Hudson River PCB Contamination - A 1985 Perspective

by

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ABSTRACT

Ten years after the recognition of the PCB contamination of the Hudson River, PCB concentrations in the water column, fish and surficial sediments are substantially lower than the very high levels observed during the late 1970's. However PCB levels in water and fish still exceed acceptable concentrations. Monitoring demonstrates the persistence of a contamination gradient along the length of the river and implicates the region near Fort Edward, N.Y. as the major contributor of the continued load of PCB to the lower Hudson. The proposed excavation of some of the most highly contaminated sediments from that area will be coordinated with the remediation of PCB contaminated landfills and exposed sediment deposits.

INTRODUCTION

Ten years ago the problem of the Hudson River's contamination by polychlorinated biphenyls (PCBs) was just beginning to unfold. Despite a series of remedial actions and a significant decline in the contamination of the rivers water and biological resources, PCBs persist as the factor most limiting use of the river. Prohibitions against fishing in much of the upper Hudson River and commercial fishing of striped bass (*Morone saxatilis*) established in the mid 1970's have been maintained. Proposed remedial actions aim to accelerate the decline in the river's contamination.

The contamination of approximately 330 km of the Hudson River is the legacy of their use and discharge for 30 years by the General Electric Company (GE) capacitor manufacturing facilities in Fort Edward and Hudson Falls, NY (Figure 1). Legal action was initiated against GE in 1975 shortly following recognition of the problem. At that time, there was little information available to estimate the mass of PCBs that had been discharged other than incomplete records of PCB purchases by the GE facilities and a 1972 discharge permit application stating an anticipated average discharge of 30 lbs/d(13.6 kg/d) of chlorinated hydrocarbons (1). The removal of the Fort Edward Dam in 1973 a slight distance downstream of the discharge appears to have greatly assisted the downstream movement of PCBs (2,3) in addition to exposing highly contaminated nearshore sediment known as the remnant deposits. Dredging operations in the Fort Edward area during 1974-1975 removed most of the sediment that was released downstream (3).

Legal action against GE produced a settlement in 1976 requiring the phased elimination of the PCB discharge and providing for assessments of the contamination of the Hudson River and environs of Fort Edward, NY, and remedial alternatives (4). The subsequent collection and analysis of approximately 1,000 sediment samples indicated 158,000 kg of PCBs in the bed of the upper Hudson of which 57 percent were in 40 hot spots comprising less than 10 percent of the river surface area (5, 6). Twenty hot spots within the 8-km reach near Ft. Edward referred to as the Thompson Island Pool appeared to contain 40 percent of the upper Hudson's PCB burden. A 1979 analysis of sediment transport indicated that without remedial action PCB transport to the lower river would average 3,600 kg/y for the next twenty years (7). The analysis indicated that dredging of the Thompson Island Pool hot spots and removal of the remnant deposits would reduce PCB transport to 2,800 kg/year during that period. A 1978 analysis of fish contamination suggested that with no action it could "be longer than a decade before any noticeable reduction is detected in the striped bass fishery" (8). The analysis suggested that dredging in the Thompson Island Pool could affect a 50 percent reduction in fish PCB levels in the upper Hudson and about a 20 percent reduction in the estuary.

The remedial strategy for the Hudson River Basin's PCB contamination problem pursued by the New York State Department of Environmental Conservation (DEC) in cooperation with the General Electric Company, the U.S. Environmental Protection Agency (EPA), and the New York State - General Electric PCB Settlement Advisory Committee include a series of actions which began with the 1975 reduction and 1977 elimination of the PCB discharge. In 1978, exposed sediment deposits upstream of the former dam were stabilized and one deposit was excavated. During 1977 and 1978, 200,000 cubic yards of contaminated sediment were dredged from the Hudson at Fort Edward area and placed in a clay-lined and clay-capped landfill (9). Several PCB-contaminated landfills in the Fort Edward area were also remediated. In 1979, Congress authorized the Hudson River PCB Reclamation Demonstration Project through section 116 of the Clean Water Act which provides 20 million dollars to demonstrate methods for the selective removal of PCB-contaminated sediments. The scope of the project as defined in the Federal Environmental Impact Statement that was approved in 1982 included the excavation of 20 hot spots in the Thompson Island Pool, the excavation of two remnant deposits, and the containment of PCB contaminated dredge spoils at two upland sites (10).

During successive years of legal and regulatory struggle involved in carrying out the demonstration project, continued and improved monitoring of PCB levels in fish, water and sediment has altered perception of the river's contamination problem.

TRENDS IN PCB TRANSPORT

The United States Geological Survey (USGS) in cooperation with DEC has been monitoring river discharge and sediment and PCB concentrations at a number of locations in the upper Hudson since 1977. Methods and results of this program have been detailed elsewhere (11, 12, 13). PCB transport in the upper Hudson results from PCB desorption and resuspension from the sediment bed (11, 14). Desorption produces a water-borne PCB composition enriched in the more soluble and generally less chlorinated PCB compounds (14, 15). The relatively short periods of river discharge that produce significant erosion typically occur during winter and spring. The annual peak PCB concentrations associated with these events are characterized by heavier and less soluble compounds.

Monitoring of PCB transport at four locations in the upper Hudson demonstrated a decline from more than 2,000 kg/y during the late 1970's to less than 1,000 kg/y during the early 1980's downstream of Schuylerville, N.Y. (Figure 3). Variations in annual hydrology appear to account for some of the variability in this trend. The approximately 50 percent increase between 1982 and 1983 is attributable to a single discharge event having an expected return frequency of one in ten years. Transport of PCB during periods of non-scouring discharge, which ranges from 20 to 80 percent of total annual PCB transport, shows a pattern very similar to that presented in Figure 3 (15). The average annual PCB flux for the period 1981 - 1984 at the four monitored locations as a function of river distance from Fort Edward provides some indication of the contribution of PCB by river section to the lower river (Figure 4). During this period, respective annual transport at Fort Edward, Schuylerville and Stillwater averaged 37, 92 and 97 percents of the 756 kg/y transport at Waterford. The 20-km river reach between Schuylerville and Ft. Edward includes the highly contaminated 9-km length of the Thompson Island Pool. Upstream of the Fort Edward sampling location, the remnant deposits and scattered in-river sediment deposits serve as likely sources of water-borne PCB.

