8. FORECAST SIMULATIONS FOR NO ACTION

8.1 OVERVIEW

In 1984 the U.S. Environmental Protection Agency (USEPA) issued an interim decision of No Action concerning PCB contaminated sediments in the Upper Hudson River. In December 1990, USEPA issued a Scope of Work for a Reassessment of the 1984 No Action decision. The modeling work presented in this report is part of Phase 2 of the three-phase Remedial Investigation and Feasibility Study being conducted for the Reassessment. The HUDTOX model was developed to answer two of the three principal study questions posed in the Reassessment:

- When will PCB levels in fish populations recover to levels meeting human health and ecological risk criteria under continued No Action?

- Can remedies other than No Action significantly shorten the time required to achieve acceptable risk levels?

Question one is addressed in this chapter through prediction of the future course of PCB concentrations in the Upper Hudson River using the HUDTOX model developed and calibrated as described in Chapters 5 through 7. Question two will be addressed through application of the HUDTOX model in Phase 3, the Feasibility Study. The third principal study question:

- Are buried contaminated sediments likely to become "reactivated" following a major flood, possibly resulting in an increase in contamination of the fish population?

was answered through use of the Depth of Scour Model (Chapter 4) and HUDTOX.

The Depth of Scour Model (DOSM) presented in Chapter 4 was developed specifically to address the third principal question of the Reassessment. The DOSM computes the depth of scour expected under peak flow conditions and was used to evaluate the likelihood that buried PCB sediments would become reactivated. However, DOSM does not account for subsequent longer-term transport and redistribution of resuspended sediment and PCBs. Hence, the DOSM formulations for cohesive sediment resuspension were incorporated into the HUDTOX model, and HUDTOX was used to calculate the long-term system response to a flood induced resuspension event. HUDTOX was not designed to simulate short-term transient events, hence the focus of the 100-year peak flow simulation with HUDTOX is on long-term system response.

The No Action simulation was conducted for a 70-year forecast period beginning January 1, 1998. The 70-year water and sediment concentrations computed by the model were provided as input to the fish bioaccumulation modeling effort (presented in Books 3 and 4 of the Revised Baseline Modeling Report) and the Human Health Risk Assessment, which are also being conducted under this Reassessment. The results of the No Action forecast and 100-year peak flow simulations are presented in this chapter, along with the design and implementation of these scenarios. An important aspect of the forecast simulations is that the load at the upstream boundary at Fort Edward was specified as a constant PCB (Tri+) concentration, ranging from zero to 30 ng/L, the average concentration in 1998. Also presented are results of sensitivity analyses conducted for upstream solids loading conditions.

The following major sections are included in Chapter 8:

8.2 NO ACTION FORECAST SIMULATION DESIGN

The forecast state variable for the No Action simulation and the 100-year flow simulation is Tri+, the sum of the tri through decachlorinated PCB homologues. This PCB group was the principal model calibration parameter. This PCB group was selected for the historical calibration and forecasts because it provided a consistent basis for comparison among the site-specific datasets over the historical period, and because it is a good represention of the distribution of PCB congeners that bioaccumulate in fish.

In order to conduct forecast simulations with the HUDTOX model, it was necessary to specify future conditions in the Upper Hudson River for flows, solids loads, and Tri+ loads. Estimates were made based on historical observations and current information regarding PCB loading trends.

It is important to recognize that forecast results have inherent uncertainty due to uncertainties in estimating future flow and loading conditions. This uncertainty can be assessed and accounted for in management decision making by evaluating predictions across a range of alternate scenarios for these inputs. To the extent that one or another scenario may be considered the most likely, it is possible to compute a best estimate of future PCB concentration trends with the model.

Presented in the next few subsections are discussions of forecast model inputs for the flow hydrograph, solids loads, PCB loadings, model initial (start-up) conditions, and specifications of the other inputs.

8.2.1 Hydrograph

Specification of daily flow inputs at Fort Edward and all tributaries was required for the 70-year No Action forecast simulation. Flow inputs were based on the historical 1977-1997 Fort Edward and tributary hydrographs presented in Chapter 6. To construct the 70-year forecast flow inputs, randomly selected annual hydrographs from the 1977-1997 period were linked sequentially until a continuous 70-year daily flow series was produced. If the average flow over the synthesized 70 years was within 10 percent of the average flow of the actual 1977-1997 period, the hydrograph was accepted for possible use in the No Action forecast. This process was repeated to produce four randomly generated 70-year Fort Edward hydrographs. For each of the four hydrographs developed for Fort Edward, corresponding tributary hydrographs were used (See Chapter 6), tributary flows were assembled sequentially in the same order as the Fort Edward hydrograph to produce 70-year flow inputs for all tributaries.

The four sets of alternative Fort Edward and tributary hydrographs developed above were assessed by conducting No Action forecast simulations with each and selecting the one producing the approximate median result. The hydrograph selected for forecast modeling is presented in Table 8-1 and Figure 8-1. The other three alternative hydrographs were used to show sensitivity of the forecast predictions to the choice of hydrograph in Section 8.6.1.

8.2.2 Solids Loads

Solids loads play an important role in determining Tri+ concentrations in the river, due to burial of PCB in the sediment bed by solids deposition. As with flow, future solids loads are uncertain and forecast inputs are best based on historical data. As discussed in Chapter 6, upstream solids loading relationships at Fort Edward changed over time. Comparison of solids rating curves for 1991 through 1997 data and for 1977 through 1990 data indicate that solids loading decreased over time. This suggests that future solids load estimates at Fort Edward may be best estimated by the solids rating curves developed for the period 1991-1997, Equation 6-13. This equation was used with the forecast hydrograph selected as described in the preceding section, to compute solids loads at Fort Edward for the baseline No Action forecast.

Sensitivity of the forecast simulations to the method of developing the solids rating curve at Fort Edward was assessed using Equation 6-8, which is based on all available data from 1977 to 1997. These results are presented in Section 8.6.2.

8.2.3 PCB Loads

Specification of Tri+ loads at Fort Edward has a large influence on forecast results of Tri+ concentrations in the Upper Hudson River. However, due to the variable nature of Tri+ loading at Fort Edward, specification of future loading conditions is very uncertain. In spite of extensive remediation of upstream sources conducted by GE over the last decade, PCB loading continues from contaminated sediment deposits and direct discharge of PCB oil through bedrock fissures (USEPA, 1997). While average loads generally continue to decline, high concentrations continue to be periodically observed at Fort Edward. For example on January 10, 1998 a concentration of 190 ng/L was observed at Fort Edward during the spring high-flow event and a concentration of 85 ng/L was observed on September 9, 1998 during a period of low flow (Figure 8-2). Pulse loads due to these periodic high concentrations have been observed in the past and the total annual load delivered to Thompson Island Pool has been estimated to be as much as 660 kg/year based on analysis of data from 1977 to 1998 (QEA 1999).

Year to year variability in PCB loads at Fort Edward are seen in Figure 8-3 for 1991 through 1997 (and previously shown in Figure 6-26 for 1977 through 1997). Available data collected by GE in 1997 and 1998 show that annual average Tri+ concentrations were about 9.9 ng/L and 30.4 ng/L, respectively (based on using one-half detect limit concentrations for non-detect values).

As a result of the uncertainty associated with estimates of future Tri+ loads at Fort Edward, baseline No Action forecasts were conducted with a range of assumptions that may reasonably bound future behavior. Simulations were run with constant Tri+ concentrations of zero, 10 and 30 ng/L specified for the incoming flows at Fort Edward. The 30 ng/L simulation represents an upper bound for the 70-year forecast based on the assumption that future annual average concentrations will not increase substantially above 1998 observed average levels. The 10 ng/L simulation roughly approximates the 1997 Tri+ loads and approximates the analytical detection limit. The zero boundary sensitivity provides a lower bound for simulation and assumes complete upstream remediation. Based on the average flow, a constant concentration of 10 ng/L Tri+ produces an annual load of about 47 kg/yr at Fort Edward, and 30 ng/l produce a load of 141 kg/yr.

All downstream tributary Tri+ loads were assumed to be negligible and set to zero for the forecast simulations because historical concentrations were very low. This assumption may be significant in calculating loads to the Lower Hudson River (over Federal Dam). Conditions in the Mohawk River are particularly important because of its large flow; however, the Mohawk River enters just above the downstream boundary of the model and it has little impact on model results for the Upper River. For a Lower Hudson River assessment, different assumptions for tributaries (especially the Mohawk River) might be considered, but these were not the focus of this report. Any independent estimates of Tri+ loading to the Lower Hudson River from the Mohawk River could simply be added to the HUDTOX estimates of load over Federal Dam.

8.2.4 Initial Conditions for the Forecast

Sediment initial conditions for the 1998 through 2067 forecast simulations were based on the end results of the 1991 through 1997 model hindcast application. In effect, this corresponds to initializing the forecast simulations with measured conditions in 1991. This approach utilizes the most recent, reliable and comprehensive dataset to begin the model forecasts. In particular, in terms of accuracy, vertical resolution and spatial coverage for the Upper Hudson River, the 1991 sediment measurements represent the best match between available sediment data and model requirements. The initial conditions for the forecast are presented on a reach-average basis for cohesive and non-cohesive sediments in Table 8-2. These concentrations are model results on the last day of the simulation from January 1, 1991 to September 30, 1997.

8.2.5 Specification Of Other Model Inputs

In addition to specification of flows, solids loads and Tri+ loads, the forecast simulation required specification of air and water temperatures and atmospheric Tri+ concentrations. The same annual air and water temperature series applied in the model calibration (Section 6.8) were repeated for the forecast simulations. Atmospheric Tri+ concentrations were assumed to be zero for the entire forecast period. All other model inputs remained the same as those in the historical Tri+ calibration.

8.3 No Action Forecast Results

As discussed in Section 8.2.3, there is large uncertainty in estimated upstream Tri+ concentrations entering Thompson Island Pool at Fort Edward over the forecast period. Consequently, a single most likely estimate of future concentrations is not presented. Rather, a likely range of estimates is presented, bounded by results based on specification of constant 30 ng/L and zero Tri+ concentrations at Fort Edward. An additional simulation was done with a concentration of 10 ng/L, the approximate analytical detection limit. Results of the 70-year No Action forecast simulation are presented for:

- Surface sediment (0-4 cm) Tri+ concentration time series for the whole Upper Hudson River (Figure 8-4,a-e);
- Annual average and summer average water column Tri+ concentration time series for the long-term monitoring stations (Figures 8-6, a and b; and 8-7, a and b); and,
- Annual Tri+ mass loading to the Lower Hudson River over Federal Dam (Figure 8-9, a and b).

These results are discussed in the subsections below.

8.3.1 Forecast Results: Surface Sediment PCB Concentrations

Several important observations are made from the No Action forecast results for surface sediment PCB concentrations (Figure 8-4, a-e). First, the influence of the upstream PCB load on surface sediment PCB concentrations is immediately apparent. Following the first few years of the forecast period, large separation occurs between the three upstream Tri+ load scenarios (zero, 10, and 30 ng/L Tri+ at Fort Edward). For the zero Tri+ loading simulation, concentrations in the sediment and water column exhibit a continual decline, at a rate of between 7 and 8 percent per year. This rate is consistent with observed historical trends. For the simulations using constant upstream concentrations of 10 ng/L and 30 ng/L, similar recovery rates are initially observed, however, upstream loads control sediment concentrations by about 2030.

All three loading simulations show concentrations approaching various asymptote values throughout the river. For the zero Tri+ loading simulation, surface sediment concentrations asymptotically approach zero. For the simulations using constant upstream concentrations of 10 ng/L and 30 ng/L, results asymptotically approach a quasi steady-state concentration determined by the upstream load and processes acting on Tri+ in the river. This is not a true equilibrium because the declining sediment releases still have minor effects on concentrations, and natural variability causes year to year fluctuations. The quasi steady-state concentrations approached in Thompson Island Pool cohesive sediment for the 30 ng/L and 10 ng/L are approximately 1.8 mg/kg and 0.7 mg/kg, respectively. Respective non-cohesive sediment concentrations in Thompson Island Pool level off at about 0.75 mg/kg and 0.27 mg/kg for these simulations. In downstream reaches, asymptote concentrations are slightly lower due to “clean” tributary flow and solids load inputs as well as volatilization losses.

The 70-year forecast results showed increases in surface sediment concentrations in localized areas in Thompson Island Pool (Figure 8-4a) and Stillwater Pool (Figure 8-4c) as a result of small *long-term* average sediment erosion in some model segments that eventually exposes Tri+ contamination in deeper layers. These results do not occur in response to singular high flow events. This response was not observed during the calibration period, although erosional behavior did occur. This behavior is predicted to occur 40 to 50 years in the future because of the long-term impact of small sediment erosion rates in certain locations. These computed increases in surface sediment Tri+ concentrations serve to slow or interrupt apparent rates of recovery. However, due to factors described later below, the exact timing and magnitude of the events are dependent on forecast assumptions.

In year 2044, two of the 15 cohesive sediment segments in the Thompson Island Pool (below water column Segments 10 and 25, Figure 5-5) increase approximately 0.4 mg/kg and again in 2051 by about 0.3 mg/kg. The minimum poolwide average cohesive sediment concentration before the increase in 2044 ranges from 0.27 mg/kg for the zero upstream loading simulation to 1.92 mg/kg for the simulation with a constant Tri+ concentration of 30 ng/L at Fort Edward. Non-cohesive sediments in the Stillwater reach (below water column Segments 37, 38 and 39, Figure 5-4c) also experience a series of increases, most notably in 2039 when concentrations rise by about 0.4 mg/kg. Prior to this increase, average non-cohesive concentrations ranged from 0.03 to 0.47 mg/kg for the zero and 30 ng/L Fort Edward Tri+ simulations, respectively.

These results are manifested as relatively sharp rises in surface concentrations that occur when buried sediments of higher concentration are incorporated into the mixed layer due to erosive loss of the surface sediment layer. Gradual increases are also observed in non-eroding surface sediments downstream due to transport and subsequent deposition from upstream sediment erosion. The relative magnitude of these increases is very small when compared in the context of historical observations (Figure 8-5, a-e). These forecasted increases will be considered during the development of the Feasibility Study.

The actual occurrence, magnitude and timing of the predicted increases in surface sediment concentrations is uncertain due to the uncertainty in future conditions, especially tributary solids loads. Also, the occurrence of these increases may be in part due to solids dynamics in the model calibration and/or the specification of sediment initial conditions that would not be apparent in 21-year historical calibration period. Solids burial rates, which were determined by model calibration, determine the net erosional or depositional nature of each sediment area in the model. Solids burial rates are strongly driven by external solids loadings. Variations in these solids inputs, which may be within calibration uncertainty, can result in slight net deposition instead of slight net erosion for these localized areas. However, it is equally possible that such variations could enhance the occurrences of predicted increases. Also, alternate specification of the sediment initial condition profile and/or the mixed layer depth may reduce the magnitude of these events. These possibilities are assessed through sensitivity analysis, presented below.

Model results indicating that not all areas of the river are net depositional is a reasonable expectation and is corroborated by independent modeling and data analysis. The computed erosional behavior of some areas of the river is not unique to HUDTOX. The HUDTOX solids results are based on a calibration guided, in part, by calculations from the SEDZL sediment transport model (QEA, 1999). The SEDZL model also computed some areas of both cohesive and non-cohesive sediments to be net erosional over the historical calibration period from 1977 to 1997. This is discussed in more detail in Chapter 7.

General findings of the Low Resolution Sediment Coring Report (USEPA, 1998a) seem to also offer corroborative support for the findings of the forecast simulations that localized sediment areas in the river are experiencing long-term erosional behavior. The general conclusion from the Low Resolution Sediment Coring Report that burial is not sequestering PCBs on a widespread basis is borne out to some extent by the results observed in the model. It is likely that there are localized areas of continuing scour and PCB erosion on scales smaller than the HUDTOX model segmentation. The HUDTOX results may not show these areas to be net erosional because they fall within larger model segments that are on average (across the whole segment), net depositional. While the findings presented in the Low Resolution Sediment Coring Report are based on analyses at much finer spatial scales than the HUDTOX calculations, results are comparable in a general sense and seem to indicate that long-term burial may not effectively sequester buried PCBs at all locations in the river.

8.3.2 Forecast Results: Water Column PCB Concentrations

Forecasted annual average and summer average water column concentrations are also presented for all three loading simulations at Thompson Island Dam, Schuylerville, Stillwater and Waterford in Figures 8-6 (a and b) and 8-7 (a and b). These results show large separation in water column Tri+ concentrations throughout the system under the different assumptions regarding PCB loads at Fort Edward. For the zero Tri+ concentration assumption at upstream boundary, water column concentrations decline to less than 10 ng/L within 10 years at all locations. With upstream concentrations at Fort Edward set to 30 ng/L and 10 ng/L, water column concentrations at Thompson Island Dam begin to level off around 2015 to about 27 ng/L and 9 ng/L Tri+ respectively. Downstream, annual average concentrations level off at lower values due to dilution from tributary inputs and losses from the water column.

Water column concentration results show significant year to year variability, caused by variability in flows and solids loading. The noticeable difference in average concentrations observed in the third year of the forecast period versus those in the first two years is due to differences in summer flow conditions (Figure 8-7). Computed summer average Tri+ concentrations in 2000 are much lower than in 1998 and 1999 because summer time flows were higher, diluting inputs of Tri+ from the sediment. This point is illustrated below in the simulations showing model sensitivity to choice of forecast hydrograph.

The predicted increases in surface sediment Tri+ concentrations in Thompson Island Pool and in non-cohesive sediments in the Stillwater reach do not significantly impact the water column concentrations. This is because water column concentrations are being driven by upstream Tri+ loads at the time the sediment increases occur. Additional Tri+ inputs due to the increased surficial sediment concentrations is small relative to the upstream load contribution.

Figure 8-8 (a and b) presents the forecasted water column PCB concentrations along with the historical calibration concentrations. At this temporal scale, forecasted increases in water column concentrations in the Stillwater and Waterford reaches are very small. From a transport and fate standpoint, these increases may be considered insignificant; however, they may be important in a potential remediation decision.

8.3.3 Forecast Results: PCB Loads to the Lower Hudson River

Annual and cumulative forecasted Tri+ loads over Federal Dam to the Lower Hudson River are also presented for all three upstream PCB loading simulations (Figure 8-9 a and b). Tri+ loads to the Lower Hudson River mirror water column concentration declines and decrease from approximately 150 kg/yr to less than 10 kg/yr by about 2015 under assumptions where Tri+ loading at Fort Edward ceases in 1998 (0 ng/L boundary concentration). For the upstream load simulations based on 30 ng/L and 10 ng/L Tri+ concentrations at Fort Edward, loads continue to decline until about 2015 and then essentially level off at about 125 kg/yr and 45 kg/yr, respectively. These loads assume zero downstream tributary inputs which may be an important consideration especially for the Mohawk River at the downstream boundary of the model.

8.4 100-YEAR PEAK FLOW SIMULATION DESIGN

As discussed in Section 8.1, one of the principal questions of this Reassessment concerns the possibility that deeply buried contaminated sediments might become “reactivated” during a major flood, possibly resulting in an increase in PCB contamination of the fish population. The available historical data for the Upper Hudson River can not provide a direct answer to this question because there were no very large floods during the period 1977 to 1997. The peak flow during this period was 35,200 cfs in May of 1983, a 15-year peak flow. The 100-year peak flow in the Upper Hudson River at Fort Edward is estimated to be 47,330 cfs (Butcher, 2000a). The Depth of Scour Model presented in Chapter 4 was developed specifically to address this question, through application to the Thompson Island Pool. The 100-year flood impacts were also assessed for the whole Upper Hudson River through application of the HUDTOX model.

8.4.1 Specification of the 100-year Flood Hydrograph and Loadings

In the 100-year peak flow simulation, the HUDTOX model was run for a 70-year forecast simulation identical to the No Action forecast with the exception of a peak flow corresponding to the 100-year flood peak imposed in the spring of the first year. The 100-year flood simulation was conducted with zero PCB loading at Fort Edward and compared to the corresponding No Action simulation to maximize the observation of an effect. External solids loads were not increased during simulation of the 100-year peak flow, but remained the same as in the continued No Action simulation. This design was a single factor, worst-case experiment in which the only differences between continued No Action and the 100-year peak flow would be due to changes in flow-dependent sediment resuspension. This design was a worst-case scenario because the peak flow was placed in the first year of the simulation when sediment contamination was greatest and because there was no increase in external loads of “clean” solids to sorb PCBs in the water column or enhance PCB burial rates.

Figure 8-10 illustrates the base flow at Fort Edward during the continued No Action simulation and the scaling of the first spring peak to match the 100-year peak flow. The value of 12,000 cfs for the maximum spring peak in 1988 (the hydrograph for 1988 was randomly selected to represent the hydrology of the first year of the 70-year forecast) was nearly half of the historical average spring peak flow of 21,339 cfs at Fort Edward. Due to the relatively quiescent nature of this spring flood during the first year of the forecast, daily flows at Fort Edward were scaled by applying exponential trends to the rise and fall periods between March 26 and April 18. The 1988 peak spring flow in the time series was scaled up from 12,000 cfs to a value of 47,330 cfs on April 5, approximately a factor or four. The duration, rise and fall of the 100-year flow in this modified hydrograph were generally consistent with other observed peak flows in the 21-year historical period. The rise period from 50 percent of the peak flow was approximately five days, and the fall period to 50 percent of the peak flow was just under seven days. This modified hydrograph represents a 100-year peak flow but does not necessarily represent the duration, rise and recession characteristics of an actual 100-year flood event.

8.5 100-YEAR PEAK FLOW SIMULATION RESULTS

Table 8-3 presents the impact of the 100-year peak flow on sediment bed solids in Thompson Island Pool (TIP) and downstream reaches of the Upper Hudson River. Cohesive sediments in the Pool were computed to be scoured with a net bed elevation decline of approximately 0.28 cm (on a poolwide average basis). The poolwide average non-cohesive sediment bed elevation declined by approximately 0.05 cm. Some individual HUDTOX cohesive and non-cohesive sediment segments experienced higher erosion depths. As noted above and in the discussion of the HUDTOX calibration, resuspension of non-cohesive sediment is treated in a relatively simple fashion so these predictions are more uncertain for simulation of event impacts.

The small erosion depths predicted throughout the Upper Hudson in response to the 100-year peak flow produce only minor fluctuations in surface sediment concentrations. This finding is in agreement with the findings reported in Chapter 4 from the separate DOSM application to cohesive sediments in Thompson Island Pool.

The 100-year event does not produce increased surface sediment concentrations of the nature observed later in the 70-year forecast. This is because the increases observed in the forecast are a result of long-term net erosional behavior that over time works to expose buried concentrations. The incremental impacts of the 100-year event on the long-term erosion depth speeds the occurrence of these increases by about one year relative to the No Action forecast.

Differences in water column Tri+ concentrations between the No Action scenario and imposition of a 100-year flood event are of relatively short duration. A comparison of predicted water column concentrations between the 100-year peak flow and No Action is shown for Thompson Island Dam and Federal Dam in Figures 8-11 and 8-12, respectively. Although a significant increase in water column Tri+ levels occurs during the event due to resuspension, the differences are short-lived and decline to a fairly insignificant levels fairly rapidly once the event is completed. The impact of the 100-year peak flow on surface sediment levels (i.e., the top 2 HUDTOX sediment layers) was minimal. Cohesive sediment Tri+ concentrations in the TIP increased marginally (on the order of 0.1 ppm), and then decline nearly back to No Action forecast levels within less than 4 years. Impacts on non-cohesive surface sediment contamination levels were insignificant.

Figure 8-13 shows the impact on Tri+ mass loading at various locations in the Upper Hudson River caused by imposing the 100-year peak flow on the base No Action scenario. The event causes an increase of slightly less than 26 kg (57 lbs.) in cumulative Tri+ mass loading across

Thompson Island Dam by the end of the first year of the forecast. This increase represents approximately 13 percent of the average annual Tri+ mass loading across Thompson Island Dam during the 1990s. The Tri+ mass loading increase at Federal Dam during the first year was approximately 73 kg (161 lbs.)

Also note that almost all of the increase in Tri+ mass loading over No Action levels depicted by Figure 8-13 occurs during the course of the flood event (March 26 through April 18). In general, the in-river mass loading effect of the 100-year peak flow is very short-lived. Subsequent (post-first year) increases over the No Action predictions generally amount to less than 2 kg per year at Thompson Island Dam and downstream locations, and this impact eventually declines to negligible levels.

A similar analysis of 100-year peak flow impacts was conducted by General Electric (QEA, 1999). Both analyses used the same peak daily average flow for the 100-year event. On the basis of predicted sediment scour depths, results for these two modeling analyses were comparable when corrected for the flood plain effects, which were not included in the GE model.

8.6 SENSITIVITY ANALYSIS

Results of sensitivity analyses are provided for the No Action forecast simulation to illustrate the impact of the assumptions made regarding future flow and solids loading conditions. In addition, sensitivity analyses for non-cohesive sediment particle mixed depth and sediment initial conditions are presented to show the influence of these parameters on the magnitude of the increases in surficial sediment concentrations observed in the No Action forecast results. All sensitivity results presented here are compared to the No Action forecast based on specification of a constant Tri+ concentration of 10 ng/L at Fort Edward.

8.6.1 Sensitivity to Specification of Forecast Hydrograph

To demonstrate the forecast sensitivity to the choice of simulation hydrograph, No Action forecasts were conducted with three alternative synthetic 70-year hydrographs in addition to the baseline forecast hydrograph. These hydrographs were developed as described in Section 8.2.1. Sensitivity results are presented for surface sediment Tri+ concentrations (8-14 a-e) and annual average water column concentrations (Figure 8-15 a-b).

In general, specification of the forecast hydrograph does not change either the long-term rates of decline in concentrations or the quasi steady-state concentrations based on the 10 ng/L Tri+ concentration at Fort Edward. Hydrograph choice does, however, significantly affect the timing of the computed increases in surface sediment Tri+ concentrations. In Thompson Island Pool, surface sediment concentration increases due to sediment erosion occur as early as 2013 versus 2044 with the baseline forecast hydrograph. In non-cohesive sediments in the Stillwater reach, timing of the largest increase in sediment concentrations is affected by about 13 years among the four hydrographs.

The water column results from the alternative hydrographs show significant year-to-year variability relative to each other, although the overall trends are the same. The impact of the hydrograph on the forecast results does show notable differences in the first few years of the forecast period. However, these differences are based on the choice of forecast hydrograph. The apparent rate of recovery is different over the first few years, but then overall trends normalize to similar conditions for all 4 simulations.

8.6.2 Sensitivity to Solids Loads at Fort Edward

The magnitude of solids loading plays an important role in determining future Tri+ concentrations in the Upper Hudson River. As discussed in Section 8.1.1.2, the specification of future solids loads at Fort Edward was estimated by the solids rating curve developed for the 1991-1997 period. The possibility that solids loads may occur at a level observed during earlier periods of the historical calibration cannot be excluded. To assess the significance of this on forecast results, a sensitivity analysis was conducted with a solids rating curve based on all available historical data from 1977 to 1997 at Fort Edward (Equation 6-8).

Results indicate that higher solids loads at Fort Edward produce a faster rate of decline of Tri+ surface sediment concentrations and concentrations asymptotically approach a slightly lower quasi steady-state concentration with the upstream load (Figure 8-16). The higher solids loads also result in more solids deposition and delay the occurrence of the predicted concentration increases in cohesive surface sediments. Overall the impact of using the solids rating curve estimated based on the 1991 to 1997 period relative to use of the 1977 to 1997 period is small.

8.6.3 Sensitivity to Tributary Solids Loads

The solids mass balance described in Chapter 6 estimated tributary solids loads downstream of Thompson Island Pool from limited available data. This solids balance was premised on the assumptions that the Upper Hudson River below TIP was net depositional over the 21-year historical calibration period, and that solids trapping efficiencies estimated using data for TIP could also be applied to reaches downstream of TIP. To show the sensitivity of the forecast results to tributary solids loads, sensitivity analyses were conducted with 50 percent upward and downward adjustments to all tributary solids loads to the river.

The result of 50 percent increases and decreases in tributary solids loads is generally to speed and slow rates of Tri+ concentration declines, respectively. Responses in Thompson Island Pool (Figure 8-17a) are smaller than responses in downstream reaches (Figure 8-17b, e) because tributaries account for most of the solids inputs to downstream reaches and only a small portion of solids loadings to TIP. The occurrence, magnitude and timing of computed increases in surface sediment Tri+ concentrations are strongly influenced by changes in solids loadings. Increases of 50 percent in tributary solids loadings cause the complete disappearance of computed increases in Tri+ concentrations. Decreases of 50 percent in tributary solids loadings cause increases in both the frequency and magnitude of computed increases in Tri+ concentrations. Furthermore, new increases in Tri+ concentrations are now computed to occur in the surface sediments of the Waterford and Federal Dam reaches (Figure 8-17d, e). The 50 percent adjustments to tributary solids loads in this sensitivity analysis are considered to be within the uncertainty of the load estimates, therefore, these alternative results are all considered plausible. Use of the forecast results in decision making should consider the possibility that long-term erosional behavior downstream of Thompson Island Pool may occur on a more frequent basis than indicated by the baseline forecast results, or may not occur at all depending on future solids loadings.

8.6.4 Sensitivity to Particle Mixing

The sediment mixed layer depth and particle mixing rate are parameters for which direct measurements are not available. In the historical calibration and the base forecast simulation, sediment mixed layer depths were 10 cm and 6 cm, respectively, in the cohesive and non-cohesive sediment areas of Thompson Island Pool. In reaches downstream of TIP, sediment mixed layer depths were 10 cm and 4 cm, respectively, in cohesive and non-cohesive sediment areas. Initial estimates of sediment particle mixed depths were guided by available information from vertical profiles of sediment Tri+ concentrations, and then adjusted as part of the model calibration process. A sensitivity analysis to non-cohesive sediment mixed layer depth was conducted for the forecast by changing the mixed layer depth from 4 to 6 cm in reaches downstream of TIP. This was done primarily to assess sensitivity of computed sediment Tri+ concentration increases in the Stillwater reach. These simulations used sediment initial conditions for 1991-1997 simulations also computed with mixed layer depth set to 6 cm.

Results indicated slower declines in surface sediment Tri+ concentrations in all reaches downstream of TIP (Figure 8-18 a-e), compared to the baseline No Action case. These responses were due to greater upward mixing of Tri+ mass from the depth interval between 4 and 6 centimeters. The computed increase in surface sediment Tri+ concentration in the non-cohesive sediments of the Stillwater reach was approximately 20 percent less than the increase in the base forecast simulation. Water column Tri+ concentrations are shown in Figure 8-19 at Stillwater.

8.6.5 Sensitivity to Sediment Initial Conditions

Sediment initial conditions for the 1998 through 2067 forecast simulations were based on the end results of the 1991 through 1997 model hindcast application. In effect, this corresponds to initializing the forecast simulations with measured conditions in 1991. This approach utilizes the most recent, reliable and comprehensive dataset to begin the model forecasts. In particular, in terms of accuracy, vertical resolution and spatial coverage for the Upper Hudson River, the 1991 sediment measurements represent the best match between available sediment data and model requirements. An alternate approach would have been to use the end results of the 1977 through 1997 historical calibration. This would correspond to initializing the forecast simulations with measured conditions in 1977.

A forecast sensitivity analysis was conducted to investigate the impacts of changes in sediment initial conditions. This analysis involved initializing the forecast simulation with measured conditions in 1977. The principal result from this sensitivity analysis was that computed increases in surface sediment Tri+ concentrations in TIP and the Stillwater reach were magnified relative to computed increases in the base forecast simulation (Figure 8-20 a-e). Water column Tri+ concentration increases were also magnified (Figure 8-21 a, b). This indicates that the magnitudes of computed increases in surface sediment Tri+ concentrations during the forecast simulations depend on the temporal history of Tri+ vertical concentration profiles in the sediments.

8.7 EXPOSURE CONCENTRATIONS FOR AUGUST 1999 AND DECEMBER 1999 RISK ASSESSMENTS

The HUDTOX model was developed and refined over a period of years, and EPA conducted the risk assessments for the Reassessment concurrently with this modeling effort. Accordingly, EPA used the most updated version of HUDTOX and the latest model results that were available at the time the risk assessments were conducted. The processing of HUDTOX results for linkage with the FISHRAND bioaccumulation model is discussed in Book 3 of this report.

The computed total PCB concentrations in water and surface sediment in the No Action forecast from the May 1999 BMR were used in the August 1999 Ecological Risk Assessment and the Human Health Risk Assessment for the Upper Hudson River. These results are based on initial conditions in sediment specified from the 1991 GE composite data set and 10 ng/L PCBs in water at the upstream boundary (see, Appendix A).

The computed Tri+ concentrations in water and surface sediment in the No Action forecast from this RBMR report were used in the December 1999 Ecological Risk Assessment for Future Risks in the Lower Hudson River and the Human Health Risk Assessment for the Mid-Hudson River. These results are based on initial conditions in sediment specified from the 1977 data set and 10 ng/L PCBs in water at the upstream boundary (see, Appendix A).

8.8 PRINCIPAL FINDINGS AND CONCLUSIONS

Several important conclusions were drawn from the No Action and 100-year peak flow simulations provided in this report. The conclusions drawn from these simulations are based on the No Action forecast and 100-year event applications of the HUDTOX model that was successfully calibrated to long-term trends of water column and surface sediment Tri+ concentrations. Findings and conclusions from the No Action forecast, the 100-year event simulation and the selected sensitivity analyses are addressed in the sections below.

8.8.1 No Action Forecast

The principal findings and conclusions from the No Action forecast simulations are the following:

- Forecasted surface sediment Tri+ concentrations continue to decline at approximately 7 to 9 percent per year over the next two decades, consistent with long-term historical trends.

- Forecasted surface sediment Tri+ concentrations eventually reach levels determined by upstream boundary Tri+ loadings at Fort Edward. Under the assumptions in the forecast simulations, this occurs after the first two decades of the forecast period. For the first two decades, the in-place Tri+ reservoir in the sediments and sediment-water transfer processes control long-term responses of surface sediment concentrations.

- Forecasted water column Tri+ concentrations continue to decline for the first one to two decades and are very sensitive to Tri+ loading at Fort Edward. Based on specification of constant Tri+ concentrations of 10 ng/L and 30 ng/L at Fort Edward, the Fort Edward load begins to control average annual water column responses after 12 to 15 years.

- Declines in Tri+ loads to the Lower Hudson River mirror water column Tri+ declines. They reach a quasi steady-state asymptote of 45kg/yr and 125 kg/yr for the 10 and 30 ng/L Tri+ concentration assumptions at Ft. Edward.

- Surface sediment Tri+ concentrations in localized areas in Thompson Island Pool and the Stillwater reach are forecasted to increase 40 to 50 years in the future. These computed increases occur due to the long-term consequences of small sediment erosion rates that eventually expose Tri+ contamination originally present in deeper sediment layers.

- The relative magnitudes of computed increases in surface sediment Tri+ concentrations are small within the context of long-term trends in historical concentrations; however, they may be important in a potential remediation decision. The occurrence, magnitude and timing of these computed increases are dependent on forecast assumptions.

- Forecasted responses of water column and surface sediment Tri+ concentrations in the Upper Hudson River were sensitive to changes in hydrology, solids loadings, sediment particle mixing depth and sediment initial conditions. Long-term responses were most sensitive to changes in tributary solids loadings and sediment mixing depth. Computed increases in surface sediment Tri+ concentrations were most sensitive to changes in tributary solids loadings and sediment initial conditions.

The No Action forecast findings are affected by uncertainty in upstream Tri+ loads. In general, if Tri+ loads stay at or below levels observed in the past few years (1997 through 1999), surface sediment Tri+ concentrations are expected to show declines consistent with historical rates. Model forecasts show that concentration declines are likely to exhibit half-lives of about 7 to 10 years. In other words, every 7 to 10 years, concentrations will decrease by 50 percent. However, beyond two decades, forecasted surface sediment Tri+ concentrations will reach levels determined by the assumed constant upstream boundary concentrations at Fort Edward.

8.8.2 100-Year Peak Flow Simulation

The principal findings and conclusions from the 100-year peak flow simulation are the following:

- Results of the 100-year peak flow simulation show that a flood of this magnitude would result in only a small additional increase in sediment erosion beyond what might be expected for a reasonable range of annual peak flows. A 100-year peak flow is 39 percent larger than the peak flows included in the base No Action forecast simulation.

- The small sediment scour depths produced by the 100-year peak flow result in only very small increases in surface sediment Tri+ concentrations. These increases are short-lived and decline to values in the base forecast simulation (without the 100-year peak flow) in approximately four years.

- Increases in water column Tri+ concentrations in response to a 100-year peak flow are very short-lived and decline rapidly after occurrence of the event. The event causes an increase of 26 kg (57 lbs) in cumulative Tri+ mass loading across Thompson Island Dam by the end of the first year of the forecast. This increase represents approximately 13 percent of the average annual Tri+ mass loading across Thompson Island Dam during the 1990s.

- The occurrence of a 100-year peak flow is not likely to have a substantial effect on the future course of Tri+ concentrations in the water or sediments of the Upper Hudson River relative to the base No Action forecast simulation.

Results from simulation of a 100-year peak flow with HUDTOX are consistent with those reported for the Depth of Scour Model in Chapter 4.

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9. HUDTOX VALIDATION

9.1 OVERVIEW

Model validation is the process of confirming the ability of a model to predict observed behavior using datasets that are independent of the datasets used to calibrate the model. Validation is a test of the scientific rigor of a model and of its utility as a predictive tool. Should a model fail a validation exercise, its predictive ability is suspect. Conversely, should a model's predictions compare well with validation datasets, its suitability for forecasting is considered validated and conclusions drawn from model predictions are strengthened. With this in mind, a validation of the HUDTOX model was pursued using an independent dataset collected after the calibration period.

Water column data collected by GE in 1998 were available to conduct an independent validation of the HUDTOX model. These data are not included in Release 4.1b of Hudson River Database, the main data source for the modeling work presented in this report. The GE 1998 data include PCB measurements of water column and sediment concentrations. A portion of these data are presented in O'Brien and Gere 1999a and 1999b. Validation of the model to the water column dataset provided an assessment of the sediment-water mass transfer processes in the model.

Observed sediment concentrations served as the primary calibration targets for the 1977 to 1997 historical calibration. The calibrated model predicts the observed sediment concentrations in 1998 reasonably well. However, year to year changes in sediment concentrations are small. Therefore, focus of the validation testing of HUDTOX was on the water column data for 1998, available at Fort Edward, Thompson Island Dam and Schuylerville. Model results for 1998 agreed very well with the observed seasonal variations in water column data.

9.2 VALIDATION APPROACH

The validation simulation was conducted for the period of January 1, 1998 through September 30, 1998 because USGS flow records extending beyond this date were not available when this analysis was conducted. Beyond specification of 1998 flows and loads, all other model input in this validation runs were unchanged from the historical calibration.

Tributary solids loads and input hydrographs were calculated based on USGS flow data, solids data, and solids to flow regressions used in the calibration. The major tributaries which contribute significant solids and flow (Hoosic River and the Mohawk River) are all located downstream of the two locations where 1998 data was available for comparison to model output. Thus, any uncertainty in assumptions for these sources should not significantly affect the results of this validation exercise. Improved estimates of solids loads from Batten Kill would make the comparisons of model output and data at the Schuylerville location slightly more accurate.

Linear interpolation of Fort Edward Tri+ concentrations was used to specify the upstream boundary condition for the validation. Computed surficial sediment concentrations at the end of the model calibration period were specified as sediment initial conditions, the same as described in Chapter 8 for the No Action simulation. All other model parameters and coefficients were identical as employed in the calibration period simulations.

9.2.1 Validation Results

Year to year changes in surface and sediment concentrations are small and hence 1998 sediment conditions were not used as a primary measurement of validation. In fact, 1998 sediment data were used in the historical calibration in Chapter 7. However, water column PCB concentrations can vary significantly year to year, season to season or even day to day due to changes in hydrology, loads, and sediment effects.

Water column PCB observations are available for Tri+ at Fort Edward, Thompson Island Dam and Schuylerville. The sampling frequency was approximately weekly with a few exceptions. Model results were compared with these data by visual inspection of time series concentrations. Results are shown for the last three years of the calibration period and the validation period, 1998 (Figures 9-1 and 9-2). Model comparisons to just the 1998 data are presented in Figure 9-3.

Good agreement is observed between model results and observations. The model generally reproduces the observed concentrations through the entire 1998 validation period. Figures 9-4 and 9-5 show scatter diagrams comparing model output and data at Thompson Island Dam and Schuylerville on a monthly average basis. Based on the good agreement of the model with observed concentrations at Thompson Island Dam and Schuylerville, the HUDTOX model validation appears reasonably successful. While the extent of this validation period does not necessarily lead to a validation of the model's ability to make accurate long-term projections of exposure concentrations, it does provide a test of the model to represent annual fluxuations in water column PCB concentrations outside of the calibration period. This tends to strengthen the model's utility as a predictive tool.

9.2.2 Validation Summary

The model validation was conducted by comparing predicted water column Tri+ concentrations to observed concentrations in 1998. Results indicate good agreement between predicted and observed concentrations at both Thompson Island Dam and Schuylerville over an entire year, spanning a range of environmental conditions. The validation is considered successful and it enhances the model's credibility as a predictive tool for use in assessing the future course of the river's recovery from historical contamination under continued No Action.

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Table 8-1. Sequencing of Annual Hydrographs to Develop 70-year Forecast Hydrograph.

Forecast Year	Annual Hydrograph	Average Annual Flow (cfs)	Forecast Year	Annual Hydrograph	Average Annual Flow (cfs)
1	1998	3,904	36	2033	4,981
2	1999	4,240	37	2034	5,985
3	2000	5,985	38	2035	5,879
4	2001	7,183	39	2036	6,265
5	2002	4,955	40	2037	6,265
6	2003	4,981	41	2038	5,049
7	2004	4,240	42	2039	7,183
8	2005	4,889	43	2040	4,981
9	2006	5,879	44	2041	5,171
10	2007	5,991	45	2042	3,904
11	2008	3,904	46	2043	7,183
12	2009	3,675	47	2044	6,762
13	2010	7,183	48	2045	6,045
14	2011	5,991	49	2046	5,985
15	2012	6,265	50	2047	5,260
16	2013	6,762	51	2048	5,260
17	2014	5,985	52	2049	4,605
18	2015	5,985	53	2050	6,045
19	2016	3,904	54	2051	6,265
20	2017	4,240	55	2052	4,981
21	2018	4,943	56	2053	4,605
22	2019	4,134	57	2054	4,605
23	2020	5,049	58	2055	6,045
24	2021	4,955	59	2056	3,904
25	2022	4,240	60	2057	4,889
26	2023	4,240	61	2058	5,147
27	2024	6,265	62	2059	4,955
28	2025	4,955	63	2060	6,265
29	2026	4,981	64	2061	7,183
30	2027	4,462	65	2062	4,955
31	2028	5,049	66	2063	4,955
32	2029	5,049	67	2064	4,605
33	2030	5,171	68	2065	5,171
34	2031	6,045	69	2066	5,049
35	2032	5,260	70	2067	4,605

Table 8-2. Surface Sediment Tri+ Initial Conditions for the No Action and 100-Year Event Simulations.

