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Mr. Douglas Tomchuk
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26 Federal Plaza
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Dear Mr. Tomchuk:

Enclosed please find a report abstract of my review of the historic data of upper Hudson discharge - sediment - PCB relations, as was mentioned at the last STC meeting in Latham, NY.

Except as noted, the illustrations used are from a masters thesis in preparation by Mrs. Laura Smith of the State University of New York at Albany. Unless you indicate otherwise, I will provide a copy of the enclosed to STC Chairman William Nicholson. Please advise if additional copies should be sent to other parties.

If you have any questions or need more detail on any aspect of the enclosed, please let me know. I can be reached most efficiently at the letterhead address and phone, rather than at SUNY Albany.

Very truly yours,

George W. Putman

George W. Putman

Discharge-Suspended Sediment - PCB transport in the Upper Hudson; Comments on 1978-1992 Data.

The following is a summary of the significant findings from my perspective.

I. PCB Concentrations in the River

The highest total PCB concentrations (μg/ℓ) measured in raw water samples have come from the Ft. Edward monitor station, and in upstream sampling by G.E. (see Figures B.3-8 to 11, and B.4-10, 4-11, from the Phase I Report, August 1991; G.E. 1992-93 data of O'Brien and Gere; U.S.G.S. provisional data 1992-93). The highest concentrations measured in any river water samples, in fact all came from Ft. Edward (9 and 25.7 μg/ℓ, 1984; 77 μg/ℓ reported Figure B.4.10; 11.0 μg/ℓ in U.S.G.S. provisional data, 4/29/93). This data usually does not appear on PCB vs. discharge or time plots because it is off scale.

These erratic high concentration "pulses" are considered to represent the presence of free phase PCB emulsion or droplets; they also indicate a primary PCB source location.

High flow events especially in 1979, 1983, and 1987 are generally reflected in increased PCB contents at all monitor stations (Ft. Edward, Figure B.4-10; Schuylerville, Stillwater, Waterford); however, the highest contents at low flow are presently also observed at Ft. Edward and in upstream sampling.

Sampling at Ft. Edward is complicated by the presence of two river channels, and the variability in PCB source and upstream distribution recently described by the G.E. Company (See also Tofflemire, 1984). These factors are also a potential source of sample bias in comparisons of PCB concentrations with results from downstream monitor stations.

Other sources of bias among all stations are noted below.

II. PCB Sampling Bias and the Comparison of River Stations

Much has been made of the increased transport of PCB during high discharge (flow) events and the presumed threat of sediment scour in "hot spots" as a factor in producing elevated PCB loading. To examine this the estimated PCB transport rate (PCB concentration x mean discharge, or instantaneous discharge if available) is plotted vs. discharge at the four stations in Figures 1 and 2 (USGS data). While PCB transport may increase with discharge, there is much scatter, especially in the 1984-1989 water year data. Note that in 1983, a 50 year high discharge event (USGS), the indicated PCB transport rate at Stillwater and Waterford (1.5-2 g/s) was higher than at Schuylerville and Ft. Edward (< 1g/s). 1984 was marked by a series of winter-spring discharge events, none of which were particularly large - yet the above relation is reversed. A similar loading trend that consistently decreased downstream was derived from the high discharge event of April 1-2, 1987 (see notation on Figure 2).

An essential piece of information in assessing this data, as well as various estimates of annual PCB loading, is some idea of the inherent variability of the PCB statistic. Unfortunately, no direct test is available, but what information there is sounds a clear note of caution and is consistent with part I above. In the period 1981-1984 the U.S.G.S. collected multiple water samples at all stations during several high discharge events. The sampling was designed to follow the same stage of the discharge downstream, and was performed over several days at each station. According to my information, depth integrated samplers were used so as to represent the entire water column at the point of sample collection.

The most extensive data comes from the Stillwater station where 15 samples were collected during the April 18-20, 1982 spring high discharge event. The PCB concentrations, or derived loadings, are variable over a range of 0-1.2 g/s as shown on Figure 3. Moreover, this variation is unsystematic, i.e. there is no regular pattern in the change of values with time (Figure 3B). The variation in suspended sediment concentration (mg/ℓ) is also very large, but is systematic. Observations on April 18 record the rise cycle of the discharge event and the peak of suspended sediment concentrations. On April 19 the peak of the discharge is reached while sediment concentrations are falling rapidly, i.e. the sediment discharge peak precedes the river discharge peak. On the upper Hudson this is typical behavior during high flow events, as is the sharp rise and fall in the sediment content relative to the river discharge.

Observations at other stations and for other events are fewer but show patterns comparable to Figure 3, including the variation in PCB contents (e.g. Schuylerville, Feb. 21, 1981; 4 samples analyzed for PCB).

While higher PCB loadings are certainly more probable during high discharge events, these loadings are erratic and appear to occur as "spikes" or pulses during the event. Under these circumstances most of the recorded data cannot be used to compare intervals between stations as to sources of PCB loading, or to make accurate estimates of annual loadings. Single samples on a daily basis, even if composited, are simply unreliable as estimators of PCB loading during high discharge.

Another bias factor in comparing PCB loadings between stations arises from differences in the timing and frequency of sampling between stations. This is especially true in comparing 1978 and 1979 data for Ft. Edward and Schuylerville in Figure 1. The 1979 high discharge event was the second largest in the 1978-1992 period, but sampling at Ft. Edward was less frequent and late relative to the discharge peaks as compared to Schuylerville. The apparently higher 1979 PCB loadings at Schuylerville have been cited as an indication of a Thompson Island PCB hot spot source, but this may largely be an artifact of the sampling.

Timing of sampling during the 1983 event was better, and there is no real difference in the apparent PCB loading ranges of the two stations (Figure 1); still, Schuylerville was sampled 15 times while only 8 were taken at Ft. Edward.

Results of recent and much more extensive sampling by the G.E. Company at Ft. Edward and upstream (1991-) are consistent with the above remarks and part I. Erratic PCB loading "pulses" are evident, and although overall PCB release during the summer season may recently have increased, similar behavior at low flow in the past is seen in the data of Figures 1 and 2, i.e. random PCB loadings of 1-2 μg/ℓ or 0.1-0.2 g/s (or greater) at a discharge <200cm/s at Ft. Edward (see also Tofflemire, 1984).

Prior to about 1981, the data at low flow conditions does suggest that additional PCB loading occurred in transit of the Thompson Island pool. This can be explained as a desorption effect from contaminated surficial sediment relative to flow path length, and does not require an additional primary PCB source below Ft. Edward. Since 1983, there has been little difference in the apparent low-flow PCB loadings between Ft. Edward and Schuylerville, suggesting little or no further contribution from sediments transported into the Thompson Island pool from the remnant deposits area in the high discharge events of 1976 and 1979 (the remnant deposits were largely stabilized before 1983). The low flow data, however, is still subject to the same sample bias as that cited for the high discharge events.

The increased sampling in the Ft. Edward area since 1990 helps to define the nature of PCB loading at a primary source. The USGS has also increased the frequency of sampling at the Ft. Edward, Stillwater, and Waterford stations beginning in 1992, but better coordination with the G.E. sampling is needed to maximize the use of this data in interpreting downstream PCB loading in response to variations at Ft. Edward. An analysis of short term variance in PCB contents is also needed since little information is available at sampling intervals of less than one week.

Subject to the limitations noted above, the available data does suggest that PCB loadings passing Ft. Edward can account for those observed downstream, and that loadings may decrease downstream. Some specific examples:

Date and PCB concentrations (μg/ℓ)

Ft. Edward		**Stillwater**	**Waterford**
G.E.	**USGS**	**USGS**	**USGS**
9/3/92 - 0.37	9/4/92 - 0.16	9/4/92 - 0.10-0.12*	9/4/92 - 0.06-0.10*
9/23/92 - 0.94	9/25/92 - 0.20	9/25/92 - 0.10	9/25/92 - 0.06
7/24/92 - 0.33	7/22/92 - 0.43	7/22/92 - 0.14	7/22/92 - 0.06
6/18/92 - 0.16	6/19/92 - 0.11	6/19/92 - 0.19	6/19/92 - 0.06
7/8/92 - 0.20	7/10/92 - 0.10	7/10/92 - 0.18	7/10/92 - 0.07

Notes:

G.E. samples collected from the west channel, except 9/23/92 is a composite of both channels.
U.S.G.S. data for 1992 is provisional and not released for publication. The sampling procedure at Ft. Edward is not stated.
* Range of 5 samples, this date.

Closer timing of the G.E.-USGS sampling at Ft. Edward is obviously desirable, but the trend of higher values in the G.E. analyses vs. the USGS results is general and needs to be resolved. This is also an illustration of my remarks at the end of section I. The data cited above must be factored with the discharge to derive PCB loadings on a given date, but the general trend is the same.

