Final Second Five-Year Review Report for the Hudson River PCBs Superfund Site

APPENDIX 1

EVALUTION OF WATER COLUMN PCB CONCENTRATIONS AND LOADINGS

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FINAL SECOND FIVE-YEAR REVIEW REPORT FOR THE HUDSON RIVER PCBs SUPERFUND SITE

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1 INTRODUCTION

This appendix reviews water column polychlorinated biphenyl (PCB) concentration data collected and PCB loads estimated after the issuance of the Record of Decision (ROD) (EPA, 2002), and compares to them to expectations for the remedy as expressed in the ROD. The appendix begins with a summary of relevant background related to planning and implementation of the remedy, summarizes available data, and compares data and loading estimates to expectations for periods before, during, and after dredging, and to remedial action objectives (RAOs).

2 RELEVANT REMEDIAL PLANNING AND IMPLEMENTATION BACKGROUND

Water column PCB concentration is a key metric for tracking the success of the remedy as reflected in two of the project RAOs: 1) reduce PCB levels in sediments in order to reduce PCB concentrations in river (surface) water that are above surface water Applicable or Relevant and Appropriate requirements, or ARARs; and 2) reduce the PCB load to the lower river. In addition, water column concentrations were monitored as part of the resuspension performance standard during implementation. The Engineering Performance Standards (EPS) were designed to monitor the implementation of the project, and allowed for adjustments to maximize the likelihood of remedy success. After the first year of dredging (Phase 1), the EPS were revised for subsequent dredge years (Phase 2) based on lessons learned during Phase 1 and a peer review. The following subsections provide a brief overview of the elements of the remedy and implementation that are directly relevant to PCBs in the water column.

2.1 Elements of the Remedy

Two of the Operable Unit 2 (OU2) RAOs concern reductions in concentrations and loads of PCBs in surface water, namely:

- to reduce PCB levels in sediments in order to reduce PCB concentrations in river (surface) water that are above ARARs, including
  - 500 nanogram per liter (ng/L) total PCBs (TPCBs), the federal maximum contaminant level (MCL) for drinking water;
  - 90 ng/L TPCBs, the New York State (NYS) standard for protection of human health and drinking water sources;
  - 14 ng/L TPCBs, the criteria continuous concentration (CCC) Federal Water Quality Criterion (FWQC) for protection of aquatic life in freshwater; and

- 30 ng/L TPCBs, the CCC FWQC for protection of aquatic life in saltwater;[1] and
- to minimize the long-term downstream transport of PCBs in the river.

In addition to sediment removal, transport, disposal, backfilling, and institutional controls, the remedy provided for

- resuspension rate performance standards to be applied during dredging;
- an extensive monitoring program, including water column monitoring;
- evaluation of the work with respect to performance standards, including peer review of the first year (Phase 1) of dredging;
- monitored natural attenuation (MNA) of PCB contamination that remains in the river after dredging, as well as during the period between the issuance of the ROD and the commencement of dredging; and
- monitoring to assess achievement of Remediation Goals.

2.2 Phase 1 Implementation

In April 2004, the United States Environmental Protection Agency (EPA) issued peer-reviewed EPS which included a Resuspension Standard, a Residuals Standard, and a Productivity Standard. The Resuspension Standard included a far-field concentration standard of 500 ng/L, where far-field was defined as at least 1 mile downstream of dredging, and a limit of 650 kilograms (kg) of TPCBs[2] above baseline conditions to be transported downstream of dredging areas over the life of the project. There were also far-field standards for total suspended solids (TSS).

[1] In the 2002 ROD, EPA waived three ARARs that also were identified for the project (1 ng/L TPCB federal Ambient Water Quality Criterion, the 0.12 ng/L TPCB NYS standard for protection of wildlife, and the 0.001 ng/L TPCB NYS standard for protection of human consumers of fish) due to technical impracticability.

[2] TPCBs represents the sum of all measured PCB congeners. PCBs are a group of chemicals consisting of 209 individual compounds known as congeners. The congeners can have from one to ten chlorine atoms per molecule, each with its own set of chemical properties.

The Performance Standard for Dredging Resuspension was designed to limit the concentration of PCBs in river water, such that water supply intakes downstream of the dredging operations would be protected and the downstream transport of PCB-contaminated dredged material would be appropriately constrained. The 500 ng/L concentration is the EPA's MCL for PCBs in drinking water supplies.

The PCB mass export load limit was one of the action levels developed for the resuspension standard because of the potential for PCB to impact areas downstream of the dredging, including the Lower Hudson River. The Phase 1 export limit was initially set at 65 kg, which was just below 1 percent of the initial Feasibility Study estimate of the mass inventory to be removed. The remedial design projected an increase in the percentage of PCB mass removed during Phase 1 dredging activities, so the limit was adjusted upward to 117 kg.

The first phase of dredging (Phase 1) was conducted in 2009, and extensive sampling and monitoring were conducted throughout. Both EPA and General Electric Company (GE) completed individual Final Phase 1 Evaluation Reports in March 2010 (EPA 2010a; General Electric 2010a) and both reports proposed modifications to the performance standards. The EPA Phase 1 Evaluation Report indicated that

- the mass of PCBs removed (20,000 (kg) represented an 80 percent increase over what had been expected (11,000 kg) for the 10 Certification Units (CUs) actually dredged in Phase 1;
- the Resuspension Standard functioned as designed, and monitoring data were used to temporarily halt dredging operations when the 500 ng/L criterion was exceeded on three occasions. These temporary operational halts consumed less than 6 percent of the available dredging hours and EPA concluded they did not have a major impact on the ability to meet the Productivity Standard;
- the PCB mass loss varied between 1 to 2 percent on a weekly basis at Thompson Island. The mass of PCB lost to the Lower Hudson River during most of the dredging period, as estimated at Waterford, was less than 1 percent. Therefore, EPA's goal of a 1 percent loss rate to the Lower Hudson River was achieved; and

- the most likely factors that contributed PCBs to the water column were mass and volume removal, vessel traffic, disturbance of exposed contaminated surface sediments, processes associated with backfilling, and the extent to which dredge buckets may have been overly full or dredging hurried.

2.3 Engineering Performance Standards Peer Review

After the completion of Phase 1, EPA and GE each prepared a Phase 1 Evaluation Report that evaluated the Phase 1 dredging relative to the EPS, and propose changes to those standards as appropriate. An independent peer review panel was asked to consider the adequacy and practicability of recommendations by EPA and GE for dredging and monitoring in Phase 2. The Panel found that the 2004 EPS for resuspension, residuals, and productivity were not met individually or simultaneously during Phase 1 and could not be met in Phase 2 without substantive changes. The Panel developed and recommended the implementation of modified EPS and best management practices. The Panel expressed that a key obstacle to simultaneously achieving the EPS, including the Resuspension Standard, was incomplete characterization of the depth of contamination (DoC), combined with adherence to the 2004 EPS residual target levels. Repeated dredging passes and prolonged exposure of dredged and non-dredged residual PCBs to the water column had resulted in increased PCB resuspension and release. The Panel proposed a revision to the Residuals Standard to accelerate CU closure by establishing an elevation-focused dredging design paradigm, which would reduce resuspension, manage residuals, and improve productivity. For Phase 2 Year 1, the Panel proposed that the Resuspension Standard and Productivity Standard should be informed by Phase 1 performance. The goal of these proposed interim standards was to establish baseline targets during Phase 2 Year 1 and to allow dredging to recommence in 2011, while near-field and far-field data were collected.

2.4 Phase 2 Changes in Response to Peer Review

For Phase 2, the EPS were modified based on the findings of EPA and GE as reported in their respective Phase 1 evaluation reports, on the recommendations and observations of the Peer Review Panel, and on additional analyses by EPA. The standards were also simplified and streamlined to more directly reflect the conditions that were observed during the day-to-day operations of the dredging project.

During Phase 1 dredging, inadequate characterization of DoC had contributed to unexpected increases in PCB mass removed. Phase 2 included changes in methodology to improve sampling in order to obtain a better characterization of the DoC. GE was required to adjust the DoC calculations to account for variability encountered in establishing the DoC, and GE agreed to re-sample predesign sediment cores that had less than a 60 percent recovery rate.

Also in Phase 1, elevated water column PCBs had been attributed to dredging and backfilling procedures that allowed for residual exposures to flow and to boat traffic. A revised Residuals Standard was developed for Phase 2 to reduce losses of PCB to the water column to downstream transport. The revised standard entailed a maximum of two dredging passes, followed by backfill or capping as appropriate, with one exception. In circumstances when concentrations of PCBs were encountered above 500 milligrams per kilogram (mg/kg) Tri+ PCBs[3] (the mass of PCB molecules containing greater than two chlorine atoms) after the second dredging pass, EPA required a third pass. Areas near shore above 27 mg/kg Tri+ PCBs (or 50 mg/kg TPCBs) after the first pass required a second dredging pass. EPA also set limits on capping as a percent of total project area and areas of higher post-dredging residual concentration.

For the Resuspension Standard, if at a designated far-field measuring location, concentration was found to exceed 500 ng/L TPCBs for 5 days out of any 7, GE was to take steps which could include a temporary slowdown of operations. The mass of PCBs allowed to travel downstream was not to exceed 2 percent of the total mass of PCBs actually excavated from the river bottom as measured at the first designated location downstream of ongoing dredging. At Waterford, the farthest downstream measuring

[3] Tri + PCBs represents the sum of all measured PCB congeners with three or more chlorine atoms per molecule. PCBs are a group of chemicals consisting of 209 individual compounds known as congeners. The congeners can have from one to ten chlorine atoms per molecule, each with its own set of chemical properties.

station, the load was not to exceed 1 percent of the amount excavated. If these limits were exceeded for 14 consecutive days, then GE could be required to temporarily slow down operations.

2.5 Phase 2 Implementation

Revisions of the Residuals Standard for Phase 2 reduced the resuspension of PCBs during dredging. An automated station at Thompson Island was found to be unreliable due to fouling and was replaced with the Thompson Island buoy station. Apparent exceedances at that automated station prior to its replacement could not be confirmed. Aside from those readings from the automated station at Thompson Island, daily exceedances of the Resuspension Standard control level of 500 ng/L were rare during Phase 2 (Table A1-1): this happened on two occasions in 2010, during non-dredging periods, four days in 2012, one in 2013, and none in 2014 or 2015. The two exceedances in March 2010 occurred on high flow days, as did the exceedance in June 2013.

2.6 Deviations in Dredging Schedule and Sequence, Relative ROD Expectations

A number of modifications to the implementation of the remedial activities were made subsequent to the release of the 2002 ROD. The 2002 ROD modeling effort assumed dredging activities would begin in 2005 and be completed in 2009. However, due to delays not anticipated at the time of the 2002 ROD, dredging did not begin until 2009. OU2 dredging ended in October 2015 and backfilling and capping were completed in November 2015. This delay resulted in four unanticipated years of natural recovery of PCBs in the river sediments prior to commencement of dredging activities. As a result of this delay, and the longer-than-anticipated dredging period, the beginning of the post-dredging MNA recovery of water column and fish tissue PCB concentrations was delayed by six years. Presently, only one year of data (from 2016) is available post-dredging, and additional years of monitoring data will be required to sufficiently evaluate MNA trends following completion of dredging activities.

At the time of issuance of the ROD, the sequence of dredging was planned to be uniformly upstream to downstream throughout the course of the project, but dredging in upstream portions of River Section 1 and River Section 2 (RS 1 and RS 2, respectively), including an area upstream of CU1, the most upstream dredging target area in RS 1, did not occur until 2015, the final year of Phase 2. For this reason, the commencement of post-dredging recovery in River Sections 1 and 2 was delayed until the completion of Phase 2. This was contrary to the ROD expectation, which was that recovery in RS 1 would begin as soon as dredging moved downstream from RS 1 to RS 2, and that recovery in RS 2 would begin as soon as dredging moved from RS 2 to RS 3, all in an upstream-to-downstream fashion.

3 WATER COLUMN DATA DESCRIPTION

Water column concentration data derived from various sampling programs were combined to produce a single long-term database (1995 through present) of water column PCB concentrations, in the Upper Hudson River (UHR) for monitoring stations located near Thompson Island Dam (TID), Schuylerville, Stillwater and Waterford, and the Lower Hudson River for monitoring stations Albany and Poughkeepsie. Because different entities collected the data with different data quality objectives for each sampling program, the frequency and location of data collection varied across programs and years. In this section we provide a brief overview of the different datasets included in this appendix, including the entities that collected the data, the stations that were monitored, and the frequency of data collection. A more complete description of activities conducted during the Baseline Monitoring Program (BMP) and Remedial Action Monitoring Program can be found in Data Summary Reports submitted each year (General Electric 2005c, 2006a, 2007b, 2008c, 2009b, 2010c, 2011c, 2012e, 2013e, 2014d, 2015c, 2016d).

3.1 Thompson Island Dam

The dataset utilized in this appendix includes data collected in the vicinity of TID for the years 1997 through 2016 (Table A1-2). Data from 1997 to 2003 were collected by GE at station TID-PRW2 located at River Mile (RM) 188.4 as part of the Post-Construction Remnant Deposit Monitoring Program (PCRDMP) instituted following remedial work performed under the 1984 ROD (EPA, 1984).