River Reach	Surface Sediment Tri+ Concentration (mg/Kg)	
	Cohesive Sediment	Non-cohesive Sediment
Thompson Island Pool	13.70	6.47
TI Dam to Schuylerville	9.91	2.03
Schuylerville to Stillwater	2.42	1.48
Stillwater to Waterford	1.98	0.96
Waterford to Federal Dam	-	0.76

Table 8-3. Effect of the 100-Year Flood Event on the Non-cohesive (N) and Cohesive (C) Sediment Bed in Upper Hudson River Reaches between Fort Edward and Federal Dam (Year 1 - 3/28 to 4/13).

Upper Hudson River Reach	Thompson Island Pool (TIP)		TI Dam to Schuylerville		Schuylerville to Stillwater		Stillwater to Waterford		Waterford to Federal Dam
Sediment Type	N	C	N	C	N	C	N	C	N
Solids Deposited (MT)	119	157	158	350	2,114	1,306	4,395	1,217	1,192
Solids Resuspended (MT)	-1,103	-1,161	-164	-5,336	-2,970	-105	-5,358	-3,715	-901
Net Change in Sediment Solids Mass (MT)	-984	-1,004	-5	-4,985	-855	1,202	-963	-2,498	291
Net Change in Sediment Bed Elevation (cm)	-0.051	-0.281	-0.001	-1.105	-0.015	0.153	-0.018	-0.569	0.008

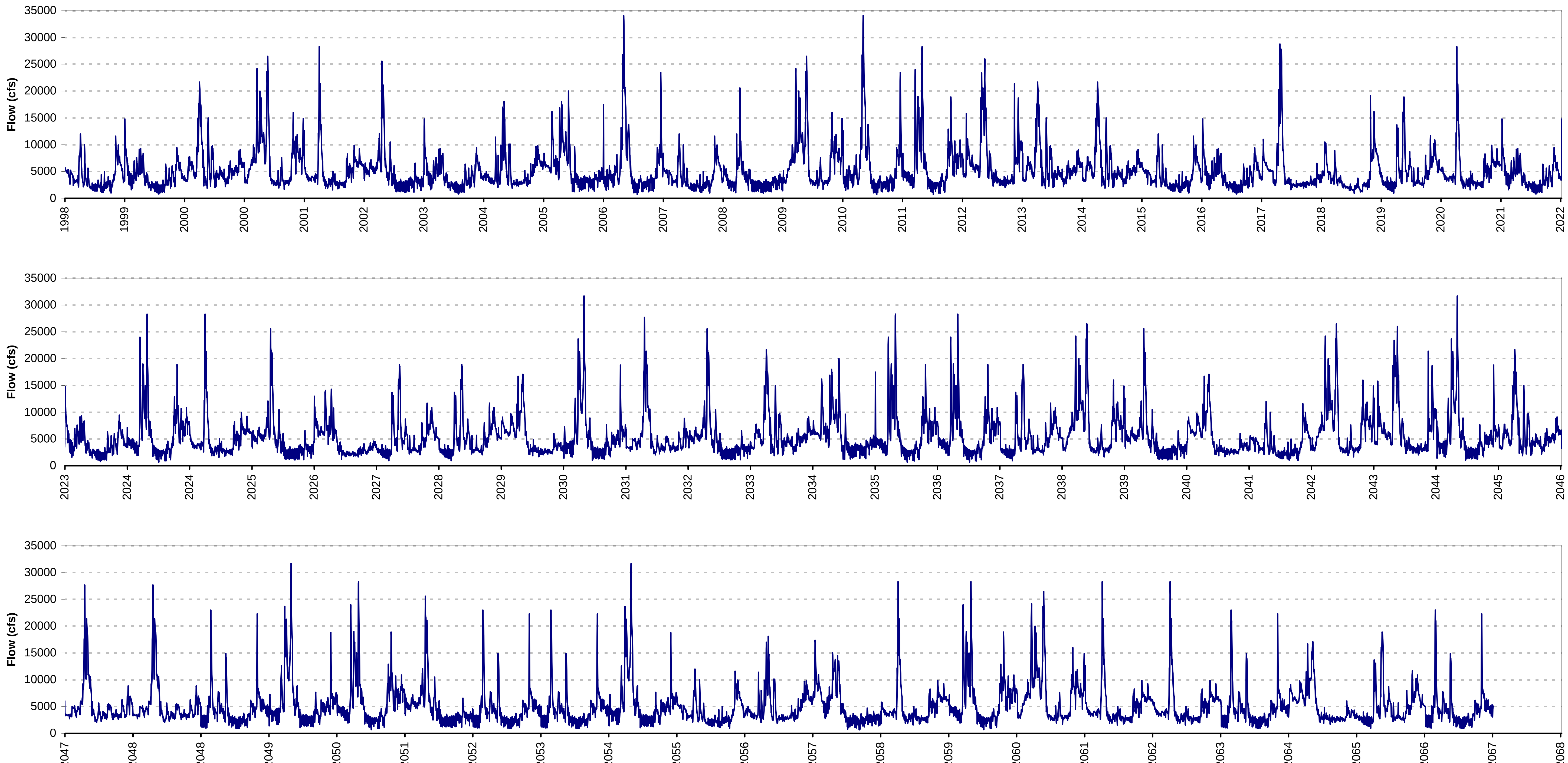


Figure 8-1. 70-Year Hydrograph for the No Action Forecast Simulation: 1998-2067

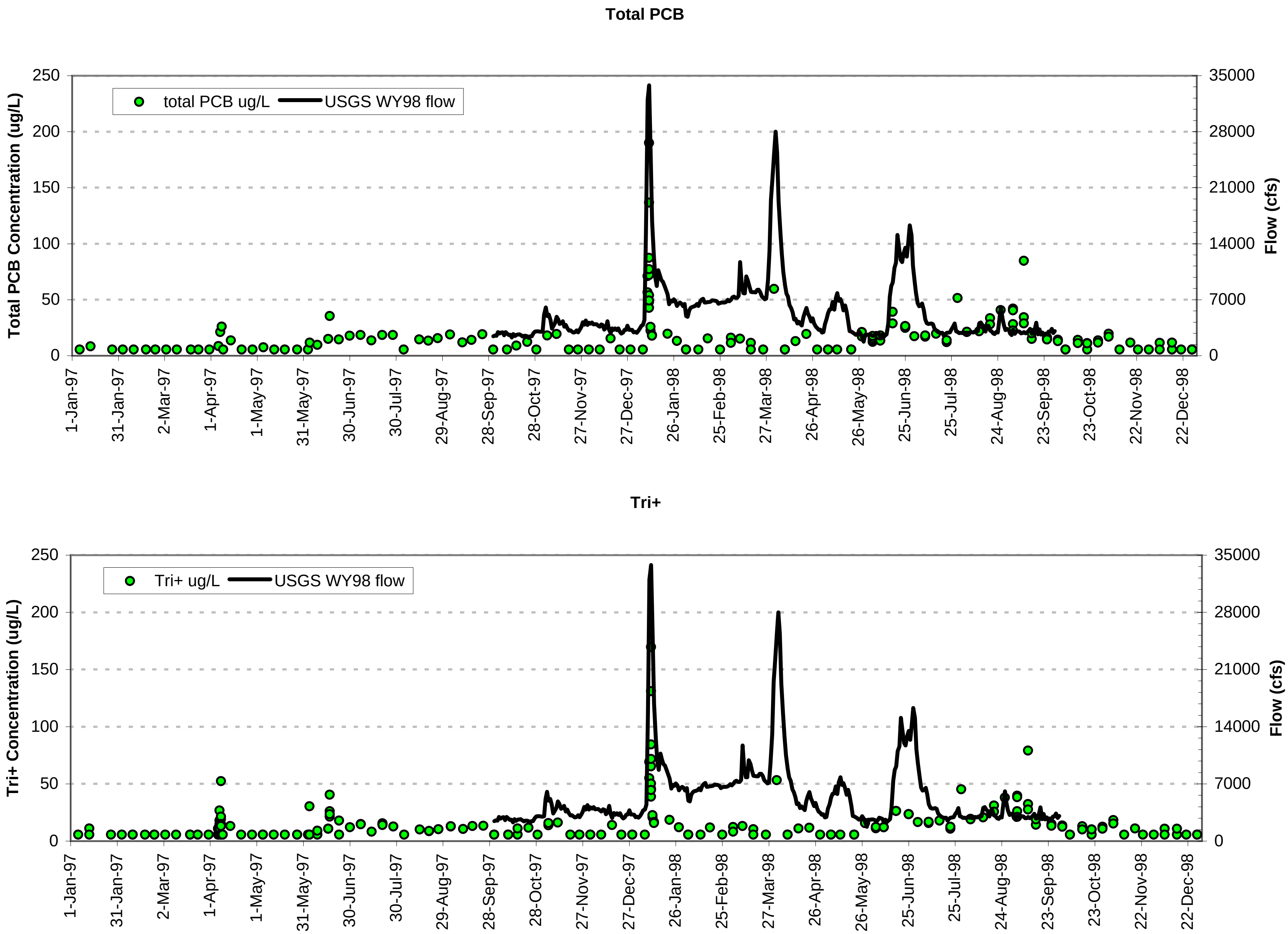


Figure 8-2. Observed Total PCB and Tri+ PCB Concentrations at Fort Edward During 1997 and 1998.

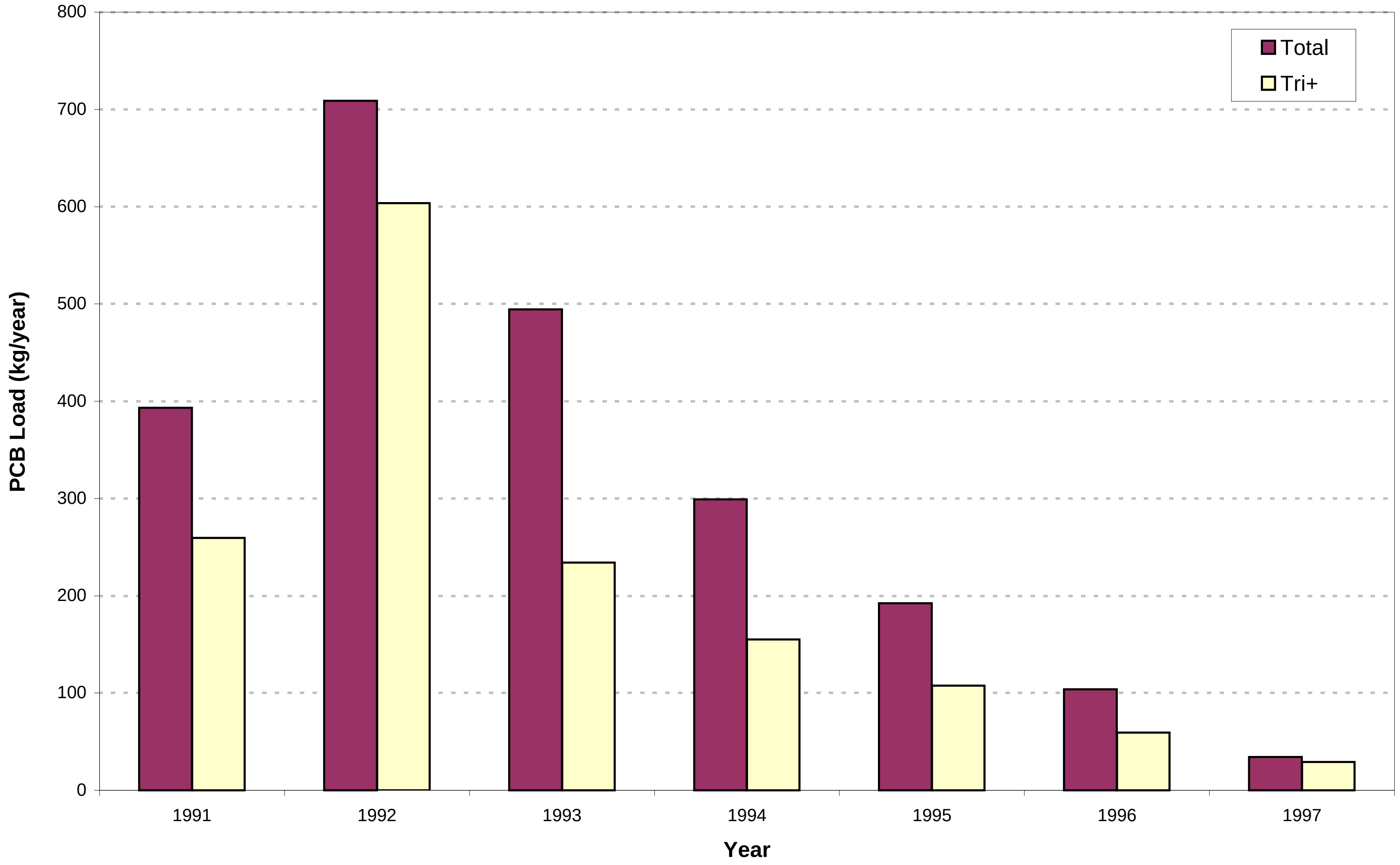


Figure 8-3. Data-Based Estimate of Annual Total and Tri+ PCB Load by Year at Fort Edward, 1991-1997.

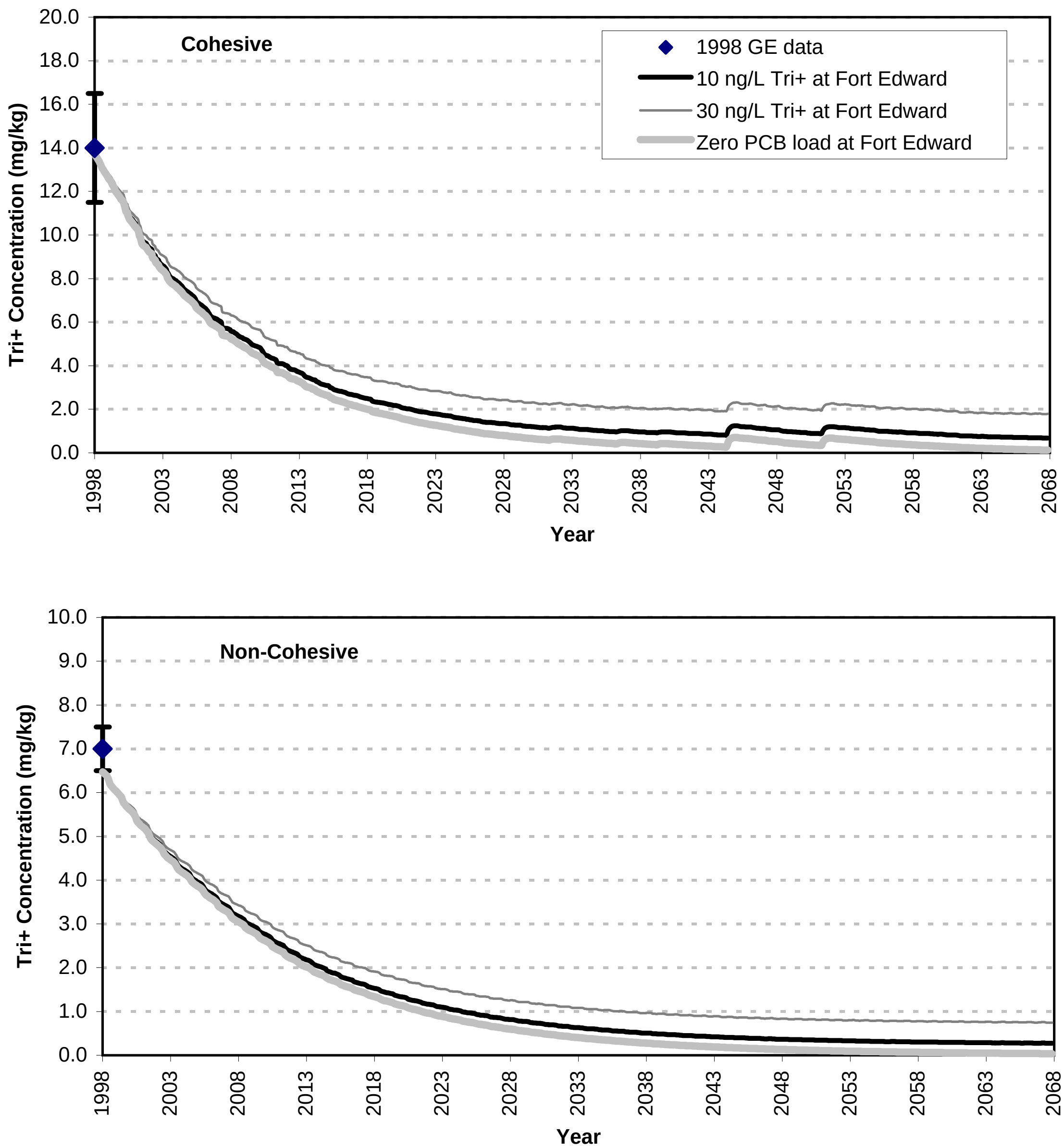


Figure 8-4a. Forecast Sediment Tri+ Concentrations for Thompson Island Pool with Constant Upstream Tri+ Concentrations at 10 ng/L, 30 ng/L, and 0 ng/L, 1998-2067.

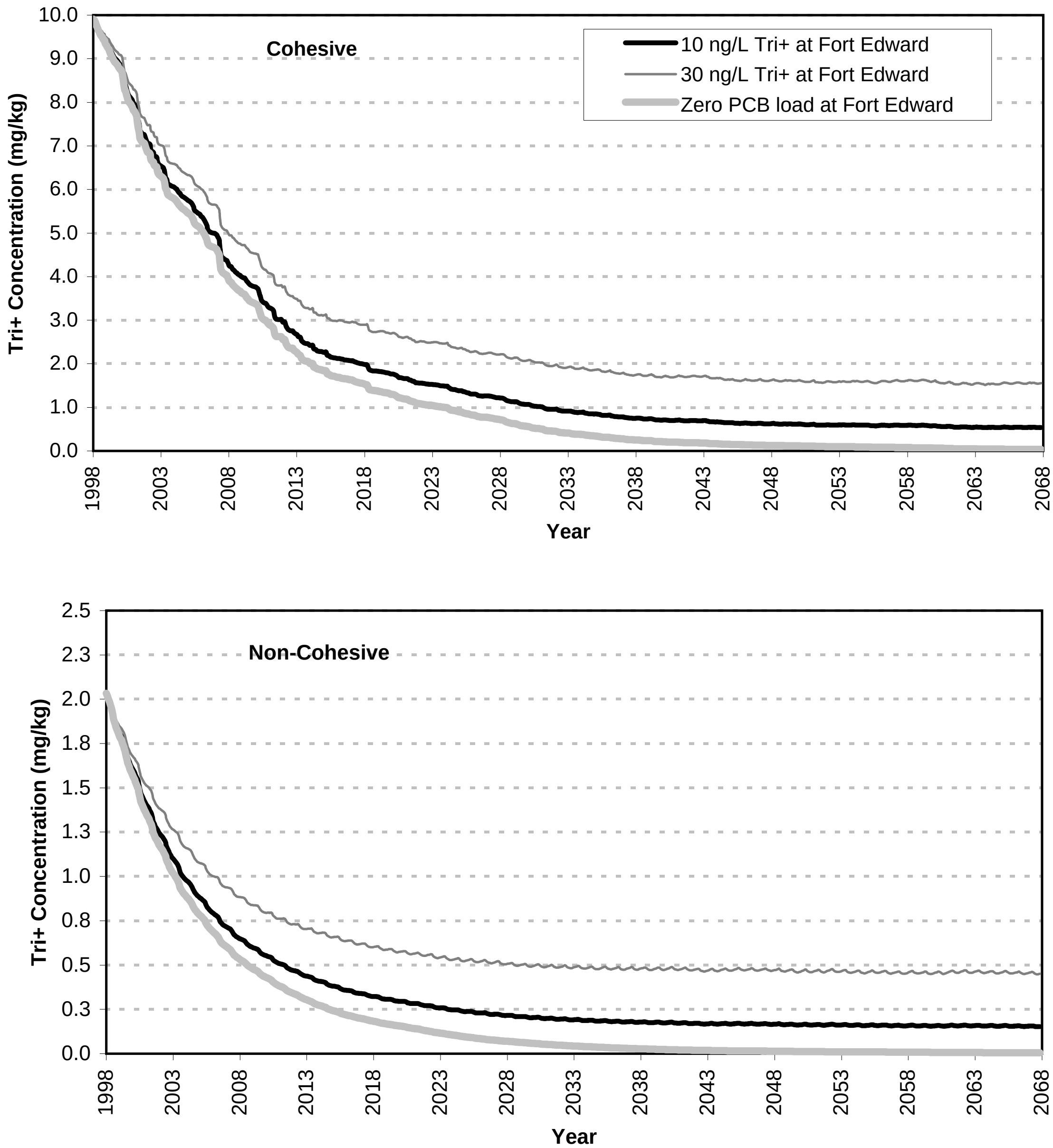


Figure 8-4b. Forecast Sediment Tri+ Concentrations for the Schuylerville Reach with Constant Upstream Tri+ Concentrations at 10 ng/L, 30 ng/L, and 0 ng/L, 1998-2067.

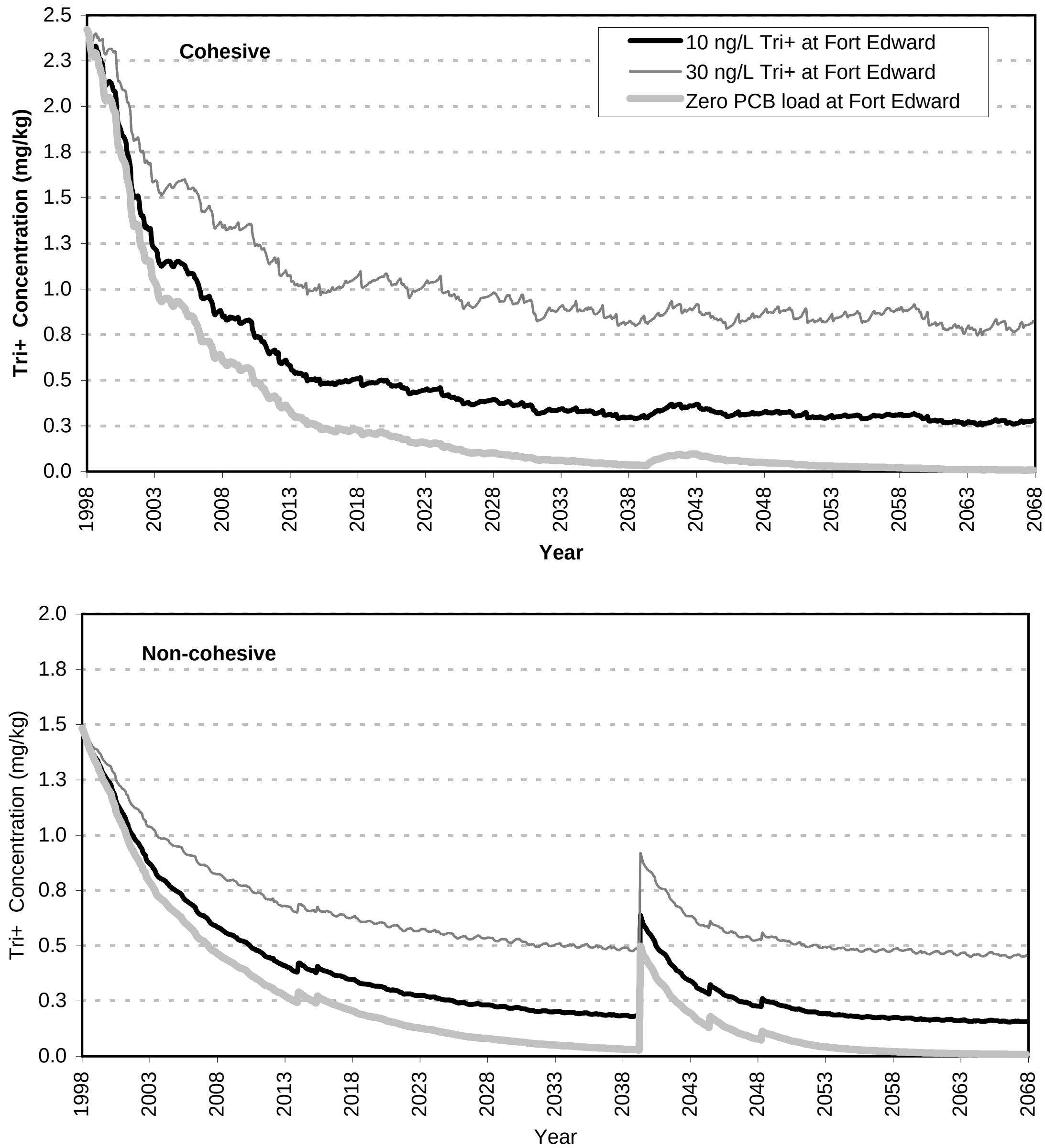


Figure 8-4c. Forecast Sediment Tri+ Concentrations for the Stillwater Reach with Constant Upstream Tri+ Concentrations at 10 ng/L, 30 ng/L, and 0 ng/L, 1998-2067.

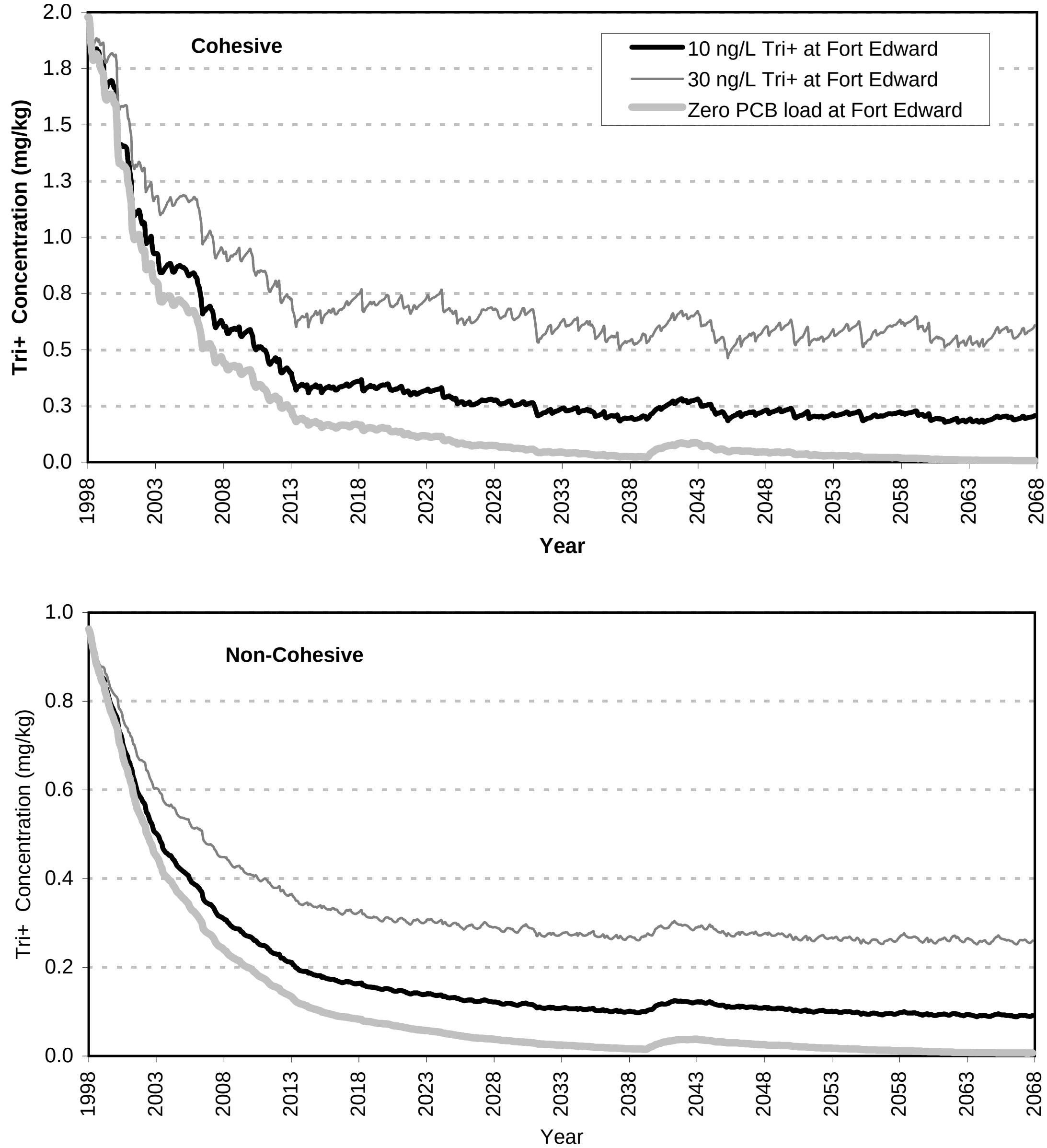


Figure 8-4d. Forecast Sediment Tri+ Concentrations for the Waterford Reach with Constant Upstream Tri+ Concentrations at 10 ng/L, 30 ng/L, and 0 ng/L, 1998-2067.

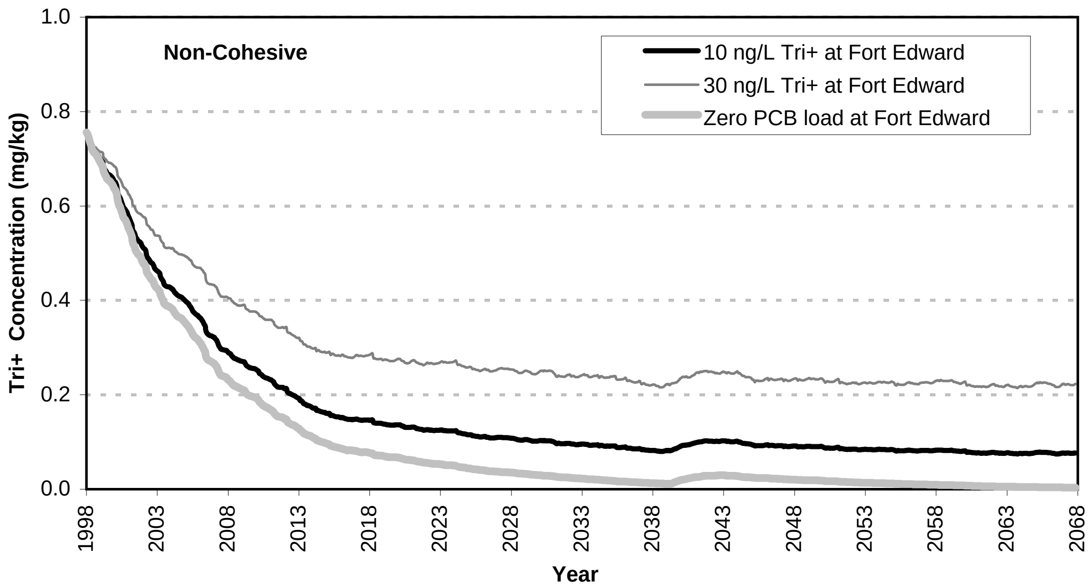
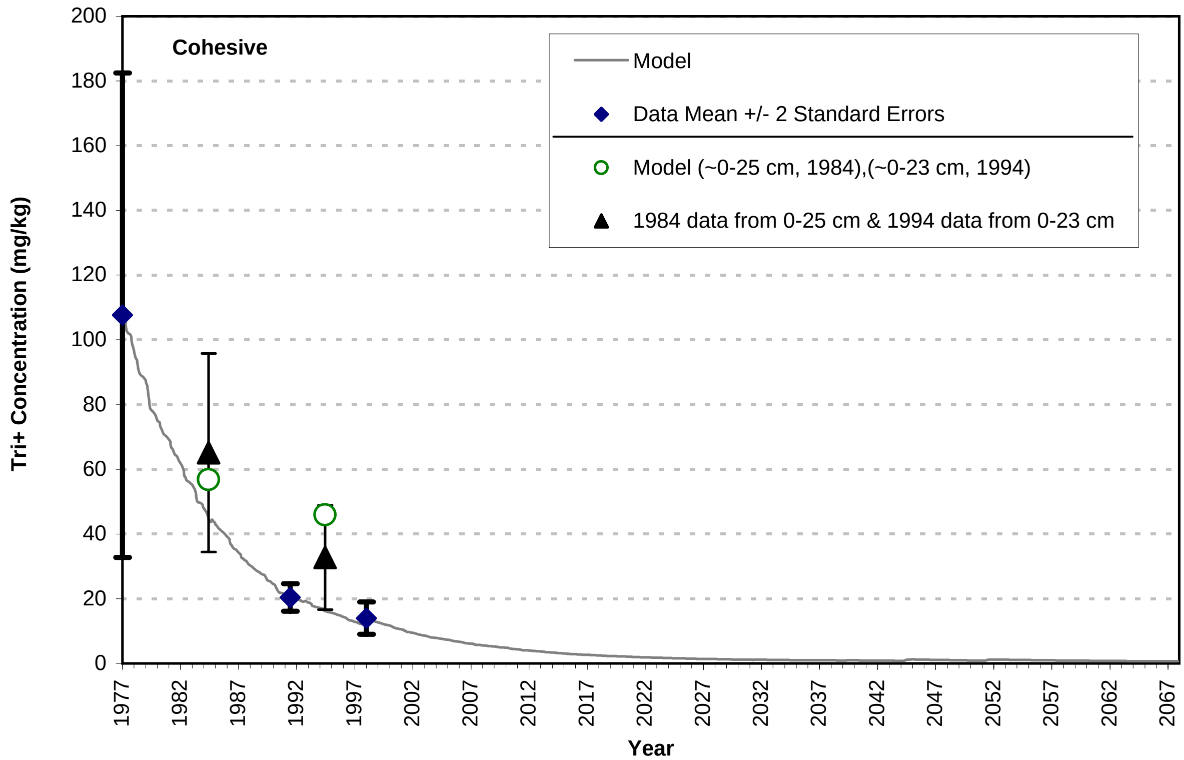


Figure 8-4e. Forecast Sediment Tri+ Concentrations for the Federal Dam Reach with Constant Upstream Tri+ Concentrations at 10 ng/L, 30 ng/L, and 0 ng/L, 1998-2067.



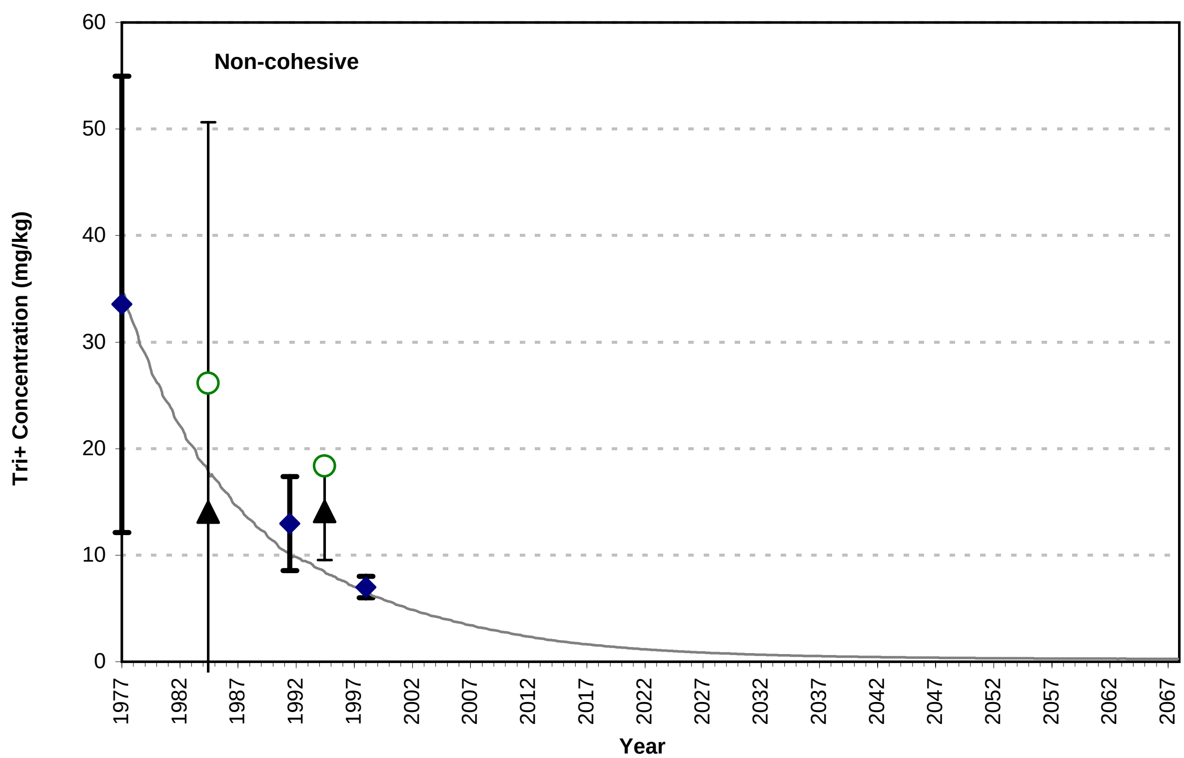


Figure 8-5a. Predicted Sediment Tri+ Concentrations for Thompson Island Pool with Forecasted Constant Upstream Tri+ Concentration at 10 ng/L.

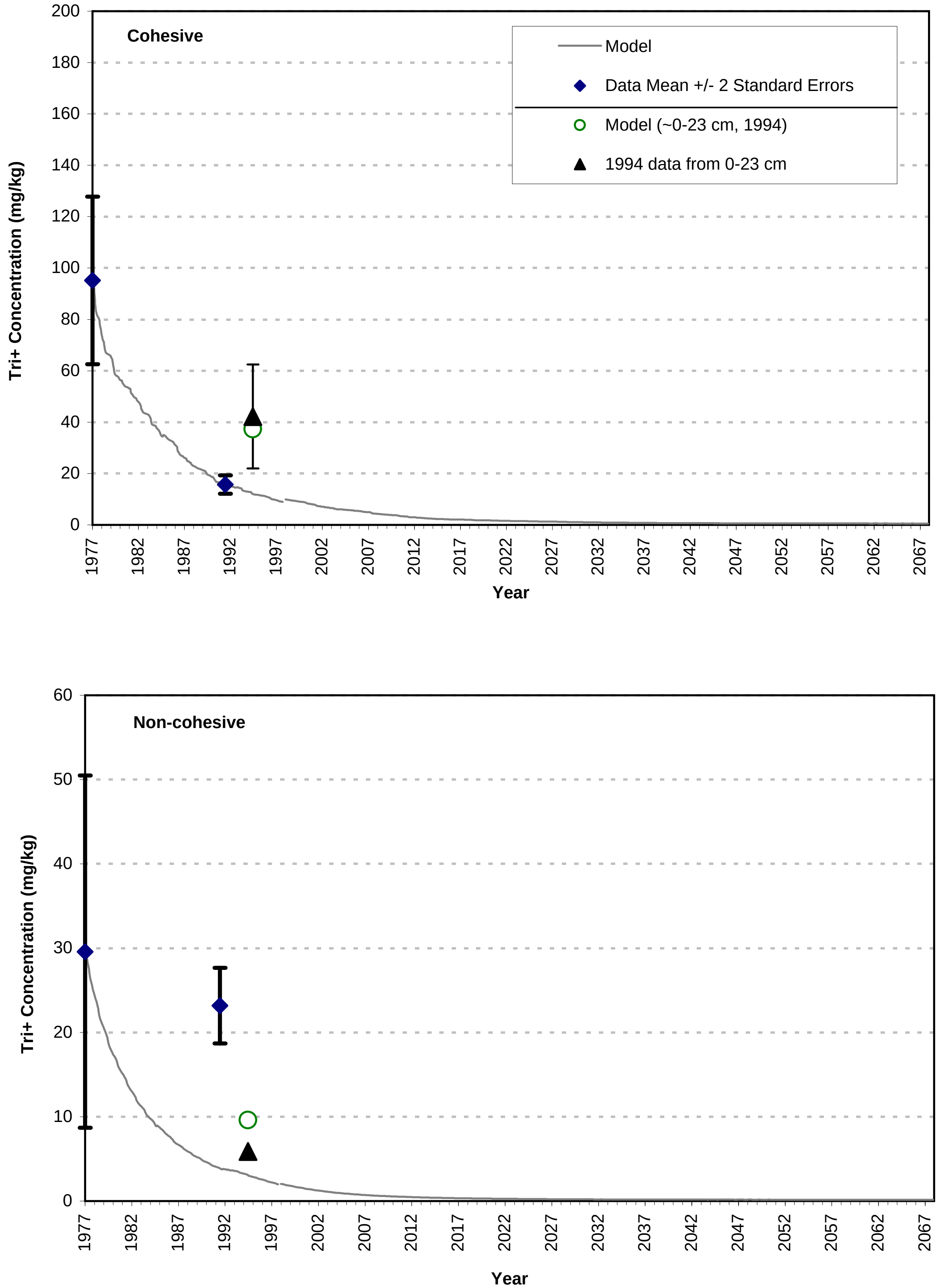
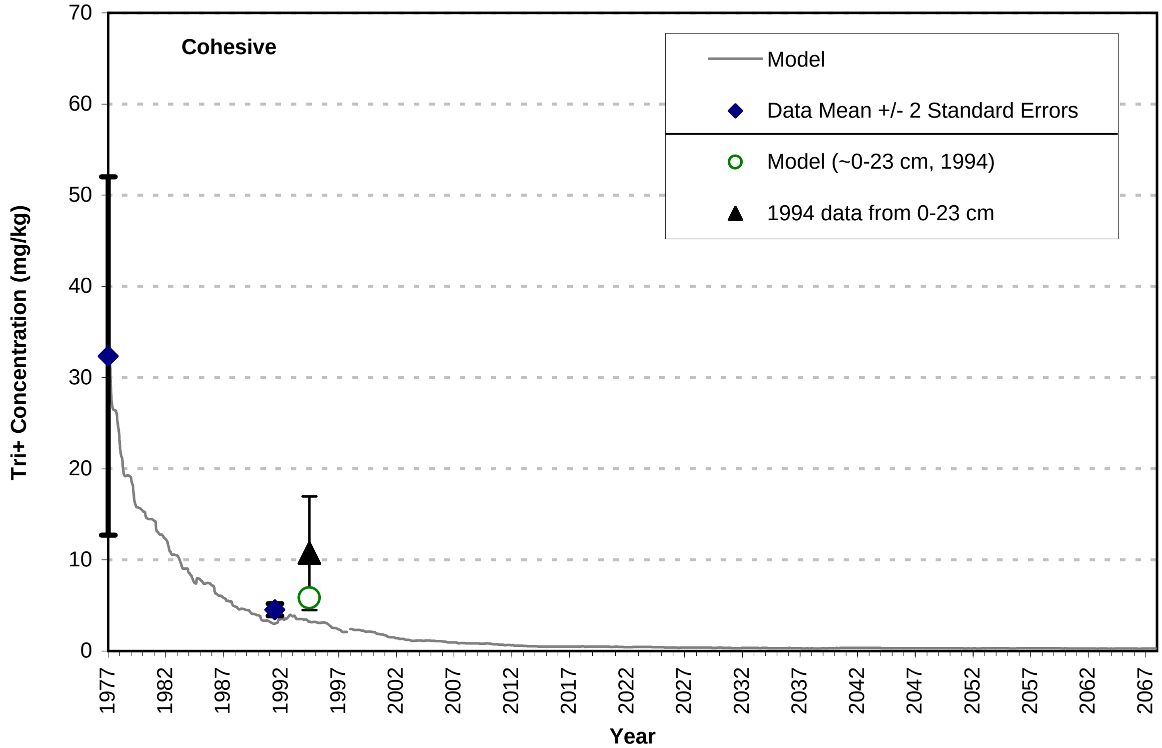


Figure 8-5b. Predicted Sediment Tri+ Concentrations for Schuylerville Reach with Forecasted Constant Upstream Tri+ Concentration at 10 ng/L.