III. Sediment Transport, River Hydrology, and PCB Loading

The second part of the statement made at the start of section II involves the relations between sediment source and sediment transport with river discharge and PCB loading. Plots of suspended sediment concentration vs. PCB concentration at the four stations are shown in Figures 4 and 5. If sediment scour and resuspension is a major source of PCB at high discharge then some correlation should be observed at one or more stations; however, none is seen.

Admittedly, this may be a simplistic view but considerations of PCB partitioning effects between water and sediment, and the PCB congener distribution patterns in various media, leave little room to expect that no relationship should exist.

Sediment characteristics and distributions in the upper Hudson have been described in some detail in reports by Tofflemire and Quinn (1979; NYSDEC), and Barnes (1987; USGS), among others. In high discharge events suspended sediment concentrations increase markedly downstream, with the largest increases normally recorded at the Schuylerville and Waterford stations. These stations are downstream of the mouths of the Battenkill and Hoosic Rivers, respectively; two of the largest tributaries to the upper Hudson. The overall sediment character in the Hudson changes accordingly, becoming much finer grained below Schuylerville.

An illustration of suspended sediment behavior during a high discharge event was previously cited in Figure 3. Another example is shown in Figure 6 (Schuylerville, April 1982). Suspended sediment loading peaks which precede the river discharge peaks are evidence of a derivation from tributaries; sediment which is declining while the discharge peaks is very unlikely to be a result of scour and resuspension in the Hudson itself (in this context the Hudson above Ft. Edward can also be considered a tributary).

Another important feature of sediment-discharge relations is shown in Figure 7 (Schuylerville spring cycle, 1979). The time scale is compressed on this plot and only daily mean sediment and discharge trends are shown (which tends to make the peaks coincident). Suspended sediment peak concentrations decline during this three-event high discharge cycle, reaching the lowest proportion in the last, and maximum, event which ranks #2 in the period 1978-1992. Needless to say, this is not consistent with a sediment source by scour in the Thompson Island pool, but is consistent with a depletion of available sediment in the tributary watersheds. PCB loading in this cycle is erratic and sampling is obviously inadequate. Note that one sample during the discharge maximum recorded no PCB.

It should be clear that this discussion refers to suspended sediment, and not to reported features of bottom sediment transport, disturbance, and channel scour, e.g. as inferred in the side-scan sonar imaging. The integrated water column sampling used for the suspended sediment and PCB analyses is not representative of the river bed load and surficial sediment zone, or of dynamics therein. The extent or distribution of disturbed/eroded sediment features in "hot spot" areas is largely unknown. Nevertheless, the mass of hotspot sediments are in depositional settings, and sediment disturbance/redeposition features were not reported to be significant in the extensive sediment core surveys conducted by Tofflemire and Quinn (1977-1979).

PCB in river sediment may be acquired or incorporated directly from water column transport as a free phase, it may be deposited as contaminated sediment transported from an upstream source (e.g. wood chips and and sawdust), probably it can be directly adsorbed from the water column at the sediment-water interface, dissolved or free phase PCB may also be adsorbed on suspended sediment which settles out, and finally it may be a component of incorporated residual organic matter.

Except for desorption loss or transport of contaminated sediment, these mechanisms act to produce a net removal of PCB from the water column. Sustantial discharges of suspended sediment from the tributaries may in fact act as significant PCB "sinks" in this regard. In spite of the problems of obtaining representive samples, the overall results of Figure 2 and recent data (e.g. Part II table) suggest this may be the case when loading at Waterford is compared to that upstream.

IV. Limitations on Monitoring PCB Loading vs. the Discharge Cycle

In this reassessment action, considerable thought has been given to water column sampling during high and low discharge conditions as embodied in the present study plan, and to attempt to model river flow extremes so as to assess the risk of PCB loading via scour and sediment resuspension.

Problems of sample bias, unstable statistics, and sediment dynamics have been cited in previous sections, but a basic limitation remains in any sampling plan facing temporal variation. This can be illustrated with the aid of Figure 8, which is from the Mississippi River but has general application. The flow velocity pattern is typical, as is the more than 2x velocity range.

The asymmetric suspended sediment pattern resulting from lateral introduction possibly is analogous to the case of PCB discharge from the east bank at Hudson Falls as documented by the G.E. Company (see also Tofflemire, 1984). At Ft. Edward there is the added complication of two channels with cross section bias to be integrated in the sampling (Tofflemire, 1984). Reference to Figure 8 also illustrates the difficulty of obtaining representative water column sampling at one point, even with an integrated sampler, or by using transect samples at fixed depth (which is a horizontal integrated sample). This is a potential limitation for the flow-averaged sampling plan described in the phase 2 Work Plan.

Sampling bias of this nature, which can be called cross section bias, will be most acute in approaching a point source which is asymmetrically located, and will lessen with downstream flow dispersion. Downstream flow, however, introduces a flow bias due to the differential velocity distribution that becomes more acute in the case of an erratically discharged component from a point source. This is the basic problem in atttempting to sample high discharge events to compare PCB loadings at different monitor stations. Timing the event by peak discharge or dye travel does not alter the fact that it is impossible for a given cross section package of water at one point in time to remain intact with downstream flow.

The flow-averaged sampling plan of the Phase 2 Work Plan is a reasonable approach if representive cross section sampling can be assumed - a big "if", particularly in the case of the Ft. Edward station. An analysis of variance is still needed, however, to define the confidence level of the PCB loading statistic using the given sample interval and total number of samples.

V. Summary of Conclusions

1) Much of the existing data on PCB loading among the upper Hudson monitor stations is subject to various sources of bias and cannot be used to infer sources of PCB between stations at high or low discharge, at least after 1983. This limitation applies as well to the Thompson Island pool in relation to PCB loading at Ft. Edward.
2) Regardless of sample bias, the highest recorded PCB concentrations and loadings have occured at Ft. Edward. This is an unstable statistic, however, because of erratic and short term pulse-like discharge at the source. Recent work has improved the definition of this source, but an analysis of variance and better coordination of monitor station sampling is needed to optimize data interpretation.
3) The available data suggest that suspended sediment transported in high discharge events is mainly derived from tributaries, notably the Battenkill and Hoosic Rivers. There is no correlation between suspended sediment concentration and PCB loading, to suggest that scour and resuspension of upper Hudson sediment below Ft. Edward was a significant factor in any high discharge event of record (1978-1992). However, this method of sampling suspended sediment provides no information about bedload or bottom sediment behavior in these events.
4) The sampling strategy outlined in the Phase 2 Work Plan is an improvement over past procedures, and should prove adequate for most of the parameters cited in the rationale. However, neither the transect or flow averaged sampling is free of sampling bias in respect to comparisons of PCB loading between stations. This is because of cross-section and flow velocity (temporal) variation in the river during downstream discharge. Without an analysis of variance, the error statistics of each sampling procedure are unknown. In particular, how are these procedures to be applied at the Ft. Edward station?

5) Data obtained since 1990 (with a greater sampling frequency) suggests that PCB loading passing Ft. Edward is adequate to account for all downstream loading, and no mass contribution from a downstream source(s) can be resolved. Congener specific analyses may permit better resolution, but until the Hudson Falls - Ft. Edward source is removed or shutdown, and subsequently tested, it is pointless to consider remediation action elsewhere. For example, desorption of partially altered PCB may add to low flow loading from the Thompson Island Pool, but the ultimate source could still be PCB discharged above Ft. Edward that is adsorbed or incorporated in surficial sediment deposited in the previous high discharge cycle.

6) The premise that a significant risk of scour of the hot spots exists at high discharge is not supported by the available data. I am concerned that any meaningful model of scour at high discharge can be made and calibrated in the absence of an actual determination of the flow velocity pattern - discharge relations, and a better knowledge of total sediment distributions. Even with such data as can be realistically obtained in the time frame of this reassessment, I question whether the confidence level of model predictions will be adequate for any decision to take remediation action elsewhere than above Ft. Edward.

I do not think potentially available empirical data that bears on the question of erodability at high discharge has been sufficiently searched. The 100 year discharge event of 1976 passed over the Thompson Island hotspots potentially subject to erosion. If erosion occurred, then a depositional truncation or gap in sediment chronology would exist in respect to subsequent sedimentation. The 1976 boundary was depositional, not eroded, in the cores studied by Tofflemire and Quinn (1979). As an alternative to modelling, this work could be expanded in the Thompson Island pool via high resolution coring.

George W Putman

George W. Putman
November 22, 1993

References Cited

Barnes, C. (1987) PCB Transport Rates in the Upper Hudson River, New York, 1977-83 (with USGS Addendum to 1985 Data); Northeastern Environmental Science; v. 6, #1, p. 31-36.

Tofflemire, T. (1984) PCB Transport in the Ft. Edward Area; Northeastern Environmental Science, v. 3, #3/4, p. 202-208.

