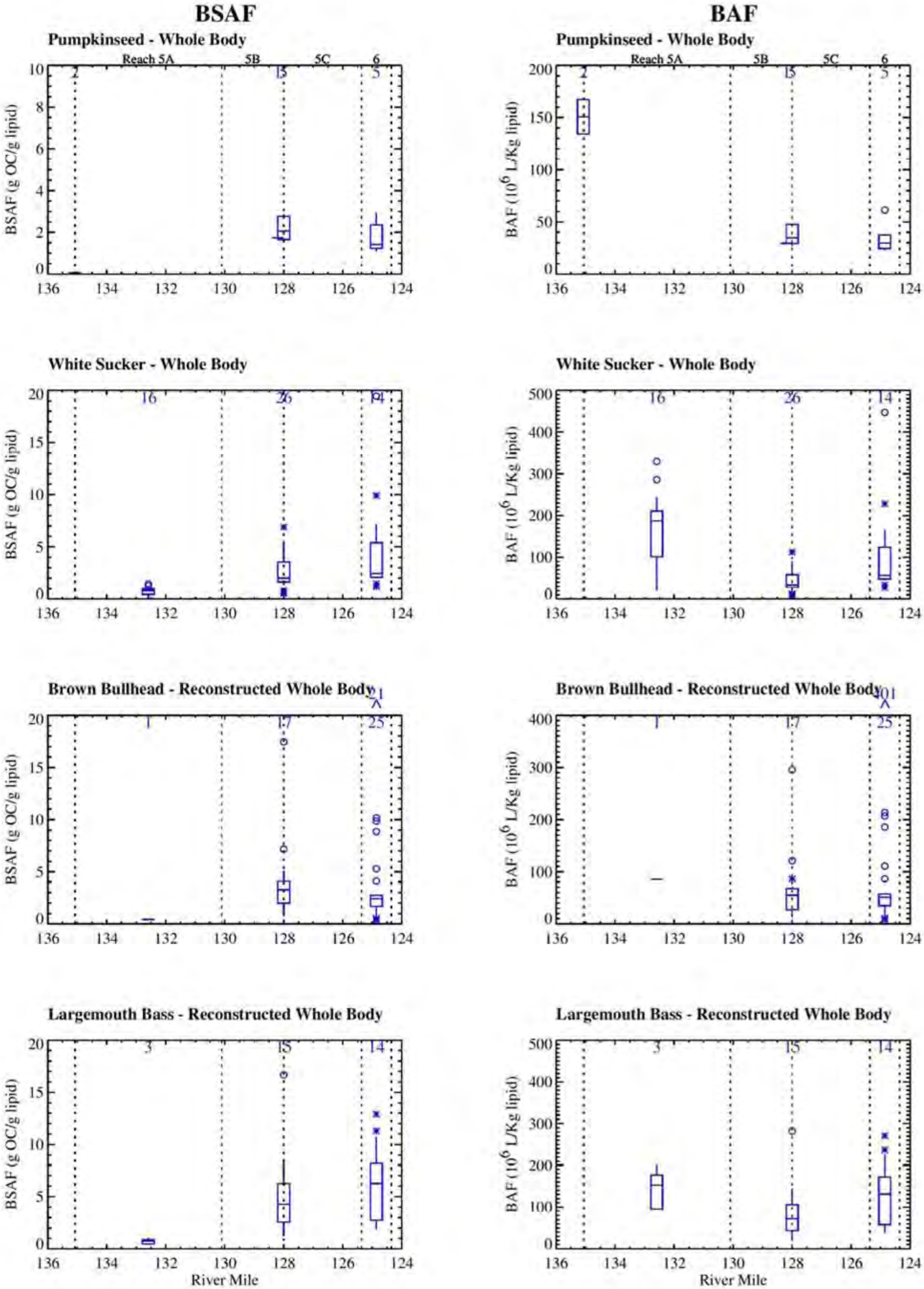

Figure 8-35. PCB BSAFs and BAFs for representative fish species.

BSAFs calculated using reach averages of 1998-2001 sediment concentrations; BAFs calculated using May-October averaged water column concentrations for the year in which the fish were caught.
Data are presented as standard Tukey box plots by location.
Fish data from EPA collected in 1998 except white sucker collected in 2000; GE 1998 pumpkinseed data plotted at RM 135 and 127.
One outlier (low lipid value) for white sucker in Woods Pond was removed; total PCB = 44.7 mg/kg wet weight, lipid = 0.1%.
For EPA data, medians were calculated for Shallow Reach (5A), Deep Reach (5B+5C), and Woods Pond (6) and plotted at reach midpoints.

Section 9

9. Conceptual Site Model

9.1 General

Based upon the various data, analyses, and calculations presented throughout this report, this section presents a conceptual model for PCBs for the Rest of River. It discusses sediment transport within the system, followed by a summary of sources and sinks of PCBs, the major PCB fate and transport processes within the system, and a discussion of bioaccumulation. This section also discusses PCB temporal trends, and it concludes with a short summary regarding other constituents, notably PCDDs/PCDFs.

9.2 Sediment Transport

Watershed sediment loading to the River is relatively low (~15 to 30 MT/mi^2-yr) and consistent with a largely forested (71%) drainage area. The River channel is characterized as sinuous in Reach 5A and minimally to moderately meandering in Reaches 5B and 5C. Overall, the main channel appears to be relatively stable, with significant meandering occurring over timescales greater than 50 years. However, a few specific subreaches, which are relatively small compared to the entire reach, experience more active channel movement. Bank erosion occurs along a fraction of the channel shoreline in Reaches 5A and 5B and may produce significant sediment loads to the system, particularly during high-flow events.

Sediment transport in Reach 5A is dominated by suspended and bed load transport of non-cohesive sediment. The sediment bed in this reach appears to be in dynamic equilibrium (i.e., erosion and deposition approximately balance one another), with certain areas being net erosional and others net depositional. A percentage of the total sediment load entering Reach 5A from the East Branch is bed load. As the channel gradient decreases between the upstream and downstream limits of the reach, the sediment bed becomes finer and bed load transport decreases, with less (if any) bed load occurring at and downstream of New Lenox Road Bridge, except at very high flow conditions. Cohesive sediment transport becomes more important in Reach 5B, but the sediment bed is still primarily non-cohesive, although finer than that in Reach 5A because of the lower channel gradient. In most of Reach 5B, the channel is likely in dynamic equilibrium or depositional. Deposition is dominant in Reach 5C and Woods Pond, where most of the sediment bed is composed of cohesive sediment. The floodplain and backwaters are important during overbank floods, which occur almost annually. These areas act as sinks for suspended sediments because the presence of floodplain vegetation and submerged aquatic vegetation in the backwaters make these areas conducive to deposition.

Within Woods Pond and the nearby backwater regions, internal production enhances deposition. Significant growth of periphyton, phytoplankton, and macrophyte populations during the summer occurs in response to nutrient inputs from the WWTP; during the fall die-off period, a large fraction of the associated solids and organic matter is returned to the sediment bed where they are subject to decomposition. The depositional nature of Woods Pond is evidenced by the radioactive Cs-137 dating analyses, which indicate a net deposition rate of approximately 0.5 cm/yr in that impoundment. The deposition in Woods Pond and upstream backwaters is likely a combination of solids entering these reaches from upstream (i.e., Reaches 5A and 5B), growth of algae and macrophytes, and solids delivered by the tributaries (i.e., Roaring Brook and Yokun Brook).

Downstream of Woods Pond, the River is likely in a state of dynamic equilibrium in the free-flowing reaches. Additional solids inputs from tributaries cause the in-River suspended sediment loading to increase with downstream distance. The River is net depositional within the impoundments associated with the various dams in these reaches, as evidenced by radioactive Cs-137 dating analyses (e.g., about 1 cm/yr in Rising Pond).

The annual average sediment loads calculated for various locations along the River are plotted on Figure 9-1 to help to illustrate this conceptual model. Loads that originate from watershed and tributary inputs and in-channel erosion entering the Rest of River at Dawes/Pomeroy Avenue and the West Branch combine to a total of approximately 3700 MT per year. This value is similar to the load of 3200 MT per year at Holmes Road calculated from TSS concentrations measured at this location. Between the Confluence and New Lenox Road, the annual average sediment load increases to 4200 MT, which reflects the combined effects of tributary inputs (e.g., Sackett Brook) and net erosion of River sediments, and bank soils to some extent. Between New Lenox Road and Woods Pond Dam, the more quiescent environment associated with the decreased channel slope coincides with an approximate 60% decrease in the average suspended sediment load, indicating the net depositional character of the River in these reaches. The increase in average sediment load to 3800 MT downstream at Great Barrington indicates the additional inputs of solids from tributaries and the watershed over this 20 mile stretch of the River.

9.3 PCB Sources, Fate, and Transport

The only significant external PCB sources to the Rest of River are the inflows to the system at the Confluence. The existing water column data indicate that loads entering from the East Branch total approximately 10 kg/yr; most of this occurs at high flows, which is likely due to erosion of PCB-containing sediments and possibly bank soils along the reaches between the GE Plant area and the Confluence (see Section 8.6.1.1). An unmeasured quantity of PCBs associated with sediment bed load also enters the system from the East Branch; this contribution may be on the order of a few percent of the total load. These loads will likely decrease in the future in response to remediation efforts upstream of the Confluence. Estimated PCB loads entering from the West Branch are on the order of 2 kg/yr, but this value is uncertain due to less frequent monitoring and a high proportion of PCB concentrations below the detection limit.

The average estimated PCB loads are plotted on Figure 9-2 for stations representative of upstream loadings and of Reaches 5A, 5B, 5C, 6, and 8. These loads are shown separately for low-flow conditions (< 100 cfs at Coltsville) and higher-low conditions.. Under low-flow conditions, PCB loadings increase gradually, approximately tripling between the Confluence and Woods Pond Headwaters. This pattern is indicative of widespread diffusion of PCBs from surficial sediment pore waters, where PCBs desorb from sediment organic carbon under a state of equilibrium. On average, low-flow PCB loads decrease by approximately 20% across Woods Pond. This decrease is likely attributable to deposition within the Pond and sorption of dissolved PCBs to algae and periphyton associated with the macrophyte community, which are consequently sequestered within the Pond and returned to its sediments during the fall die-off period. The latter phenomenon enhances the net sediment deposition within these areas, and may serve as a mechanism to sequester PCBs within the surficial sediments. The backwater regions in the vicinity of Woods Pond likely experience little hydraulic exchange with the main channel under low flow, and are therefore likely characterized by higher water column PCB concentrations, which reflect a steady-state balance of diffusion flux from surface sediments and volatilization losses at the air-water interface. Low-flow PCB loading estimates (Figure 9-2) indicate a 20% decrease between Woods Pond and Division Street, which is likely caused by losses from volatilization and deposition that exceed PCB inputs associated with diffusion from surface sediments over this 20-mile stretch (although the higher proportion of non-detects at Division Street adds uncertainty to this loading estimate).

Loadings under higher-flow conditions (> 100 cfs at Coltsville) dominate PCB transport within the system, accounting for between 70% (Division Street) and 90% (Holmes and New Lenox Roads) of the total annual average load at these locations (Figure 9-2). The spatial changes in PCB loadings across the system reflect its sediment transport characteristics under these higher flows. PCB loads under these conditions increase by almost a factor of 4 between the Confluence and New Lenox Road, indicative of inputs from erosion of channel sediments and bank soils over this reach (i.e., Reach 5A and the upper portions of Reach 5B). A small fraction of the PCBs that are resuspended into the water column partitions to the dissolved phase. Substantial deposition of suspended solids and associated PCBs in Reach 5C and Woods Pond during these higher flows is evident in the net decrease in annual PCB loadings of 12% between New Lenox Road and the Headwaters and 43% across Woods Pond. Under high-flow conditions when the River overtops its banks, PCBs are also transported to the floodplains and backwaters in these reaches, where their deposition is enhanced by the submerged, emergent, and terrestrial vegetation in these areas. A net decrease in higher-flow PCB loading occurs between Woods Pond and Division Street; this trend is likely attributable to deposition within the various impoundments, as well as volatilization, which occurs at a greater rate under higher flows due to increased turbulence, especially in the fast-flowing stretches and over the dams located on the River over this reach.

On an annualized basis, internal PCB sources associated with sediments and bank soils exceed the loads entering the Rest of River, and are greatest in Reach 5A and the upper portion of Reach 5B (Figure 9-2). The flatter River gradient and lower-energy flow regime between Reach 5C and Woods Pond Dam promote the deposition of PCBs sorbed to sediments, some of which originated from within Reach 5A and the upper portion of Reach 5B. A portion of the PCB loads travel downstream of Woods Pond Dam, and decrease gradually due to deposition and volatilization.

This conceptual model of PCB fate is further illustrated by the spatial patterns in surface sediment data (one-mile reach averages) plotted on Figure 9-3 (repeated from Figure 4-12, above). Surface sediment PCB concentrations are relatively high in Reach 5A (i.e., the Confluence to RM 130), which is closest to the upstream source area, has been impacted by particulate PCB loadings (associated with suspended and bed loads), and is a region of active erosion during high flows. Low TOC concentrations in this reach are indicative of relatively coarse sediments and result in the highest organic carbon-normalized PCB concentrations, averaging approximately 10,000 mg/kg organic carbon. PCB concentrations in surface sediments are lower in Reach 5B (i.e., RM130 to RM128), likely due to a number of factors, including addition of "clean" solids from tributaries and the WWTP, increased internal biological production (associated with nutrient inputs from the WWTP), a shift in sediment grain size, and deeper, slower waters associated with shoaling river gradients. Surface sediment PCB concentrations increase across Reach 5C, and are highest in Woods Pond, averaging approximately 30 to 40 mg/kg. This increase is associated with the depositional nature of these reaches. The significantly higher organic carbon content of the sediments in Reach 5C and Woods Pond (i.e., averages in the range of 4% to 8%), which are associated with the fine-grained sediments in these areas coupled with the influence of algae and macrophyte production and decomposition, contribute to the higher PCB concentrations by providing a greater PCB sorption capacity. The organic carbon-normalized PCB concentrations in these reaches are more than an order of magnitude less than in Reach 5A, indicating that the higher dry-weight PCB concentrations can be explained, in part, by the higher organic carbon content. In other words, the flux of organic carbon to the Reach 5C and Woods Pond surface sediments results in lower organic carbon-normalized PCB concentrations (which, in turn, determine the uptake of PCBs by benthic organisms).

Surface sediment PCB concentrations downstream of Woods Pond decrease significantly, with typical averages of about 1 mg/kg. This decrease is related to the reduction in PCB transport caused by deposition in Reach 5C and Woods Pond and the progressive increase in clean solids flux to the River that serves to reduce PCB concentrations. Surface sediment PCB concentrations are slightly higher in Rising Pond, which is likely due to the depositional nature of that impoundment and the higher inventory of organic carbon associated with fine sediment accumulation in this impoundment. From Rising Pond to Connecticut, surface sediments PCBs average less than 1 mg/kg and organic carbon-normalized concentrations are variable, but in the range of 100 mg/kg organic carbon or less, which is approximately 100 times lower than concentrations in Reach 5A. The continual decrease in organic carbon-normalized PCBs evident on Figure 9-3 is consistent with increasing distance from the source area.