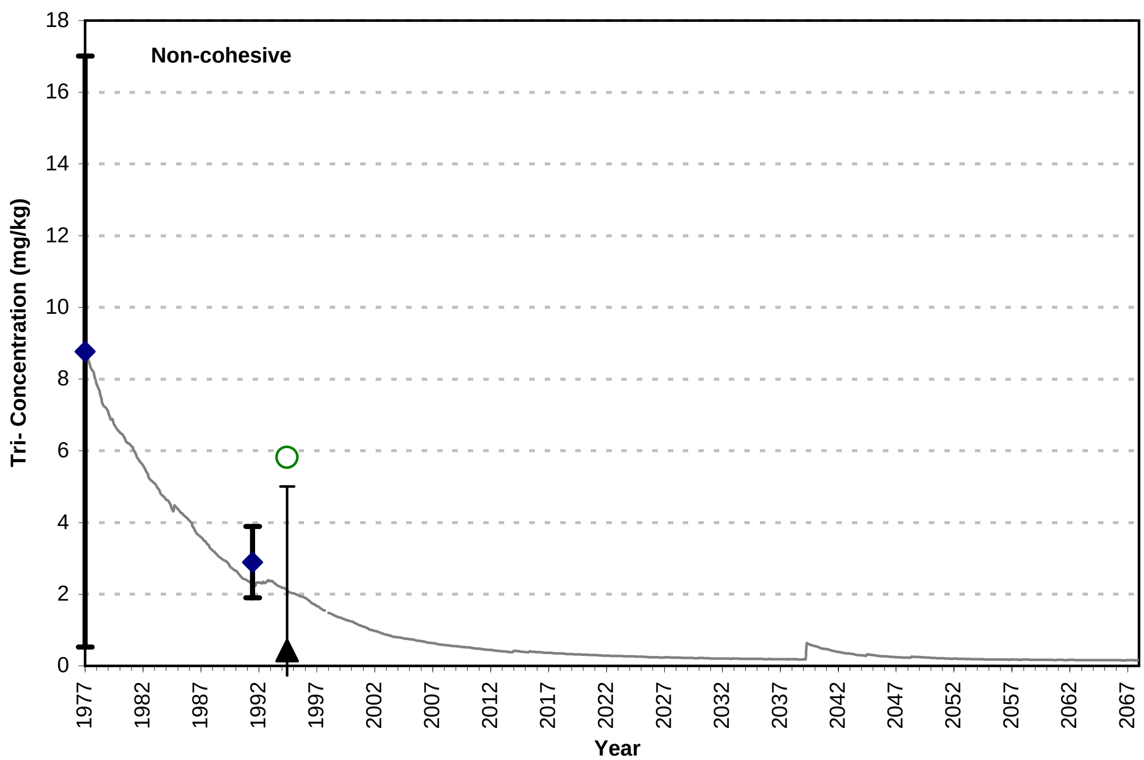
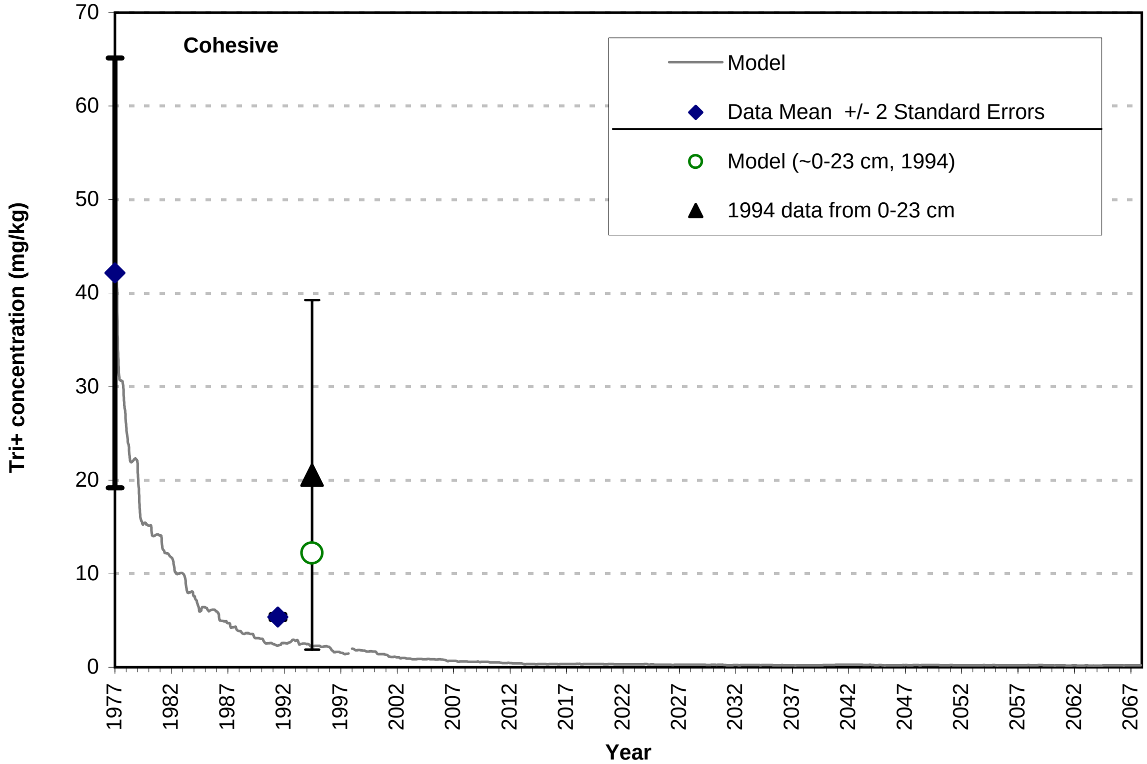


Figure 8-5c. Predicted Sediment Tri+ Concentrations for Stillwater Reach with Forecasted Constant Upstream Tri+ Concentration at 10 ng/L.



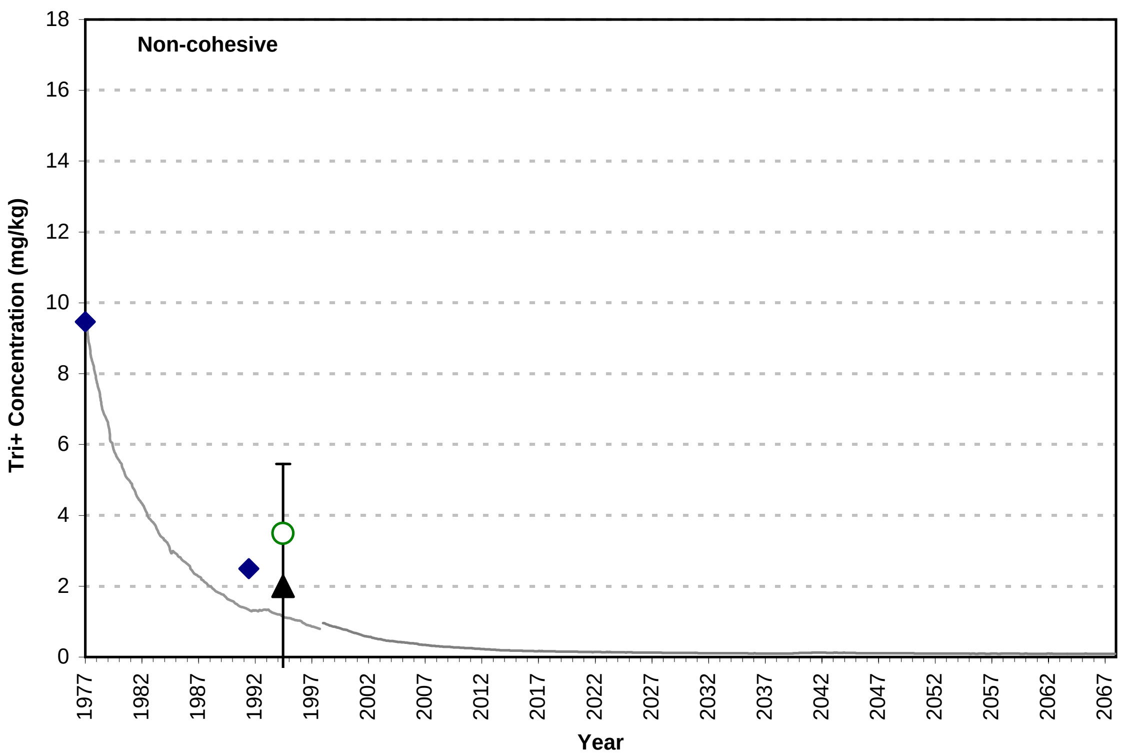


Figure 8-5d. Predicted Sediment Tri+ Concentrations for Waterford Reach with Forecasted Constant Upstream Tri+ Concentration at 10 ng/L.

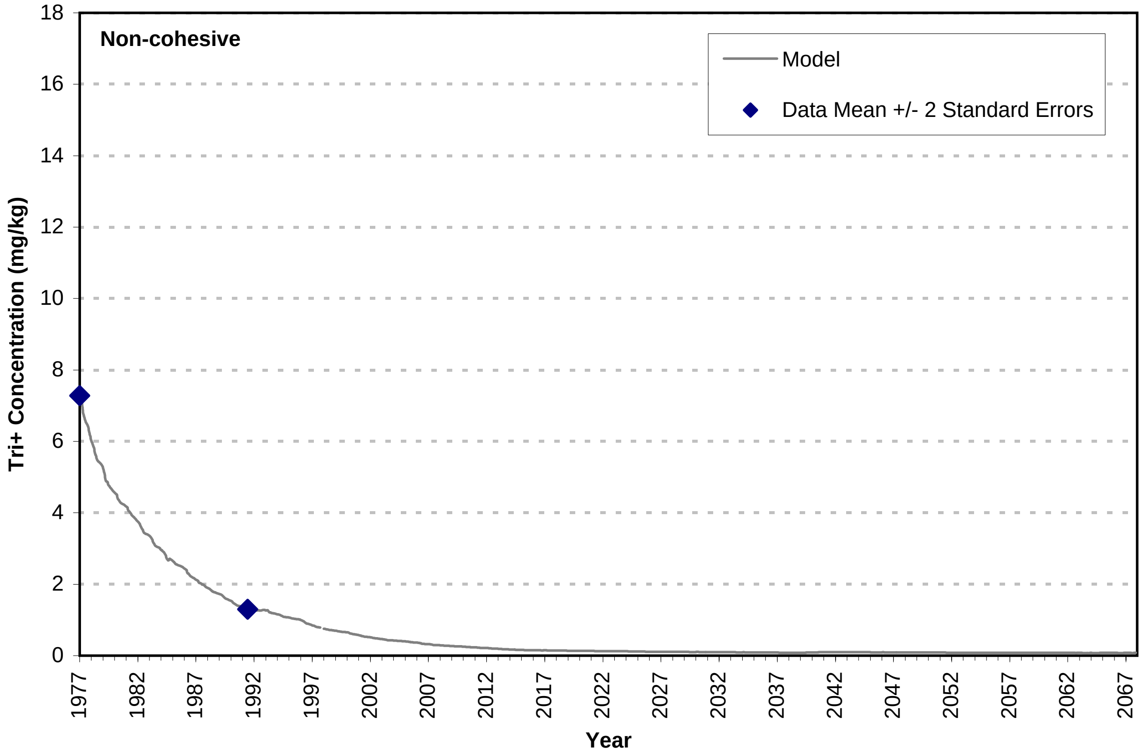
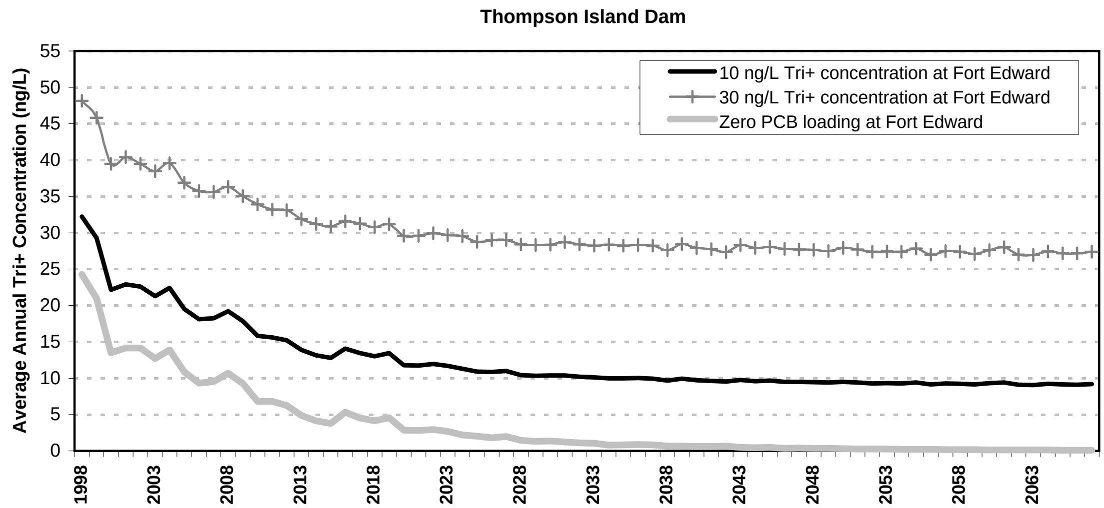


Figure 8-5e. Predicted Sediment Tri+ Concentrations for Federal Dam Reach with Forecasted Constant Upstream Tri+ Concentration at 10 ng/L.



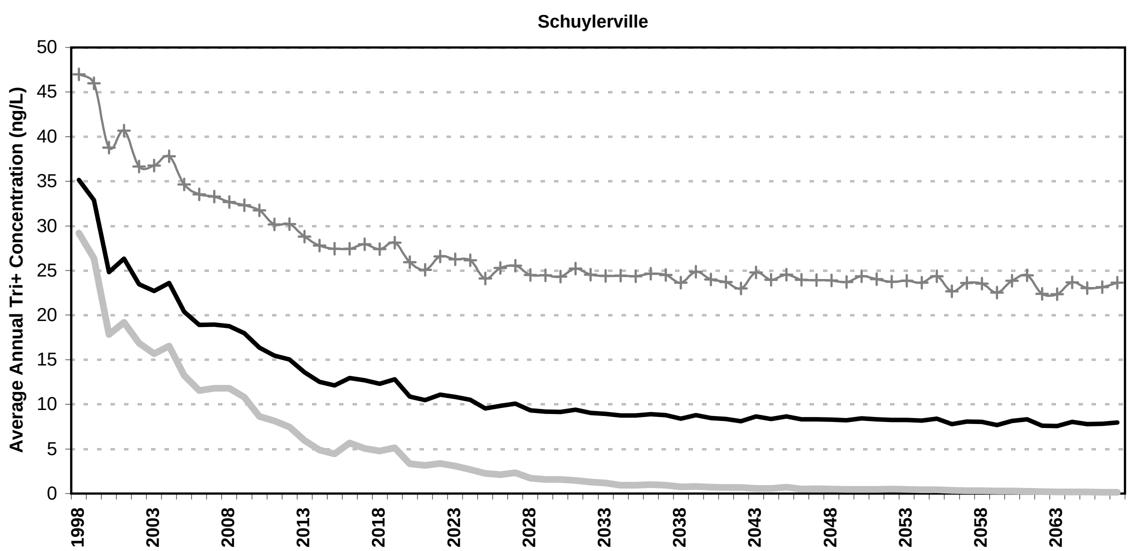
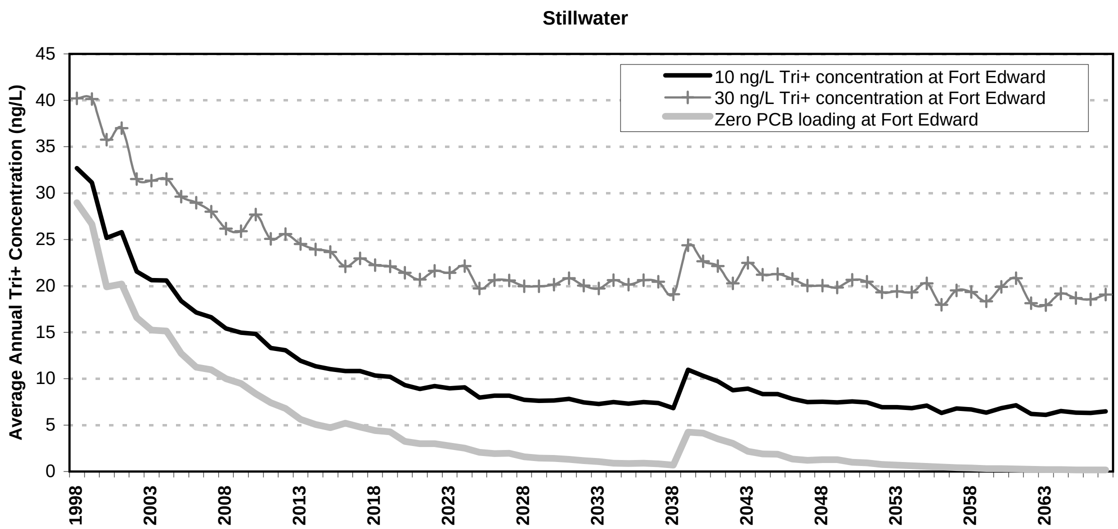


Figure 8-6a. Forecast Average Annual Tri+ Concentrations at Thompson Island Dam and Schuylerville with Constant Upstream Concentrations of 10 ng/L, 30 ng/L, and 0 ng/L Tri+ at Fort Edward, 1998 - 2067.



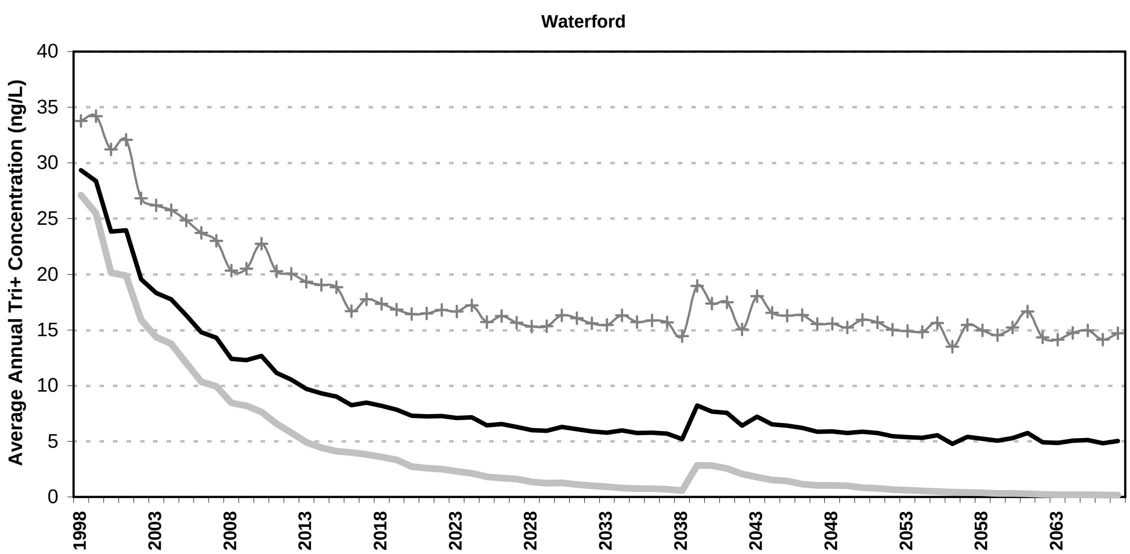
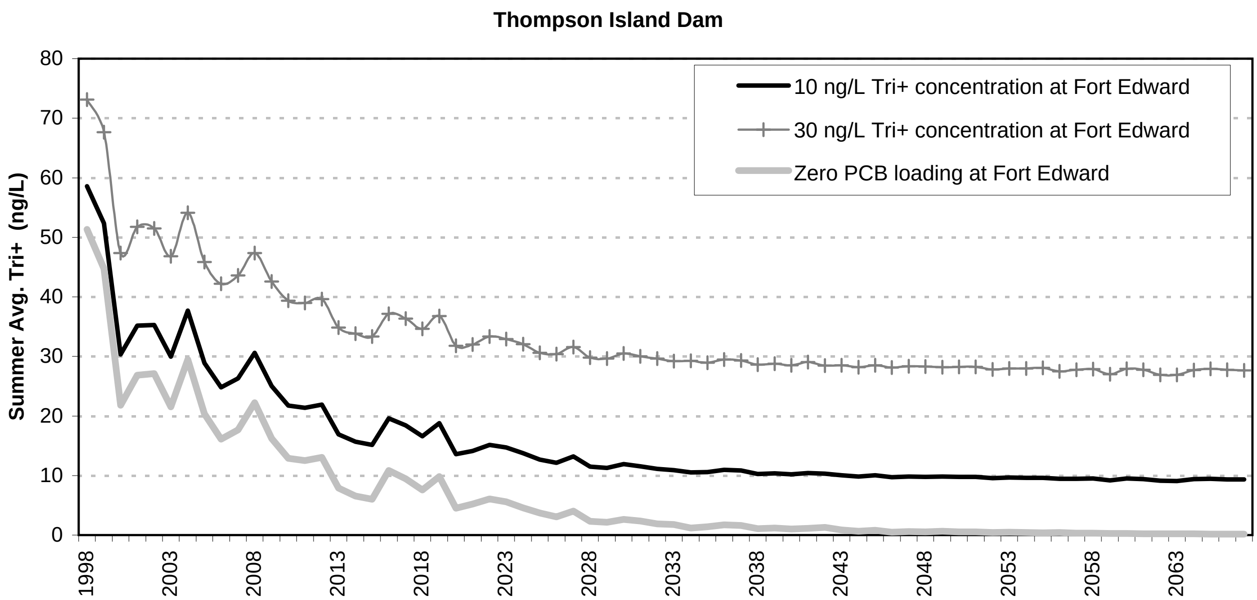


Figure 8-6b. Forecast Average Annual Tri+ Concentrations at Stillwater and Waterford with Constant Upstream Concentrations of 10 ng/L, 30 ng/L, and 0 ng/L Tri+ at Fort Edward, 1998 - 2067.



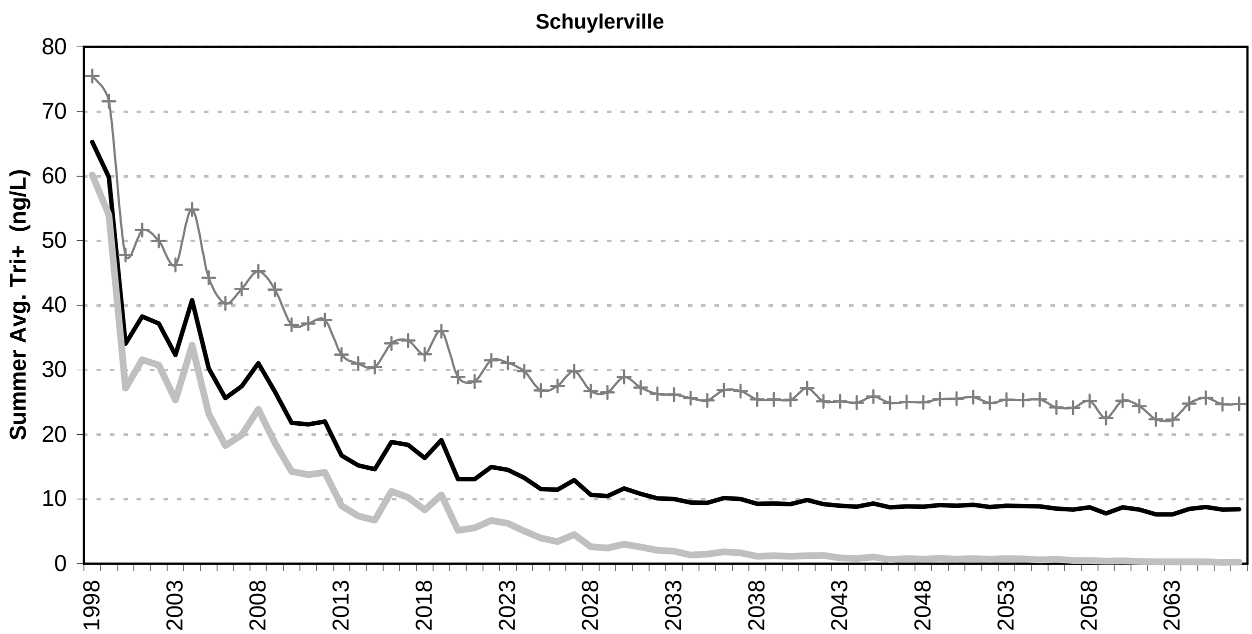


Figure 8-7a. Forecast Average Summer Tri+ Concentrations at Thompson Island Dam and Schuylerville with Constant Upstream Concentrations of 10 ng/L, 30 ng/L, and 0 ng/L Tri+ at Fort Edward, 1998 - 2067.

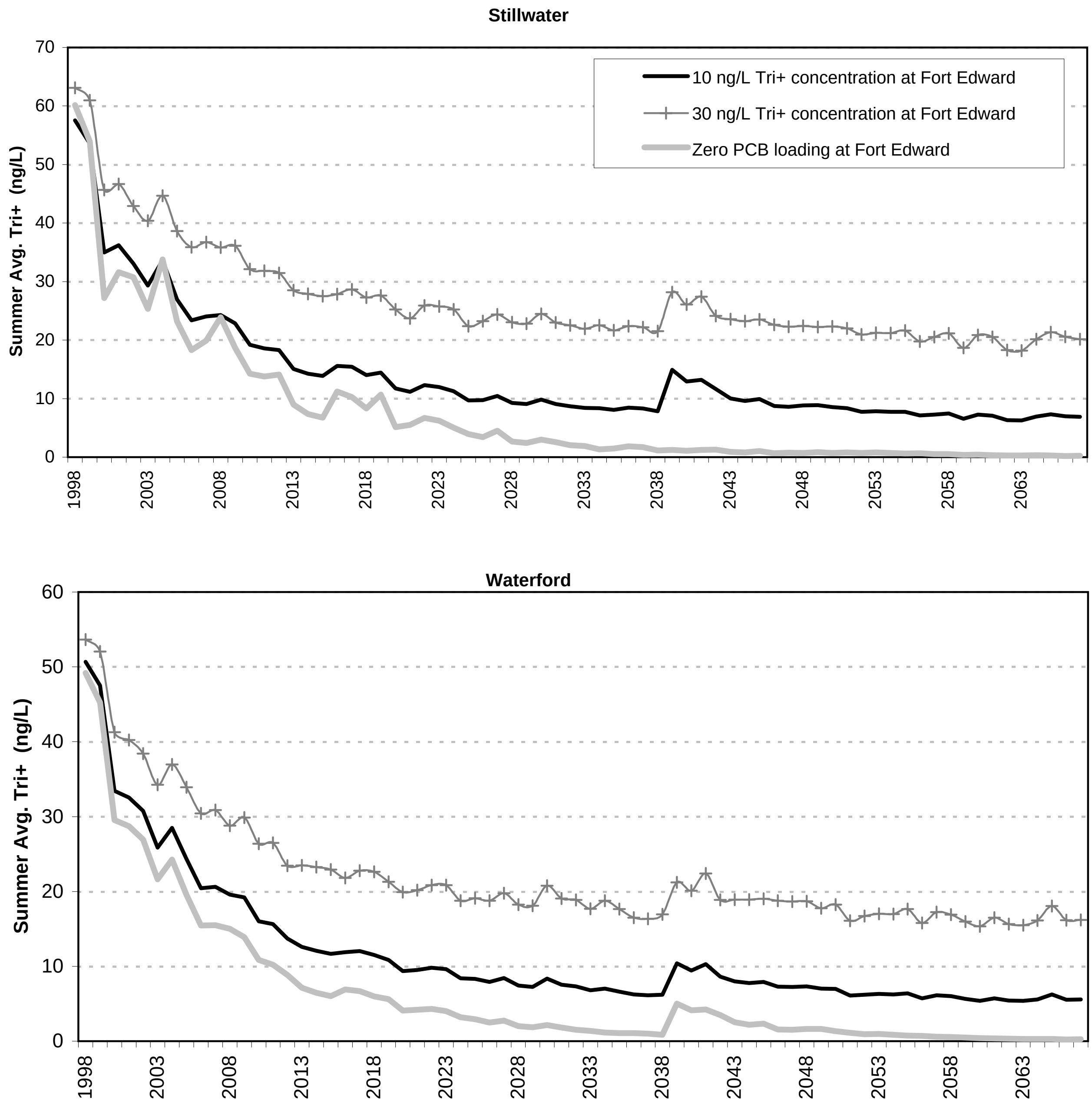
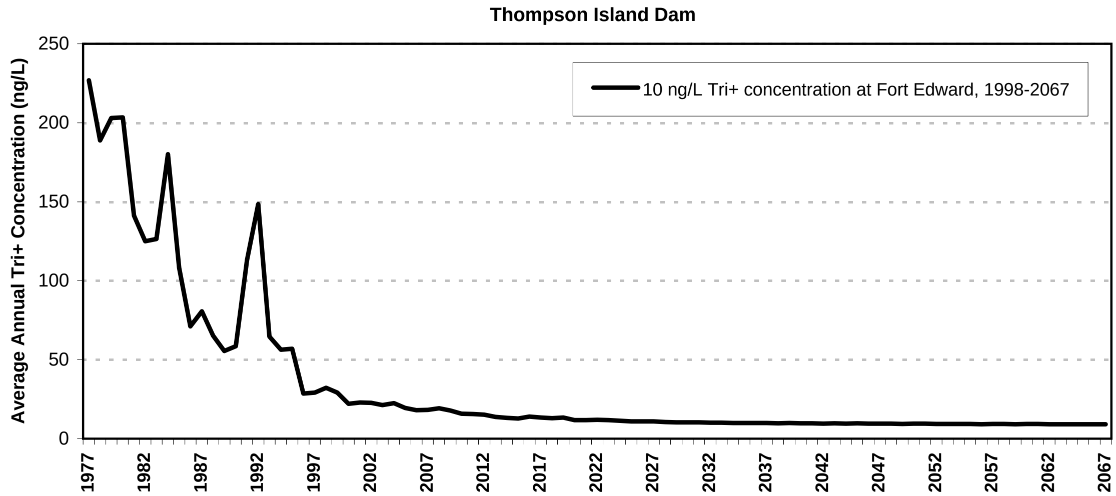
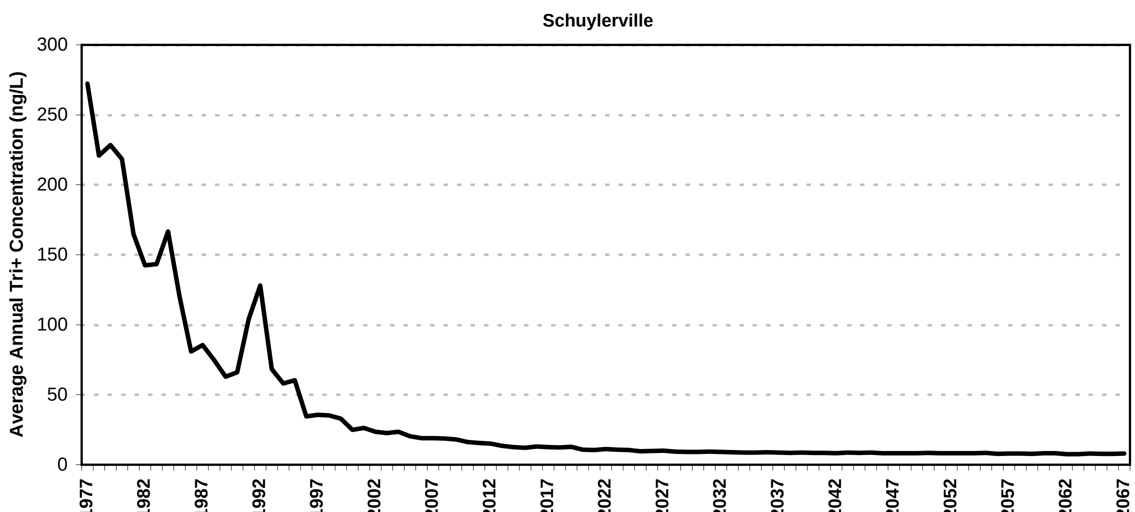
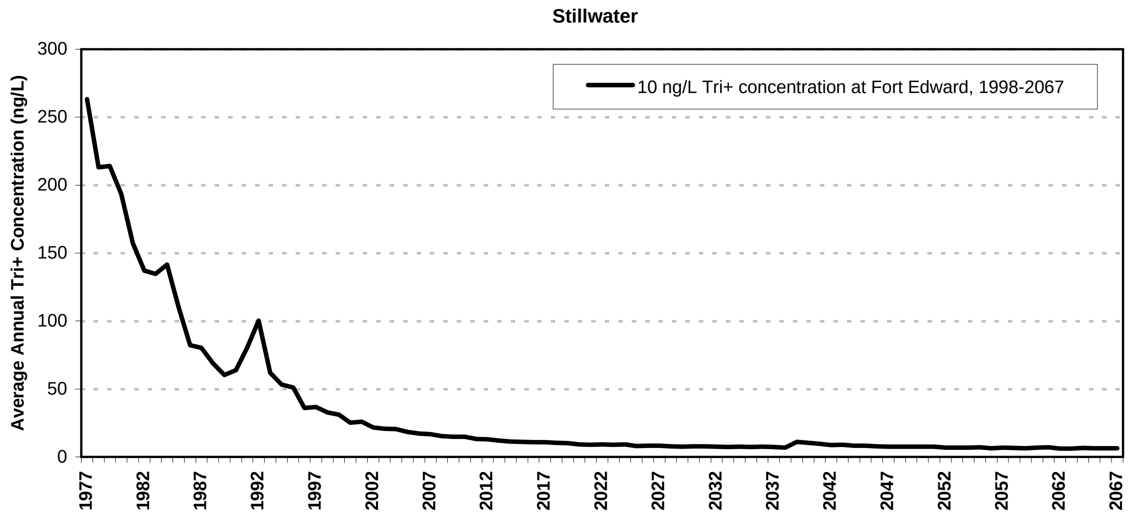


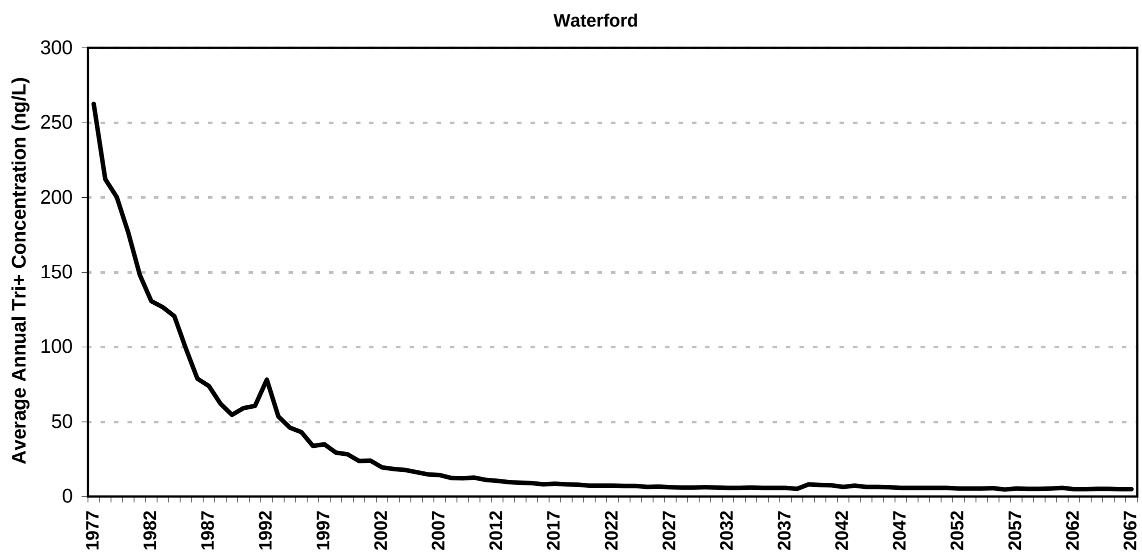
Figure 8-7b. Forecast Average Summer Tri+ Concentrations at Stillwater and Waterford with Constant Upstream Concentrations of 10 ng/L, 30 ng/L, and 0 ng/L Tri+ at Fort Edward, 1998 - 2067.





8-8a. Predicted Average Annual Water Column Tri+ Concentrations at Thompson Island Dam and Schuylerville with Forecasted Constant Upstream Tri+ Concentration at 10 ng/L, 1977-2067.





8-8b. Predicted Average Annual Water Column Tri+ Concentrations at Stillwater and Waterford with Forecasted Constant Upstream Tri+ Concentration at 10 ng/L, 1977-2067.

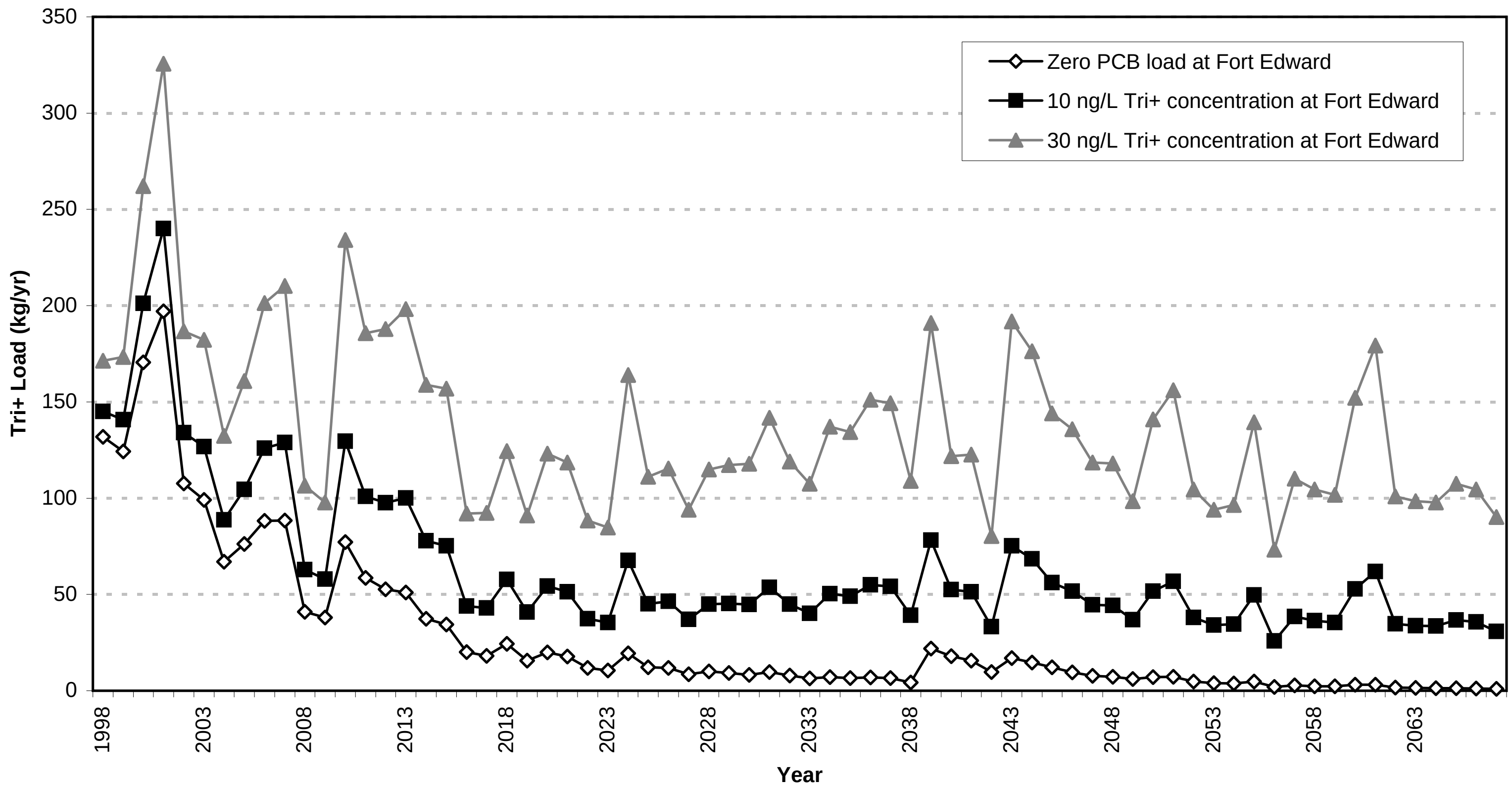


Figure 8-9a. No-Action Forecast Annual Tri+ Load to the Lower Hudson River with Constant Upstream Concentrations of 10 ng/L, 30 ng/L, and 0 ng/L Tri+ at Fort Edward, 1998-2067.