Tofflemire, T. and Quinn, S. (1979) PCB in the Upper Hudson River: Mapping and Sediment Relationships; NYSDEC Technical Paper No. 56, April.

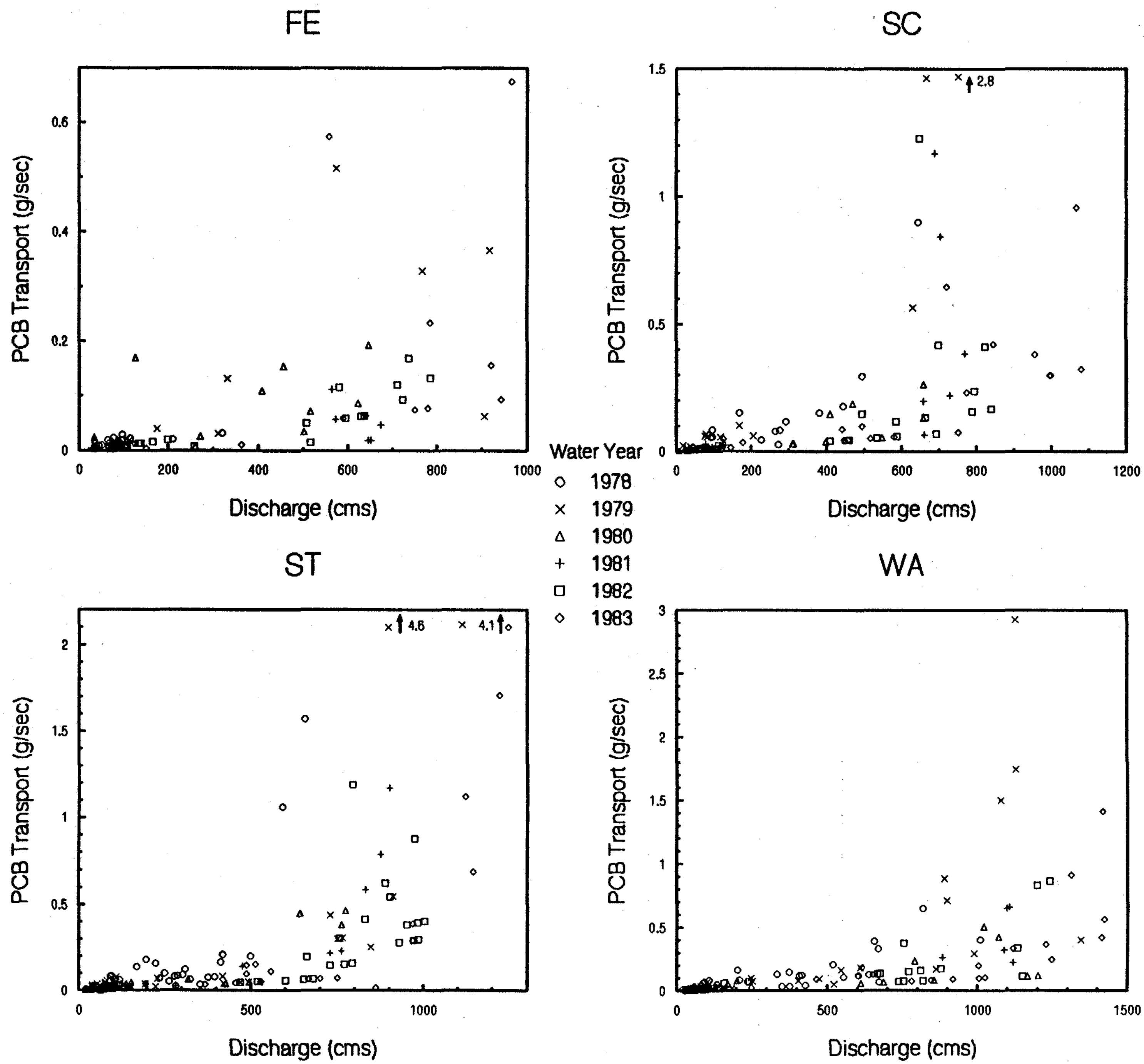
U. S. Geological Survey: Water Resources Data, New York, vol. 1, Water Years 1978-1992.

Illustrations

Figures B.3-8 to 11, and B.4-10,11 are reproduced from the USEPA Phase I Report, August 1991, Vol. 1, book 2.

FIGURE 1.

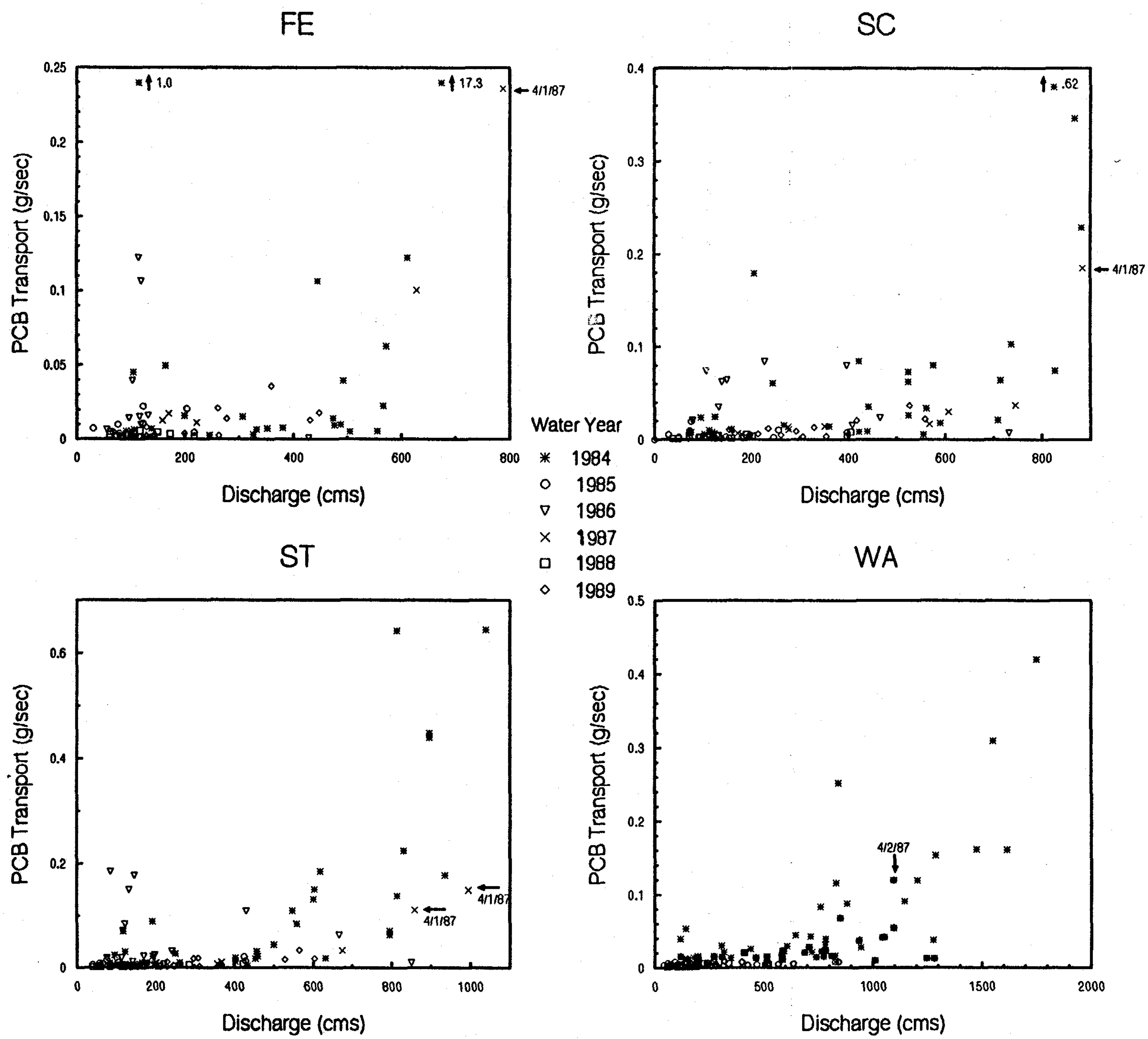
PCB Transport versus Discharge 1978-1983



10.11657

FIGURE 2.