Measured PCB concentrations in the upper river downstream of Fort Edward are consistently above the 0.01 μg/L human health based water quality standard for PCBs in surface water. Average concentrations during summer months as recently as 1984 are a factor of ten higher than the standard. Downstream of Waterford, PCB derived from the Hudson River is substantially diluted by discharge from the Mohawk River. Long-term discharge records indicate an average of 42 percent of river flow entering the lower Hudson at Green Island, NY is derived from the Mohawk. There have been comparatively few measurements of water-borne PCB concentrations downstream of the Mohawk since the reduced concentrations do not lend themselves to reliable determination using the methods employed by the USGS. However, PCB concentrations in a limited number of water samples suggest an approximately 50 percent reduction in water-borne PCB concentrations downstream of the Mohawk River.

TRENDS IN FISH PCB CONTAMINATION

DEC has been monitoring levels of PCB in Hudson River fish since 1976 with particular focus on striped bass. Several presentations of the methods and results of that program have been made (13, 16, 17, 18). The results show a clear decline in PCB concentrations in all monitored resident species and striped bass during the 1978-1981 period. The distribution of PCB concentrations in the annual sample of Hudson River striped bass since 1978 are presented in Figure 2. (Since 1978, samples have been analyzed by a single analytical laboratory and data have been judged to be of better quality than earlier data.) PCB concentrations in striped bass samples are more variable than concentrations in samples of resident species apparently due to variations in migratory behavior among other factors (17). For all species, the median of the distribution of concentrations expressed per unit wet weight appears to be a better measure of central tendency than arithmetic average since sample distributions appear to be log-normal rather than normal. However, average concentrations probably better represent the expected concentration in the 10-fish composite sample prescribed by the Food and Drug Administration (FDA) to gage compliance with tolerance levels. Median PCB concentrations in the annual striped bass sample declined from 9.9 µg/g to 2.8 µg/g between 1978 and 1982. During that period the proportion of fish with PCB concentrations below the FDA 5 ppm tolerance limit, in effect at that time, increased from 11 to 75 percent stimulating the development of policy regarding re-opening of the commercial fishery. The recent reduction of the FDA tolerance level to 2 µg/g has resulted in not only the maintenance of the commercial fishing ban for striped bass but its extension to include Western Long Island Sound. Seventy eight percent of the fish in the 1985 Hudson River sample exceed the 2 ppm tolerance level (Figure 3). A continued decline in striped bass PCB concentrations since 1981 is not apparent. Indeed, one could speculate that the apparent increase in the median striped bass sample between 1982 and 1983 is attributable to the known increase in annual PCB transport to the lower river due to a one-in-ten year runoff event during spring 1983.

A strong gradient in fish PCB concentration between the upper and lower Hudson persists with concentrations generally decreasing downstream. This gradient and a declining trend is evident in PCB concentrations in largemouth bass (Micropterus salmoides) collected in the lower Hudson at Catskill, NY and in the upper Hudson at Stillwater (Figure 5) and in the Thompson Island Pool. Average concentrations presented in Figure 5 ranged from 18.7 µg/g in the Thompson Island Pool to 6.7 µg/g at Catskill in 1984 samples. Median concentrations ranged from 16 - 3.2 µg/g over the same reach.

The PCB concentration per unit lipid in yearling pumpkinseed (Lepomis gibbosus) collected during September exhibit little variability at a given location and time appear to be the most sensitive indicator of trends in the contamination of the river's biota (15, 18). In general, there is a significant positive correlation between PCB and fat concentrations in samples of resident fish species (16, 17). Hence PCB concentrations expressed per unit lipid are generally less variable than concentrations expressed per unit wet weight. Figure 6 presents the relationship between PCB concentrations in yearling pumpkinseed collected during September at Stillwater and mean water-borne PCB concentrations in samples collected at Schuylerville and Stillwater during the May - September period which would appear to represent the relevant exposure period. The high degree of correlation evident in Figure 6 suggest that water column PCB concentrations at least reflect fish PCB exposure if not determine fish PCB concentrations. This relationship is consistent with early predictions that a reduction in water-borne levels of PCB would produce a proportional decrease in fish PCB concentrations (8) although the rapid rate of reduction was unanticipated.

PCB DISTRIBUTION IN RIVER SEDIMENT

Natural processes such as the mixing of relatively clean sediment with the more contaminated sediment at the sediment water interface and the depletion of some of the more soluble PCB compounds have likely mediated the expression of remedial actions in producing the observed decline in fish and water-borne PCB concentrations. A suggested chronology of PCB deposition in sediments of the lower Hudson based upon PCB and radionuclide analyses of sediment cores show that surficial sediment PCB concentrations increased from first detectable quantities during the mid-1950's to peak concentrations in 1973 (2). Since 1973, concentrations appear to have declined monotonically (2). Similar profiles have been observed in cores of fine-grained sediment from the upper

Hudson (6, 15). Bopp et al. (2) attribute the 1973 peak and subsequent decline to massive PCB transport shortly following the Fort Edward Dam removal. However, Tofflemire and Quinn (6) attribute this pattern to variations in the industrial discharge of PCBs.