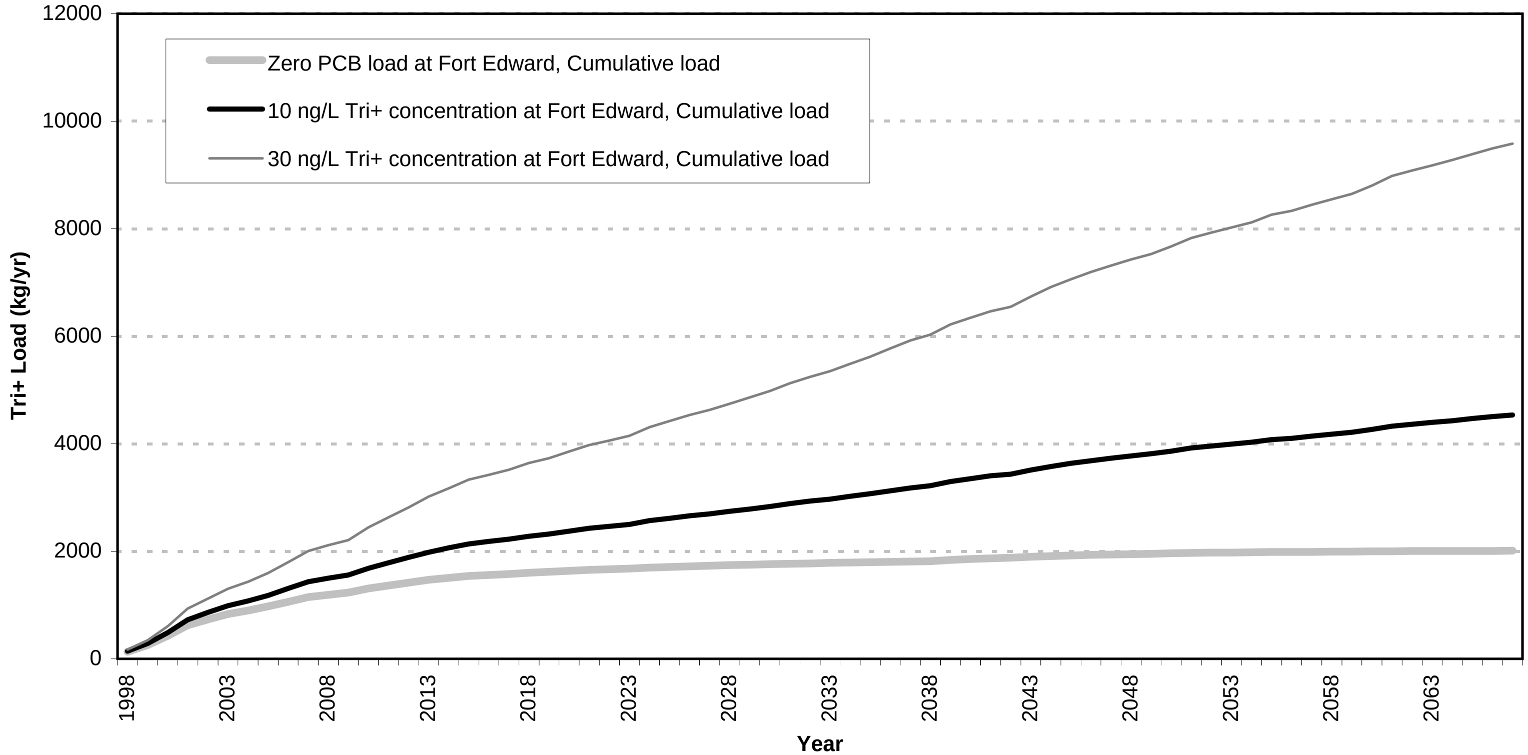


Figure 8-9b. No-Action Forecast Cumulative Annual Tri+ Load to the Lower Hudson River with Constant Upstream Concentrations of 10 ng/L, 30 ng/L, and 0 ng/L Tri+ at Fort Edward, 1998-2067.

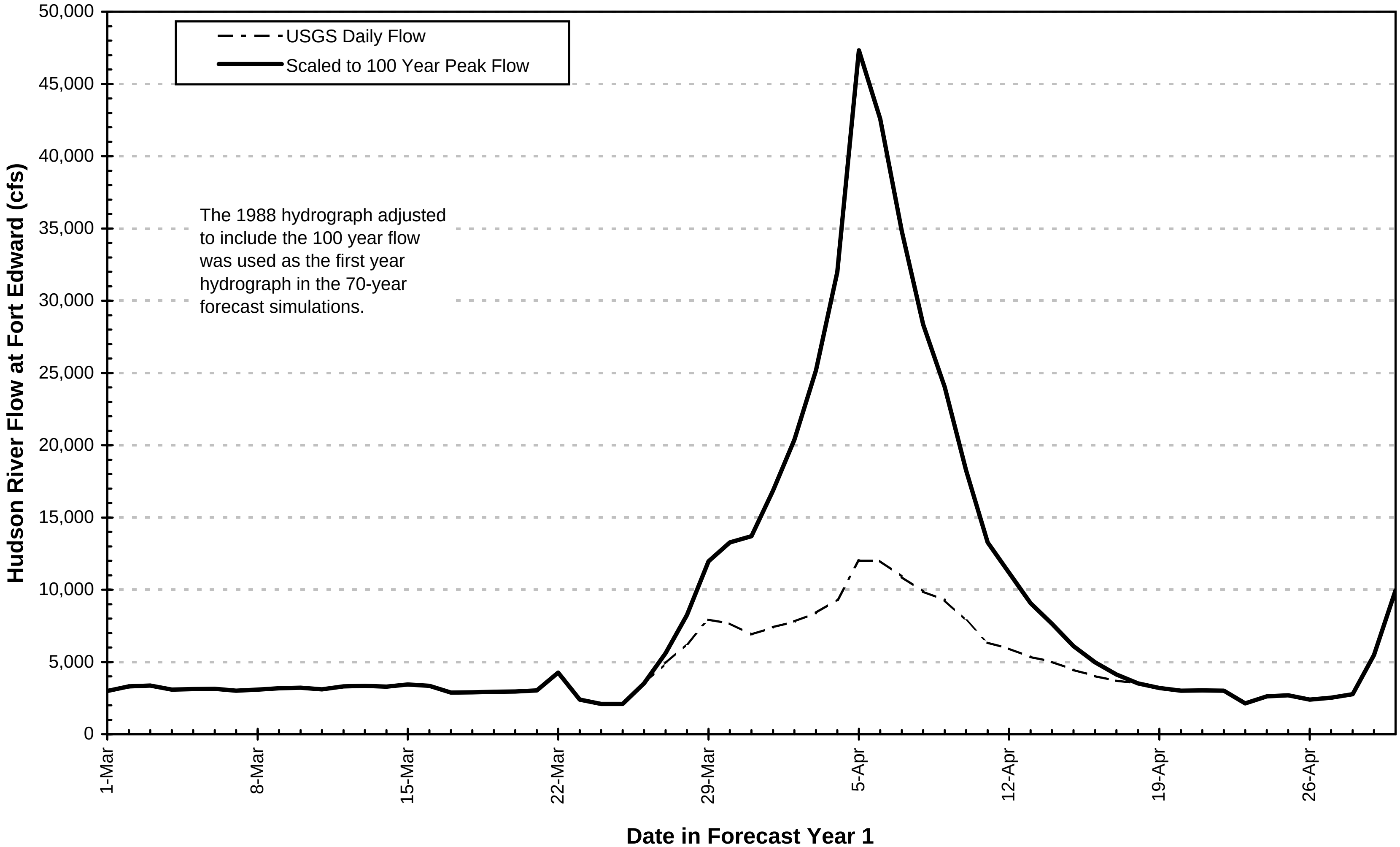


Figure 8-10. Adjustment of the Fort Edward Hydrograph to Include the 100 Year Flow (47,330 cfs).

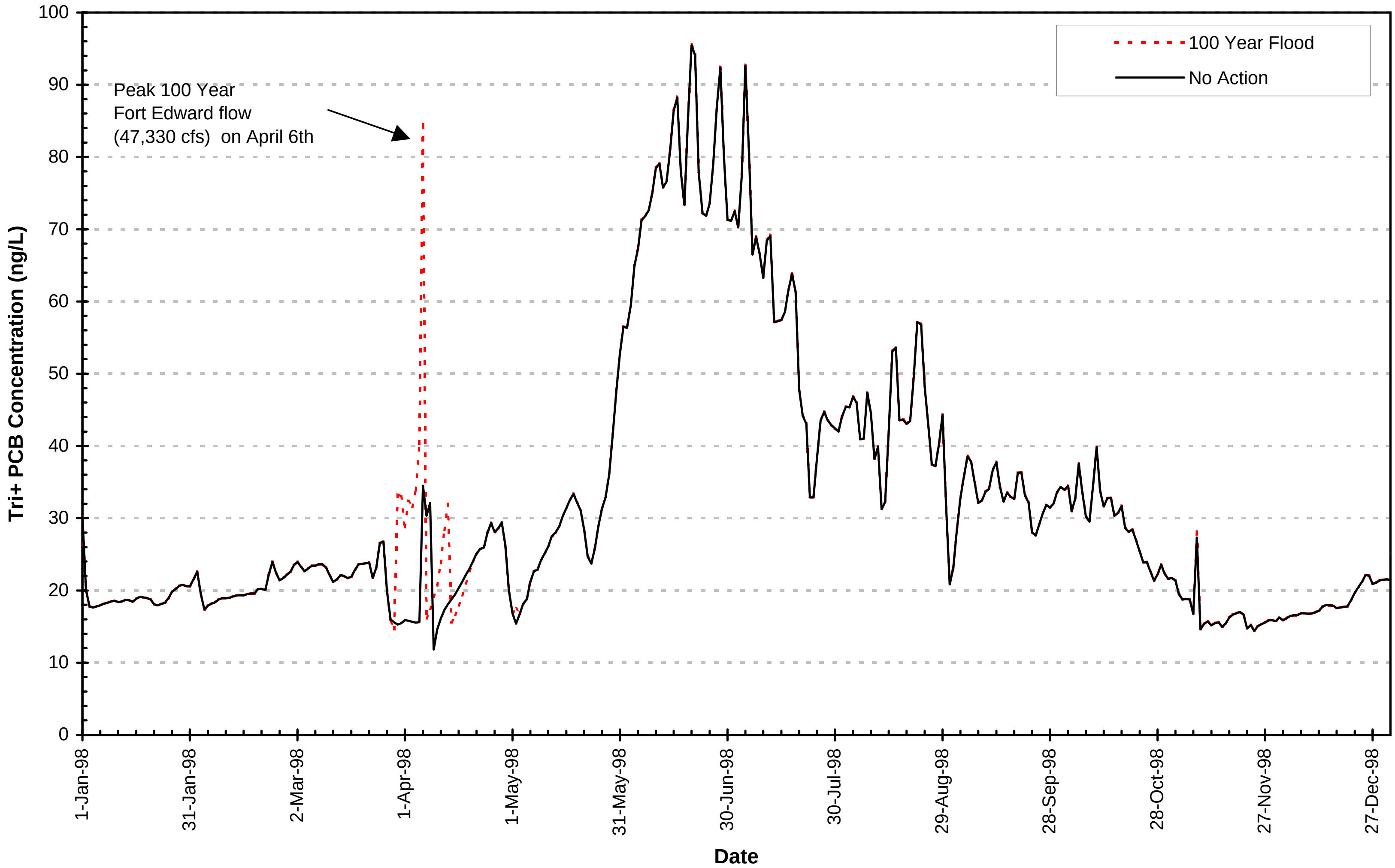


Figure 8-11. Predicted 100 Year Event (3/28 to 4/13) Impact on Tri+ PCB Levels at Thompson Island Dam (West)

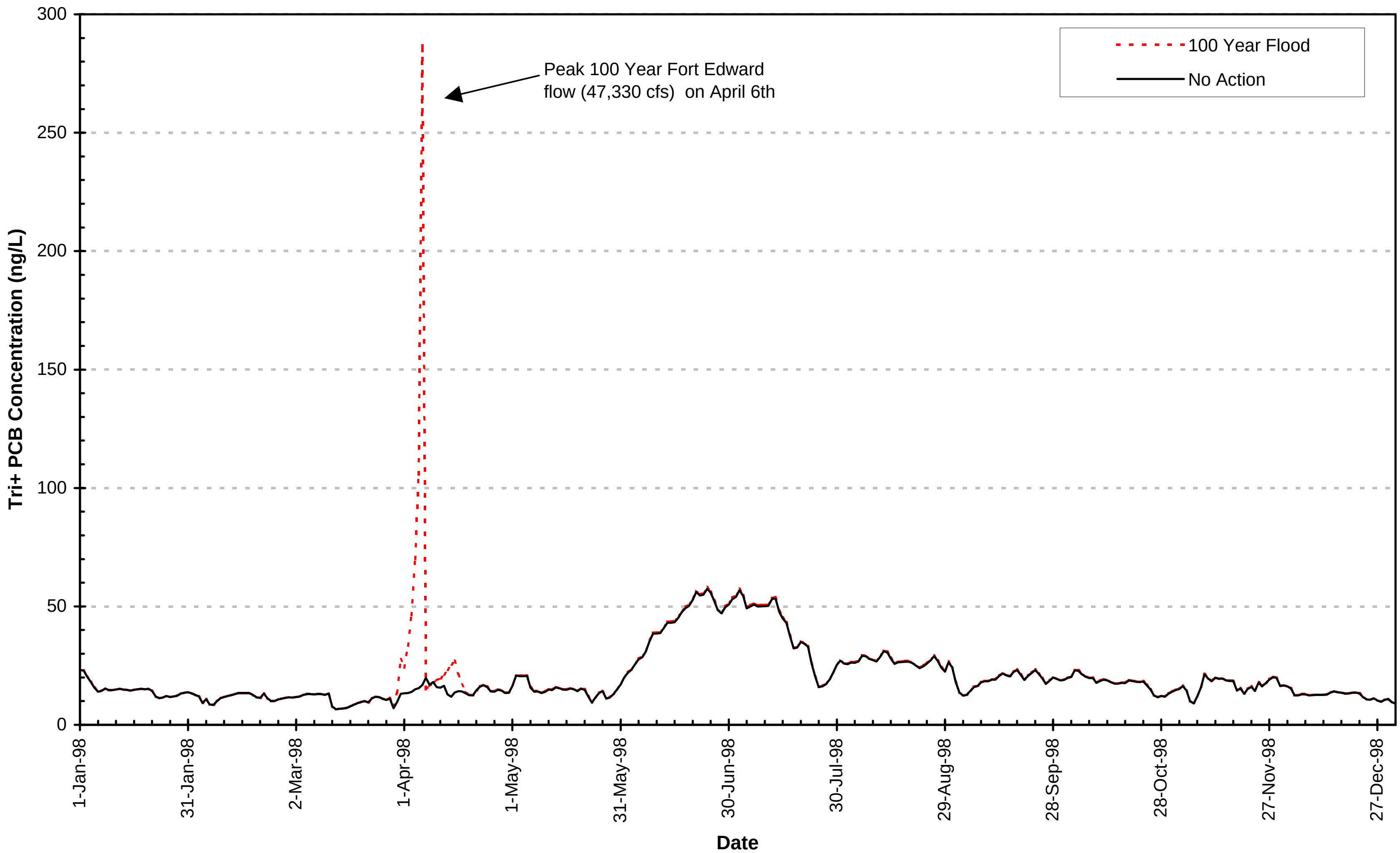


Figure 8-12. Predicted 100 Year Event (3/28 to 4/13) Impact on Tri+ PCB Levels at Federal Dam.

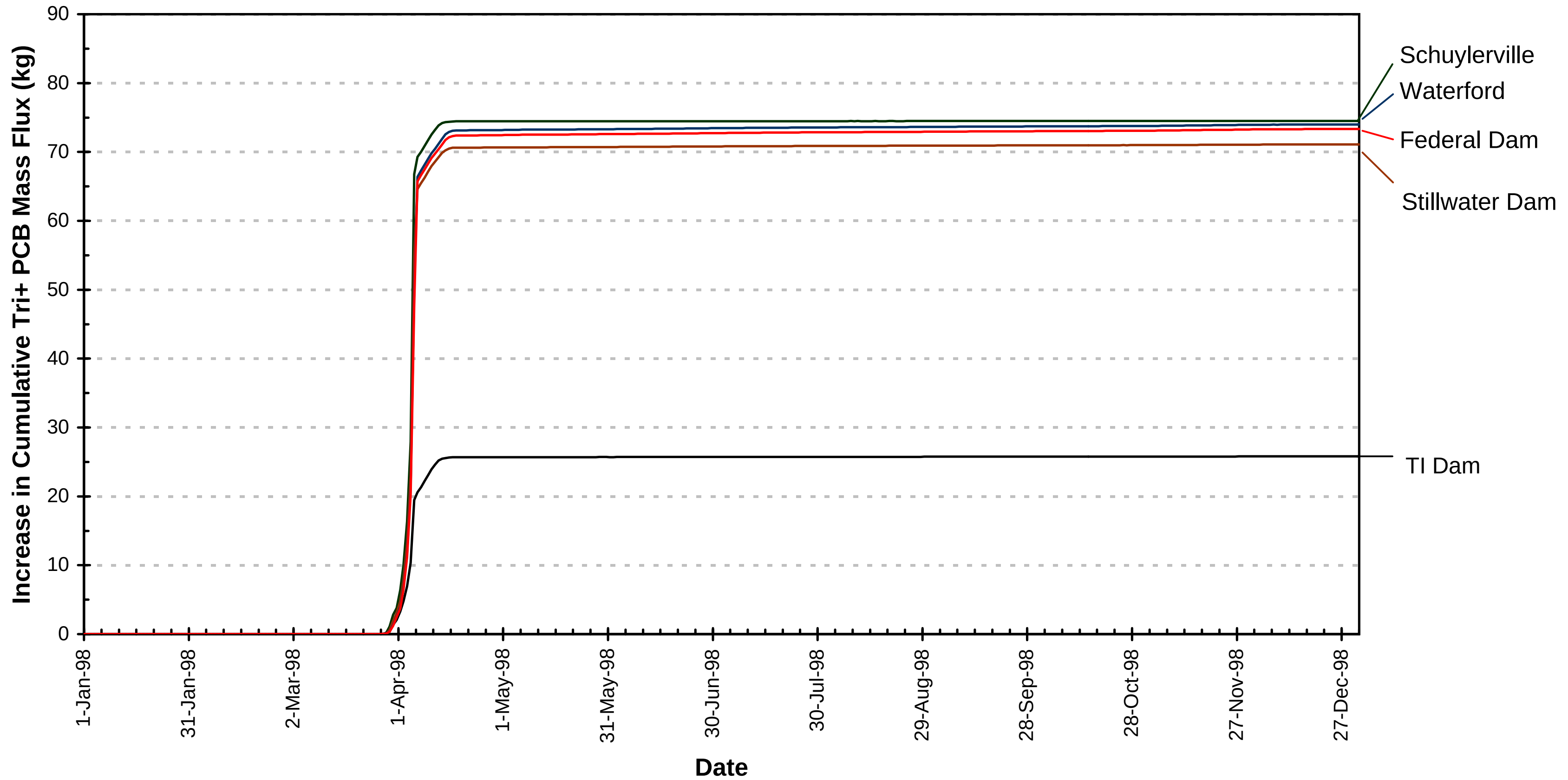


Figure 8-13. Cumulative Net Increase of Tri+ PCB Mass Loading at Various Locations in the Upper Hudson River Due to the 100 Year Flood Event (versus the No Action Scenario).

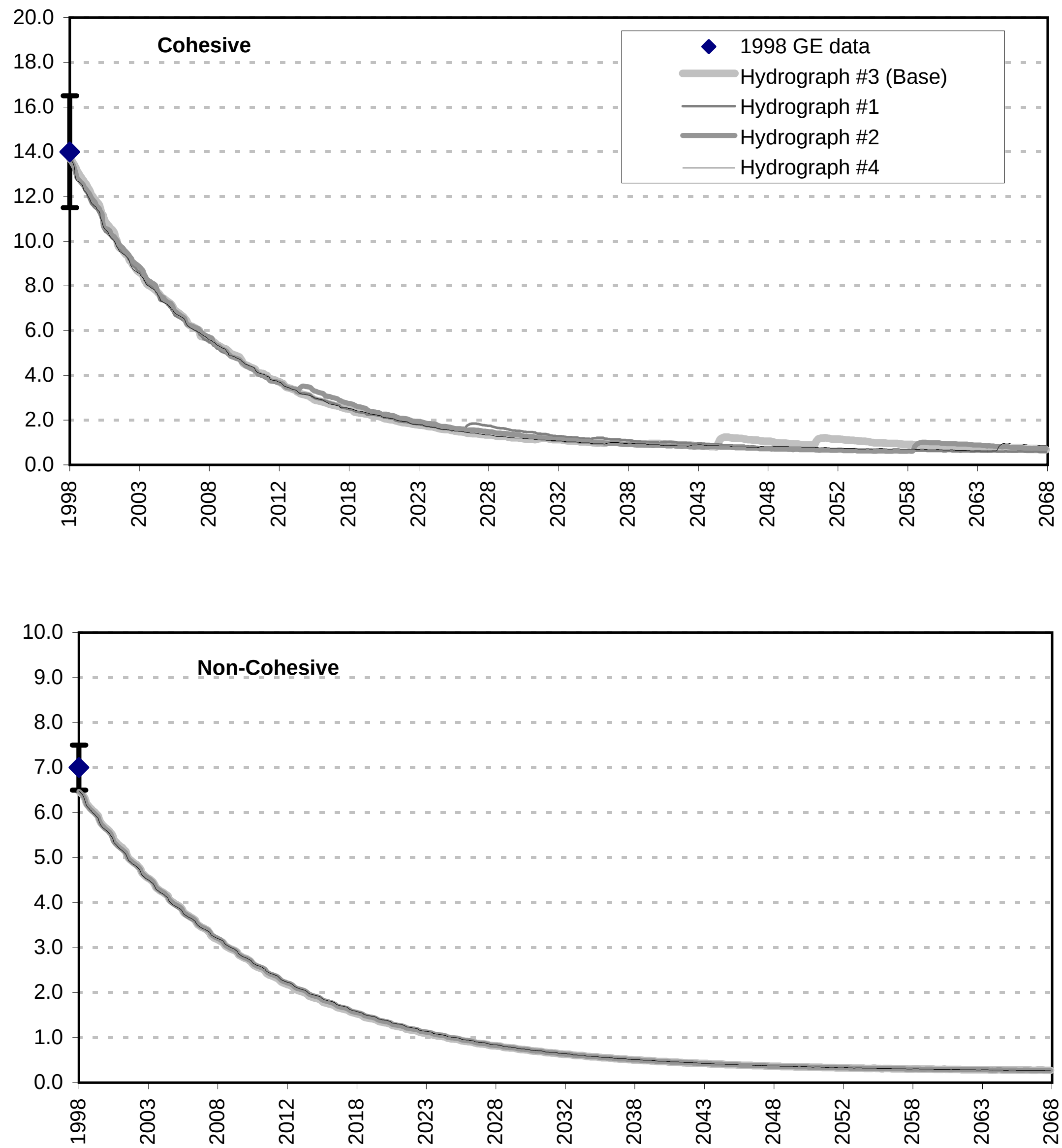


Figure 8-14a. Forecast Sediment Tri+ Concentrations for Thompson Island Pool for Alternative Hydrographs (Constant Upstream Tri+ Concentration of 10 ng/L) at Fort Edward.

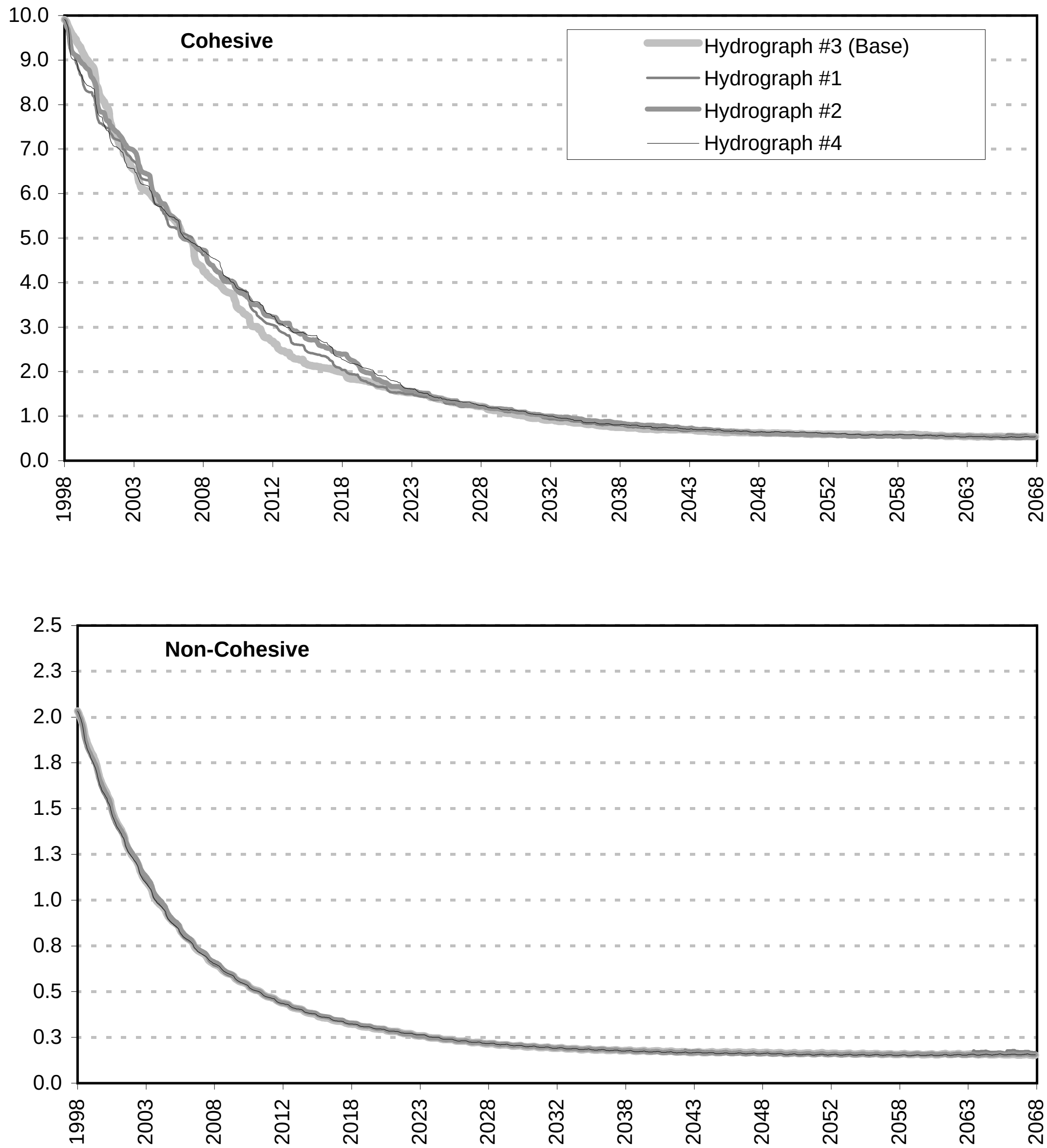


Figure 8-14b. Forecast Sediment Tri+ Concentrations for the Schuylerville Reach for Alternative Hydrographs (Constant Upstream Tri+ Concentration of 10 ng/L) at Fort Edward.

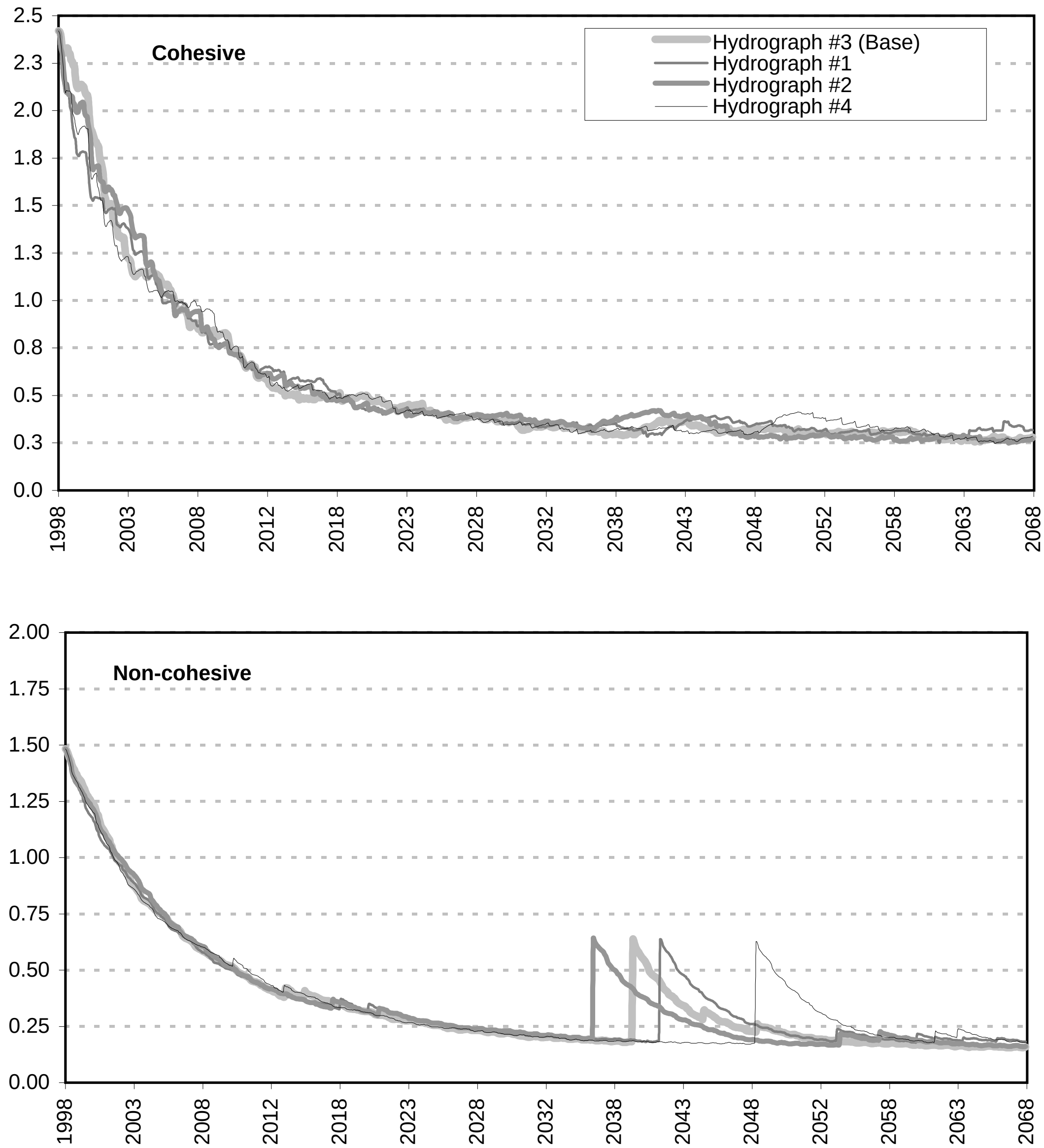
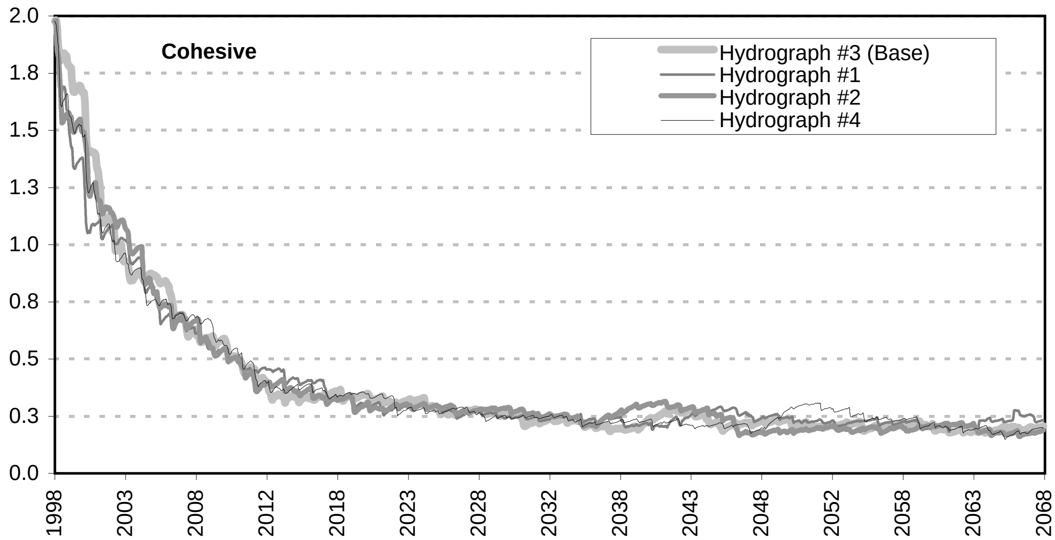


Figure 8-14c. Forecast Sediment Tri+ Concentrations for the Stillwater Reach for Alternative Hydrographs (Constant Upstream Tri+ Concentration of 10 ng/L) at Fort Edward.



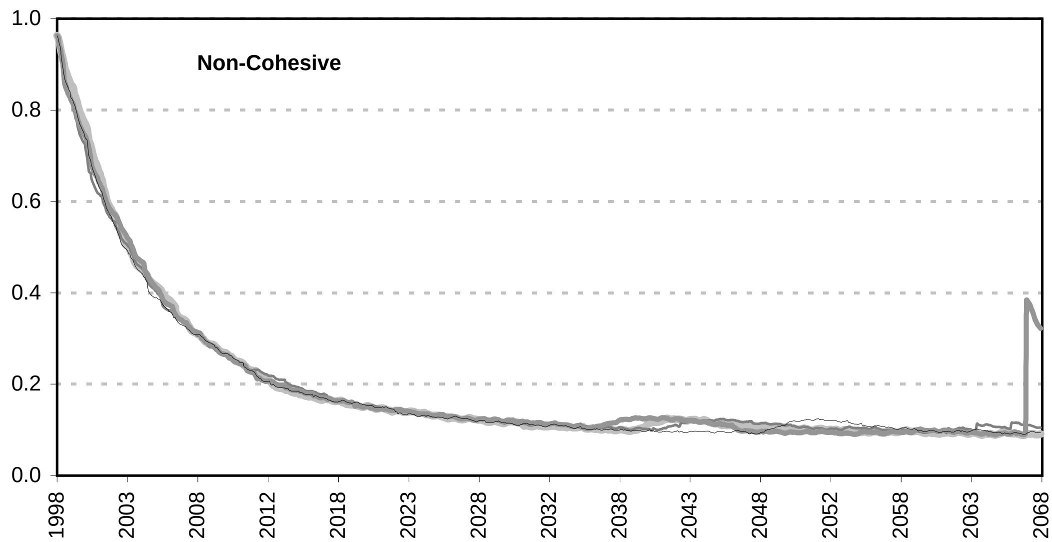


Figure 8-14d. Forecast Sediment Tri+ Concentrations for the Waterford Reach for Alternative Hydrographs (Constant Upstream Tri+ Concentration of 10 ng/L) at Fort Edward.

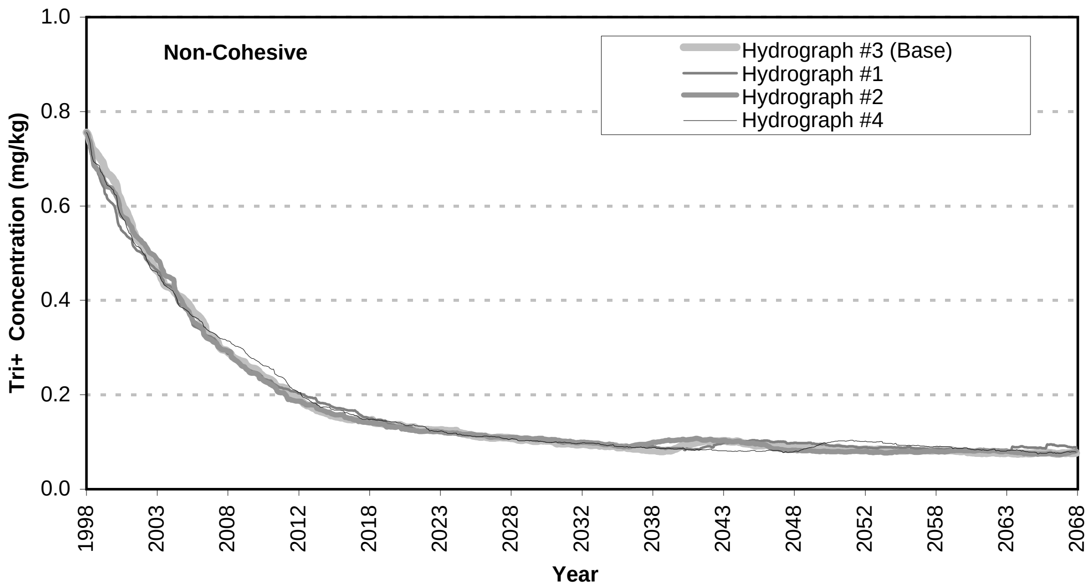
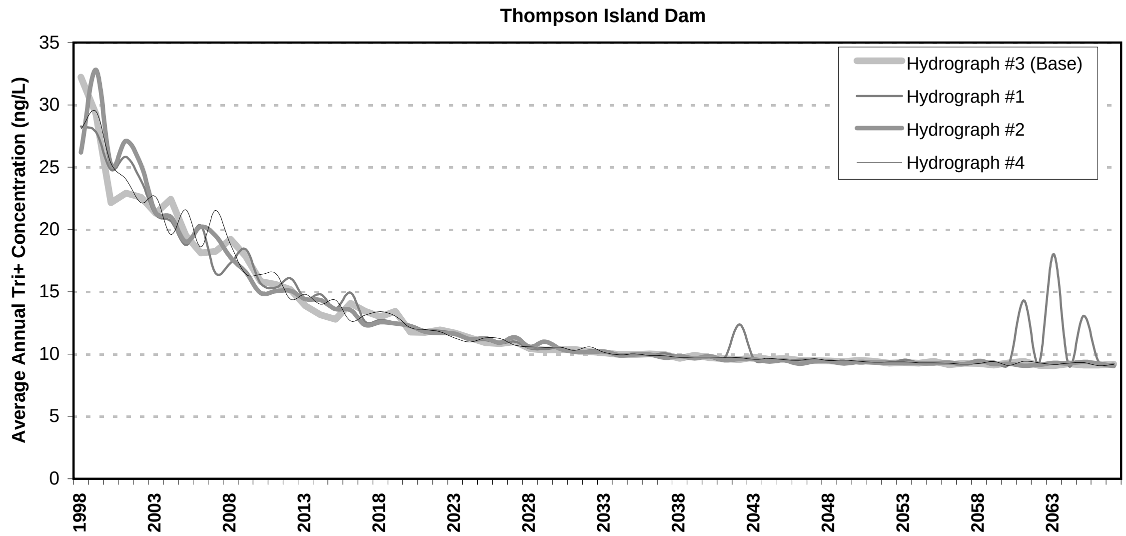


Figure 8-14e. Forecast Sediment Tri+ Concentrations for the Federal Dam Reach for Alternative Hydrographs (Constant Upstream Tri+ Concentration of 10 ng/L) at Fort Edward.



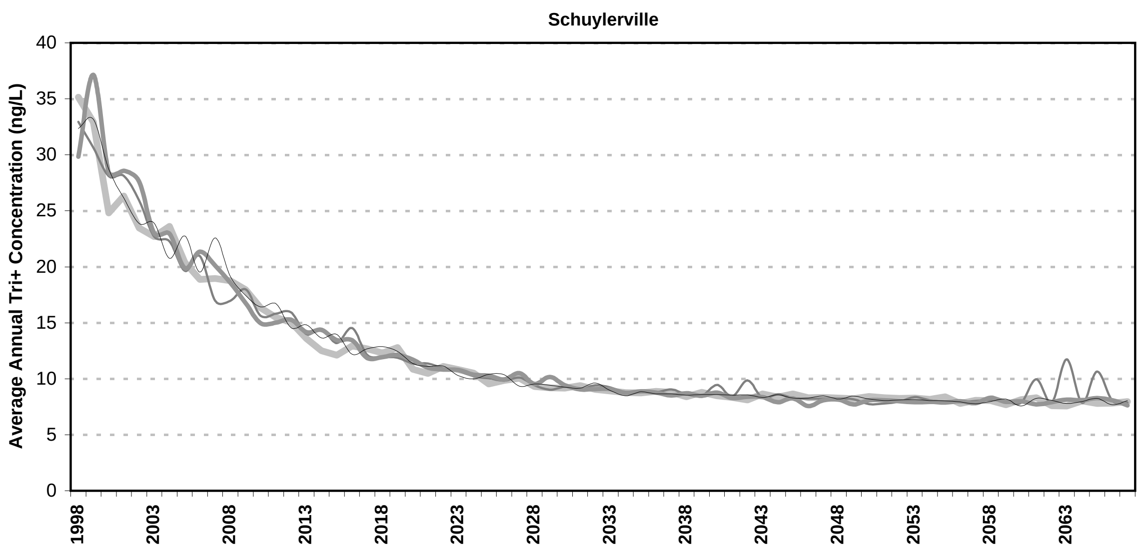
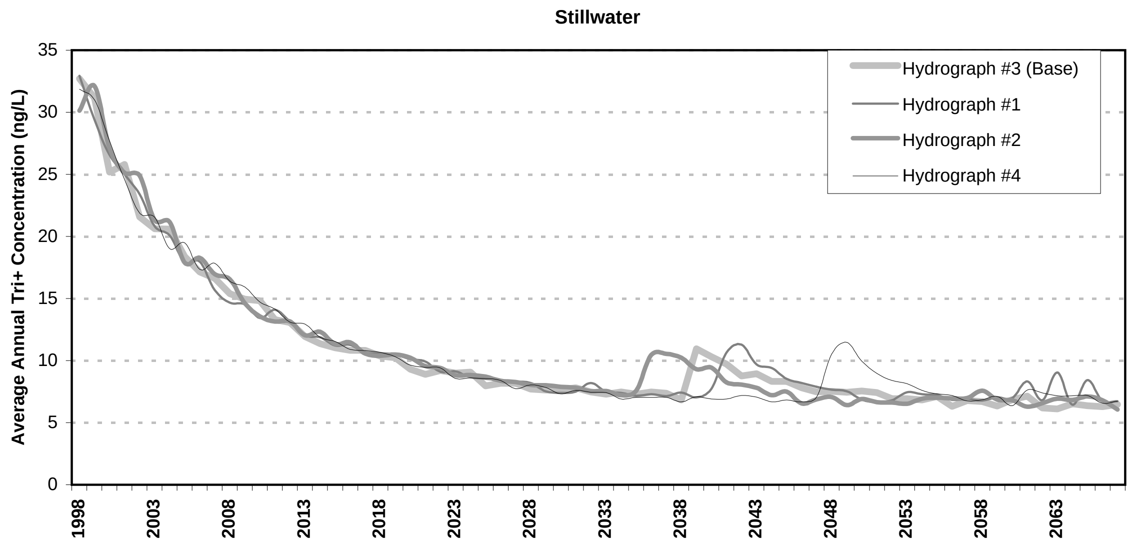


Figure 8-15a. Forecast Annual Average Tri+ Concentrations at Thompson Island Dam and Schuylerville for Alternative Hydrographs (Constant Upstream Tri+ Concentration of 10 ng/L at Fort Edward), 1998-2067.