PCB Transport versus Discharge 1984-1989



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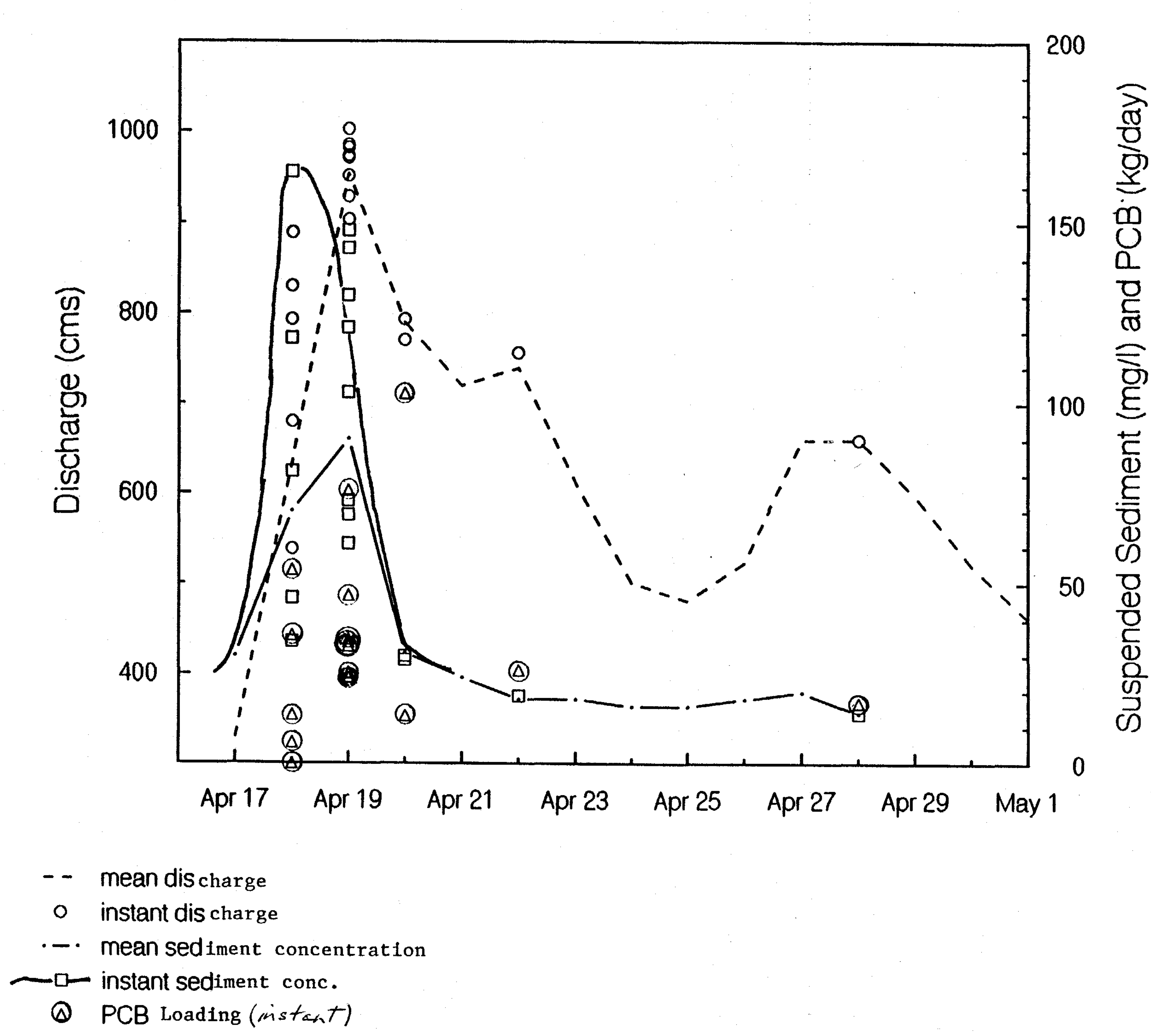
F..URE 3A

Stillwater 1982 B



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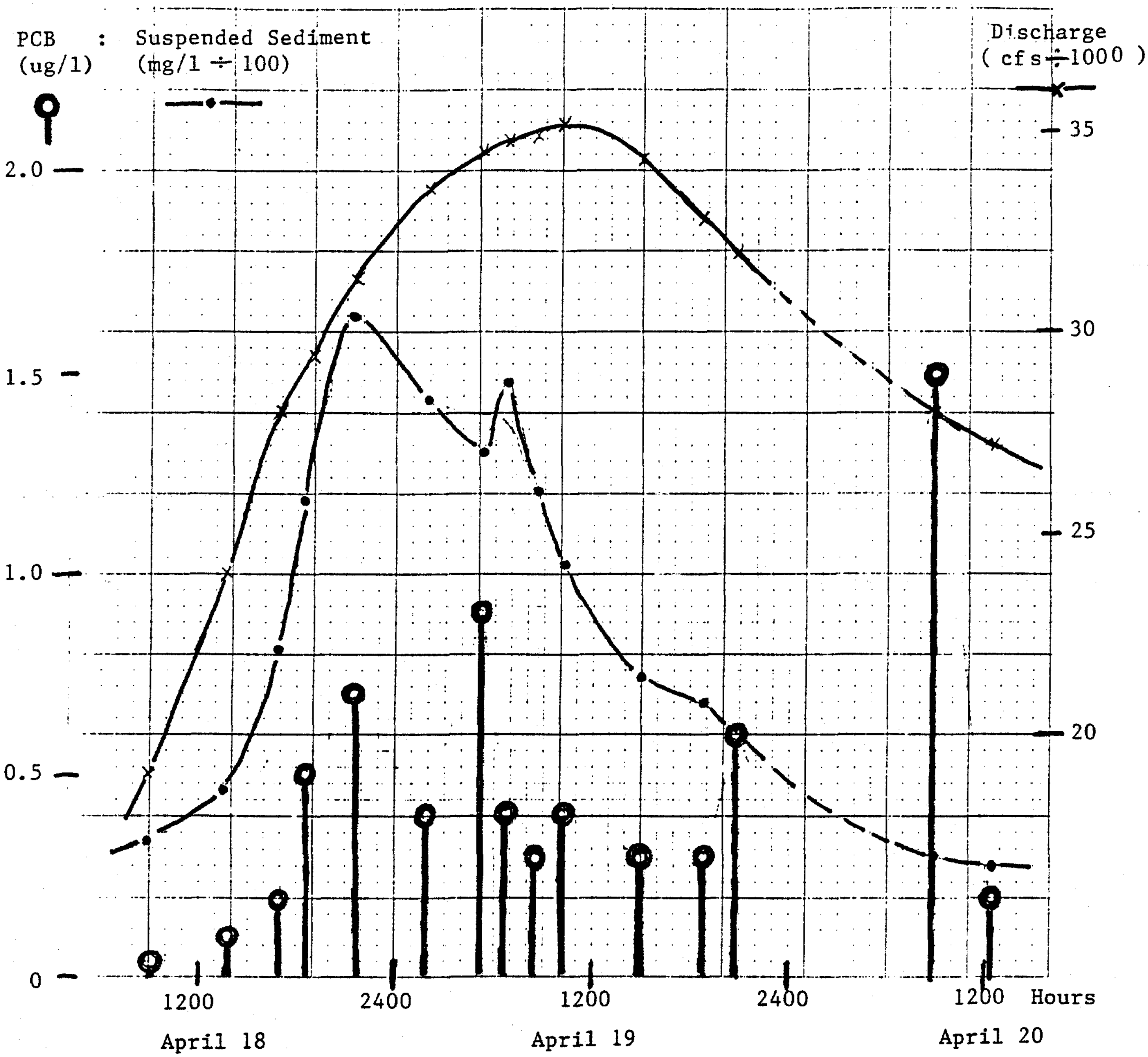
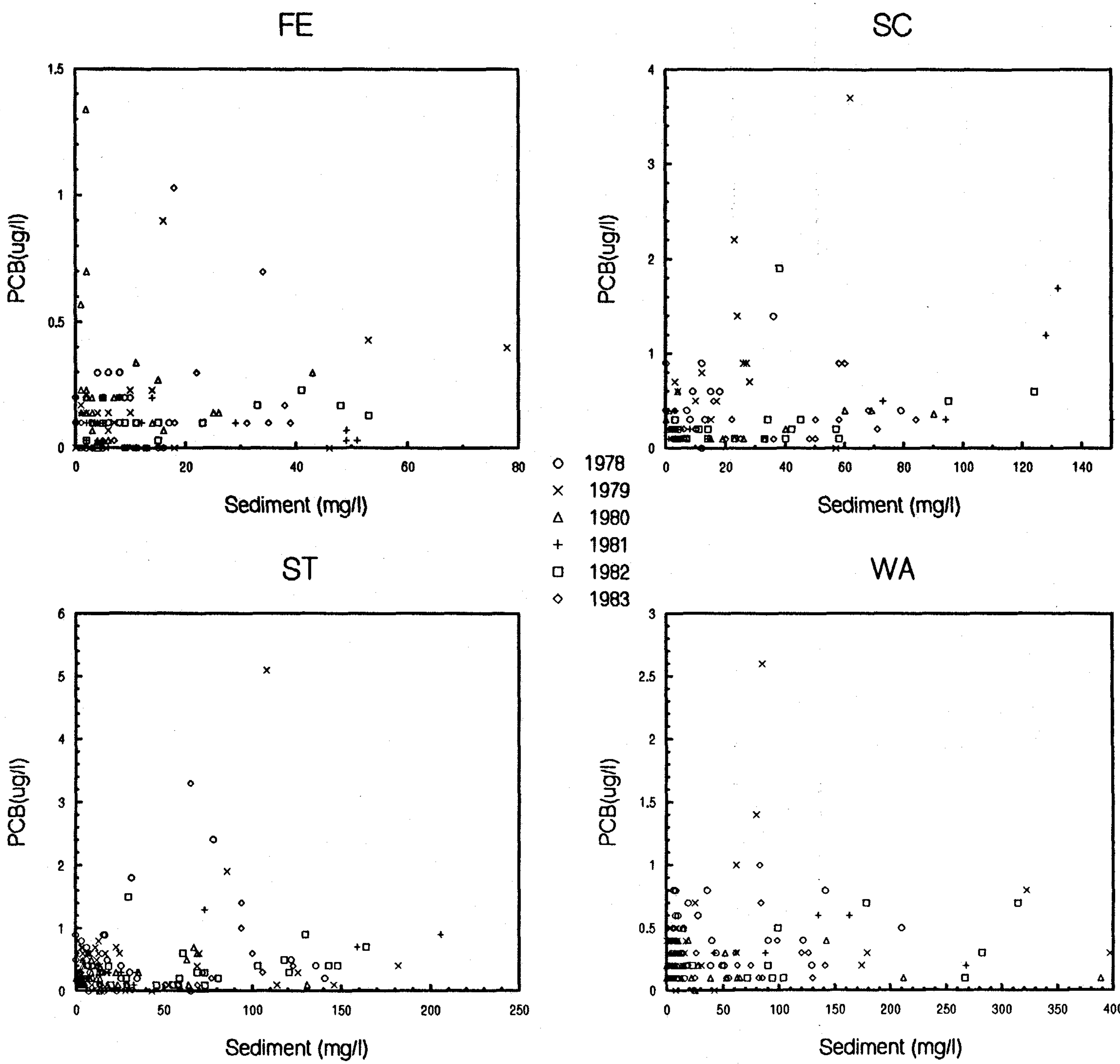