As part of renewed activity on the Hudson River PCB Reclamation Demonstration Project approximately 400 sediment cores and 600 grab sediment samples from the Thompson Island Pool were collected and analyzed during 1984. The results of the survey show both PCB concentrations and unit area PCB masses, derived from the depth integration of PCB concentrations, are highly variable. On the average, correlation between estimated unit area PCB mass at sampling points is limited to distances of less than 12 m (19). The more highly contaminated areas conform with minor exceptions to the previous definition of PCB hot spots developed during 1978 (5,6) with considerably less data. To estimate PCB mass, concentrations were integrated to 0.5, 1.0 and 1.5 m sediment depths, based upon the resolution of core-sample sectioning and dredge controllability. Essentially all (99.91 percent) of the total mass of 23.2 tonnes appears to be above the 1-m depth. Approximately 95 percent or 21.9 tonnes appears to be above 0.5 m in the sediment. Using highly correlated linear relationships between PCB and lead concentrations and between lead and cadmium concentrations, it was estimated that the Thompson Island Pool also contains 76 tonnes of lead and 5 tonnes of cadmium derived from anthropogenic sources.

The recent estimate of 23 tonnes of PCB in the Thompson Island Pool differs significantly from the 1978 estimate of 61 tonnes in this reach. Application of the calculation methods and assumptions employed in the earlier estimate (5) to the 1984 data accounted for a total of 85 percent of the difference between estimates. Much of the difference was attributable to the previous assumption of a 24 in. (61 cm)-thick contaminated sediment layer to which PCB concentrations in surficial sediment samples were applied. Differences in methods used to account for specific weight of sediment in calculations and differences in chemical analysis methods also contributed to differences between estimates (19). The net PCB transport from the Fort Edward-Schuylerville reach, from water monitoring by the USGS, during the water years 1978 - 1984 was 5.8 tonnes.

The new estimate does not warrant a change in the perception of the relative importance of the Thompson Island Pool in the river's contamination which can be gained from monitoring of fish (Figure 5) and water (Figure 3). However, the new estimate warrants reconsideration of previous estimates of the river-wide distribution of PCBs using the calculation methods and data from the late 1970's.

1986 PERSPECTIVE ON THE DISTRIBUTION OF PCBs DISCHARGED TO THE UPPER HUDSON

As previously indicated there is relatively little data specific to the industrial discharge on which to base a reliable estimate of the total quantity of PCB discharged by GE. Applying the 30 lb/d (13.6 kg/d) rate, reported by GE in their 1972 discharge permit application, to 30 years produces a total of approximately 150 tonnes. Several budgets of the PCB distribution resulting from the PCB discharge to the upper Hudson have been developed (6, 20, 21). The largest estimate of total discharge implied by a budget is 610 tonnes.

Table 1 contains a composite of previous working estimates of PCB mass in various locations derived from the GE discharge and a more current perspective. There has been no data collection regarding PCB distribution in the sediment disposal sites subsequent to a 1979 estimate (20) and no apparent reason to alter the estimate of PCB removed from the upper Hudson due to dredging activities. The estimate of PCB quantity in the remnant deposits was reduced from 63 tonnes (5) to 29 tonnes (6) based upon additional sampling although the former estimate is occasionally cited. The current estimate includes approximately 7.7 tonnes of PCB were excavated from the remnant deposits during 1978 as part of remedial activities and transferred to a clay-lined sediment containment facility (6). The 1984 sediment survey resulted in the reduced estimate of PCB in the Thompson Island Pool. In light of demonstrated errors in the methods used in the interpretation of the 1976-1977 sediment survey data, the estimate of PCB contained in the Thompson Island - Troy reach is roughly reduced from 97 to 45 tonnes. The reduction is not proportional to that for the Thompson Island Pool since the contaminated layer height assumed in the earlier calculation (5) does not appear to be as overestimated as that assumed for the Thompson Island Pool.

Estimates of PCB in sediments of the lower river (6) and the quantity transported to the ocean (21) appear to be based upon the analysis of sediment cores from the lower river by Bopp (22). The estimate for transport to the ocean includes dredge spoil disposal in addition to water-borne transport. There are several sources of information on which to base an improved estimate of historical PCB transport from the upper River to the lower river: 1) Aroclor 1242 PCB concentrations from a sediment core collected in 1984 from New York Harbor which provides a good chronology of PCB deposition (23); 2) monitored annual PCB transport to the lower river during 1977 - 1983; and, 3) previous analyses by Bopp et al. (2) which suggest that variations in PCB transport from the upper Hudson are expressed on a time scale of months in the sediments deposited in New York Harbor. Total PCB transport to the lower river was estimated by a proportional calculation that related measured PCB transport during 1977 - 1983 to sediment PCB concentrations in the New York Harbor core during the same period and since 1954. Specifically, total transport was calculated as the product of the PCB mass deposited since 1954 and the ratio of PCB mass transported during 1977 - 1983 to the PCB mass deposited in sediments sampled by the core during the same period. PCB mass in sediment was approximated by the integration of dry weight PCB concentrations provided by Bopp (16). The total of 229 tonnes implied by the revised estimates is in line with one of the earliest estimates of the mass of PCB discharged by G.E. (1).

PLANNED REMEDIAL ACTIONS

The objective of the Hudson River PCB Reclamation Demonstration Project is to reclaim and contain PCB from the bed of the Hudson River and thereby reduce PCB transport and PCB levels in the biota. Of the 23 tonnes of PCB in the Thompson Island Pool, approximately 15 tonnes appear to be recoverable in a limited volume ($\sim$ 500,000 m^3) of sediment. The process of dredge specification currently underway involves optimization of PCB quantity, dredging costs and sediment erodibility variables. In conjunction with the 1984 sediment survey, sediment erosion in 32 sub-reaches of the Thompson Island Pool was projected for several hydrologic events using the U.S. Army Corps of Engineers HEC-6 Model (24) to provide a means of prioritizing areas for excavation.

The exact reduction in PCB transport and fish PCB concentrations that would be achieved by the project over a specific period of time is technically difficult to predict. The difficulty is highlighted by the significant departure of current levels of contamination from the best predictions of deterministic models (7, 8) used several years ago to assess the consequences of no action. However, a perspective of the benefits of the proposed project can be empirically derived. The 9-km length of Thompson Island Pool is the most highly contaminated reach of the Hudson as evident in fish (Figure 5) and sediment (Table 1) PCB data. Water monitoring suggests this reach to be a major contributor of PCB transported annually to the lower river. In the lower river, striped bass PCB concentrations, although reduced from the high levels of the late 1970's, do not appear to have declined since 1981.