The PCB distribution within the floodplains further illustrates the fate and transport characteristics of the Rest of River. PCB concentrations in floodplain soils are highest within Reach 5, similar to the sediments. PCBs are higher in riverbank soils and decrease with lateral distance from the River channel, which reflects the lower frequency of inundation in the distal portions of the floodplain. This is demonstrated by the approximate five-fold decrease in average PCB concentrations between the 2-year and 2- to 10-year floodplains. PCBs are non-detect or considerably lower beyond the 10-year floodplain. PCB concentrations are higher in vernal pools, which is related to the significantly higher organic carbon content of these areas. The floodplain does not encompass a significant area in the vicinity of Woods Pond. Downstream of Woods Pond, floodplain PCB concentrations are significantly lower, which again is consistent with the sediment data and indicates that a majority of the PCB loads that originated upstream are sequestered within the sediments and floodplains of Reaches 5 and 6.

9.4 PCB Bioaccumulation

In general, concentrations of PCBs in the biota within Reaches 5 and 6 reflect a response to PCBs contained in the water column and surface sediments. Exposure to local sediment and water column sources promotes PCB partitioning into the lower trophic levels of the food chain: that is, to algae and macrophyte-associated periphyton and subsequently the benthic and water column invertebrate populations. PCBs are then transferred up the food chain to foraging fish (e.g., pumpkinseed, white sucker, and brown bullhead) feeding on invertebrates. PCBs bioaccumulate in predatory fish (e.g., largemouth bass) that feed on smaller fish. Bioconcentration, the net direct uptake from water through gill exchange, may contribute to fish body burdens, but to a lesser extent than these food web transfers. Growth dilution and excretion across the gut wall are the primary mechanisms by which PCB concentrations in fish tissue are reduced.

Spatial patterns of BAF and BSAF within Reaches 5 and 6 indicate that the dietary exposures for invertebrates and most fish species consist of a mixture of water column-based and sediment-based food sources, and thus fish tissue PCBs likewise originate from a mixture of food consumed from water column and sediment sources. Data from Rising Pond suggest that PCB uptake by fish (e.g., yellow perch) in this impoundment may be more linked to water column-based dietary sources than to those based in the sediments. Because of the complexity of the gradients in sediment organic carbon (indicative of potential food resources) and PCB concentrations, the relative importance of sediment-based organisms and water column-based organisms as dietary sources of PCBs cannot be determined solely by patterns in BAF and BSAF values.

Overall, PCB concentrations in fish represent a mixture of exposure to water column-based and surface sediment-based PCB sources. Changes to exposure from these sources over time will therefore be reflected by the biota, although at different rates. Fish with a predominantly water column-based exposure route are likely to respond more rapidly to reductions in upstream PCB loads.

9.5 Temporal Trend Evaluation

Temporal trends in water column, surface sediments, and fish PCB concentrations were described in previous sections of this report. Considerable within-year variability, data limitations (e.g., limited sample numbers in 1980s data), and changes in sampling procedures (e.g., differences in fish tissue preparation) preclude drawing definitive conclusions regarding the significance of these trends. However, analyses of the data on temporal trends in the Rest of River provide some evidence of a decline in PCB concentrations in the water column and, to some extent, in surface sediments over the past 20 years, although there is considerable variability in the data and the trends are not clear or strong. As discussed in Section 3.7, regression analyses indicate statistically significant ($p < 0.05$) declining trends in surface water PCB concentrations since the late 1980s at most of the primary surface water sampling stations in Massachusetts, and these trends are also visually apparent when the data are averaged and plotted by location and grouped by years (Figure 3-19b). However, the trend lines provide only a weak fit to the data because of the high variability. With respect to the sediments, as discussed in Section 4.6, regression analyses indicate a downward (but not statistically significant) temporal trend in the surface (0-6") sediment PCB data from Woods Pond and Rising Pond. However, analysis of radionuclide and PCB profiles from finely-segmented sediment cores collected from depositional areas within these impoundments indicates that the PCB concentrations on depositing sediment particles in these areas have significantly declined ($p < 0.05$) since the 1960s, although these data do not provide information about other areas within these impoundments and thus about the entire reaches.

The fish PCB data in Massachusetts are insufficient to make a temporal trend evaluation for fish in the Massachusetts portion of the River over a comparable period, because: (a) while the recent adult fish data are extensive, the older adult fish data are sparse, used different sampling and analytical techniques, and/or had varied or uncertain locations, thus precluding any reliable comparisons with the newer data; and (b) the YOY fish data have been collected only since 1994 and show no discernible temporal trend over that 8-year period. However, the fish data from Connecticut show a clear decline in PCB concentrations since the late 1970s (see Section 6.3.4.2).

9.6 Other Constituents

As discussed in prior sections, various non-PCB constituents have been detected in the water, sediments, floodplain and riverbank soils, and biota in the Rest of River. However, based on EPA's screening evaluations for its risk assessments, these constituents, other than potentially PCDDs/PCDFs, are not considered constituents of concern for the Rest of River. With respect to PCDDs/PCDFs, the spatial distribution of these compounds in the sediments suggests that such constituents have entered the Rest of River from sources within the East Branch, with potential additional contributions from sources within the Rest of River. PCDD/PCDF concentrations within Reaches 5 and 6 indicate that these compounds have, to a large extent, accumulated within the fine sediments associated within Woods Pond. High concentrations of PCDDs/PCDFs are also observed in Rising Pond; these concentrations, together with composition differences between these PCDDs/PCDFs and those detected upstream, suggest that additional PCDD sources exist within Reaches 7 and/or 8. The fate and transport of these constituents is similar to that of PCBs, due to their similarity in physical-chemical properties.

Section 9 Figures

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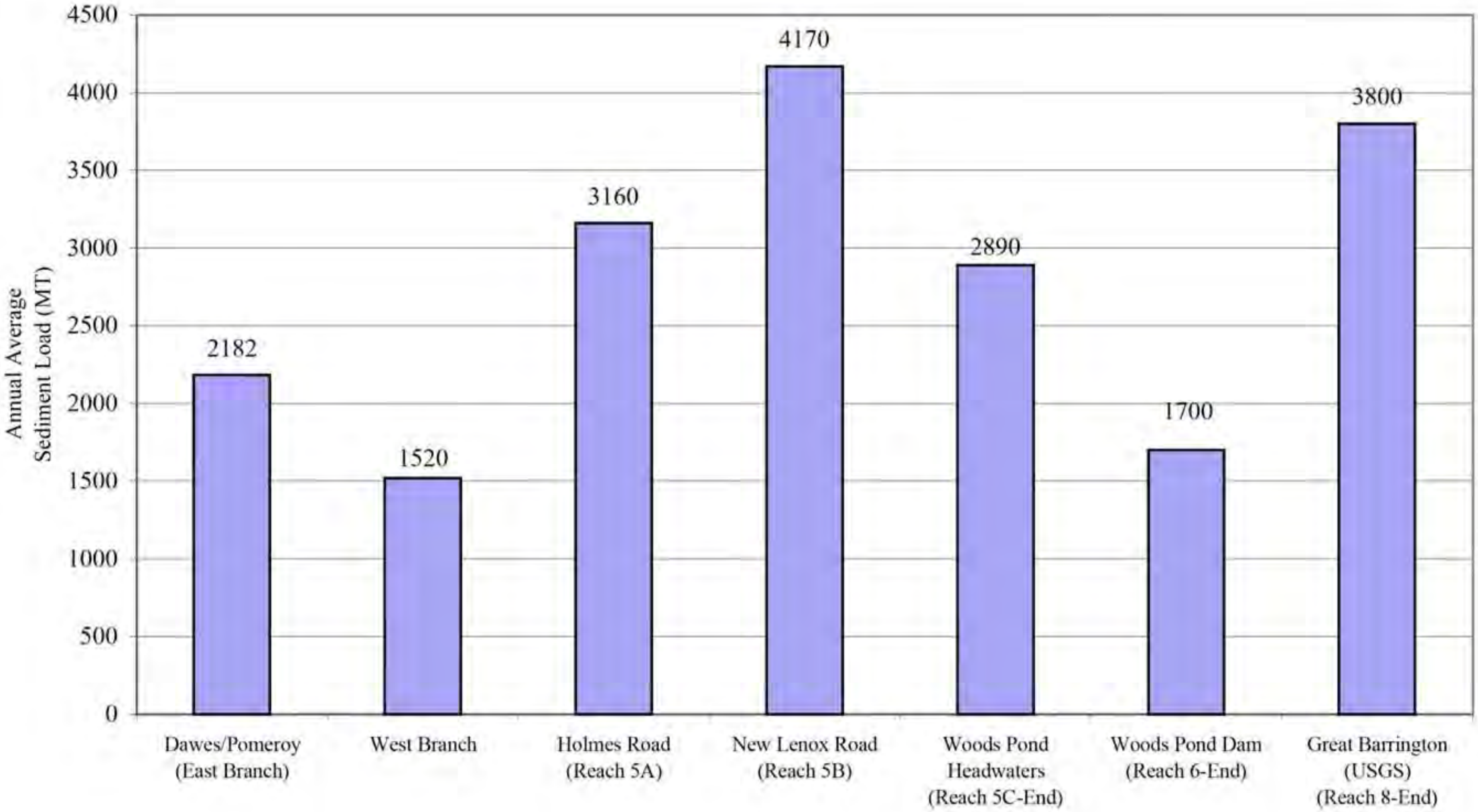

Figure 9-1. Summary of annual average sediment loadings at various locations along the Housatonic River.

Note: Great Barrington Estimate from USGS (2000).

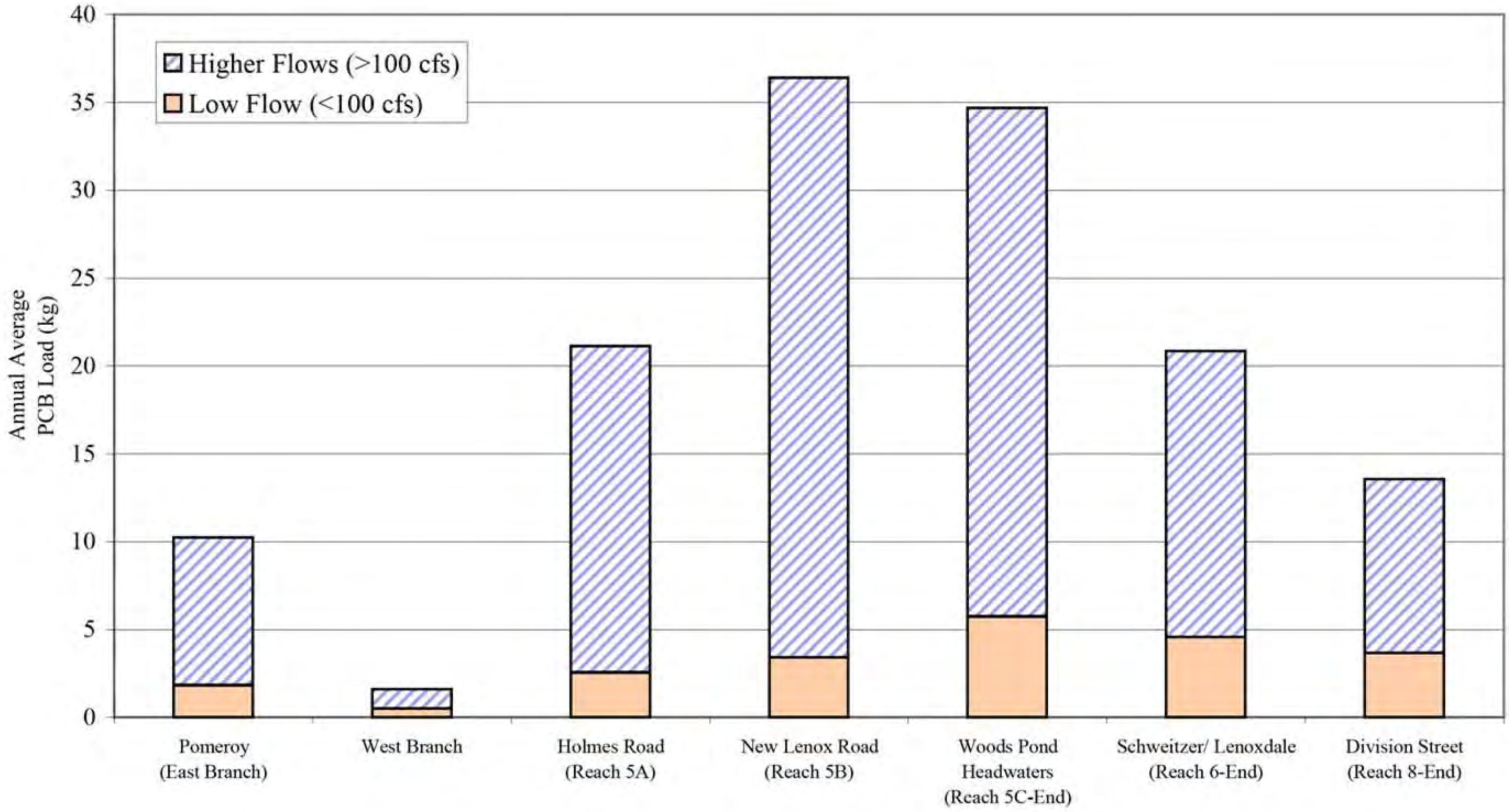

Figure 9-2. Summary of annual average PCB loadings at various locations along the Housatonic River.

Notes: Loads calculated using non-detects at 1/2 the MDL; high/low flow based on cutoff of 100 cfs at Coltsville.

