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PCBs in the Upper Hudson River

Volume 3
Predictions of Natural Recovery and the Effectiveness of Active Remediation

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Introduction

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SECTION 1
INTRODUCTION

An action plan to address PCBs in the Upper Hudson River should be based on an understanding of the reductions in risk to humans, wildlife and aquatic biota expected from each remedial action considered. Proposed remedial actions must be considered in light of the historical trends in PCB concentration and loading. The levels measured over more than 20 years indicate that reductions occur naturally in the water column, sediment and biota. The goal of active remediation (such as further upstream source reduction or dredging, described in detail in this volume) would be to accelerate the rate of reduction of PCB concentration in fish and in the water column and surface sediment to which wildlife and humans may be exposed. Furthermore, active remediation must be technologically feasible, economically justifiable and its ecological and social effects must be weighted against whatever advantage it provides. Our ability to accelerate recovery depends upon the effectiveness of each remedial action in reducing PCB sources and how rapidly the river system responds to the source reduction. The PCB sources in the Upper Hudson River include a combination of upstream and surface sediment inputs. The response of the river system to additional upstream source reduction or sediment remediation is a function of various PCB fate mechanisms. Thus, estimation of the efficacy of any remedial action is an ambitious task. The quantitative Upper Hudson River model provides the best available tool for this task because it has been shown to describe the various PCB fate mechanisms and the relationship between PCB sources and exposure concentrations with great accuracy.

In this Volume of the report, we present the Upper Hudson River model's forecasts of PCB levels in water, surface sediment and fish over the period from 1999 to 2029. Natural recovery and several active remedial actions are simulated. The remedial actions include upstream source control and removal of sediments. In addition, a 100-year flood event is simulated to examine its effects on natural recovery.

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The Upper Hudson River model was developed, calibrated and validated under rigorous scientific review; nevertheless, like all models, predictions made using the Upper Hudson River model necessarily have caveats. For example, an estimate of the time needed to reduce PCB concentrations to a given threshold level is subject to the model's approximate representation of the river system and to the assumed future hydrological and sediment conditions. These limitations are partially overcome by simulating alternate future conditions and by using bounding and best estimate models. Maximum accuracy likely resides in the relative differences among alternatives because such comparisons eliminate some portion of the absolute error. For this reason, emphasis is placed on differences in recovery rate among the various alternatives evaluated.

It is important to note that for the active remediation scenarios, the feasibility of large scale dredging or additional source control has not yet been evaluated. Assumptions, that may prove to be untrue, about the implementation were made so that the theoretical effectiveness of the options could be evaluated. If any of the active remedial options are considered, a full evaluation of feasibility will need to be made, including a full evaluation of environmental, and community impacts, cost and technical capabilities.

Section 2

Approach

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SECTION 2
APPROACH

To use the Upper Hudson River model to forecast natural recovery and the effects of active remediation it is necessary to first specify future hydrologic conditions, solids loadings and PCB loadings. Additionally, assumptions must be made about the physical characteristics of the river in the future and the future structure and function of the food web. Of particular importance in this regard is the fat (lipid) content of the fish which has exhibited significant year-to-year changes over the twenty year monitoring period.

Future hydrologic conditions were estimated based upon statistical analyses of historical annual flow rates, including year-to-year correlation and random variability. Annual average estimates were combined with daily average flow rates to produce a 30-year daily synthetic hydrograph. Suspended solids rating curves were applied to these estimated daily average flow rates to generate daily solids loadings to the Upper Hudson River. Upon determination of hydrologic conditions and solids loadings, the calibrated and bounding hydrodynamic and sediment transport models developed for the 1977-1998 period, as described in detail in Volume 2, were used to estimate future flows, volumes, depths, suspended solids concentrations, and sediment resuspensions and deposition fluxes.

The upstream source, as expressed by PCB_{3+} loading at Fort Edward, was assigned a magnitude of 0.2 lb/d throughout the 30-year projection. This load represents a mean water concentration of 7 ng/l and is based upon recent measurements of values less than the detection limit of 11 ng/l at Fort Edward.

The physical characteristics of the river and the structure and function of the food web were presumed to remain constant over the 30-year prediction period. The lipid content of each species of fish at each location was assumed to remain constant and was set equal to the values used in the last year of calibration.

For sediment remediation, the schedule for implementation was developed using estimates from current engineering practices applied in other river systems.

Model predictions of PCB_{3+} concentrations in water, sediment, and biota were made using both the calibrated model and the bounding model. The calibrated model provides the best estimate of future conditions because it has been successfully calibrated and validated using the best estimates of each of the model parameters. The bounding model was developed to provide an estimate of uncertainty in the direction of a slower rate of recovery. In the figures showing predictions of PCB concentrations generated by the model, the estimate of concentrations is shown as a solid black line. A shaded area delineates the range between the best estimate and the prediction using the bounding model.

The presentation of the predictions focuses on metrics illustrative of the components of river recovery: surface sediment PCB_{3+} concentrations in the TIP, PCB_{3+} load passing Waterford to the lower river and PCB_{3+} concentrations in largemouth bass from the Thompson Island Pool and Stillwater. Projected concentrations under a scenario of "Natural Recovery" (i.e., the upstream source control achieved over the last 7 years remains in place, no further active remediation is undertaken) are compared to concentrations achieved by modeling active remedies.

Prediction of Future Hydrologic Conditions and Solids Loadings

Section 3

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SECTION 3
PREDICTION OF FUTURE HYDROLOGIC CONDITIONS AND SOLIDS LOADINGS

3.1 PREDICTION OF FUTURE HYDROLOGIC CONDITIONS

The 30-year projection simulations required development of synthetic hydrographs to specify discharge at upstream and tributary inflows. Historical USGS flow rate data collected at the Fort Edward, Hadley and Stewart gauging stations were used to accomplish this task.

Flow data have been collected at the Fort Edward gauging station since 1977. To augment this data record, flow data collected at the Hadley and Stewart gauging stations were used to estimate discharge at Fort Edward. A correlation was developed between Fort Edward discharge and the sum of the Hadley and Stewart flows. This correlation was then used to estimate Fort Edward discharge, on a daily average basis, from 1930 through 1976. This 47-year estimated record was augmented with 18 years of Fort Edward observations, from 1977 through 1993. The annual average flow rate at Fort Edward was calculated for the 65-year period from 1930 through 1993 (Figure 3-1). Figure 3-2 shows maximum daily flow rates at Fort Edward for each year during that period.

The 65-year record of annual average flow rates at Fort Edward was used to generate the synthetic hydrograph needed for projection simulations. A Markovian (lag-one) flow model was developed to predict annual average flow rates for year n (Q_n) based on the previous annual average discharge (Q_{n-1}) (Fiering and Jackson 1971):

$$Q_n = Q_{mean} + R_a\left(Q_{n-1} - Q_{mean}\right) + t_n S_a\left(1 - R_a^2\right)^{1/2} \tag{3-1}$$

where:

Q_{mean}	=	mean of historical annual average flow rates
S_a	=	standard deviation of historical annual average flow rates
R_a	=	correlation coefficient for historical annual average flow rates

t_n = normally distributed, serially independent random variable with zero mean and unit standard deviation

Equation (3-1) will produce a synthetic hydrograph with normally distributed flows that preserves the mean, variance and first-order correlation coefficient of the historical discharge record (Fiering and Jackson 1971).

Statistical analysis of the 65-year record of annual average flow rates yielded values for Q_{mean}, S_a and R_a that were used in Equation (3-1). A random number generator was used to specify t_n in year n. A synthetic hydrograph was generated using Equation (3-1) that was 1000 years long, i.e., a time-series of 1000 annual average flow rates. To eliminate the transient effects due to initial conditions, the first 200 years of the synthetic hydrograph were discarded, leaving a synthetic hydrograph that was 800 years long. A number between 1 and 770 was then selected randomly to determine the first year of the 30-year synthetic hydrograph of annual average flow rates.

The synthetic hydrograph described above produced a time-series of annual average flow rates. However, model input requires specification of daily average flow rates. The historical record at Fort Edward, with 65 years of measured or estimated daily discharge, was used in conjunction with the annual average synthetic hydrograph to generate the necessary model inputs. Annual average discharge for the first year in the synthetic hydrograph was compared to the historical record of annual average flows. The minimum deviation between year 1 of the synthetic hydrograph and historical annual average discharges occurred for 1989. Thus, the daily average hydrograph for 1989 was used for year 1 of the synthetic hydrograph. Next, the second year of the synthetic hydrograph was compared to the remaining 64-year record of historical discharge; 1989 was removed from the historical record after it was used for year 1. For the second year of the synthetic hydrograph, the annual average discharge for 1981 was in best agreement. This process was then repeated until all 30 years of the synthetic hydrograph were replaced with historical data. The sequence of years from the historical record used to construct the 30-year hydrograph for model input is presented in Table 3-1.

Table 3-1. 30-Year Synthetic Hydrograph			
Projection Year	Hydrograph Year	Projection Year	Hydrograph Year
1	1989	16	1958
2	1981	17	1968
3	1959	18	1983
4	1979	19	1953
5	1954	20	1938
6	1942	21	1939
7	1992	22	1963
8	1948	23	1935
9	1988	24	1940
10	1971	25	1966
11	1960	26	1944
12	1977	27	1930
13	1932	28	1975
14	1967	29	1986
15	1943	30	1946

Generating a 30-year hydrograph for daily average flow rate at Fort Edward by piecing together different years from the historical record created discontinuities at the end of each year, i.e., between December 31 of year n and January 1 of year n+1. Generally, the flow rate discontinuities were not large. However, to provide a smooth transition between years, discharge was linearly varied from 1-5 days before January 1 to 1-5 days after that date, depending upon the size of the discontinuity. The 30-year hydrograph resulting from this process, and used in projection simulations, is shown in Figure 3-3a and b. It was assumed that the projection simulation began on January 1, 1999.

Addition of the synthetic hydrograph, for annual average discharge, to the historical data at Fort Edward is shown in Figure 3-4. The synthetic hydrograph appears to provide a realistic extension of the historical hydrograph, as was intended. Variations about the mean flow rate (5,200 cfs) during the 30-year projection period follow a pattern that is very similar to that observed during the 22-year historical record. Maximum daily average flow rates also follow a similar, realistic pattern during the 30-year projection period (Figure 3-5).

Tributary flow rates for the 30-year projection simulation were specified using the modified drainage area proration method described in Volume 2, Section 2.2.3. Flow rate data collected at the Kayaderosseras Creek and Hoosic River gauging stations were used to estimate tributary discharge. The synthetic hydrograph for each of these gauging stations corresponded to the synthetic time-series generated at Fort Edward, e.g., 1989 data were used to estimate tributary flows in year 1 (1999), 1981 data were used for year 2, and so on. Similar to the Fort Edward synthetic hydrograph, discontinuities at the yearly interfaces (December 31 and January 1) were linearly smoothed. The resulting hydrographs for Kayaderosseras Creek and the Hoosic River are shown in Figures 3-6a and b and 3-7a and b, respectively.

3.2 PREDICTION OF FUTURE SOLIDS LOADING

Sediment loading to the Upper Hudson River for the 30-year projection period was estimated using the rating curves and estimation methods discussed in Volume 2, Section 3.2.2. Composition of the incoming sediment load was assumed to have a 25% sand content at all flow rates, as was done in all calibration and validation simulations.

Annual sediment loading to the TIP, at the Fort Edward boundary and from the tributaries, during the 30-year projection period is compared to annual loads during the 22-year validation period (1977 through 1998) in Figure 3-8. The projection period loads varied realistically about the mean sediment load. Similar to the 22-year validation period, the range of annual loads for the 30-year projection ranged between about 50% and 200% of the mean annual load. Total annual average load to the Upper Hudson River was 7% lower for the 30-year simulation than that specified from the 22-year validation period.

A sediment mass balance on the Upper Hudson River over the 30-year projection period is presented in Figure 3-9. The total mass deposited in the TIP during the 30-year projection was 106,400 MT, which corresponds to a trapping efficiency of about 10%. As in the 22-year validation (Volume 2, Section 3.3.3), most (about 89%) of the deposition occurred in the cohesive bed areas (about 95,000 MT). The 30-year projected average sedimentation rate in the cohesive areas of the TIP was higher than during the 22-year validation period, increasing from 0.81 cm/yr to 0.92 cm/yr. This 14% increase in average sedimentation rate during the 30-year projection period is a relatively minor change in deposition rate. Sensitivity of deposition rate to variation in sediment loading during the projection period is discussed below. The projected trapping efficiencies for Reaches 1 to 7 were comparable to those calculated for the validation period. The overall trapping efficiency for the Upper Hudson River during the 30-year projection was approximately 21%, which is 4% higher than the validation trapping efficiency.

Sensitivity of the 30-year projection simulation to TIP sediment loading was also investigated. Similar to sensitivity analyses conducted on the 22-year validation period (for the PCB fate model), sediment loading to the TIP was decreased by adjusting rating curve exponents (see Volume 2, Section 3.4 and Table 3-10). This conservative adjustment produced a 11% decrease in the total TIP sediment load for the 30-year projection period.

3.3 IMPACTS OF RARE FLOOD EVENTS

Impacts of rare flood events on the 30-year projection results were investigated by incorporating a 100-year flood in the synthetic hydrograph for some simulations (see Section 9). Three different synthetic hydrographs were created with the inclusion of one 100-year flood during each 30-year period. We evaluated floods that would occur in 2006, 2013 or 2020. These years were chosen to represent near-, mid- and far-future. The earliest occurrence evaluated was 2006 because impacts of earlier floods could not be mitigated by remediation based on the remediation schedule presented in Section 5. The 100-year flood hydrograph, which was 9 days long, was inserted into the location of the first significant flood in the spring of the desired year. Linear smoothing of flow rates in the hydrograph after the end of the flood, for 2-4 days, was done to prevent significant discontinuities in the hydrograph. Insertion of 100-year flood hydrographs was done on all tributaries, as well as at Fort Edward. The modified synthetic hydrograph for Fort Edward with a 100-year flood occurring in 2006 is shown in Figure 3-10a and b.

The impact of a 100-year flood occurring in the year 2006 is presented on a mass balance basis in Figure 3-11. Although the total sediment load entering the TIP increased by 6% over the base case 30-year projection, the total mass deposited decreased by almost 7%. This corresponded to a 1.2% decrease in the 10% TIP trapping efficiency projected without the 100-year flood. The total sediment loading to the Upper Hudson River increased by 3.3% over the 30-year projection, while the overall trapping efficiency decreased by about 1.5%.

The sediment transport results for 100-year floods in the years 2013 and 2020 were very similar to the 2006 projection. Total sediment load to both the Upper Hudson River and the TIP for the three simulations were all within 1% of each other. Trapping efficiencies for the three simulations were also very close, as is shown in Table 3-2.

Table 3-2. Relative Impact of a 100-Year Flood Occurring in 2006, 2013, and 2020 During the 30-Year Projection.

		Base Case	2006 Flood	2013 Flood	2020 Flood
TIP	Total Sediment Load (MT)	1,074,300	1,138,700	1,139,200	1,143,200
	Total Deposition (MT)	106,400	99,100	99,000	98,300
	Trapping Efficiency (%)	10	8.8	8.8	8.7
UHR	Total Sediment Load (MT)	4,908,100	5,069,800	5,078,300	5,086,624
	Total Deposition (MT)	1,021,400	995,100	1,017,939	1,008,524
	Trapping Efficiency (%)	21	20	20	20

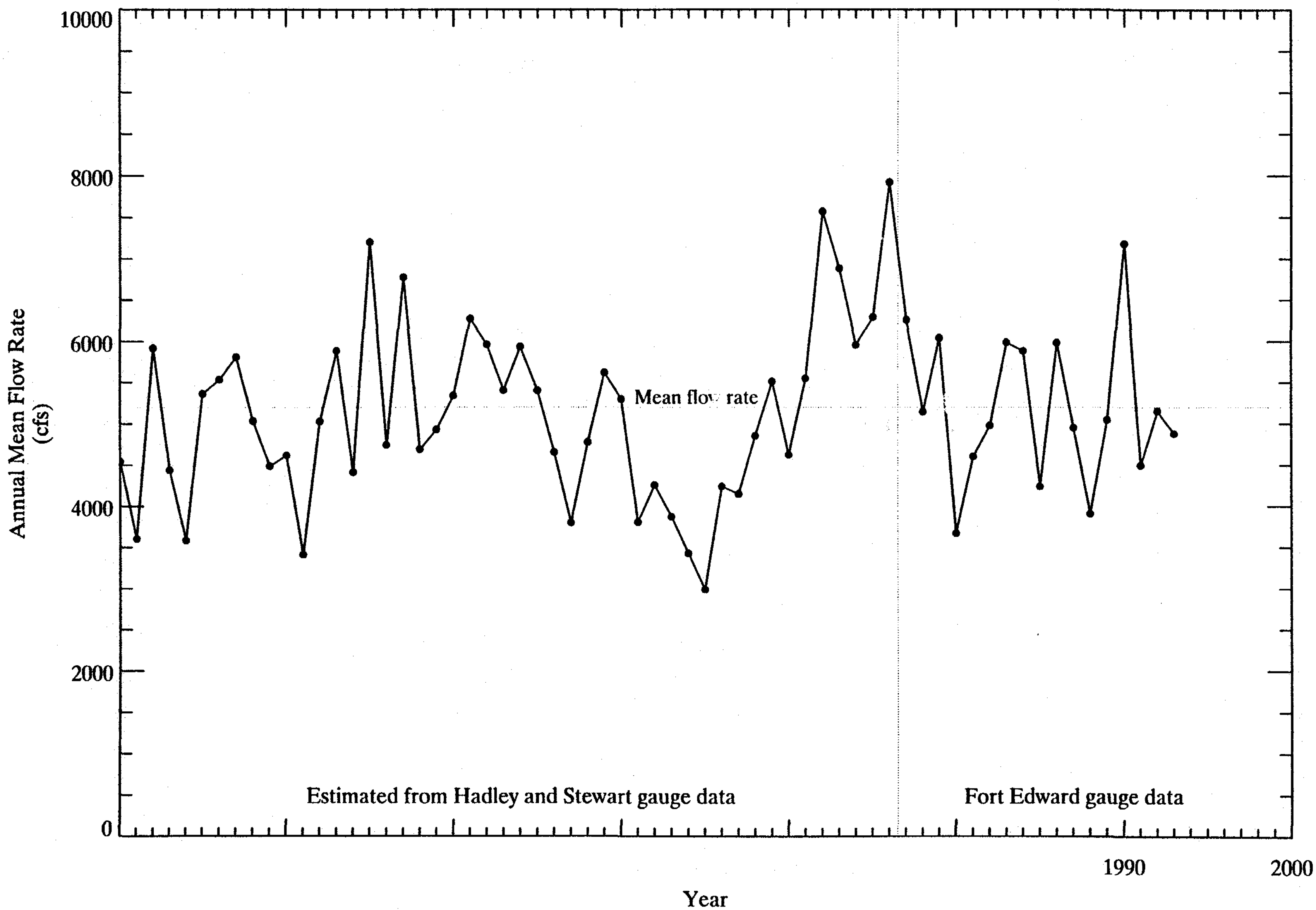

Figure 3-1. Annual mean flow rate at Fort Edward (1930 to 1993).

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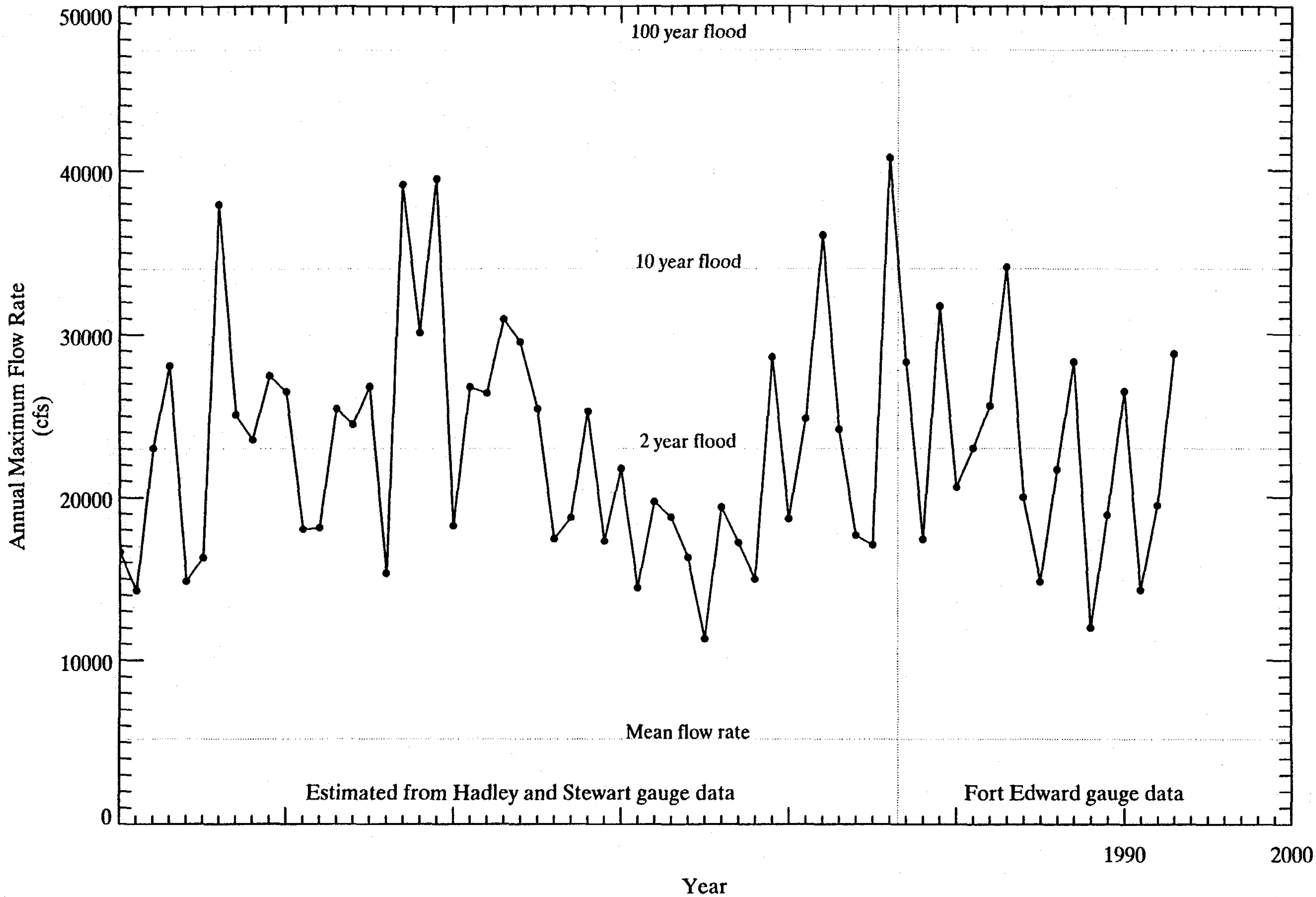

Figure 3-2. Annual maximum daily flow rate at Fort Edward (1930 to 1993).