FIGURE 3B. Discharge (cm/s), Suspended Sediment (mg/1), and PCB (ug/1) Relations at Stillwater, NY, April 1982

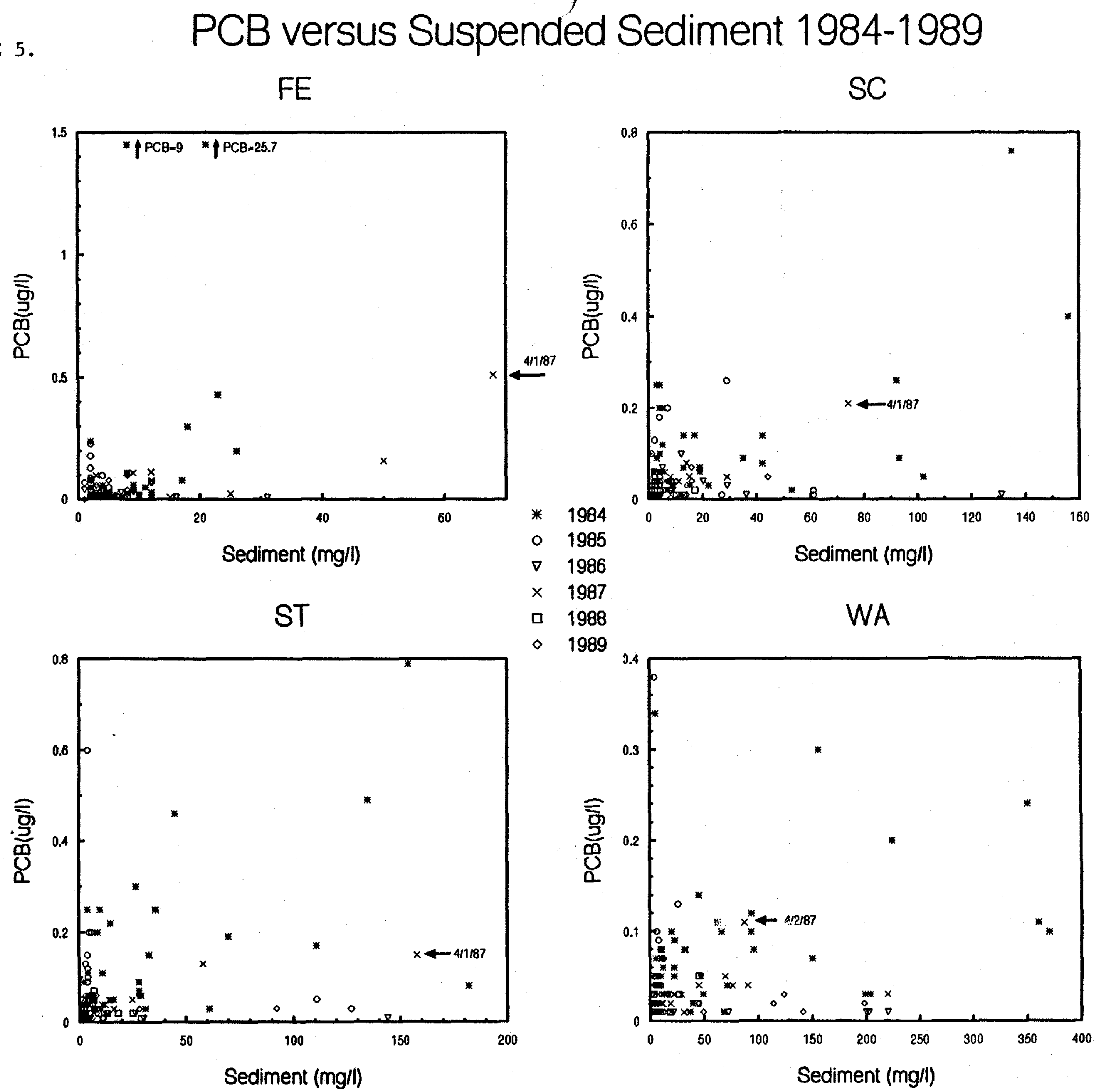
FIGURE 4.

PCB versus Suspended Sediment 1978-1983



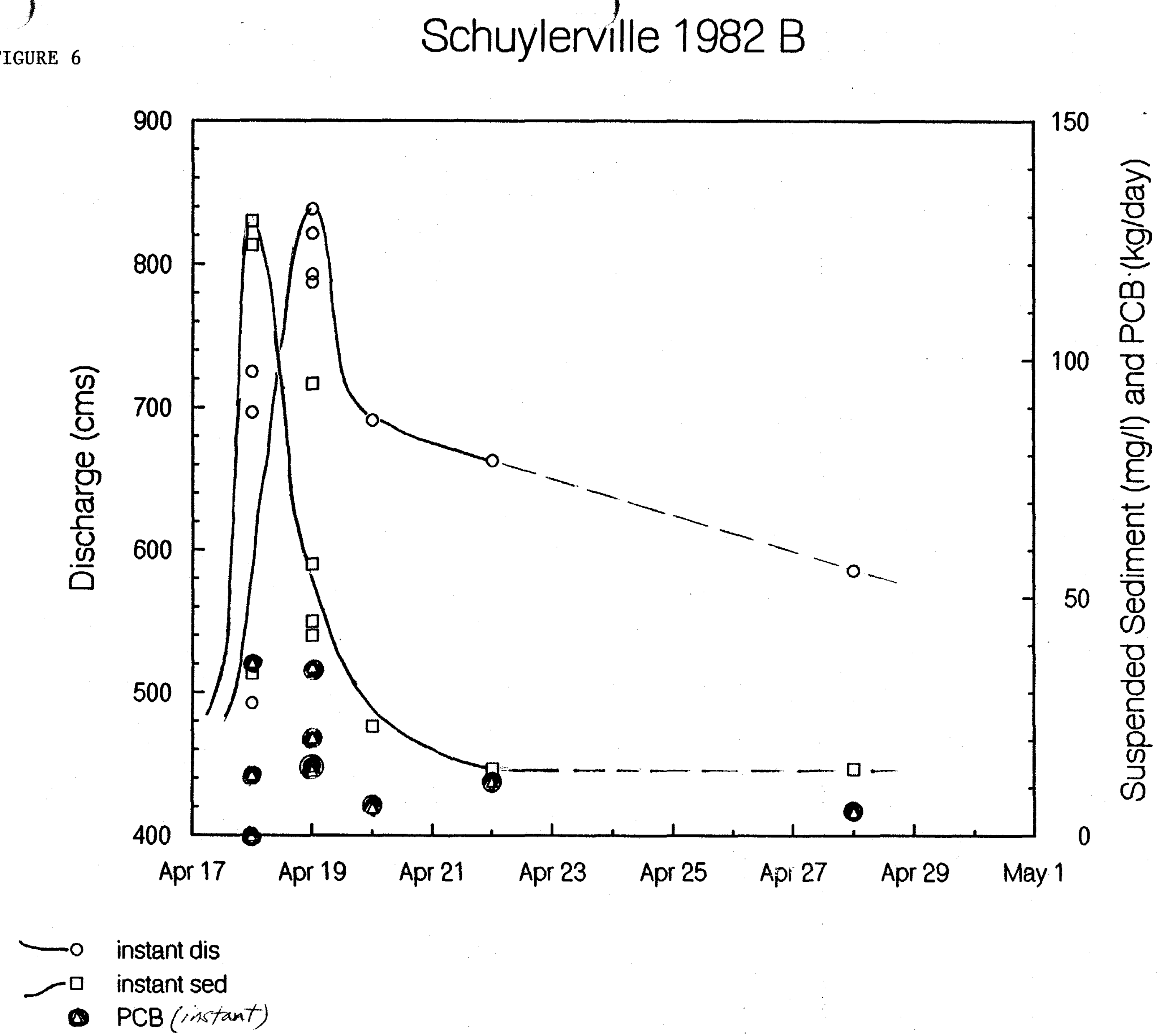
10.11661

FIGURE 5.