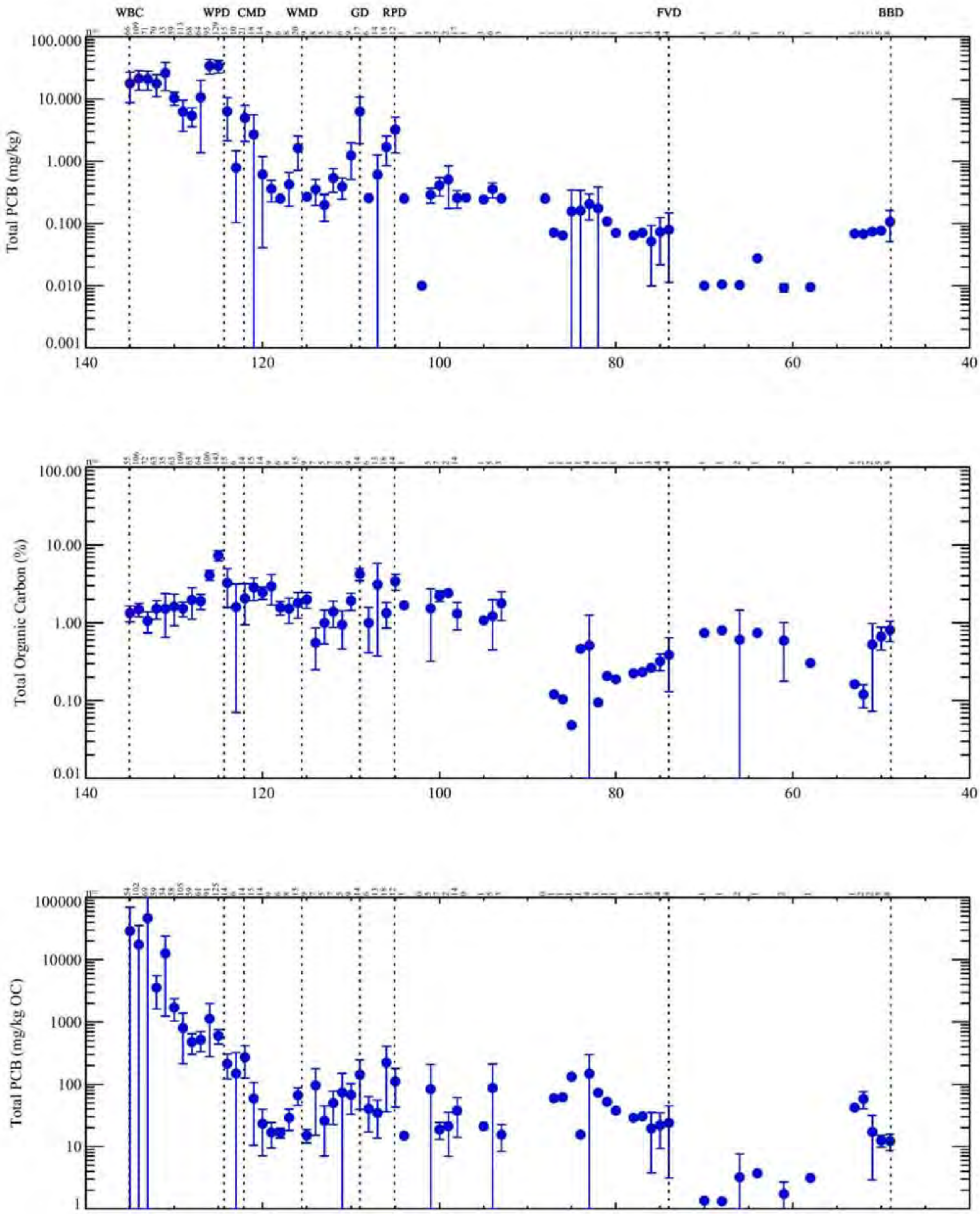

Figure 9-3. Spatial distribution of average PCB, TOC and organic carbon-normalized PCB in surface sediment.

Note: Data shown are 1998-2002 EPA and 1997-1998 GE data sets. Values shown are one-mile averages of the data. Error bars represent 2 standard errors of the mean.

Abbreviations: West Branch Confluence (WBC), Woods Pond Dam (WPD), Columbia Mill Dam (CMD), Willow Mill Dam (WMD), Glendale Dam (GD), Rising Pond Dam (RPD), Falls Village Dam (FVD), and Bulls Bridge Dam (BBD).

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REPORT

Housatonic River - Rest of River RCRA Facility Investigation Report

Volume 2. Appendix A Summary of Sampling and Analysis Activities

General Electric Company
Pittsfield, Massachusetts

September 2003

Quantitative Environmental Analysis, LLC

BLASLAND, BOUCK & LEE, INC.
engineers & scientists

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Appendix A - Summary of Sampling and Analysis Activities

This appendix describes the surface water, sediment, soil, and biota investigations designed to assess the nature and extent as well as the fate and transport of hazardous constituents in the Housatonic River Rest of River area. The investigations cover a time span of more than 20 years, and include sampling conducted as part of the United States Environmental Protection Agency's (EPA's) Supplemental Investigation (SI). The various efforts are discussed throughout this appendix and are organized by medium to present a comprehensive review of medium-specific data sources. Program descriptions and results of collection activities were compiled from available literature sources and supplemented, when necessary, by the databases developed by the General Electric Company (GE) and EPA (November release).

1.1 Surface Water Investigations

Numerous surface water investigations have been conducted since the late 1970s to study relevant surface water characteristics as well as the presence, extent, and transport of polychlorinated biphenyls (PCBs) and other hazardous constituents in the water column of the Housatonic River.

1.1.1 Ambient PCB Trend Monitoring

Ambient PCB trend monitoring (monthly water column sampling, low-flow, and high-flow sampling) of the Housatonic River water column has been performed as part of several investigations to determine the presence, extent, and/or transport of PCBs and other hazardous constituents in the water column and to characterize the general water quality.

Beginning in 1978, the Connecticut Agricultural Experiment Station (CAES), in conjunction with the Connecticut Department of Environmental Protection (CDEP) and United States Geological Survey (USGS), performed water column monitoring at USGS gaging stations at Great Barrington, Massachusetts and Falls Village and Gaylordsville, Connecticut. Depth-integrated suspended sediment samples were collected daily during an 18-month period between April 1979 and September 1980, resulting in the collection of 549 samples from each location. In addition, water column samples were collected as frequently as hourly during five high-flow events (October and November 1979 and March, April, and June 1980) and analyzed for total and dissolved PCBs. At Great Barrington and Falls Village, 14 high-flow water column samples were collected, while 13 samples were collected at Gaylordsville. In conjunction with sampling for PCB during high-flow events, suspended sediment measurements were made during the November 1979 and March, April, and June 1980 high-flow events at Great Barrington (seven samples); November 1979 and March and April 1980 high-flow events at Falls Village (six samples); and November 1979 and March 1980 high-flow events at Gaylordsville (seven samples) (Frink et al., 1982).

Following the CAES investigations, Stewart Laboratories, Inc. (Stewart) conducted an analysis of surface water PCB concentrations at three locations on the Housatonic River (Schweitzer/Lenoxdale, Division Street, and Andrus Road Bridges) during three short-term transport investigations conducted in February, March, and April 1980. The February 1980 sampling event was conducted during "typical winter background conditions" (Stewart, 1982). The March 1980 sampling event occurred at higher stream flow rates during a snowmelt period, and the April 1980 investigation was conducted during a precipitation storm-flow event. Sampling activities conducted during the three flow events resulted in the collection of 40 depth-integrated water column samples for total suspended solids (TSS) and total and dissolved PCB analyses (Stewart, 1982).

Subsequently, in cooperation with the USGS, CDEP performed water column monitoring during high-flow events between June 1984 and September 1988 at five USGS gaging stations (Great Barrington and Ashley Falls, Massachusetts, and Canaan, Kent, and Falls Village, Connecticut). A total of 32 water column composite samples were analyzed for TSS and total and dissolved PCBs (Lawler, Matusky and Skelly Engineers [LMS], 1991).

Between 1989 and 1991, Blasland & Bouck collected water column samples on approximately a monthly basis at six locations (Dawes Avenue Bridge, New Lenox Road Bridge, Woods Pond Headwaters, Former Housatonic Street Abutments, Schweitzer/Lenoxdale Bridge, and Division Street Bridge) on the Housatonic River. A total of 123 water column samples (including duplicate samples) were collected during the investigation and submitted for laboratory analysis. All 123 samples were analyzed for total and dissolved PCBs (one sample collected on February 6, 1992 at the Former Housatonic Street Abutments was only analyzed for total PCBs), while 77 samples were measured for total organic carbon (TOC). In addition, of the 123 samples analyzed for PCBs, 63 samples were also analyzed for chlorophyll *a* and TSS was measured in 118 samples. In addition, conventional water quality parameters (i.e., conductance, pH, and temperature) were measured upon collection in the field.

As part of the Housatonic River Massachusetts Contingency Plan (MCP) Supplemental Phase II Investigations, additional monthly water column samples were collected between 1996 and 1998 to fill apparent data gaps. Between March 1998 and February 1999, under the direction of the General Electric Company (GE), Blasland, Bouck & Lee, Inc. (BBL) instituted a bi-weekly sampling schedule. Monthly water column monitoring resumed in October 1999 and continued through October 2001. During the monthly monitoring, BBL collected surface water samples to provide PCB data upstream and downstream of the GE facility and more up-to-date surface water PCB data below Rising Pond. The remainder of this section provides a brief summary of the sampling activities carried out between 1996 and 2002.

1.1.1.1 1996 Sampling

BBL conducted monthly water column monitoring at the following 16 locations in 1996 (number in parentheses represents total number of samples collected):

- Hubbard Avenue Bridge (9)
- Newell Street Bridge (9)
- Newell Street Parking Lot Footbridge (9)
- Lyman Street Bridge (9)
- Elm Street Bridge (9)
- Dawes Avenue Bridge (9)
- Upstream of the Confluence with the Housatonic River (4)
- Holmes Road Bridge (9)
- Adjacent to Joseph Drive (14)
- Holmes Road Waste Water Treatment Plant (WWTP) (4)
- EPRI Facility (4)
- New Lenox Road Bridge (13)
- Headwaters to Woods Pond (10)
- Former Housatonic Street Abutments (10)
- Schweitzer/Lenoxdale Bridge (9)
- Division Street Bridge (10)

Surface water samples were collected as grab or depth-integrated (i.e., DH-76 sampler) samples on approximately a monthly basis. A total of 143 samples (including duplicates) were collected for laboratory analysis and analyzed for total PCBs. Of these 143 samples, 77 samples were also analyzed for dissolved PCBs, and TSS was measured in 106 samples.

In addition, sampling was conducted upstream and downstream of the Unkamet Brook Confluence to supplement the results of pre-1996 sampling events. Two surface water samples were collected (one upstream and one downstream) in December 1996. Samples were analyzed for total and dissolved PCBs.

1.1.1.2 1997 Sampling

BBL conducted monthly water column monitoring at the following 15 locations in 1997 (number in parentheses represents total number of samples collected):

- Hubbard Avenue Bridge (13)
- Newell Street Bridge (7)
- Newell Street Parking Lot Footbr idge (8)
- Lyman Street Bridge (17)
- Elm Street Bridge (14)
- Dawes Avenue Bridge (12)
- Holmes Road Bridge (13)
- Adjacent to Joseph Drive (12)
- New Lenox Road Bridge (15)
- Headwaters to Woods Pond (12)
- Former Housatonic Street Abutments (15)
- Schweitzer/Lenoxdale Bridge (25)
- Division Street Bridge (14)
- Andrus Road Bridge (4)
- Bulls Bridge Dam (4)

Surface water samples were collected as grab or depth-integrated (i.e., DH-76 sampler) samples on approximately a monthly basis. A total of 185 samples (including duplicates) were collected for laboratory analysis and analyzed for total PCBs. Of these 185 samples, 138 samples were also analyzed for particulate organic carbon (POC), and chlorophyll *a* and TSS were measured in 165 samples.

1.1.1.3 1998 Sampling

BBL conducted monthly water column monitoring in January and February 1998 at the following 13 locations (number in parentheses represents total number of samples collected):

- Hubbard Avenue Bridge (2)
- Newell Street Bridge (2)
- Newell Street Parking Lot Footbridge (2)
- Lyman Street Bridge (4)
- Elm Street Bridge (2)
- Dawes Avenue Bridge (2)

- Holmes Road Bridge (2)
- Adjacent to Joseph Drive (2)
- New Lenox Road Bridge (2)
- Headwaters to Woods Pond (2)
- Former Housatonic Street Abutments (2)
- Schweitzer/Lenoxdale Bridge (2)
- Division Street Bridge (2)

A total of 28 grab samples (including duplicates) were collected for laboratory analysis and analyzed for total PCBs, POC, chlorophyll *a*, and TSS.

In March 1998, bi-weekly sampling was instituted; BBL collected water samples at the following seven locations (number in parentheses represents total number of samples):

- Hubbard Avenue Bridge (33)
- Dawes Avenue Bridge (20)
- Holmes Road Bridge (19)
- New Lenox Road Bridge (18)
- Headwaters to Woods Pond (18)
- Schweitzer/Lenoxdale Bridge (18)
- Division Street Bridge (18)

Surface water samples were collected as grab samples between March and June 1998 and as composite samples between July and December 1998. A total of 144 samples (including duplicates) were collected and analyzed for total PCBs, POC, chlorophyll *a*, and TSS. In addition, between November and December 1998 water conductance, temperature, and pH were measured in the field.

In addition, sampling was conducted upstream and downstream of the Unkamet Brook Confluence to supplement the results of previous sampling events. Five surface water samples were collected (three upstream and two downstream) during the May and December 1998 sampling events. Samples were analyzed for total and dissolved PCBs.

EPA conducted surface water sampling in August and October 1998, during which BBL obtained split samples. EPA collected samples at the following 16 locations (number in parentheses represents total number of samples):

- Housatonic Street Bridge Behind Crane & Co. (2)
- Hubbard Avenue Bridge (3)
- Upstream of the Unkamet Brook Confluence (2)
- Newell Street Bridge (2)
- Newell Street Parking Lot Footbridge (2)
- Lyman Street Bridge (3)
- Elm Street Bridge (2)
- West Branch Confluence (2)
- Holmes Road Bridge (2)
- Adjacent to Joseph Drive (2)
- Holmes Road WWTP (1)
- New Lenox Road Bridge (2)

- Headwaters to Woods Pond (2)
- Former Housatonic Street Abutments (2)
- Schweitzer/Lenoxdale Bridge (2)
- Division Street Bridge (2)

BBL obtained a total of 33 split samples for laboratory analysis. All 33 samples were analyzed for total PCBs, TSS, and chlorophyll *a*; 16 were analyzed for dissolved PCBs; and 17 were analyzed for POC. In addition, water temperature, conductance, and pH were measured during the October 1998 sampling.

1.1.1.4 1999 Sampling

BBL conducted bi-weekly water column monitoring between January and March 1999 and resumed monthly sampling in October 1999. Surface water samples were collected from the following seven locations (number in parentheses represents total number of samples):

- Hubbard Avenue Bridge (16)
- Dawes Avenue Bridge (8)
- Holmes Road Bridge (8)
- New Lenox Road Bridge (8)
- Headwaters to Woods Pond (7)
- Schweitzer/Lenoxdale Bridge (8)
- Division Street Bridge (7)

A total of 62 surface water samples (including duplicates) were collected and analyzed for total PCBs, POC, chlorophyll *a*, TSS, and water quality parameters (i.e., temperature, conductance and pH).

In addition, sampling was conducted upstream and downstream of the Unkamet Brook Confluence to supplement the results of previous sampling events. A total of four surface water samples were collected (two upstream and two downstream) during sampling events in April and October 1999. These samples were analyzed for total and dissolved PCBs.

Between March and September 1999, BBL obtained split samples from EPA sampling efforts conducted at the following 17 locations (number in parentheses represents total number of samples collected):

- Housatonic Street Bridge Behind Crane & Co. (7)
- Hubbard Avenue Bridge (7)
- Upstream of the Unkamet Brook Confluence (7)
- Goodrich Pond Tributary (1)
- Newell Street Bridge (7)
- Newell Street Parking Lot Footbridge (8)
- Lyman Street Bridge (7)
- Elm Street Bridge (7)
- First Pomeroy Avenue Bridge (7)
- West Branch Confluence (7)
- Holmes Road Bridge (13)
- Adjacent to Joseph Drive (7)
- Holmes Road WWTP (7)

- New Lenox Road Bridge (7)
- Headwaters to Woods Pond (7)
- Upstream of Woods Pond Dam (7)
- Schweitzer/Lenoxdale Bridge (7)

BBL obtained a total of 120 split samples for laboratory analysis. All 120 samples were analyzed for total PCBs, POC, TSS, and chlorophyll *a*, while 17 of these samples were also analyzed for dissolved PCBs and TOC. Water temperature, conductance, and pH were measured and recorded during these collection activities.