As part of the remedial design to implement the 2002 ROD (EPA, 2002), GE initiated a BMP between 2004 and 2009. During the BMP, sample collection occurred weekly during the months of March to November. As was done for the Schuylerville and Waterford monitoring stations for 2009, BMP sampling also took place for approximately two months (March 3, 2009 to April 30, 2009) prior to commencement of 2009 Phase 1 dredging activities. For the BMP program, the location of the TID station moved to RM 187.5, slightly downstream of TID-PRW2. Grab sampling at this station was conducted from a boat at six equal discharge increment (EDI) stations placed along a transect located downstream of the southern tip of TID using a programmable, variable speed crane that lower a custom-designed multiple aliquot depth integrating sampler (MADIS).

Beginning in 2009, coincident with the onset of Phase 1 dredging, GE implemented the Remedial Action Monitoring Program (RAMP), which included near-field and far-field re-suspension monitoring during dredging activities, off-season (*i.e.*, no active dredging) water column monitoring as well as high flow sampling in the spring. RAMP samples were collected at TID every year between 2009 and 2016, with the exception of 2014, when no RAMP samples were collected. In 2010, no dredging activities took place in the UHR and only off-season monitoring took place at TID. Similarly, in 2012, only off-season monitoring took place at TID. Both automated and manual sample collection at TID were utilized for the RAMP program. The TID automated sample collection system was located in close proximity to the BMP transect and consisted of a sampler located along the western shore of the river with piping extended into the river, forming an EDI transect consisting of 5 intake ports. When far-field sampling took place during dredging activities, the automated station collected daily, 24-hour composite samples. During the off-season monitoring program, frequency decreased to either weekly grab or 24-hour composite samples from the automated sampler. In the spring of 2011, abnormal readings at the TID station resulted in ISCO samplers replacing the gravity feed valve systems that had been in place at TID, Schuylerville (Lock 5) and Waterford. In the spring of 2014, the TID automated sampling station was dismantled in order to permit dredging at the automated sampling location. For dredging activities in 2015, depth-integrated composite grab samples were collected from five EDI locations across the river approximately 1,000 feet downstream of the southern end of Thompson Island. Water column sampling at TID during 2016 was performed in the same manner as off-season monitoring during dredging activities. High flow samples were collected in 2010 and 2011 at TID.

3.2 Schuylerville (Lock 5)

The dataset utilized in this appendix includes data collected in the vicinity of Schuylerville (also referred to as Lock 5) for the years 1997 through 2016 (Table A1-3). Data collected between 1997 and 2003 were collected by GE as part of the PCRDMP that was instituted following remedial work performed under the 1984 ROD that covered the Remnant Deposits (EPA, 1984). Samples collected between 1997 and 2003 were collected at a station located at the Rt. 29 Bridge, located at RM 181.4.

As part of the remedial design to implement the 2002 ROD (EPA 2002), GE initiated a BMP between 2004 and 2009. Grab sample collection occurred weekly throughout the year during the BMP, as safety and weather conditions permitted. As was done for the Thompson Island and Waterford monitoring stations for 2009, BMP sampling also took place for approximately two months (March 3, 2009 to April 30, 2009) prior to commencement of 2009 Phase 1 dredging activities. For the BMP program, the location of the Schuylerville sample location remained at RM 181.4. Transect sampling at Schuylerville was conducted along the upstream side of the Rt. 29 Bridge at six EDI stations using a MADIS.

Beginning in 2009, coincident with the onset of Phase 1 dredging, GE implemented the RAMP, which included sampling related to near-field and far-field re-suspension monitoring during dredging activities, off-season (*i.e.*, when no active dredging is occurring) water column monitoring as well as high flow sampling in the spring. RAMP samples were collected at the Lock 5 Automated station every year between 2009 and 2016. In 2010, no dredging activities took place in the UHR and only off-season monitoring took place at Schuylerville. During the RAMP program, only automated sample collection occurred at Schuylerville. The Schuylerville automated sample collection system was located in close proximity to the BMP transect and consisted of a sampler located along the western shore of the river, with piping extended into the river, forming an EDI transect consisting of five intake ports. When far-field sampling took place during dredging activities, the automated station collected daily, 24-hour composite samples. During the off-season monitoring program, frequency decreased to either weekly grab or 24-hour composite samples from the automated sampler. During the 2013 season, dredging operations were occasionally conducted in relatively close proximity to Lock 5, and during these periods, with EPA approval, no far-field data was collected at this station. Water column sampling at Schuylerville during 2016 was performed under the off-season monitoring program using either the automated station to collect weekly 24-hour composite samples, or the MADIS to collect grab samples at the BMP station described above. High flow events were sampled at the Lock 5 automated stations in 2010, 2011, and 2013.

3.3 Stillwater

The dataset utilized in this appendix includes data collected in the vicinity of Stillwater for the years 1995 to 1997 and 2004 through 2016 (Table A1-4). Data collected between 1995 and 1997 were collected by the U.S. Geological Survey (USGS) as part of their water quality monitoring program (EPA 1995). USGS samples were grab samples collected at USGS gage station #01331095 located at RM 168.

As part of the remedial design to implement the 2002 ROD (EPA 2002), GE initiated a BMP between 2004 and 2009. Grab sample collection occurred from May through November. For the BMP program, the Stillwater sample location was located at RM 168.4. Sampling of this station was conducted from the County Rt. 125 Bridge using a programmable, variable speed crane or from a boat with a boat-mounted sampling crane.

Beginning in 2009, coincident with the onset of Phase 1 dredging, GE initiated the RAMP, which included sampling related to near-field and far-field re-suspension monitoring during dredging activities, off-season (*i.e.*, when no active dredging is occurring) water column monitoring, as well as high flow sampling in the spring. RAMP samples were collected at the Stillwater station every year between 2009 and 2016 with the exception of 2010, when no dredging activities took place in the UHR. As Stillwater was not used as an off-season monitoring station during Phase 1 or Phase 2 dredging activities, limited samples were collected at Stillwater in 2016. Both manual transect composite MADIS grab sampling and automated 24-hour sample collection occurred at Stillwater during the RAMP program. The Stillwater manual sampling collection was the same as used during the BMP above. For portions of 2013 and 2014, an automated sample collection system was deployed at RM 169.25, approximately 1 mile upstream of the BMP location, that consisted of four monitoring buoys deployed along a cross-river transect that contained sampling intake ports at mid-depth. During the dredging season in 2013 and 2014, automated 24-hour composite samples were collected daily at Stillwater using monitoring buoys deployed at RM 169.25, except that manual samples were collected using the MADIS on an intermittent basis. During the 2013 dredging season, the buoy-based station was sampled daily except from June 14 through 17 when the Stillwater manual station was sampled instead due to a high flow event that prevented safe access to the monitoring buoys. During the 2014 dredging season, the buoy-based station at RM 169.25 was sampled daily for far-field compliance. Manual samples were collected at Stillwater during the off-season.

3.4 Waterford

The dataset utilized in this appendix includes data collected in the vicinity of Waterford for the years 1995 to 1998, 2001, and 2004 through 2016 (Table A1-5). Data between 1995 and 2001 were collected by the USGS as part of their water quality monitoring program (EPA1995). USGS grab samples were collected at USGS gage station #01335770 located at RM 156.5.

As part of the remedial design to implement the 2002 ROD (EPA, 2002), GE initiated a BMP between 2004 and 2009. Grab sample collection occurred weekly throughout the year during the BMP, as safety and weather conditions permitted. As was done for the Thompson Island and Schuylerville monitoring stations for 2009, BMP sampling took place for approximately two months (March 3, 2009 to April 30, 2009) prior to commencement of 2009 Phase 1 dredging activities. For the BMP program, the Waterford sample location was located at RM 156, approximately 2 miles downstream of the USGS gage station at Lock 1. Sampling of this station was conducted from the upstream side of the Rt. 4 Bridge at five EDI locations placed along a transect using a programmable, variable speed crane to lower a custom-designed MADIS.

Beginning in 2009, coincident with the onset of Phase 1 dredging, GE implemented the RAMP, which included sampling at Waterford related to near-field and far-field re-suspension monitoring during dredging activities, off-season (*i.e.*, when no active dredging was occurring) water column monitoring, as well as high flow sampling in the spring.

RAMP samples at Waterford were collected from both automated and manual monitoring stations. The Waterford automated station was located upstream of the Rt. 4 Bridge and consisted of piping that extended from the sampling house on the west bank of the river to approximately the center of the river channel, though outside of the navigation channel. Concurrent sampling at the BMP location and the automated station was carried out in 2009 to compare PCB concentrations at both stations. It was determined that both stations provided comparable results and, based on this analysis, during Phase 2 the automated station was the primary sampling station at Waterford. At the automated station, water samples were collected using a programmable automatic sampler from a stilling well that is continuously supplied with river water through pumps mounted within the pump house. Waterford manual station samples were collected using the BMP method above.

Waterford far-field monitoring was carried out in 2009 and 2011 through 2015, as no active dredging took place in 2010. In portions of 2013, 2014 and 2015, Waterford was also used as a near-field resuspension monitoring station as dredging activities were within one mile of the Waterford station. Off-season monitoring took place in 2009 through 2016. When far-field sampling was taking place during dredging activities, the automated station collected daily, 24-hour composite samples. During the off-season monitoring program, collection decreased to either weekly grab or 24-hour composite samples from the automated sampler. In 2016, automated samples were collected at Waterford. After early February, samples consisted of grab samples using the MADIS.

Spring high flow sampling took place in 2009 through 2011, 2013 and 2014. High flow conditions are defined as flow at the USGS gauging station at Fort Edward, NY (Station ID: 01327750) exceeding 15,000 cubic feet per second (cfs) or peak flow at Waterford expected to reach 22,500 cfs. For high flow sampling, samples were either collected as 6-hour composite samples from the automated samplers or were collected at a centroid location from the Route 4 Bridge using a MADIS.

3.5 Lower Hudson River Stations

The dataset utilized in this appendix includes water column samples collected at two Lower Hudson River locations: the Albany manual station located at RM 145 and the Poughkeepsie manual station located at RM 75 (Table A1-6). At both of these locations, depth-integrated samples were collected during both the BMP and RAMP sampling programs from a single centroid location of the river using the custom-designed MADIS. During the BMP program, samples were collected at the Albany and Poughkeepsie stations on a monthly basis between May and November. Monthly sampling was continued during the RAMP between 2009 and 2016 as part of Phase 1 and Phase 2 dredging activities. During the off-season monitoring program (which included 2010 when no dredging activities took place, as well as in 2016 post-dredging), the Albany and Poughkeepsie stations were sampled on a monthly basis, as safety and weather conditions permitted.

In 2013, additional water column monitoring was conducted at the Albany station in response to elevated PCB concentrations measured at Waterford. Similarly, in 2013 during dredging of CU-99 and 100, the Albany station was monitored daily for informational purposes.

4 COMPARISON OF WATER COLUMN DATA AND LOADING ESTIMATES TO ROD EXPECTATIONS

The model development and calibration conducted for the 2002 ROD focused on the period prior to 1998. Water column data collected after the issuance of the ROD, as well as during the period from 1998 to 2002, can be compared to ROD expectations for three distinct periods:

1. an MNA period from 1998 to 2008,
2. the dredging period, from 2009 to 2015 (including a one-year pause in 2010), and
3. a post-dredging MNA period beginning in 2016.

When PCBs are released into the environment, various processes can alter the pattern of PCB congeners from the original Aroclors. Analytical techniques vary and have improved over time. Because older data were reported by groups of, or total, Aroclors, a translation method was developed for the Reassessment Remedial Investigation/Feasibility Study (RI/FS) to allow use of historical and recent data sets on a common basis of measurement. The parameter common to all data sets is Tri+ PCBs, which represents the sum of PCBs with 3 to 10 chlorine atoms per molecule, and accounts for almost all of the PCB found in fish. Modeling performed for the RI/FS and numeric remedial goals are stated in terms of Tri+ PCBs.

Figure A1-1 presents Tri+ PCB concentrations at four monitoring stations (TID, Schuylerville, Stillwater and Waterford, located at RM 187.5, RM 181.4, RM 168, and RM 156, respectively) for the years 1995 through 2016.

Figure A1-2 presents water column Tri+ PCB data for 2004-2016 for the two monitoring stations in the Lower Hudson River. The Albany monitoring station is at RM 145 and the Poughkeepsie station is at River Mile 75.

4.1 Pre-dredging MNA Period 1998-2008

The 1998 to 2008 time period, prior to Phase 1 dredging, provides an opportunity to evaluate natural recovery rates in the UHR in relation to the expectations of the ROD. The data points in blue in Figure A1-1 show water column Tri+ PCB data for monitoring stations at TID, Schuylerville, Stillwater, and Waterford for the period 1995-2008. (Figure A1-7, which is discussed in Section 5, shows similar trends for TPCBs.) In 1991-92, a gate failure at the Allen Mill, immediately adjacent to the GE Hudson Falls facility, caused new releases of PCBs into the Upper Hudson. During the following several years, elevated PCB concentrations were observed at Rogers Island due to ongoing releases from the mill. Remedial efforts by GE gradually decreased these releases, which were largely eliminated by April of 1995. Thus, the period from 1995 to 2008 represents a period of MNA subsequent to the Allen Mill event.

Apparent in the 1995 to 2008 period at each of the Upper Hudson monitoring stations, the data exhibit a characteristic seasonal trend, cycling between the lowest concentrations in winter and the highest concentrations in late spring and early summer. The greater releases during late spring and early summer are thought to reflect a combination of increased biological activity in sediments, which promotes mixing of PCBs in the upper sediment layer; weaker sorption of PCBs to sediment solids at higher temperatures; and greater groundwater flux through sediments (EPA 2000f [Section 6, pp. 113-114]). Data at each of the four stations also show declining concentrations on a decadal time scale, confirming the long-term attenuation that was anticipated in the ROD for MNA periods. Rates of attenuation for 1995-2008 were estimated by fitting an exponential decline to the data at each station. This produced the following data-based estimates of water column PCB attenuation rates, shown with 95 percent confidence intervals:

- 9.7 percent +/- 1.9 percent per year at TID,
- 13.1 percent +/- 2.0 percent per year at Schuylerville,
- 4.5 percent +/- 1.7 percent per year at Stillwater, and
- 6.3 percent +/- 1.7 percent per year at Waterford.