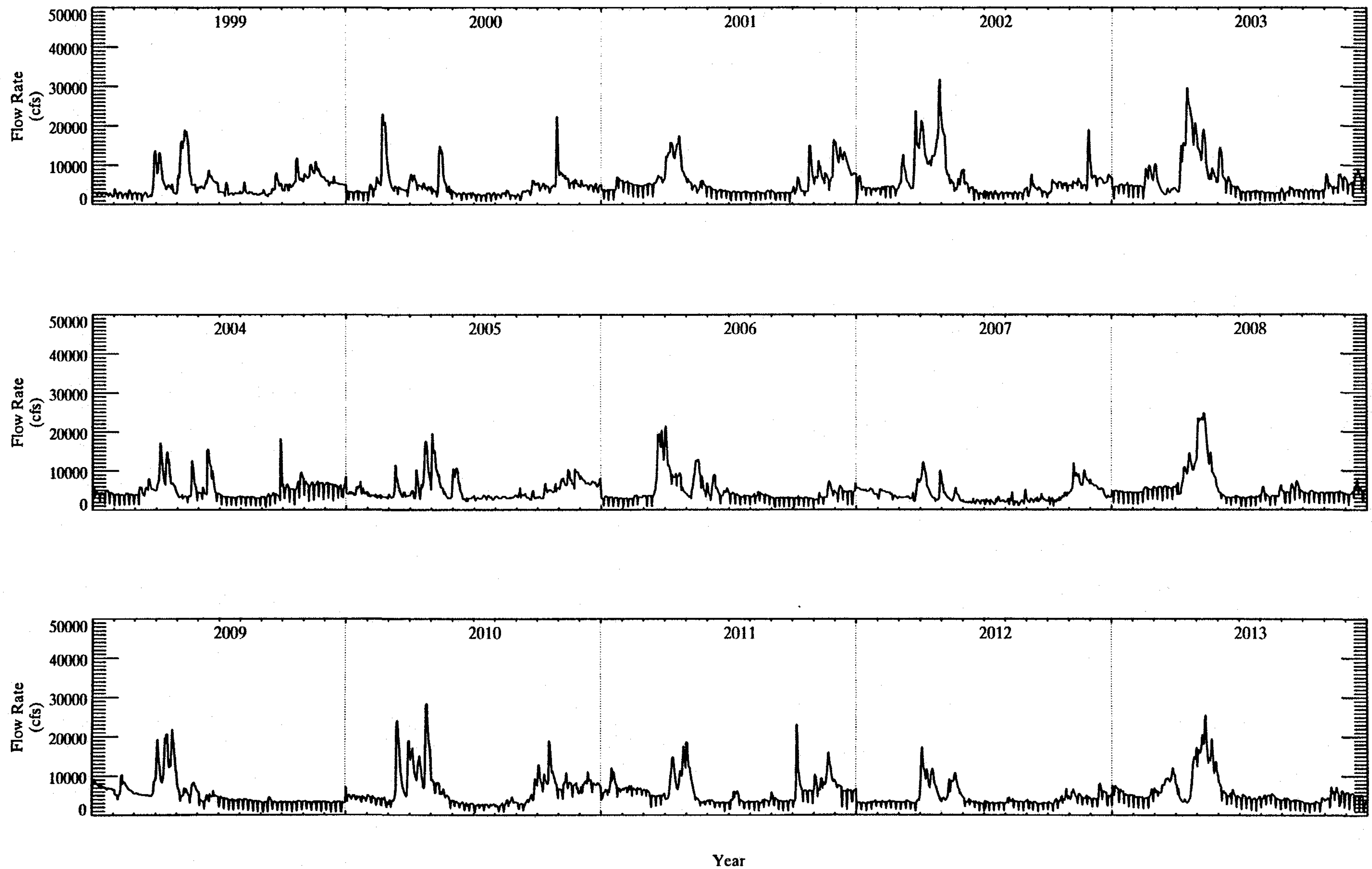

Figure 3-3a. Synthetic hydrograph at Fort Edward (30 years).

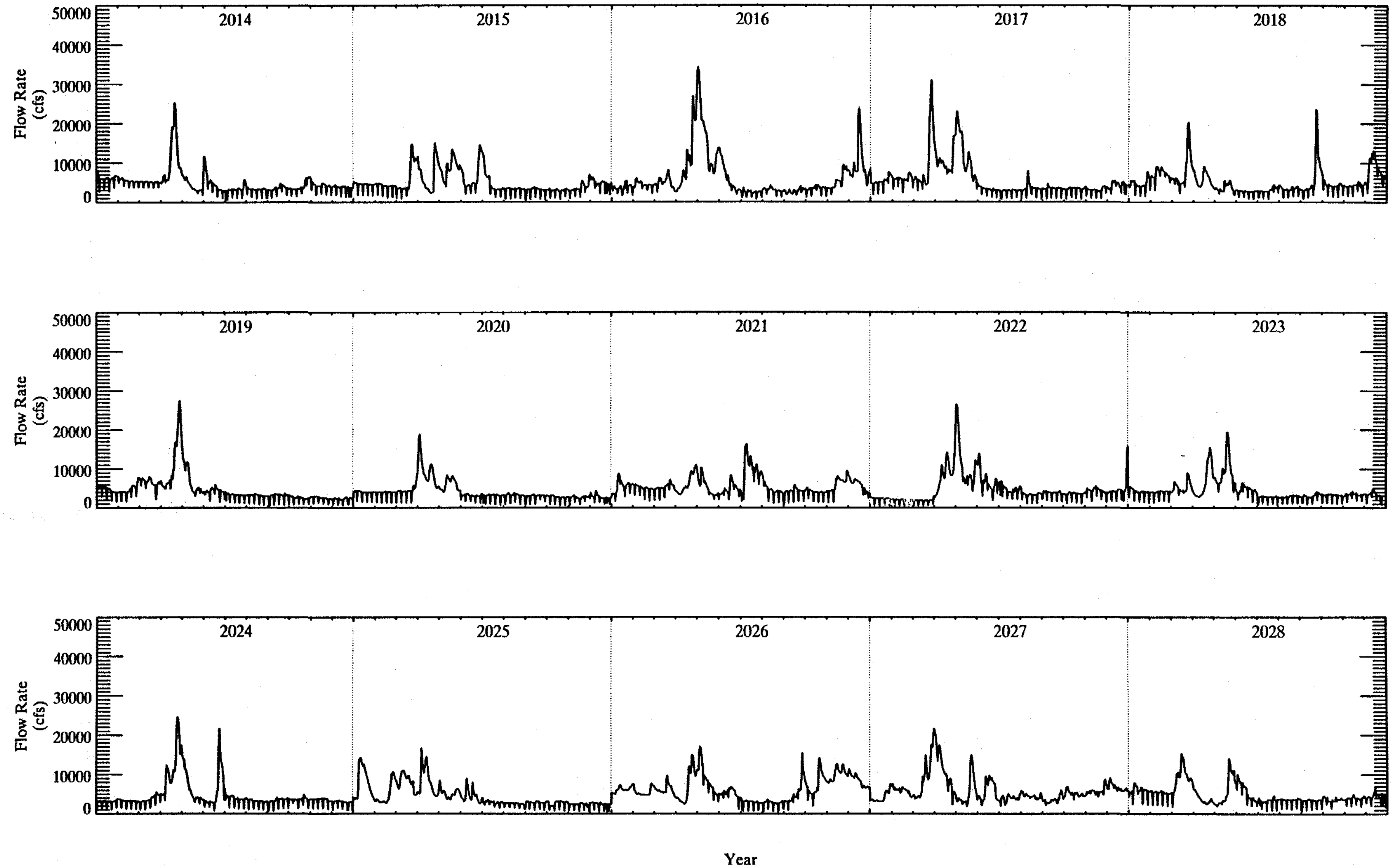

Figure 3-3b. Synthetic hydrograph at Fort Edward (30 years).

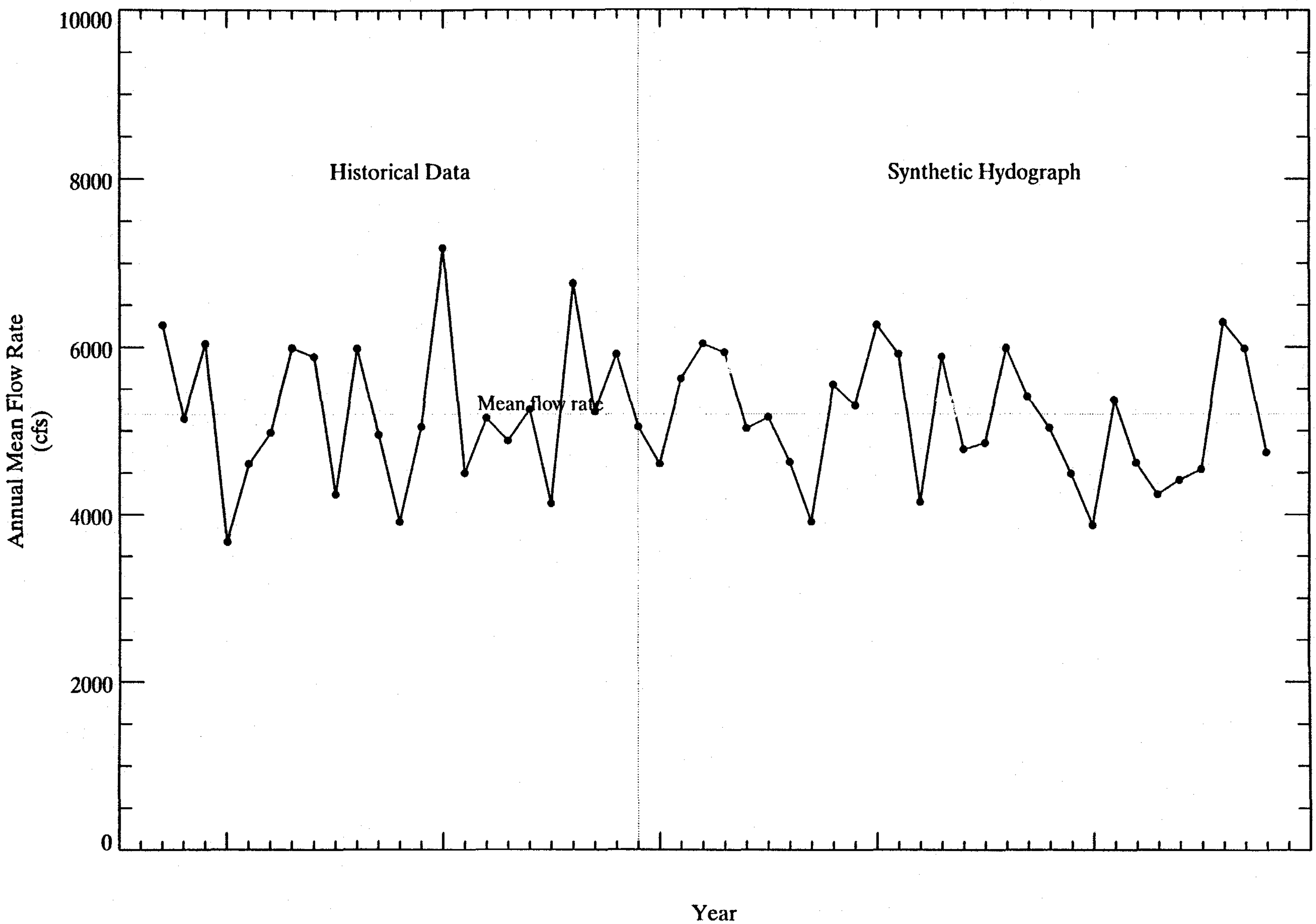

Figure 3-4. Annual mean flow rate at Fort Edward (1975 to 2028). The extended synthetic hydrograph begins in 1999.

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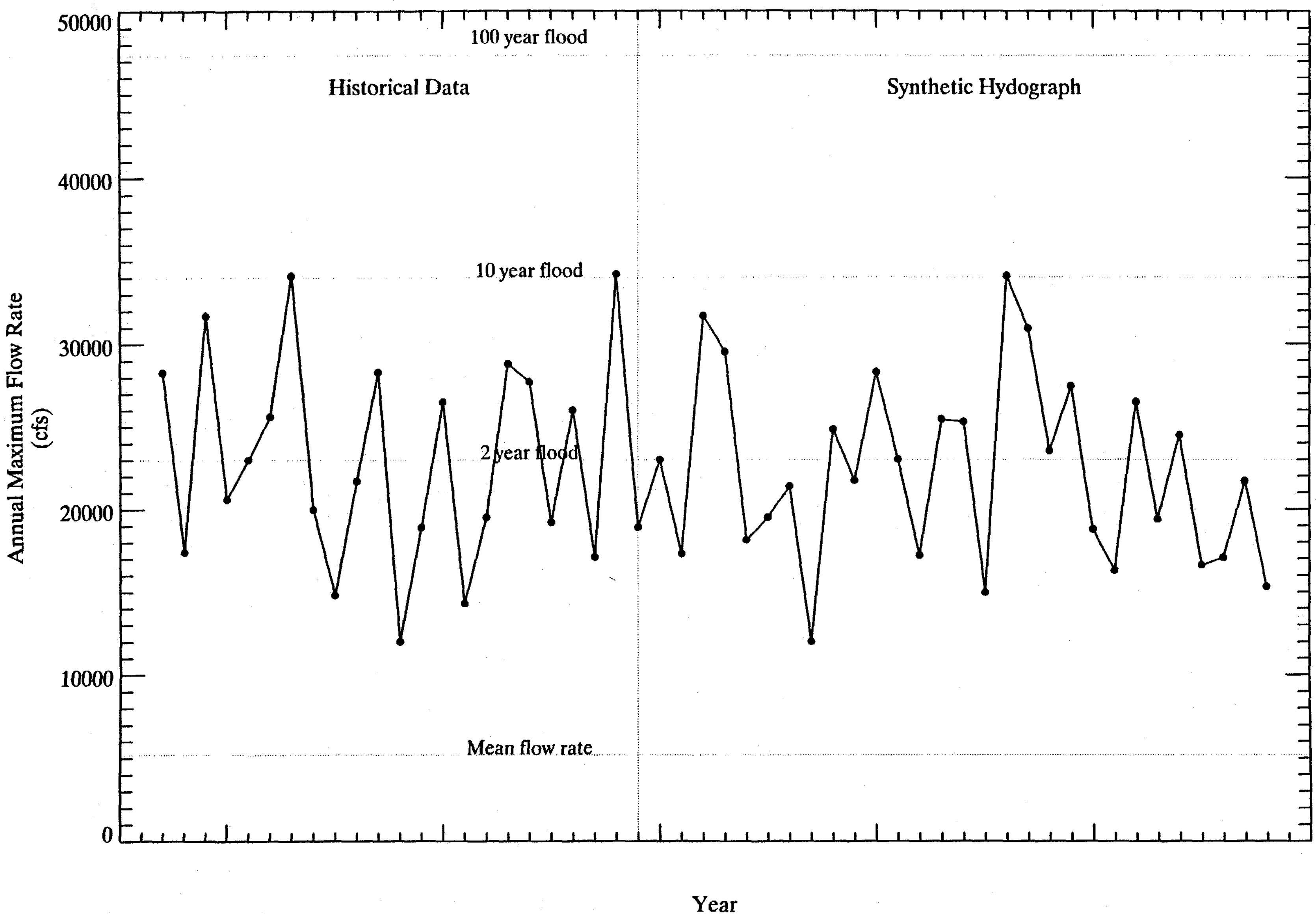

Figure 3-5. Annual maximum daily flow rate at Fort Edward (1975 to 2028). The extended synthetic hydrograph begins in 1999.

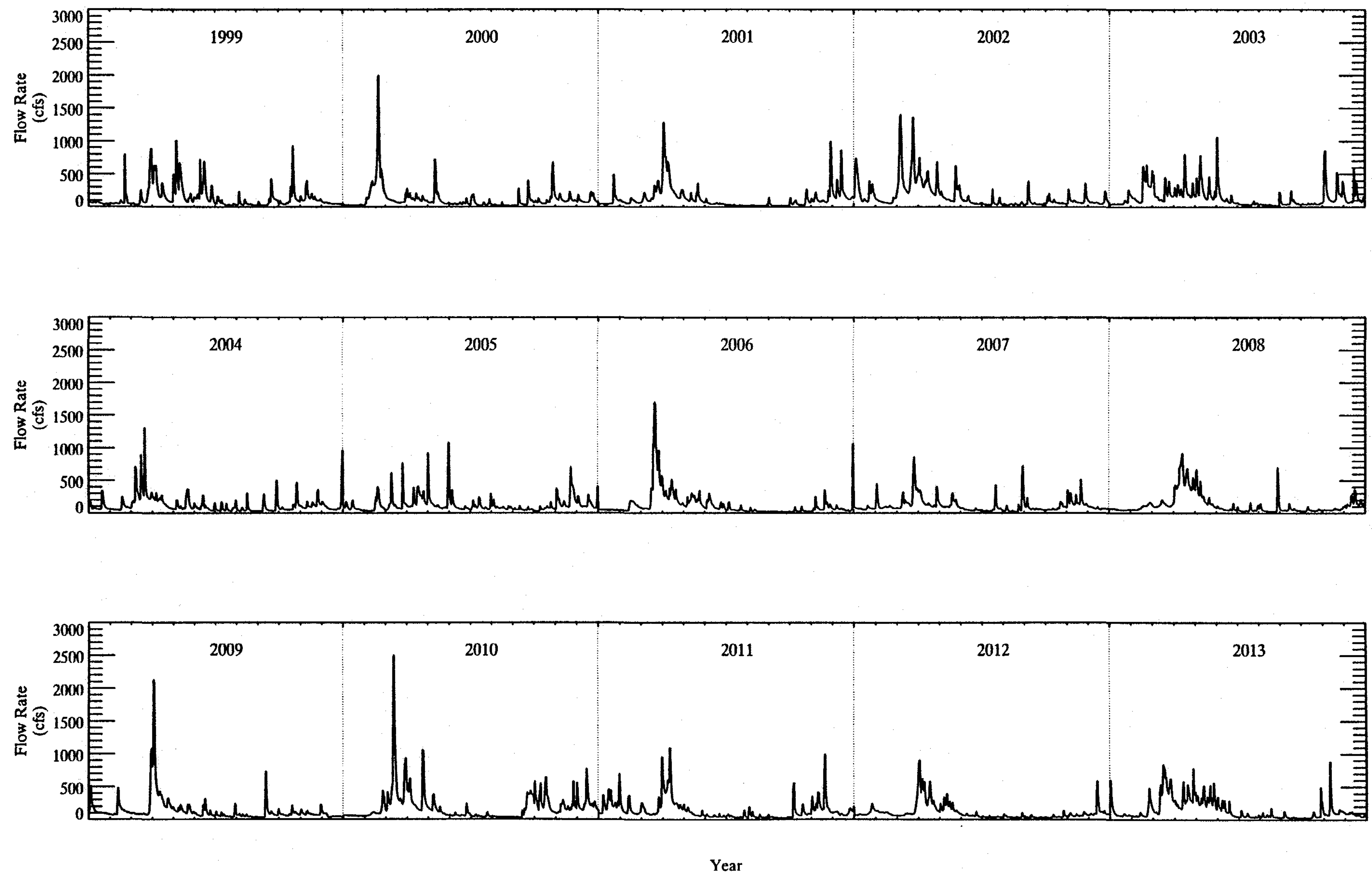

Figure 3-6a. Synthetic hydrograph at Kayaderosseras Creek (30 years).