1.1.1.5 2000 Sampling

BBL conducted monthly water column sampling at the following seven locations (number in parentheses represents total number of samples collected):

- Hubbard Avenue Bridge (24)
- Dawes Avenue Bridge (12)
- Holmes Road Bridge (12)
- New Lenox Road Bridge (12)
- Headwaters to Woods Pond (12)
- Schweitzer/Lenoxdale Bridge (12)
- Division Street Bridge (12)

A total of 96 surface water samples (including duplicates) were collected and analyzed for total PCBs, POC, chlorophyll *a*, and TSS.

In addition, sampling was conducted upstream and downstream of the Unkamet Brook Confluence to supplement the results of previous sampling events. Two surface water samples were collected (one upstream and one downstream) in May 2000. Samples were analyzed for total and dissolved PCBs.

1.1.1.6 2001 Sampling

Between January and December 2001, BBL conducted monthly water column sampling at the following eight locations (number in parentheses represents total number of samples collected):

- Hubbard Avenue Bridge (24)
- Dawes Avenue Bridge (9)
- First Pomeroy Avenue Bridge (3)
- Holmes Road Bridge (12)
- New Lenox Road Bridge (12)
- Headwaters to Woods Pond (10)
- Schweitzer/Lenoxdale Bridge (12)
- Division Street Bridge (12)

A total of 94 surface water samples (including duplicates) were collected and analyzed for total PCBs, POC, chlorophyll *a*, and TSS. In addition, conventional water quality parameters were measured.

1.1.1.7 2002 Sampling

Between January and November 2002, BBL conducted monthly water column sampling at the following 12 locations (number in parentheses represents total number of samples collected):

- Hubbard Avenue Bridge (22)
- Upstream of Unkamet Brook (4)
- Unkamet Brook (4)
- Downstream of Unkamet Brook (4)
- Newell Street Bridge (4)
- Lyman Street Bridge (4)
- First Pomeroy Avenue Bridge (11)
- Holmes Road Bridge (11)
- New Lenox Road Bridge (11)
- Headwaters to Woods Pond (11)
- Schweitzer/Lenoxdale Bridge (11)
- Division Street Bridge (11)

A total of 108 surface water samples (including duplicate samples) were collected and analyzed for total PCBs, POC, chlorophyll *a*, and TSS. In addition, conventional water quality parameters were measured in the field.

1.1.2 Suspended Solids Harvesting

On behalf of GE, suspended solids harvesting was conducted to aid in understanding the movement of suspended particulates and associated PCBs within the water column of the Housatonic River. PCB transport can occur as a result of partitioning from the sediment bed to the water column (dissolved flux) or as a result of resuspension and transport (particulate flux). As explained in the *MCP Supplemental Phase II Scope of Work and Proposal for RCRA Facility Investigation of Housatonic River and Silver Lake* (Phase II SOW/RFI Proposal) (BBL, 1994a), resuspension of sediment (particularly during high-flow events) is a critical mechanism governing PCB transport in the Housatonic River.

Therefore, sampling of suspended sediments commenced at four key locations (Newell Street Bridge, the first Pomeroy Avenue Bridge, New Lenox Road Bridge, and Woods Pond Headwaters) in October 1995. In November 1995 and November 1996, suspended sediment sampling was conducted at the same four locations with the addition of a Schweitzer/Lenoxdale Bridge location. A total of 31 suspended sediment samples were collected and analyzed for PCBs, TOC, and grain size. Surface water samples were collected at the same times and analyzed for PCBs and TSS.

1.1.3 Woods Pond Sediment Traps

As part of the suspended sediment and PCB transport investigations, BBL placed three sediment traps in Woods Pond in October 1994. In August 1995, sampling of the sediment traps was attempted with varied success. Only one of the three sediment traps was successfully sampled, since one had been lost and the other was displaced from its original position and was thus compromised. A sample of the captured sediment and a duplicate sample were analyzed for PCBs, TOC, and grain size.

1.1.4 High-Flow Sampling

On behalf of GE, LMS collected water column samples during two high-flow sampling events in 1991 (41 samples), four high-flow events in 1992 (118 samples), and two high-flow events in 1993 (58 samples) at Great Barrington, Massachusetts and downstream locations in Connecticut. Depth-integrated water column samples were collected as part of the Connecticut Cooperative Agreement between GE and CDEP to help verify/validate information related to fate and transport modeling. High-flow events were defined as flows greater than or equal to 1,000 cubic feet per second (cfs) at the Great Barrington USGS gage. All samples were analyzed for PCBs, TOC, dissolved organic carbon (DOC), and TSS (LMS, 1994).

In November 1995, January 1996, and May 1996, BBL collected samples during three high-flow events as part of the Housatonic River MCP Supplemental Phase II Investigation. Consistent with the 1991-1993 LMS investigations, high-flow conditions were defined as flows greater than or equal to 1,000 cfs at Division Street in Great Barrington, Massachusetts (location of the USGS gage). Water column monitoring was conducted at 12 locations during the November 1995 sampling event and at 13 locations during the 1996 sampling events between the Hubbard Avenue Bridge (Pittsfield, Massachusetts) and the Division Street Bridge (Great Barrington, Massachusetts). A total of 40 water column grab samples were collected at one-half the water depth and analyzed for PCBs (total and filtered) and TSS.

1.1.5 Housatonic River High-Flow Sediment Loading Study

BBL collected daily water column composite samples between March and May 1997 and in May 1998 to provide suspended solids data in support of the Housatonic River high-flow sediment loading study. The daily composite samples were collected by an automated TSS sampler at several locations along the Housatonic River and at select tributaries downstream of the USGS gaging station at Coltsville, Massachusetts.

During the 1997 sampling events, automated TSS samplers were placed and composite samples were collected from the following seven sampling locations (number in parentheses represents total number of samples collected):

- Hubbard Avenue Bridge (75)
- West Branch Confluence (68)
- Sackett Brook (76)
- Headwaters to Woods Pond (87)
- Woods Pond Dam (81)
- Rising Pond Dam (72)
- Konkapot River (82)

During the 1998 sampling event, automated TSS samplers were placed and composite samples were collected from the seven locations sampled in 1997, with the addition of a sampling location at the Bulls Bridge Dam. The sampling locations and total number of samples collected are summarized below (number in parentheses represents total number of samples):

- Hubbard Avenue Bridge (13)
- West Branch Confluence (13)
- Sackett Brook (13)
- Headwaters to Woods Pond (13)

- Woods Pond Dam (13)
- Rising Pond Dam (12)
- Konkapot River (13)
- Bulls Bridge Dam (12)

Each sample collected represents a daily composite sample of 24 discrete samples collected at a rate of approximately one sample per hour. All composite samples were analyzed for TSS.

1.1.6 EPA Monthly Water Column Monitoring and Storm Flow Sampling

To support the data collection needs for hydrodynamic modeling, water quality modeling, and risk assessments, Weston (on behalf of EPA) conducted surface water sampling on a monthly basis between August 1998 and September 1999 and sampled specific storm flow events between May and December 1999 to provide data on general water quality and suspended sediments.

1.1.6.1 Monthly Water Column Monitoring

Weston collected monthly surface water samples at 17 locations along the Housatonic River between the Crane Paper Company (Dalton, Massachusetts) and the Schweitzer/Lenoxdale Bridge. Sampling, filtration, and analysis methods were based on those developed for the Hudson River (TAMS Consultants, Inc. and Gradient Corporation, 1993). Surface water samples were analyzed for PCBs (filtered and unfiltered), solids (total suspended and total dissolved), organic carbon (TOC and DOC), Appendix IX constituents, and various other field parameters (see Weston, 2002 Section 2.3.1.1 for a complete list). In addition, beginning in 1999, analyses were conducted for PCB congeners. Of the 270 proposed surface water samples, 253 samples were collected for chemical analysis (Weston 2002).

1.1.6.2 Storm Flow Sampling

Storm flow sampling was conducted between May and December 1999 to provide suspended solids information, PCB, and water quality data for modeling efforts. Water and suspended sediment data were used to assist in the determination of resuspension and redistribution of PCB-containing sediment and the effects of storms on water quality and hydrodynamics. Weston conducted storm flow sampling at three primary locations: Pomeroy Avenue Bridge (River Mile [RM] 135.7), New Lenox Road Bridge (RM 129.2), and Woods Pond Dam (RM 124.4) with the objective of harvesting suspended sediments from the water column for chemical analysis. In addition, water samples were collected from five secondary locations (Hubbard Avenue Bridge, Unkamet Brook, West Branch Housatonic River, Sackett Brook, and Roaring Brook) to measure suspended solids between the Hubbard Avenue Bridge (RM 140.6) and Woods Pond Dam (see Weston, 2000 Section 5.3.2 for locations). Water samples were analyzed for PCBs (total, Aroclors, and congeners for both filtered and unfiltered), TSS, organic carbon (TOC, POC, and DOC), and various other field parameters. Harvested suspended sediment samples were analyzed for grain size, total PCBs (< 250 millimeters [mm]), and TOC.

Between May and September 1999, storm flow sampling was conducted at the following eight locations (number in parentheses represents total number of samples):

- Hubbard Street Bridge (196)

- Unkamet Brook (184)
- Pomeroy Avenue Bridge (430)
- West Branch Confluence (205)
- New Lenox Street (540)
- Roaring Brook (178)
- Sackett Brook (163)
- Woods Pond Footbridge (577)

A total of 2,473 water samples were collected for laboratory analyses during the 1999 storm flow sampling (see Weston, 2002 Section 2.3.4.1 for a list of specific analyses).

Between May and September 1999, storm flow sampling was also conducted at the following three locations for suspended solid samples (number in parentheses represents total number of samples):

- Pomeroy Avenue Bridge (35)
- New Lenox Street (35)
- Woods Pond Footbridge (29)

A total of 99 samples were collected for laboratory analyses during the 1999 storm flow sampling (see Weston, 2002 Section 2.3.4.1 for a list of specific analyses).

1.1.7 EPA Discrete River Sampling

In addition to monthly (or biweekly) water column monitoring, EPA also conducted a discrete sampling program between 1998 and 2001. Discrete sampling was conducted to support individual programs that required particular types of data from specific locations (Weston, 2002). Typically, data were collected to address identified data gaps and to improve the overall utility of the data set for use in achieving data quality objectives (Weston, 2002). Specifically, discrete surface water samples were collected for the purposes of ecological-risk endpoints (i.e., sediment toxicity, mussel exposure), long-term remediation monitoring, or other non-routine surface water sampling. Data collection activities, tasks, and programs completed by EPA were documented in EPA's *Supplemental Investigation Data Report* (SI Data Report) (Weston, 2002).

1.1.8 Modeling/Fate and Transport-Related Investigations

EPA/GE conducted a PCB partitioning study and EPA conducted a bed load sampling study to support its modeling efforts. These studies are described in the subsections below.

1.1.8.1 2001-2002 EPA/GE PCB Partitioning Study

PCB sorption in the Housatonic River was investigated through a joint EPA/GE field sampling and analysis program conducted during the fall of 2001 and spring of 2002. This program consisted of sampling and analysis to evaluate the PCB and TOC phase distribution in surface sediments (and associated pore water) and surface water (including suspended matter). The sediment/pore water sampling consisted of:

- Collection of approximately 50 sediment cores from within Reaches 5 and 6 and sectioning the 0- to 6-inch segments of these cores;
- Extraction of the pore water by centrifugation followed by high pressure filtration; and
- Analysis of congener-specific PCBs and TOC for the sediment and pore water samples.

The surface water sampling was conducted in three events, covering low, moderate, and high-flow conditions. Samples were collected at the Pomeroy Avenue Bridge, New Lenox Road Bridge, and Woods Pond Footbridge, and were prepared as follows:

- Large volume (27 liter [L]) samples were collected from the River with a peristaltic pump;
- Samples were pressure filtered to separate the dissolved and particulate phases; and
- Both the filtrate and filter residues were analyzed for congener-specific PCBs and TOC.

Surface water sampling was conducted for three different events covering low-flow (October 2001), moderate-flow (April 2002), and high-flow (June 2002) conditions. The daily average flow measured at the Coltsville gage for these events was 25, 230, and 330 cfs, respectively, with respective peak flows of approximately 300 and 440 cfs during the moderate- and high-flow events.

1.1.8.2 Bedload Sampling Study

EPA sampled bed load (i.e., coarse grained sediment being transported by the River current near the sediment-water interface) during a storm event in May 2002. Ten cross-channel composite samples were collected at the Pomeroy Avenue Bridge and submitted for PCB, TOC, and grain size analyses. Water column samples were also collected at the same times, and were analyzed for TSS, PCBs, and TOC.

1.1.9 Investigation of Other Hazardous Constituents

In addition to the assessment of PCBs in the water column of the Housatonic River, several investigations were conducted to evaluate the presence and extent of non-PCB hazardous constituents in the Housatonic River water column. In 1991, surface water sampling for non-PCB hazardous constituents was conducted by Blasland & Bouck as part of the MCP Phase II water column investigation, and in 1995 by BBL as part of the MCP Supplemental Phase II/RFI activities.

During the 1991 investigation, surface water sampling was conducted upstream of, adjacent to, and downstream of the GE facility in Pittsfield, Massachusetts. Water column samples were collected during both low-flow and high-flow conditions and analyzed for Appendix IX+3 constituents. A total of 14 surface water samples were collected during the 1991 activities and analyzed for PCBs, Appendix IX+3 volatile organic compounds (VOCs), semi-volatile organic compounds (SVOCs), and inorganics.

These results were originally reported in the *Interim Phase II Report/Current Assessment Summary* (Interim Phase II Report/CAS; Blasland & Bouck, 1991), along with an assessment of the hazardous constituents detected that may be related to releases from the GE facility. In addition, an evaluation was performed to determine which constituents posed potential health or environmental concern and therefore warranted further downstream water column sampling. The evaluation in the Interim Phase II Report/CAS concluded that none of the constituents detected in the water column (aside from PCBs) are of potential health or environmental concern (Blasland & Bouck, 1991); therefore, no other "target constituents" were identified.

In response to comments from the Massachusetts Department of Environmental Protection (MDEP) (which disagreed in part with the evaluation provided in the Interim Phase II Report/CAS and a re-analysis presented in the addendum to that report), further water column sampling and Appendix IX+3 analysis were performed in 1995 as part of the MCP Supplemental Phase II/RFI activities.

As part of the 1995 activities, surface water samples were collected by BBL from eight River locations, upstream of, adjacent to, and downstream of the GE facility in Pittsfield during low-flow (March 1995) and high-flow (June 1995) conditions. A total of 16 samples were collected during the 1995 sampling activities and analyzed for PCBs, TSS, Appendix IX+3 VOCs, SVOCs, and inorganics.

Detailed information on the water sampling discussed above is provided in the *Supplemental Phase II/RCRA Facility Investigation Report* (1996 RFI Report; BBL, 1996).