Pre-dredging data (2004-2008) for the two Lower Hudson River stations are shown in Figure A1-2. These data are sparser than Upper Hudson water column data for the same period: data for both Lower Hudson stations typically include one sampling event per month for May through November of each year, with no data for the other months of the year. This lack of cold weather data obscures the seasonality of concentrations that is expected, based on patterns seen in the Upper Hudson data in Figure A1-1.

EPA's expectations for water column PCB attenuation were based in part on EPA's mechanistic PCB fate and transport model, HUDTOX. HUDTOX was constrained through calibration to UHR data for the period 1977-1997 (EPA 2000f). That long-term historical calibration of HUDTOX to all the available data provided the foundation for its use, in combination with the food chain PCB model FISHRAND, in forecasting long-term responses to remedial alternatives in the RI/FS. HUDTOX and FISHRAND were subject to a rigorous peer review by a panel of international experts (ERG, 2000). After extensive document review and a series of public meetings, the modeling peer review panel determined that the models were acceptable and adequately reproduced historical data. The panel noted that the models did not reflect a fully mechanistic understanding of all chemical, physical, and biological processes, and expressed concern about the uncertainty in the models' forecasts**.** In its Response to Peer Review Comments, EPA acknowledged uncertainties in the models, but stated its belief that it had a sufficient understanding of the system on which to base a decision for the Site.

HUDTOX simulations of remedial alternatives required an assumed long-term series of daily future flows, so for the RI/FS, a representative series was constructed from prior years' flow records. This was appropriate because actual flows cannot be known in advance, but differences between simulated and actual outcomes on any given date resulted, based in part on differences in assumed and actual flows for that date. In order to eliminate this bias in comparing actual 1998-2008 MNA conditions to ROD expectations, EPA adjusted its HUDTOX simulations through 2008, using observed Hudson River flows for the period as inputs to the model. These calculations were originally included on a limited basis as part of the EPA Phase 1 Evaluation Report (EPA 2010a), and are provided in greater detail here. The adjusted simulations also include estimated tributary flows and solids loads for this period, using the same methods that were developed when HUDTOX was built and calibrated. Note that these adjustments do not represent any revision to the HUDTOX and FISHRAND models themselves, but rather just a change to the input conditions for the models.[4] Figure A1-3 compares simulated water-column concentrations at the four UHR sampling locations to available data for 1998-2008. The model-data comparison shows the HUDTOX simulation of water column PCBs to be generally faithful to both seasonal and long-term trends in water-column PCBs for the full period, including the intensive data collection period of 2004-2008, which were the final 5 years of an 11-year simulation.

Table A1-7 presents average annual Tri+ PCB concentrations for the ROD MNA forecast and the MNA forecast with updated flows and solids, both for the period 1998-2008. Both series are augmented with HUDTOX calibration results for 1995-1997 for comparability to the 1995-2008 data shown in this appendix. Rates of exponential decay for the period 1995-2008 are fit to each series and also shown in Table A1-7.

The ROD model forecast decay rates between 9.6 percent and 10.6 percent for all four stations. These model estimated decay rates are comparable to the data-based rates for TID (9.7 percent +/- 1.9 percent) and Schuylerville (13.1 percent +/- 2.0 percent) shown above in this section, and somewhat faster than the data-based rates estimated for Stillwater (4.5 percent +/- 1.7 percent) and Waterford (6.3 percent +/- 1.7 percent) for 1995-2008.

The updated HUDTOX MNA model forecast slightly faster decay at TID and Schuylerville and slightly slower decay at Stillwater and Waterford than the ROD MNA version of the model. Decay rates at TID remain similar to the data-based rates, and like the ROD MNA

[4] Note that the EPA models were not designed for, nor capable of, predicting weather-dependent future hydrodynamic conditions in the river. The information used in the original analysis was a sampling of the long term flow records and associated external solids loads, which would be expected to match the long term average flow conditions and solids delivery over the entire period of simulation. However, this approach would not be expected to match the daily flow conditions for any given date or the average annual flow for any year. This is directly related to knowing the average annual rainfall for the region but not being able to predict the occurrence or the amount of rainfall for a given day or given year. Thus, to evaluate the true performance of the models against the PCB conditions they were designed to simulate, the model simulations were adjusted to incorporate the actual hydrologic conditions.

version of HUDTOX, forecasted rates at Stillwater and Waterford are somewhat faster than the data-based recovery estimates.

For the RI/FS, a model of the Lower Hudson River developed by Dr. Kevin Farley of Manhattan College and colleagues (Farley et al. 1999) was used to simulate water column and surficial sediment concentrations below Federal Dam. Simulated HUDTOX flow and Tri+ PCB load outputs at the model's downstream boundary (Federal Dam at Troy) were used as inputs to the Farley model. Water column and sediment PCB concentrations simulated by the Farley model were used as inputs to the food web model FISHRAND, which generated fish tissue forecasts for Lower Hudson River stations.

As with HUDTOX, Farley model forecasts made as part of the RI/FS were driven by a synthetic series of flows and associated solids loads. To eliminate this source of error in the MNA forecast, EPA has rerun the Farley model through 2008 using flows and loads from HUDTOX that reflect actual UHR flows and associated tributary flow and solids load estimates. The resulting Tri+ PCB forecasts are compared to data for 2004-2008 at Albany and Poughkeepsie in Figure A1-4.

Figure A1-4 shows that simulated Tri+ PCB at Albany, which is in the first model segment downstream from Troy, are in close agreement with 2004-2008 data. The model-data comparison for Poughkeepsie shows that the Farley model systematically under-predicts Tri+ PCB at this station for the period 2004-2008. These simulated concentrations serve as inputs to FISHRAND, so that the downward bias would tend to also bias FISHRAND fish tissue predictions downward for the same period at mid-Hudson Stations near Poughkeepsie.

Concentrations measure potential water column exposures per unit volume of water, while loadings express the mass of a contaminant transported downstream per unit time, computed as flow times concentration. Estimated loadings at Waterford for the period 1998-2008 were calculated and are shown in Table A1-8.

The estimates in Table A1-8 combined daily monitored flow data for 1998-2008 with PCB data collected on a subset of those days, using the Beale's Ratio Estimator method to impute loads as a function of flow on any days that PCB concentration data were not collected. Because of the imputation of loads for unsampled days and variability associated with the choice of imputation method and the representativeness of the available data, the baseline loading estimates in Table A1-8 are subject to uncertainty, and this is reflected in the coefficients of variation reported in Table A1-8. While the USGS collected data for the years 1999 and 2000, loads for these years were not calculated. This is because data from these years are clear outliers from the rest of the available data for this station and were similarly excluded from trend analysis in EPA's Phase 1 Evaluation Report Addendum (EPA 2010a). While the reason these years are outliers is unknown, it may be due to changes in analytical procedures that the USGS implemented in 1999.

Table A1-8 also compares HUDTOX load predictions to the empirical load estimates, using the HUDTOX MNA forecasts as performed for the ROD and updated with actual flows and associated solids estimates. Neglecting 1999-2000, where data concerns render the empirical loading estimates unreliable, the use of updated flows rendered HUDTOX predictions closer to the empirical load estimates for most years. The updated HUDTOX model produced high predictions for 1998, relative to the empirical estimate, and under-predicted the load at Waterford in the other years shown. The largest differences between simulated loads, using updated HUDTOX and empirical load estimates, are seen during the final three years of the pre-dredge MNA period (2006-2008).

4.2 Dredging Period, 2009-2015

With respect to PCB concentrations, the ROD anticipated localized temporary increases in suspended PCB concentrations in the water column, and possibly in fish PCB body burdens, as a result of dredging activities (EPA 2002, p. 85):

> … the release of PCBs from the contaminated sediments into the surface water during construction (dredging and cap placement), will be controlled by operational practices (*e.g.*, control of sediment removal rates, use of environmental dredges and

use of sediment barriers). Although precautions to minimize resuspension will be taken, it is likely that there will be a localized temporary increase in suspended PCB concentrations in the water column and possibly in fish PCB body burdens. Analysis of yearly sediment resuspension rates, as well as resuspension quantities during yearly high flow events, shows the expected resuspension due to dredging to be well within the variability that normally occurs on a yearly basis. The performance standards and attendant monitoring program that are developed and peer reviewed during design, will ensure that dredging operations are performed in the most efficacious manner, consistent with the environmental and public health goals of the project.

As noted in this ROD excerpt, EPA's expectations of resuspension were predicated on an engineering analysis of yearly resuspension rates expected during the dredging period. This analysis assumed a PCB mass to be dredged and a schedule of removal, as expected at the time of the ROD. In fact, the actual inventory of PCBs removed was much greater than anticipated at the time of the ROD, and there were deviations from the upstream-to-downstream pattern of dredging anticipated at the time of the ROD. Ideally, dredging proceeds in an upstream-to-downstream sequence to avoid recontamination of dredged areas, whereas resuming dredging in an upstream location potentially promotes resuspension of PCBs in a river reach that would otherwise be recovering.

The resuspension analysis also assumed

- that resuspended PCBs would be associated primarily with resuspended solids,
- that those solids would have the same PCB concentrations as the dredged material,
- that resuspended solids would compose less than 0.3 percent solids dredged, and
- that the only PCBs that would be transported to far-field locations would be those associated with fine solids removed by dredging (EPA 2000b).

The data points that are shown in orange in Figure A1-1 show water column Tri+ PCB concentrations at the UHR stations during the dredging period 2009-2015. (Figure A1-7 shows similar trends for TPCBs and is discussed in Section 5.) Figure A1-1 shows, contrary to ROD expectations, that the upper range of elevated PCBs during dredging at these four stations did exceed the variability that normally occurs on an annual basis (where normal annual variability is reflected in the blue pre-dredging data series). Notably, this was true not only for the Phase 1 and Phase 2 dredging periods, but also to a lesser degree for 2010, a pause year between the Phase 1 and Phase 2 dredging periods. (Figure A1-5 spotlights water column concentrations from 2008-2016 to highlight the dredging period, also including one year before and one year after dredging to permit comparison to non-dredging conditions.) The data suggest that Phase 1-redeposited sediments remained susceptible to resuspension early in 2010. Figure A1-5 also indicates that resuspended PCBs were mobile throughout the Site: in particular, monitoring at Waterford showed elevated PCBs throughout Phases 1 and 2, although dredging did not reach River Sections 2 and 3 until 2013, the third year of Phase 2 dredging.

In Phase 1, a Resuspension Standard seasonal net load criterion of 117 kilograms per year (kg/yr) TPCBs loading was exceeded at all three monitoring stations (EPA, 2012). For Phase 2, the Resuspension Standard was revised to 1 percent of mass removed, tracked as 7-day running averages of Tri+ PCBs attributable to dredging activities, as monitored at Waterford, consistent with the recommendation of the Peer Review Panel. Net loads due to dredging were computed relative to estimated annual loads at Waterford for 2005-2008 by calculating the 7-day average net load and seasonal (cumulative) load of Tri+ PCBs as specified in the Revised EPS for Phase 2 (EPA, 2010d). Because 2004 sampling started in June, data for 2004 were excluded from the estimation of annual baseline loads for the purpose of computing net loads attributable to dredging.

The remedy was in compliance during all five years of the Phase 2 period. This is shown in Table A1-9. The Phase 2 Resuspension Standard also included a TID load criterion of 2 percent of mass removed, but the TID station was abandoned in spring of 2012 because of evidence of unreliable data obtained during the first year of Phase 2.

Figure A1-2 shows measured concentrations in the Lower Hudson during the dredging period, shown in orange as in Figure A1-1, as monitored at Albany and Poughkeepsie. The

Albany data show some dredging impacts, with peak concentrations during the dredging period exceeding the maxima observed during the pre-dredge period (shown in blue). The Poughkeepsie data do not, indicating that water column concentrations at Poughkeepsie are regulated by local conditions.

A number of special studies were designed to investigate the impact of dredging on downstream transport of PCBs in the water column. The 2011 Special Study on PCB Release, Fate, and Transport (Felty, 2011) indicated that dissolved PCB concentrations were generally higher than water column concentrations of PCBs associated with suspended particulate matter. At low flows, dissolved PCBs were approximately ⅔ of the PCB mass in the water column measured immediately downstream of dredging, and approximately ½ of the mass at higher flows. Truly dissolved PCBs are readily bioavailable, so this finding of elevated dissolved PCB concentrations indicated the potential to impact local aquatic organisms, particularly in the vicinity of dredging activities. As noted above and despite the occurrence of high dissolved-phase concentrations, the dredging activities still met the 2010 RevisedEPS (EPA, 2010d) for both water column PCB concentrations and PCB loads for the entire Phase 2 period.

In 2011-2013, GE conducted a deposition study in River Section 1 (DeSantis, 2011; EPA 2012) as required by the 2010 Revised EPS. Surface sediment samples were collected using a transect approach that targeted sediments from 0 to 2 inches within the dredging prisms and in areas outside of the dredging prisms, including samples taken before and after dredging, to assess the impact of dredging activities on localized redistribution of PCB-contaminated sediments downstream of dredging activities. For both RS 1 and RS 2 and for locations inside and outside of the CUs, there was no discernable change in the average TPCB concentration in the 0-2 inch layer between the June and November sampling events. This set of observations suggests that dredging-related resuspension did not have a measurable impact on surface sediment concentrations, even though water column data showed far-field transport of resuspended PCBs.