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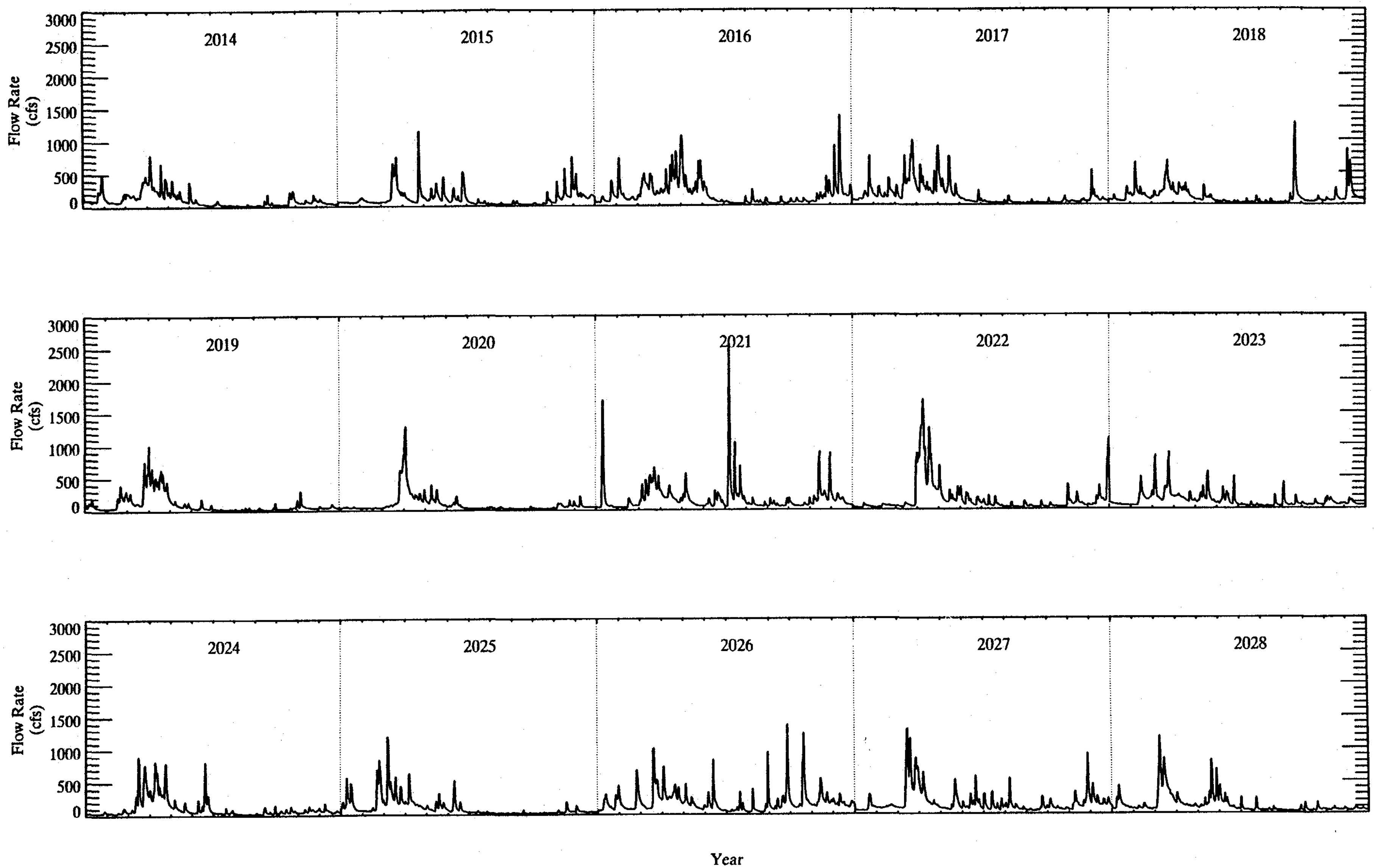

Figure 3-6b. Synthetic hydrograph at Kayaderosseras Creek (30 years).

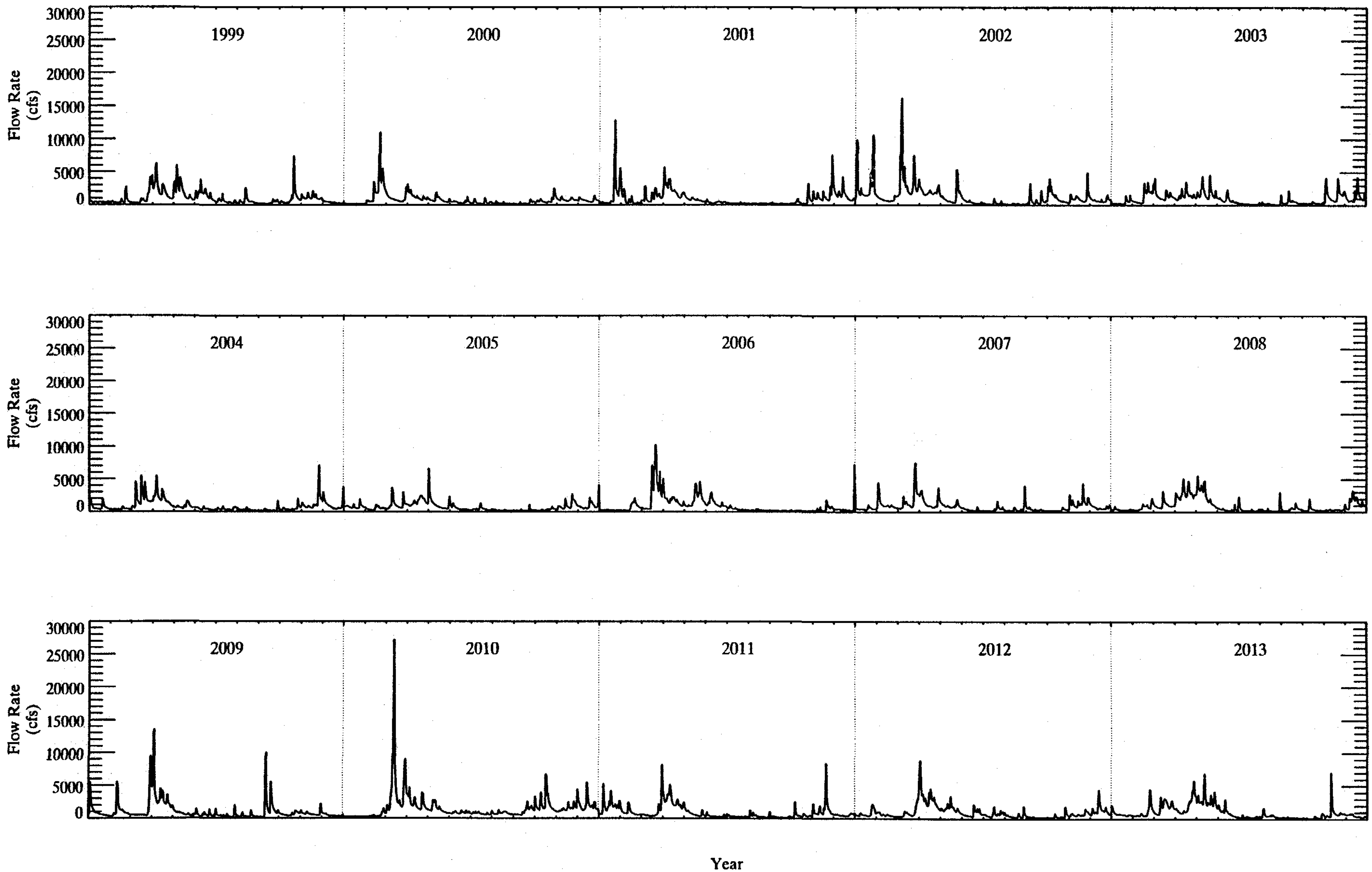

Figure 3-7a. Synthetic hydrograph at the Hoosic River (30 years).

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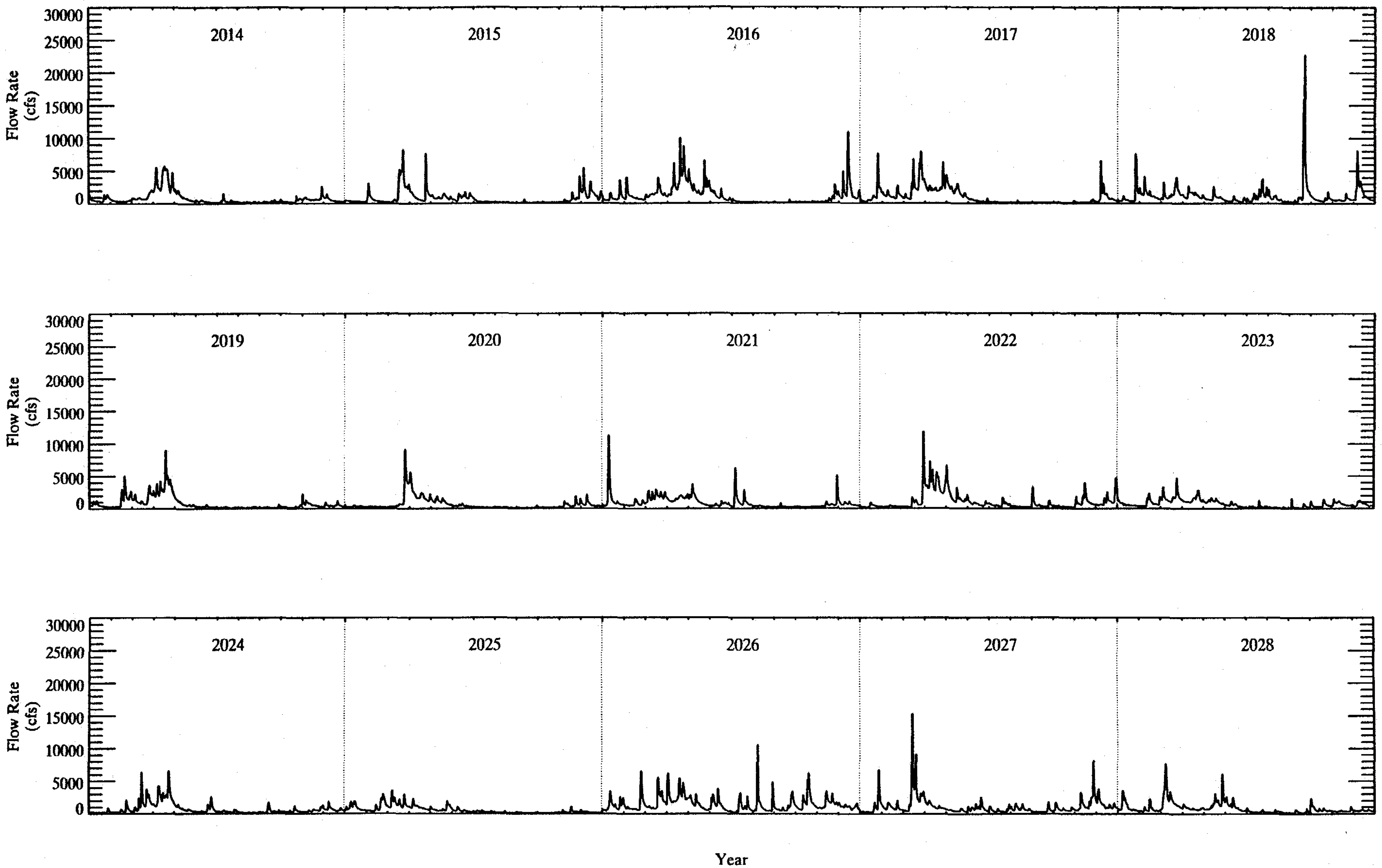

Figure 3-7b. Synthetic hydrograph at the Hoosic River (30 years).

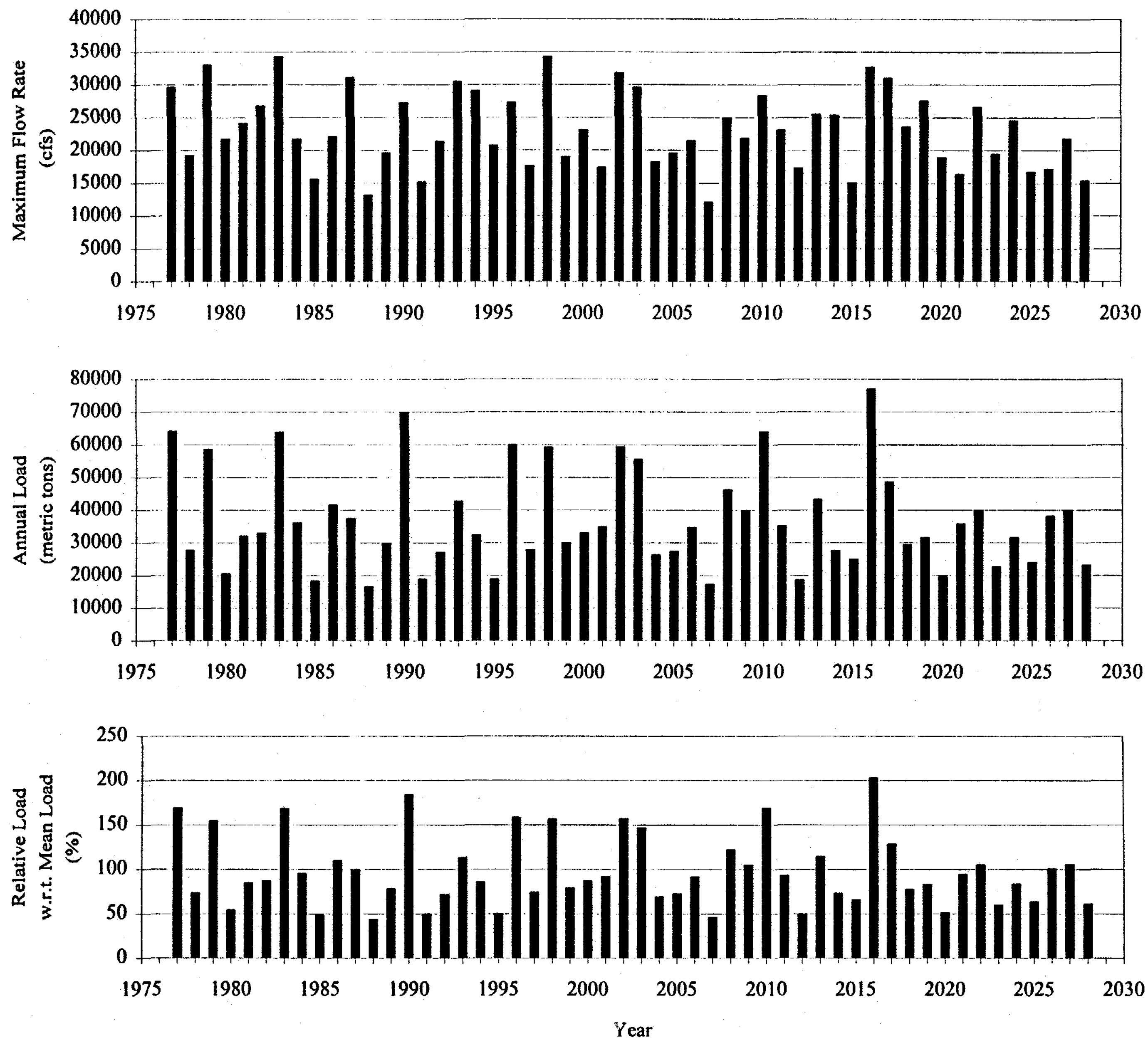

Figure 3-8. Maximum annual flow rate at Fort Edward, total TIP annual sediment load and relative annual sediment load for 1977 to 2028. Note that the synthetic hydrograph begins in 1999.

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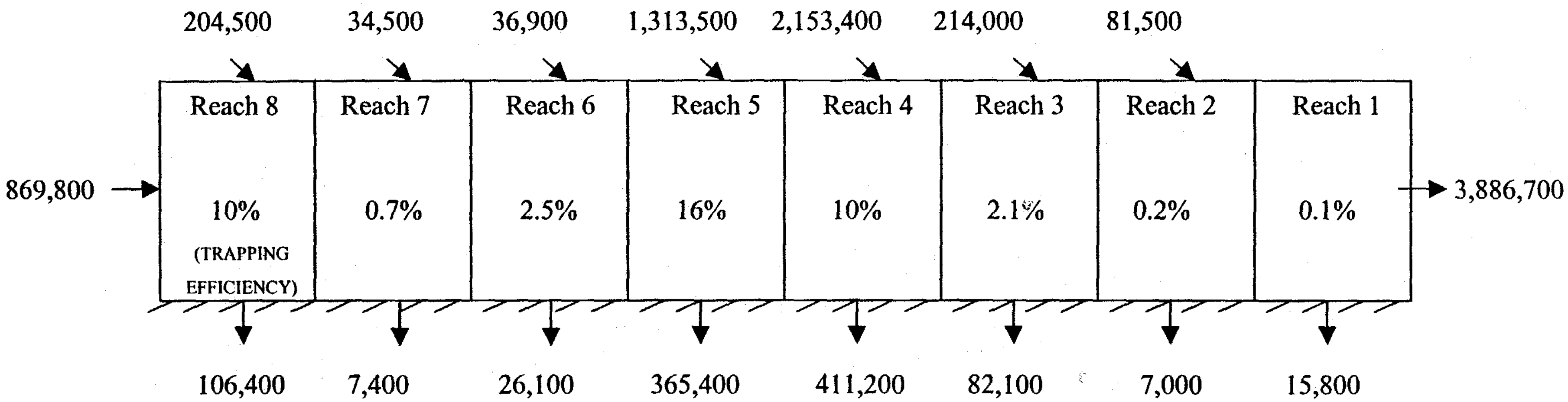

Figure 3-9. Sediment mass balance for the 30-year projection (1999-2028), Reaches 1-8. Sediment masses are in MT.

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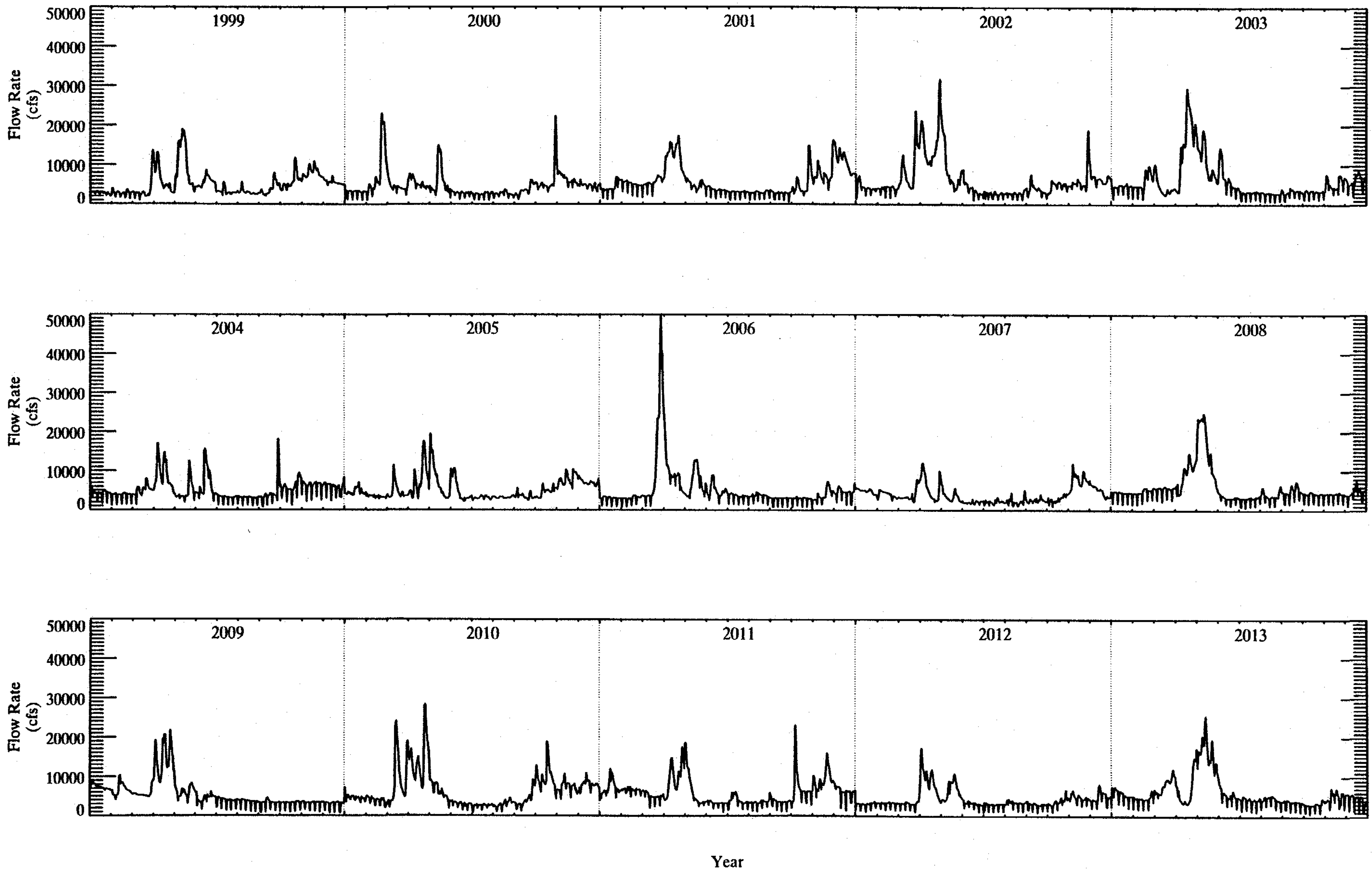

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Figure 3-10a. Synthetic hydrograph at Fort Edward with a 100-year flood occurring in 2006.