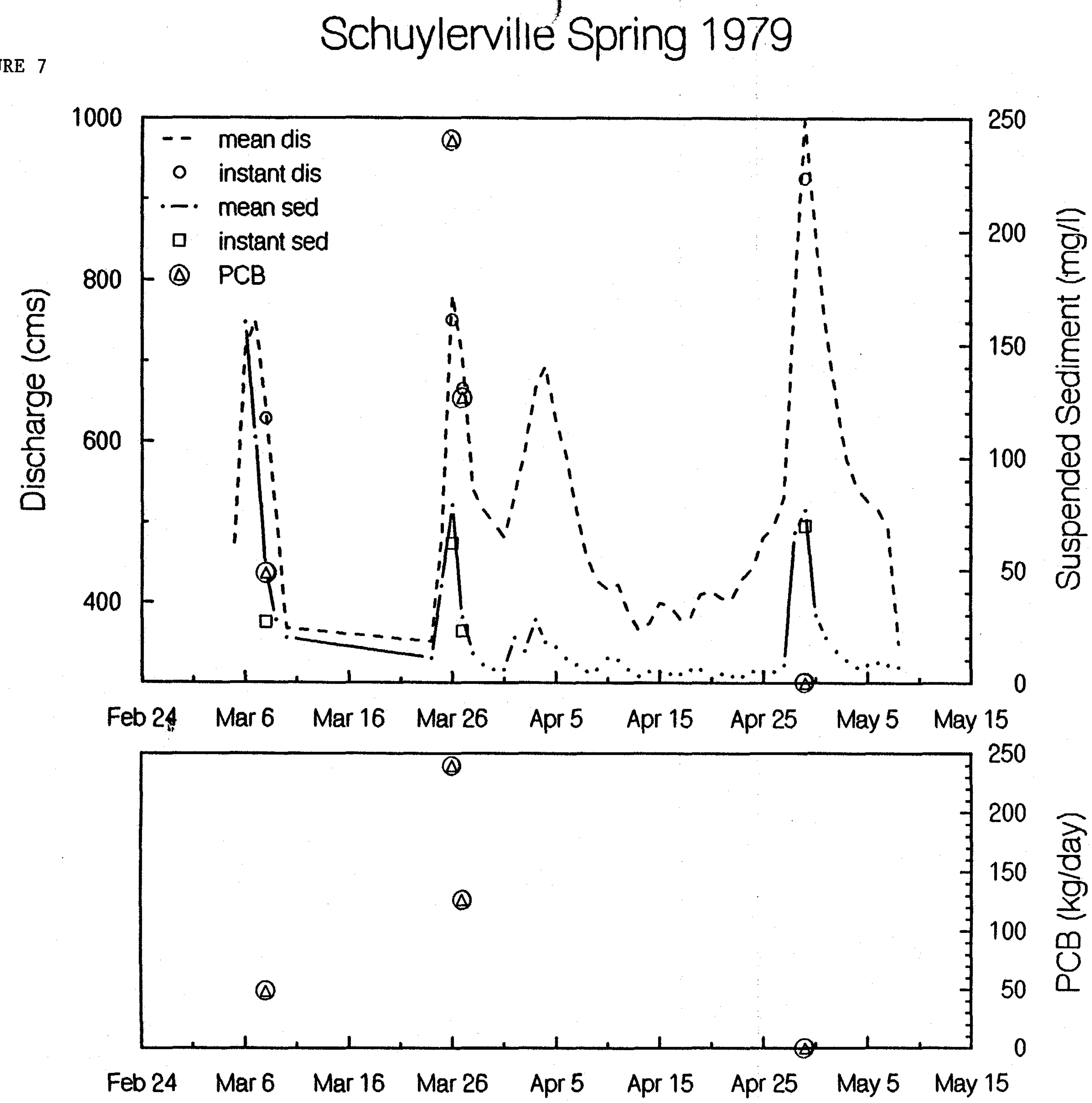
10.11662

FIGURE 6



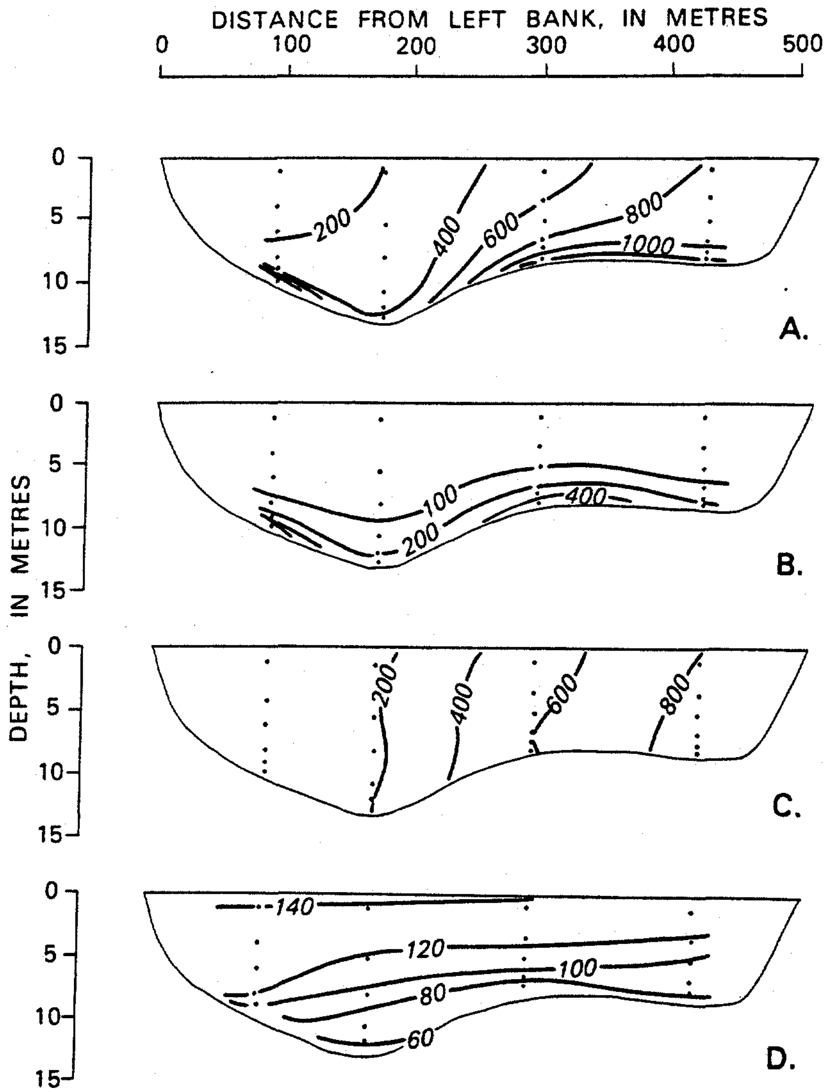
10.11663

FIGURE 7



10.11664

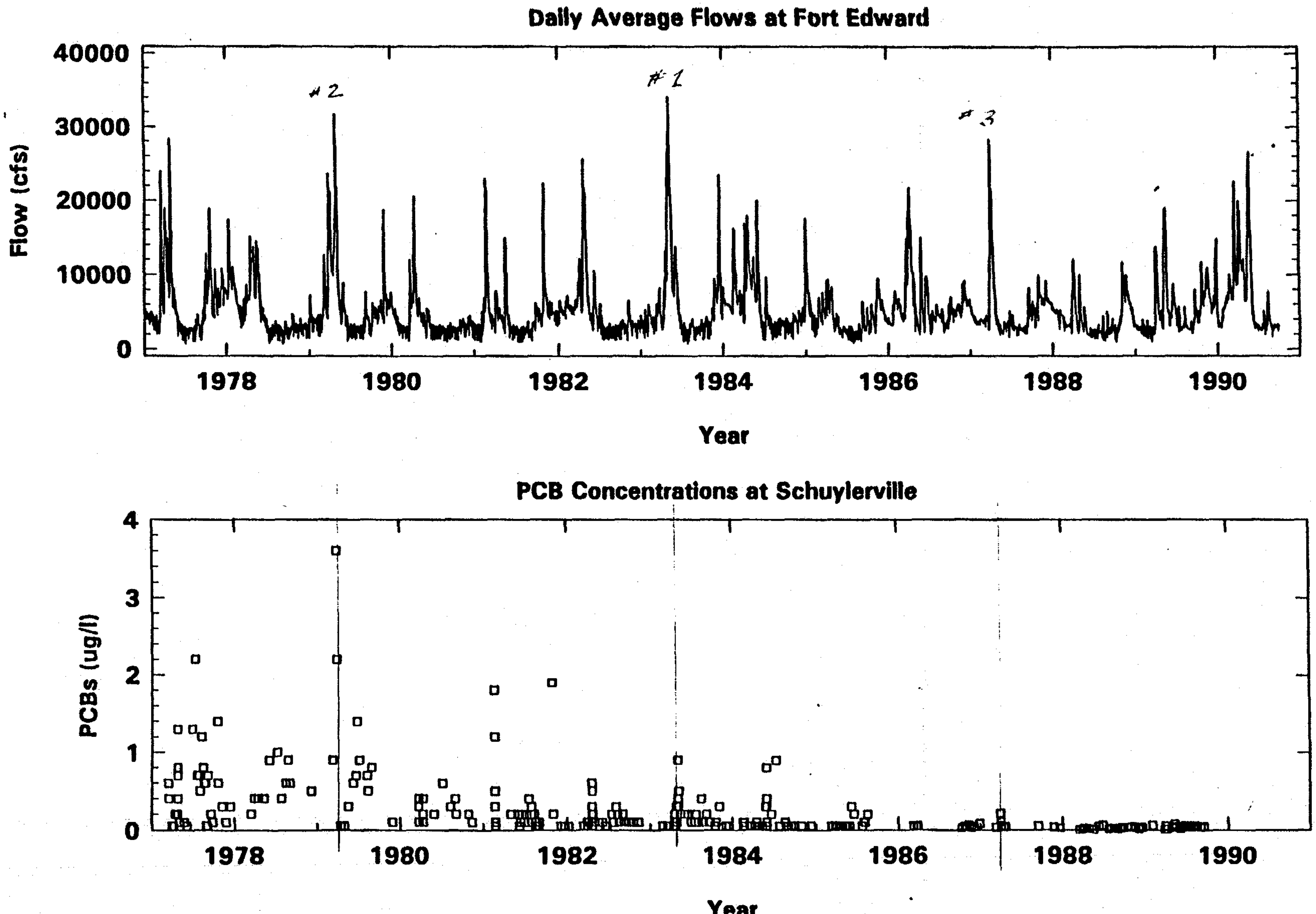
FIGURE 8



Vertical and lateral distributions of suspended-sediment concentration and water velocity in a cross section of the Mississippi River at St. Louis, Missouri, May 9, 1956; based on point samples and point measurements (Jordan, 1965, p. 50, 61–62). Viewer is facing downstream. The sediment-laden Missouri River enters the right side at a point 25 km upstream of St. Louis. A: Total suspended-sediment concentration, in milligrams per