4.3 Post-dredging MNA Period, 2016

Data points in green in Figures A1-1 and A1-5 show 2016 water column Tri+ PCB concentrations for the four UHR monitoring stations, and show that water column Tri+ concentrations were visibly lower in 2016 than during the dredging period, and also lower than in 2008, the last year prior to dredging. To make the latter comparison more clearly, Figure A1-6 arrays 2016 data by day of the year against Tri+ water column concentrations from 2004-2008, in order to standardize for seasonal fluctuations in water column concentrations. For TID, Schuylerville, and Waterford, Figure A1-6 shows that the improvement in water column concentrations between the BMP (2004-2008) and post dredging (2016) was particularly marked in the warmer months: with a few exceptions, 2016 water column concentrations sampled between May and September, when concentrations tend to be highest, clustered at the bottom of the range seen in 2004-2008. The curved lines shown on the charts represent LOESS fits[5] to the data to represent the variation in concentration through time. The red curve, representing 2004 to 2008, also includes a 95 percent confidence interval about the curve. These curves are intended to aid in visual interpretation of the data and are not used for rigorous statistical analysis in this appendix. From these diagrams, it is evident that 2016 conditions in early summer are about two to three times lower than average conditions during the BMP. It can also be seen that differences between 2016 and 2004-2008 concentrations were smaller in the cooler months, when concentrations tend to be lower. An exception to the seasonal and temporal trends was a spike in 2016 concentrations at Waterford that was measured during elevated flows on February 25th and 26th (9,370 and 11,700 cfs, respectively, according to provisional USGS flow data for Fort Edward), when redeposited sediments generated in the prior year may still have been available for resuspension. Stillwater[6] data for 2016 were collected in February and March, whereas 2004-2008 data were collected later in the year, so no direct comparison between 2016 and 2004-2008 is possible for Stillwater.

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5 The regression fits were carried out using the LOESS method, which uses a locally-weighted polynomial regression model to fit a line to the data points.

6 As Stillwater was not used as an off-season monitoring station during Phase 1 or Phase 2 dredging activities, limited samples were collected at Stillwater in 2016.

Data collected in 2016 establish a post-dredging baseline against which ROD expectations for recovery can be compared. Table A1-10 presents HUDTOX modeling forecasts for water column Tri+ PCB concentrations the first year after dredging (envisioned in the ROD to occur in 2010), under the Selected Remedy (Source: unpublished HUDTOX simulation of preferred remedy). Concentrations in 2016 at TID, Schuylerville, Stillwater, and Waterford were generally consistent with ROD expectations for the first post-dredging year: Table A1-10 shows that average and median values for 2016 at each station were generally consistent with ROD expectations. Notably, the measured mean values for Thompson Island and Waterford include the ROD-expected value within their 95 percent confidence intervals (mean ± 2* standard error). The mean concentration at Waterford (9.3 ng/L) exceeded the ROD mean expectation (6.6 ng/L), but much of the difference was due to the elevated concentrations during the February event: for the remainder of the year following that event, March 1-December 31, 2016, the average of measured concentrations at Waterford was 7.6 ng/L.

For TID, Schuylerville, and Waterford, the sample collection included more than 30 samples for each station, resulting in the summary statistics shown. Summary statistics were not produced for Stillwater because only three 2016 samples were obtained. Additionally, the 2016 Stillwater data were collected in February and March, when relatively low concentrations are expected due to low water temperatures, so the Stillwater averages cannot be interpreted as representative of the full year 2016. The reduced concentrations at Waterford after the late February 2016 event are also reflected in the loading estimate for 2016, shown in Table A1-11. Using AutoBeale, the estimated load at Waterford for 2016 is 63 kg, with a Root Mean Squared Error of 10 kg. This is very similar to the predicted load in a simulation of the preferred remedy for the RI/FS, where HUDTOX predicted a Tri+ PCB load of 60 kg for the first year after dredging (then expected to be 2010). More than half of the estimated loading occurred during the first two months of 2016, when redeposited sediments from dredging may have been susceptible to resuspension during the late February event. Even considering the full year, the estimated

2016 Tri+ PCB load at Waterford of 63 kg was much less than the estimated 2004-2008 Baseline loads at the same location, which ranged from 103 to 174 kg (see Table A1-8).

The 2002 ROD (p. 77) anticipated that post-dredging MNA would lead to water column Tri+ PCB concentrations of approximately 5 ng/L at TID and Schuylerville in 2067, the end of the HUDTOX forecast period in the ROD. Table A1-12 presents projected year for concentrations at the four UHR water column monitoring stations to decline to 5 ng/L, assuming attenuation rates of 1, 3, 6, and 14 percent per year. These recovery rates encompass the attenuation rates for all four stations estimated in Section 4-1 above, using observed data for the 1995-2008 pre-dredging MNA period. Table A1-11 assumes the 2016 data-based averages shown in Table A1-10 as starting points for post-dredging MNA.

Table A1-12 shows that water column concentrations would fall to 5 ng/L sooner than 2067 (by 2036) at TID and by 2067 at Schuylerville, if one assumes a post-dredging MNA recovery rate of 1 percent per year. This recovery rate would be well below the rates estimated above for these stations, using the observed data for the 1995-2008 pre-dredging MNA period. With a recovery rate of 3 percent, lower than any of the water column recovery rates estimated in Section 3-1, concentrations at TID and Schuylerville would still reach 5 ng/L decades before 2067.

Time to reach 5 ng/L can also be projected for Waterford, conservatively using 2016 averages that include the elevated February 2016 concentrations, and assuming a range of recovery rates. With a 1 percent per year recovery rate, concentrations at Waterford would reach 5 ng/L by 2078, and would reach that level much sooner with recovery rates of 3 percent or better. As noted above, data representative of the full year 2016 are not available for Stillwater, so years to reach 5 ng/L as an annual average at Stillwater are not estimated in Table A1-12.

5 COMPARISON OF WATER COLUMN TPCBs TO ARARs

As noted above, the RAOs also include four non-waived ARARs expressed in terms of TPCBs. Figure A1-7 shows the time trend in TPCBs at the four Upper Hudson monitoring stations from 1995-2016, computed as the sum of Aroclors. These trends are similar to those observed in Tri+ PCB concentrations. Although the trends are similar, the TPCB concentrations are not consistently determined through time. For example, at Waterford the USGS data from 1995 to 2001 did not measure Aroclors that represented the monochloro and dichloro congeners accurately. TPCB values are estimated by simply multiplying the Tri+ PCB value by a constant derived from earlier EPA studies. There are also potential issues with the GE monochloro and dichloro congener quantitation, particularly in the earlier years. As a result, EPA did not estimate an independent rate of decline for TPCB concentrations for water column stations. However, given the close correlation between Tri+ PCB and TPCB in both sediment and water, and that Tri+ PCB comprises a large fraction of the TPCB in these matrices, EPA expects that the rate of decline for TPCBs in the water column of the Hudson will be similar to the rates observed for Tri+ PCBs.

Figure A1-8 compares 2016 TPCB data by calendar date to data for 2004-2008, similarly to Figure A1-6, in order to standardize for seasonal fluctuations in the water column concentrations. As was done for Figure A1-6, LOESS curves are added to facilitate comparison between the 2016 and the BMP data. Similar to Figure A1-6 for TID, Schuylerville, and Waterford, Figure A1-8 shows that the improvement in water column TPCB concentrations between 2008 and 2016 was particularly marked in the warmer months. With a few exceptions, 2016 water column TPCB concentrations sampled between May and September, when concentrations tend to be highest, clustered at the bottom of the range seen in 2004-2008. As compared to the Tri+ PCB data, the TPCB concentrations appear to have declined for a larger portion of the year, as indicated by the decreased degree of overlap of the LOESS curves and uncertainty bands for more of the year in the TPCB plots. Like the Tri+ PCB data, absolute differences were smaller in the cooler months, when concentrations tend to be lower. Stillwater data for 2016 were collected in February and March, whereas 2004-2008 data were collected later in the year, so no direct comparison between 2016 and 2004-2008 is possible for Stillwater. For the three stations with sufficient records, Figures A1-6 and A1-8 show that water column concentrations have substantially decreased relative to observations during the BMP period. This suggests that the impact of any dredging-related PCB releases on water column concentrations has substantially dissipated. EPA intends to require continued monitoring, as described in the Operations, Maintenance, and Monitoring (OM&M) plan described in the Revised EPS (EPA, 2010).

5.1 Federal MCL for Drinking Water (500 ng/L TPCBs)

Figure A1-1 shows that this threshold was exceeded on occasion at each of the four stations during dredging, but was not exceeded during 2016 at any of the stations, or during the prior MNA period from 1995-2008. It is expected that this ARAR will be met consistently in the future.

5.2 New York State Standard for Protection of Human Health and Drinking Water Sources (90 ng/L)

This criterion was not exceeded at any station in 2016, although it was exceeded at times during the prior 1995-2008 MNA period, and regularly during dredging. Based on 2016 data, it is expected that this ARAR will be met consistently in the future.

5.3 Criterion Continuous Concentration (CCC) Federal Water Quality Criterion (FWQC) for Freshwater (14 ng/LTPCBs)

This criterion was routinely exceeded prior to 2016, during both the pre-dredging MNA period and the dredging period. During 2016, the majority of TPCB samples were below this threshold at Thomson Island Dam, Schuylerville, and Waterford, while all three observations at Stillwater were below 14 ng/L. Based on 2016 data and past evidence of recovery trends during MNA periods, it is expected that this ARAR will be met consistently within several decades.

5.4 Criterion Continuous Concentration (CCC) Federal Water Quality Criterion (FWQC) for Saltwater (30 ng/L TPCBs)

The upstream limit of salt intrusion in the Hudson River depends on flows rates and tides, but is typically far downstream of Federal Dam in Troy, and the Mohawk River dilutes flows between Waterford and Federal Dam. The monitoring data shown for Waterford in Figure A1-1 are therefore conservative overestimates of TPCB concentrations encountered by aquatic organisms in salt water due to loadings from the Upper Hudson. While 30 ng/L was routinely exceeded at Waterford prior to 2016, during both the pre-dredging MNA period and the dredging period, it was exceeded at that location on only three sampling occasions in 2016. Based on 2016 data, past evidence of recovery trends during MNA periods, and the effect of dilution by the Mohawk River between Waterford and Troy Dam, it is expected that this ARAR will be met consistently in the future. In addition, there have been no exceedances of the 30 ng/L criterion at Poughkeepsie in 2014-2016 monitoring (as shown in Figure A1-2), and only two exceedances at this location in the 2004-2016 period of record, further reinforcing the expectation that this criterion will be met consistently in the future.

6 SUMMARY AND CONCLUSIONS

Major conclusions of this appendix are as follows:

<u>Pre-dredging period (through 2008)</u>:

- Estimated UHR water column PCB attenuation rates for the pre-dredging period 1995-2008, shown with 95 percent confidence intervals, are:
  - 9.7 percent +/- 1.9 percent per year at TID,
  - 13.1 percent +/- 2.0 percent per year at Schuylerville,
  - 4.5 percent +/- 1.7 percent per year at Stillwater, and
  - 6.3 percent +/- 1.7 percent per year at Waterford.
- HUDTOX simulations of water column PCBs for the 1998-2008 pre-dredging period, using updated flows and loads reflecting actual conditions for those years, are generally faithful to both seasonal and long-term trends in water-column PCBs for the UHR.
- Simulated Tri+ PCBs at Albany, using the Farley model with updated flows and loads from HUDTOX, are in close agreement with 2004-2008 pre-dredging data. For Poughkeepsie, the updated Farley model systematically under-predicts Tri+ PCB for the period 2004-2008. This would tend to also bias FISHRAND fish tissue predictions downward for the same period at mid-Hudson stations near Poughkeepsie.
- The updated HUDTOX model produced high Tri+ PCB loading predictions at Waterford for 1998, relative to an empirical estimate, and under-predicted the load at Waterford for the other years during the period 1998-2008 for which reliable empirical estimates could be produced. The largest differences between those simulated loads and empirical load estimates occur during the final three years of the pre-dredge MNA period (2006-2008).

Dredging period (2009-2015):

- Contrary to ROD expectations for the dredging period, the upper range of elevated water-column PCBs during dredging at the four UHR monitoring stations exceeded the variability that normally occurs on an annual basis. This was true not only for the Phase 1 and Phase 2 dredging periods, but also to a lesser degree for 2010, a pause year between the Phase 1 and Phase 2 dredging periods.
- Nevertheless, with Phase 2 operational controls in place, the remedy was in compliance with the Phase 2 net load performance standard during all five years of the Phase 2 period.
- With respect to the Lower Hudson, Albany dredging-period data show some dredging impacts, with peak Tri+ PCB concentrations during the dredging period exceeding the maximum values observed during the pre-dredging period, Poughkeepsie data do not exhibit this elevated pattern during dredging, indicating that water column concentrations at Poughkeepsie are regulated by local conditions.

Post-dredge period (2016):

- Upper Hudson water column Tri+ concentrations were visibly lower in 2016 than during the dredging period, and also lower than in 2008, the last year prior to dredging. Concentrations in early summer were about two to three times lower than average conditions during the BMP. Differences between 2016 and 2004-2008 concentrations were smaller in the cooler months, when concentrations tend to be lower. An exception to the seasonal and temporal trends was a spike in February 2016 concentrations at Waterford that was measured during elevated flows, when redeposited sediments generated in the prior year may still have been available for resuspension.
- Concentrations in 2016 at TID, Schuylerville, Stillwater, and Waterford were generally consistent with ROD expectations for the first post-dredging year. The mean concentration at Waterford exceeded the ROD mean expectation, but much of the difference was due to elevated concentrations during the February event.