The significant decline in both striped bass PCB concentrations and PCB transport to the lower river suggest a greater sensitivity of striped bass PCB concentrations to annual transport from the upper River than earlier thought. Monitoring of fish and water PCB concentrations in the upper Hudson demonstrated reversal in the declining trend in PCB concentrations and transport apparently due to erosion caused by a single discharge event of one in ten year frequency. As a protective action, dredging would not only prevent the eventual erosion or other disturbance of a significant quantity of PCB, but remove larger quantities of heavy metals derived from anthropogenic sources in addition to trace contaminants such as polychlorinated dibenzofurans and dioxins.

Sediments dredged from the river by the Demonstration Project would be transferred to a containment facility that would be designed to comply with the Toxic Substances Control Act. Specifications include two synthetic liners in addition to impermeable soils, leachate detection and collection systems and monitoring wells. Court decisions subsequent to the revocation of a 1982 New York State permit for the proposed facility have clarified the essential requirement of compliance with local zoning and hence community acceptance in siting the facility.

A recently completed evaluation of potential sites for the sediment containment facility identified a geologically well-suited area adjacent to municipal landfills in Fort Edward and Kingsbury, NY (25). These landfills appear to contain several thousand tonnes of PCB. A coordinated negotiation initiated by officials of the two communities resulted in the formal assumption of 75 percent of the towns' court-determined fiscal liabilities for closure of the landfills by New York State. The towns have made no formal commitments to the Demonstration Project. An application for site permits is anticipated for 1986. To comply with a 1984 consent order between EPA and New York, the state permit for the site must be obtained by May 1987 or remaining funds currently authorized for the project will revert to sewage-treatment plant construction funds. Dredging is currently proposed for 1988.

In 1984, EPA awarded 2.9 million dollars from the Federal Superfund to remediate the remnant deposits. Prior to the award, remnant deposit excavation and transfer to the sediment containment facility was within the scope of the Hudson River PCB Reclamation Demonstration Project. Current plans, which have not entered the design phase, would stabilize and cap the remnant deposits. However, it would appear that approval of the sediment containment facility within the next year would permit reconsideration of excavation.

TABLE 1. Fate of PCBs discharged to the upper Hudson River.

Component	Former Estimates (tonnes)		Reference	Current Estimates (tonnes)		Reference
Dredged from Upper River	73	(14)*	20	73	(32)	20
Remnant Deposits	63	(12)	5	29	(13)	6
Upper River Sediments						
Thompson Island Pool	61	(12)	5	23	(10)	19
Thompson Island to Troy	97	(19)	5	45	(20)	19
Transported to Lower River				59	(26)	
Lower River Sediments	77	(15)	6			
Ocean	135	(27)	21			
Total	506			229		

* percent of total

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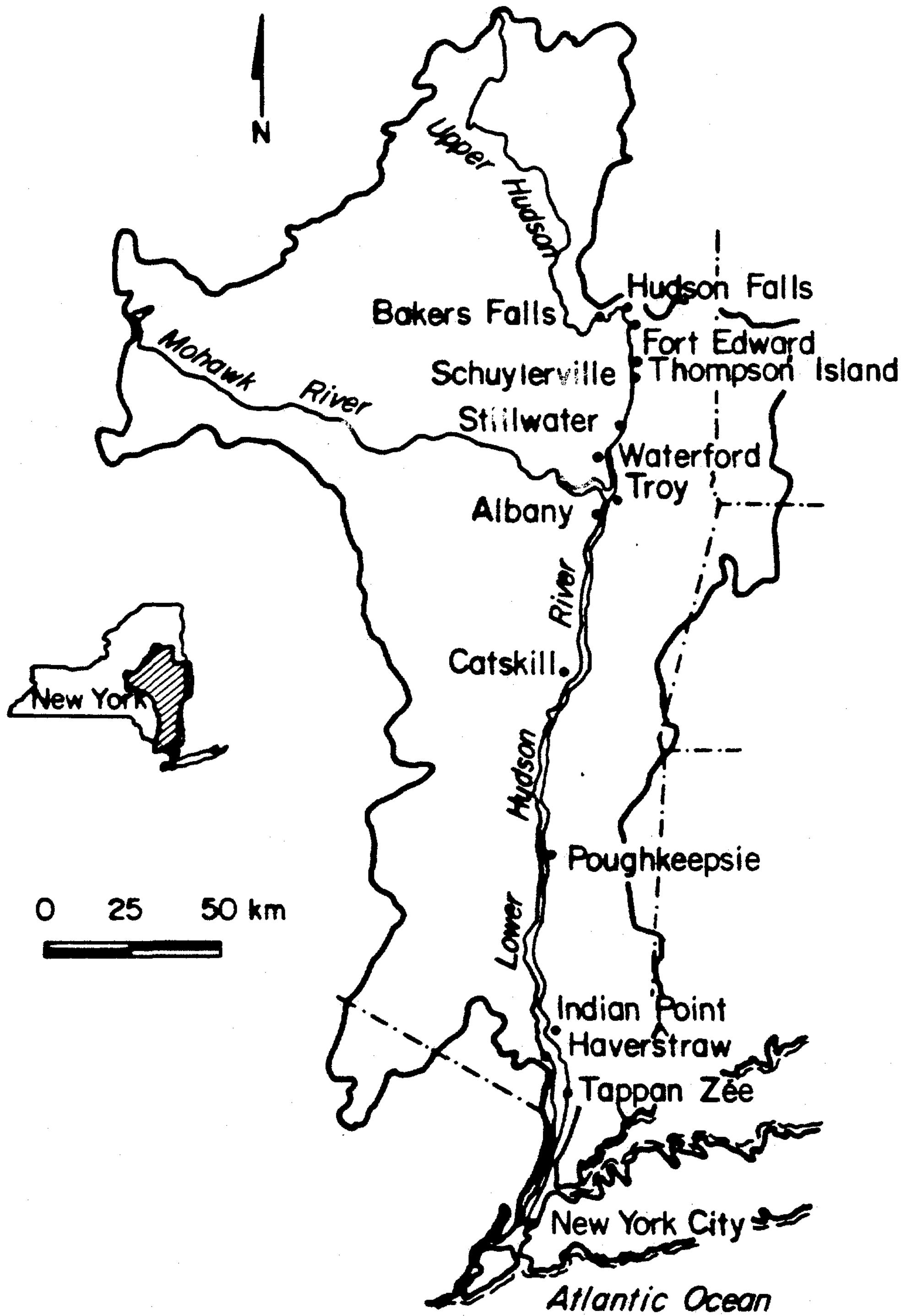