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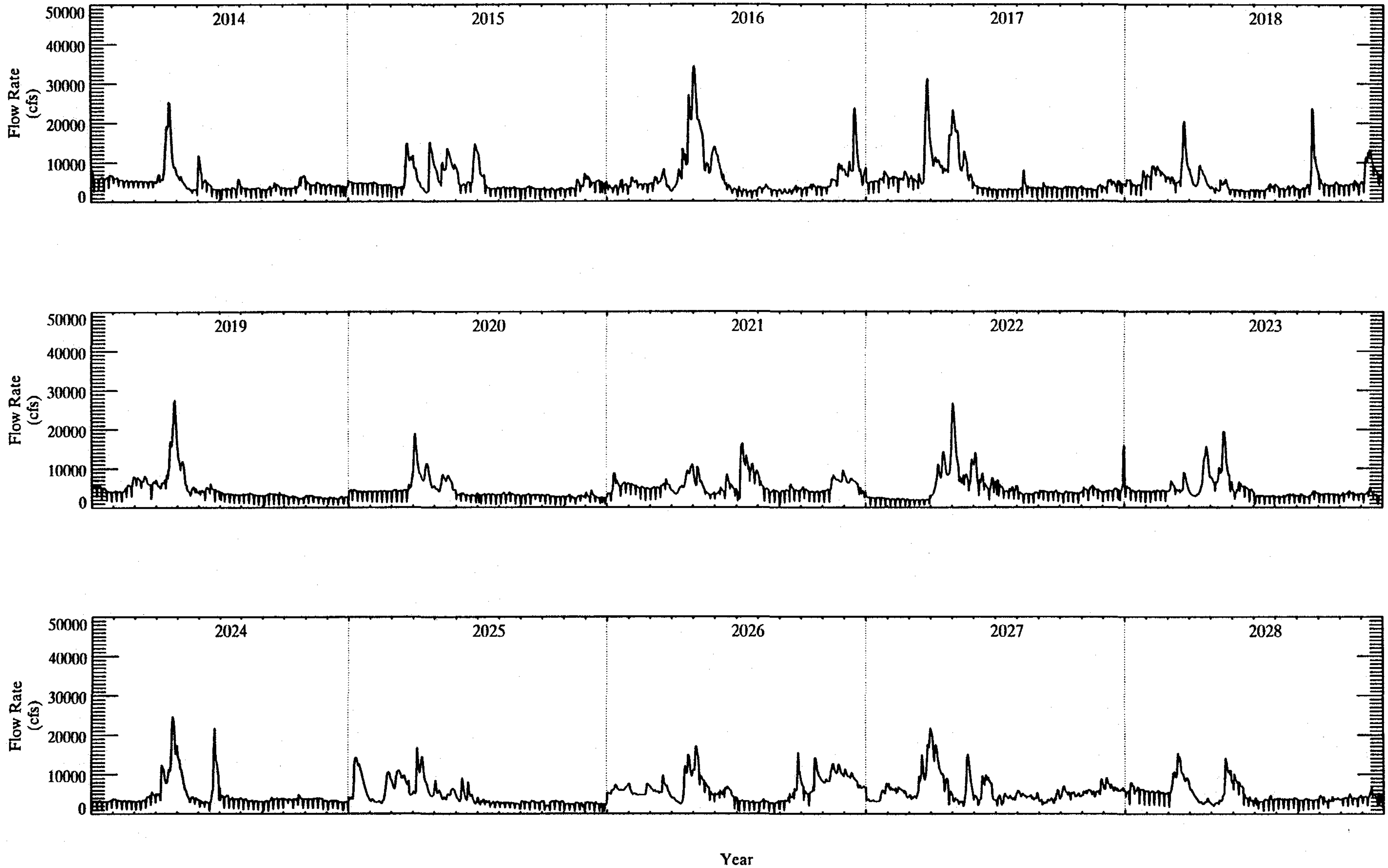

Figure 3-10b. Synthetic hydrograph at Fort Edward with a 100-year flood occurring in 2006.

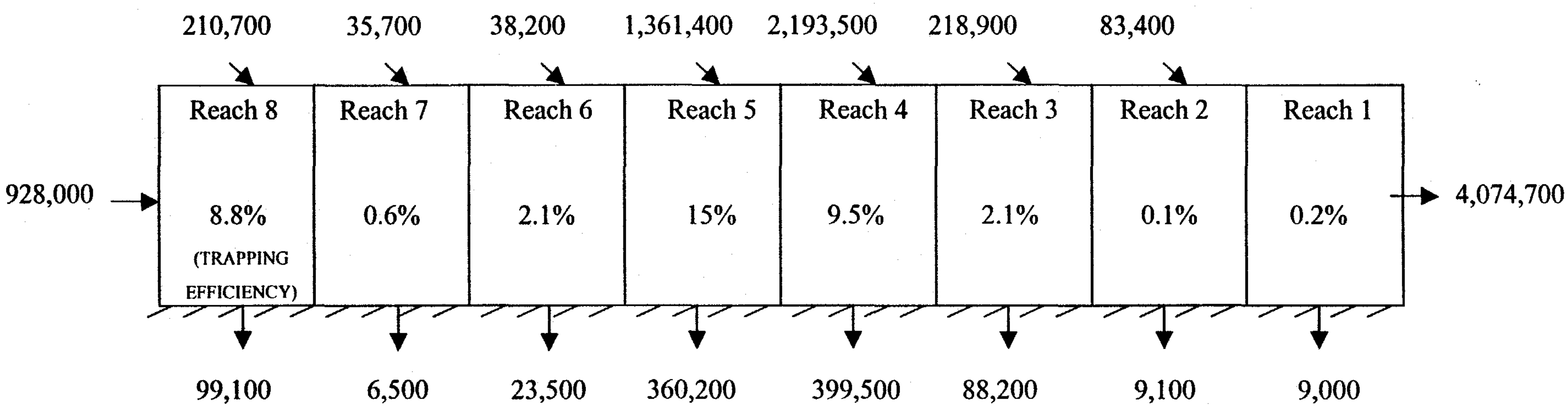

Figure 3-11. Sediment mass balance for the 30-year projection with a 100-year flood occurring in 2006. Sediment masses are in MT.

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Remedial Actions

Section 4

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SECTION 4
REMEDIAL ACTIONS

The USEPA Feasibility Study Scope of Work (USEPA, 1998) lists the following remedial scenarios which it may evaluate for the Upper Hudson River:

- Natural recovery or "No Action"
- Removal or isolation of all sediment in the Upper Hudson (Rogers Island to Federal Dam) with average PCB concentrations greater than 50 mg/kg;
- Removal or isolation of all sediment in the Upper Hudson with average PCB concentrations greater than 1 mg/kg;
- Removal or isolation of all sediment in the Upper Hudson with average PCB concentrations greater than the risk assessment-derived acceptable concentrations;
- Removal or isolation of all contaminated sediment in NYSDEC hot spots;
- Removal or isolation of all sediment with average inventories greater than 10 g/m^2 (mass of PCBs per unit area of sediments);
- Removal or isolation of all fine-grained sediment based on the side-scan sonar results (which extend to Lock 5) and removal of hot spot areas below Lock 5;
- Bank-to-bank dredging of the Thompson Island Pool (TIP) sediments;
- Bank-to-bank dredging of the TIP sediments and removal of NYSDEC hot spots below the TI Dam;
- Removal of contaminated sediments with average PCB concentrations greater than 10 mg/kg within 50 ft of shore and removal or isolation of sediments greater than 50 mg/kg for deeper locations; and
- Removal of all contaminated sediment associated with the proposed NYSDEC dredge locations as documented in Malcolm Pirnie, 1992.

EPA presently plans to evaluate these scenarios using the following benchmarks:

- Time to achieve a threshold fish tissue concentration (e.g., the FDA limit or an ecological threshold)
- Time to achieve water column concentrations conforming to ARAR-specified or risk assessment-derived levels

For both of these benchmarks, various locations within the river will be examined (e.g., TIP and Stillwater Pool).

The Upper Hudson River model provides the most accurate means of estimating the benchmarks. For the purposes of this report, we have evaluated a subset of the scenarios listed above supplemented by an evaluation of upstream source control. The subset was chosen to provide a contrast among natural recovery, sediment remediation and upstream source control. The remaining scenarios will be evaluated in an addendum to this report that will be issued in the near future.

The following base set of scenarios were evaluated:

- Natural recovery (assumes that upstream source control achieved over last 7 years remains in place)
- Eliminate the upstream PCB load
- Dredge cohesive sediments in Reaches 8, 7 and 6 (Rogers Island to Northumberland Dam)
- Dredge NYSDEC hot spots 1 to 35

The scenarios were evaluated with varying assumptions about the upstream PCB load, the residual PCB concentration remaining in sediments after dredging and the occurrence of a 100-year flood event. Regarding the upstream PCB load, a bounding estimate of 0.4 lb/d was used to evaluate natural recovery. The dredging scenarios assumed that the post-dredging sediment PCB concentration was either 1 ppm or 0. Neither of these levels is based on demonstrated technology. The 1 ppm level has been used at other sites as an action level or a remedial goal. The zero value represents the ideal case of complete elimination. The impact of a 100-year flood event on natural recovery was examined by simulating the occurrence of this event in the years 2006, 2013 and 2020. These years were chosen to represent near-, mid- and far-future. The earliest occurrence evaluated was 2006 because impacts of earlier floods could not be mitigated by remediation based on the remediation schedule presented in Section 5.

Remediation Methods and Schedule

Section 5

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SECTION 5
REMEDIATION METHODS AND SCHEDULE

5.1 REMEDIATION METHODS

5.1.1 Natural Recovery

This remedy allows natural processes to continue under specified conditions agreed to among the parties which could include monitoring and some form of institutional controls. To some extent "Natural Recovery" is a misnomer: considerable upstream source control has been achieved through GE's remedial actions since the reassessment began; this source control is assumed as part of the baseline conditions for all model predictions. Natural processes, principally associated with sediment transport from within the watershed and PCB fluxes at the sediment-water interface, result in a continual decline of surface sediment concentrations.

5.1.2 Upstream Source Control

Within the context of the model, upstream source refers to water borne PCBs entering the TIP as measured at the Fort Edward monitoring station. These PCBs originate predominately from sources associated with the GE Hudson Falls plant site and include riverbed PCB DNAPL seeps and contaminated ground water discharges to the river. GE has been involved in an extensive remedial program to eliminate these sources of PCB to the river, however, PCBs are still detected sometimes at the Fort Edward station. While various levels of future PCB loading from the Upstream Source area have been assumed, the actual loading level is uncertain due to the complexity of remediating PCB DNAPL from fractured bedrock adjacent to the Hudson River. Upstream source control, as represented in the model, consists of complete elimination of PCBs at the Fort Edward monitoring station at the start of model projections in 1999. This date was chosen because one cannot estimate whether or when further remediation or elimination of the upstream source may be possible.

5.1.3 Dredging

Development of a schedule for dredging and estimation of the post-dredging residual concentration are difficult because of the unprecedented nature of the scenarios proposed by USEPA. For example, the scenarios described below are roughly a factor of ten larger than any remedial dredging project implemented to-date. Nonetheless, we have used optimistic estimates of annual production rates in order to determine the probable maximum effectiveness of dredging alternatives. Accordingly, a more rigorous examination of feasibility should be conducted before a final determination of dredging effectiveness is rendered. Further, the evaluations presented here do not consider any negative environmental impacts that might result from a large-scale dredging program.

EPA's current schedule calls for issuance of the proposed plan in December 2000 with a final record of decision (ROD) in June 2001. Given the complexity of legal issues, design work, the government approval processes, contracting and mobilization, it is assumed that any large-scale dredging project would not begin before 2005.

Sediments would be dredged to a uniform depth of 3 feet, without re-placement with clean backfill. Prior to dredging, the areas to be dredged would be isolated by sheetpiling to preclude sediment transport downstream. Dredging was assumed to occur from May into October or November of each year, 5 days per week for 8-10 hours per day.

The average production rate of a dredge (cubic yards removed per hour) is difficult to forecast. It depends on the type and size of the dredge; the nature, depth and accessibility of the area being dredged; the cleanup level being targeted; the environmental controls imposed; and the ability of land-based processing units to keep pace with the water and solids generated by the dredge. Average production rates at other remedial dredging projects have ranged from as low as 5 yd^3/hr up to about 100 yd^3/hr. For the removal scenarios, average production rates of 40 yd^3/hr were assumed for the small dredges (Mud Cat type dredges) and 100 yd^3/hr for the larger dredges. Time delays from land-based processing (dewatering, drying, analyzing, trucking, etc.) have not been factored into the schedule.

We estimate that 85,000 to 150,000 yd^3 could be removed from the TIP each year. This optimistic estimate exceeds the 60,000 to 70,000 yd^3 used by USEPA in an early action assessment for the TIP (USEPA 1999). For the area downstream of the TIP, we estimate 110,000 to 200,000 yd^3/yr could be removed. The range in our estimation is due to assumptions regarding (1) the number of dredges operating simultaneously and (2) the size of each dredge (smaller dredges are assumed for the most-upstream reaches). We have assumed that dredging would occur in a more or less upstream to downstream direction. We have also assumed that targeted hot spots or cohesive sediment areas would be completed in the year they were started (with one exception; see Table 5-1). The level of effort and projected finish date varies somewhat from year to year. As shown in Table 5-1, we project 9 years to dredge NYSDEC hot spots 1 to 35 and 12 years to dredge the cohesive sediments.

Table 5-1. Assumed Schedule for Sediment Removal

Year	Historical NYSDEC Hot Spots Removed in a Hot Spot Dredging Program		Volume (yd^3) of Sediment Removed in a Cohesive Sediment Dredging Program
	Hot Spots	Volume (yd^3)	
2005	1-5	85,621	111,583
2006	6-7	148,511	95,545
2007	8	158,736	121,015
2008	9-13, one-half 14	112,899	99,647
2009	14, 16	107,663	160,856
2010	15, 17-20	75,541	109,439
2011	21-27, 29-30	109,551	96,805
2012	28, 31-33, 35	208,937	139,299
2013	34	115,464	132,675
2014			116,415
2015			116,415
2016			133,109

Section 6

Natural Recovery

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SECTION 6
NATURAL RECOVERY

Cohesive sediments have higher PCB_{3+} concentrations and a higher rate of natural recovery than non-cohesive sediments. In 1977, the average concentration within the TIP surface sediments was four times higher in cohesive sediments than in non-cohesive sediments (105 versus 28 ppm). By 1998, this difference had been reduced to a factor of two (15 versus 7.5 ppm). The prediction of future conditions in these sediments (Figure 6-1a and b) indicates that PCB_{3+} concentrations would be about equal by 2005. After this time, non-cohesive sediments may contain slightly higher PCB_{3+} concentrations (2 versus 1 ppm).

The rate of recovery in both cohesive and non-cohesive sediment would decline over time as a dynamic steady state, at an upstream loading of 0.2 lb/d, is approached. The steady-state concentration is about 0.5 ppm in cohesive sediments and about 1 ppm in non-cohesive sediments.

TIP cohesive sediments would reach 2 ppm by 2015 and by 2029 would be about 1ppm. The estimated uncertainty based on the bounding model is such that the concentration in 2015 could be as high as 4 ppm and reach 2 ppm by 2029. The non-cohesive sediments have a much smaller relative uncertainty that does not appreciably affect the time at which particular concentrations would be reached. Non-cohesive sediments would decline to 2 ppm by 2028 or 2029.

The PCB_{3+} load past Waterford is variable in nature, being dependent on river hydrology and sediment dynamics. Overall, PCB_{3+} fluxes past Waterford are projected to decline from about 300 lb/yr to 90 lb/yr (Figure 6-1c). When the Upper Hudson River sediments (primarily non-cohesive sediments) achieve dynamic steady state with the water, the load past Waterford would be approximately equal to the upstream load (73 lb/yr) minus small volatilization and burial losses. The relative uncertainty in flux past Waterford is small and does not increase significantly by the end of simulation. The relative uncertainty does tend to increase during years of higher loading. This is most likely due to the increased contribution of cohesive sediments to water column fluxes during high flow resuspension events.

Natural recovery within the river would result in a continual decline in average largemouth bass PCB concentrations in the TIP and Stillwater. The model projects that, in the TIP, largemouth bass tissue PCB levels would decline by about a factor of two within 7 years and reach 2 ppm in about 2010. By 2029, largemouth bass tissue PCBs would decline to about 0.9 ppm (Figure 6-2). In Stillwater, PCB concentrations in largemouth bass would reach 2 ppm about the year 2000 and exhibit a slower decline thereafter. The continuing decline results in largemouth bass tissue PCB concentrations in 2029 of about 0.4 ppm. The bounding model estimates largemouth bass PCB levels that are higher on average by about 1 ppm at the TIP and 0.5 ppm at Stillwater, thus extending the times required to reach 2 ppm. Results of the bounding projections suggest PCB levels in largemouth bass may reach 2 ppm in 2023 and 2004 for TIP and Stillwater, respectively.

There is a degree of uncertainty associated with the estimation of the upstream loading. Figure 6-3 shows the natural recovery of the system at an alternative upstream loading of 0.4 lb/d. The effect of a higher upstream loading is a reduction in the recovery rates of both cohesive and non-cohesive sediments. Cohesive sediments (Figure 6-3a) would reach 2 ppm by 2018, three years later than if the upstream source were 0.2 lb/d. By the end of the simulation, TIP cohesive sediment PCB_{3+} would be about 1.5 ppm (bounding estimate at 2.5 ppm) and would decline thereafter towards steady-state of about 1 ppm. The upstream source would have a greater impact on the recovery of non-cohesive sediments (Figure 6-3b). Upstream loading at 0.4 lb/d would result in sediment concentrations at 2.5 ppm by 2029, eight years later than the 0.2 lb/d scenario would achieve the same concentration. The PCB_{3+} loading past Waterford (Figure 6-3c) would exhibit the same temporal behavior for both upstream loading scenarios. The higher loading would result in an increase of about 40-50 lb/yr in the loading past Waterford.

PCBs in the TIP and Stillwater largemouth bass originate from both the water column and sediment. Thus, increased PCB loadings from upstream sources would result in higher PCB levels in largemouth bass throughout the Upper Hudson River as well as extend the time required for these fish to reach 2 ppm. For example, an increase in upstream PCB loadings from 0.2 to 0.4 lbs/day would result in a 40 percent increase on average in largemouth bass PCB levels at both TIP and Stillwater (Figure 6-4). Under these conditions, largemouth bass in TIP would require an additional 7 years to reach 2 ppm (2017 versus 2010). Because average PCB concentrations in largemouth bass in Stillwater are about 2 ppm at the beginning of the simulation, variations in the upstream loading would have no effect on the time to reach this level at that location.

The bounding calculation suggests that increased PCB loadings from upstream would extend the time required for largemouth bass in the TIP to reach 2 ppm to beyond 2029. Largemouth bass at Stillwater would reach 2 ppm in 2009, rather than in 2004 if the PCB loading remained at 0.2 lb/d (Figure 6-4).