1.1.10 Physical Parameter Data Collection during 2000-2001 Largemouth Bass Study

On behalf of GE, R2 Resource Consultants, Inc. (R2) collected water temperature, DO, and pH data from locations along the Housatonic River as part of a largemouth bass reproduction and population structure study conducted during 2000 and 2001 (R2, 2002). In 2000, measurements of DO concentrations, pH, conductivity, and water temperature were collected using hand-held digital meters at 13 locations along the River. In addition, continuous water temperature recorders were installed at each of the 13 locations and used from May through September 2000. In 2001, temperature recorders were installed at 12 locations from late March or mid-April to mid-October. Nine continuous DO recorders were deployed in three backwater areas (one unit in the main channel and two within the backwater in each area) in June 2001 and maintained through mid-October 2001. These recorders measured DO, as well as water temperature and pH.

1.2 Sediment Investigations

This section summarizes the recent and historical sediment investigation programs conducted in the Housatonic River.

1.2.1 CAES Sediment Study

CAES, in cooperation with CDEP and USGS, performed a detailed study of the sediments in portions of the Housatonic River in Connecticut and, to a lesser extent, Massachusetts after the initial identification of PCBs in the River sediments. Conducted between 1979 and 1982, the study was designed to assess the extent of PCBs in the River system and "to determine the mass of PCBs in the bottom sediments of the Housatonic River and determine the rate of transport of suspended sediment and PCBs down the river" (Frink et al., 1982). During this joint effort by CAES, USGS, and CDEP, 104 surficial sediment samples and 49 sediment cores were collected from 148 locations in the Housatonic River between the GE facility in Pittsfield, Massachusetts and the mouth at Long Island Sound. In areas where bottom sediments were coarse or thin, surficial sediment samples were collected using a Ponar grab sampler or Eckman dredge, resulting in the collection of the upper 3 to 6 inches of sediment. In areas where sediments were characterized as fine and thick, sediment cores were collected via piston or gravity core sampler. Sediment cores were generally sectioned into 6-inch increments to the bottom of the core (core depths ranged from 6 to 66 inches), and samples were analyzed for PCBs and TOC. A total of 152 surficial sediment samples (i.e., upper 6 inches) were analyzed for PCBs; CAES analyzed 99 surficial sediment samples and USGS analyzed 81 surficial samples for total PCBs (28 samples were independently analyzed by both groups). A total of 174 sediment core samples (of various depth increments) were analyzed for PCBs; USGS analyzed 147 sediment core samples and CAES analyzed 32 core samples (five core sections were analyzed by both). In addition, CAES analyzed 29 core samples and 92 surficial samples for TOC; USGS analyzed 87 core samples and 60 surficial samples for TOC.

A more detailed description of the sampling events and results can be found in *Polychlorinated Biphenyls in Housatonic River Sediments in Massachusetts and Connecticut: Determination, Distribution, and Transport* (Frink et al., 1982).

1.2.2 Stewart Study

In accordance with a 1981 Consent Order issued by MDEP and EPA, GE commissioned Stewart to conduct an extensive study of the presence and distribution of PCBs within the sediments of the Housatonic River system. As part of the 1982 Stewart study, initial review of aerial photographs and topographic maps resulted in the selection of 36 major sediment sampling stations between Center Pond in Dalton, Massachusetts and the Connecticut state border. The stations were chosen to be representative of the various physical characteristics found in the Housatonic River.

After establishing the 36 sampling stations, the entire River area was methodically examined, probed, and/or sonar-scanned for the purpose of further characterizing the River sediment. As a result of this study, 226 substations were established to represent distinct sediment accumulation areas within the 36 sampling stations. One or more sediment cores were collected in 16-centimeter (cm) increments from the 226 sediment sampling substations, resulting in the collection of 892 sediment samples for PCB and grain size analyses.

The Stewart studies are described in more detail in Sections 4.2 and 4.3.2 of the Interim Phase II Report/CAS (Blasland & Bouck, 1991).

1.2.3 LMS Impoundment Study

In October 1986, on behalf of GE, LMS collected one sediment core from each of six locations including Falls Village Impoundment, Bulls Bridge Impoundment, Route 133 Bridge, Shepaug Dam, Route 84 Bridge, and immediately upstream of the dam at Stevenson, Massachusetts. Sediment cores, ranging in depth from 7 to 31 inches, were sectioned into 1-inch increments, resulting in 100 samples for PCB and TOC analyses. The results of these samples were used to assess transport and distribution of PCBs within these impounded areas.

The LMS impoundment investigation is described in more detail in Section 4.3.3 of the Interim Phase II Report/CAS (Blasland & Bouck, 1991).

1.2.4 MCP Phase II Investigation

In 1990, GE entered into a Consent Order with MDEP to further investigate the nature and extent of PCB contamination within the Housatonic River. This agreement led to the development of a MCP Phase II Investigation, which was conducted by Blasland & Bouck on behalf of GE.

Prior to performing MCP Phase II field sampling activities, a thorough site reconnaissance was conducted in 1990 to assess the then-current state of sediment depositional areas for comparison to assessments developed during prior investigations. At 32 sampling transects established from just upstream of the GE facility to Woods Pond, sediment was probed and cores were collected at one to nine equidistant locations across the River width. At each of the core collection locations, water depth, sediment depth penetrated, sediment depth recovered, and field core description were recorded.

The objective of the 1990 sediment survey was to supplement the extensive existing database generated during the Stewart studies and to attempt to confirm the distribution of PCBs in the portion of the Housatonic River between Pittsfield and Rising Pond. After reviewing the Stewart sediment data, 39 core locations previously sampled by Stewart (in addition to the 32 transect core locations mentioned above) were selected for re-sampling as part of the MCP Phase II investigation. The core locations were selected from those found in the Stewart study to have yielded core samples with PCB concentrations in excess of 50 milligrams per kilogram (mg/kg). Between October and November 1990 and January and February 1991, 39 sediment cores were collected. At each core location, water depth, sediment depth, length of recovered sediment, and a visual description of the sediment core were recorded. Sediment cores were sectioned into 6-inch increments to a depth below the level of the previously identified PCB "hot spot" concentrations (identified in the Stewart study) and then into 1-foot increments to the end of the core, resulting in 213 samples for chemical analysis. Sediment samples were analyzed for PCBs and TOC (analysis was held on 29 samples).

In addition to PCB analysis, another objective of the MCP Phase II Investigation was to determine the presence, if any, of other hazardous constituents in River sediments and to identify which of these constituents could be considered "target" constituents (i.e., constituents that are of potential health or environmental concern) potentially related to releases from the GE facility. Nine core samples were collected in 1990 and 1991 by Blasland & Bouck from two locations in Rising Pond and nine locations in the River between the Hubbard Avenue Bridge and Elm Street Bridge. Recovered cores ranged in length from 0.95 feet to 1.7 feet. The entire core was composited, thoroughly mixed, and analyzed for Appendix IX+3 constituents. The evaluation of these data is presented in Section 4.4.3 of the Interim Phase II Report/CAS (Blasland & Bouck, 1991).

As a result of the Appendix IX+3 constituent evaluation, it was determined that additional sampling downstream of the GE facility was necessary, since the samples contained relatively low PCB levels and may not have reflected good sediment depositional areas. Therefore, in 1992, two additional locations were sampled between the Silver Lake Outlet and Elm Street Bridge, resulting in three sediment samples (including one duplicate) for the analysis of Appendix IX+3 constituents. Sediment samples were analyzed from the 11- to 16-inch (one sample) and 2- to 8-inch (one sample and duplicate) depth intervals.

In 1992, additional upstream sampling was conducted to further define upstream and/or background levels of inorganic compounds to compare with downstream sediment concentrations and to aid in identifying "target" inorganic constituents. Four locations were sampled between the Center Pond and Hubbard Avenue Bridge, one sample per location, for analysis of Appendix IX+3 metals. Samples were generally collected from the upper 6 inches of sediment, the exception being a single sample collected from the 0- to 16-inch depth interval.

Additional information from the MCP Phase II Investigation can be found in the Interim Phase II Report/CAS (Blasland & Bouck, 1991) and the addendum to that report (Blasland & Bouck, 1992a).

1.2.5 GZA Rising Pond Sediment Characterization Study

In 1991, a sediment sampling program was conducted by GZA GeoEnvironmental, Inc. (GZA) and GE (with Blasland & Bouck oversight) to identify the potential presence of chemicals in Rising Pond as a result of releases from the GE facility. The purpose of the investigation was to identify any impacts that sediment quality might have on management options for the Rising Pond Dam. Sediment core samples were collected from 33 locations in Rising Pond to depths of 3 feet to 4.5 feet below the sediment/water interface. A total of 78 sediment core section samples were collected from the 33 locations in Rising Pond and screened for VOCs using a photoionization detector. Based on the screening results, certain samples were selected for further analyses. Analyses conducted on the sediment samples based on the screening results included: VOC analysis (seven samples), total petroleum hydrocarbon (TPH) analysis (18 samples), and eight Resource Conservation and Recovery Act- (RCRA-) regulated metals (17 samples). In addition, PCB analysis was conducted on 63 sediment samples from 10 core locations.

Additional information regarding the results of the MCP Phase II Investigation can be found in Sections 4.3.5 and 4.4.2 of the Interim Phase II Report/CAS (Blasland & Bouck, 1991).

1.2.6 MCP Supplemental Phase II Investigation

The data obtained as part of the MCP Phase II Investigation and prior Housatonic River investigative efforts addressed many of the MCP Phase II requirements and EPA Permit goals as they related to PCBs. However, additional investigative activities were necessary to address either specific MDEP/EPA concerns, or to satisfy data needs previously identified in the *Proposal for the Preliminary Investigation of Corrective Measures for Housatonic River and Silver Lake Sediment* (PICM Proposal; Canonie Environmental, 1995) related to the assessment of various potential remedial approaches to the sediments of the Housatonic River. In response, the following activities were proposed and conducted in 1994 and 1995 as part of the MCP Supplemental Phase II Investigation implemented by GE and BBL.

1.2.6.1 Field Reconnaissance/Sediment Probing/Visual Characterization

Pursuant to Section 2.2.3.1 of the Phase II SOW/RFI Proposal (BBL, 1994a), sediment reconnaissance/probing activities were conducted in October 1994 to provide additional information related to sediment accumulation/deposition areas between the GE facility and Woods Pond. As part of these activities, the River was divided into seven River reaches. Six of these designated River reaches (excluding Woods Pond) were further subdivided into 36 subreaches. Within these 36 subreaches, sediments were physically probed and visually characterized. This activity included visual identification of sediment depositional environments and sediment probing to measure the extent, thickness, and type of various sediment deposits. It also included visual identification of aquatic vegetation, water depths, and accessibility from shore. Sediment depositional environments were characterized as backwater, channel, terrace, or aggrading bar deposits. A total of 221 locations were probed and classified during this portion of the investigation.

Additional information on the field reconnaissance/sediment probing/visual characterization investigation is provided in Section 2.2.3.1 of the Phase II SOW/RFI Proposal (BBL, 1994a).

1.2.6.2 Sediment Sampling to Further Delineate Horizontal and Vertical Extent of PCBs

The sediment reconnaissance/probing data was used to select additional sediment sampling locations to further define the presence of PCBs in sediments where such data were considered limited. In 1994, cores were collected from 25 locations between the GE facility and New Lenox Road and sectioned into 6-inch increments, resulting in a total of 174 sediment samples that were analyzed for PCBs. In addition, 51 samples (core lengths ranging from the top 1.5 feet to 4.5 feet) were selected from 48 core locations and analyzed for oil and grease and TOC.

In addition, due to an unusually high PCB concentration measured during the 1994 sediment sampling activities near the Dawes Avenue Bridge, four additional core locations were sampled in close proximity to further evaluate the presence of PCBs at that location. A total of seven sediment samples were analyzed for PCBs from the four core locations.

As part of the MCP Supplemental Phase II Investigation, BBL conducted additional sediment sampling in Rising Pond. Sampling was conducted at three locations previously sampled by GZA in 1991. At these locations, GZA identified the presence of PCBs at a depth of 4 feet. Therefore, to further delineate the vertical extent of PCBs, sediment samples were analyzed from the 4- to 4.5-foot and 4.5- to 5.0-foot (one location) and 4- to 4.5-foot depth intervals (one location), resulting in three sediment samples for PCB analysis (sediment could not be recovered at depths greater than 4 feet at one location).

Lastly, sediment samples were collected from core locations co-located with biota collection sites. Additional fish samples (young-of-year [YOY] bluegill, largemouth bass, and perch, respectively) were collected during MCP Supplemental Phase II/RFI activities from three locations along the Housatonic River (near New Lenox Road Bridge, Woods Pond, and near the Connecticut border). Due to the large amount of sediment data available for Woods Pond, and limited data collected near New Lenox Road Bridge and the Connecticut border, a total of seven surficial sediment samples (four near New Lenox Road and three near the Connecticut border) were collected from the upper 6 inches and submitted for PCB and TOC analyses.

Additional information on this investigation is provided in the 1996 RFI Report (BBL, 1996).

1.2.6.3 Grain Size versus PCBs and Oil and Grease

As part of the MCP Supplemental Phase II/RFI program, sediment sampling and analysis activities were performed to identify any potential correlation between sediment PCB concentrations and oil and grease concentrations. The information obtained was intended for use in estimating the performance of several potential treatment technologies as described in the PICM Proposal (Canonie Environmental, 1995).

Samples were collected between June 1994 and December 1995 from four reaches previously defined in the PICM Proposal (GE facility to the Confluence, Confluence to New Lenox Road, New Lenox Road to Woods Pond Headwaters, and Woods Pond) (Canonie Environmental, 1995). Two composite samples were collected from each of the four designated River reaches. Core depths ranged from 1.5 to 5 feet. Prior to chemical analysis, each sample was separated by particle grain size into three categories: larger than a No. 10 sieve (coarse sands and gravel), smaller than a No. 10 sieve but larger than a No. 200 sieve (medium to fine sands), and smaller than a No. 200 sieve (silts and clays). A total of 43 samples were analyzed for PCB and 18 samples were analyzed for oil and grease.

Additional information and results of the analysis are provided in Section 3.2.5 of the 1996 RFI Report (BBL, 1996).

1.2.6.4 Evaluation of Historic Sedimentation Rates

The MCP Supplemental Phase II/RFI program included an evaluation of the historical sedimentation rates between the GE facility and the Woods Pond Dam using geochronological dating analyses. These efforts, conducted in November and December 1994, included a two-phased approach. The initial phase (or screening phase) included the collection of 44 sediment cores. The locations of these sediment cores were selected based on the 1994 sediment reconnaissance/probing activities described previously. Sediment cores were sectioned into 1-inch intervals and submitted to the lab for analysis. Various 1-inch segments of each core were analyzed for Cs-137 and Be-7 to generally classify the depositional chronology and identify the maximum depth of Cs-137 presence. Typically, the 0- to 1-inch, 5- to 6-inch, 11- to 12-inch, and 17- to 18-inch core segments were analyzed (38 cores), with the 23- to 24-inch and 28- to 29-inch segments analyzed from six cores. The screening phase resulted in 188 sediment samples for geochronological dating analysis.

Based on the results of the screening phase, 26 of the previous 44 core locations were selected for more detailed analysis. At each of these locations, a second sediment core was collected in July 1995 and sectioned into the 0- to 0.5-inch interval and 1-inch increments to the bottom of the core. Between one and 10 sections from each sediment core were analyzed, resulting in 155 sediment samples for PCB, Cesium-137 (Cs-137), Beryllium-7 (Be-7), and TOC analyses. Data from these analyses were evaluated to estimate approximate rates of sedimentation and to evaluate whether PCB-containing sediments had been buried over time through the deposition of progressively cleaner sediments.