FIGURE 1. HUDSON RIVER DRAINAGE BASIN.

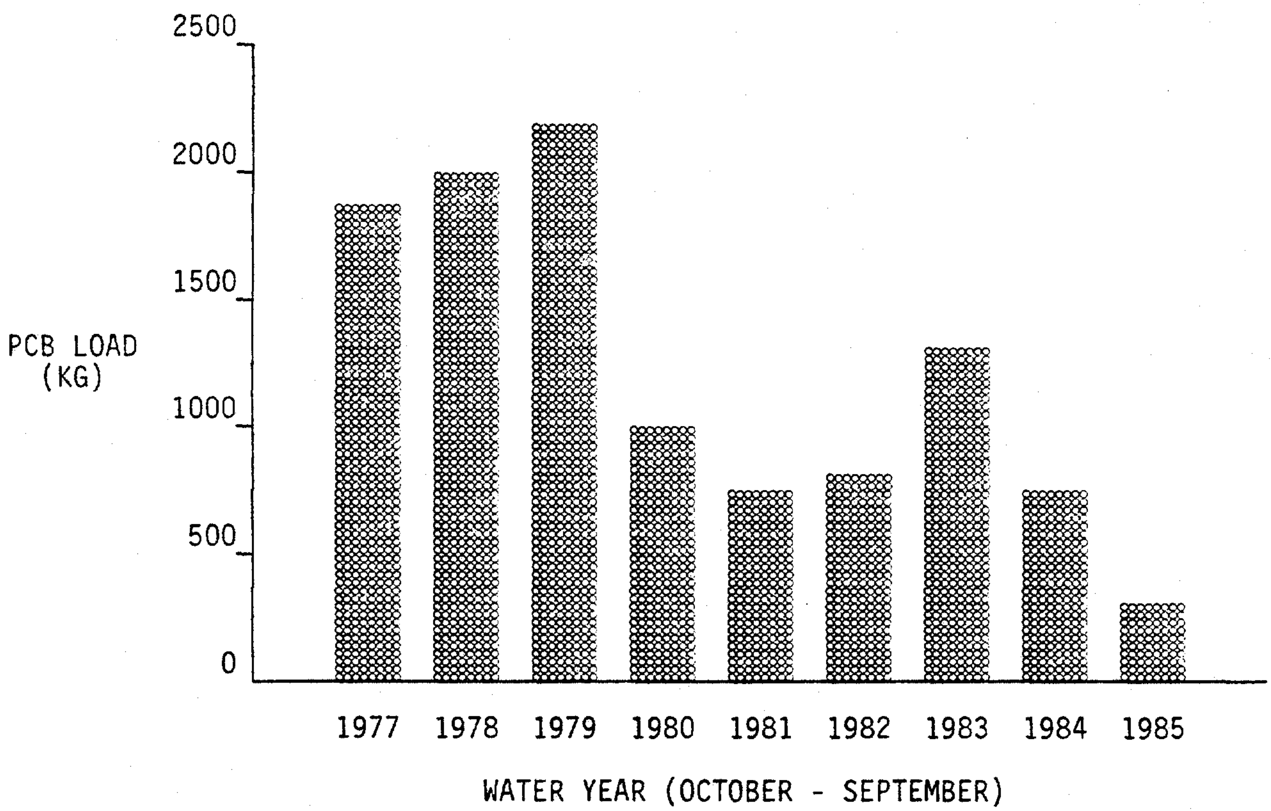

Figure 2. Annual PCB transport in the Hudson River at Waterford, New York. (Figure updated 6/86 to include 1985 water year)