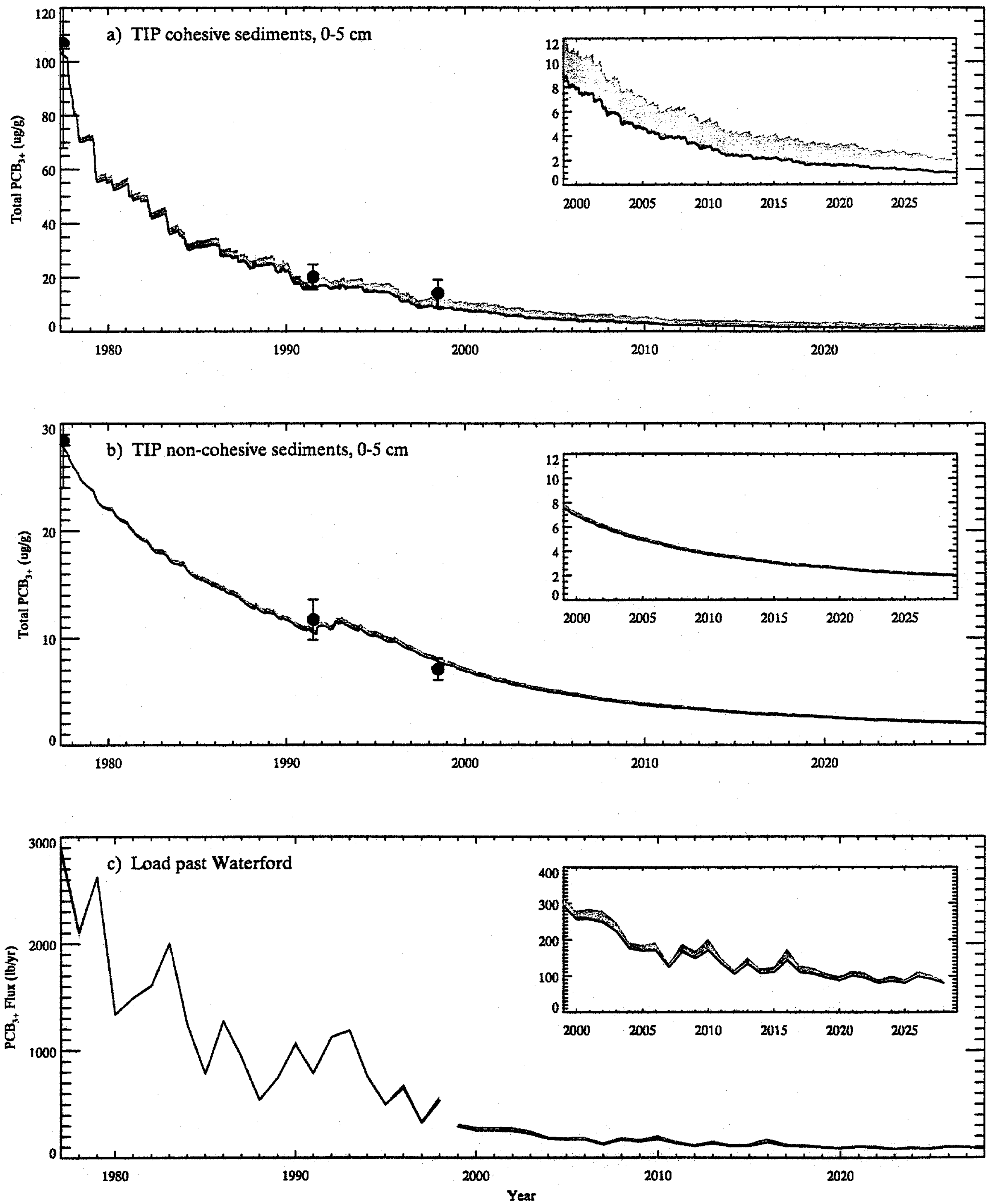
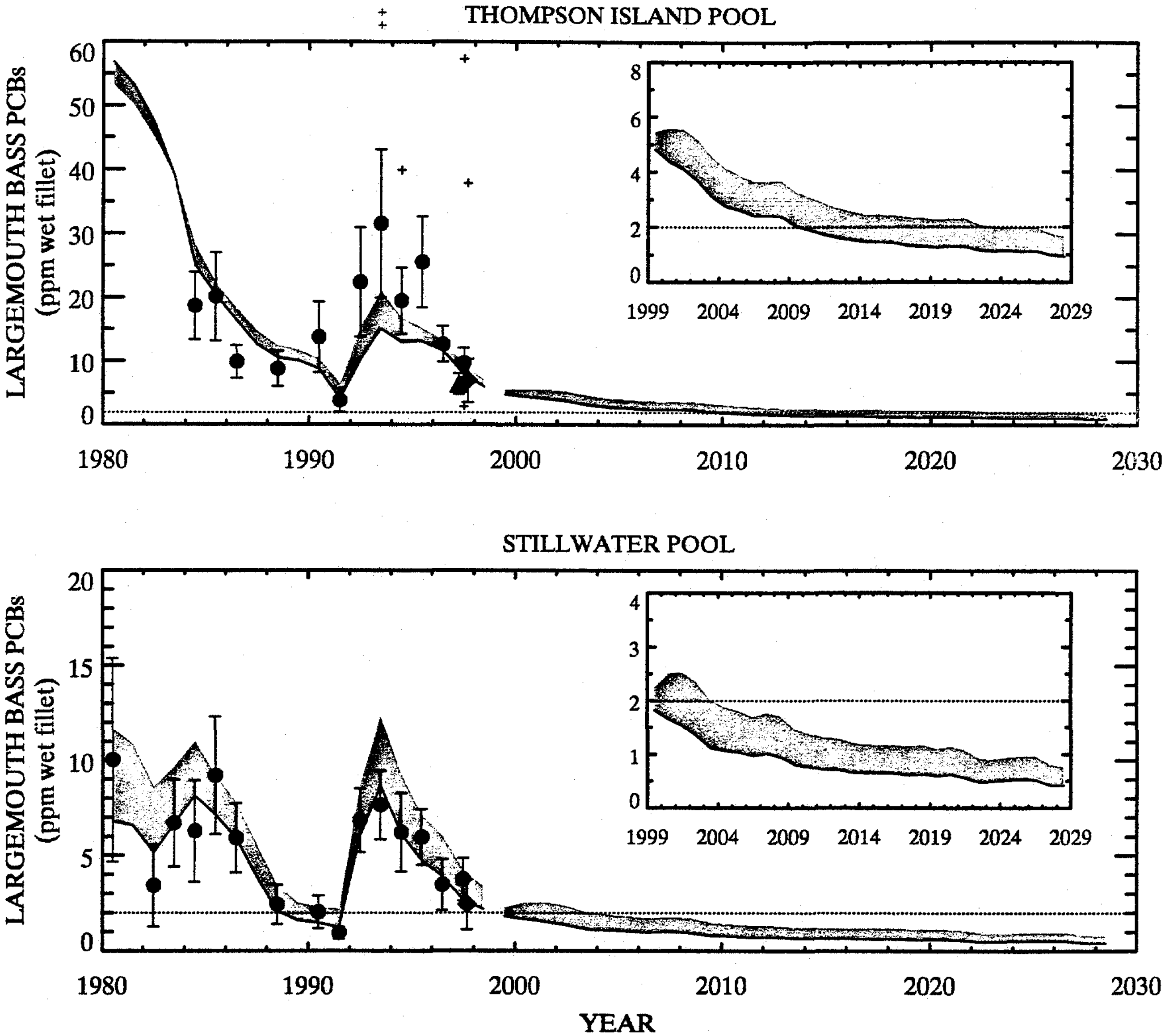


Figure 6-1. Predicted PCB_{3+} concentrations in TIP surface sediments and annual PCB_{3+} load passing Waterford to the Lower Hudson River over the time period from 1977 to 2029 under natural recovery.



Dotted line at 2 ppm represents FDA Tolerance Limit
Circles = NYSDEC
Triangles = Exponent
Diamonds = GE
Crosses indicate values excluded from the annual averages.

Figure 6-2. Predicted PCB_{3+} concentrations in TIP and Stillwater largemouth bass over the time period from 1980 to 2029 under natural recovery.

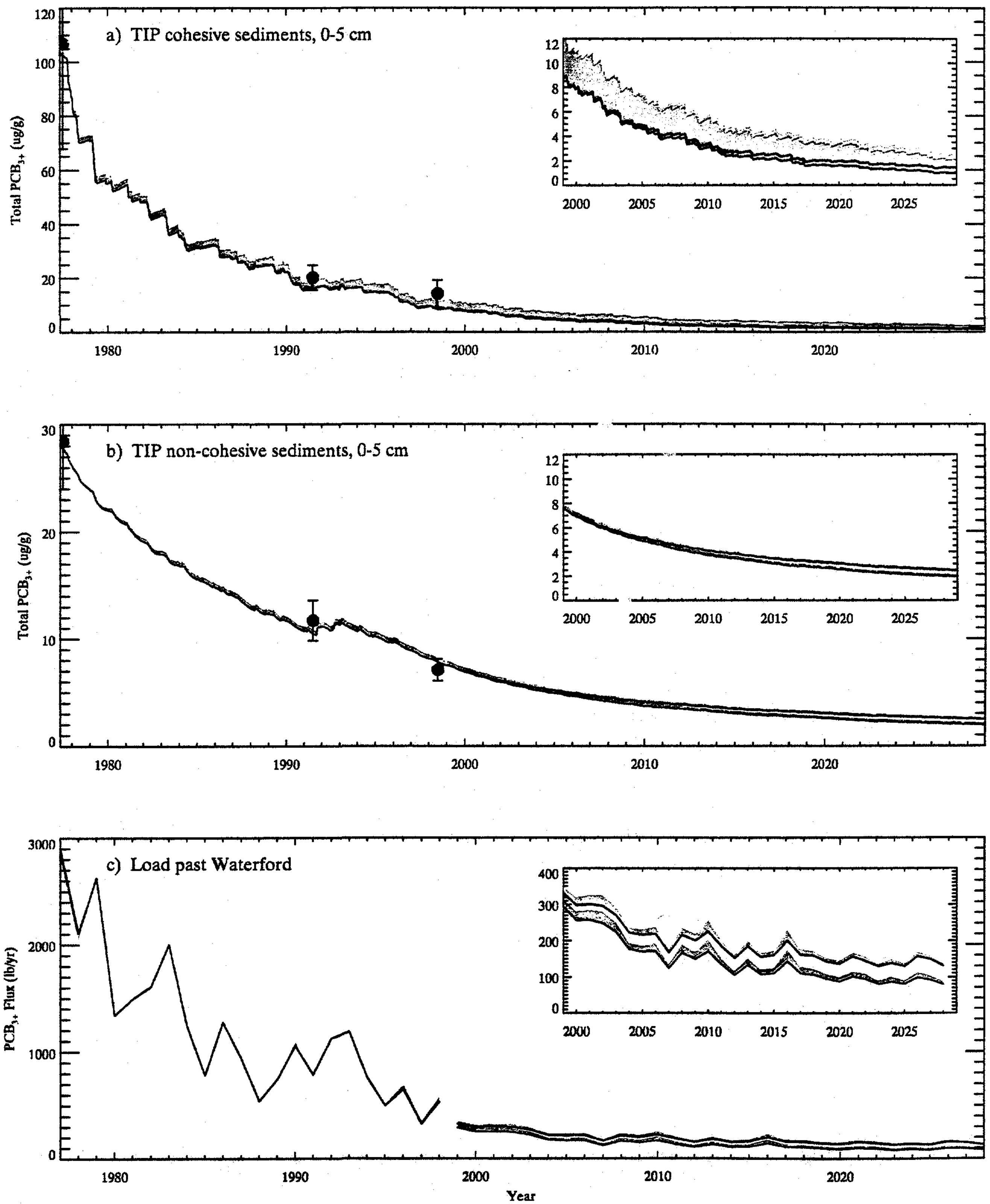
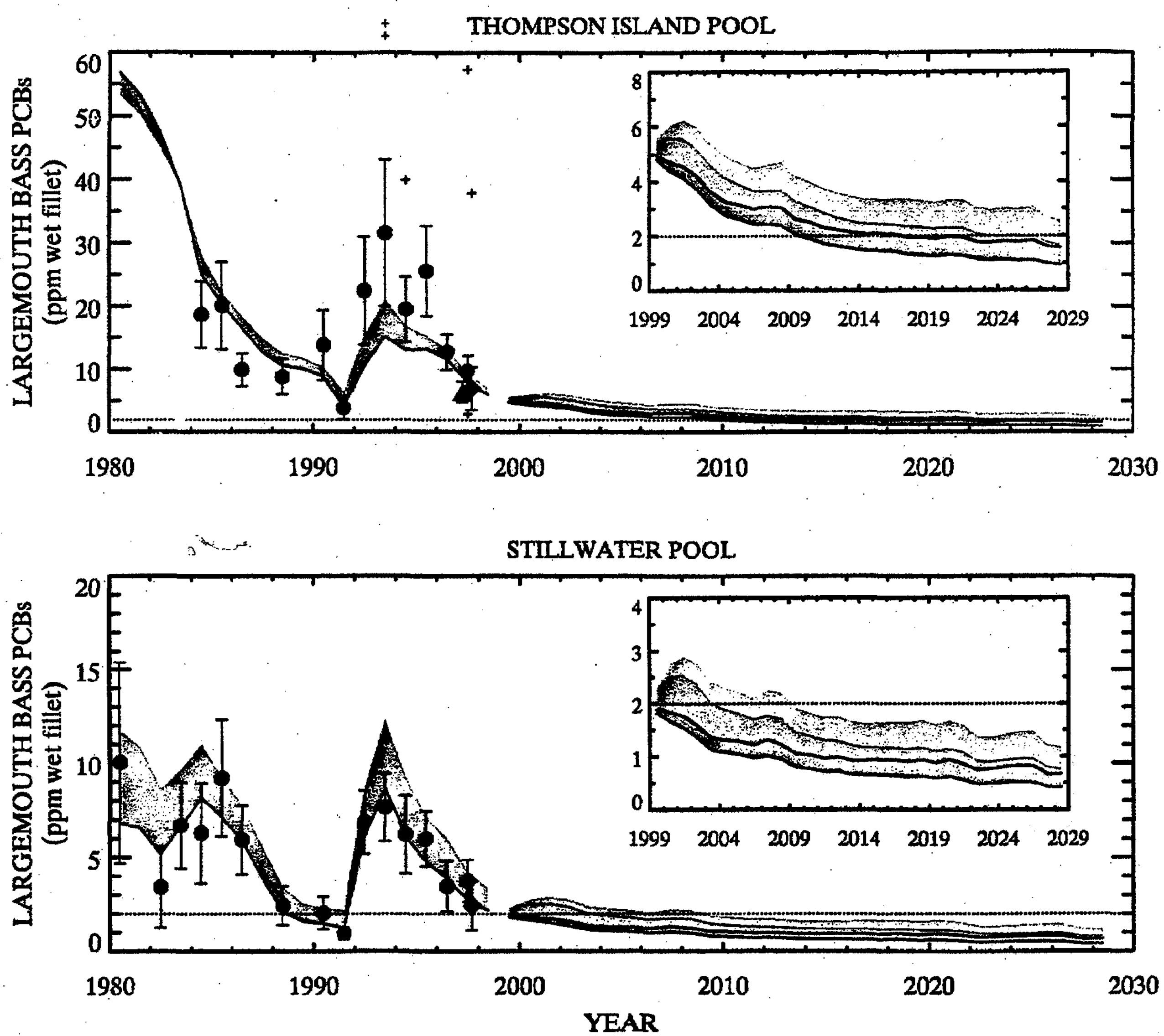


Figure 6-3. Predicted PCB_{3+} concentrations in TIP surface sediments and annual PCB_{3+} load passing Waterford to the Lower Hudson River over the time period from 1977 to 2029 for both natural recovery (line and abutting blue shading) and an elevated upstream source from 1999 to 2029 of 0.4 lb/d (line and abutting orange shading).



Dotted line at 2 ppm represents FDA Tolerance Limit
Circles = NYSDEC
Triangles = Exponent
Diamonds = GE
Crosses indicate values excluded from the annual averages.

Figure 6-4. Predicted PCB_{3+} concentrations in TIP and Stillwater largemouth bass over the time period from 1980 to 2029 for both natural recovery (line and abutting blue shading) and an elevated upstream source from 1999 to 2029 of 0.4 lb/d (line and abutting orange shading).

Section 7

Upstream Source Control

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SECTION 7
UPSTREAM SOURCE CONTROL

In the Natural Recovery scenario, we used 0.2 and 0.4 lb/d estimates of upstream PCB loading. Upstream source control assumes a 0.0 lb/d loading; it increases the recovery rate in the river as shown in (Figure 7-1). TIP cohesive sediments would reach 2 ppm PCB_{3+} by 2012 (Figure 7-1a), three years earlier than under natural recovery. By 2029, concentrations would be reduced by about a factor of two (0.5 versus 1 ppm). Non-cohesive sediments would have a greater acceleration of recovery, reaching 2 ppm eight years earlier than is estimated under natural recovery. Despite the greater benefit in non-cohesive sediments, the recovery rate would be greater in cohesive sediments that decline with a half-life of about 6 years in contrast to a half-life of 11 years in non-cohesive sediments. Full source control would reduce the annual PCB_{3+} load past Waterford by about 40 lbs initially increasing to about 50 lbs by 2029 as the load approaches the steady-state condition of 0 lb/yr (Figure 7-1c).

Upstream source control would accelerate the decline of fish PCB levels throughout the Upper Hudson River (Figure 7-2). In the TIP, average PCB concentrations in largemouth bass would decline with a half-life of about 5 years to about 2.2 ppm in 2004. The elimination of upstream PCB sources would permit largemouth bass in TIP to reach 2 ppm in about 2006, approximately 4 years sooner than without upstream source control. By 2029, predicted PCB concentrations are about a factor of three lower than levels achieved through natural recovery (0.3 versus 0.9 ppm). Reductions in largemouth bass tissue PCB concentrations at Stillwater would be similar; PCB levels would decline with a half-life of about 5 years. The control of upstream sources would result in about a factor of 2.5 reduction in largemouth bass PCBs by 2029. Bounding calculations indicate times to reach 2 ppm may extend to 2002 in Stillwater and 2011 in the TIP.

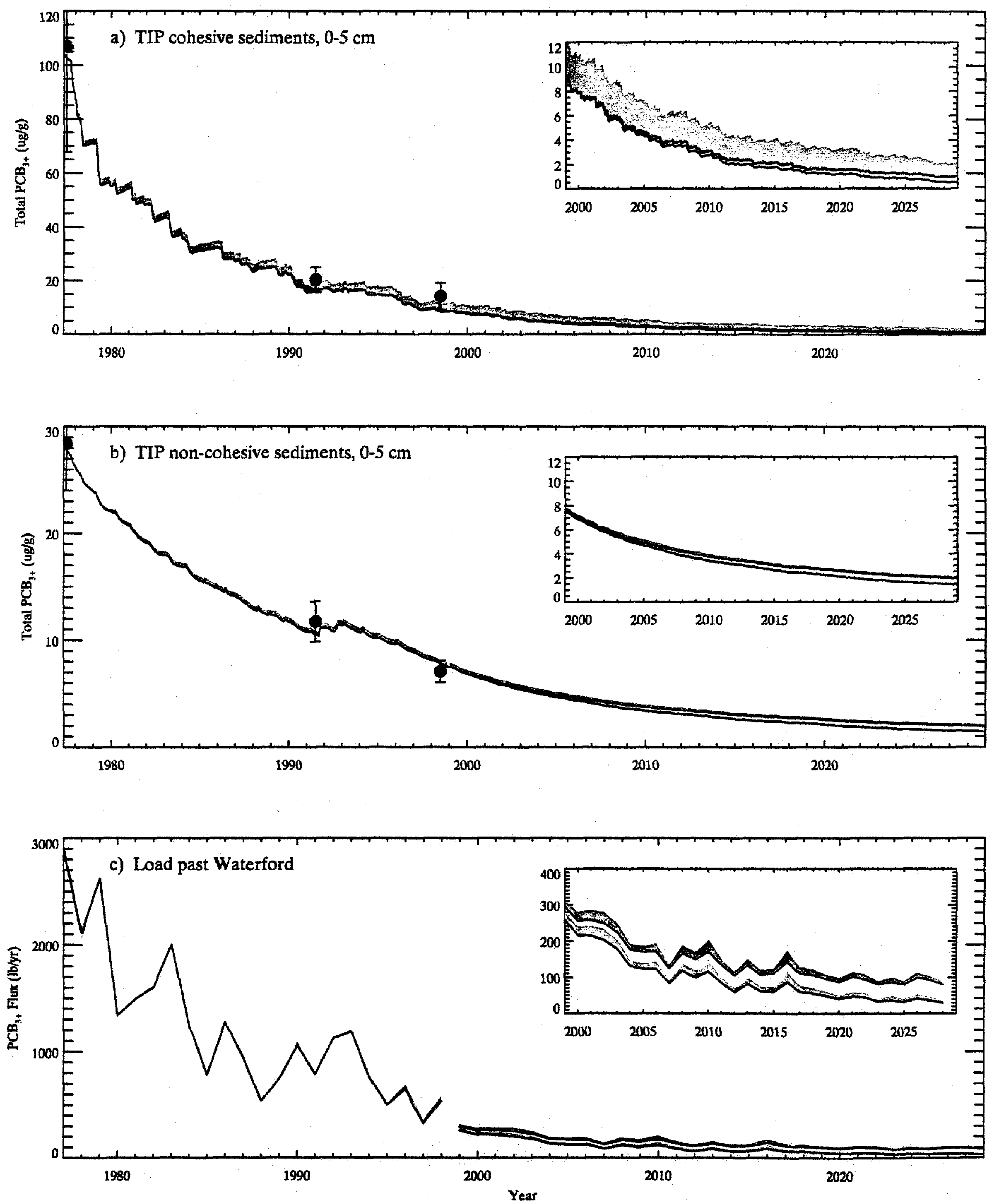
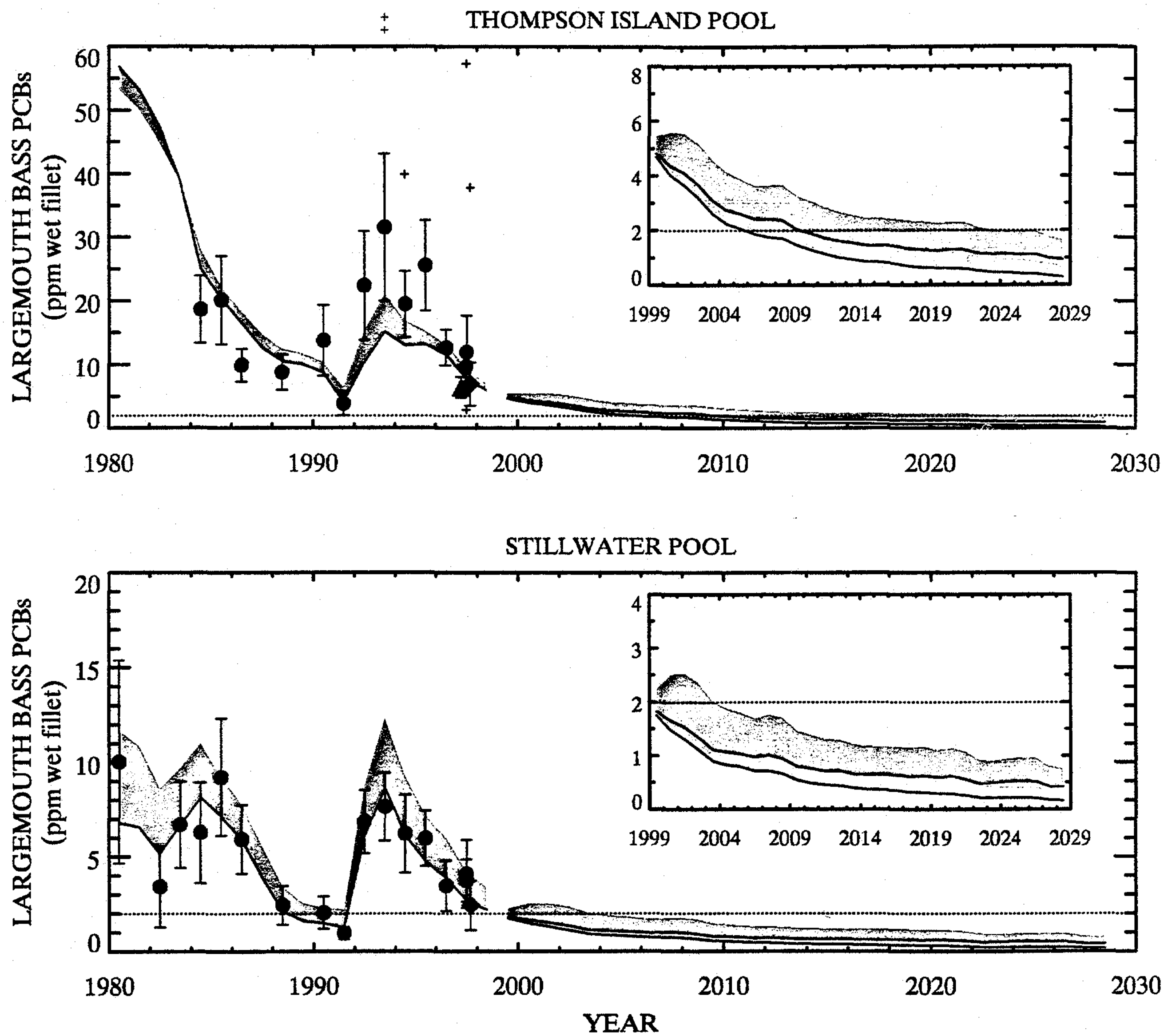


Figure 7-1. Predicted PCB_{3+} concentrations in TIP surface sediments and annual PCB_{3+} load passing Waterford to the Lower Hudson River over the time period from 1977 to 2029 for both natural recovery (line and abutting blue shading) and elimination of the upstream source in 1999 (line and abutting orange shading).