- The estimated load at Waterford for 2016 was very similar to the predicted load for the first post-dredging year in a simulation of the preferred remedy for the RI/FS. More than half of the estimated loading occurred during the first two months of 2016, when redeposited sediments from dredging may have been susceptible to resuspension during the late February event. Even considering the full year, the estimated 2016 Tri+ PCB load at Waterford was much less than each of the estimated 2004-2008 baseline loads at the same location.
- The ROD expressed the expectation that post-dredging MNA would lead to water column Tri+ PCB concentrations of approximately 5 ng/L at TID and Schuylerville in 2067. Assuming a recovery rate of 3 percent, which is lower than any of the water column recovery rates estimated for the pre-dredging MNA period, concentrations at TID and Schuylerville would reach 5 ng/L decades before 2067.
- Trends in water column TPCB concentrations are similar to those observed in Tri+ PCB concentrations, although TPCB concentrations are not consistently determined through time, complicating evaluation of long-term trends. Nevertheless, given the close correlation between Tri+ PCB and TPCB in both sediment and water, and the fact that Tri+ PCB comprises a large fraction of the TPCB in these matrices, EPA expects that the rate of decline for TPCBs in the water column of the Hudson will be similar to the rates observed for Tri+ PCBs.
- It is expected that all non-waived ARARs will be met consistently in the future, based on comparisons of recent monitoring data, including 2016, to relevant criteria.

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Final Second Five-Year Review Report for the Hudson River PCBs Superfund Site

APPENDIX 1

EVALUTION OF WATER COLUMN PCB CONCENTRATIONS AND LOADINGS

Tables and Figures

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April 2019

Date	Location	Total PCB Concentration (ng/L)	Dredging Activity	Flow at Fort Edward (cfs)
March 24, 2010	Waterford	1890	No dredging	20,700
March 25, 2010	Schuylerville	560	No dredging	16,500
August 2-3, 2012	Schuylerville	511.9	Dredging in CU 38	2,690-2,650
August 3-4, 2012	Schuylerville	780.1	Dredging in CU 38	2,650-2,470
August 4-5, 2012	Schuylerville	693.8	No dredging	2,470-2,540
September 16-17, 2012	Schuylerville	594.4	Dredging in CUs 43,44, and 45	2,250-2,290
June 11-12, 2013	Stillwater	561.8	Dredging in CUs 55, 67, 68,69, and 70	11,900-15,200

Confirmed Exceedances of 500 ng/L Total PCB Control Level During 2010-2015

Table A1-1

April 2019

Year	Collection Agency (Program)	Station Used	TID No. of Samples	No. of High Flow Events	Sampling Method
1995					
1996					
1997	GE (PCRDMP)	TID-PRW2 (RM188.4)	18		Single Point Center Channel Grab Sample
1998	GE (PCRDMP)	TID-PRW2 (RM188.4)	42		Single Point Center Channel Grab Sample
1999	GE (PCRDMP)	TID-PRW2 (RM188.4)	42		Single Point Center Channel Grab Sample
2000	GE (PCRDMP)	TID-PRW2 (RM188.4)	31		Single Point Center Channel Grab Sample
2001	GE (PCRDMP)	TID-PRW2 (RM188.4)	41		Single Point Center Channel Grab Sample
2002	GE (PCRDMP)	TID-PRW2 (RM188.4)	33		Single Point Center Channel Grab Sample
2003	GE (PCRDMP)	TID-PRW2 (RM188.4)	6		Single Point Center Channel Grab Sample
2004	GE (BMP)	Thompson Island (RM 187.5)	26	No High Flow Samples	June - Nov weekly transect-composite MADIS samples
2005	GE (BMP)	Thompson Island (RM 187.5)	35	No High Flow Samples	March - Nov weekly transect-composite MADIS samples
2006	GE (BMP)	Thompson Island (RM 187.5)	35	No High Flow Samples	March - Nov weekly transect-composite MADIS samples
2007	GE (BMP)	Thompson Island (RM 187.5)	30	No High Flow Samples	March - Nov weekly transect-composite MADIS samples
2008	GE (BMP)	Thompson Island (RM 187.5)	37	No High Flow Samples	March - Nov weekly transect-composite MADIS samples
2009	GE (BMP), GE (RAMP)	TID Automated Station, TID Manual Station, Thompson Island (RM 187.5)	279	No High Flow Samples	March - April weekly transect-composite MADIS samples (BMP); Daily 12 and 24-hr composite samples (In-Season); Weekly transect-composite MADIS samples (Off-Season)
2010	GE (RAMP)	TID Automated Station	97	3 High Flow Events (43 samples)	Weekly transect-composite grab samples (Off-Season); 6-hour composite samples (High Flow)
2011	GE (RAMP)	TID Automated Station , TID Manual Station	220	4 High Flow Events (19 samples)	Weekly grab or 24-hour transect-composite samples (Off-Season); Daily transect-composite MADIS or 24-hr transect-composite samples (In-Season); 6 and 24-hour composite samples (High Flow)
2012	GE (RAMP)	TID Automated Station	24	No High Flow Samples	Weekly 24-hour transect-composite samples (Off-Season); Daily 24-hour transect composite samples were collected as part of Near Field monitoring during a portion of the month of November (In-Season)
2013	GE (RAMP)	TID Automated Station	25	No High Flow Samples	Not used for Far Field monitoring in 2013; Weekly 24-hour transect-composite samples (Off-Season)
2014	GE (RAMP)	TID Automated Station	2	No High Flow Samples	Weekly transect-composite samples (Off-season)
2015	GE (RAMP)	TID Manual Station	13	No High Flow Samples	Weekly transect-composite MADIS samples (In-Season and Off-Season)
2016 [1]	GE (RAMP)	TID Manual Station	27	No High Flow Samples	Weekly transect-composite MADIS samples (Off-Season)

[1]: 2016 water column data reflects samples collected through September 2016.

Hudson River PCBs SUPERFUND SITE

Water Column Data Description for Thompson Island Dam (TID) Station

Table A1-2

April 2019

Year	Collection Agency (Program)	Station Used	Schuylerville No. of Samples	No. of High Flow Events	Sampling Method
1995					
1996					
1997	GE (PCRDMP)	Rt.29 Br. (RM 181.4)	16		Single Point Center Channel Grab Sample
1998	GE (PCRDMP)	Rt.29 Br. (RM 181.4)	61		Single Point Center Channel Grab Sample
1999	GE (PCRDMP)	Rt.29 Br. (RM 181.4)	48		Single Point Center Channel Grab Sample
2000	GE (PCRDMP)	Rt.29 Br. (RM 181.4)	45		Single Point Center Channel Grab Sample
2001	GE (PCRDMP)	Rt.29 Br. (RM 181.4)	61		Single Point Center Channel Grab Sample
2002	GE (PCRDMP)	Rt.29 Br. (RM 181.4)	51		Single Point Center Channel Grab Sample
2003	GE (PCRDMP)	Rt.29 Br. (RM 181.4)	16		Single Point Center Channel Grab Sample
2004	GE (BMP)	Schuylerville (Transect) (RM 181.4)	28	No High Flow Samples	June - Dec weekly transect-composite MADIS samples
2005	GE (BMP)	Schuylerville (Transect) (RM 181.4)	43	No High Flow Samples	Year-round weekly transect-composite MADIS samples
2006	GE (BMP)	Schuylerville (Transect) (RM 181.4)	50	No High Flow Samples	Year-round weekly transect-composite MADIS samples
2007	GE (BMP)	Schuylerville (Transect) (RM 181.4)	42	No High Flow Samples	Year-round weekly transect-composite MADIS samples
2008	GE (BMP)	Schuylerville (Transect) (RM 181.4)	39	No High Flow Samples	Year-round weekly transect-composite MADIS samples
2009	GE (BMP), GE (RAMP)	Lock 5 Automated Station, Schuylerville (Transect) (RM 181.4)	241	No High Flow Samples	March - April weekly transect-composite MADIS samples (BMP); Daily 24-hr composite samples (In-Season); Weekly grab samples (Off-Season)
2010	GE (RAMP)	Lock 5 Automated Station	97	3 High Flow Events (45 samples)	Weekly grab samples (Off-Season); 6-hour composite samples (High Flow sampling)
2011	GE (RAMP)	Lock 5 Automated Station	221	4 High Flow Events (19 samples)	Weekly grab or 24-hour transect-composite samples (Off-Season); Daily 24-hr composite samples (In-Season); 6 and 24-hour composite samples (High Flow sampling)
2012	GE (RAMP)	Lock 5 Automated Station	227	No High Flow Samples	Weekly 24-hour transect-composite samples (Off-Season); Daily 24-hr transect-composite samples (In-Season)
2013	GE (RAMP)	Lock 5 Automated Station	59	1 High Flow Event (2 samples)	Weekly 24-hour transect-composite samples (Off-Season); Daily and Weekly 24-hr transect-composite samples (In-Season); Grab samples (High Flow sampling)
2014	GE (RAMP)	Lock 5 Automated Station , Lock 5 Temp Transect Station at RM 182.2	113	No High Flow Samples	Weekly 24-hour transect-composite samples (Off-Season); Daily 24-hr transect-composite samples for portion of dredging season (In-Season)
2015	GE (RAMP)	Lock 5 Automated Station	171	No High Flow Samples	Weekly 24-hour transect-composite samples (Off-Season); Daily and weekly 24-hr transect-composite automated samples (In-Season)
2016 [1]	GE (RAMP)	Lock 5 Automated Station, Schuylerville Manual Station	26	No High Flow Samples	Weekly MADIS or 24-hour transect-composite samples (Off-Season)

[1]: 2016 water column data reflects samples collected through September 2016.

	Stillwater				
Year	Collection Agency (Program)	Station Used	No. of Samples	No. of High Flow Events	Sampling Method
1995	USGS (WQData)	STILLWATER (USGS Station 01331095, RM 168)	21		Single Point Grab Sample
1996	USGS (WQData)	STILLWATER (USGS Station 01331095, RM 168)	22		Single Point Grab Sample
1997	USGS (WQData)	STILLWATER (USGS Station 01331095, RM 168)	18		Single Point Grab Sample
1998					
1999					
2000					
2001					
2002					
2003					
2004	GE (BMP)	Stillwater (RM 168.4)	26	No High Flow Samples	June - Nov weekly transect-composite MADIS samples
2005	GE (BMP)	Stillwater (RM 168.4)	31	No High Flow Samples	May - Nov weekly transect-composite MADIS samples
2006	GE (BMP)	Stillwater (RM 168.4)	31	No High Flow Samples	May - Nov weekly transect-composite MADIS samples
2007	GE (BMP)	Stillwater (RM 168.4)	31	No High Flow Samples	May - Nov weekly transect-composite MADIS samples
2008	GE (BMP)	Stillwater (RM 168.4)	30	No High Flow Samples	May - Nov weekly transect-composite MADIS samples
2009	GE (RAMP)	Stillwater Manual Station	33	No High Flow Samples	Weekly transect-composite MADIS samples (In-Season)
2010					
2011	GE (RAMP)	Stillwater Manual Station	23	No High Flow Samples	Weekly transect-composite MADIS samples (In-Season)
2012	GE (RAMP)	Stillwater Manual Station	28	No High Flow Samples	Weekly transect-composite MADIS samples (In-Season)
2013	GE (RAMP)	Stillwater-RM169.25 , Stillwater Manual Station	180	No High Flow Samples	Daily 24-hr composite transect automated samples (In-Season); Limited Weekly and daily transect-composite MADIS samples (In-Season)
2014	GE (RAMP)	Stillwater-RM169.25 , Stillwater Manual Station	74	No High Flow Samples	Weekly transect-composites MADIS samples (Off-Season); Daily 24-hr composite automated samples for portion of dredging season (In-Season)
2015	GE (RAMP)	Stillwater Manual Station	43	No High Flow Samples	Weekly transect-composite MADIS samples (In-Season and Off-Season)
2016 [1]	GE (RAMP)	Stillwater Manual Station	5	No High Flow Samples	Weekly transect-composite MADIS samples (Off-Season)

[1]: 2016 water column data reflects samples collected through September 2016.