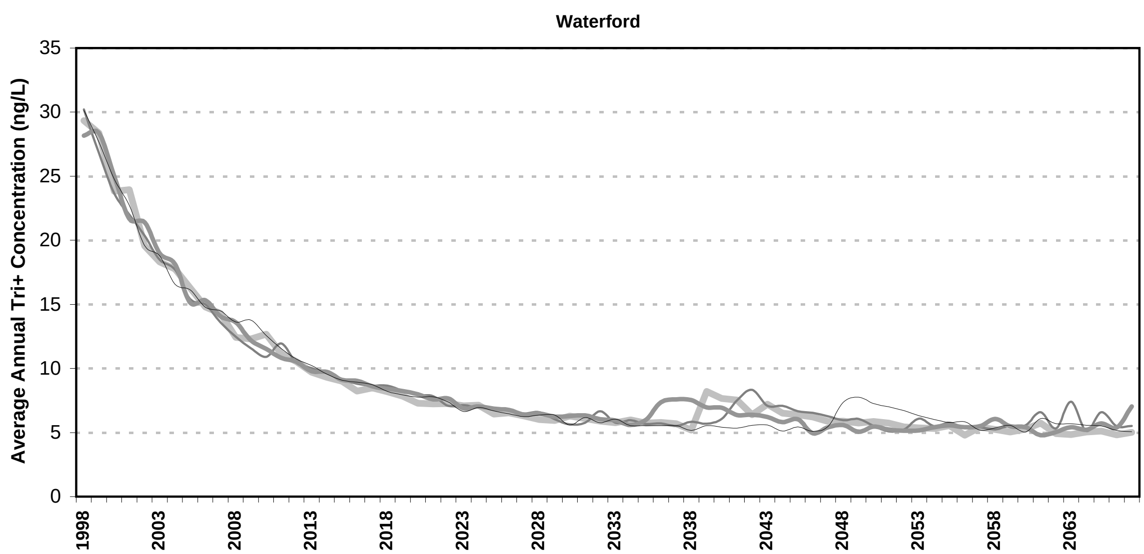
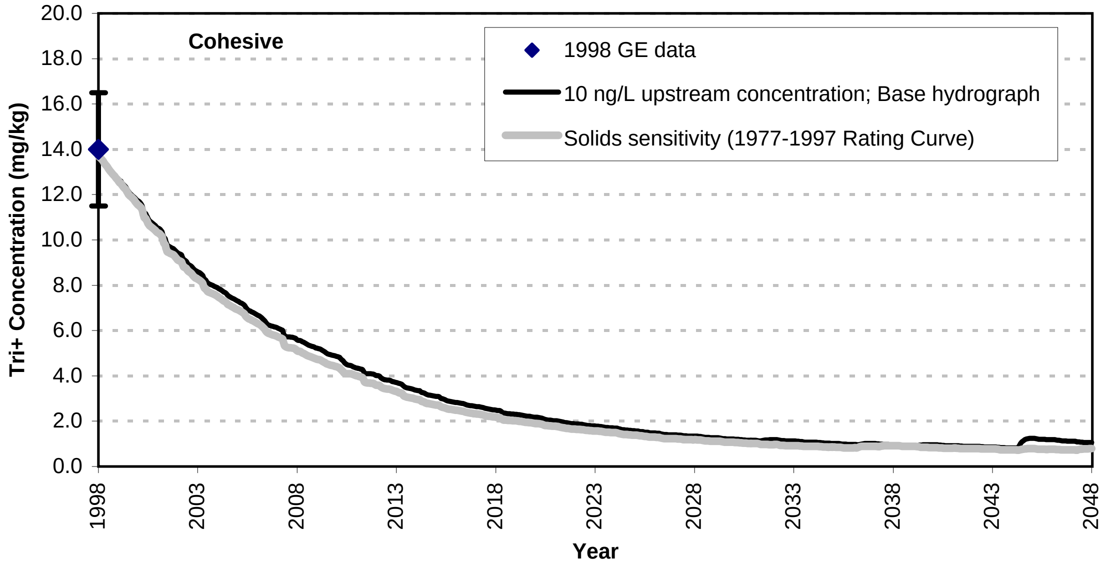


Figure 8-15b. Forecast Annual Average Tri+ Concentrations at Stillwater and Waterford for Alternative Hydrographs (Constant Upstream Tri+ Concentration of 10 ng/L at Fort Edward), 1998-2067.



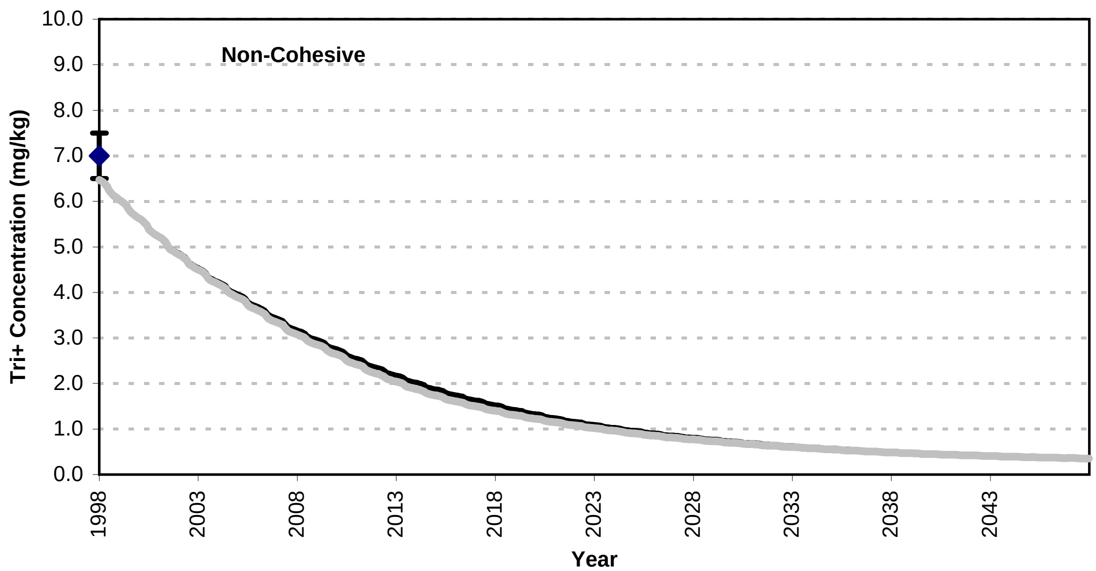
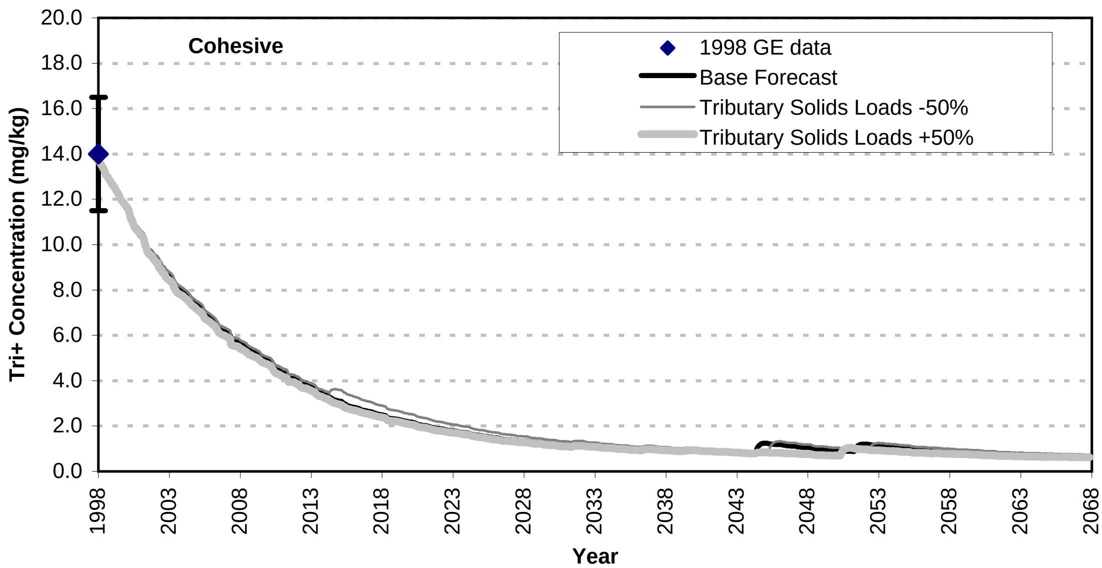


Figure 8-16. Sensitivity of Thompson Island Pool Surface Sediment Tri+ Concentrations to an Alternate Total Suspended Solids Load at Fort Edward, 1998-2047.



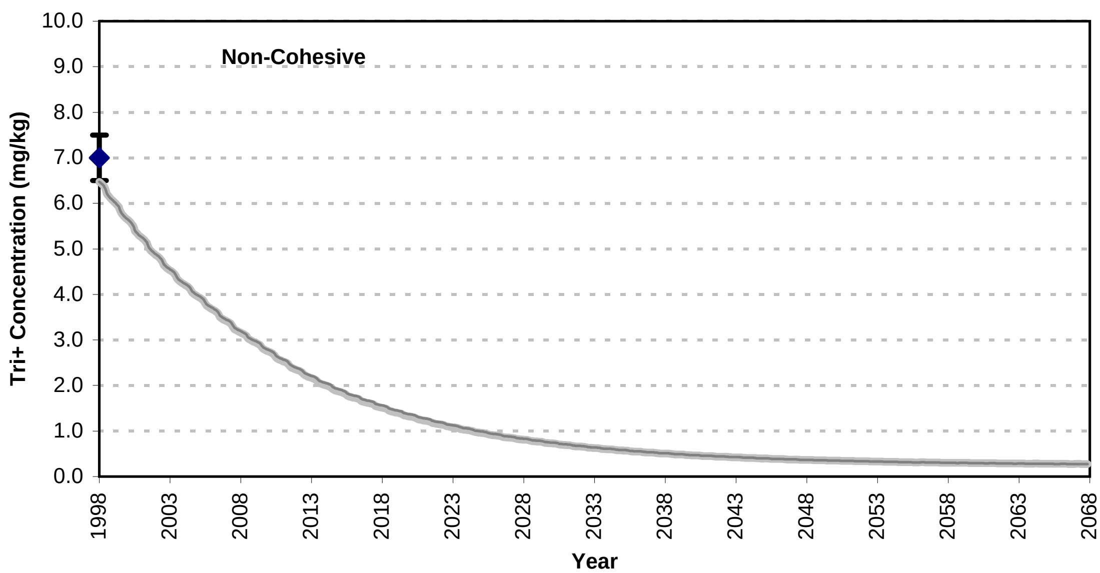


Figure 8-17a. Sensitivity of Thompson Island Pool Surface Sediment Tri+ Concentrations to Changes in External Tributary Solids Loadings, 1998-2067.

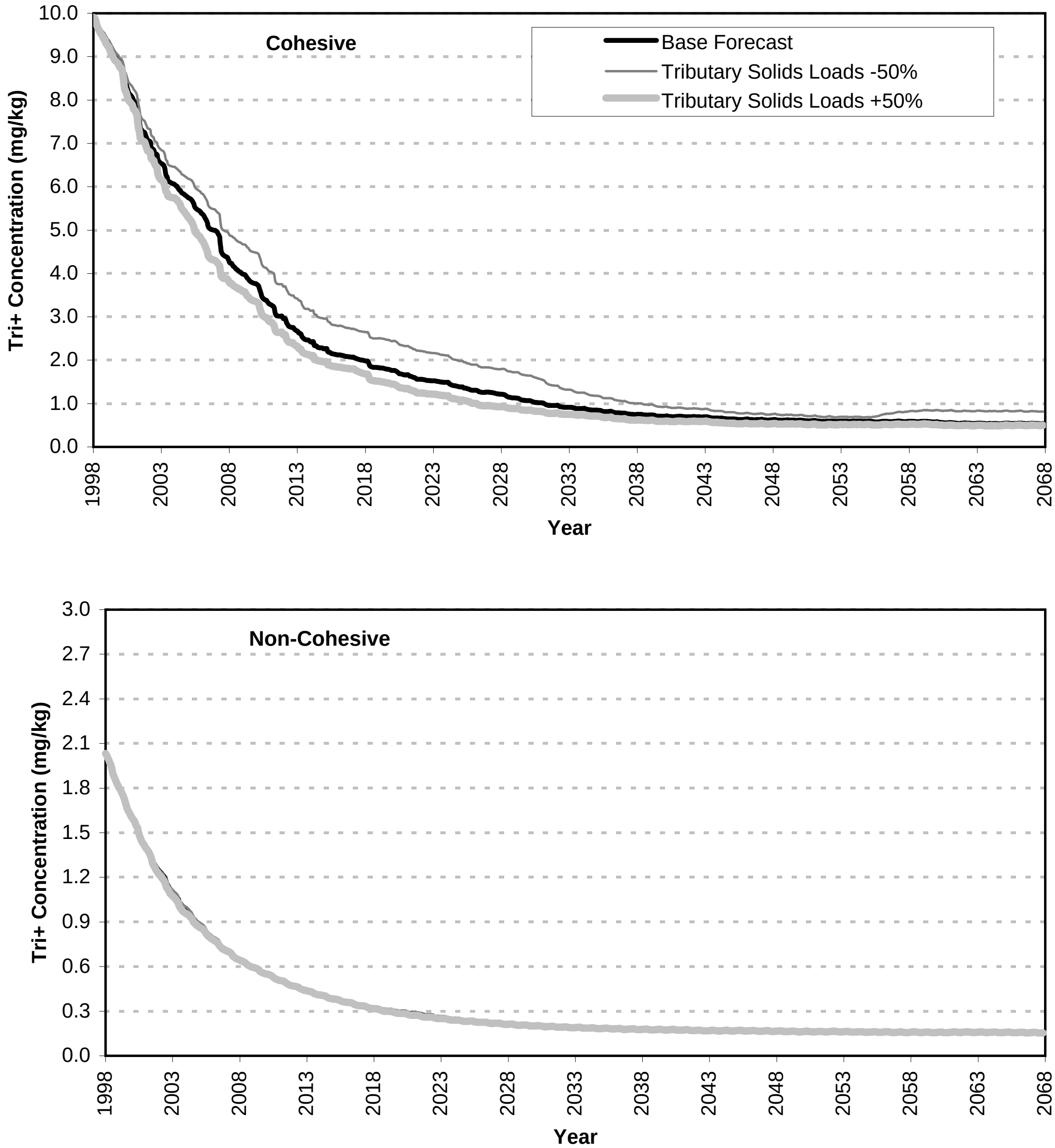


Figure 8-17b. Sensitivity of Thompson Island Dam to Schuylerville Surface Sediment Tri+ Concentrations to Changes in External Tributary Solids Loadings, 1998-2067.

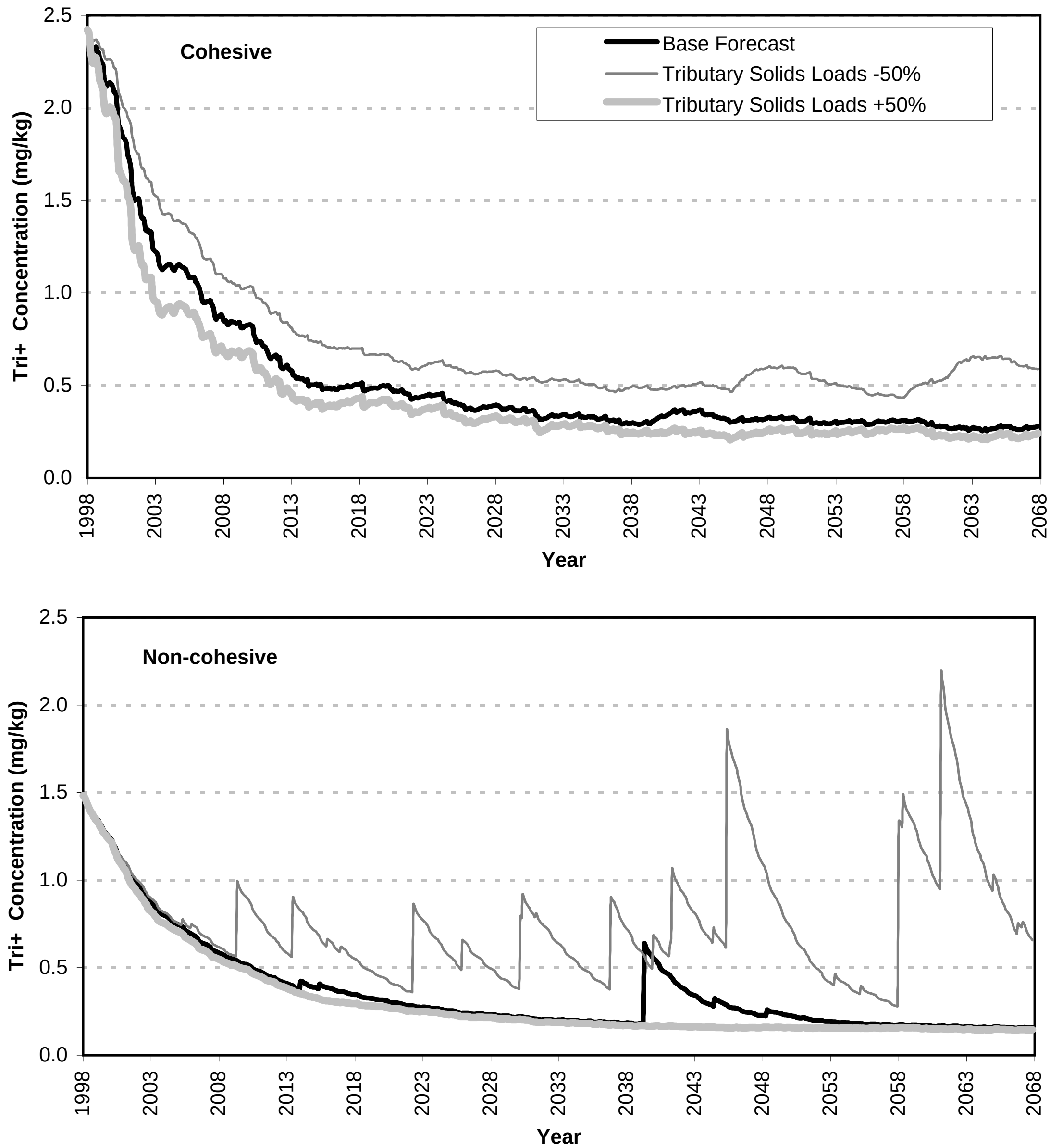
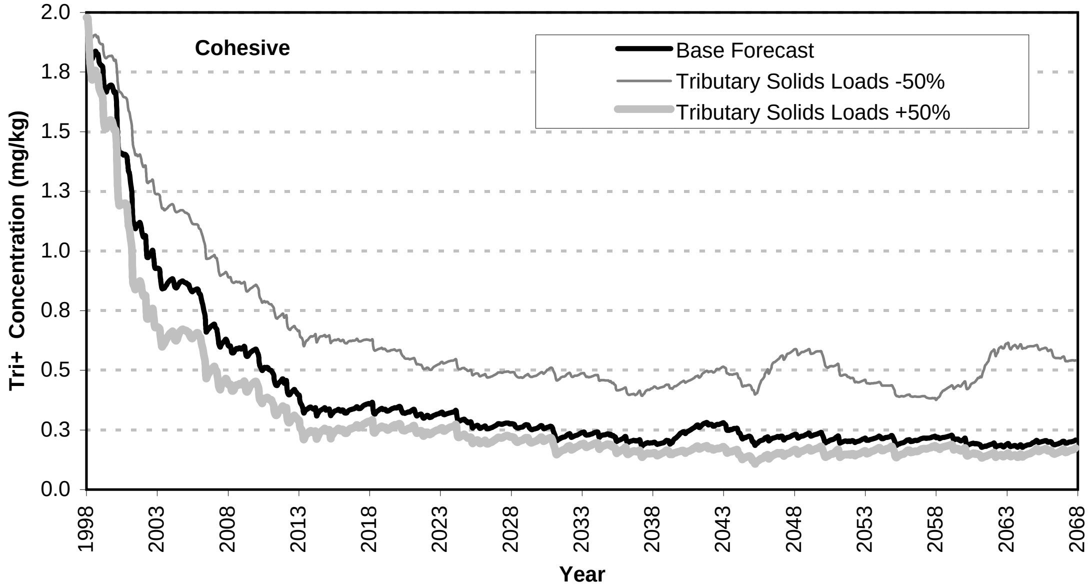


Figure 8-17c. Sensitivity of Schuylerville to Stillwater Surface Sediment Tri+ Concentrations to Changes in External Tributary Solids Loadings, 1998-2067.



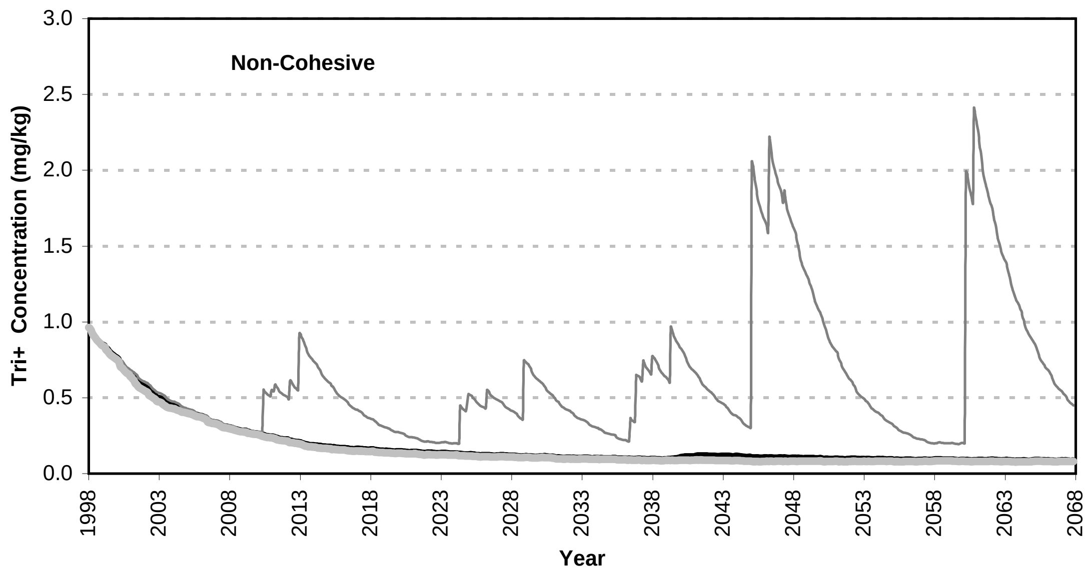


Figure 8-17d. Sensitivity of Stillwater to Waterford Surface Sediment Tri+ Concentrations to Changes in External Tributary Solids Loadings, 1998-2067.

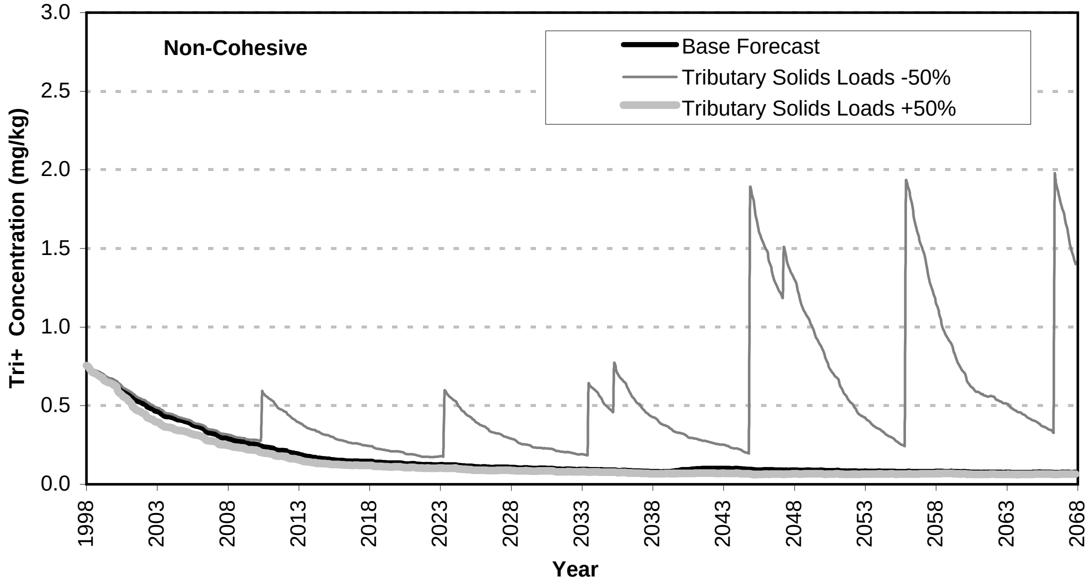
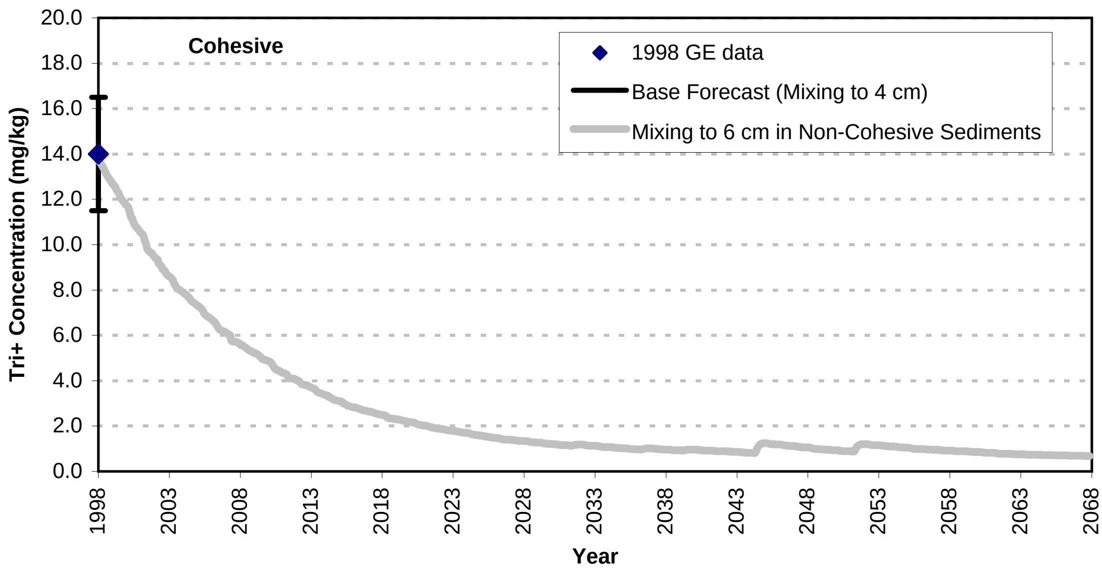


Figure 8-17e. Sensitivity of Waterford to Federal Dam Surface Sediment Tri+ Concentrations to Changes in External Tributary Solids Loadings, 1998-2067.



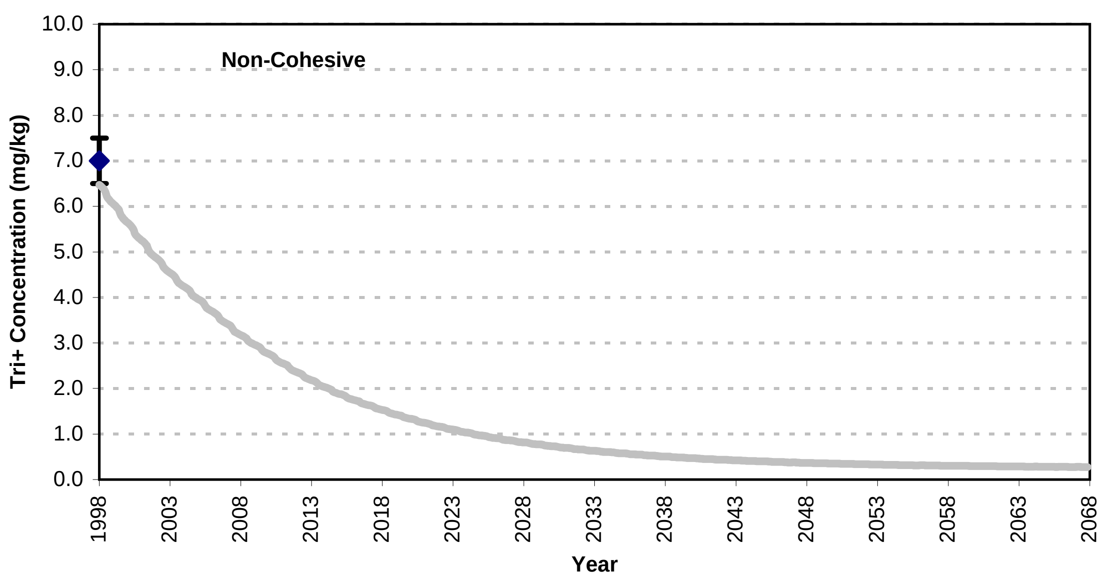
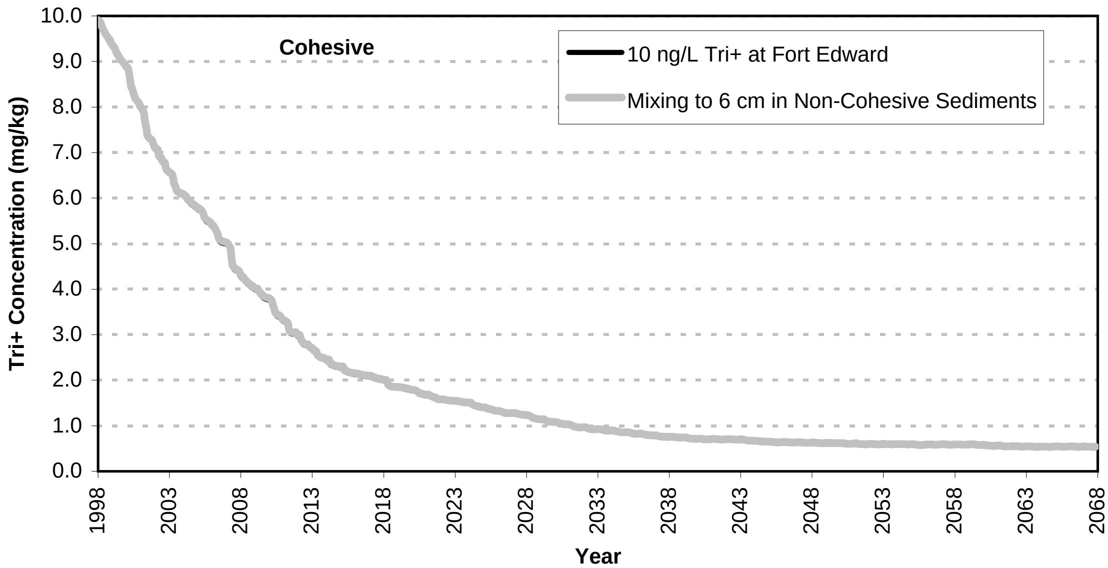


Figure 8-18a. Sensitivity of Thompson Island Pool Surface Sediment Tri+ Concentrations to Enhanced Mixing (top 6 cm) in Non-Cohesive Sediments, 1998-2067.



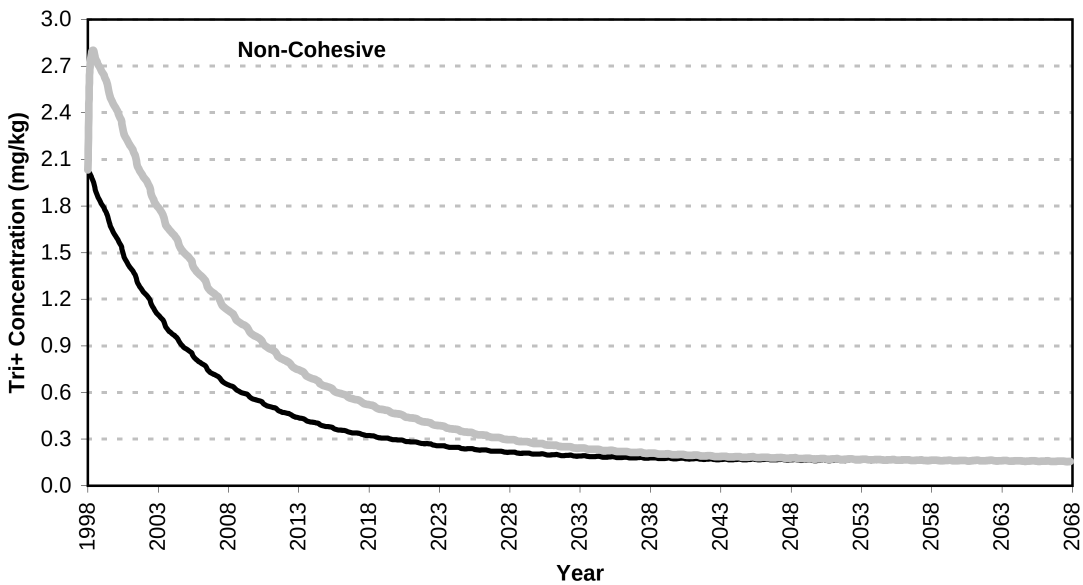
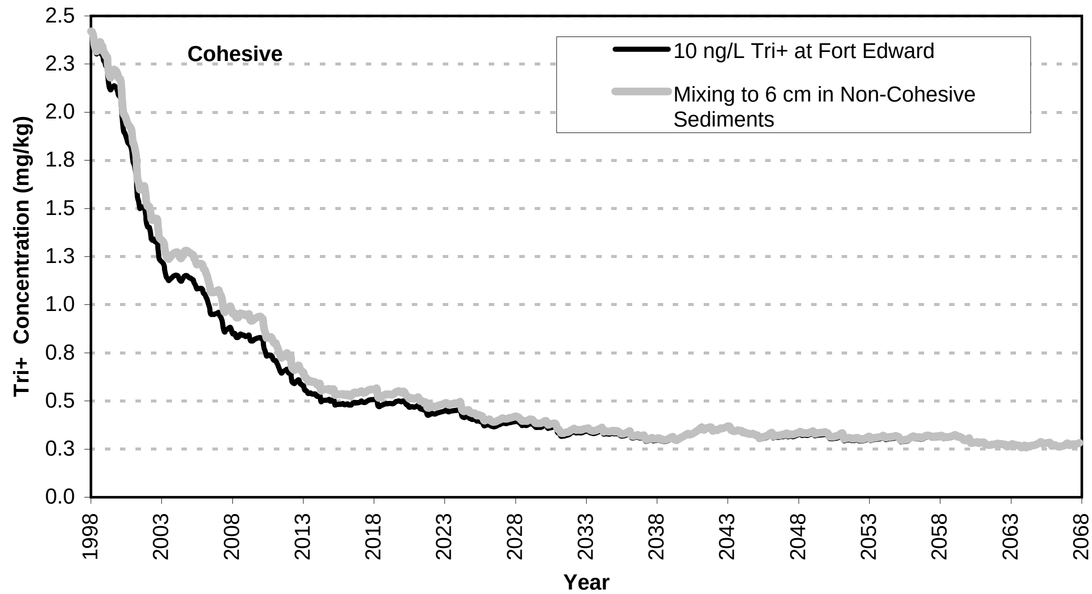


Figure 8-18b. Sensitivity of Thompson Island Dam to Schuylerville Surface Sediment Tri+ Concentrations to Enhanced Mixing (top 6 cm) in Non-Cohesive Sediments, 1998-2067.



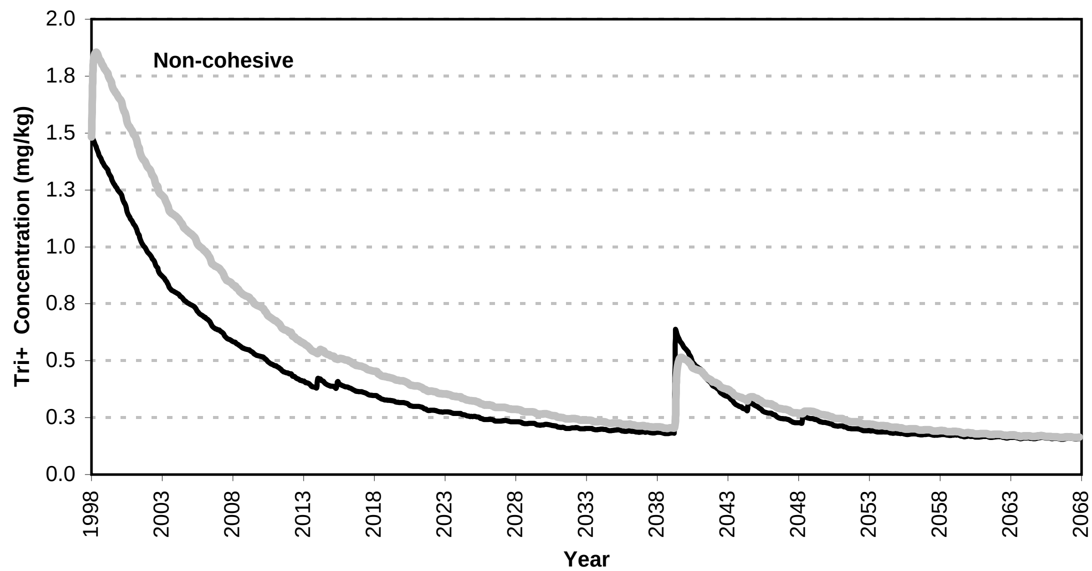


Figure 8-18c. Sensitivity of Schuylerville to Stillwater Surface Sediment Tri+ Concentrations to Enhanced Mixing (top 6 cm) in Non-Cohesive Sediments, 1998-2067.

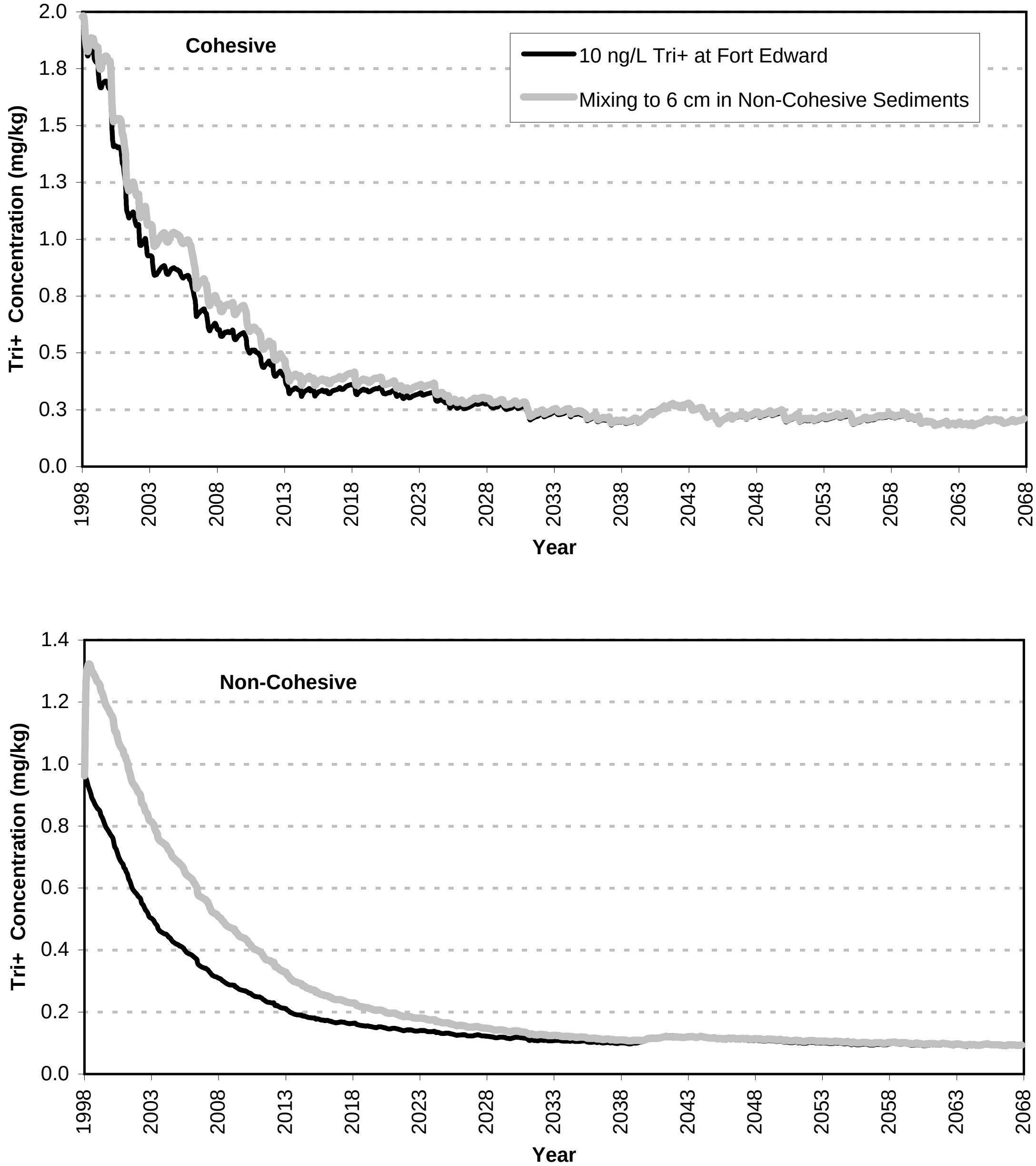


Figure 8-18d. Sensitivity of Stillwater to Waterford Surface Sediment Tri+ Concentrations to Enhanced Mixing (top 6 cm) in Non-Cohesive Sediments, 1998-2067.

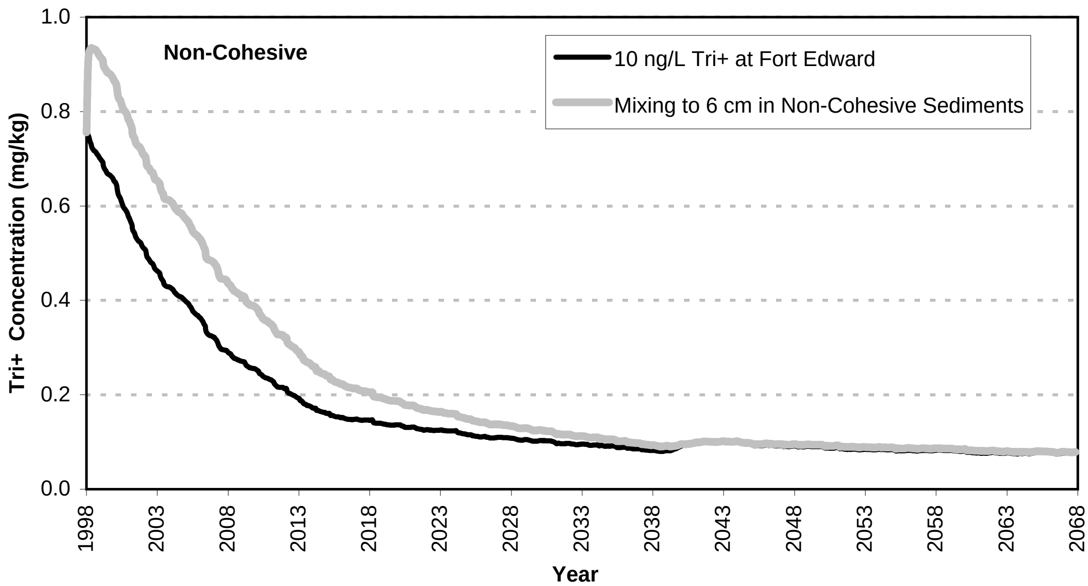


Figure 8-18e. Sensitivity of Waterford to Federal Dam Surface Sediment Tri+ Concentrations to Enhanced Mixing (top 6 cm) in Non-Cohesive Sediments, 1998-2067.