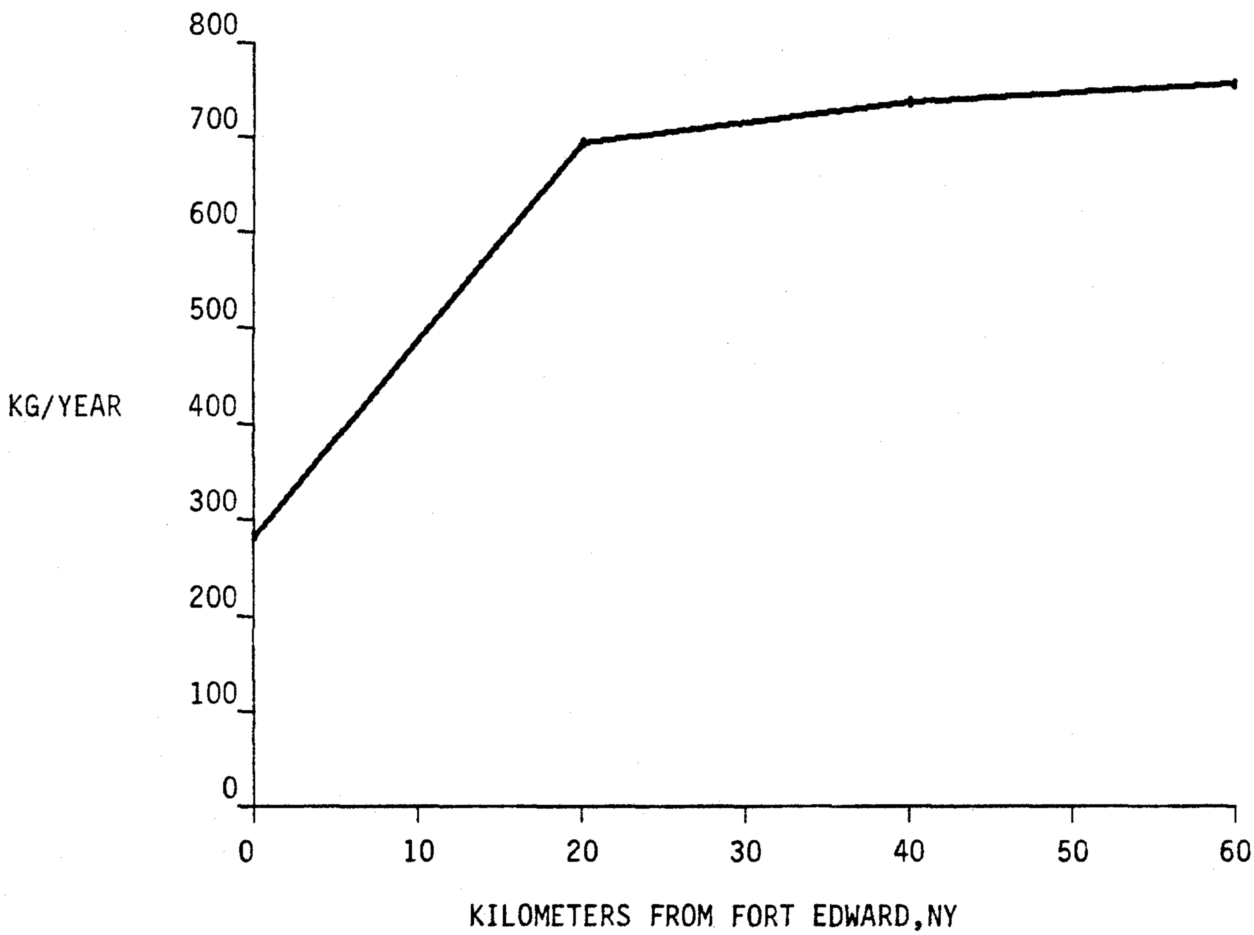

FIGURE 3. AVERAGE ANNUAL TRANSPORT OF PCB IN THE UPPER HUDSON, 1981-1984.

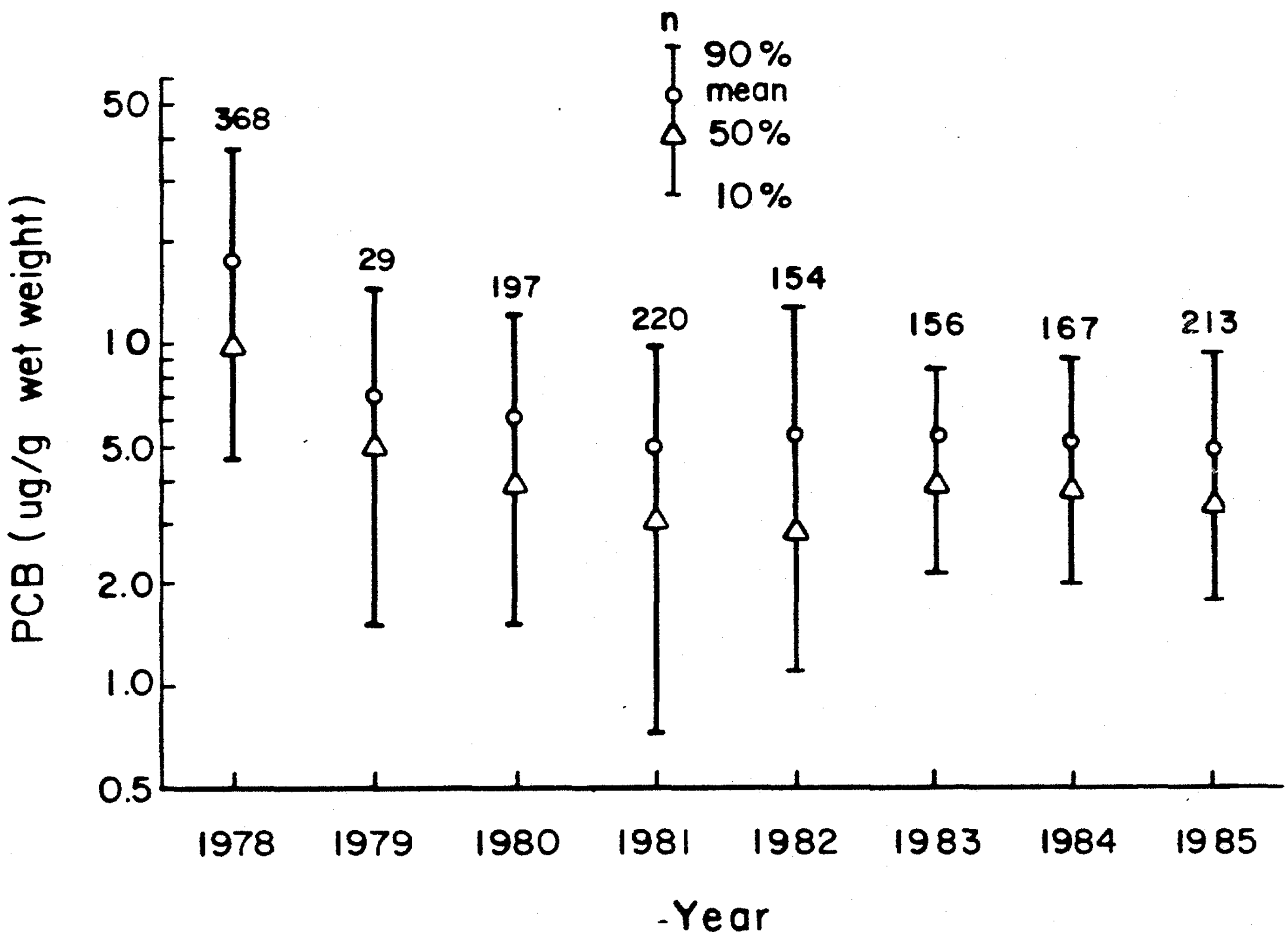

FIGURE 4. DISTRIBUTION OF PCB CONCENTRATIONS IN FILLETS OF STRIPED BASS COLLECTED FROM THE HUDSON RIVER 1978-1984.