Hudson River PCBs Superfund Site

Water Column Data Description for Stillwater Station

Table A1-4

April 2019

Year	Collection Agency (Program)	Station Used	No. of Samples	No. of High Flow Events	Sampling Method
			Waterford		
1995	USGS (WQData)	WATERFD (USGS Station 01335770, RM 156.5)	22		Single Point Center Channel Grab Sample
1996	USGS (WQData)	WATERFD (USGS Station 01335770, RM 156.5)	26		Single Point Center Channel Grab Sample
1997	USGS (WQData)	WATERFD (USGS Station 01335770, RM 156.5)	25		Single Point Center Channel Grab Sample
1998	USGS (WQData)	WATERFD (USGS Station 01335770, RM 156.5)	28		Single Point Center Channel Grab Sample
1999	USGS (WQData)	WATERFD (USGS Station 01335770, RM 156.5)	N/A[1]		
2000	USGS (WQData)	WATERFD (USGS Station 01335770, RM 156.5)	N/A[1]		
2001	USGS (WQData)	WATERFD (USGS Station 01335770, RM 156.5)	18		Single Point Center Channel Grab Sample
2002					
2003					
2004	GE (BMP)	Waterford (RM 156)	22	No High Flow Samples	June - Dec weekly transect-composite grab samples
2005	GE (BMP)	Waterford (RM 156)	65	5 High Flow Events (23 samples)	Year-round weekly transect-composite MADIS samples (BMP and High Flow sampling)
2006	GE (BMP)	Waterford (RM 156)	79	7 High Flow Events (29 samples)	Year-round weekly transect-composite MADIS samples (BMP and High Flow sampling)
2007	GE (BMP)	Waterford (RM 156)	77	6 High Flow Events (34 samples)	Year-round weekly transect-composite MADIS samples (BMP and High Flow sampling)
2008	GE (BMP)	Waterford (RM 156)	76	8 High Flow Events (36 samples)	Year-round weekly transect-composite grab samples; MADIS composite sampling (High Flow sampling)
2009	GE (BMP), GE (RAMP)	Waterford Automated Station, Waterford Manual Station, Waterford (RM 156)	243	4 High Flow Events (6 samples)	March - April weekly transect-composite MADIS samples (BMP); Daily 24-hr composite samples (In-Season); Weekly grab samples (Off-Season); Composite MADIS samples (High Flow sampling)
2010	GE (RAMP)	Waterford Automated Station	99	3 High Flow Events (43 samples)	Weekly transect-composite grab samples (Off-Season); 6-hour composites (High Flow sampling)
2011	GE (RAMP)	Waterford Automated Station, Waterford Manual Station	222	4 High Flow Events (19 samples)	Weekly grab or 24-hour transect-composite samples (Off-Season); Daily 24-hr transect-composite samples (In-Season); 6 and 24-hour composites (High Flow sampling)
2012	GE (RAMP)	Waterford Automated Station	227	No High Flow Samples	Weekly 24-hour transect-composite samples (Off-Season); Daily 24-hr transect-composite samples (In-Season)
2013	GE (RAMP)	Waterford Automated Station	223	1 High Flow Event (2 samples)	Weekly 24-hour transect-composite samples (Off-Season); Daily 24-hr transect-composite samples (In-Season); Grab samples (High Flow sampling)
2014	GE (RAMP)	Waterford Automated Station, Waterford Manual Station	219	2 High Flow Events (11 samples)	Weekly 24-hour transect-composite or MADIS samples (Off-Season); Daily 24-hr composite samples (In-Season); Grab samples (High Flow sampling)
2015	GE (RAMP)	Waterford Automated Station, Waterford Manual Station, Waterford Farfield Transect Station	186	No High Flow Samples	Weekly 24-hr transect-composite or MADIS samples (Off-Season);Daily and weekly 24-hr transect-composite samples (In-Season)
2016 [2]	GE (RAMP)	Waterford Automated Station, Waterford Manual Station	39	1 High Flow Event (3 samples)	Weekly 24-hr transect-composite or MADIS samples (Off-Season)

[1]: Waterford data was collected by USGS in 1999 and 2000, but due to analytical concerns related to changes in the analytical method USGS used to quantify PCBs, these data years were excluded from the analysis.

[2]: 2016 water column data reflects samples collected through September 2016.

Year	Collection Agency (Program)	Station Used	No. of Samples[1]	No. of High Flow Events	Sampling Method (All stations are center channel stations)
		Lower Hudson River Stations (Albany and Poughkeepsie)			
1995					
1996					
1997					
1998					
1999					
2000					
2001					
2002					
2003					
2004	GE (BMP)	LHR Albany (RM 145) and LHR Poughkeepsie (RM 75)	6	No High Flow Samples	June - Nov monthly transect-composite MADIS sample
2005	GE (BMP)	LHR Albany (RM 145) and LHR Poughkeepsie (RM 75)	7	No High Flow Samples	May - Nov monthly transect-composite MADIS sample
2006	GE (BMP)	LHR Albany (RM 145) and LHR Poughkeepsie (RM 75)	7	No High Flow Samples	May - Nov monthly transect-composite MADIS sample
2007	GE (BMP)	LHR Albany (RM 145) and LHR Poughkeepsie (RM 75)	7	No High Flow Samples	May - Nov monthly transect-composite MADIS sample
2008	GE (BMP)	LHR Albany (RM 145) and LHR Poughkeepsie (RM 75)	7	No High Flow Samples	May - Nov monthly transect-composite MADIS sample
2009	GE (RAMP)	LHR Albany (RM 145) and LHR Poughkeepsie (RM 75)	8	No High Flow Samples	Monthly transect-composite MADIS sample (Off-Season and In-Season)
2010	GE (RAMP)	LHR Albany (RM 145) and LHR Poughkeepsie (RM 75)	9	No High Flow Samples	Monthly transect-composite MADIS sample (Off-Season and In-Season)
2011	GE (RAMP)	LHR Albany (RM 145) and LHR Poughkeepsie (RM 75)	8	No High Flow Samples	Monthly transect-composite MADIS sample (Off-Season and In-Season)
2012	GE (RAMP)	LHR Albany (RM 145) and LHR Poughkeepsie (RM 75)	8	No High Flow Samples	Monthly transect-composite MADIS sample (Off-Season and In-Season)
2013	GE (RAMP)	LHR Albany (RM 145) and LHR Poughkeepsie (RM 75)	23, 8	No High Flow Samples	Monthly transect-composite MADIS sample (Off-Season and In-Season); Limited daily manual sampling at Albany during partion of In-Season dredging
2014	GE (RAMP)	LHR Albany (RM 145) and LHR Poughkeepsie (RM 75)	9, 8	No High Flow Samples	Monthly transect-composite MADIS sample (Off-Season and In-Season)
2015	GE (RAMP)	LHR Albany (RM 145) and LHR Poughkeepsie (RM 75)	9	No High Flow Samples	Monthly transect-composite MADIS sample (Off-Season and In-Season)
2016 [2]	GE (RAMP)	LHR Albany (RM 145) and LHR Poughkeepsie (RM 75)	6	No High Flow Samples	Monthly transect-composite MADIS sample (Off-Season and In-Season)

[1]: If different number of samples were collected at LHR Albany and LHR Poughkeepsie, the first number indicates the number of samples collected at LHR Albany and the second number indicates the number of samples collected at LHR Poughkeepsie. If the same number of samples were collected at both stations, only one number is indicated.

[2]: 2016 water column data reflects samples collected through September 2016.

	Year	ROD MNA				MNA Update			
		TI Dam	Schuyler-ville	Stillwater	Waterford	TI Dam	Schuyler-ville	Stillwater	Waterford
PRE-ROD	1995	55.8	63.1	50.4	42.7	55.8	63.1	50.4	42.7
	1996	30.2	38.3	37.0	34.3	30.2	38.3	37.0	34.3
	1997	29.0	35.9	36.6	34.7	29.0	35.9	36.6	34.7
MNA FORECAST	1998	38.3	44.2	38.7	35.8	38.2	43.6	41.4	39.4
	1999	32.7	38.4	34.2	29.8	34.0	39.2	40.0	35.0
	2000	24.7	29.0	26.5	25.0	24.8	29.6	28.0	25.7
	2001	25.1	30.4	26.6	24.6	32.8	35.8	33.1	29.9
	2002	27.6	30.3	23.7	21.1	27.8	30.5	28.0	24.7
	2003	26.6	28.8	23.0	19.9	23.0	26.0	23.6	21.4
	2004	29.3	31.0	23.7	19.7	20.9	23.1	21.0	18.7
	2005	13.5	17.0	15.5	14.6	12.0	15.5	16.0	15.6
	2006	11.6	14.9	13.5	12.4	8.8	12.2	13.0	12.5
	2007	12.1	15.3	13.2	12.1	13.0	15.2	14.7	13.1
	2008	13.8	15.9	12.3	10.4	10.0	12.0	15.7	12.9
	Decay Rate, 1995-2008	9.7%	9.6%	10.4%	10.6%	11.7%	11.4%	9.9%	10.0%

Average Annual Water Column Tri+ PCB, ROD and Updated MNA Forecasts for 1998-2008, Augmented by Pre-MNA Calibration Results for 1995-1998

Year	HUDTOX		AutoBeale	
	Predicted Load, ROD (kg/yr)	Predicted Load, Update[1] (kg/yr)	Estimated Load[2] (kg/year)	Root Mean Squared Error[2] (RMSE) (kg/yr)
1998	326	320	239	12
1999	153	156	-	-
2000	199	222	-	-
2001	233	154	163	13
2002	135	149	-	-
2003	129	166	-	-
2004	95	137	149	2
2005	89	123	133	7
2006	102	132	174	10
2007	102	85	103	6
2008	49	104	147	13

1 Using HUDTOX updated with actual 1998 - 2008 flows.
2 USGS data for 1999 and 2000 were excluded due to very high proportion of non-detects. No data for 2002-2003.

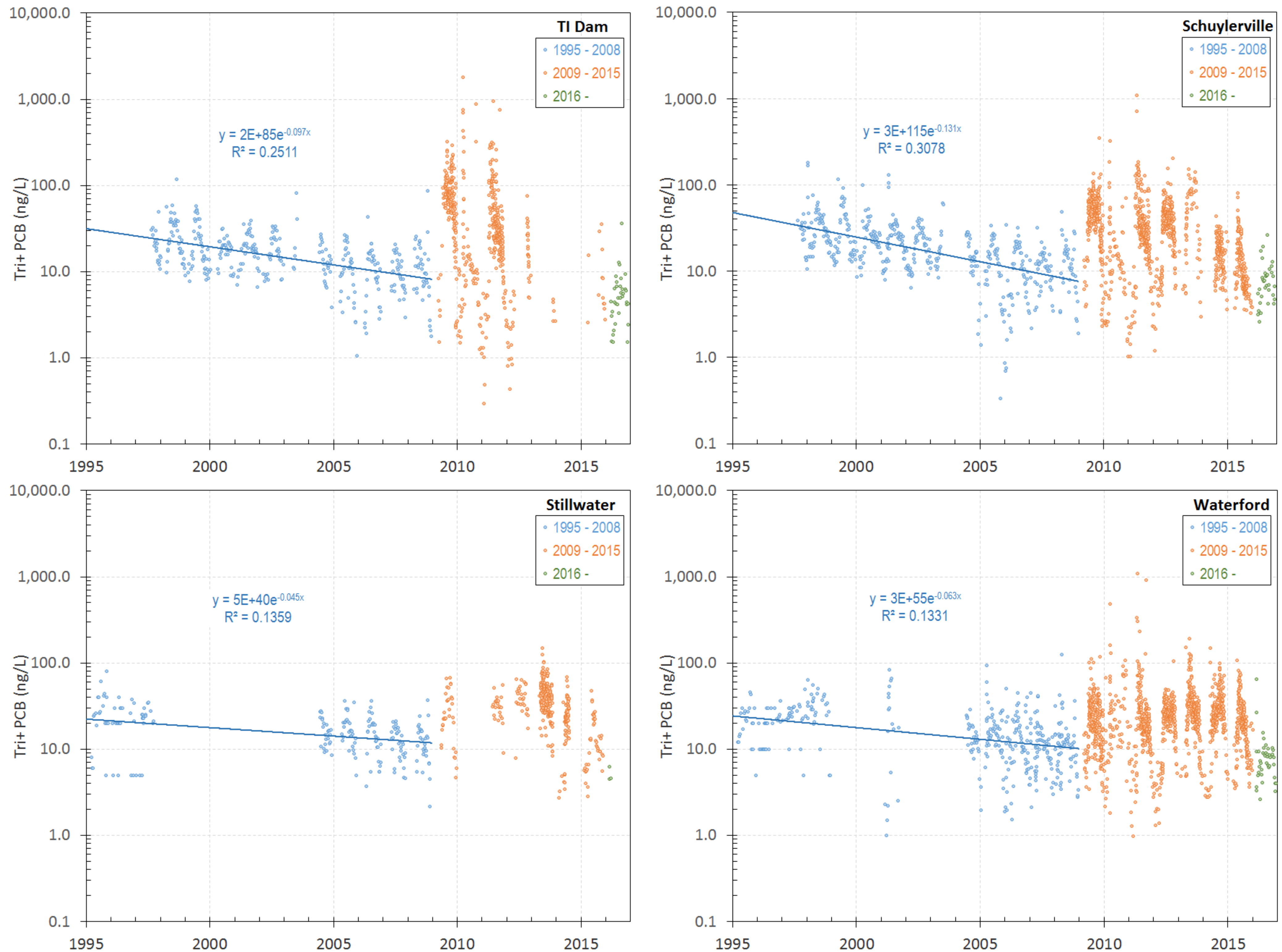
Year	Tri+ PCB Mass Removed (kg)	Tri+ PCB Net Load at Waterford (kg)	Net Load as % of Mass Removed
2011	9,070	85.0	0.9%
2012	10,080	29.3	0.3%
2013	9,275	96.2	1.0%
2014	8,915	30.3	0.3%
2015	2,991	23.8	0.8%
Phase 2 Total	40,331	264.6	0.7%

		Water Column Monitoring Stations			
		TI Dam	Schuylerville	Stillwater	Waterford
ROD Mean Expectation		5.0	5.6	6.4	6.6
Measured Water Column Concentration	Mean	6.1	8.3		9.3
	Standard Error of Mean	1.0	0.9		1.5
	Median	4.9	7.3		8.0
	Number of Samples	35	34		41

	Estimated Load (kg)	Root Mean Squared Error (RMSE) (kg)
January - February	34	
March - December	29	
January - December	63	10