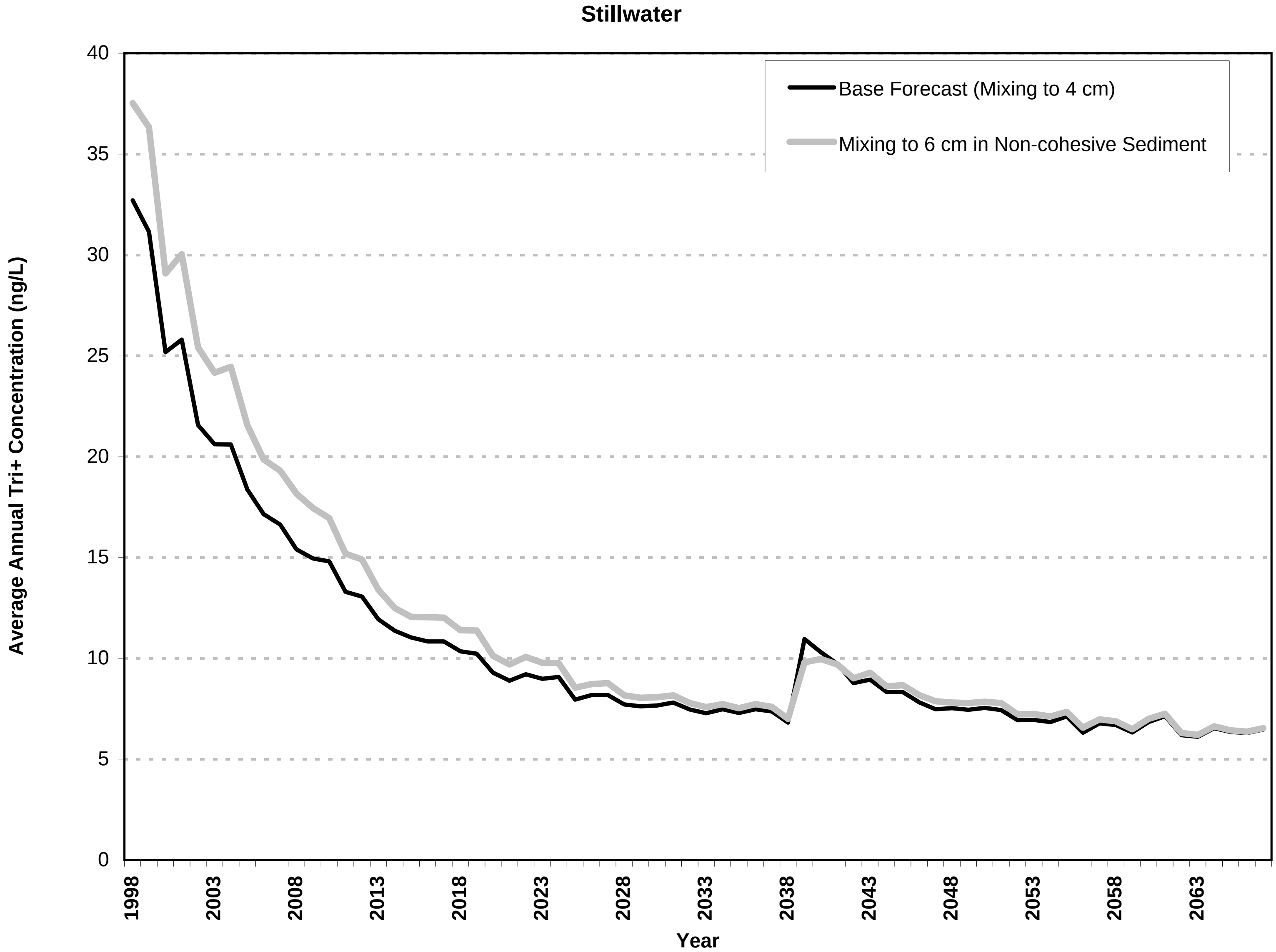


Figure 8-19. Sensitivity of Tri+ Concentrations at Stillwater to Enhanced Mixing (top 6 cm) in Non-cohesive Sediments, 1998-2067.

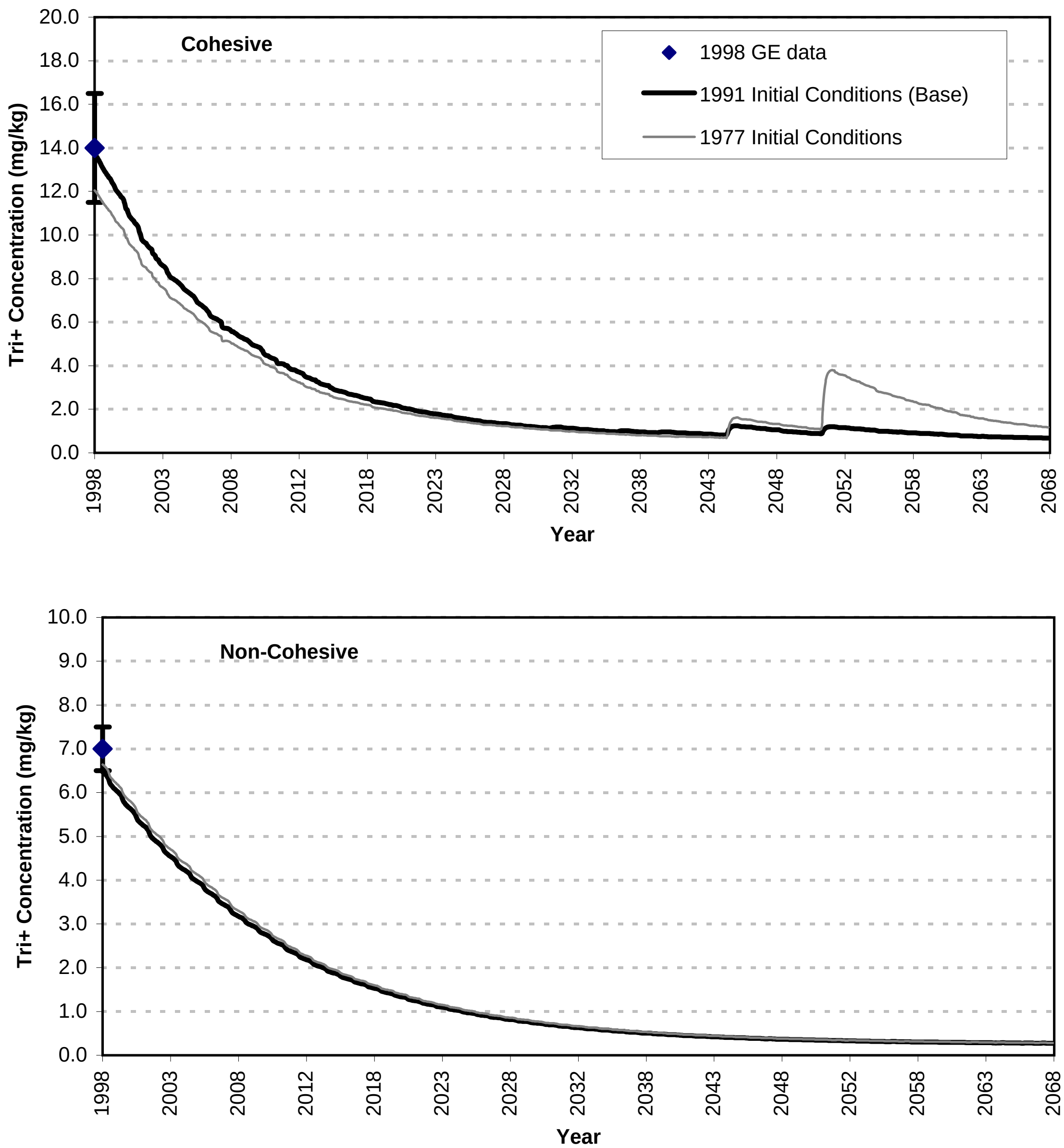


Figure 8-20a. Sensitivity of Thompson Island Pool Surface Sediment Tri+ Concentrations to Specification of Sediment Initial Conditions, 1998-2067.

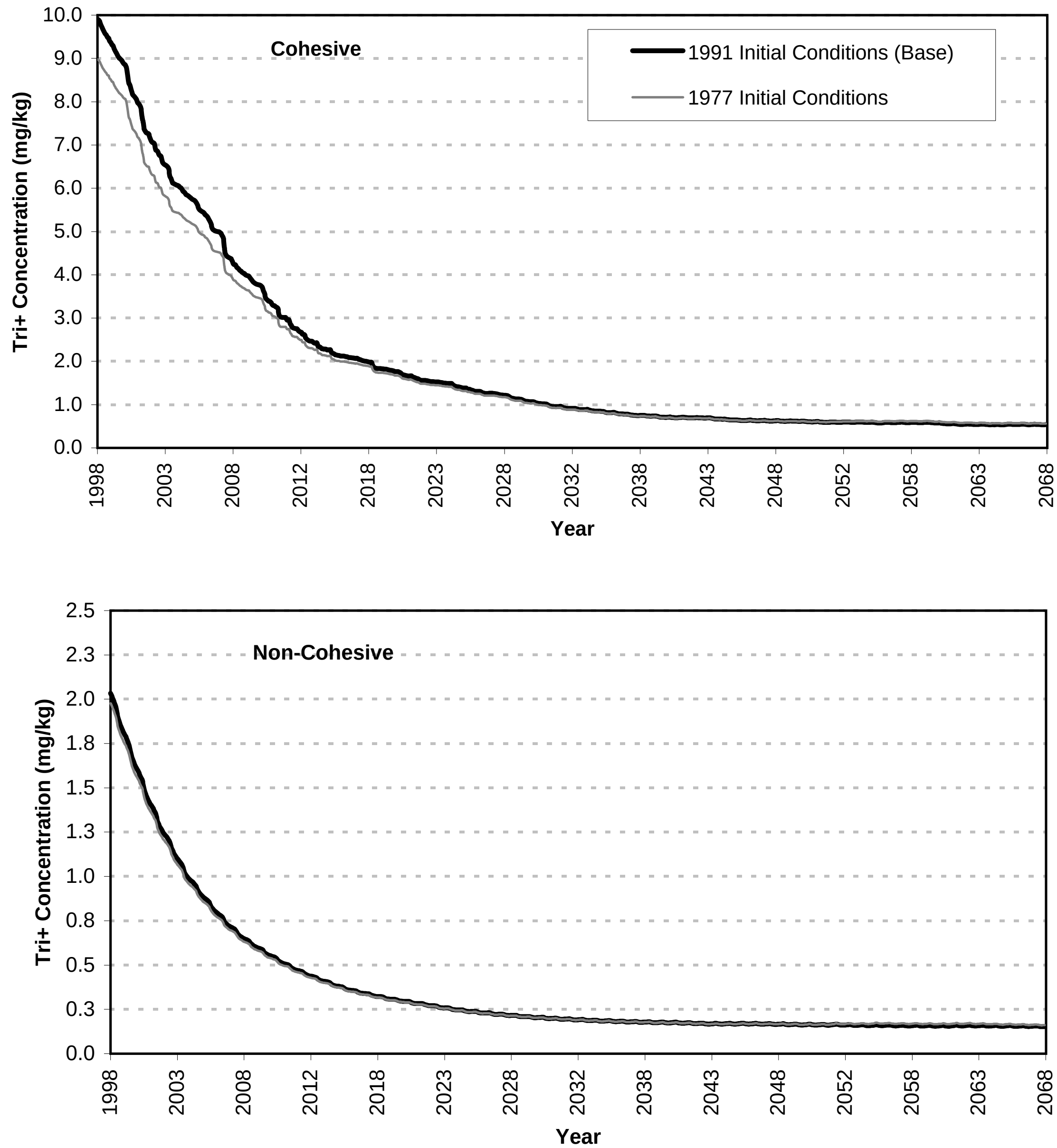


Figure 8-20b. Sensitivity of Schuylerville Reach Surface Sediment Tri+ Concentrations to Specification of Sediment Initial Conditions, 1998-2067.

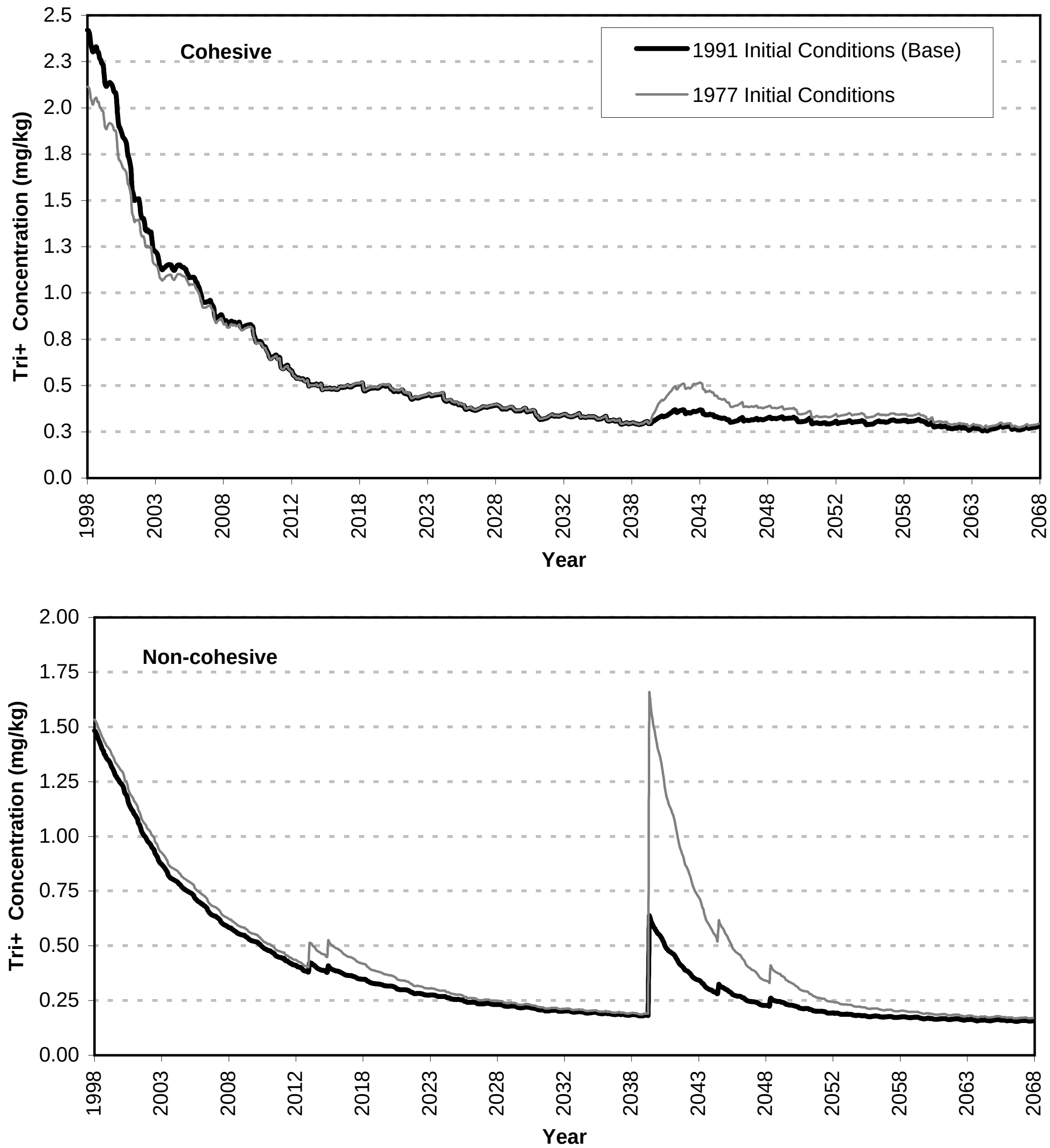
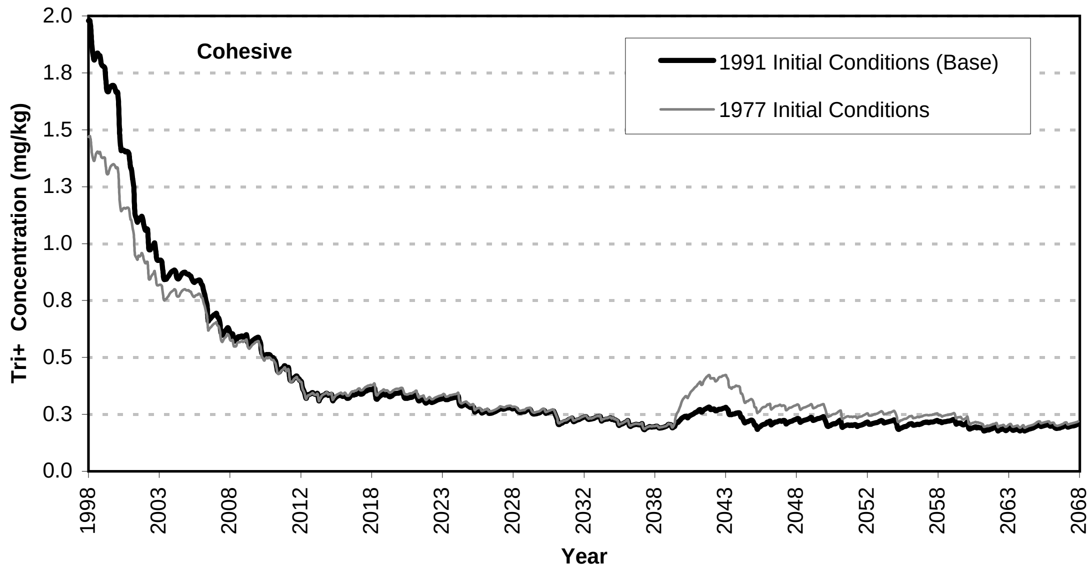


Figure 8-20c. Sensitivity of Stillwater Reach Surface Sediment Tri+ Concentrations to Specification of Sediment Initial Conditions, 1998-2067.



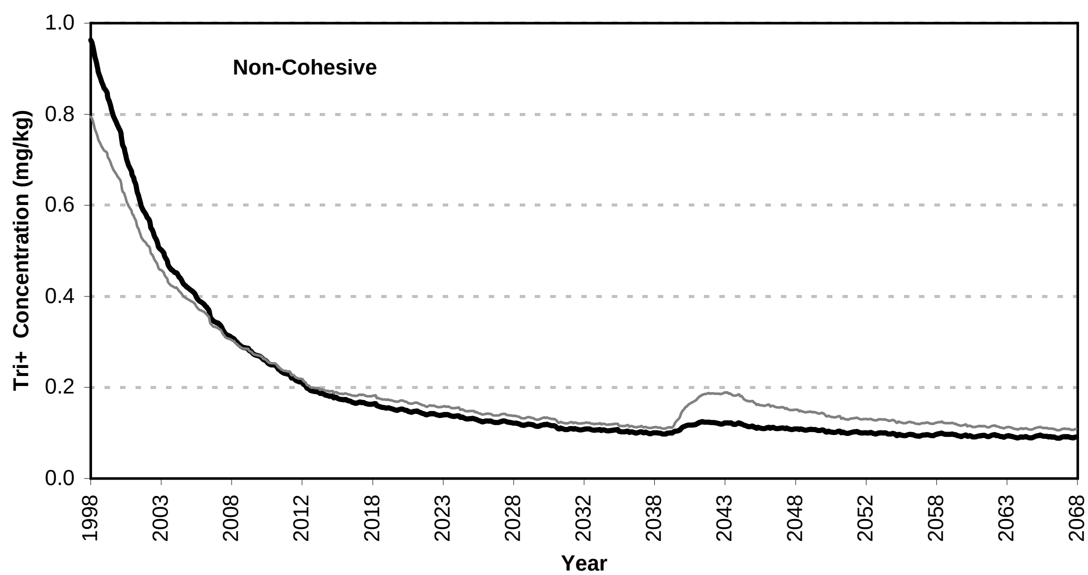


Figure 8-20d. Sensitivity of Waterford Reach Surface Sediment Tri+ Concentrations to Specification of Sediment Initial Conditions, 1998-2067.

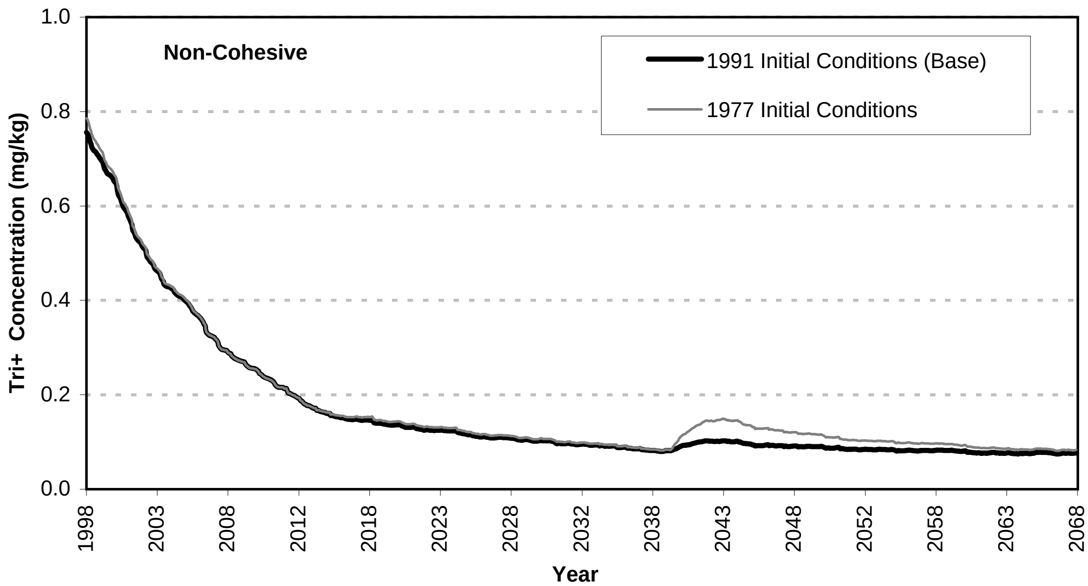
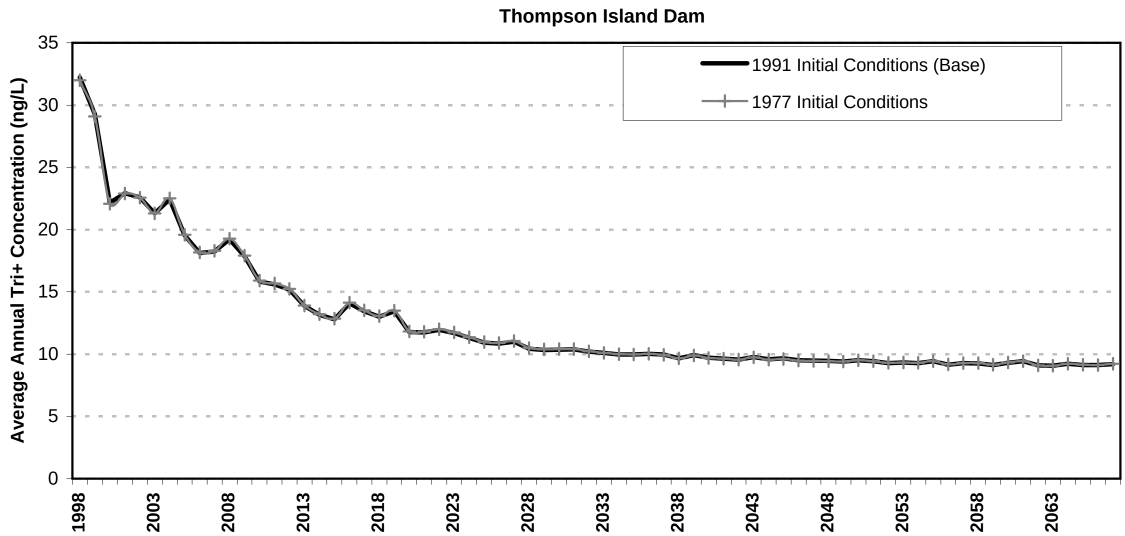


Figure 8-20e. Sensitivity of Federal Dam Reach Surface Sediment Tri+ Concentrations to Specification of Sediment Initial Conditions, 1998-2067.



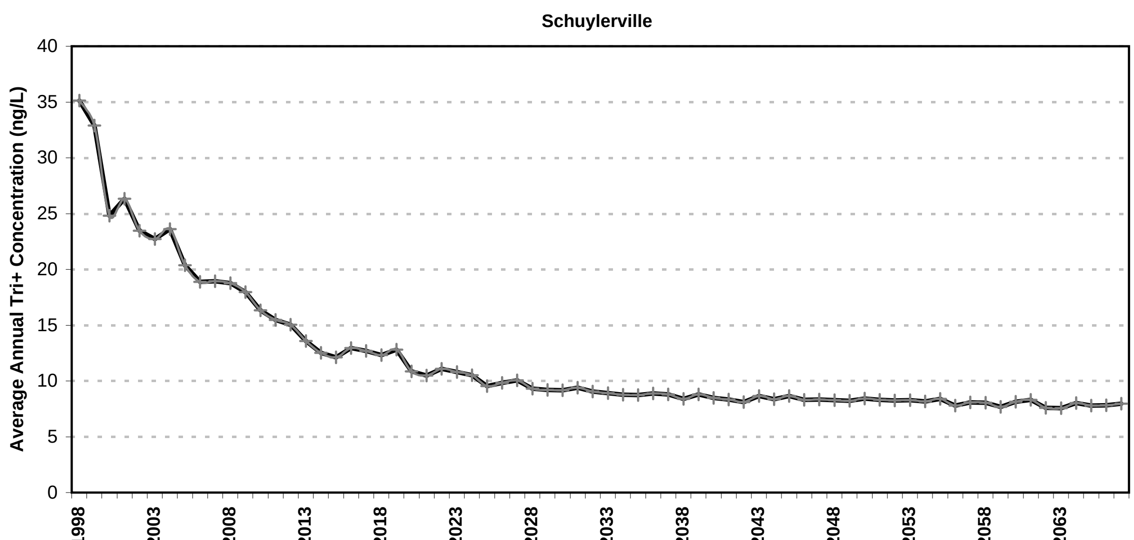
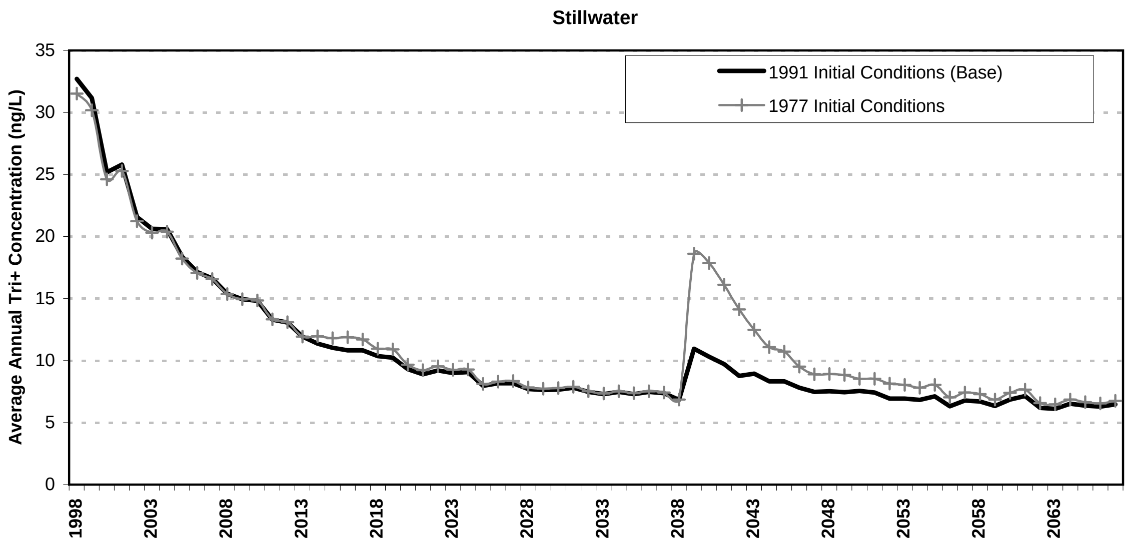


Figure 8-21a. Sensitivity of Forecasted Average Annual Tri+ Concentrations to Specification of Initial Conditions at Thompson Island Dam and Schuylerville, 1998-2067.



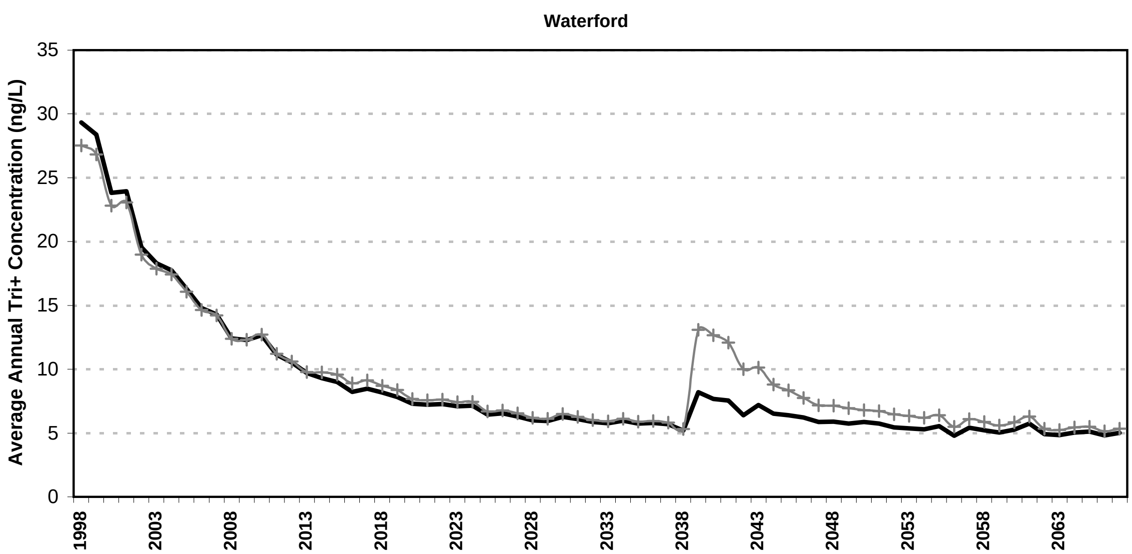


Figure 8-21b. Sensitivity of Forecasted Average Annual Tri+ Concentrations to Specification of Initial Conditions at Stillwater and Waterford, 1998-2067.

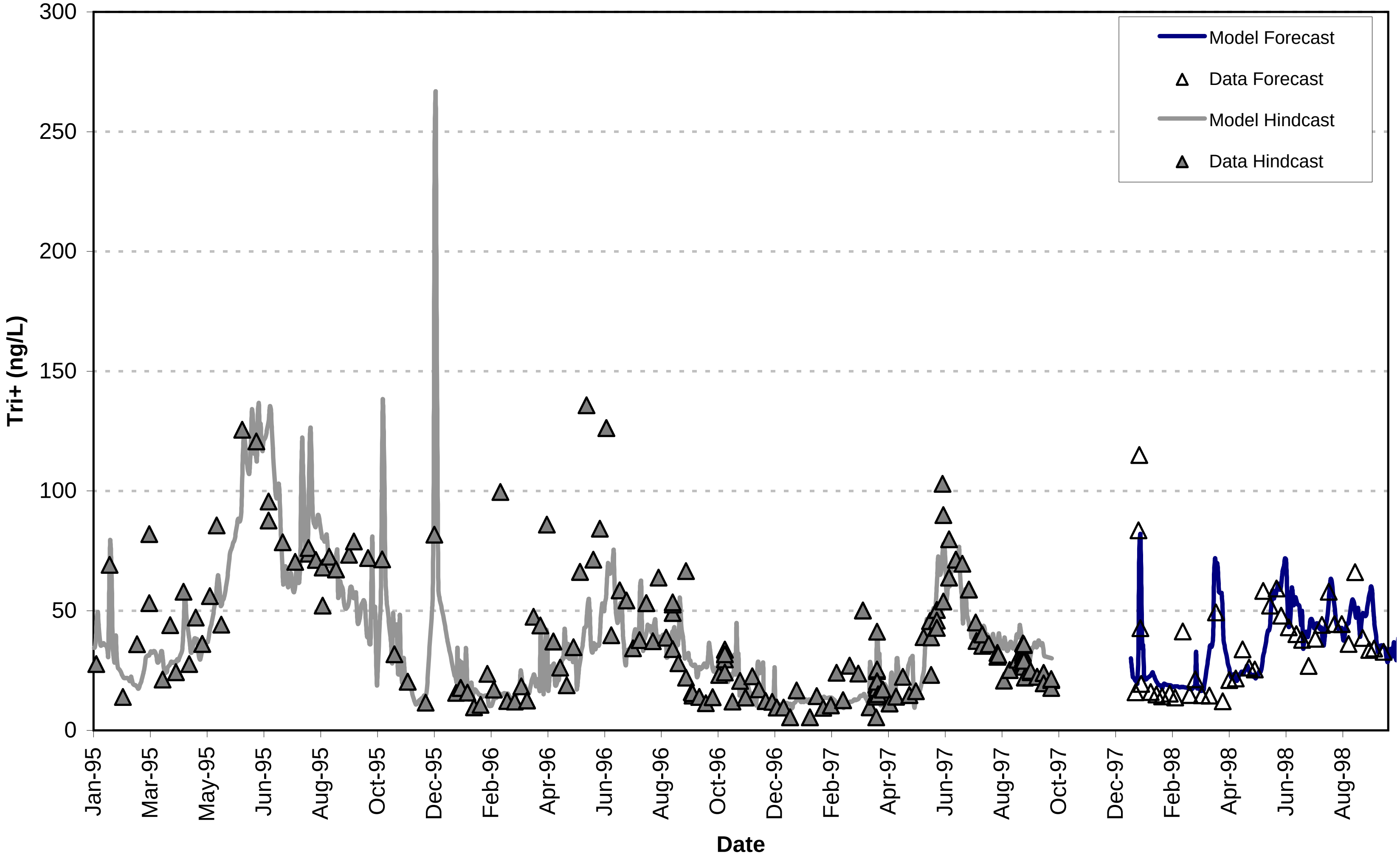


Figure 9-1. HUDTOX Validation: Comparison of Predicted and Observed Thompson Island Dam Tri+ Concentrations.

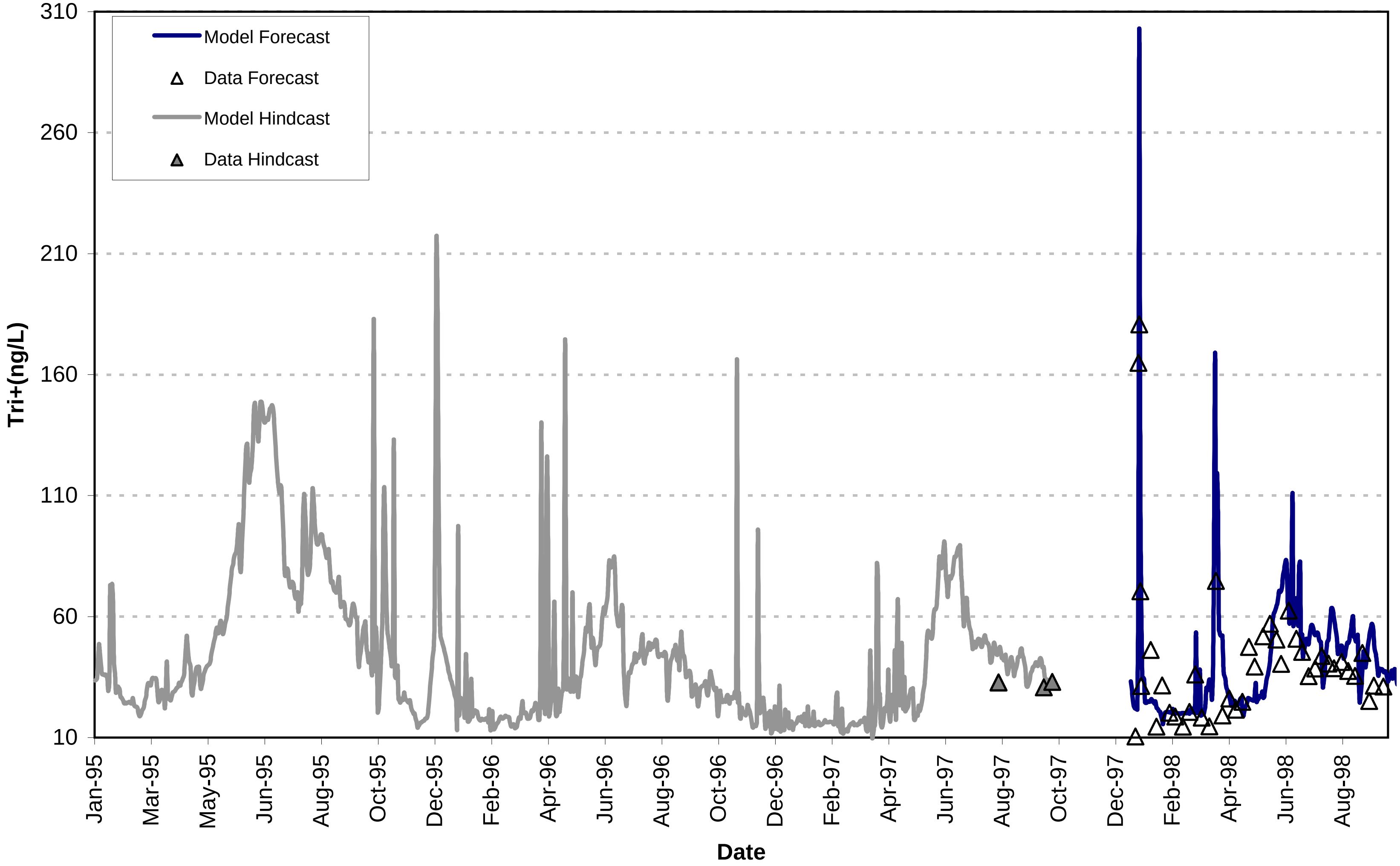
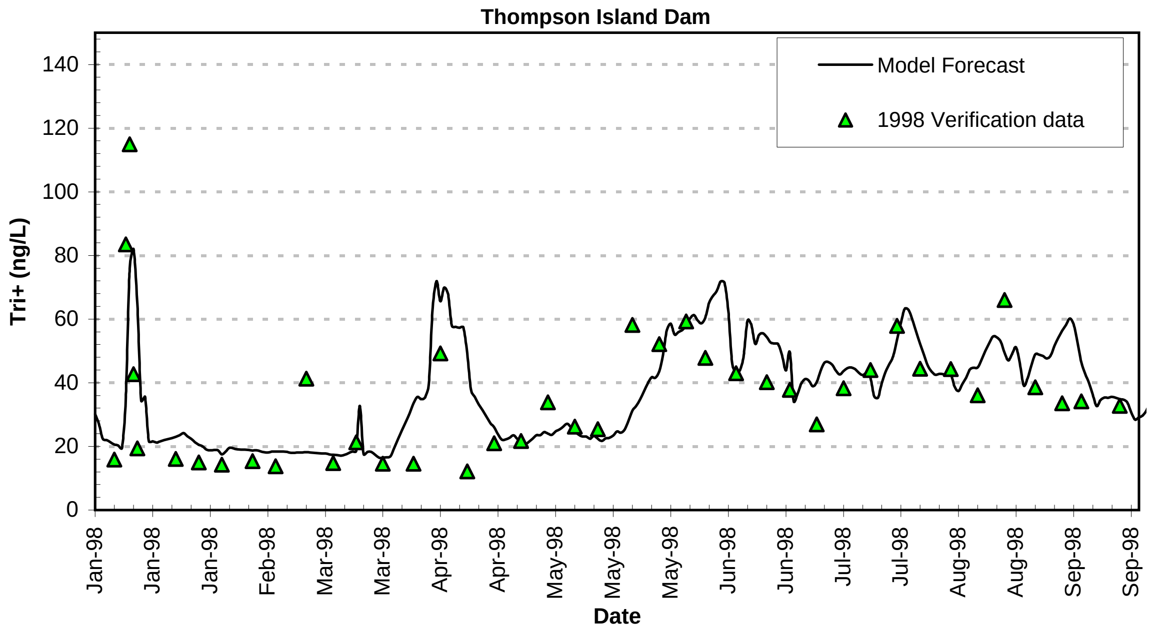


Figure 9-2. HUDTOX Validation: Comparison of Predicted and Observed Schuylerville Tri+ Concentrations.



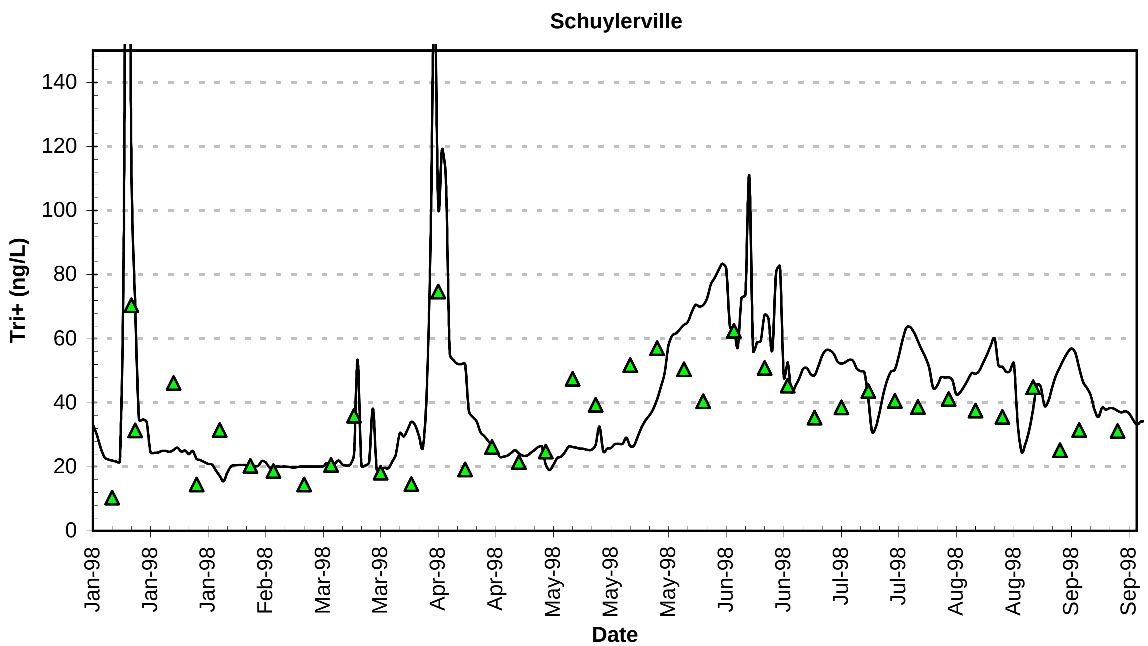


Figure 9-3. HUDTOX Validation: Predicted versus Observed Tri+ Concentrations at Thompson Island Dam and Schuylerville.