Dotted line at 2 ppm represents FDA Tolerance Limit
Circles = NYSDEC
Triangles = Exponent
Diamonds = GE
Crosses indicate values excluded from the annual averages.

Figure 7-2. Predicted PCB_{3+} concentrations in TIP and Stillwater largemouth bass over the time period from 1980 to 2029 for both natural recovery (line and abutting blue shading) and elimination of the upstream source in 1999 (line and abutting orange shading).

Sediment Remediation

Section 8

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SECTION 8
SEDIMENT REMEDIATION

8.1 SEDIMENT REMOVAL

Dredging TIP hot spot sediments over the period from 2005 to 2010 would reduce TIP cohesive sediments (Figure 8-1a) from about 2.5 ppm (upper bound at 4.5 ppm) to 1.5 ppm (upper bound at 2.5 ppm) in 2011. The dredging residual of 1 ppm would not be achieved because the hot spots constitute only 56% of the cohesive areas. Cohesive sediments would reach 2 ppm immediately after dredging, 5 years earlier than natural recovery. Recovery after dredging would be slower than natural recovery and, by 2029, cohesive sediments would reach 0.8 ppm versus 1 ppm under natural recovery. About 20% of TIP non-cohesive sediments would be dredged under hot spot dredging, reducing concentrations from 3.5 ppm to 3.0 ppm (Figure 8-1b). Non-cohesive sediments would decline to 2 ppm four years sooner than natural recovery. End-of-simulation concentrations would be about 1.7 ppm. PCB_{3+} load past Waterford estimates would be only slightly impacted under hot spot dredging; the maximum benefit would be only 10 lb/yr during years of increased resuspension (Figure 8-1c). Waterford flux benefits would be only about 2 lb/yr by 2029.

Dredging of TIP hot spots 1 to 35 would have little impact on the recovery of largemouth bass in the Upper Hudson River. Because the incremental reduction in surface sediment concentrations due to dredging would be small, the resulting reductions in largemouth bass PCBs would also be small. For example, the greatest impact of sediment removal would occur in about the year 2012 (Figure 8-2). At this time dredging would only offer about a 20 percent reduction in largemouth bass PCBs. In addition, largemouth bass tissue PCB concentrations are already estimated below 2 ppm due to natural recovery. By 2029, PCB levels would be similar to those predicted under natural recovery (about 0.8 ppm).

Although dredging TIP sediments would produce some PCB reduction in local TIP fish, removal of these sediments would not accelerate the recovery of fish in other portions of the river. For example, minimal reductions in largemouth bass tissue PCBs in Stillwater would result from the sediment removal process (Figure 8-2). Similar to the TIP, long-term benefits resulting from dredging TIP hot spots would be essentially equivalent to those predicted under natural recovery.

Cohesive sediment dredging in TIP during 2005 to 2010 would provide benefits similar to hot spot dredging. PCB_{3+} concentrations in cohesive sediment (Figure 8-3a) would be reduced from about 2.5 ppm (upper bound at 4.5 ppm) to 0.8 ppm in 2011. Average TIP cohesive sediment concentrations would fall below 2 ppm during 2009 dredging operations (6 years before natural recovery). By simulation end, concentrations would achieve near steady-state at 0.5 ppm. The non-cohesive sediments would exhibit no effect from cohesive sediment remediation (Figure 8-3b). The impact on the flux past Waterford (Figure 8-3c) would be essentially the same as under hot spot dredging.

Ideal post-dredging conditions of 0 ppm residual would produce a greater reduction in cohesive sediments immediately after dredging as shown in Figure 8-5a. As this sediment would become recontaminated from PCBs in the non-cohesive sediments, the reduction beyond natural recovery would decline and would become negligible by 2019. There would be no significant change in the annual flux past Waterford (Figure 8-5c).

Removal of the cohesive sediments to a residual concentration of 1 ppm would produce some reduction of PCB levels in fish in the TIP. Largemouth bass would reach 2 ppm by about 2009 (versus 2010 under natural recovery, Figure 8-4). Bounding calculations suggest reaching the 2 ppm level could take until 2011. Average PCB levels in 2029 would be slightly lower than those estimated under natural recovery (about 0.7 versus 0.9 ppm). Because dredging sediments would provide reductions only in the reaches it occurred, essentially no reduction would be observed in largemouth bass tissue concentrations in Stillwater (Figure 8-4).

Achieving an ideal post-dredging sediment PCB level of 0 ppm would result in additional short-term reductions in TIP largemouth bass PCBs of about 15 percent beyond that achieved by dredging alone, but would have essentially no impact on largemouth bass in Stillwater. By 2029, PCB levels in largemouth bass in the TIP would decline to about 0.7 (slightly less than the 0.9

ppm predicted under natural recovery). At Stillwater, largemouth bass levels achieved by 2029 would be the same as under natural recovery (0.4 ppm; Figure 8-6).

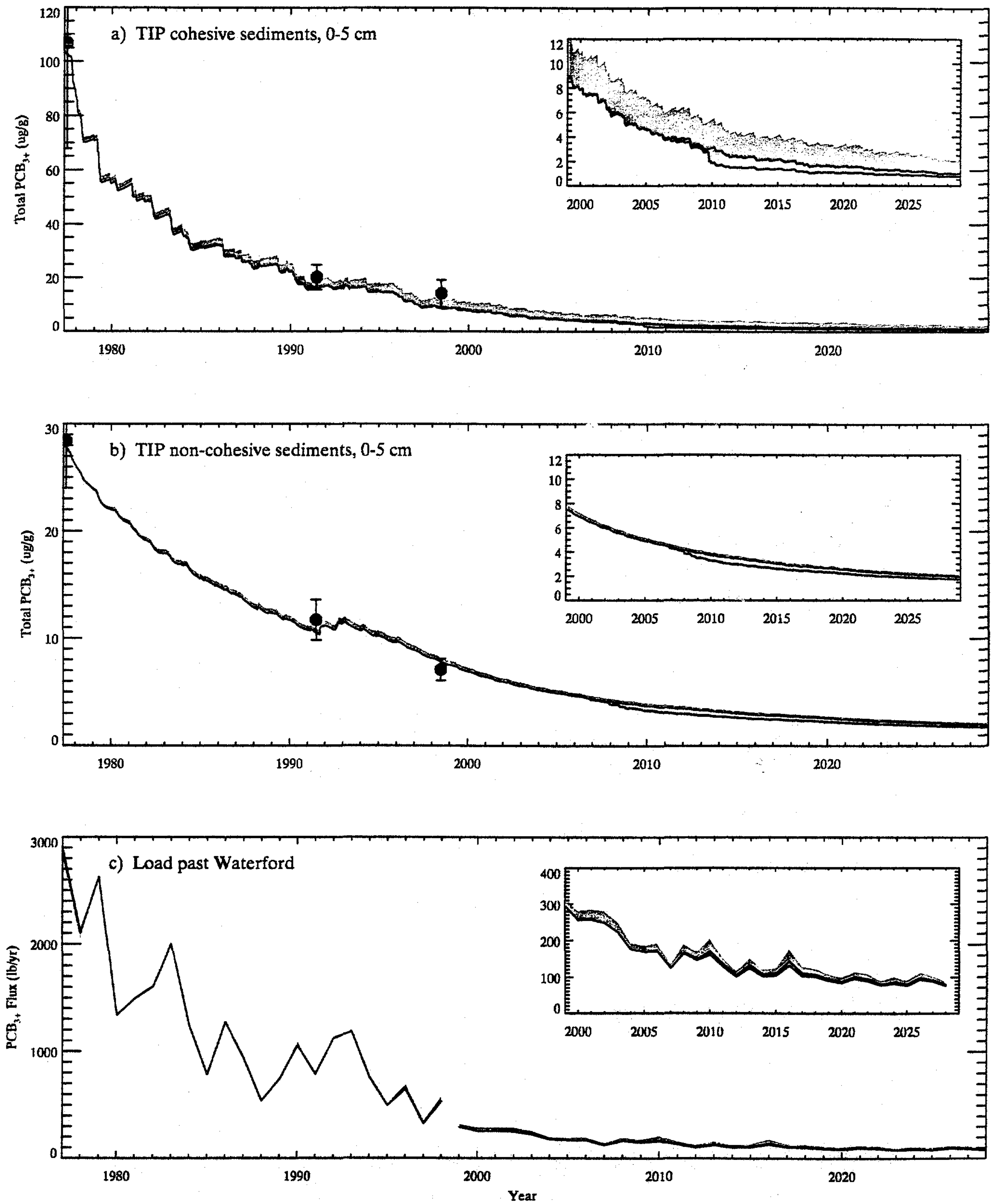

Figure 8-1. Predicted PCB$_{3+}$ concentrations in TIP surface sediments and annual PCB$_{3+}$ load passing Waterford to the Lower Hudson River over the time period from 1977 to 2029 for both natural recovery (line and abutting blue shading) and dredging of the NYSDEC hot spots between 2005 and 2013 (line and abutting orange shading)to a residual concentration of 1 ppm.

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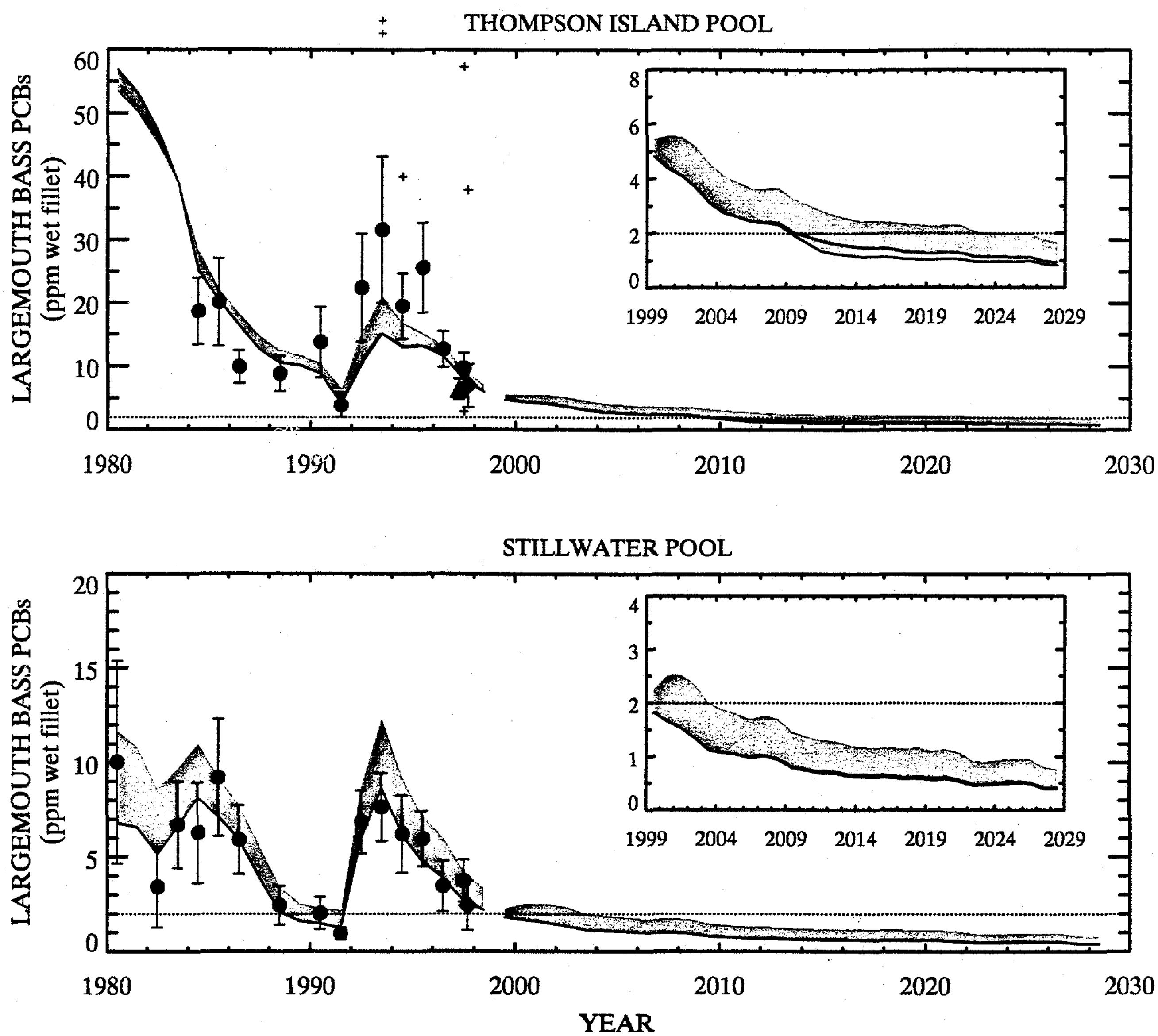

Dotted line at 2 ppm represents FDA Tolerance Limit
Circles = NYSDEC
Triangles = Exponent
Diamonds = GE
Crosses indicate values excluded from the annual averages.

Figure 8-2. Predicted PCB_{3+} concentrations in TIP and Stillwater largemouth bass over the time period from 1980 to 2029 for both natural recovery (line and abutting blue shading) and dredging of the NYSDEC hot spots between 2005 and 2013 (line and abutting orange shading) to a residual concentration of 1 ppm.

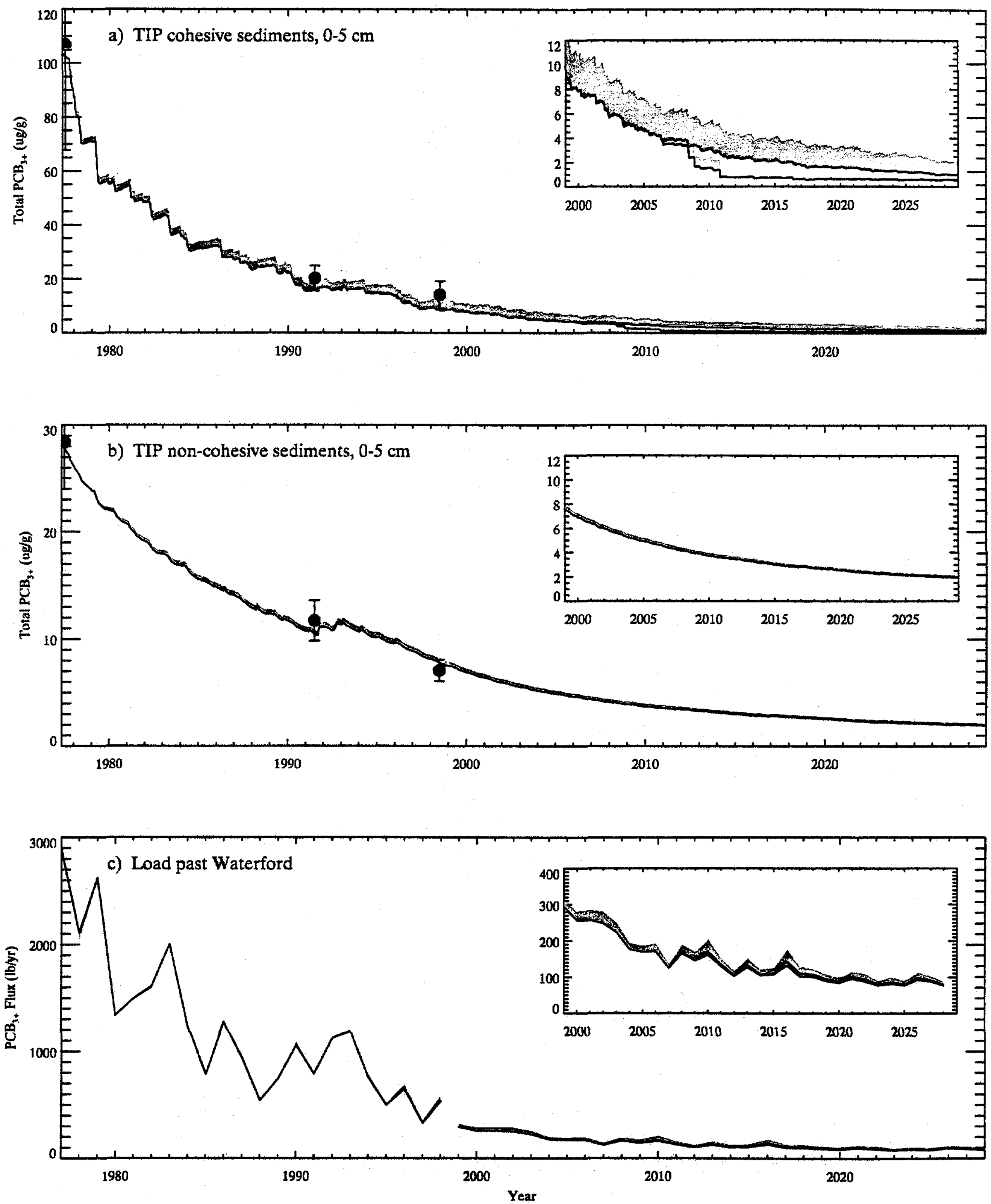

Figure 8-3. Predicted PCB_{3+} concentrations in TIP surface sediments and annual PCB_{3+} load passing Waterford to the Lower Hudson River over the time period from 1977 to 2029 for both natural recovery (line and abutting blue shading) and dredging of Reaches 8, 7 and 6 cohesive sediments between 2005 and 2016 (line and abutting orange shading) to a residual concentration of 1 ppm.

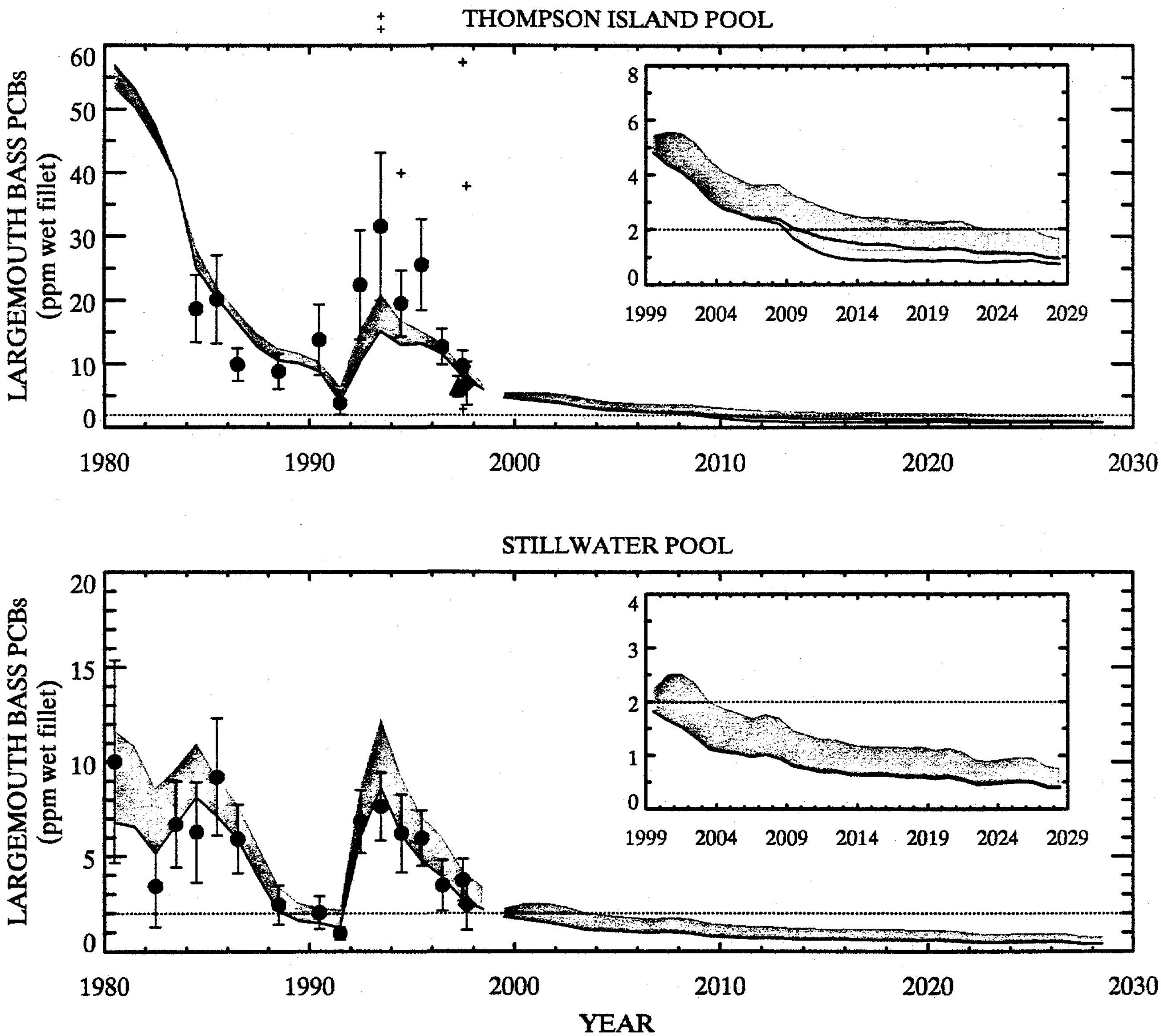

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Figure 8-4. Predicted PCB_{3+} concentrations in TIP and Stillwater largemouth bass over the time period from 1980 to 2029 for both natural recovery (line and abutting blue shading) and dredging of Reaches 8, 7 and 6 cohesive sediments between 2005 and 2016 (line and abutting orange shading) to a residual concentration of 1 ppm.