A more detailed description of the collection and analysis activities is presented in Section 3.2.6 of the 1996 RFI Report (BBL, 1996).

1.2.6.5 Sediment Investigations in the Connecticut Portion of the Housatonic River

Pursuant to a 1992 Cooperative Agreement between GE and CDEP, GE collected sediment samples at 55 stations between Great Barrington, Massachusetts and the Stevenson Dam in Connecticut during 1992 and reported the results to CDEP and EPA in February 1994. The purpose of these sampling activities was to evaluate trends in sediment PCB concentrations and develop a more up-to-date sediment characterization in this portion of the River for the fate and transport model being developed by LMS as part of the Cooperative Agreement.

Sediment samples collected at the 55 locations were analyzed as follows:

- At 42 stations, the top 3 inches of each core were composited and submitted for PCB and TOC analyses; 11 of the samples were also analyzed for bulk density and particle size.
- At seven stations, the top 3 inches of each core were sectioned into 1-inch increments; each increment sample was analyzed for PCB and TOC.
- A the remaining six stations, the entire length of sediment cores collected were sectioned into 1-inch intervals, resulting in 119 samples for PCB, TOC, and Cs-137 analyses.

Results from the 49 cores where just the top 3 inches were analyzed were used to provide a more up-to-date sediment characterization for LMS's fate and transport model, while the full core analyses were used to evaluate historical sedimentation rates.

Additional information concerning the sediment investigation in the Connecticut portion of the Housatonic River is provided in Section 3.2.7 of the 1996 RFI Report (BBL, 1996).

1.2.6.6 Investigations of Other Hazardous Constituents

Prior to the MCP Supplemental Phase II/RFI program, several investigations were conducted to assess the presence and extent of non-PCB hazardous constituents in the Housatonic River sediment bed. As previously noted in Section 1.2.4, sediment sampling for non-PCB hazardous constituents was conducted in 1990 and 1991 as part of the MCP Phase II sediment investigations, and samples were analyzed for Appendix IX+3 metals in 1992. These results were originally reported in the Interim Phase II Report/CAS (Blasland, & Bouck, 1991), along with an assessment of which hazardous constituents may be related to releases from the GE facility.

In response to comments from MDEP (which disagreed in part with the evaluation provided in the Interim Phase II Report/CAS), further sediment sampling and Appendix IX+3 analyses were performed in 1994 as part of the MCP Supplemental Phase II/RFI program. Sediment samples were collected from eight locations upstream of, adjacent to, and downstream of the GE facility, resulting in eight samples for PCB, Appendix IX+3 SVOC, and polychlorinated dibenzodioxin/polychlorinated dibenzofuran (PCDD/PCDF) analyses. Sediment samples were generally collected from the upper 20 inches of sediment, with the exception being two samples analyzed from the 2- to 8-inch and 11- to 16-inch depth intervals.

In July 1995, BBL, on behalf of GE, conducted further upstream sediment sampling for PCDD/PCDF analyses. The sample locations corresponded with locations previously sampled in 1992 for Appendix IX+3 metals. In addition, two sediment samples were collected upstream of the GE facility along the Unkamet Brook. All sediment samples were submitted for PCDD/PCDF analyses.

A more detailed description of the sampling activities and analyses is provided in Section 3.2.8 of the 1996 RFI Report (BBL, 1996).

1.2.7 MCP Supplemental Phase II - 1996 Discrete Sediment Sampling

Between May and June 1996, BBL, on behalf of GE, collected 380 discrete sediment samples in the Housatonic River. Within the Rest of River, 289 sediment samples were collected; all 289 were analyzed for PCBs, and 99 of the 289 were also analyzed for TOC. Between the Confluence and Woods Pond Headwaters, 226 samples were collected, and another 63 samples were collected in Woods Pond.

1.2.8 GE Sediment Coring Program

Between December 1997 and March 1998, BBL, on behalf of GE, conducted sediment core sampling and analysis in the Housatonic River to provide sediment data required for calibration of the sediment fate and transport models under development for the River. Sediment texture and bathymetry surveys conducted during August and September 1997 were used to develop the sample and analysis plan. The coring program consisted of three efforts:

- Surface sediment coring;
- Cs-137 coring;
- Bulk sediment cores; and

- Cohesive sediment erosion tests.

Each element is described in more detail below.

1.2.8.1 Surface Sediment Coring

The surface sediment survey provided surface sediment PCB information for comparison with historical data. Cores were collected from five to 10 sampling stations along select transects concentrated within the backwaters of the impoundments downstream of Woods Pond. Cores were segmented into 0- to 2-cm and 2- to 16-cm segments and composited in the field to yield a total of two samples per transect. Samples were analyzed for PCBs (as Aroclors) and TOC.

1.2.8.2 Cs-137 Coring

The Cs-137 coring program provided information on the depositional history of PCBs within several Housatonic River impoundments including Rising Pond, Falls Village Dam impoundment, and Bulls Bridge Dam impoundment. Two 4-inch-diameter cores were collected from each area and segmented in the field into 1-cm segments within the upper 5 cm and into 2-cm segments through the remaining length of the core. Analyses were conducted in phases, as only those cores with interpretable Cs-137 were analyzed for PCBs. As part of the first phase of analysis, the surficial 1-cm segments (five per core) and every third or fourth 2-cm segment for the full length of the core were submitted for Cs-137 and Be-7 analysis. Based on the results of the Cs-137 results, select core segments were submitted for Aroclor PCB, TOC, moisture content, and bulk density analyses in the second phase.

1.2.8.3 Bulk Sediment Cores

Bulk sediment cores provided data on bulk sediment qualities for calibration of the sediment transport model. Five cores were collected from the backwaters of each of the following dams: Woods Pond Dam, Columbia Mill Dam, Willow Mill Dam, Glendale Dam, Rising Pond Dam, Falls Village Dam, and Bulls Bridge Dam. In addition, 10 cores were collected from the meandering channels including the reaches of the River between Dawes Avenue Bridge and Woods Pond Headwaters, as well as between the Division Street Bridge and Falls Village Dam. Bulk sediment cores were segmented to yield a 0- to 8-cm core segment for analysis of sediment grain size, bulk density, and TOC.

1.2.8.4 Cohesive Sediment Erosion Tests

GE conducted a field study during June 1997 to measure the resuspension properties of cohesive sediments collected from the impoundments associated with Woods Pond, Columbia Mill, Willow Mill, Glendale, Rising Pond, Falls Village, and Bulls Bridge Dams. A portable resuspension device, commonly referred to as a shaker, was used to measure the erosion properties of 42 surficial sediment cores collected from the impoundments.

1.2.9 EPA Systematic Sediment Sampling

In 1998 and 1999, Weston, on behalf of EPA, conducted systematic sediment sampling along the five designated Rest of River reaches to provide information for the human health and ecological risk assessments and modeling study. Systematic sampling refers to a sampling strategy in which samples are collected at regular intervals over the study area. The interval distance for each reach was determined based on several factors, including expected contaminant concentrations, distance from sources, and length of River reach (Weston, 2000).

Prior to sediment core collection activities, Weston conducted a comprehensive survey of sediment depth to aid in defining the sediment profile within each reach, and assist in determining ore collection locations. Core collection locations were placed at approximately three equidistant points along each transect, unless the review of the probing information warranted otherwise.

Within the Rest of River, sediment cores were generally sectioned into the 0- to 6-inch, 6- to 12-inch, 12- to 18-inch, and 18- to 24-inch depth intervals prior to laboratory analysis. Sediment samples were analyzed for PCBs (total and Aroclors), grain size, and TOC. In addition, approximately 10% of samples were analyzed for Appendix IX constituents and 2% were analyzed for Appendix IX organophosphate pesticides and herbicides (Weston 2002).

Between the Confluence and Woods Pond, a total of 38 transects were established at approximately 1,500-foot intervals, resulting in the collection of 544 sediment samples for chemical analysis. To help define the channel geometry (needed in the modeling study), an additional 16 transects were established perpendicular to the River across the entire width of the 10-year floodplain, which resulted in the collection of 250 sediment samples for laboratory analysis. Samples collected within this reach were used in support of the human health and ecological risk assessments and modeling study.

Within Woods Pond, a total of 19 sediment cores (77 samples) were collected to supplement previously reported data from cores collected by BBL. One transect was established in the pond to help define the channel geometry information needed in the modeling study. Sediment cores were collected every 100 feet across this transect, down to a depth of 2 feet. Samples collected in Woods Pond were used in support of the human health and ecological risk assessments and modeling study.

From Woods Pond Dam to Rising Pond, a total of 41 transects were established at approximately 2,500-foot intervals, resulting in the collection of 294 sediment samples for chemical analysis. Samples collected within this reach were used in support of the human health and ecological risk assessments.

Additional information on EPA's systematic sediment sampling program can be found in the SI Data Report (Weston, 2002).

1.2.10 EPA Discrete Sediment Sampling

In addition to the systematic sampling program, EPA also conducted a discrete sampling program between 1998 and 2002. Discrete sampling refers to "random, judgmental, or focused samples collected at distinct locations" (Weston, 2000). To support the human health and ecological risk assessments and modeling study, sediment samples were collected from specific locations (e.g., aggrading bars, backwater areas), specific habitats, or areas associated with frequent human exposure (e.g., canoe launch). Further, EPA performed periodic cross-section surveys to evaluate changes in sediment and bed morphology. Each specific program is described in the SI Data Report (Weston, 2002). The data associated with these analyses is provided in the EPA database.

1.2.11 EPA Modeling-Related Sediment Studies

To assess changes in River channel morphology, EPA conducted periodic cross-section surveys along nine transects within Reaches 5A and 5B that were originally surveyed in 1999. Bed elevations at various points across the channel were measured at each transect location, at three additional times: September 2001, April 2002, and June 2002.

1.3 Floodplain and Riverbank Soil Investigations

Several studies have been conducted since 1988 to document the nature and extent of PCBs in floodplain and riverbank soils adjacent to the Housatonic River. The following sections summarize each of the major studies performed. Sections 1.3.1 through 1.3.5 describe work performed by BBL on behalf of GE; Section 1.3.6 describes EPA's efforts.

1.3.1 DeVos Property Investigation (1988-1989)

The DeVos property is located immediately south of New Lenox Road (in Lenox, Massachusetts, RM 129.2), along the eastern bank of the River channel. Due to concerns related to the possible presence of PCBs, sampling of the floodplain soils on the DeVos property was performed by BBL on behalf of GE in 1988 and 1989. A total of 52 locations were sampled; at each location, floodplain soils were sampled at 0- to 4-inch and 4- to 8-inch depths and analyzed for PCBs and percent solids. Additional detail about the study and its results are provided in the Interim Phase II Report/CAS (Blasland & Bouck, 1991).

1.3.2 MCP Phase II Investigation (1990-1992)

Since PCBs were detected in the floodplain soil samples of the DeVos property and historical flood events on the Housatonic River may have produced conditions conducive to the transport of PCB-containing sediments to the floodplain, a floodplain investigation was conducted during 1990 as part of the MCP Phase II Investigation (Blasland & Bouck, 1991). The investigation was conducted by BBL on behalf of GE to provide a more complete characterization of the nature and extent of PCB distribution in floodplain soils.

Eleven floodplain transects (designated FP1 through FP11) were identified for sampling and analysis. Ten of the 11 transects, FP2 through FP11, are located within the Rest of River reach between the Confluence and the Connecticut border. (Transect FP1 is located upstream of the GE facility in Coltsville, Massachusetts.) The sampling locations downstream of the Confluence were selected based on a review of historical aerial photographs, existing floodplain data, and topographic mapping, as well as information available from previous sampling of River depositional areas. The locations were selected to represent the various types of River conditions present.

At each sampling transect downstream of the Confluence, soil samples were collected at locations selected by field personnel based on the morphological characteristics of the floodplain. Sampling locations were generally distributed over the entire transect, with locations closer together near the riverbank and gradually becoming farther apart at greater distances from the River. A minimum of 10 sampling locations was specified for each transect. A total of 114 sampling locations were established at the 10 transects downstream of the Confluence. At each sampling location, soil cores were collected to a depth of 1 foot and sectioned into two 6-inch increments (0 to 0.5 foot and 0.5 to 1 foot). A total of 227 floodplain soil samples were collected at the 114 locations positioned along the 10 transects, and analyzed for PCBs and percent solids.

Additional sampling was performed at two of the 10 transects (FP2 and FP7) in July 1992 to better define the lateral and vertical extent of PCBs at these locations. A total of 36 samples were collected from nine locations along the two transects. Samples were collected at 6-inch intervals to a depth of 2 feet and analyzed for PCBs and TOC.

Details of this floodplain soil investigation are contained in the Interim Phase II Report/CAS (Blasland & Bouck, 1991) and the addendum to that report (Blasland & Bouck, 1992a).

1.3.3 Floodplain Properties – Short-Term Measures Evaluation (1992-1994)

BBL conducted several additional floodplain soil sampling events on behalf of GE as part of MDEP-required activities to evaluate the need for short-term measures (STMs) at specific tax parcels or properties within the floodplain. These activities included the collection of approximately 89 additional floodplain soil samples on various occasions between August 1992 and November 1993 at properties located between the Confluence and the Connecticut border that were identified as areas of likely human use (Blasland & Bouck, 1992a, 1993; BBL, 1994a, b). Samples were sectioned into 6-inch increments to a maximum depth of 3.5 feet and analyzed for PCBs, TOC, and percent solids. The majority of samples submitted for analysis were surficial soil samples collected from the 0- to 6-inch depth interval. These studies concluded that PCB concentrations greater than 1 mg/kg generally occurred within the approximate 10-year floodplain.

In May 1994, a total of 14 composite samples of floodplain soil were collected from certain wildlife habitat areas between New Lenox Road and Woods Pond for analysis of PCBs. Additionally, a total of 12 floodplain soil samples were collected from certain additional areas between New Lenox Road and Woods Pond in June 1994 for analysis of PCBs.

Detailed discussions of the results of the floodplain properties STM evaluations are contained in the following reports:

- *Summary of Housatonic River Floodplain Property Sampling and Analysis* (Blasland & Bouck, 1992b);
- *Report on January 1993 Housatonic River Floodplain Property Sampling and Analysis* (Blasland & Bouck, 1993);
- *Housatonic River Floodplain Properties – Results of Supplemental Site Characterization Sampling* (BBL, 1994b); and
- *Evaluation of the Terrestrial Ecosystem of the Housatonic River Valley* (ChemRisk, 1994).

1.3.4 MCP Supplemental Phase II/RFI Program (1994-1995)

A MCP Supplemental Phase II/RFI was conducted between 1994 and 1995 for the Housatonic River and Silver Lake. As part of this investigation, floodplain soil sampling was conducted by BBL on behalf of GE at previously established soil transects (FP2 through FP11) as well as at several new transects to further define PCB concentrations within other areas of the Rest of River between the Confluence and the Connecticut border.