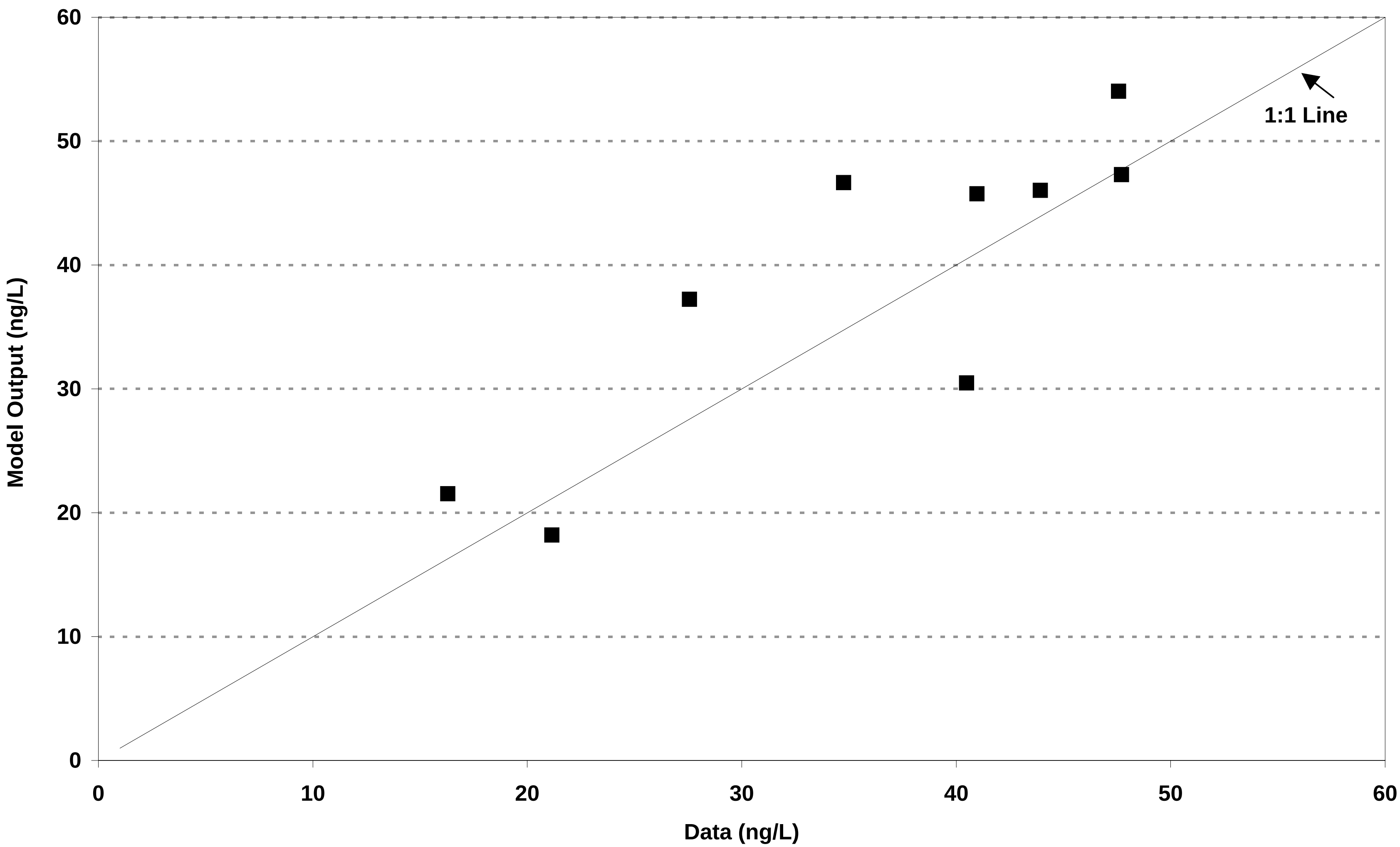


Figure 9-4. Monthly Average Scatter Plots of Observed Data and Model Output at Thompson Island Dam, 1998-1999.

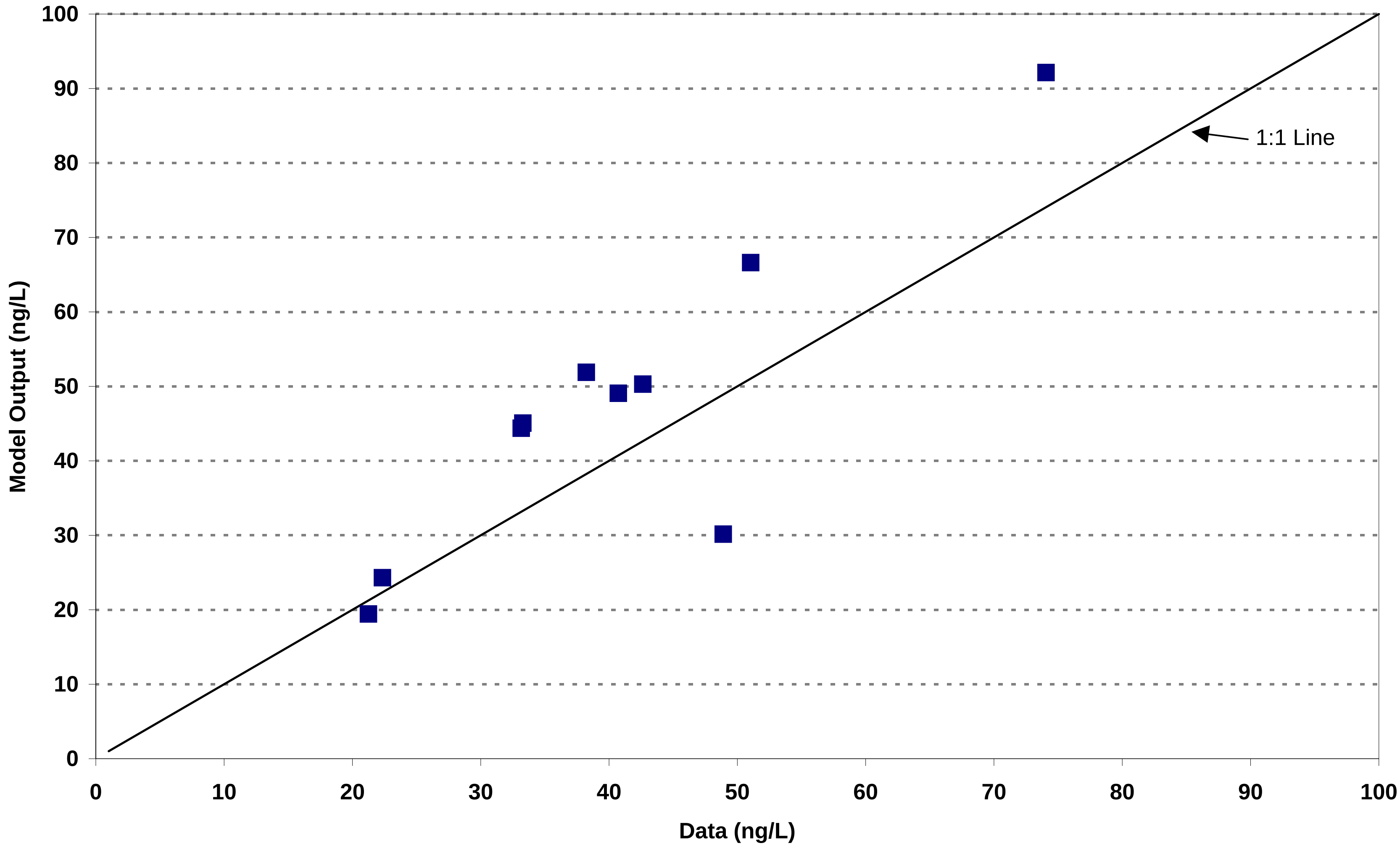


Figure 9-5. Monthly Average Scatter Plots of Observed Data and Model Output at Schuylerville, 1998-1999.

APPENDIX A

HUDTOX Exposure Concentrations for Risk Assessments

1. Introduction

The HUDTOX fate and transport model and the FISHRAND bioaccumulation model were developed and refined over a period of years. Concurrent with these modeling efforts, EPA conducted the risk assessments for the Reassessment. Accordingly, in the risk assessments, EPA used modeled concentrations of PCBs in sediment, water and fish from the most updated versions of HUDTOX and FISHRAND that were available at the time. The HUDTOX results that were used in the risk assessments are presented below. The FISHRAND results for the Upper Hudson River that were used in the risk assessments are presented in Appendix B of Book 4.

2. HUDTOX Results Used in the August 1999 Ecological Risk Assessment for the Hudson River (USEPA, 1999)[1]

For the August 1999 Ecological Risk Assessment for the Hudson River, EPA evaluated current and future risks to ecological receptors in the Upper Hudson River for the time period 1993 through 2018, using the calibration and forecast results for total PCBs in water and sediment for 1993-2018, as presented in the May 1999 Baseline Modeling Report (BMR). These were computed from HUDTOX based on initial conditions in sediment specified from the 1991 GE composite data set and a specified PCB concentration of 10 ng/L in the water column at the upstream boundary.

The HUDTOX forecasts for sediment and water that were used in the August 1999 Ecological Risk Assessment (1998 to 2018) are presented in Figures A-1 and A-2, respectively.

3. HUDTOX Results Used in the August 1999 Human Health Risk Assessment for the Upper Hudson River (USEPA, 1999)[2]

For the August 1999 Human Health Risk Assessment for the Upper Hudson River, EPA estimated average and high-end concentrations of PCBs in water and sediment for a 41-year exposure duration from 1999 to 2040 using mean and 95th percentile concentrations

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[1] U.S. Environmental Protection Agency (US EPA). Phase 2 Report – Review Copy. Further Site Characterization and Analysis. Volume 2E – Baseline Ecological Risk Assessment, Hudson River PCBs Reassessment RI/FS. Prepared for US EPA by TAMS Consultants, Inc. and Menzie-Cura & Associates, Inc., US EPA, Region II, New York, New York, August 1999.

[2] U.S. Environmental Protection Agency (US EPA). Phase 2 Report – Review Copy. Further Site Characterization and Analysis. Volume 2F - Human Health Risk Assessment for the Upper Hudson River, Hudson River PCBs Reassessment RI/FS. Prepared for US EPA by Gradient Corporation. US EPA, Region II, New York, New York, August 1999.

of total PCBs in water and sediment for 1999 through 2018, as presented in the May 1999 BMR. These results were computed from HUDTOX based on initial conditions in sediment specified from the 1991 GE composite data set and a specified PCB concentration of 10 ng/L in water at the upstream boundary.

The HUDTOX forecasts for sediment and water that were used in the August 1999 Human Health Risk Assessment for the Upper Hudson River (1999 to 2018) presented in Figures A-1 and A-2, respectively.

4. HUDTOX Results Used in the December 1999 Ecological Risk Assessment for Future Risks in the Lower Hudson River (USEPA, 1999)[3]

In the December 1999 Ecological Risk Assessment for Future Risks in the Lower Hudson River, EPA evaluated risks to ecological receptors in the Lower Hudson River for the time period 1993-2018. To evaluate these risks, EPA used calibration and forecast results for Tri+ PCBs for the Upper Hudson River for 1993-2018. These results were computed from the revised HUDTOX model based on initial conditions in sediment specified from the 1977 data set and a specified PCB concentration of 10 ng/L in water at the upstream boundary.

The HUDTOX forecasts for sediment and water in the Upper Hudson River that were used in the December 1999 Ecological Risk Assessment are compared to the results for this RBMR (as presented in Chapter 8) in Figures A-3 and A-4, respectively. These results subsequently were used as input into the Farley et al. (1999) model to calculate concentrations of PCBs in sediment and water for the Lower Hudson River (see, December 1999 Ecological Risk Assessment for Future Risks in the Lower Hudson River).

5. HUDTOX Results Used in the December 1999 Human Health Risk Assessment for the Mid-Hudson River (USEPA, 1999)[4]

For the December 1999 Human Health Risk Assessment for the Mid-Hudson River, EPA estimated average and high-end concentrations of PCBs in water and sediment for a 41-year exposure duration from 1999 to 2040, using mean and 95th percentile concentrations of Tri+ PCBs in water and sediment for 1999 through 2040. These results were computed from the revised HUDTOX model based on initial conditions in sediment specified from the 1977 data set and a specified PCB concentration of 10 ng/L in water at the upstream boundary.

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[3] U.S. Environmental Protection Agency, (US EPA). 1999. Phase 2 Report – Review Copy. Further Site Characterization and Analysis. Volume 2E–A, Ecological Risk Assessment for Future Risks in the Lower Hudson River. Hudson River PCBs Reassessment RI/FS. Prepared by TAMS Consultants, Inc. and Menzie-Cura & Associates, Inc., US EPA, Region II, New York, New York, December 1999.

[4] U.S. Environmental Protection Agency, (US EPA). 1999. Phase 2 Report – Review Copy. Further Site Characterization and Analysis. Volume 2F–A, Human Health Risk Assessment for the Mid-Hudson River. Hudson River PCBs Reassessment RI/FS. Prepared by TAMS Consultants, Inc. and Gradient Corporation, US EPA, Region II, New York, New York, December 1999.

The HUDTOX forecasts for sediment and water that were used in the December 1999 Human Health Risk Assessment (1999-2040) are compared to the results for this RBMR (as presented in Chapter 8) in Figures A-5 and A-6, respectively.

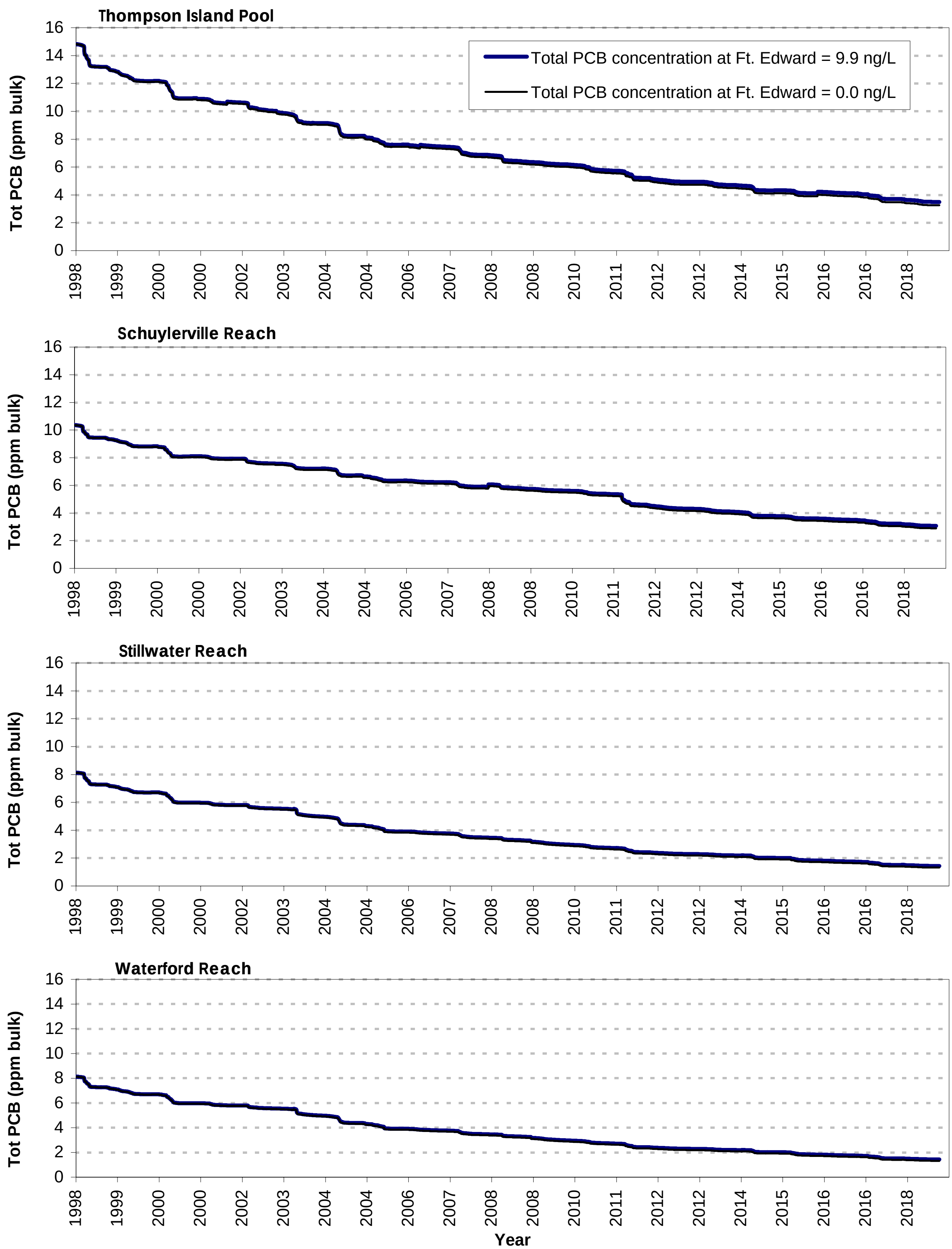


Figure A-1. Predicted Annual Average PCB Sediment Concentration Model Results (May, 1999) Used in the Human Health Risk Assessment for the Upper Hudson River.

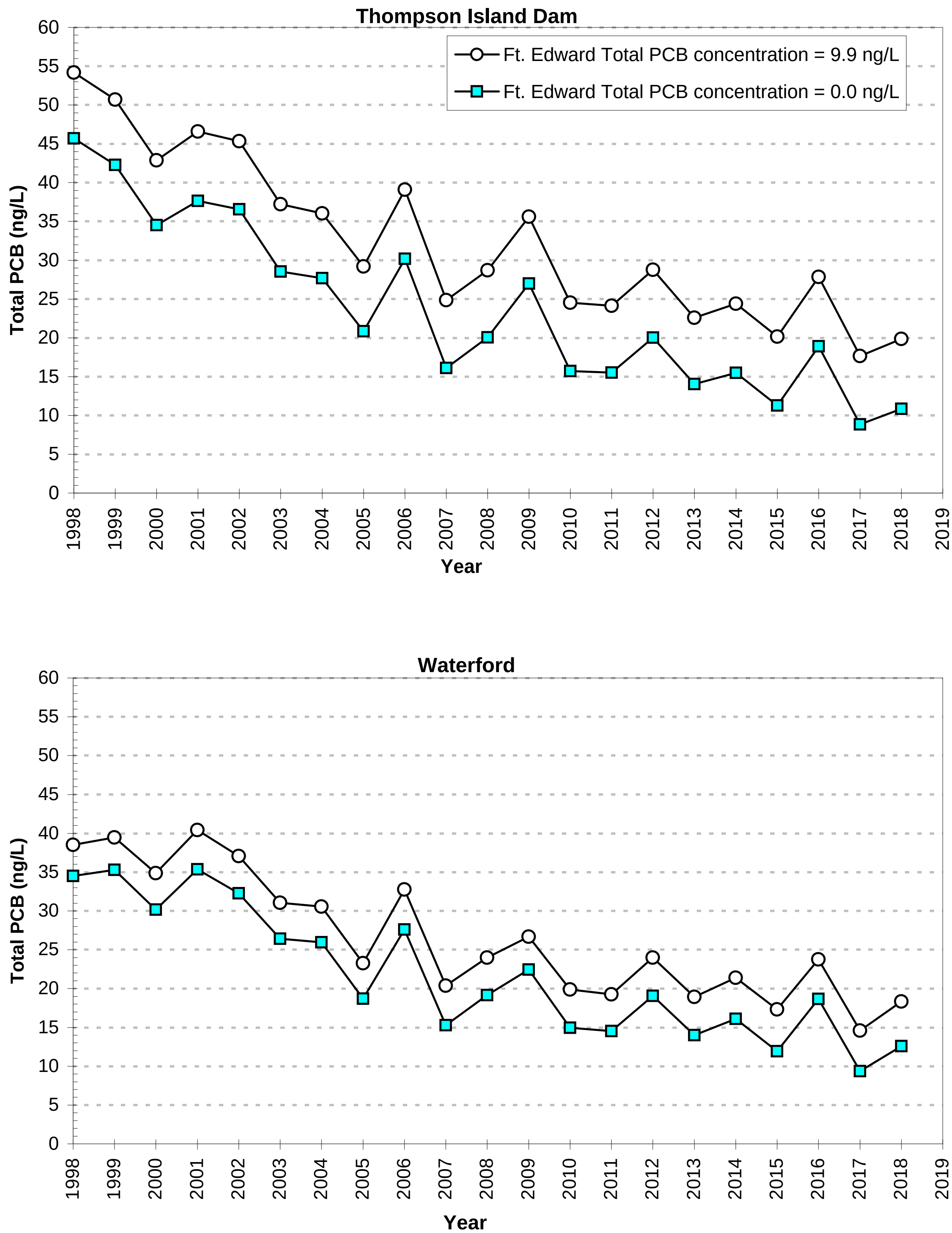
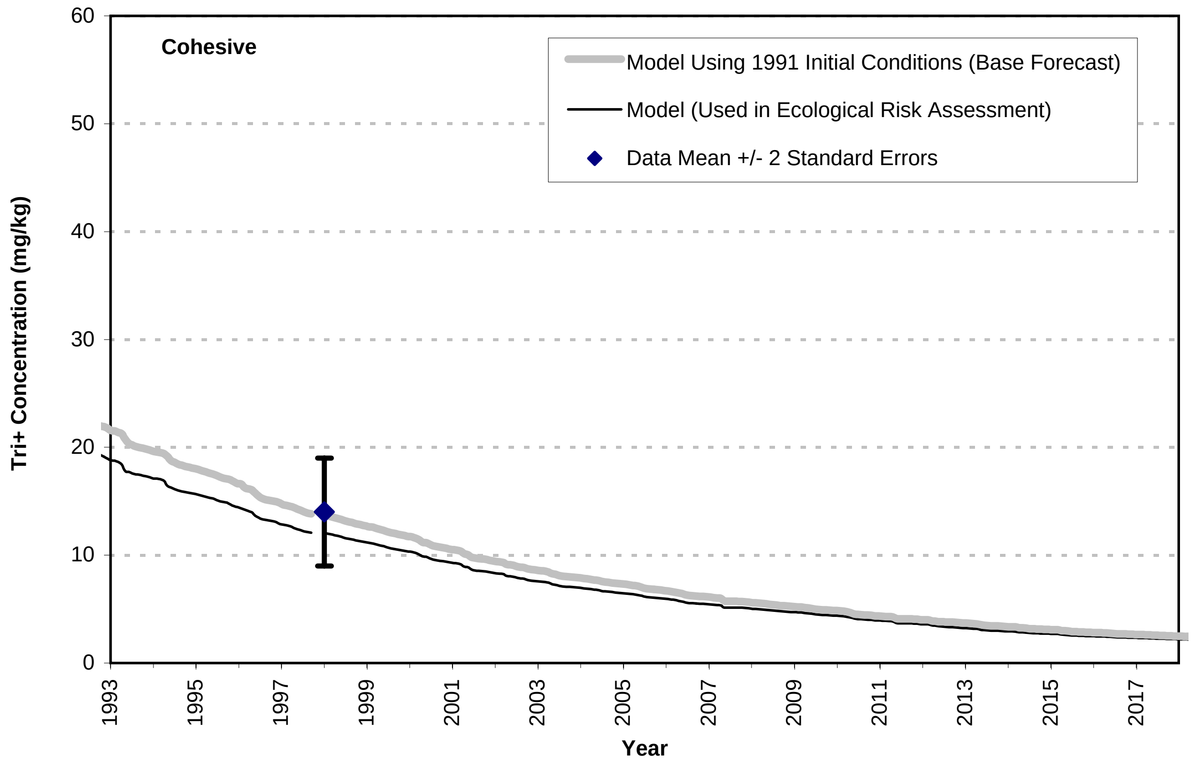


Figure A-2. Predicted Summer Annual Average PCB Concentration Model Results (May, 1999) Used in Human Health Risk Assessment for the Upper Hudson River.



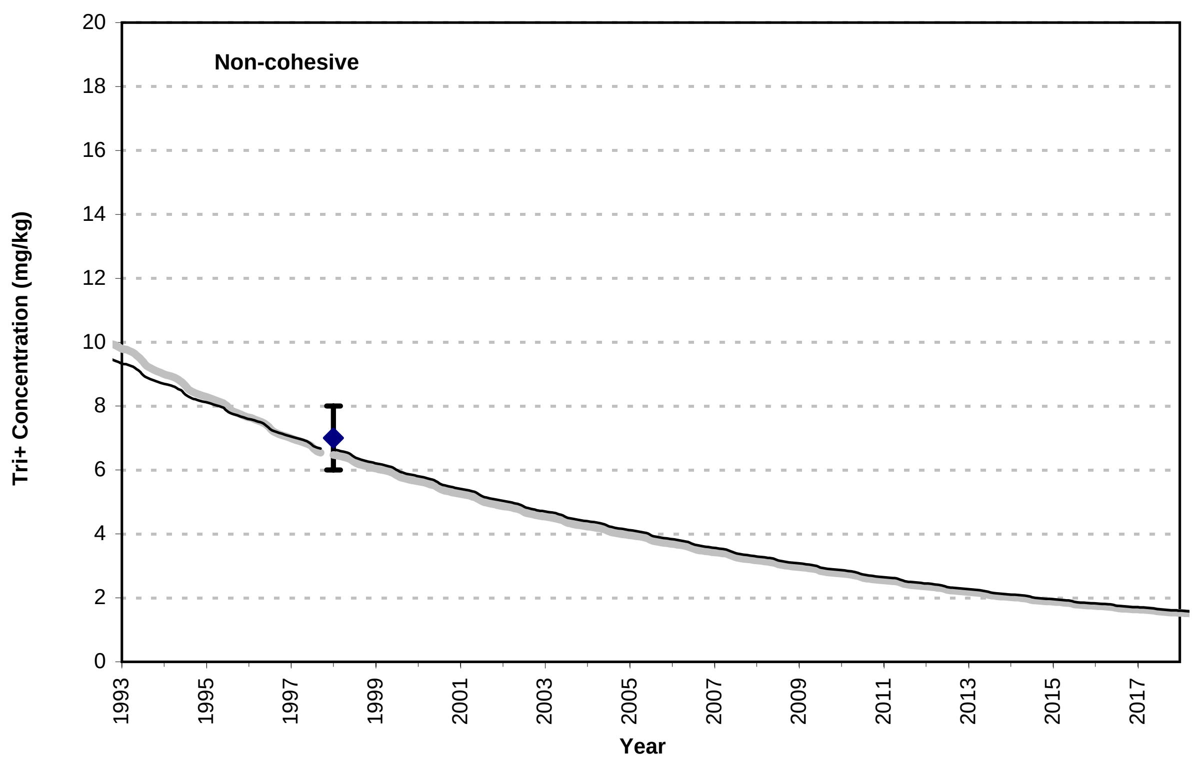
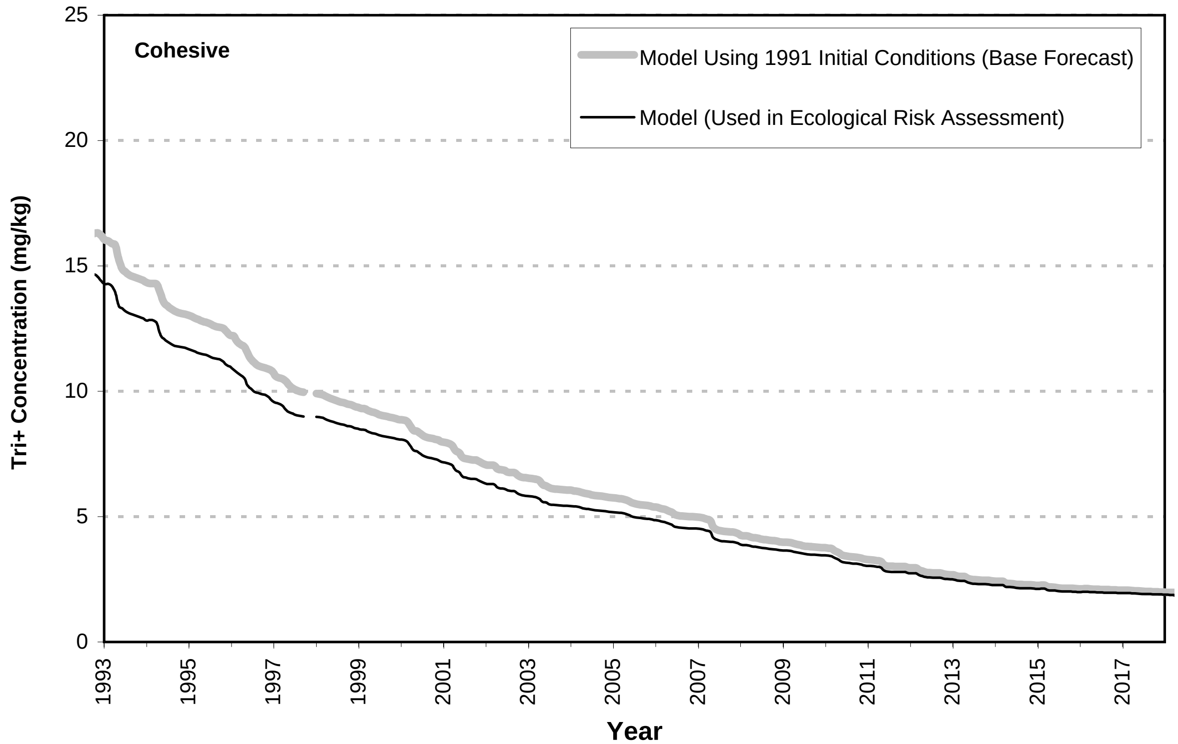


Figure A-3a. Predicted Model Results Used in Lower Hudson River Ecological Risk Assessment (Dec., 1999) Compared to Base Model Forecast in Thompson Island Pool, 1993-2018.



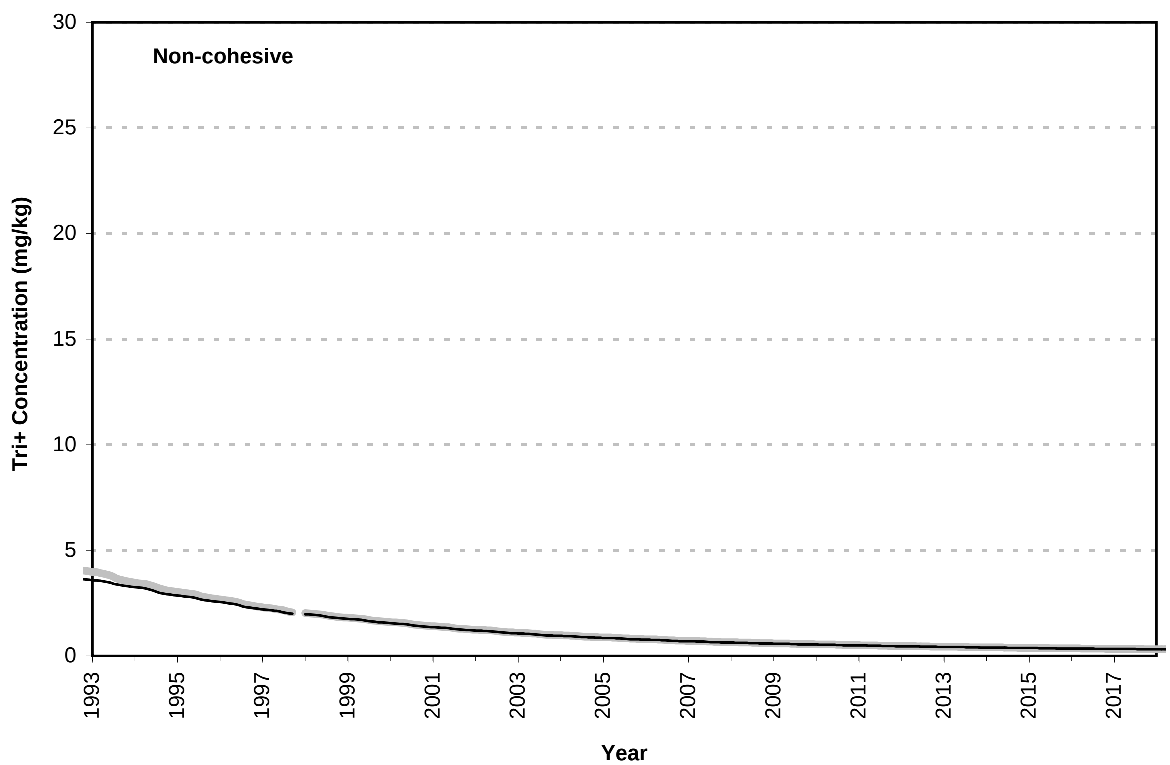
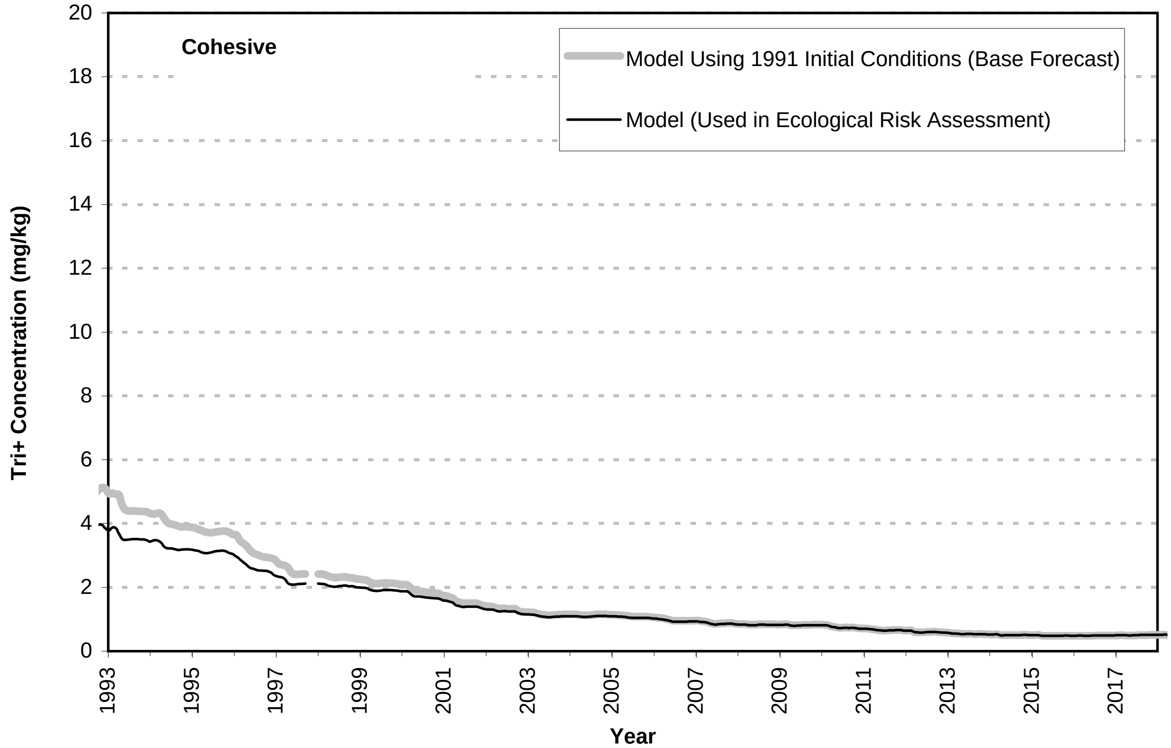


Figure A-3b. Predicted Model Results Used in Lower Hudson River Ecological Risk Assessment (Dec., 1999) Compared to Base Model Forecast in the Schuylerville Reach, 1993-2018.



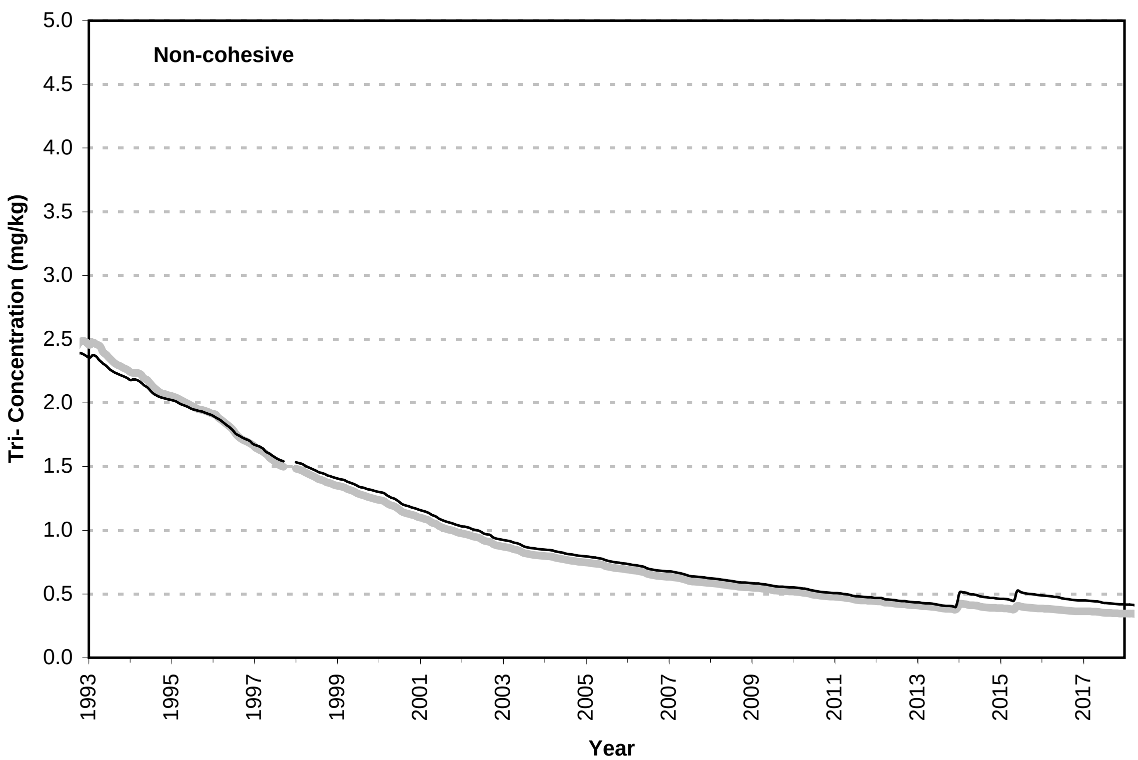
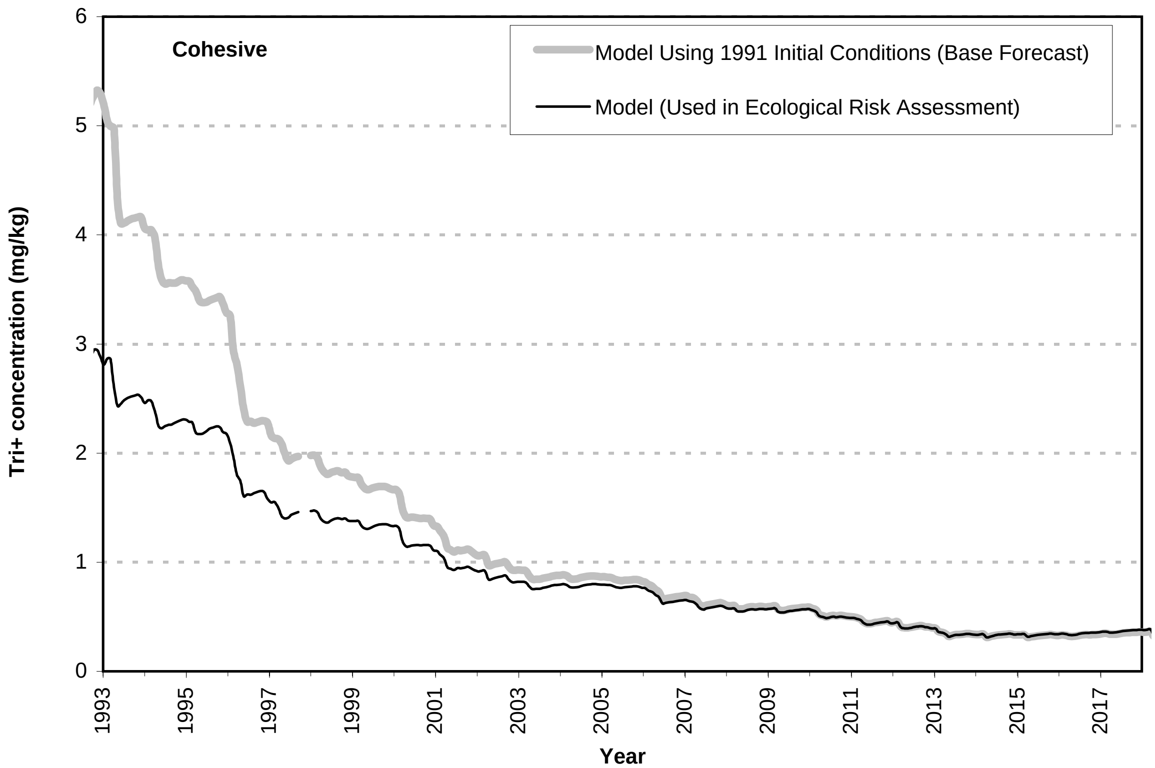


Figure A-3c. Predicted Model Results Used in Lower Hudson River Ecological Risk Assessment (Dec., 1999) Compared to Base Model Forecast in the Stillwater Reach, 1993 2018.