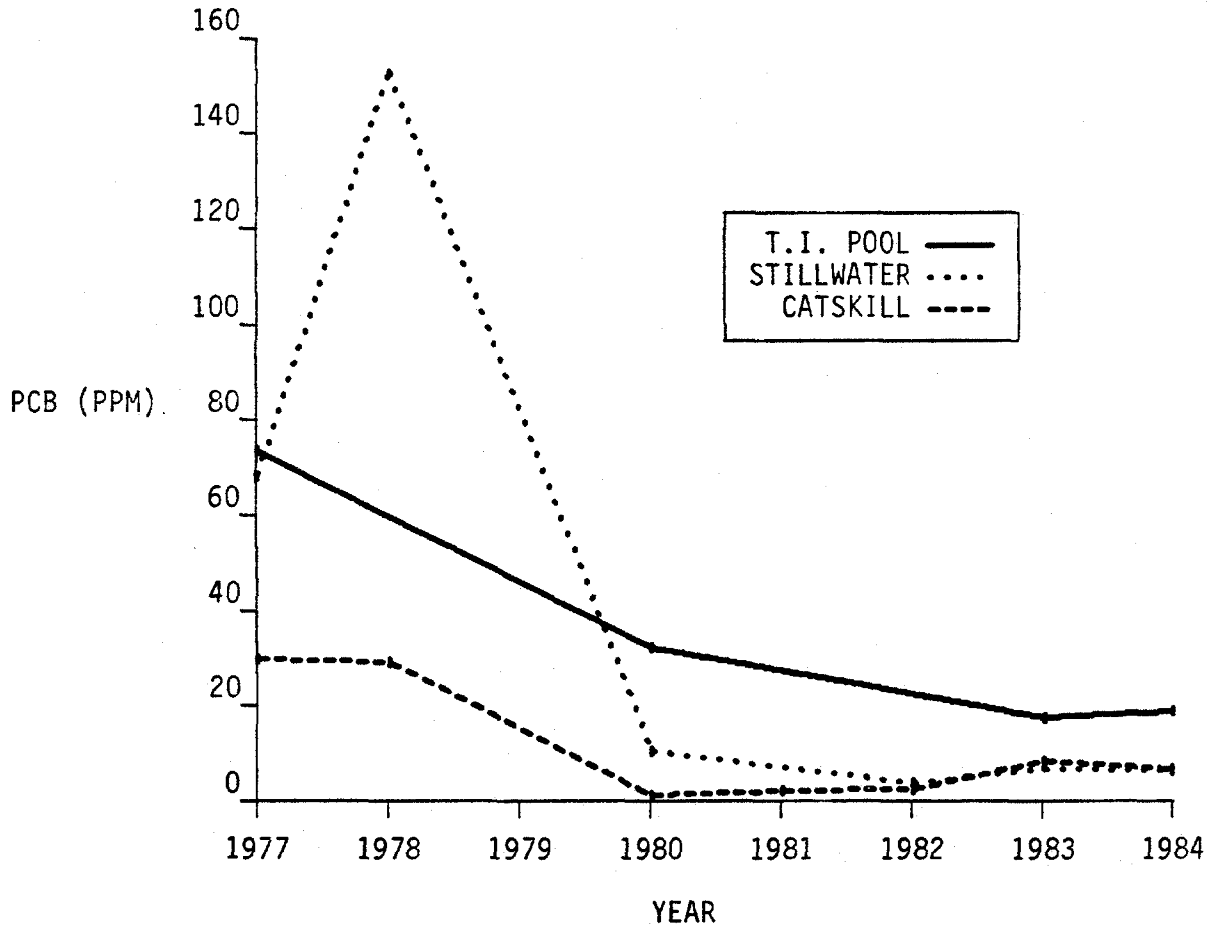

FIGURE 5. AVERAGE PCB CONCENTRATION IN LARGEMOUTH BASS COLLECTED AT THREE LOCATIONS IN THE HUDSON RIVER.