A total of approximately 430 samples were collected from 22 transects (10 existing and 12 new transects). The new floodplain sampling transects included three transects between the existing transect FP4 and Woods Pond Dam (designated FP4A, FP6A, and FP7A), four transects immediately upstream of each of the first four existing dams downstream of the Woods Pond Dam (designated FP8A [Columbia Mill Dam], FP9A [Willow Mill Dam], FP9C [Glendale Dam], and FP9D [Rising Pond Dam]), and five transects below Woods Pond (designated FP9B [Stockbridge Golf Course], FP10A, B, and C [Searles Middle School], and FP10D [Sheffield Plain]). The 1996 RFI Report (BBL, 1996) identifies transect locations. As directed by EPA and MDEP, floodplain samples were also collected from a backwater area to the west of transect FP6A. Samples were collected in 6-inch depth increments to a maximum depth of 6.5 feet and analyzed for PCBs and percent solids, and generally each of the 0- to 6-inch samples was also analyzed for TOC.

As part of further investigations to define the extent of PCBs in Housatonic River floodplain soils, a number of residential properties were sampled in 1995. These properties consisted of two parcels located in the Rest of River reaches: along Holmes Road in Pittsfield (Parcel J5-2-11) and along New Lenox Road in Lenox (Parcel 29-5). Each property was sampled at numerous locations and the samples were analyzed for PCBs and, in some cases, TOC. A total of 24 samples were collected in 6-inch increments to a depth of 1 foot at each location.

Revised HEC-2 modeling was used as part of the investigation to estimate the approximate extent of the flood recurrence interval associated with the previously defined 1 mg/kg PCB isopleth between the GE facility and Woods Pond Dam. Results of the modeling effort showed that PCB concentrations of 1 mg/kg or greater were generally limited to within the approximate 5-year floodplain, and that elevated PCB concentrations are typically confined to areas close to the River and at similar elevations. However, exceptions were observed at locations behind bridges and in topographic irregularities where local geography interfered with flood flow conveyance. Downstream of the Woods Pond Dam, the extent of the PCB-impacted floodplain soil was determined to be very limited, generally found only in close proximity to the River. The results of these studies are summarized in detail in the 1996 RFI Report (BBL, 1996).

1.3.5 Additional Floodplain Properties Soil Sampling (1997-1998)

As part of the continued investigation of the floodplain characteristics, approximately 360 samples from six floodplain parcel properties (parcels 838, 848, 33-1-2A, J3-2-2, J3-2-3, and J6-3-1; see BBL, 1996 for locations) between the Confluence and the Connecticut border were collected by BBL on behalf of GE in 1997 and 1998. Soil samples were collected in 6-inch depth increments to a maximum of 5.5 feet and analyzed for PCBs and percent solids. Results are reported in monthly status reports submitted to EPA and MDEP.

1.3.6 EPA Supplemental Investigation Riverbank and Floodplain Soil Sampling (1998–2002)

Beginning in 1998, EPA began the most extensive effort to date to fully characterize conditions in Housatonic River floodplain and bank soils. One of the objectives of EPA's SI was to define the nature and extent of PCBs and other constituents in the Rest of River and associated floodplain, and to further delineate pathways of contaminant migration. According to the *Supplemental Investigation Work Plan* (SI Work Plan) (Weston, 2000), limited floodplain soil PCB results were available in Reaches 5 through 9, considering the extent and diversity of the areas being investigated. The data generated are to be used for the site ecological risk assessment to define the concentrations of constituents in various habitats as well as to define the concentrations of constituents available to human exposure. In addition, the data will be used to validate and calibrate site models.

The majority of the sampling was conducted by EPA contractors (e.g., Weston). On behalf of GE, split samples were also collected by BBL at selected sampling locations. The sampling approach included the collection of samples from historical locations as well as additional locations and was generally conducted out to the 10-year floodplain. The sampling approach was designed to optimize the effort, and included both systematic (i.e., collection of data at regularly spaced intervals) and discrete sampling (i.e., focused on specific areas) to address specific data quality objectives (Weston, 2000).

In general, soil samples were collected at 6-inch intervals to varying depths depending upon the sampling location. All soil samples collected were analyzed for PCBs and percent solids; the majority of the samples were analyzed for total PCBs and PCB Aroclors by a field laboratory. Ten percent of the soil samples were analyzed by a fixed laboratory for PCB Aroclors, and 135 soil samples were also analyzed for PCB congeners (and homologs) by a fixed laboratory. Ten percent of the soil samples were analyzed for a modified list of Appendix IX compounds, including SVOCs, organochlorine pesticides/PCBs, PCDDs/PCDFs, and inorganics. Additionally, 2% of all samples were analyzed for a modified list of Appendix IX organophosphate pesticides and herbicides.

TOC and grain size analyses were performed on approximately 10% of the riverbank and floodplain soil samples and, as necessary, when the field sampling teams encountered changes in soil type and organic matter at riverbank and floodplain locations.

1.3.6.1 Systematic Sampling

Systematic sampling (i.e., sampling along regularly-spaced transects) was performed during EPA's 1998-2002 effort to further characterize the Housatonic River floodplain conditions. For each River reach, regularly-spaced transects were sampled to characterize the entire reach. Systematic sampling along transects was performed in all reaches, except Reaches 8 and 9 (only discrete sampling was performed in Reaches 8 and 9, which extend from Rising Pond to the Connecticut border).

For floodplain soil samples, systematic sampling was conducted through Reach 7. Samples were collected within the 10-year floodplain using a series of transects that were perpendicular to the River channel. The distance between transects increased moving downstream, as the chemical concentrations were expected to decrease with increasing distance from the Source Reach (Reach 3, between the Newell Street Bridge to the Lyman Street Bridge) (Weston, 2000).

Each transect was positioned perpendicular to the River channel, with sampling starting from one side of the floodplain across the River channel to the opposite side of the floodplain. On a typical transect, nine samples were collected from three locations in the floodplain on each side of the River, with the samples located between the riverbank and the outer extent of the 10-year floodplain at equal distances. Therefore, floodplain transects consisted of six sampling locations, each sampled at three depths (i.e., 0 to 6 inches, 12 to 18 inches, and 24 to 30 inches below ground surface [bgs]). Three to nine samples (from one to three locations) were also targeted from each riverbank (where a distinct riverbank was present) (Weston, 2000). Riverbank sampling locations included the bottom of the bank (toe of slope), mid-bank (terrace), and the top of bank. Similar to the floodplain, samples were typically collected in alternating 6-inch depth intervals to a depth of 30 inches (i.e., 0 to 6 inches, 12 to 18 inches, and 24 to 30 inches bgs).

Due to the broad floodplains characteristic of the area, only a few sizable riverbanks exist in Reach 5 (Confluence to Woods Pond). Therefore, sampling of riverbank soils was conducted only when they were encountered during the floodplain sampling program. Systematic riverbank soil sampling was not proposed for

Reach 6 (Woods Pond) since the area is characterized by a broader floodplain with low banks. Additionally, systematic bank sampling along transects was not proposed for Reaches 7 through 9 based on historical data, which indicated that the area downstream of Woods Pond contained relatively low PCB concentrations.

1.3.6.2 Discrete Sampling

Discrete sampling of soils was performed by Weston on behalf of EPA during the SI (between 1998 and 2002) to characterize specific areas or to support specific data quality objectives where relatively few data were available from previous studies. The sampling involved collecting soil samples at distinct locations, including a number riverbank and adjacent floodplain soil samples.

For floodplain and riverbank soils, discrete sampling was conducted for all Reaches in the Rest of River area (between Reach 5 and Reach 9). Discrete floodplain and riverbank sampling was conducted in association with specific biological studies or areas of frequent human exposure (Weston, 2000). These areas included recreational, residential, agricultural, and commercial/industrial areas in the 10-year floodplain. For riverbank soils at these public access areas, up to two samples (0 to 6 inches and 6 to 12 inches) were collected at each location. Data collection activities and programs completed by EPA were documented in EPA's SI Data Report (Weston, 2002).

1.3.6.3 EPA Modeling-Related Soil Studies

2000-2002 Toe Pin Measurements

Groups of toe pins were installed by EPA in October 2000 in the riverbank at five locations within Reaches 5A and 5B. The toe pins were used to measure bank locations at four different times during an approximately 20-month period, with the last data collected in June 2002.

2001-2002 River Meander Study

To evaluate movement of riverbanks, EPA conducted surveys along River meanders in Reaches 5A and 5B in November 2001 and June 2002. Bank location data (i.e., top- and bottom-of-bank) were collected along 15 riverbank stretches that ranged in length from approximately 140 feet to 525 feet. In addition, aerial photographs of the River taken in 1952, 1978, 1990, and 2000 were ortho-referenced in an attempt to produce comparable digital shorelines for each of these periods.

1.3.6.4 Vernal Pool Sampling

In support of the ecological risk assessment, approximately 56 temporary pools located in the floodplain in Reaches 5 and 6 were sampled between 1998 and 2002. Depending on the pool size, approximately two to five samples from 6-inch depth intervals were collected at each sampling location, resulting in the collection of 441 samples for chemical analysis.

1.4 Biological Investigations – Description of Sampling and Analysis Activities

Many studies have been conducted on the Housatonic River to evaluate the concentrations of PCBs and other constituents in fish, small mammals, birds, invertebrates, and other types of organisms. This section provides an overview of the sampling and analysis activities performed for the Rest of River area.

1.4.1 Housatonic River Fish Sampling

Fish sampling has been conducted in both the Massachusetts and Connecticut portions of the Housatonic River for more than 20 years. The program description, target species, and analytical parameters for each of the sampling events are discussed below, and summarized in Table 6-1.

1.4.1.1 GE/Stewart Studies (1980, 1982)

Stewart collected fish during 1980 and 1982 from eight sampling stations along a 70-mile reach of the Housatonic River in Massachusetts (from the headwaters of Center Pond in Dalton to the Massachusetts/Connecticut state line). The findings of these two sampling efforts were presented in the *Housatonic River Study: 1980 and 1982 Investigations* (Stewart, 1982). The objective of the 1980 fish collections was to collect four principal sport fish indigenous to the Housatonic River study area (i.e., trout, bass, yellow perch, and sunfish) (Stewart, 1982). In keeping with the requirements of the Consent Decree, the 1982 collection objective was altered to include fish, frogs, and other types of aquatic life that may be consumed by humans (Stewart, 1982). As such, the 1982 sampling included several additional fish species (brown bullhead, chain pickerel, crappie, and rock bass). A total of 721 fish samples were collected during the 1980 and 1982 studies. Of these fish, 382 were analyzed as 40 composite samples, and the remaining 339 fish were archived for possible analysis at a later date. Each of the fish samples was analyzed as skin-on or skin-off fillets (depending on the species) for total PCBs and percent lipids by IT Laboratories. The Stewart study also included the analysis of six fish samples (four from Massachusetts and two from Connecticut) for PCDFs. Analyses of the PCDFs were conducted by University of Umea in Sweden (Stewart, 1982). In 1982, Stewart also conducted a split sampling program with EPA for fish collected from Connecticut.

1.4.1.2 GE/BBL MCP Phase II Fish Sampling (1990)

BBL collected fish samples in November 1990 as part of the MCP Phase II Investigation. These efforts were designed to generate data for a screening-level study to supplement the previous (1980 and 1982) studies by Stewart Laboratories. The sampling locations included Woods Pond and Rising Pond, and target species were largemouth bass, yellow perch, and brown trout. The total number of samples collected included 18 fish from Woods Pond and 10 fish from Rising Pond. Each of the samples was processed as individual skin-on fillets, and analyzed for total PCBs and percent lipids. In addition, the one bass and one brown trout from each location that exhibited the highest total PCB concentrations were analyzed for PCDDs/PCDFs. Results of the 1990 fish sampling were presented in the Interim Phase II Report/CAS (Blasland & Bouck, 1991).

1.4.1.3 GE/BBL Tributary Fish Sampling (1995)

In 1995, BBL conducted limited fish sampling for two Housatonic River tributaries, the Green River and the Williams River, and a nearby reference location (Laurel Lake). A total of four to five fish were collected from each location, including two rock bass and two brown trout from the Green River, two smallmouth bass and two brown trout from the Williams River, and five largemouth bass from Laurel Lake. All samples were analyzed for total PCBs and percent lipids as skin-on/scales-off fillets. Results are presented in the 1996 RFI Report (BBL, 1996), monthly status reports submitted to EPA and MDEP, and the GE database.

1.4.1.4 GE/BBL YOY Fish Sampling (1994 – 2002)

BBL has conducted YOY fish sampling biannually from 1994 to 2002. The YOY sampling involved the collection of three species: largemouth bass, yellow perch, and bluegill (or pumpkinseed, if bluegill were not found). Seven composite samples (five to 25 fish per composite) of each species were collected from sampling locations HR2 (located south of New Lenox Road), Woods Pond, and HR6 (in Massachusetts, just north of the Connecticut border). The composite YOY fish samples were analyzed as whole-body samples for total PCBs and percent lipids. Results for all four years are presented in monthly status reports submitted to EPA and MDEP and are also contained in the GE database. Data from the 1994 and 1996 investigations are presented and discussed in the 1996 RFI Report (BBL, 1996).

1.4.1.5 GE/BBL Supplemental Fish Sampling (1998, 2002)

BBL conducted fish monitoring along several locations of the Housatonic River in November 1998. The fish sampling included three locations: from the Confluence to the Pittsfield WWTP, Rising Pond, and sampling location HR6 (located in Massachusetts, just north of the Connecticut border). Target organisms included in the sampling were bluntnose minnows, brown bullhead, yellow bullhead, yellow perch, pumpkinseed, and bluegill. Samples were processed as individual skin-on fillets and whole-body, as well as whole-body composites, and analyzed for total PCBs and percent lipids. Results are presented in monthly status reports submitted to EPA and MDEP, and are contained in the GE database.

In 2002, GE collected largemouth bass to evaluate the low lipid values reported by EPA from the agency's recent fish tissue samples. Fifteen adult largemouth bass were collected from both Reach 5B (upstream of Woods Pond) and Reach 5 (Woods Pond). The fish were processed as skin-off fillets and offal, and analyzed for PCB congeners and lipid content. During this sampling program, yearling and adult pumpkinseed were also captured; these fish had selected scales removed for age determination, and were released back to the River.

1.4.1.6 GE/ARCADIS Fish Sampling (1999)

ARCADIS conducted a fish sampling program as part of a larger fish reproduction study in 1999. Largemouth bass were collected from four locations in the Housatonic River (Deep Reach, Woods Pond, Rising Pond, the Connecticut border) and from Three-Mile Pond. Five female largemouth bass individual samples were processed as whole body and analyzed for total PCBs and percent lipids. Results are presented in monthly status reports submitted to EPA and MDEP, and are contained in the GE database.