	2016	Year Reaching 5 ng/L			
	Average of Monitoring Data	1%/yr decline	3%/yr decline	6%/yr decline	14%/yr decline
TID	6.1	2036	2023	2019	2017
Schuylerville	8.3	2067	2033	2024	2020
Waterford	9.3	2078	2037	2026	2020

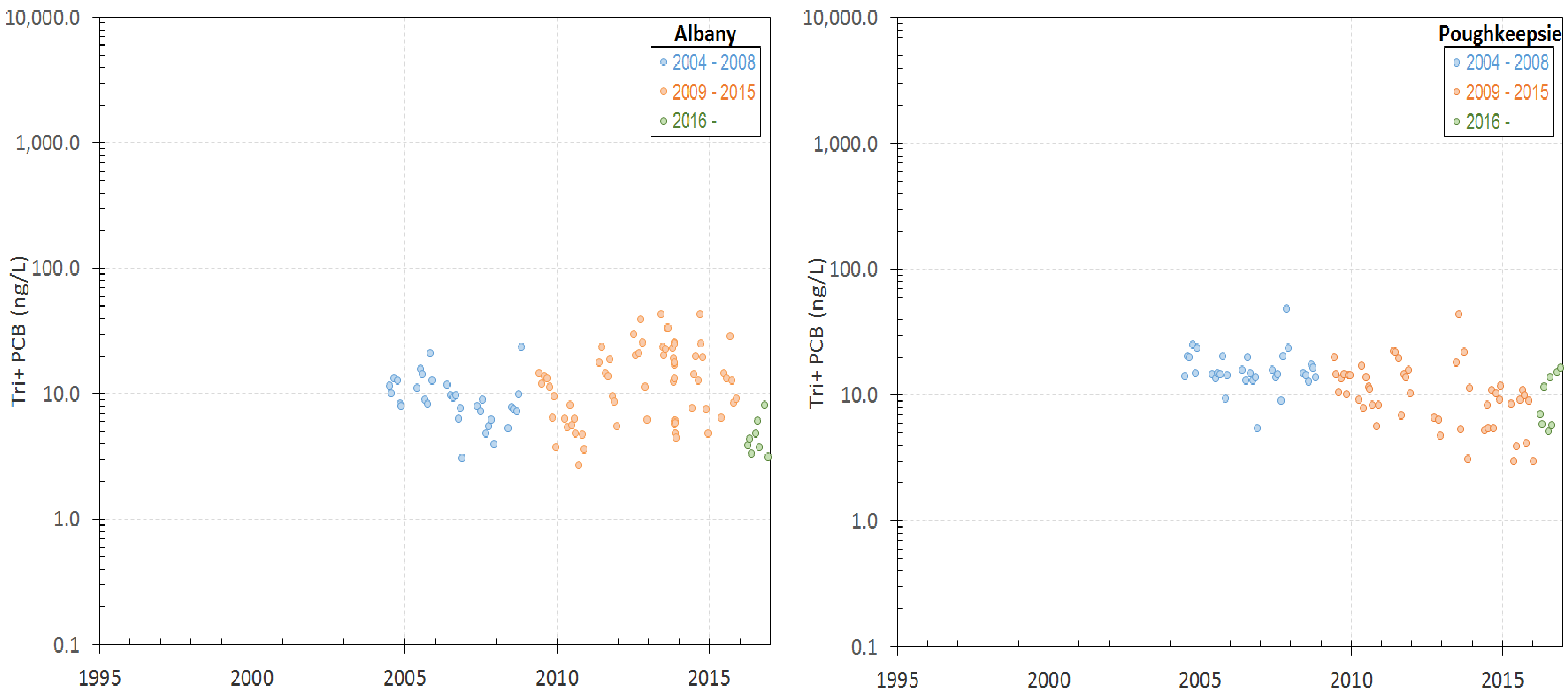
Averages of 2016 Water Column Tri+ Concentrations (ng/L) and Year Projected to Decline to 5 ng/L at Selected MNA Recovery Rates, at Upper Hudson River Monitoring Stations



Water Column Tri+ PCB Concentrations at Upper Hudson River Monitoring Stations, 1995-2016

Figure A1-1

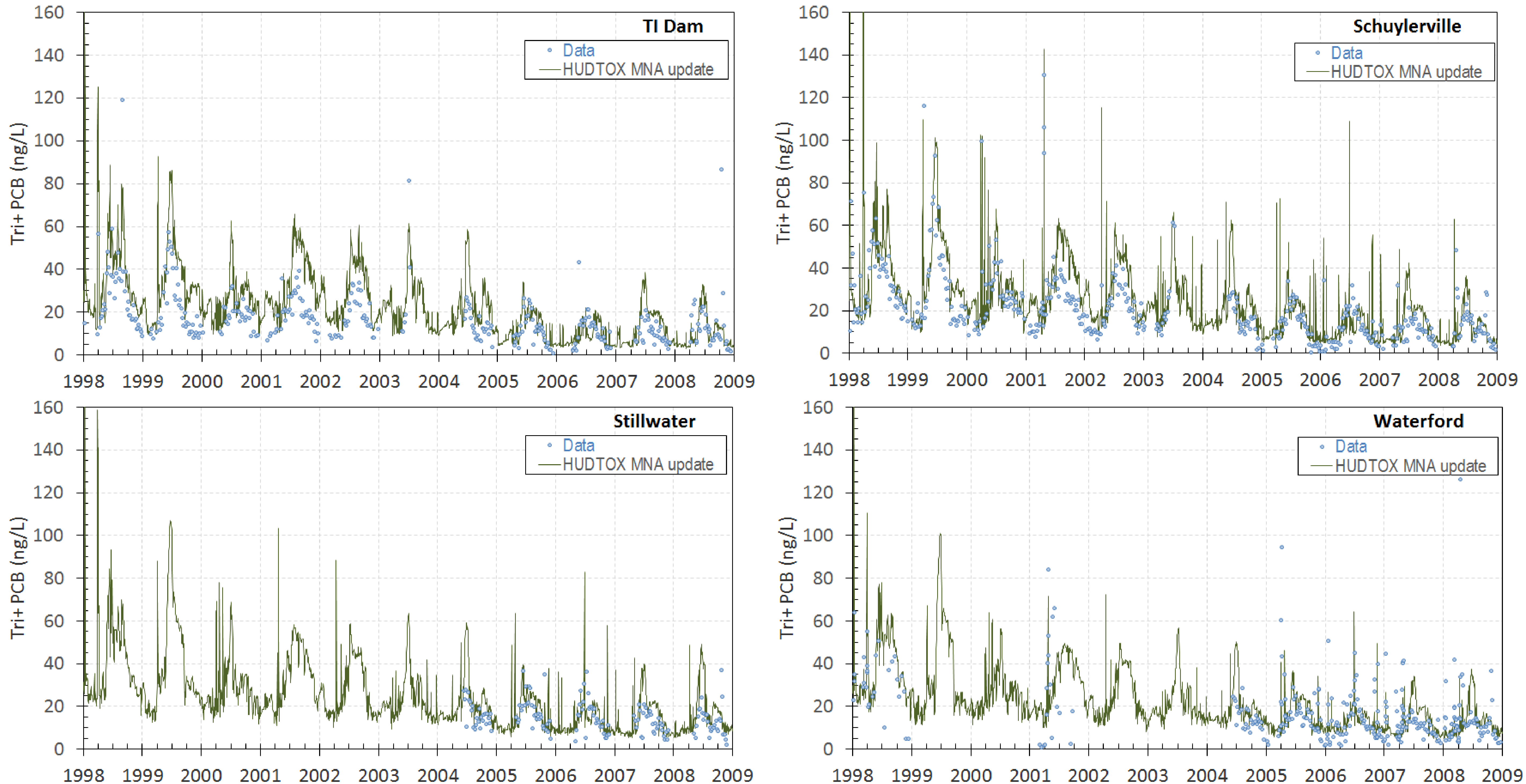
April 2019



Water Column Tri+ PCB Concentrations at Lower Hudson River Monitoring Stations, 1995-2016

Figure A1-2

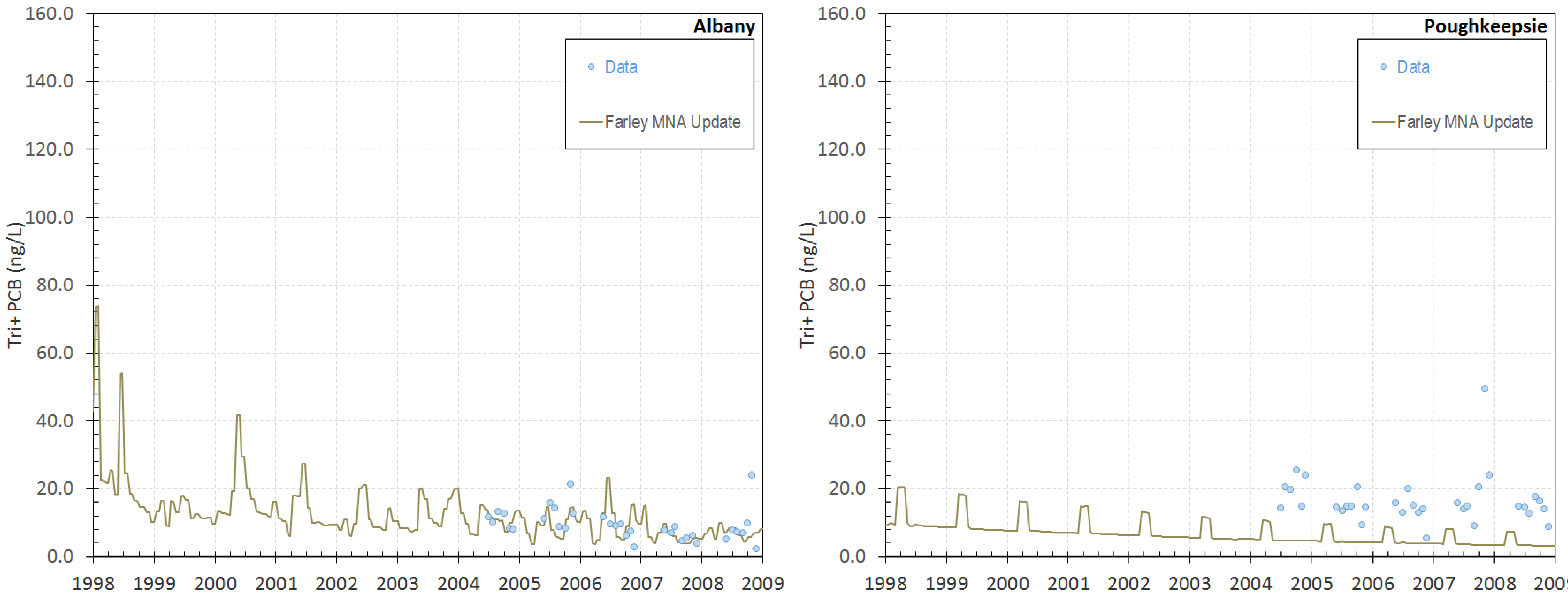
April 2019



Simulated and Monitored Water Column Tri+ PCB Concentrations at Upper Hudson River Monitoring Stations, 1998-2008

Figure A1-3

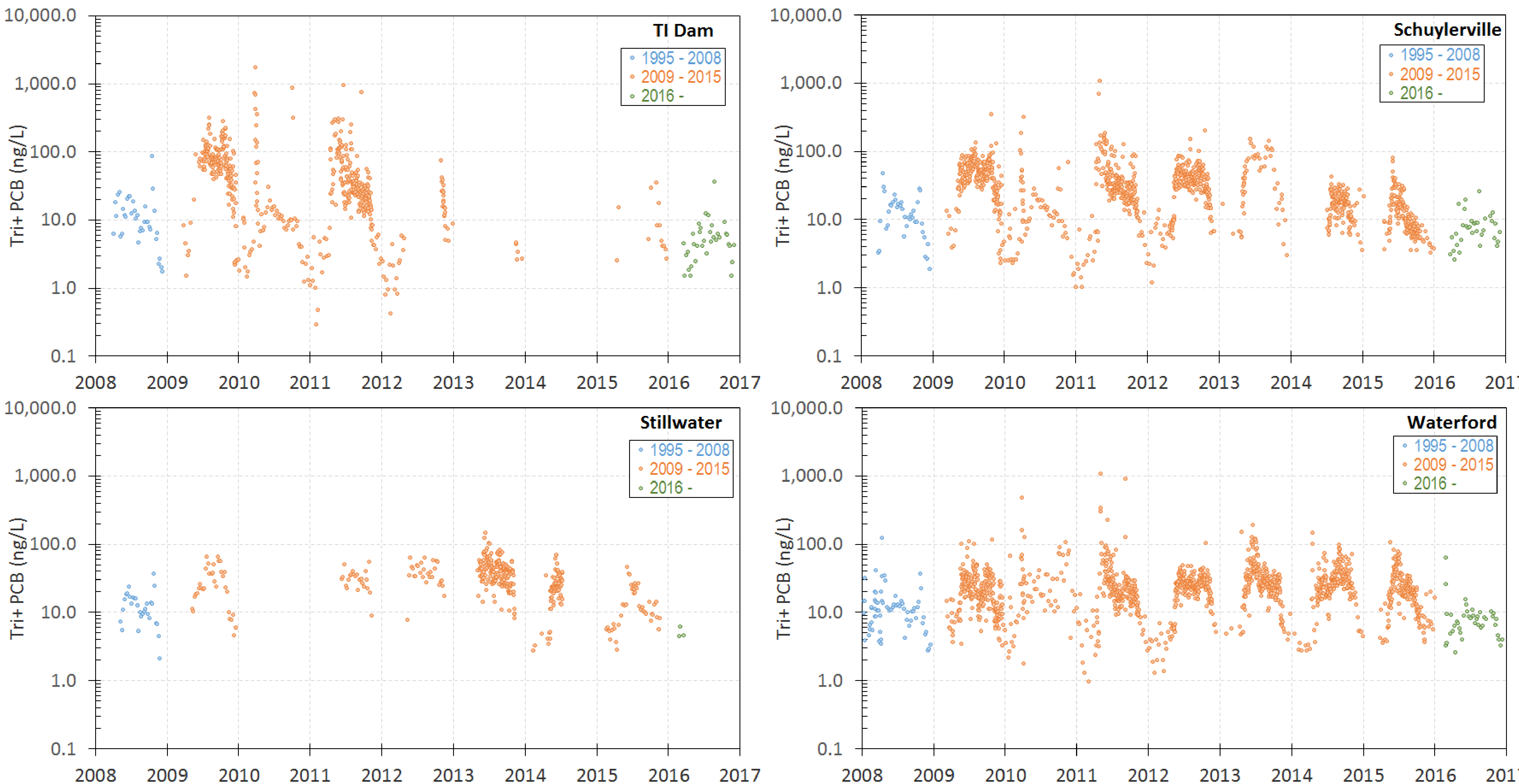
April 2019



Simulated and Monitored Water Column Tri+ PCB Concentrations at Lower Hudson River Monitoring Stations, 1998-2008