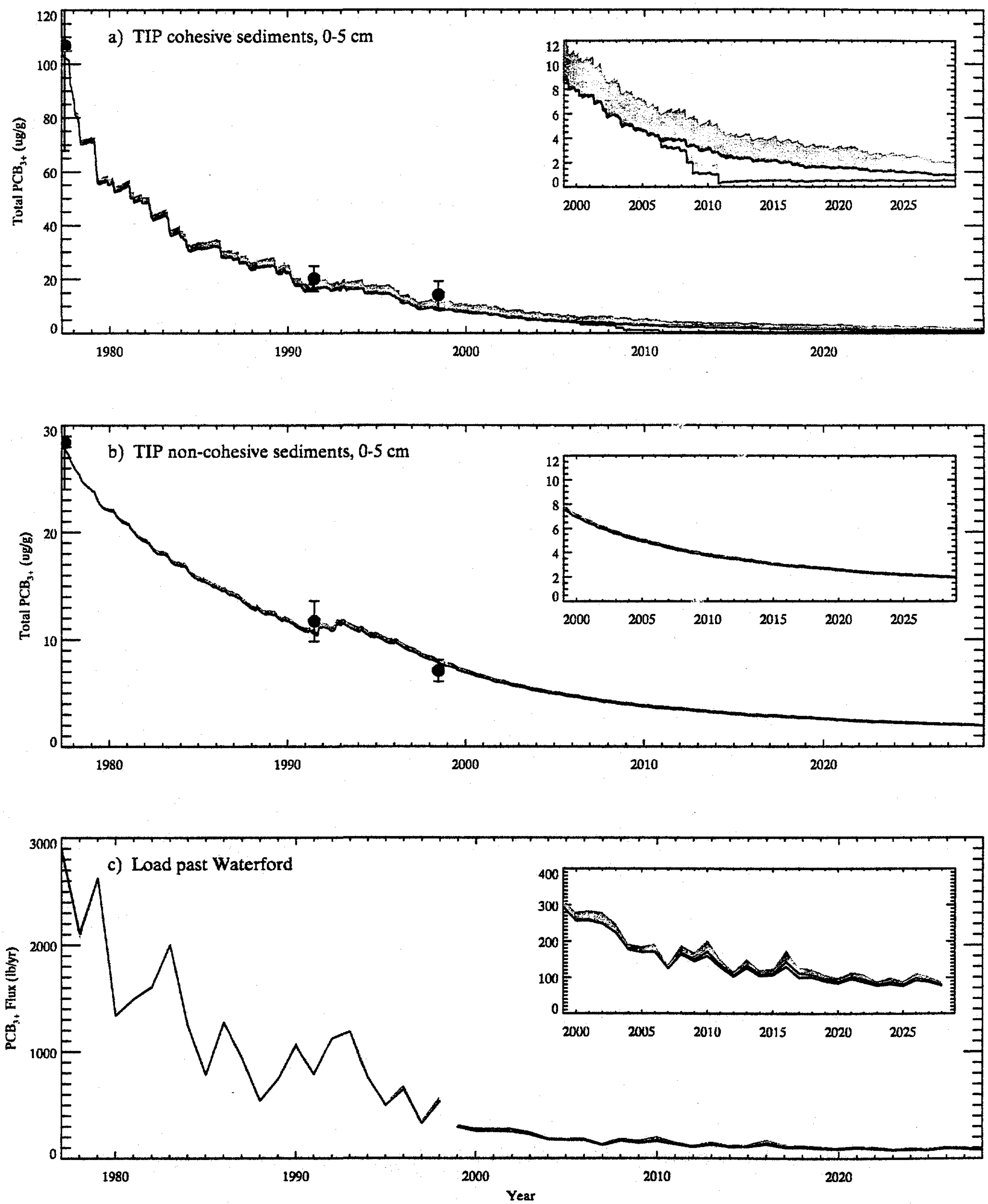
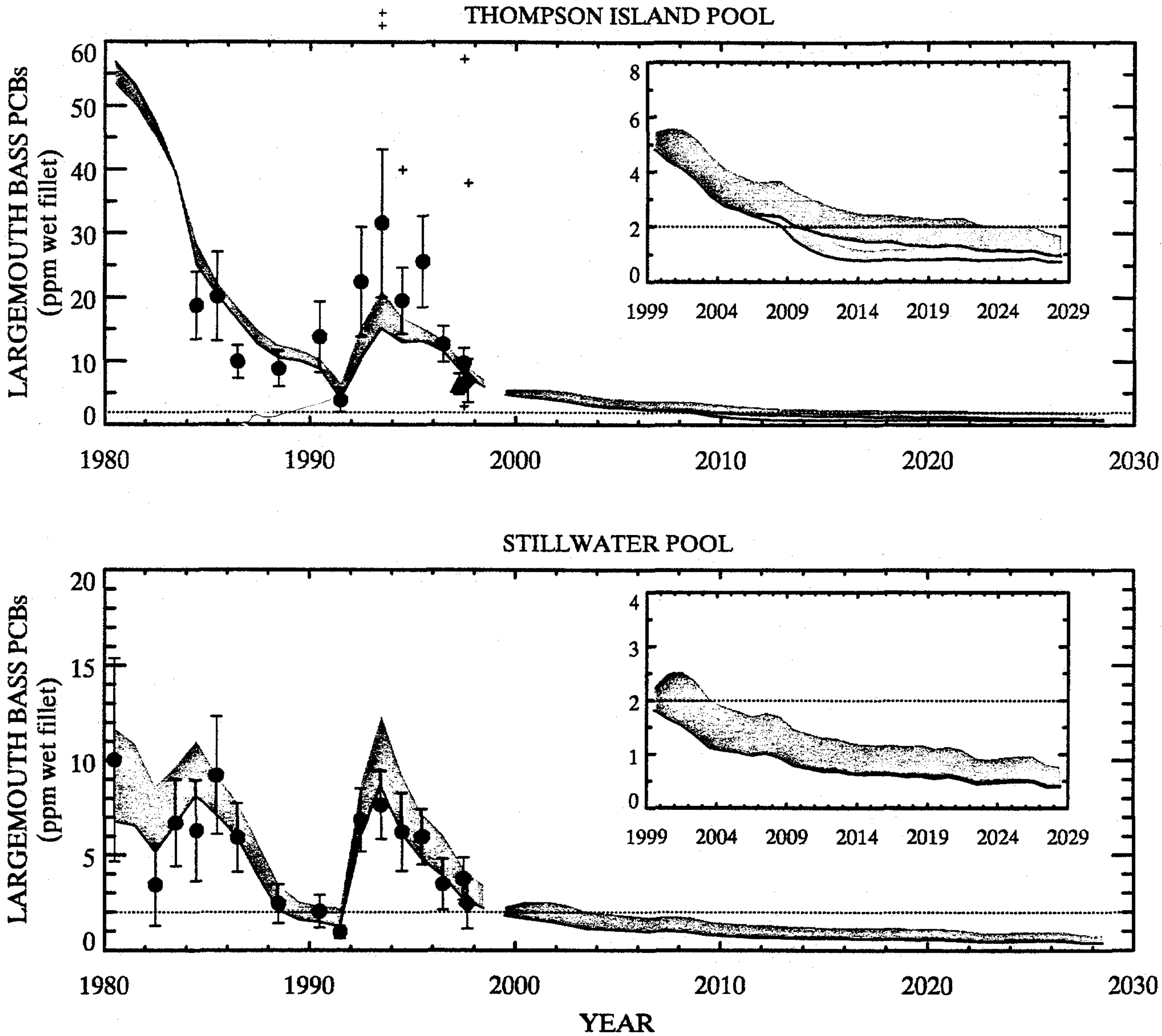


Figure 8-5. Predicted PCB$_{3+}$ concentrations in TIP surface sediments and annual PCB$_{3+}$ load passing Waterford to the Lower Hudson River over the time period from 1977 to 2029 for both natural recovery (line and abutting blue shading) and dredging of Reaches 8, 7 and 6 cohesive sediments between 2005 and 2016 (line and abutting orange shading) to a residual concentration of zero.



Dotted line at 2 ppm represents FDA Tolerance Limit
Circles = NYSDEC
Triangles = Exponent
Diamonds = GE
Crosses indicate values excluded from the annual averages.

Figure 8-6. Predicted PCB_{3+} concentrations in TIP and Stillwater largemouth bass over the time period from 1980 to 2029 for both natural recovery (line and abutting blue shading) and dredging of Reaches 8, 7 and 6 cohesive sediments between 2005 and 2016 (line and abutting orange shading) to a residual concentration of zero.

Impacts of a 100-Year Flood Event

Section 9

Quantitative Environmental Analysis, LLC

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SECTION 9
IMPACTS OF A 100-YEAR FLOOD EVENT

9.1 EFFECT OF THE FLOOD ON NATURAL RECOVERY

A 100-year flood could occur in any year. By definition from the historical flow record, it has a one-percent chance of occurring in any year. It may have last occurred in 1976. For purposes of the report, we evaluated floods that would occur in 2006, 2013 or 2020. These years were chosen to represent near-, mid- and far-future. The earliest occurrence evaluated was 2006 because impacts of earlier floods could not be mitigated by remediation based on the remediation schedule presented in Section 5.

The model predicted that a 100-year flood would cause erosion in approximately 94% of the cohesive bed area of the TIP (Volume 2, Section 3.5). In the eroded portions of the TIP cohesive bed, erosional depths of 2 cm or less were predicted for 78% of the total cohesive area and about 4% of the area had erosional depths greater than 5 cm. Scour depths of 1 cm or less were predicted in approximately 97% of the non-cohesive bed area. For the 30-year projection period, the occurrence of a 100-year flood was predicted to cause net deposition in the TIP to decrease by about 7% (Volume 3, Section 3.3).

The occurrence of a 100-year flood in the year 2006 was predicted to increase the average TIP cohesive surface sediment PCB concentration from about 4.3 ppm (bounding value of 6.5 ppm) to about 5.8 ppm (bounding value of 8.5 ppm) (Figure 9-1a). This increase would effectively set back the recovery in these sediments by about 4 years, bringing concentrations to levels predicted for 2002. In contrast, the flood would have a minimal impact on the TIP non-cohesive sediments, increasing the average level by about 0.1 ppm (Figure 9-1b). Downstream of the TIP, the flood would have little impact on either cohesive or non-cohesive surface sediment PCB levels.

The annual PCB_{3+} loading passing Waterford in 2006 would increase by about 160 pounds as a result of the flood (Figure 9-1c). An elevation in this loading of 5 to 10 pounds would persist for several years as a result of the elevated concentrations in the TIP cohesive sediments. By the end of the 30-year simulation, the impacts of the flood would be negligible.

The predicted rise in TIP cohesive surface sediment PCB concentration was predicted to cause an increase of about 0.8 ppm in average TIP largemouth bass PCB levels, extending the time to reach 2 ppm by about 4 years (2014 versus 2010) (Figure 9-2). The effects of the flood on Stillwater largemouth bass were predicted to be negligible because surface sediment concentrations in this reach would not increase.

A rare flood event in 2013 would increase TIP cohesive sediments (Figure 9-3a) from 2.3 ppm to 3.4 ppm (3.8 ppm to 5.7 ppm in bounding calculation). This is approximately equal to predicted 2008 sediment levels. The increase would be less than half the increase predicted during the 2006 flood. Under this scenario, sediments would achieve 2 ppm in 2024, three years later with 2006 flood conditions, and 1.5 ppm by 2029. Figure 9-3b shows minimal effects to the non-cohesive sediments. The flood would increase PCB_{3+} water fluxes to the lower river (Figure 9-3c) by an additional 100 lbs in 2013 and 5-10 lb/yr for about the next 4 years.

A 100-year flood in 2013 would cause average TIP largemouth bass PCB levels to increase from about 1.5 ppm to about 2 ppm by 2015, dropping below 2 ppm again within 3 years (Figure 9-4). This increase in TIP largemouth bass PCB levels would be about 40 percent lower than the increase predicted for a similar flood event in 2006. Because sediment concentrations in the Stillwater reach are unaffected by the flood, PCB levels in largemouth bass in this reach would not increase. By 2029, the difference in PCB concentrations in TIP largemouth bass due to the flood would be reduced to about 0.2 ppm and this difference would continue to decline thereafter.

Figure 9-5 shows the effects of the 100-year flood in 2020. TIP cohesive sediments (Figure 9-5a) would increase from 1.5 to 2.5 ppm (ca. 2012 concentration). This increase is slightly less than predicted for the 2013 flood. Subsequent recovery brings levels back down to 2 ppm by 2026 (compared to 2021 and 2024 for earlier floods) and 1.6 ppm by simulation end.

The occurrence of a 100-year flood in 2020 would increase PCB levels in TIP largemouth bass from about 1.1 ppm to about 1.5 ppm (Figure 9-6). After the flood, PCB levels in average TIP largemouth bass would begin to decline again. By 2029, the levels would be about 0.3 ppm greater than under natural recovery and thereafter would continue to approach levels estimated under natural recovery. The effect of a 100-year flood in 2020 on PCB levels in largemouth bass in Stillwater would be negligible.

The three flood simulations indicate that the timing of a rare flood event would have a significant impact on the increase in TIP surface cohesive sediment and fish PCB_{3+} and the increase in load to the lower river. In general, a later occurrence of a rare flood event would cause a lower elevation of sediment and fish PCB_{3+} concentrations and a lower increase in PCB_{3+} water flux past Waterford. At the same time, a later rare flood would increase the time for surface cohesive sediment to achieve specific PCB_{3+} levels.

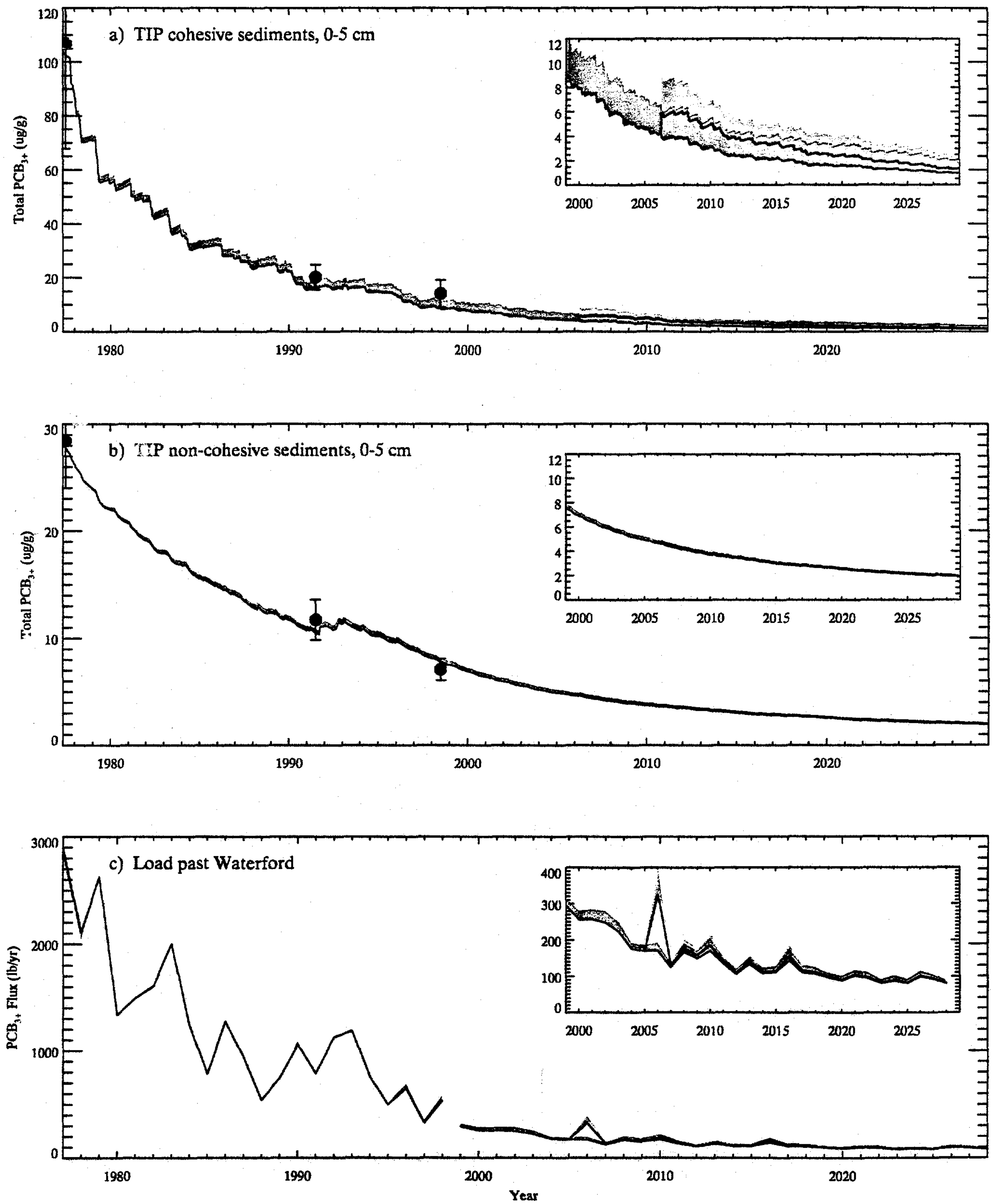

Figure 9-1. Predicted PCB_{3+} concentrations in TIP surface sediments and annual PCB_{3+} load passing Waterford to the Lower Hudson River over the time period from 1977 to 2029 for both natural recovery without (line and abutting blue shading) and with the occurence of a 100-year flood event in 2006 (line and abutting orange shading).

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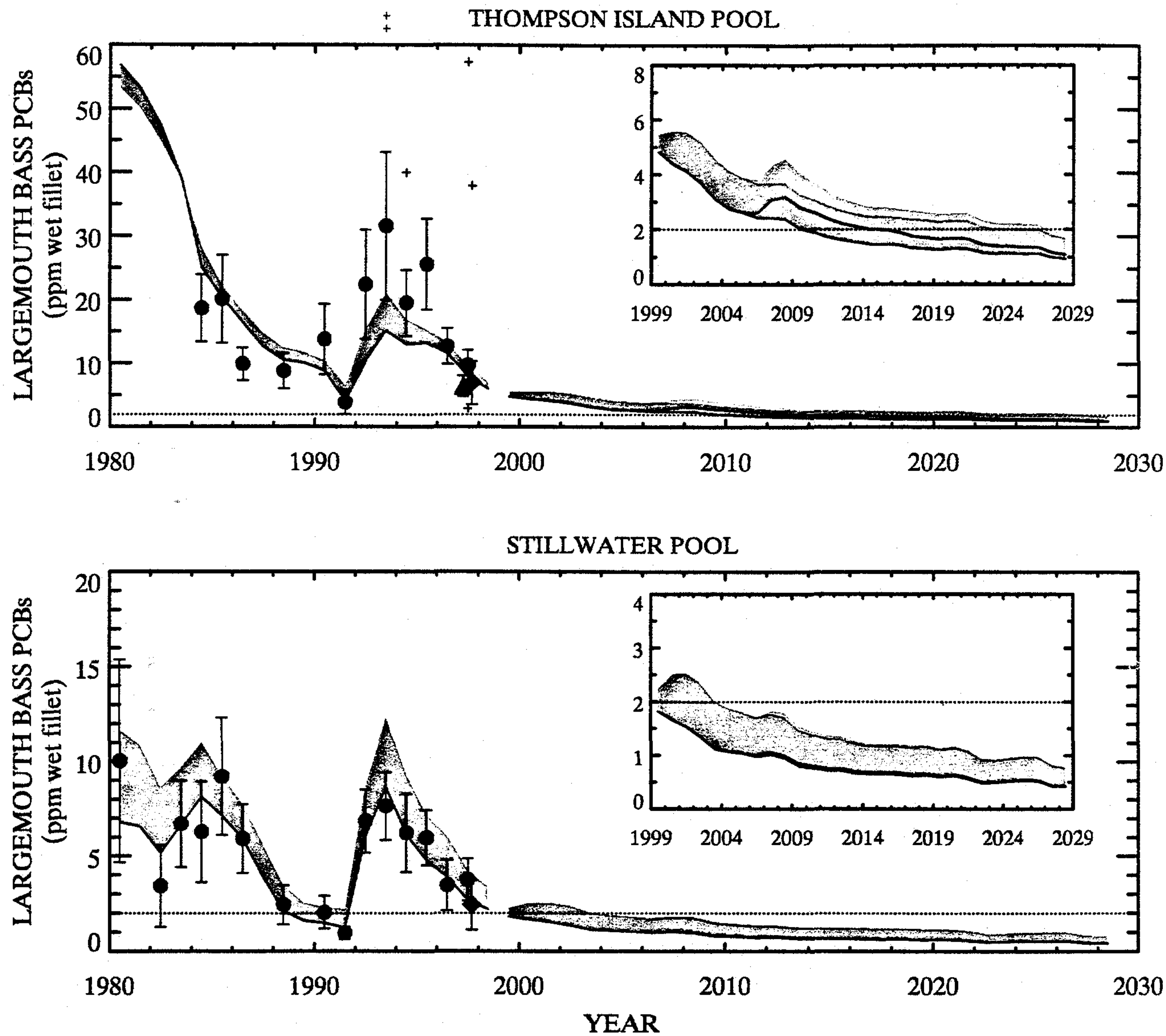


Dotted line at 2 ppm represents FDA Tolerance Limit
Circles = NYSDEC
Triangles = Exponent
Diamonds = GE
Crosses indicate values excluded from the annual averages.