1.4.1.7 EPA/USFWS Fish Sampling (1998 – 2000)

EPA and the U.S. Fish and Wildlife Service (USFWS) conducted a fish sampling program in the Massachusetts section of the Housatonic River in 1998, and to a lesser extent in 1999 and 2000. The details of the fish monitoring program were described in the SI Work Plan (Weston, 2000). The objective of the fish sampling was to characterize biological media to support human health and ecological risk assessments (Weston, 2000). In 1998, the sampling included seven locations, five downstream of the GE facility (including stretches between the Confluence and Woods Pond dam, Rising Pond, and Goodrich Pond), and two reference areas (the East Branch at Dalton and Three-Mile Pond). More than 1,000 fish samples were collected in 1998, and the target species were largemouth bass, yellow perch, brown bullhead, pumpkinseed, bluegill, goldfish, and various minnows (i.e., golden shiner, common shiner, fallfish, and bluntnose minnow). Some smallmouth bass and yellow bullhead were also collected for analysis. Fish samples were processed as either whole body or fillet/offal. The samples were analyzed for PCBs (both Aroclor and congener/homologue analyses), and some of the fish samples were also analyzed for PCDDs/PCDFs and organochlorine pesticides. In 1999, EPA collected additional fish samples for analysis of PCBs, PCDDs/PCDFs, and metals. Samples included largemouth bass from Woods Pond and a reference location (Three-Mile Pond). Again, fish samples were processed as either whole body or fillet/offal. In 2000, EPA collected a single goldfish from Woods Pond and white suckers from Woods Pond and immediately upstream of Woods Pond for PCB analysis.

1.4.1.8 CDEP Fish Sampling (1977 – 1983)

CDEP sampled resident fish at four locations along the Housatonic River from 1977 to 1983. These areas included Bulls Bridge, Cornwall, Lake Lillinonah, and Lake Zoar. Target species varied, and most of the samples were brown trout and smallmouth bass, but other species (e.g., bluegill, chain pickerel, largemouth bass, and rainbow trout) were also retained. Samples were processed as skin-on/scales-off fillets or skin-off fillets and analyzed for PCB Aroclors and percent lipids. GE and BBL reviewed results of these investigations as documented on fish monitoring data sheets obtained from CDEP.

1.4.1.9 GE/ANSP Fish Sampling (1984 - 2002)

Since 1984, the Academy of Natural Sciences of Philadelphia (ANSP) has conducted a biennial monitoring program of PCB concentrations in selected fish in the Connecticut portion of the Housatonic River. The ANSP fish monitoring program is summarized in the document titled *PCB Concentrations in Fishes from the Housatonic River, Connecticut, 1984-2002, and in Benthic Insects, 1978-2002* (ANSP, 2003). The studies from 1994 and earlier were required by the 1990 Housatonic River Cooperative Agreement between CDEP and GE. The studies were continued in 1996 and 1998; in October 1999, a new Housatonic River Follow-up Cooperative Agreement was executed, requiring continuation of biennial biological monitoring studies in 2000, 2002, and 2004. Sampling stations for the ANSP fish monitoring are West Cornwall, Bulls Bridge, Lake Lillinonah, and Lake Zoar. The primary target species were brown trout and smallmouth bass, although in 2000 (at the request of CDEP) bluegill, pumpkinseed, brown bullhead, and yellow perch were collected at Falls Village and Bulls Bridge. The objective of the supplemental sampling was to provide data to assess Connecticut's fish consumption advisory for the Housatonic River (ANSP, 2001). Samples were analyzed as skin-on/scales-off fillets, skin-on/scales-on fillets, or skin-off fillets, depending on the species. Each of the fish samples collected during the ANSP studies was analyzed for PCBs and percent lipids.

1.4.2 Housatonic River Non-Fish Biota Sampling Programs

Historically, fish have been the primary focus of the biota monitoring programs conducted on the Housatonic River; however, over the years data have been collected for biota other than fish. The non-fish biota sampling programs include the collection and analyses of reptiles and amphibians, aquatic and terrestrial invertebrates, aquatic and terrestrial vegetation, aquatic microorganisms, and birds. While the non-fish biota studies are summarized in Table 6-2, these studies are also briefly described below.

1.4.2.1 GE/Stewart Studies (1980, 1982)

The 1980 and 1982 Stewart studies collected non-fish biota samples, including limited numbers of aquatic macrophytes, frogs, and snapping turtles. The data are presented in the report titled *Housatonic River Study: 1980 and 1982 Investigations* (Stewart, 1982), and a brief summary is provided below.

- Aquatic Macrophytes – In 1980, Stewart collected aquatic vegetation from several areas along the Housatonic River, including the East Branch upstream of Newell Street, between the Confluence and Woods Pond, Woods Pond, Woods Pond to Rising Pond, and downstream of Rising Pond. Corresponding sediment samples were taken in association with each vegetation sample. A total of five samples of duck potato and 10 samples of water milfoil and lesser duckweed were analyzed for total PCBs.

- Frogs – In 1982, Stewart collected 12 bullfrogs from Woods Pond. The frogs were combined into a single composite sample and analyzed for total PCBs and percent lipids. The specific sample type (e.g., leg muscle tissue only, whole-body) is unknown.

- Snapping Turtles – In 1982, Stewart collected a single snapping turtle from Woods Pond. The sample was analyzed for total PCBs and percent lipids, although the specific sample type (e.g., muscle tissue only, whole-body) is unknown.

1.4.2.2 GE/BBL Sampling (1992, 1996)

In addition to fish, BBL collected other biota samples from the Housatonic River in 1992 and 1996. These collections consisted of frog samples collected in 1992 and a single algae sample collected in 1996, described below.

- Frogs – In 1992, BBL collected a total of 21 bullfrogs from Woods Pond. Three composite samples of leg muscle tissue (seven frogs per sample) were analyzed for total PCBs and percent lipid. Analyses were conducted by Hazleton Laboratories. Data are presented in the Addendum to the Interim Phase II Report/CAS (Blasland & Bouck, 1992a).

- Algae – In 1996, BBL collected one sample of algae from the River near the former Housatonic Street Bridge Abutment. This sample was analyzed for total PCBs. Data are presented in the 1996 RFI Report (BBL, 1996).

1.4.2.3 EPA SI Sampling (1998 – 2001)

As part of the SI, EPA conducted numerous biological investigations at various locations along the Housatonic River, including several reference areas. These investigations were completed to support the baseline human health and ecological risk assessments. The sampling details and results (i.e., number of samples and locations, collection methods) are described in the SI Data Report (Weston, 2002). The EPA studies are summarized below.

- Terrestrial Vegetation – In 1998, 1999, and 2000, EPA collected samples from various types of agricultural crops and other types of plants from fields that extended into the floodplain of the Housatonic River. In 1998, EPA collected nine samples of corn along the Housatonic River at the Confluence (Reach 5A), and the samples were analyzed for PCB Aroclors. In 1999, EPA collected corn, squash, and fiddleheads from two sites along the Housatonic River downstream of the GE facility. Twelve corn, nine squash, and two fiddlehead samples were collected from Reach 5A, and eight corn samples and one fiddlehead sample were collected along the River upstream of the Pittsfield WWTP (Reach 5B). Corn samples were processed as either ear or stalk, and squash samples were processed as either flesh or pulp and seeds. These samples were analyzed for PCB Aroclors. In 2000, EPA collected fiddleheads from the two sites sampled in 1999 (Reaches 5A and 5B) as well as the East Branch of the Housatonic River upstream of Newell Street (Reach 1/2). Four samples were collected from Reach 5A, two samples each were collected from Reaches 1/2 and 5B; all were analyzed for PCB congeners. In 2001, EPA collected 11 grass samples from Reach 5B and analyzed them for PCB congeners and PCDDs/PCDFs.

- Aquatic Microorganisms – In 2000, EPA collected composite samples of phytoplankton and zooplankton from Reaches 4, 5, and 6. The samples were analyzed for total PCBs, and a subset of the samples was analyzed for select organochlorine pesticides and PCDDs/PCDFs.

- Aquatic Vegetation – In 2000, EPA collected composite samples of periphyton (from rock and macrophyte scrapings, from the substrate, and from filtered surface water). EPA also collected samples of filamentous algae, macrophytes, and detritus. The samples were collected from several reaches, including the West Branch and Reaches 4, 5A, and 5B. The samples were analyzed for total PCBs, and a subset of the samples were analyzed for select organochlorine pesticides, PCDDs/PCDFs, and other organics.

- Aquatic Macroinvertebrates - In 1999, EPA collected composite samples of shredders and predatory insects from four sites (three sites along the Housatonic River downstream of the GE facility and one at a reference area outside the Housatonic River drainage basin). Two samples were collected from the East Branch of the River, upstream of Newell Street (Reaches 1 and 2), 13 samples were collected from the River between the Confluence and Woods Pond (Reach 5), three samples were collected from the West Branch, and two samples were collected from a reference area. In 2000, EPA collected two composite samples of caddisfly larvae. All samples were analyzed for PCB congeners, select organochlorine pesticides, and percent lipids. A subset of the samples was also analyzed for PCDDs/PCDFs.

- Crayfish – In 1999, EPA collected crayfish from three sites, including two sites along the Housatonic River downstream of the GE facility and one reference area outside the Housatonic River drainage basin. Forty samples were collected from the River between the Confluence and Woods Pond (Reach 5). Ten samples each were collected from the West Branch and a reference area. These samples were processed as individual whole body samples, and analyzed for PCB congeners, select organochlorine pesticides, and percent lipids. A subset of the samples was also analyzed for PCDDs/PCDFs.

- Frogs – In 1998, EPA collected one bullfrog sample from the Housatonic River, between the Confluence and Woods Pond. This sample was processed as a whole-body individual and analyzed for PCB congeners, select organochlorine pesticides, percent lipids, and PCDDs/PCDFs. In 1999, EPA collected bullfrogs from various locations along the River, including near the Confluence (three samples), upstream of the Roaring Brook confluence (six samples), the backwater area upstream of Woods Pond (two samples), Woods Pond (six samples), the western half of Woods Pond plus the main channel of the River upstream of the pond proper (three samples), the eastern half of Woods Pond (one sample), and a reference area (11 samples). EPA also collected leopard frogs in 1999 from Reach 5A (12 samples), Reach 5C (eight samples) and the West Branch (four samples). Tissue samples were processed as leg muscle tissue and/or offal, and analyzed for PCB congeners, select organochlorine pesticides, percent lipids, and PCDDs/PCDFs. In 2000/2001, EPA collected wood frog egg masses found in vernal pools in the Housatonic River floodplain as part of the agency's respective reproductive studies. The samples included frogs at various stages of development, including eggs, larvae, tadpoles, and metamorphs. Whole-body samples and composites were analyzed for PCB Aroclors, pesticides, herbicides, SVOCs, PCDDs/PCDFs, and/or polynuclear aromatic hydrocarbons (PAHs).

- Waterfowl – In 1998, EPA collected a total of 45 ducks (40 wood ducks and five mallards) from the Housatonic River and Three-Mile Pond. Eleven ducks (three mallard and eight wood ducks) were collected from the River between the Confluence and Woods Pond (Reach 5), and 14 ducks (two mallard and 12 wood ducks) were collected from Woods Pond (Reach 6). Twenty wood ducks were collected from Three-Mile Pond, which was used as a reference area. Each duck was processed as breast and/or liver tissue. Tissue samples were analyzed for PCB congeners, select organochlorine pesticides, percent lipids, and PCDDs/PCDFs.

- Tree Swallows – EPA conducted a 3-year study on tree swallows from 1998 through 2001. In 1998, EPA collected tree swallows from swallow boxes stationed along the West Branch of the Housatonic River and also between the Confluence and Woods Pond (Reach 5). Pippers and nestlings were collected and processed as breast tissue, and food samples were removed from the swallows' stomachs. Eggs were also collected. The samples were analyzed for PCB congeners, select organochlorine pesticides, percent lipids, PCDDs/PCDFs, and/or metals. In 1999, EPA collected tree swallows from swallow boxes at four sites (three sites along the Housatonic River downstream of the GE facility and one at a reference location outside the Housatonic River drainage basin). Breast samples, eggs, and composite food samples were collected from the River near its confluence with Woods Pond (Reach 5), the East Branch of the River upstream of Newell Street (Reaches 1 and 2), the West Branch of the River, and a reference area. The samples were also analyzed for PCB congeners, select organochlorine pesticides, percent lipids, and/or PCDDs/PCDFs. In 2000, EPA collected tree swallows from swallow boxes at the same four sites sampled in 1999, and the samples again were analyzed for PCB congeners, select organochlorine pesticides, percent lipids, PAHs, and/or PCDDs/PCDFs.

- House Wrens – In 1999, EPA collected five eggs from nest boxes along the Housatonic River between the Confluence and Woods Pond (Reach 5). The eggs were analyzed for PCB congeners, select organochlorine pesticides, and percent lipids.

- Chickadee - In 2000, EPA collected three chickadee egg samples from nests along the Housatonic River between the Confluence and Woods Pond (Reach 5). The eggs were analyzed for PCB congeners and select organochlorine pesticides.

- Small Mammals – EPA collected small mammal samples from Reach 5 in 1998 and 1999. However, the small mammal samples collected in 1998 were not submitted for analyses because the samples were lost due to a freezer failure (Weston, 2002). Small mammals were re-sampled in 1999, and a total of 24 short-tailed shrews and 52 white-footed mice were analyzed for PCBs (Aroclors and congeners) and organochlorine pesticides. A subset of the samples was also analyzed for PCDDs/PCDFs.

1.4.2.4 GE/ARCADIS Sampling (2001)

ARCADIS collected biota samples from the Housatonic River in 2001 as part of larger field studies. These collections consisted of frog and robin samples, described below.

- Frogs – In 2001, ARCADIS collected wood frog tadpoles and wood frog larvae samples from vernal pools in the Housatonic River floodplain. Five composite larvae samples and four composite tadpole samples were analyzed for total PCBs and percent lipid. Analyses were conducted by Northeast Analytical Environmental Lab Services (NAE). Results are presented in monthly status reports submitted to EPA and MDEP, and are contained in the GE database.

- Robins – In 2001, ARCADIS collected 11 robin eggs and 11 nestlings from nests situated in the floodplain between the Confluence of the East and West Branch and Woods Pond. Two eggs and six nestlings were collected from reference areas, which included Peru Wildlife Management Area, Peru State Forest, Middlefield State Forest, October Mountain State Forest, and Hinsdale Flats Wildlife Management Area. Egg and nestling samples were analyzed for total PCBs and percent lipids. Analyses were conducted by NEA. Results are presented in monthly status reports submitted to EPA and MDEP, and are contained in the GE database.

1.4.2.5 CDEP/ANSP Sampling (1978 – 2002)

CDEP and ANSP collected benthic invertebrates and periphyton from locations along the Housatonic River in Connecticut. Results from 1978 through 1991 are presented and discussed in the Interim Phase II Report/CAS (Blasland & Bouck, 1991), while data collected between 1991 and 1995 have been reported separately by ANSP. Results for the entire sampling effort are summarized in *PCB Concentrations in Fishes from the Housatonic River, Connecticut 1984-2000 and in Benthic Insects, 1978-2001* (ANSP, 2001).

- Benthic Invertebrates – CDEP collected benthic invertebrates from various locations along the River in 1978. Two samples of caddisfly larvae and three samples of stonefly larvae were collected and analyzed for total PCBs. Benthic invertebrate sampling of the Housatonic River continued at Cornwall from 1978 through 2002. Fifty total composite samples of benthic invertebrates (specifically caddisfly, hellgrammite, and stonefly) were collected during a period of 17 years. Caddisfly larvae were collected to represent a typical filter feeding aquatic insect, and hellgrammite larvae and stonefly nymphs were collected to represent predatory insects. Multiple composite samples were collected and analyzed for PCB Aroclors.

- Periphyton – CDEP collected periphyton (rock scrapings) from various locations along the River in 1978. Three samples were collected and analyzed for PCB Aroclors.

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