Figure A1-4

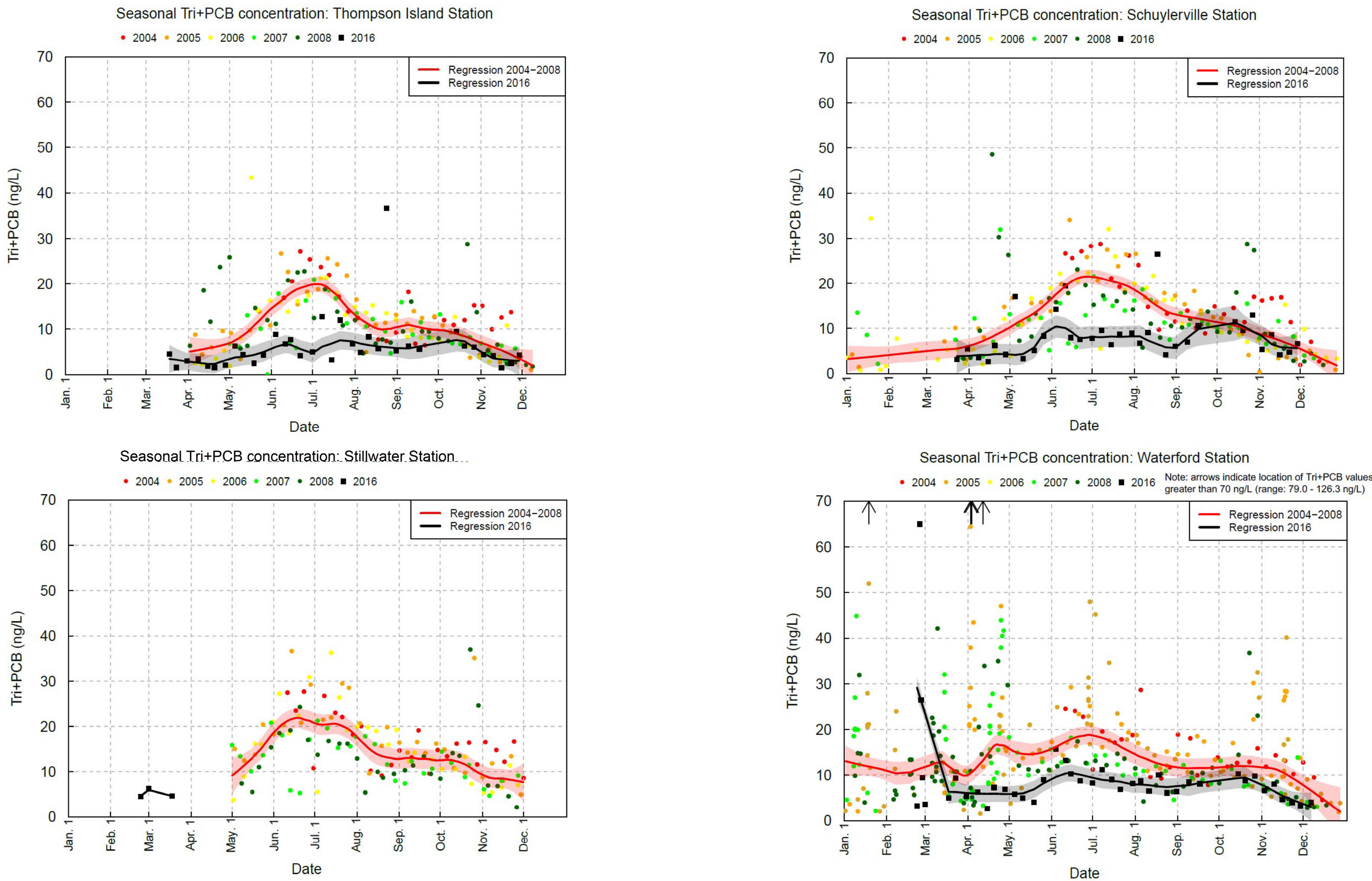
April 2019



Water Column Tri+ PCB Concentrations at Upper Hudson River Monitoring Stations, 2008-2016

Figure A1-5

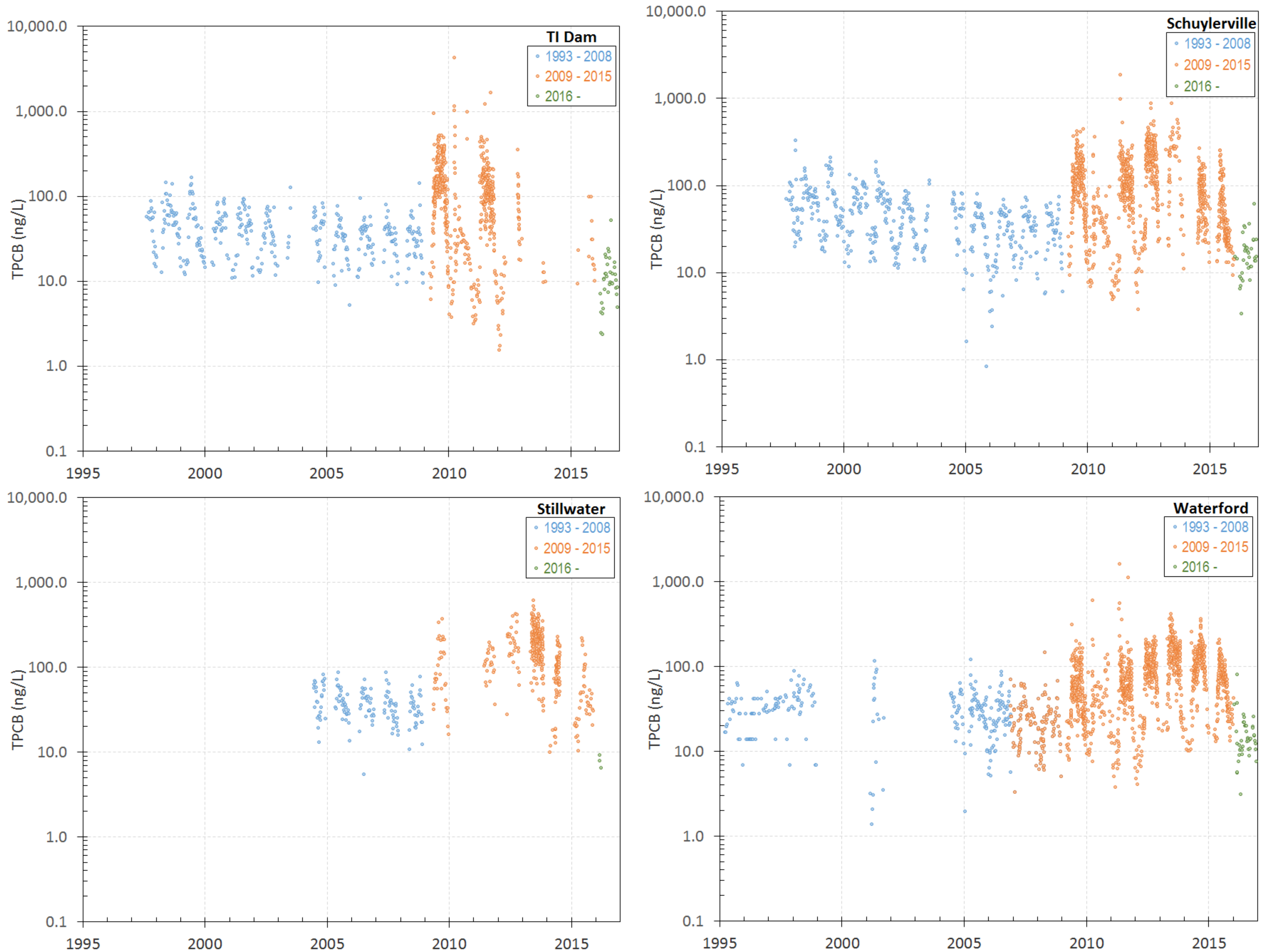
April 2019



Water Column Tri+ PCB Concentrations by Calendar Date, 2004-2008 and 2016, at Four Upper Hudson River Monitoring Stations

Figure A1-6

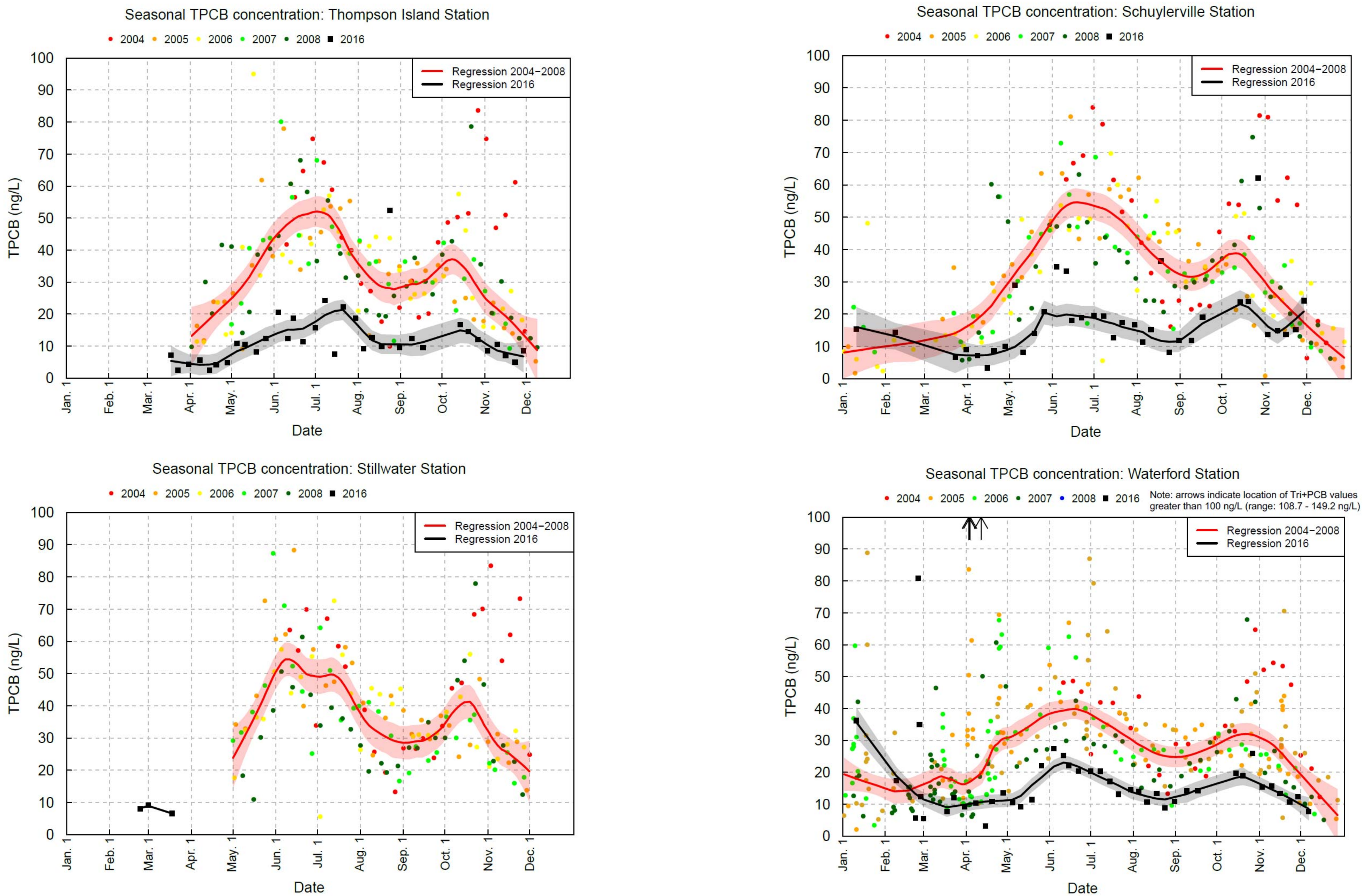
April 2019



Water Column Total PCB Concentrations at Upper Hudson River Monitoring Stations, 1995-2016

Figure A1-7

April 2019



Water Column Total PCB Concentrations by Calendar Date, 2004-2008 and 2016, at Four Upper Hudson River Monitoring Stations

Figure A1-8

April 2019