liter. B: Concentration of suspended sand (material coarser than 0.062 mm), in milligrams per liter. C: Concentration of suspended silt and clay (material finer than 0.062 mm), in milligrams per liter. D: Water velocity, in centimeters per second.

From Mead,R. et al (1990); Movement and Storage of Sediment in Rivers of the United States and Canada; in Surface Water Hydrology, Wolman and Riggs eds., The Geological Society of America, p.255-7.

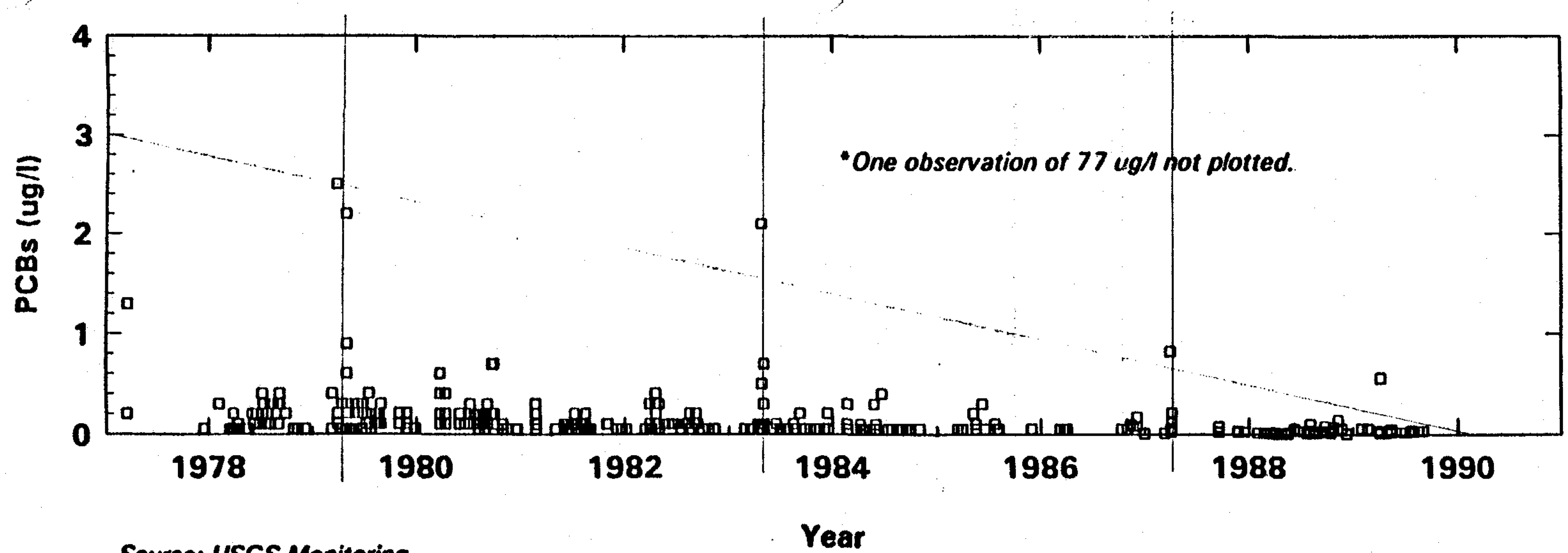
Figure B.4-11
Flow at Fort Edward and PCBs at Schuylerville



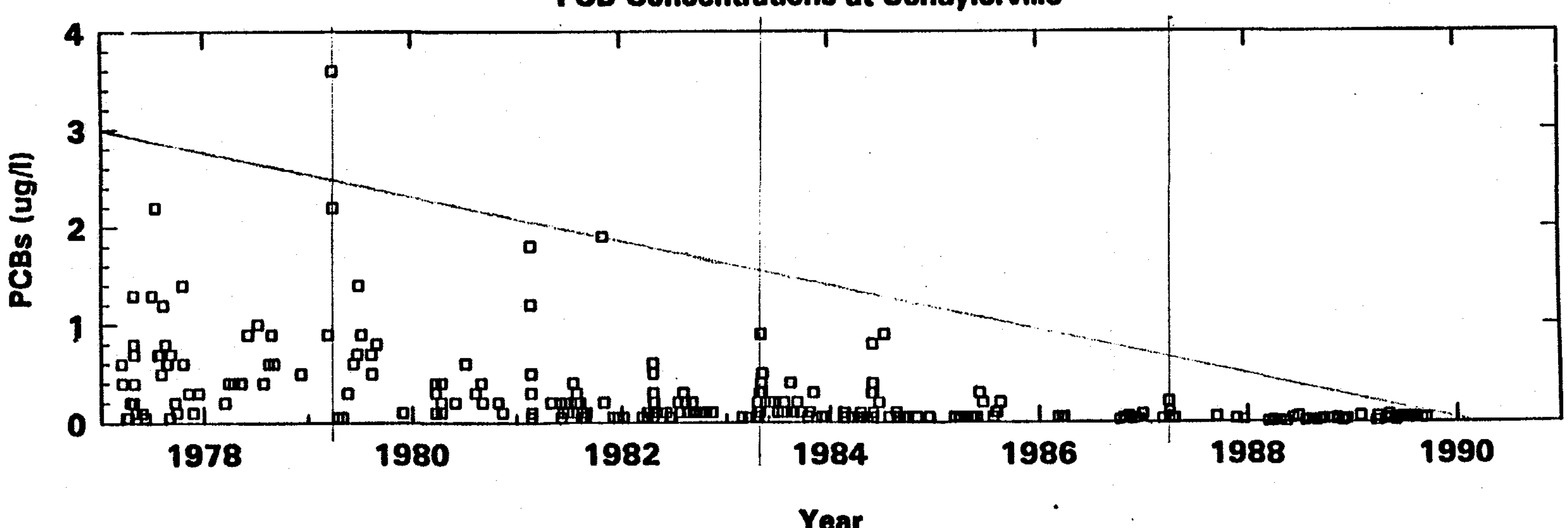
Source: USGS Monitoring.