Figure 9-2. Predicted PCB_{3+} concentrations in TIP and Stillwater largemouth bass over the time period from 1980 to 2029 for natural recovery without (line and abutting blue shading) and with the occurrence of a 100-year flood event in 2006 (line and abutting orange shading).

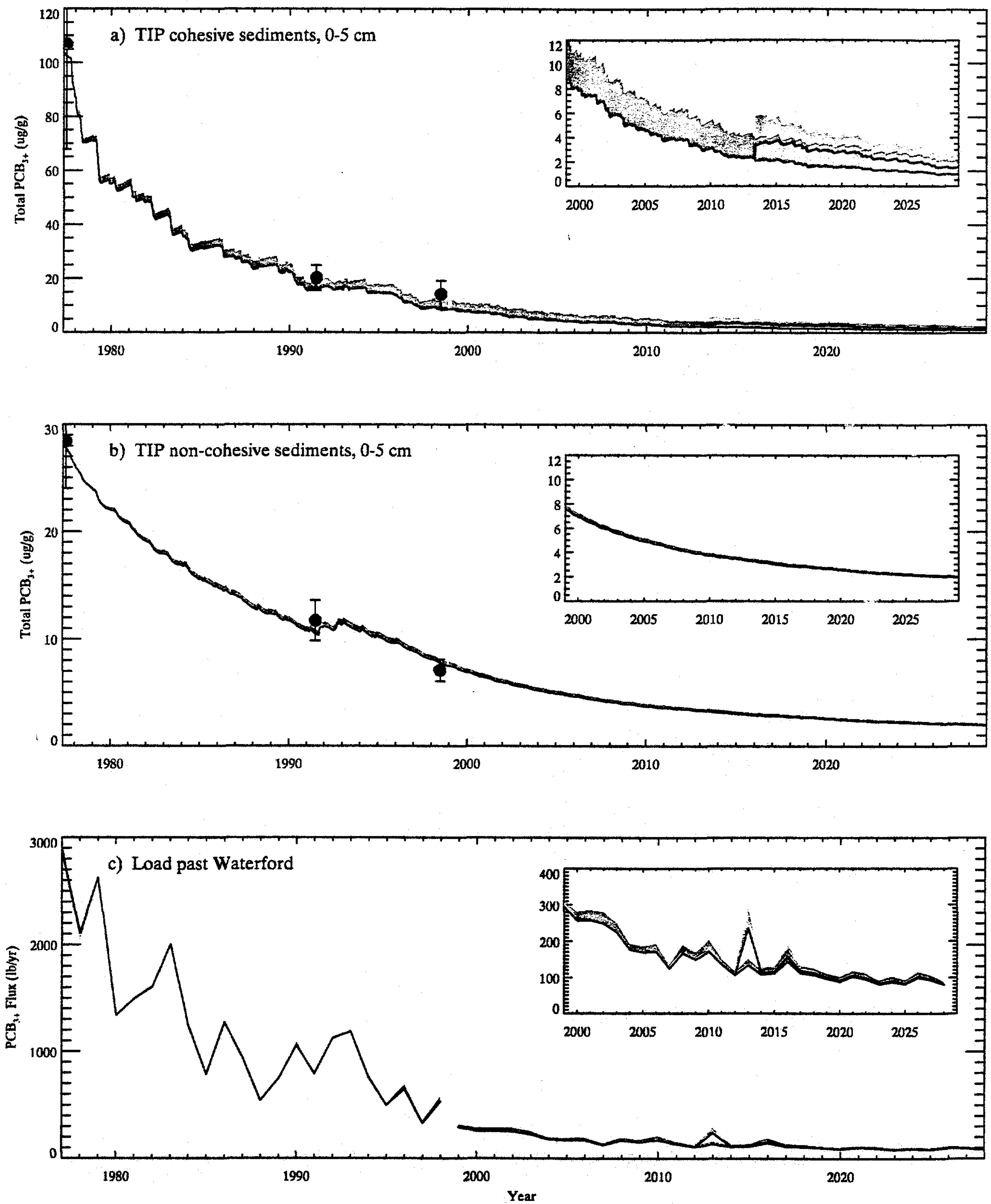
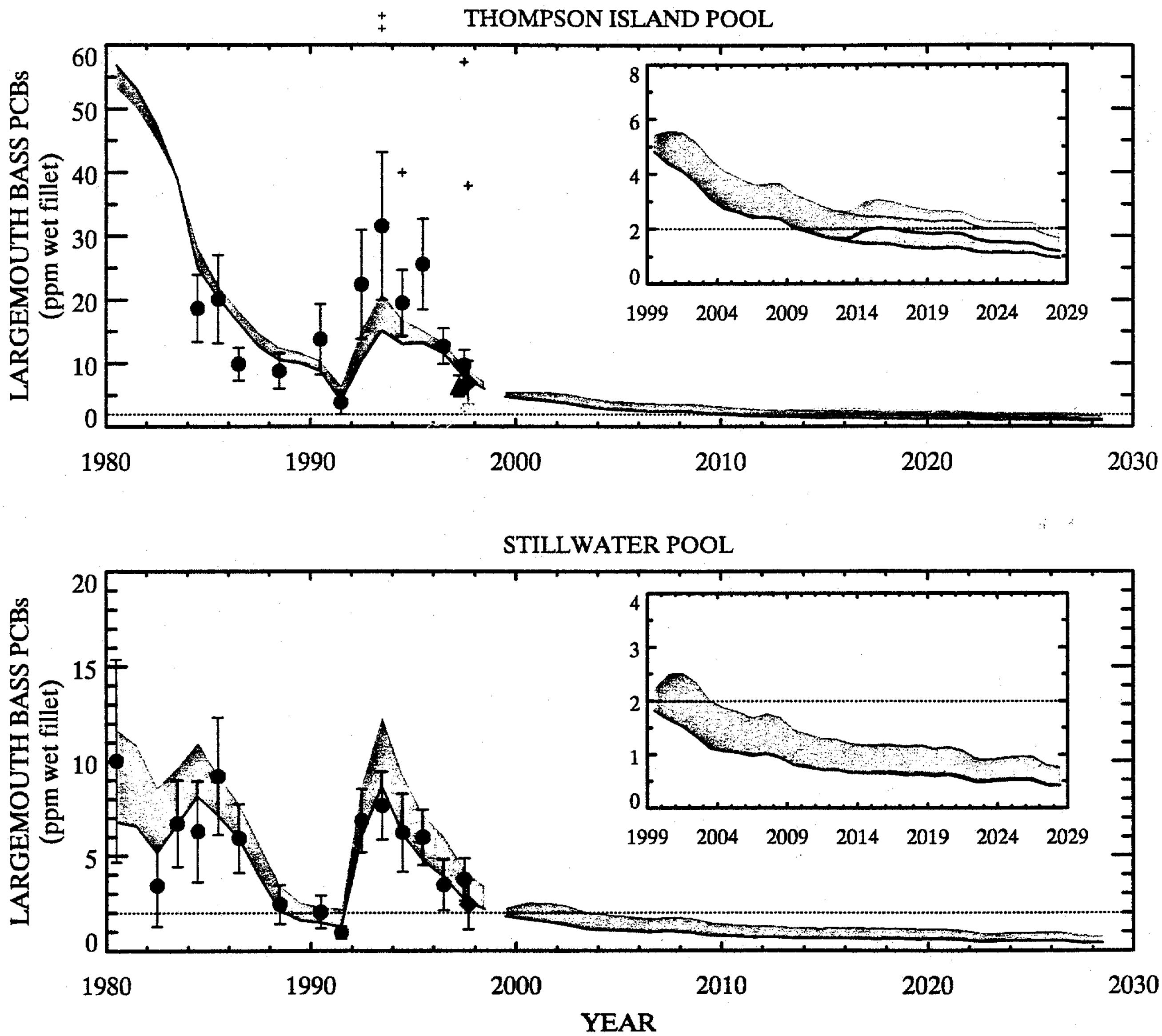


Figure 9-3. Predicted PCB_{3+} concentrations in TIP surface sediments and annual PCB_{3+} load passing Waterford to the Lower Hudson River over the time period from 1977 to 2029 for both natural recovery without (line and abutting blue shading) and with the occurence of a 100-year flood event in 2013 (line and abutting orange shading).



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Diamonds = GE
Crosses indicate values excluded from the annual averages.

Figure 9-4. Predicted PCB_{3+} concentrations in TIP and Stillwater largemouth bass over the time period from 1980 to 2029 for natural recovery without (line and abutting blue shading) and with the occurrence of a 100-year flood event in 2013 (line and abutting orange shading).

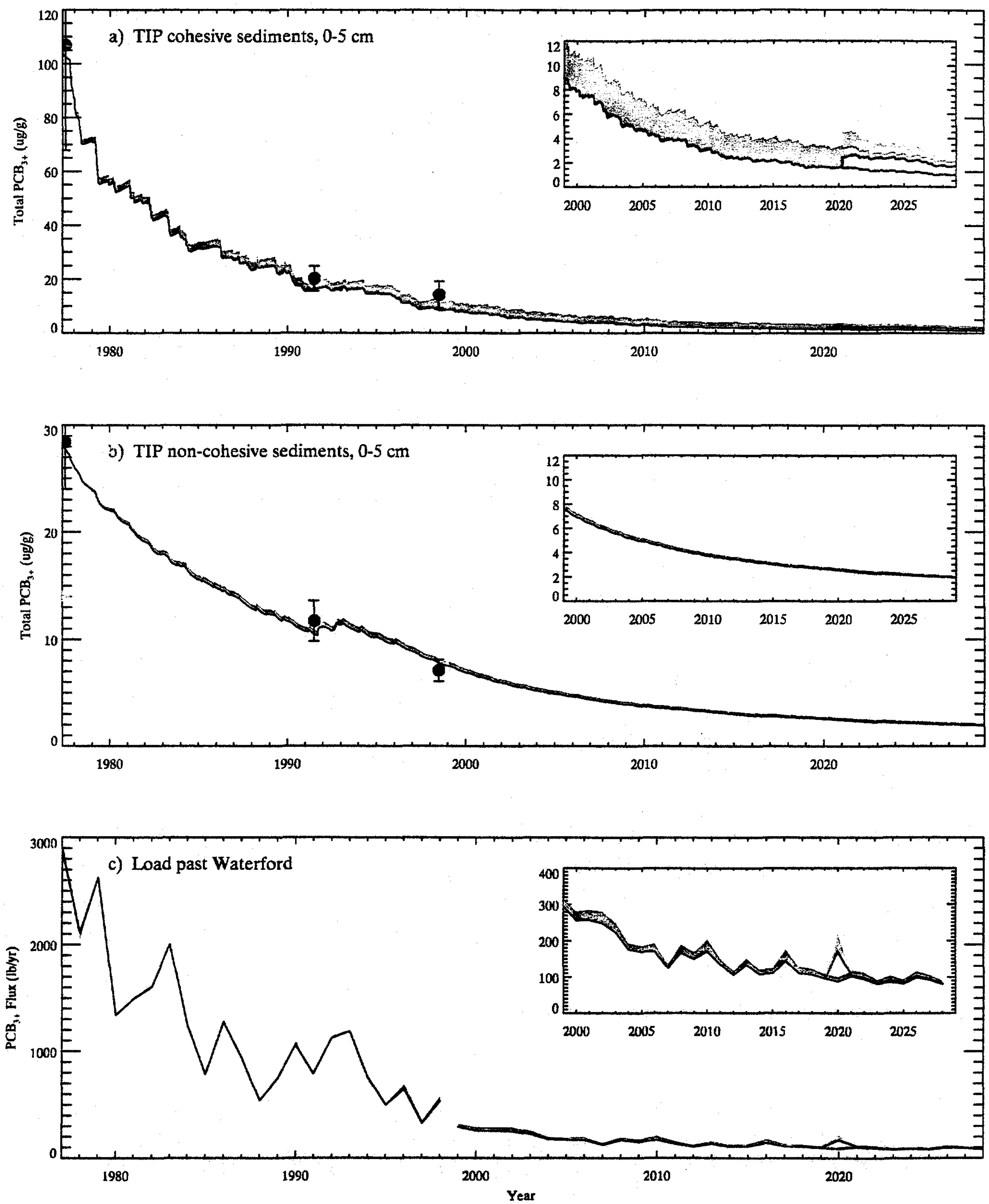
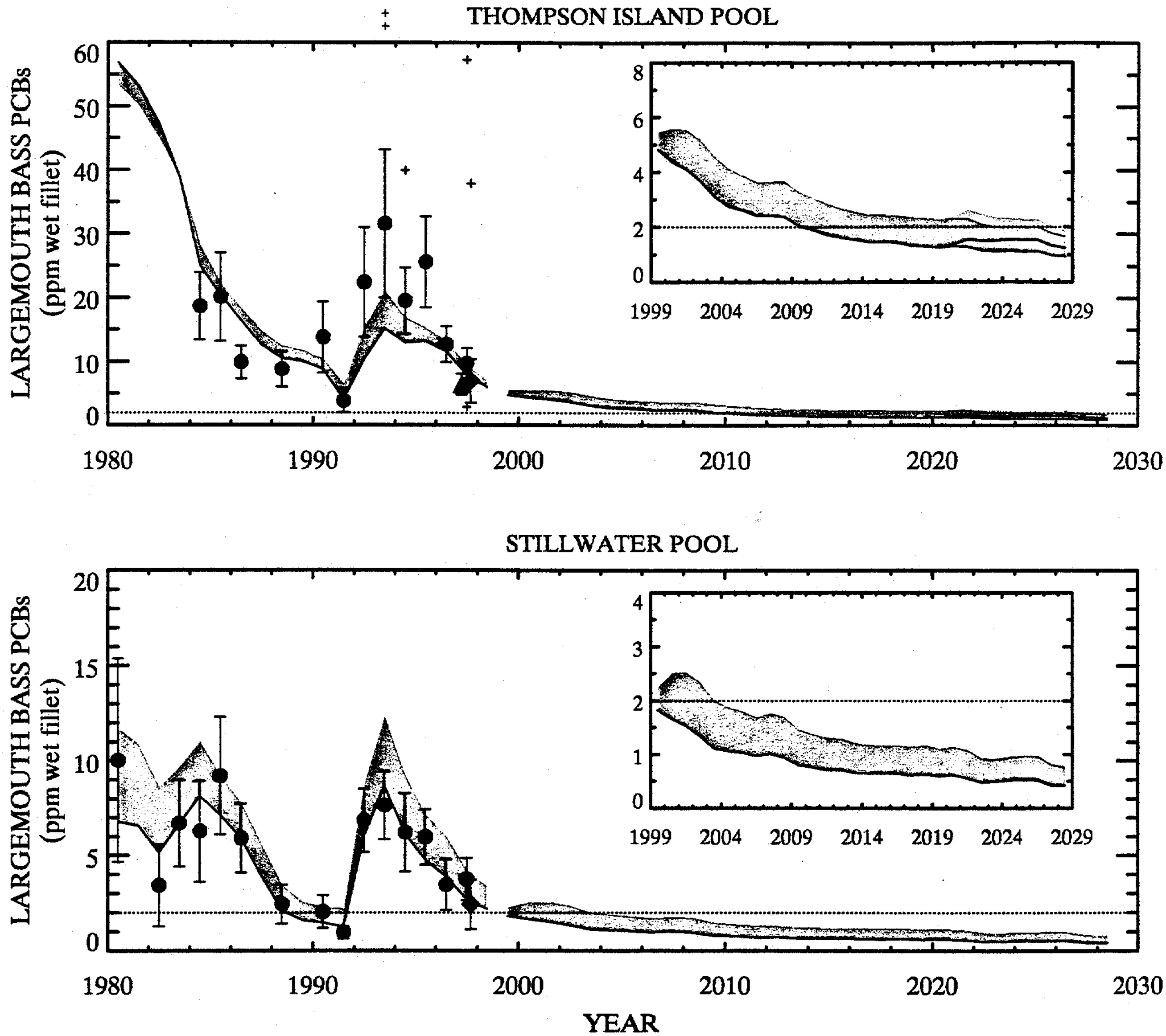


Figure 9-5. Predicted PCB_{3+} concentrations in TIP surface sediments and annual PCB_{3+} load passing Waterford to the Lower Hudson River over the time period from 1977 to 2029 for both natural recovery without (line and abutting blue shading) and with the occurence of a 100-year flood event in 2020 (line and abutting orange shading).



Dotted line at 2 ppm represents FDA Tolerance Limit
Circles = NYSDEC
Triangles = Exponent
Diamonds = GE
Crosses indicate values excluded from the annual averages.

Figure 9-6. Predicted PCB_{3+} concentrations in TIP and Stillwater largemouth bass over the time period from 1980 to 2029 for natural recovery without (line and abutting blue shading) and with the occurrence of a 100-year flood event in 2020 (line and abutting orange shading).

Summary and Conclusions

Section 10

Quantitative Environmental Analysis, LLC

SECTION 10
SUMMARY AND CONCLUSIONS

The model was used to evaluate four remedies: natural recovery; elimination of the remaining upstream PCB load; dredging cohesive sediments in Reaches 8, 7 and 6; and dredging NYSDEC hot spots 1 to 35.

10.1 NATURAL RECOVERY

The results show natural recovery, often referred to as No Action, will result in continued reductions of PCB concentrations in largemouth bass, the species at the top of the food chain. The model projected average largemouth bass PCB levels would reach 2 ppm by about the year 2000 in the Stillwater reach and 2010 in the TIP. Using a more conservative estimate moderated by bounding calculations, which take into account the uncertainty of the more important model parameters, we project it could take until 2004 in Stillwater and 2023 in the TIP to reach 2 ppm.

The model simulated Upper Hudson River conditions for the thirty-year period from 1999 to 2029. It projected that, under natural recovery, PCB concentrations in largemouth bass continue to decline to very low levels in 2029 of about 0.9 ppm in the TIP and 0.4 ppm in the Stillwater Pool. PCB flux to the Lower Hudson River was projected to drop from a current level of about 300 lb/yr to about 90 lb/yr by the year 2029.

10.2 ELIMINATION OF THE UPSTREAM PCB LOAD

The projections demonstrate that eliminating the upstream PCB source accelerates recovery more than the other remedial alternatives. Upstream source control would reduce PCB concentrations in fish throughout the Upper Hudson River; sediment remediation by dredging was predicted to yield more limited and localized reductions. If the upstream sources were completely eliminated in 1999, the model projected that the average TIP largemouth bass would reach 2 ppm 4 years sooner than under natural recovery. Furthermore, by 2029, the PCB level would be reduced about a factor of three beyond that achievable by natural recovery (0.3 ppm versus 0.9 ppm). In the Stillwater reach, the reduction by 2029 would be about a factor of two and one-half (0.15 ppm versus 0.4 ppm).

Upstream source control is projected to produce an immediate reduction in PCB flux to the Lower Hudson River to about 260 lb/yr. This reduction would increase over time as the surface sediment PCB concentrations declined. By 2029, the flux would be reduced to about 40 lb/yr, about a 50 lb/yr reduction beyond that achievable by Natural Recovery.

10.3 DREDGING

The model projects that dredging selected sediments would provide only a minimal benefit. Dredging NYSDEC hot spots 1 to 35 would reduce the time it will take for largemouth bass tissue to reach 2 ppm by about 1 year. Dredging cohesive sediments would also accelerate this time only in the TIP and only by 1 year. Both dredging options (the hot spots and Reaches 8,7,6 cohesive sediments) would produce small and temporary reductions in TIP largemouth bass levels (maxima of 0.4 and 0.6 ppm, respectively) and essentially no reduction in Stillwater largemouth bass levels. The predicted reductions were small because the incremental reductions in surface sediment concentration achieved by dredging were small. Natural recovery was predicted to reduce TIP cohesive surface sediment PCB levels to about 3 to 5 ppm by the time dredging could start in 2005 and natural recovery would continue to reduce these levels as dredging progressed over 9 to 12 years. Thus, dredging would reduce concentration by only a few parts per million. A zero post-dredging residual concentration would not provide significant additional reductions for the same reason. Further, the dredged areas would be subject to recontamination from non-cohesive sediments and from upstream sources, causing the predicted improvements in fish levels to be temporary.

Dredging would have only a minor impact on the PCB flux to the Lower Hudson River, reducing the annual flux by about 2-10 lb/yr. The reduction would decline over time as surface sediments became recontaminated.

10.4 THE 100-YEAR FLOOD

A 100-year flood event would cause an increase in TIP fish PCB levels, but almost no increase in Stillwater fish PCB levels. The extent of the increase in the TIP would depend on when the flood occurred. For example, if the flood occurred in 2006 it would result in about an 0.8 ppm increase in TIP largemouth bass, whereas the increase would be about 0.6 ppm if the flood occurred in 2013 or 0.4 ppm if it occurred in 2020. The decreasing impact further in the future is attributable to the declining surface sediment concentrations resulting from natural recovery.

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