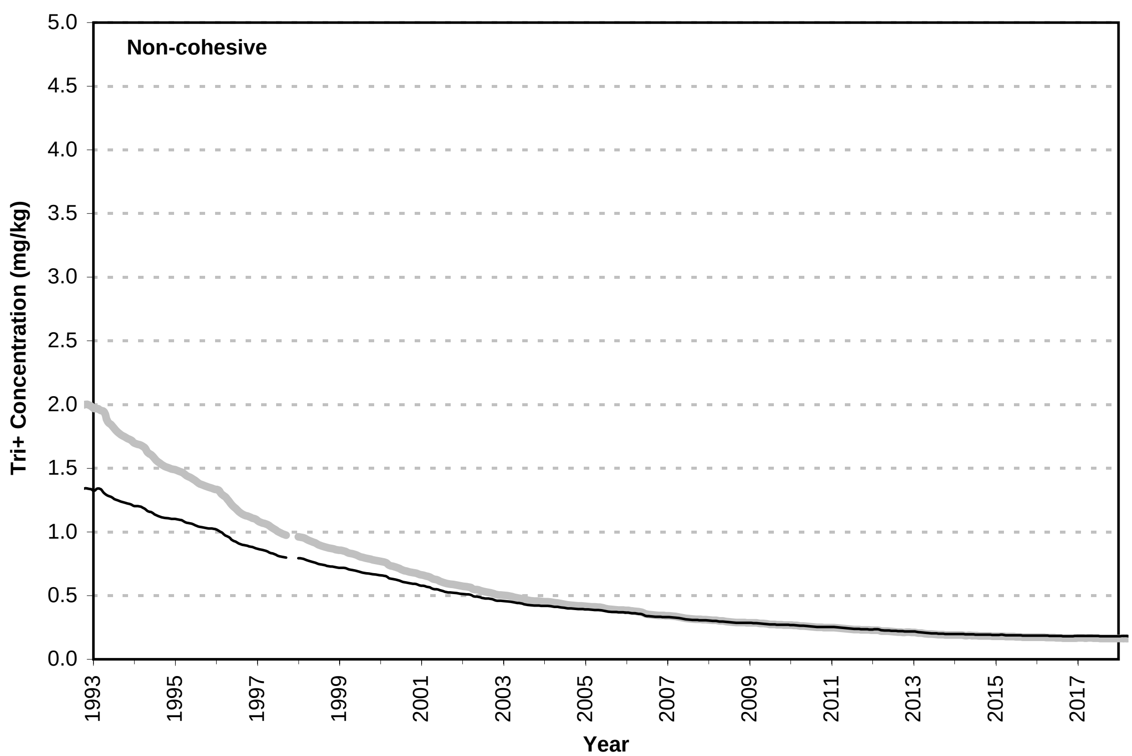


Figure A-3d. Predicted Model Results Used in Lower Hudson River Ecological Risk Assessment (Dec., 1999) Compared to Base Model Forecast in the Waterford Reach, 1993-2018.

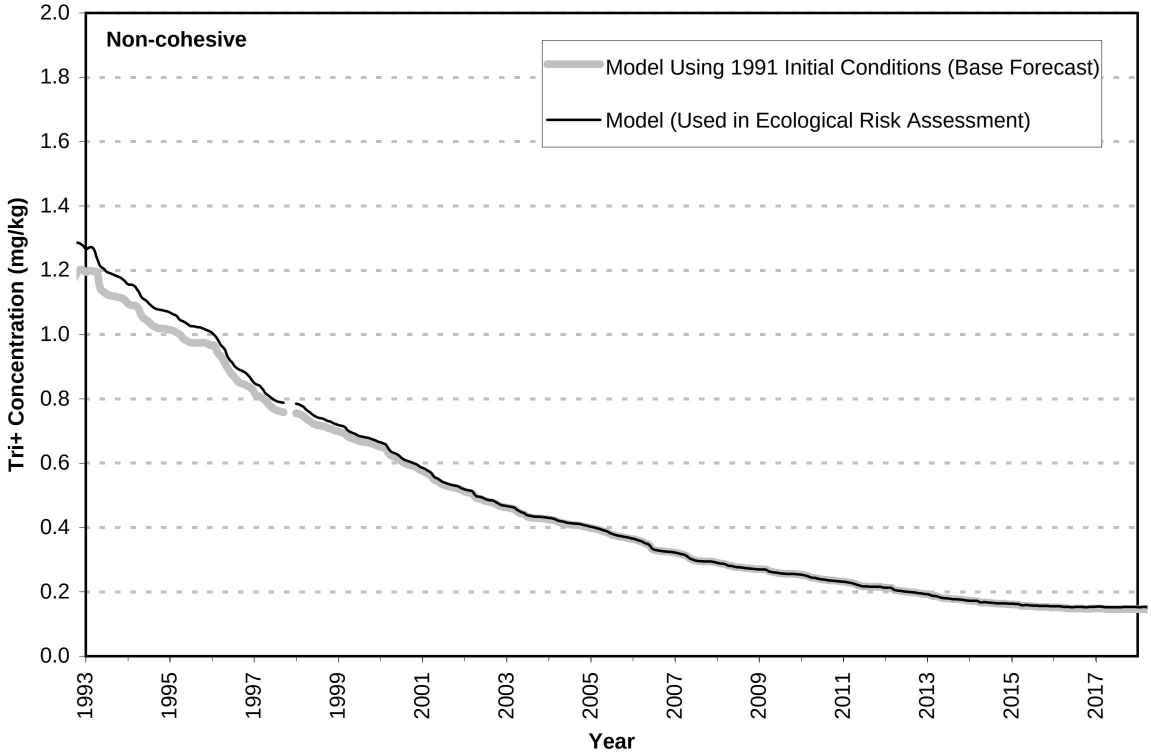
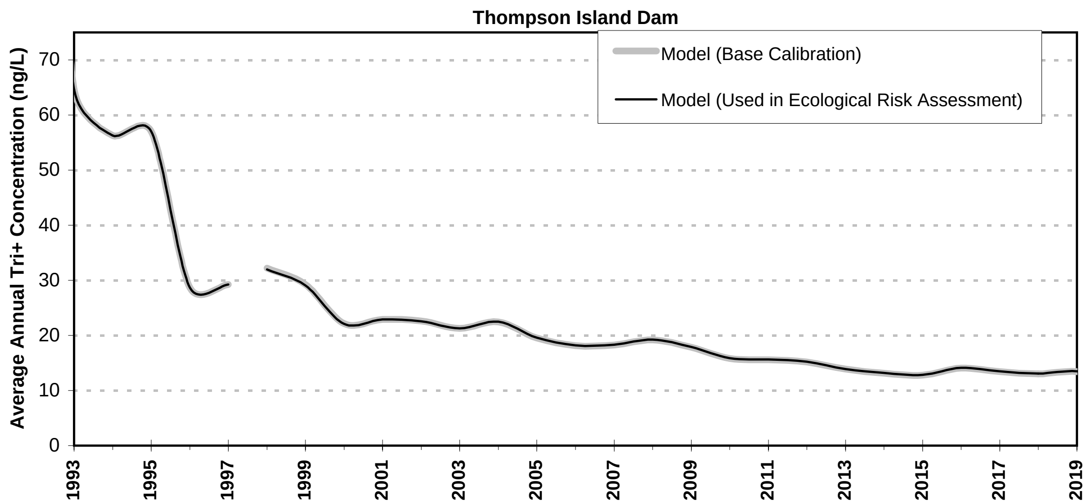


Figure A-3e. Predicted Model Results Used in Lower Hudson River Ecological Risk Assessment (Dec., 1999) Compared to Base Model Forecast in the Federal Dam Reach, 1993-2018.



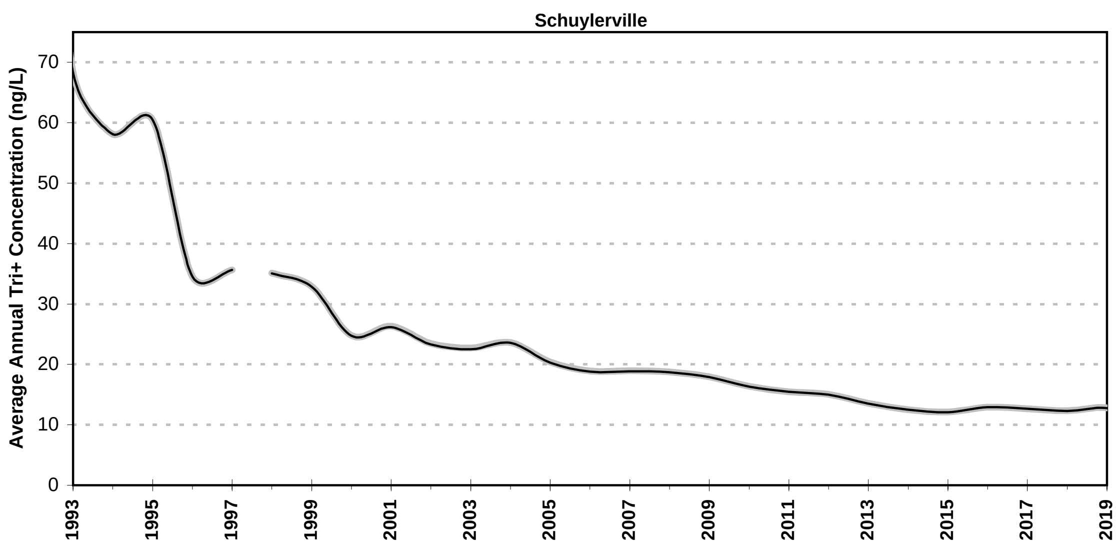
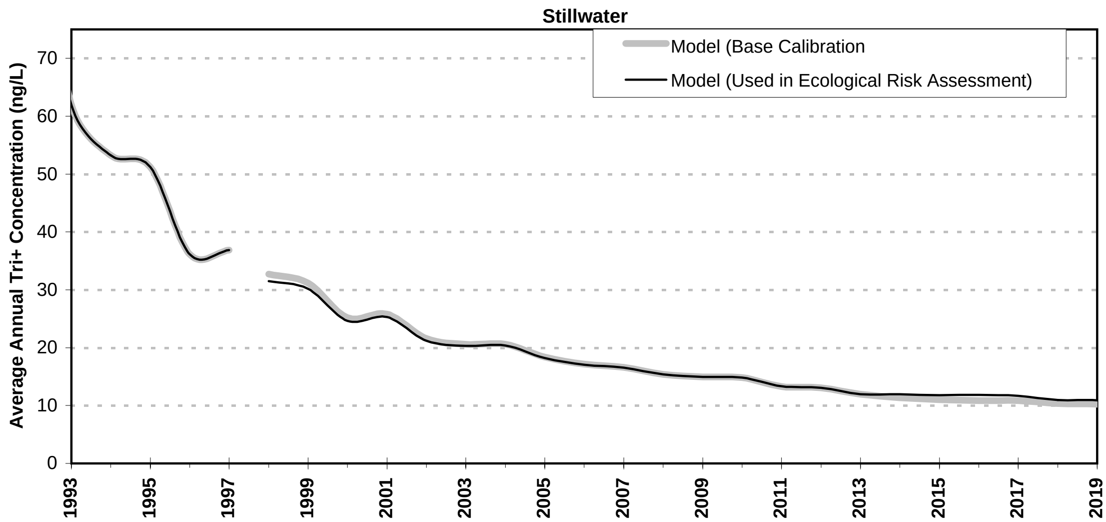


Figure A-4a. Predicted Model Results Used in Lower Hudson River Ecological Risk Assessment (Dec., 1999) Compared to Base Model Forecast at Thompson Island Dam and Schuylerville, 1993-2018.



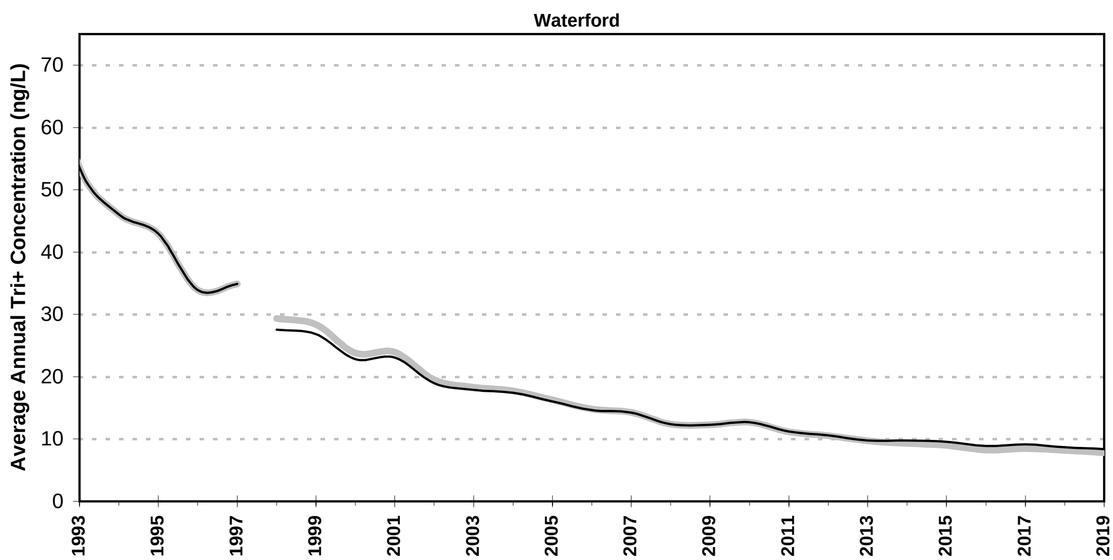


Figure A-4b. Predicted Model Results Used in Lower Hudson River Ecological Risk Assessment (Dec., 1999) Compared to Base Model Forecast at Stillwater and Waterford, 1993-2018.

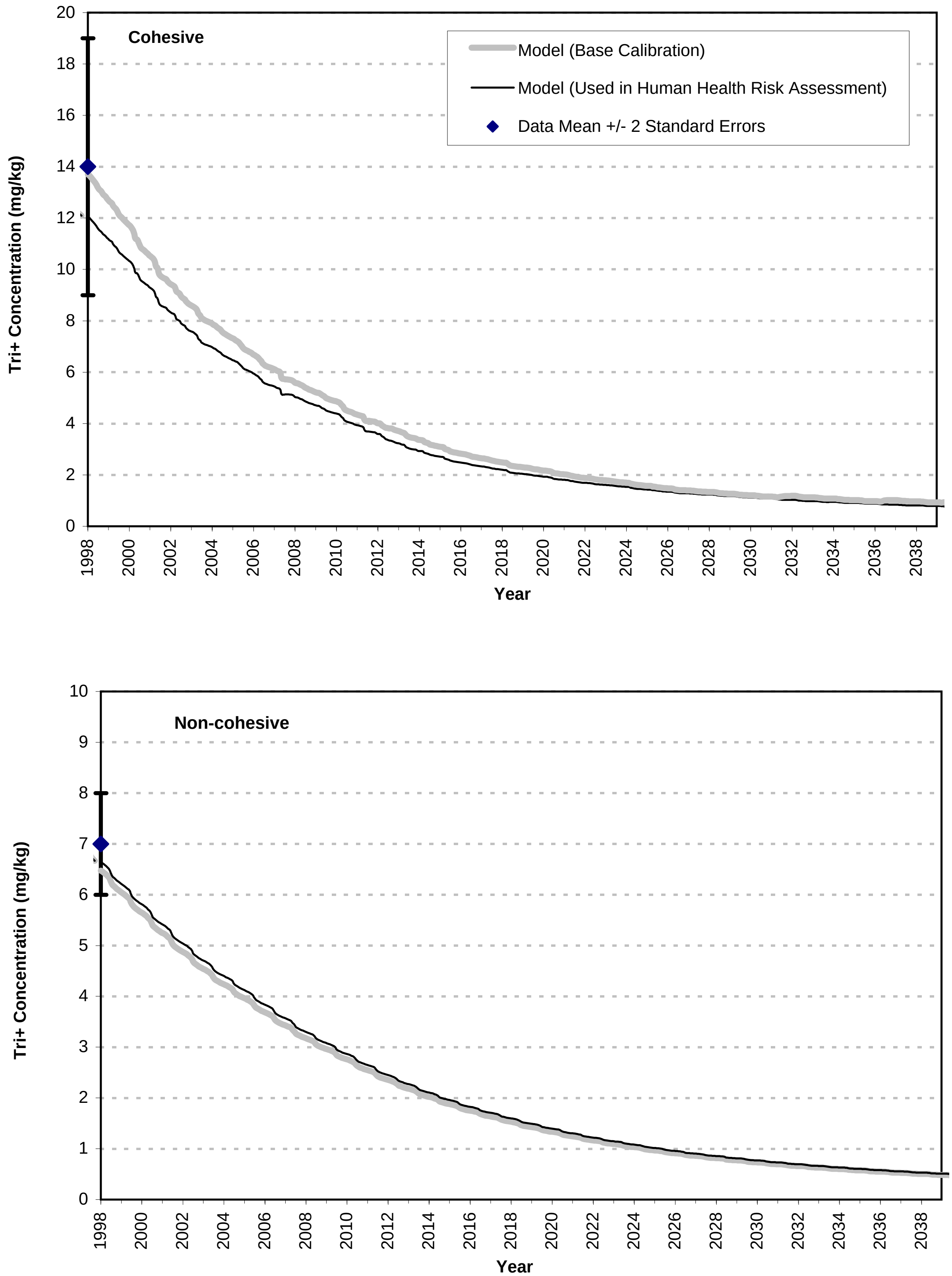


Figure A-5a. Predicted Model Results Used in mid-Hudson River Human Health Risk Assessment (Dec., 1999) Compared to Base Model Forecast in Thompson Island Pool, 1998-2038.

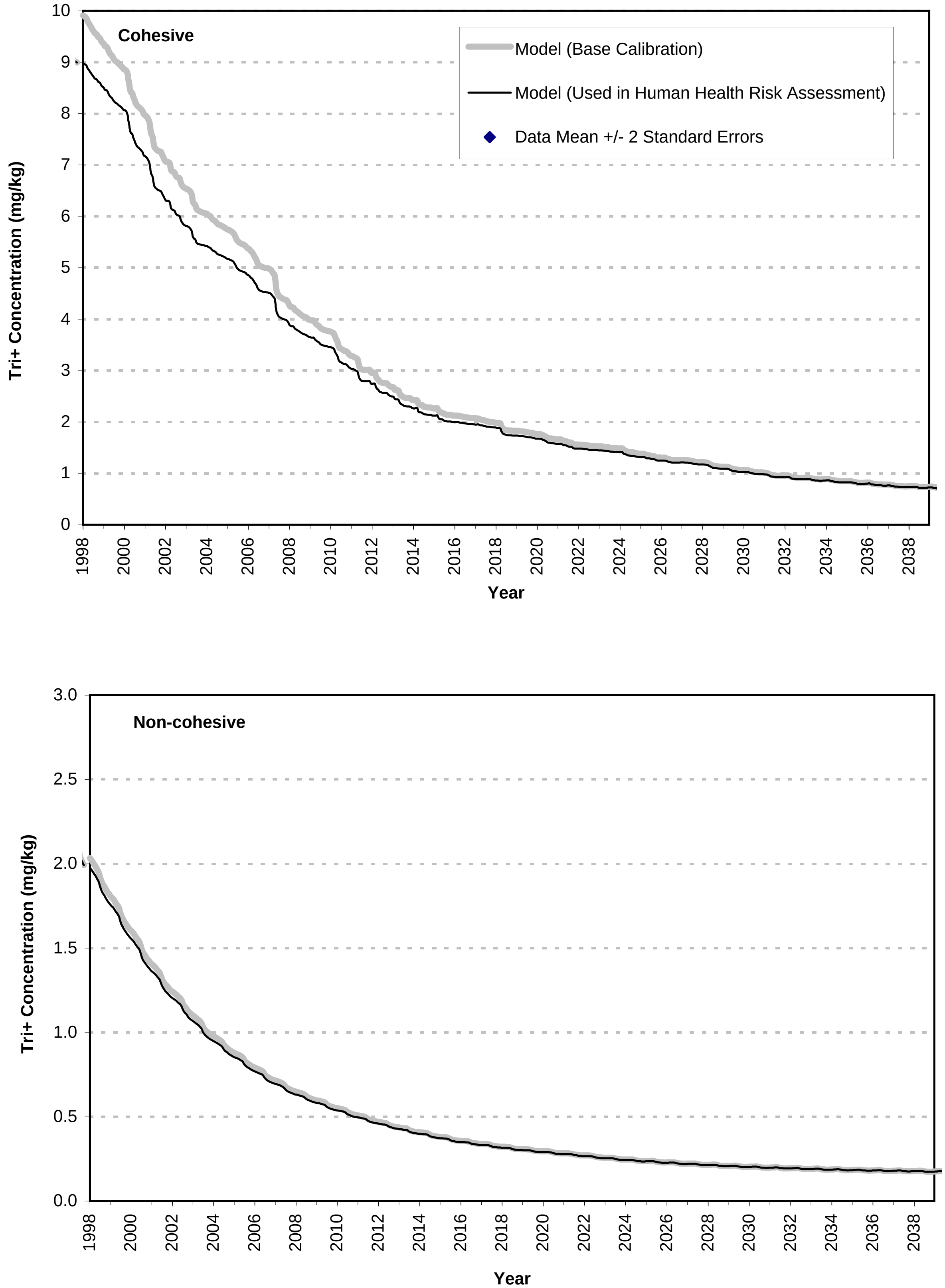
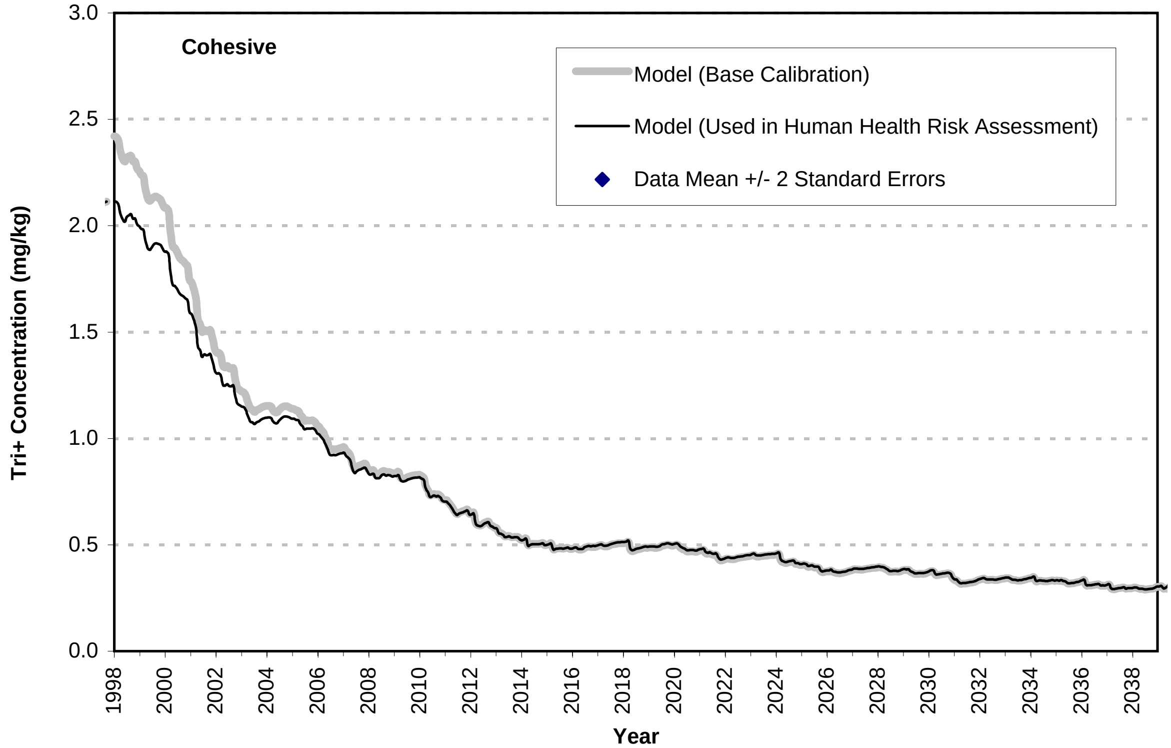


Figure A-5b. Predicted Model Results Used in mid-Hudson River Human Health Risk Assessment (Dec., 1999) Compared to Base Model Forecast in the Schuylerville Reach, 1998-2038.



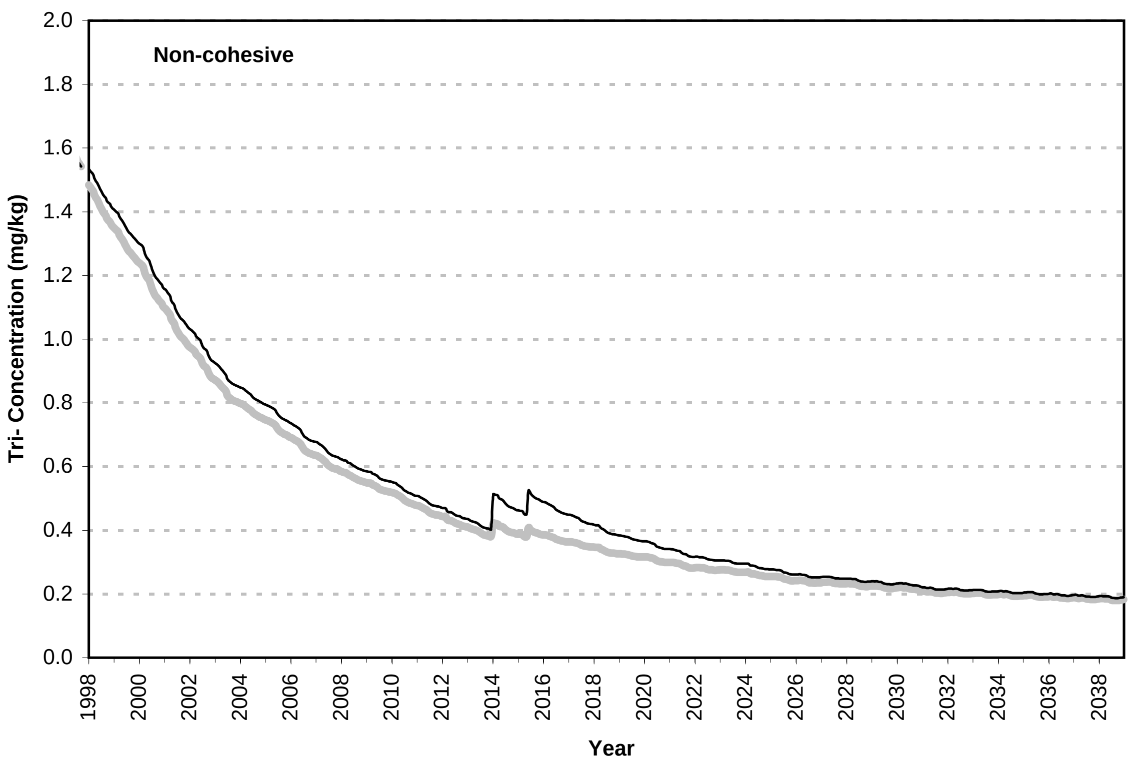
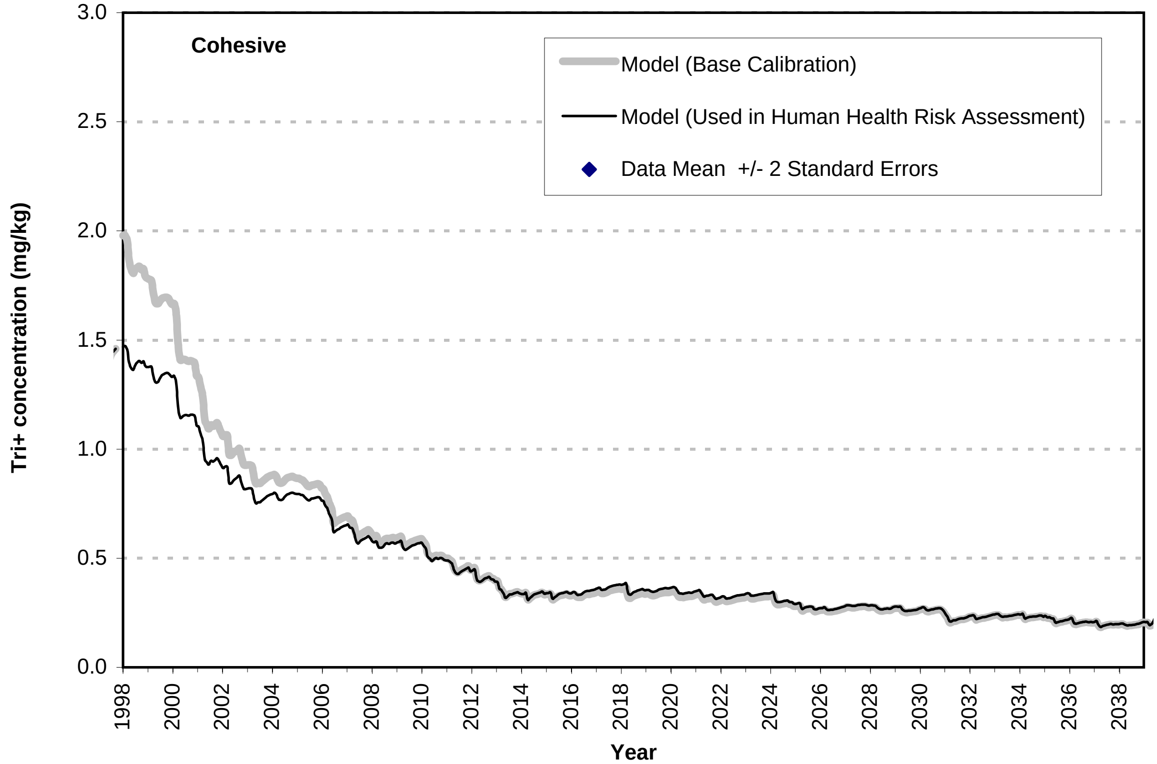


Figure A-5c. Predicted Model Results Used in mid-Hudson River Human Health Risk Assessment (Dec., 1999) Compared to Base Model Forecast in the Stillwater Reach, 1998 2038.



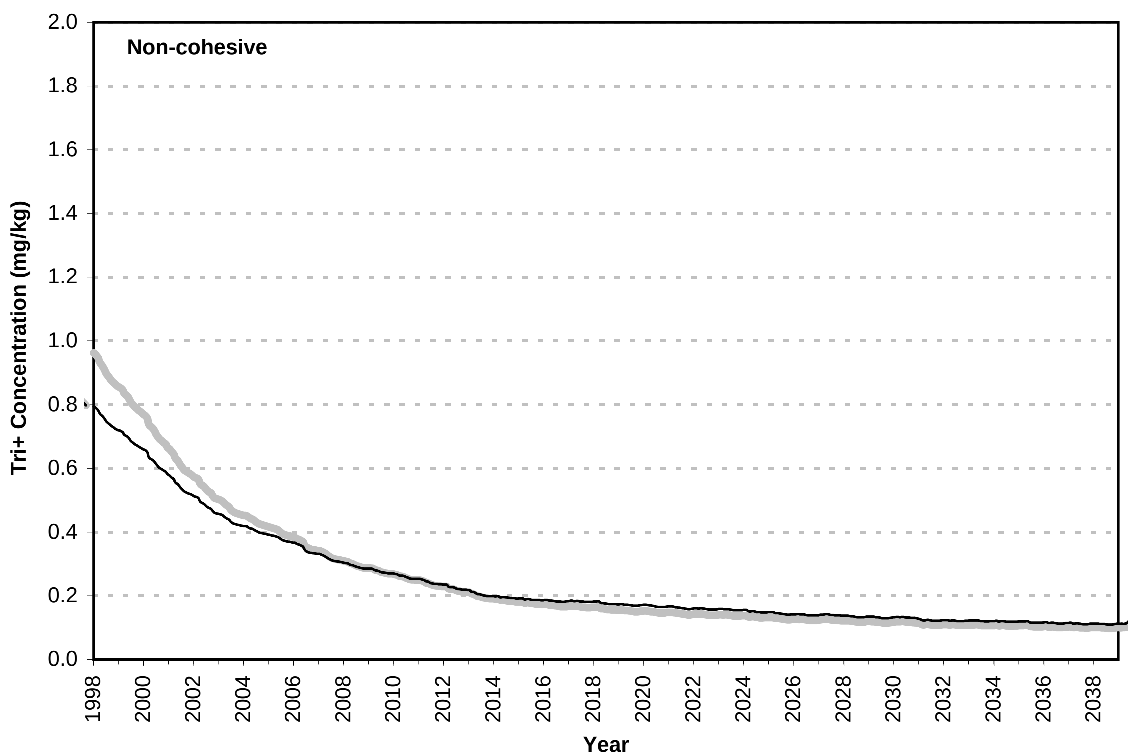


Figure A-5d. Predicted Model Results Used in mid-Hudson River Human Health Risk Assessment (Dec., 1999) Compared to Base Model Forecast in the Waterford Reach, 1998-2038.

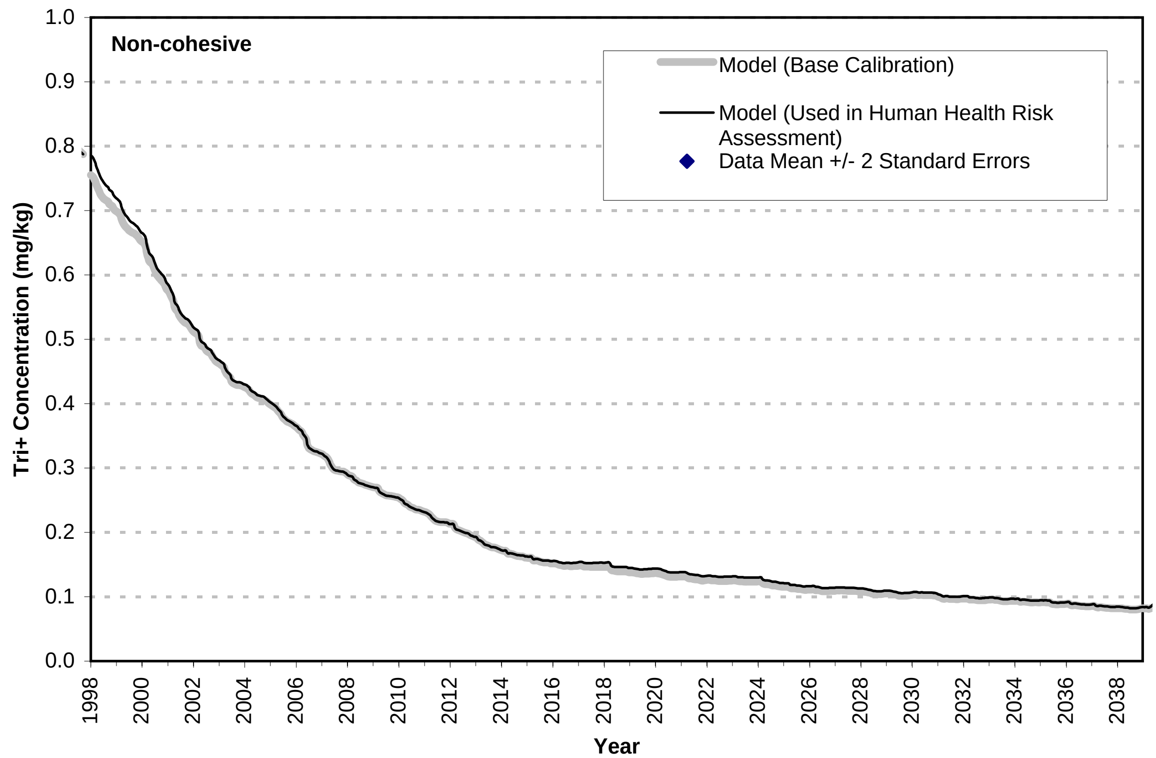
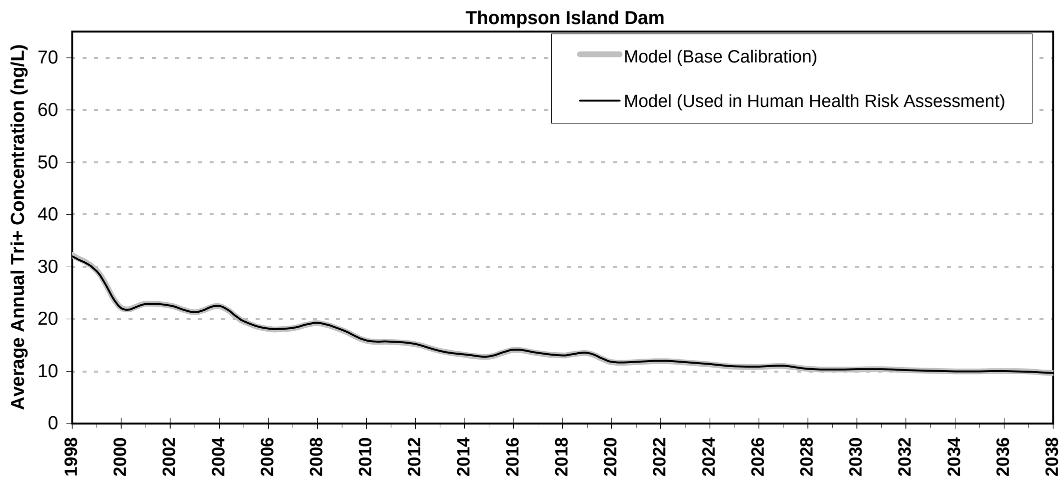


Figure A-5e. Predicted Model Results Used in mid-Hudson River Human Health Risk Assessment (Dec., 1999) Compared to Base Model Forecast in the Federal Dam Reach, 1998-2038.



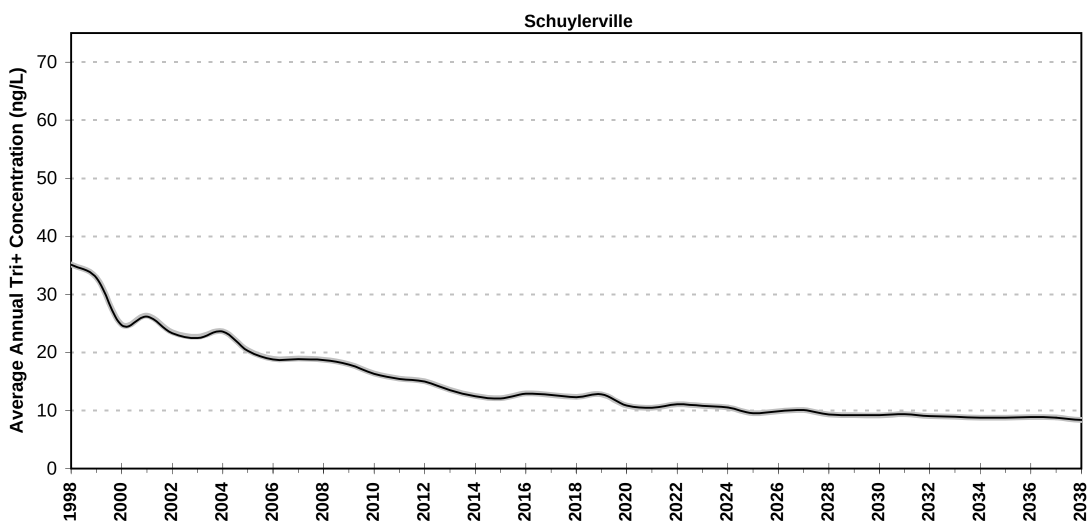


Figure A-6a. Predicted Model Results Used in mid-Hudson River Human Health Risk Assessment (Dec., 1999) Compared to Base Model Forecast at Thompson Island Dam and Schuylerville, 1998-2038.

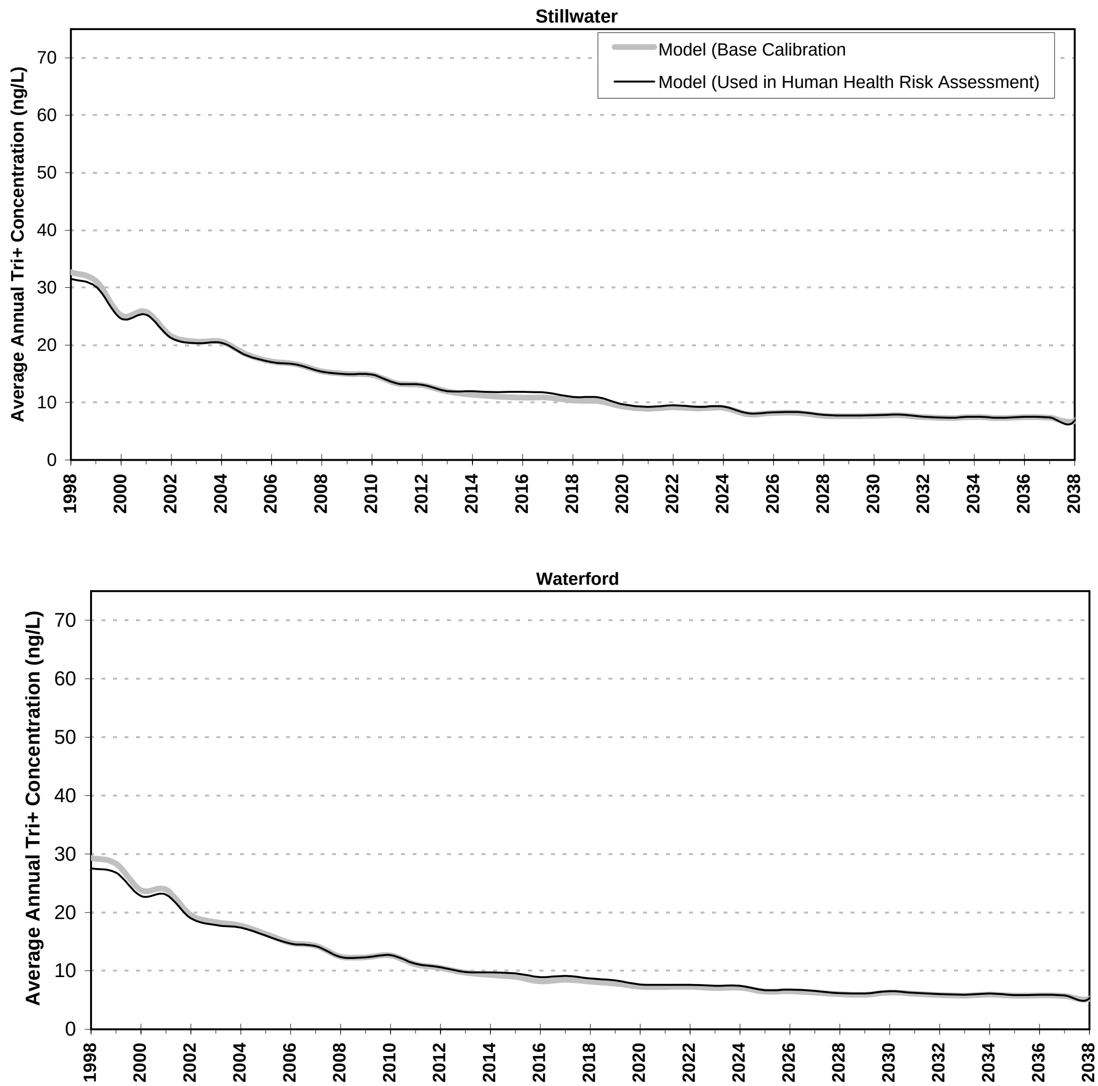


Figure A-6b. Predicted Model Results Used in mid-Hudson River Human Health Risk Assessment (Dec., 1999) Compared to Base Model Forecast at Stillwater and Waterford, 1998-2038.