Figure B.4-11

10.11666



Source: USGS Monitoring.



Source: USGS Monitoring.

From Figs. B.4-10,11 of USEPA Phase I Report

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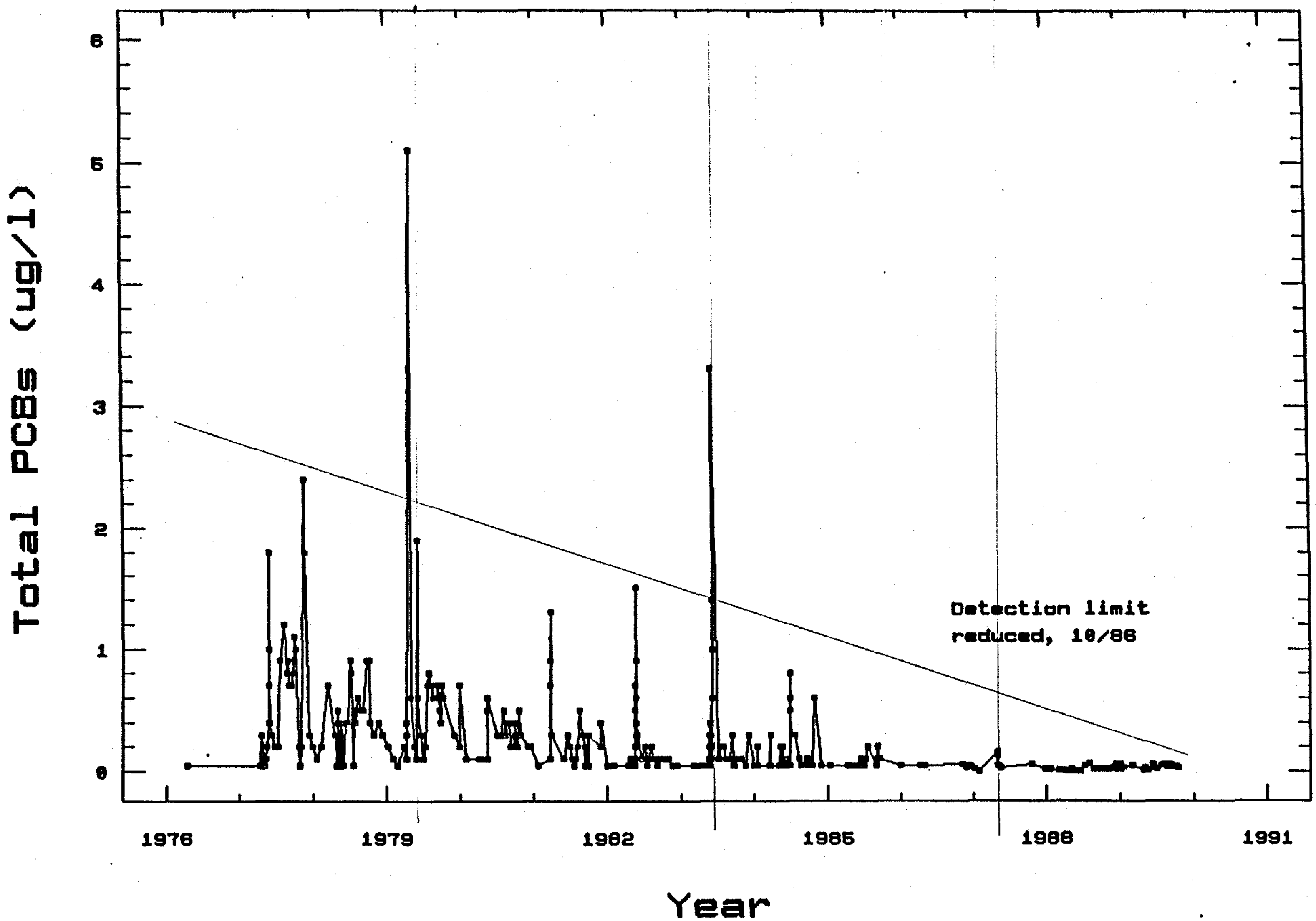
Figure B.3-10
Total PCBs in Water Column: Stillwater

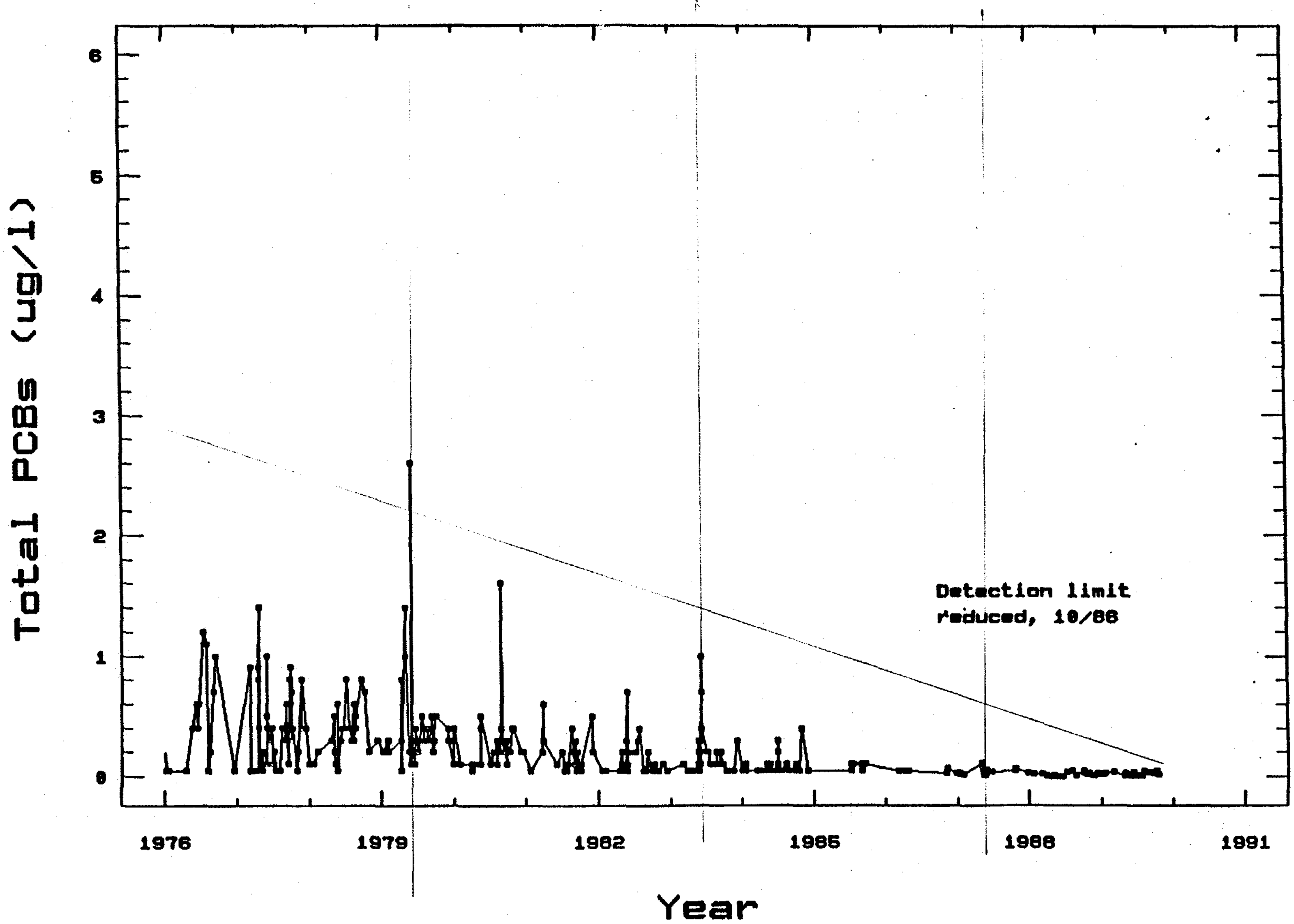


USGS Monitoring

Figure B.3-10

10.11668

Figure B.3-11
Total PCBs in Water Column: Waterford



USGS Monitoring

Figure B.3-11

10.11669