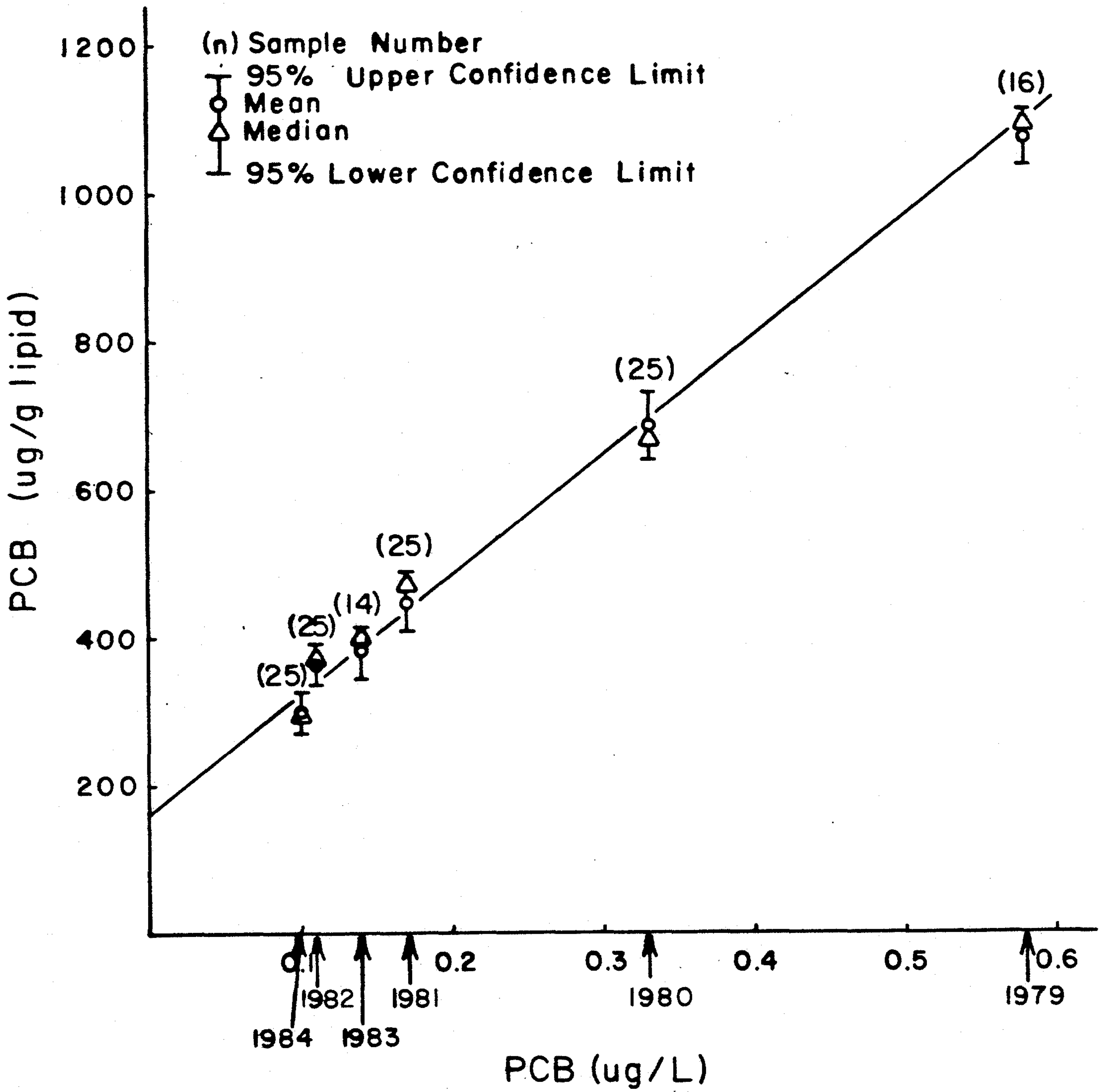

FIGURE 6. RELATIONSHIP BETWEEN SUMMER MEAN PCB CONCENTRATIONS IN WATER AND LIPID-BASED PCB CONCENTRATIONS IN WHOLE YEARLING PUMPKINSEED COLLECTED SEPTEMBER 1979-1984.

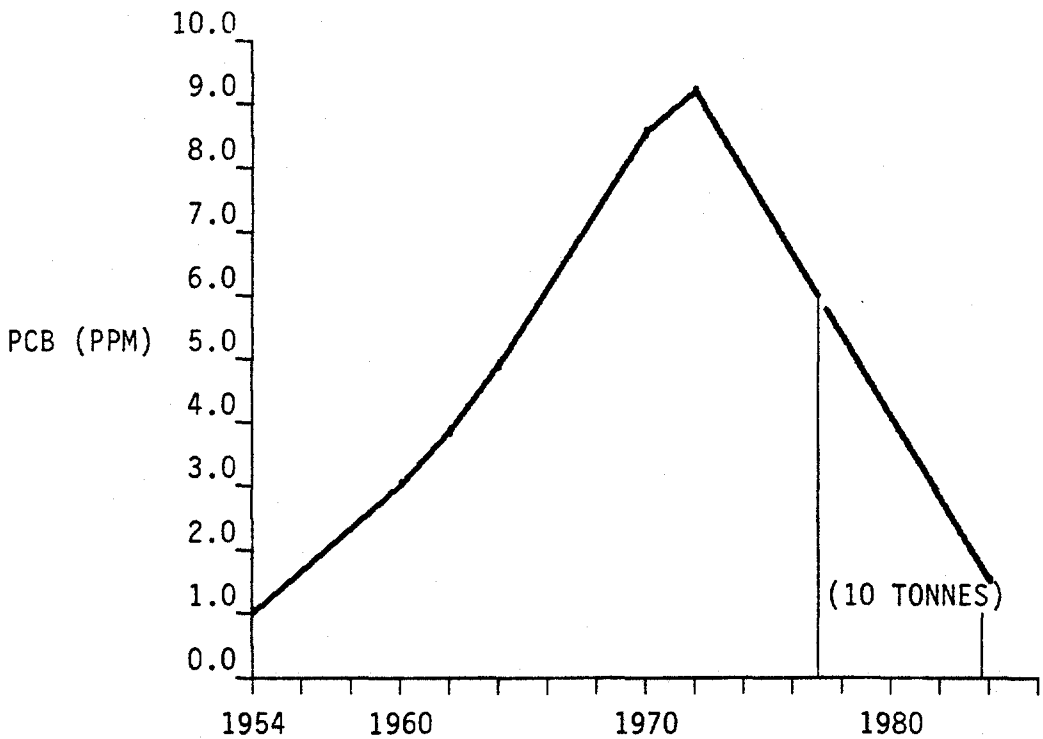

FIGURE 7. CHRONOLOGY OF AROCLOR 1242 CONCENTRATION IN NEW YORK HARBOR SEDIMENT (21) USED TO ESTMATE THE TOTAL MASS OF PCB TRANSPORTED TO THE LOWER RIVER BY PROPORTION WITH MONITORED TRANSPORT (10 TONNES) 1977-1983.