

WHAT IS HAPPENING TO THE SEDIMENT-BOUND PCBs IN THE UPPER HUDSON RIVER?

APPROACHES BEING USED TO ANSWER THIS QUESTION

- 1) Data Analysis
 - Interpretation of water column, sediment and fish PCB data
- 2) Modeling
 - Integration of all the available data within current understanding of the mechanisms affecting PCB fate in the river

THE LOW RESOLUTION CORING PROGRAM ATTEMPTS TO ANSWER THIS QUESTION BY CONSIDERING ONLY A SUBSET OF THE AVAILABLE DATA

ANALYSES USING ALL OF THE HUDSON DATA INDICATE THE FOLLOWING:

- Only a small fraction of the sediment PCB inventory has entered the water column
- Contaminated sediments continue to be buried
- PCBs enter the water column and the food chain from the surface sediments
- The flux from surface sediments occurs from the entire sediment surface and not preferentially from hot spots
- Surface sediment PCB concentrations have been declining, as evidenced by the continuing decline in fish PCB levels
- The decline in surface sediment PCB levels is the result of reductions in loading from onshore sources and deposition of less contaminated sediments

Water Column Derived Estimates of Annual PCB₃₊ Loading from TIP Sediments

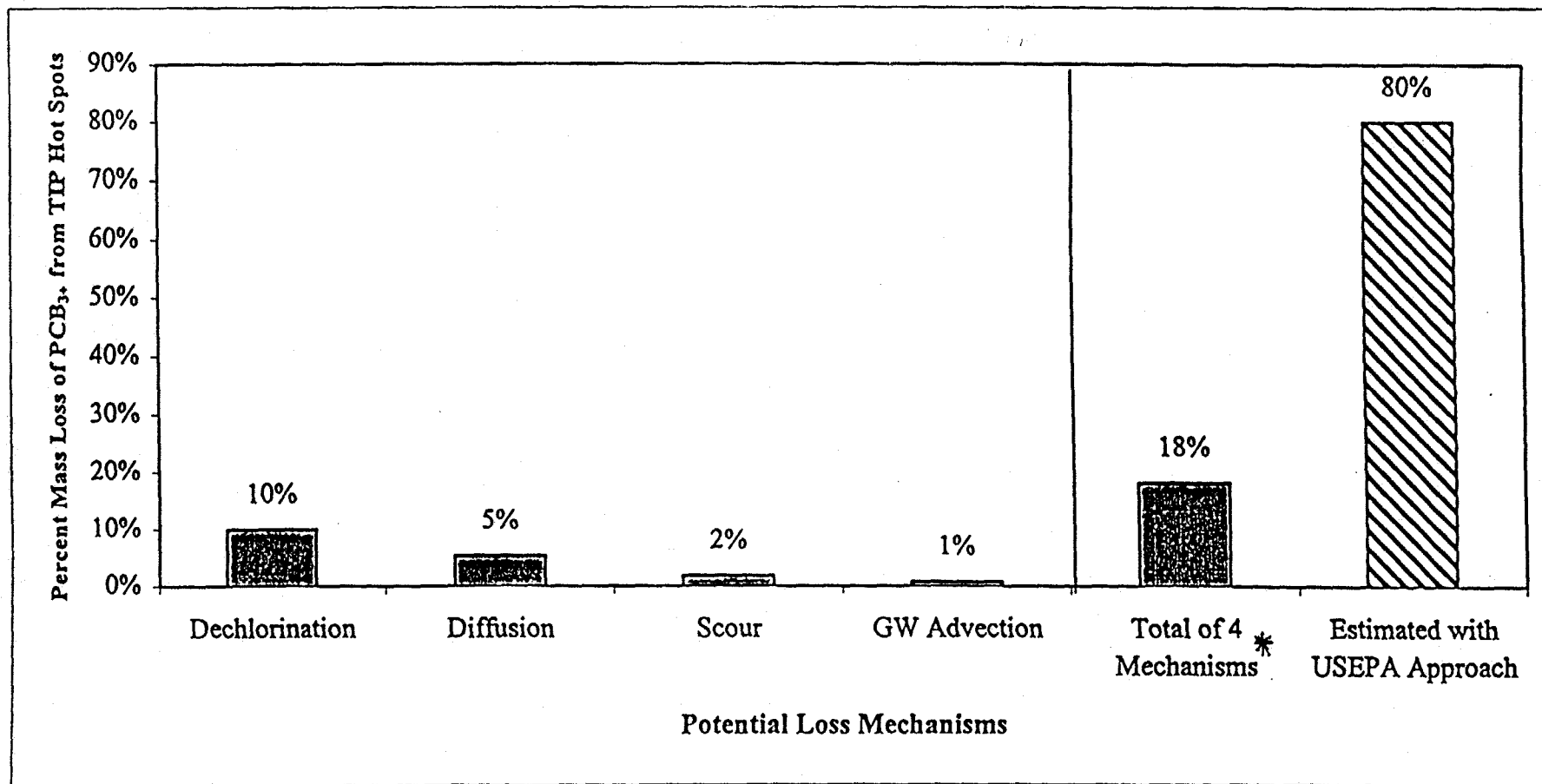
YEAR	Estimated Loading Past		Estimated Loading from TIP Sediments Metric Tons
	Thompson Isl Dam Metric Tons	Ft. Edward Metric Tons	
1984	0.45	0.36	0.09
1985	0.19	0.15	0.05
1986	0.19	0.18	0.01
1987	0.20	0.19	0.01
1988	0.10	0.07	0.03
1989	0.15	0.10	0.05
1990	0.25	0.20	0.04
1991	0.71	0.41	0.31
1992	0.85	0.58	0.27
1993	0.43	0.25	0.18
TOTAL	3.11	2.25	0.86*

Notes:

- 1) 1/84-4/91 based on PCB concentration and river flow rating curves for Fort Edward and Schuylerville stations.
- 2) 4/91-12/93 based on interpolation of approximately weekly data collected from FE and TID stations.

* Upper Bound Estimate

Comparison of TIP Sediment PCB3+ Mass Loss Attributable to Fate and Transport Mechanisms
with that Estimated using TAMS' Method

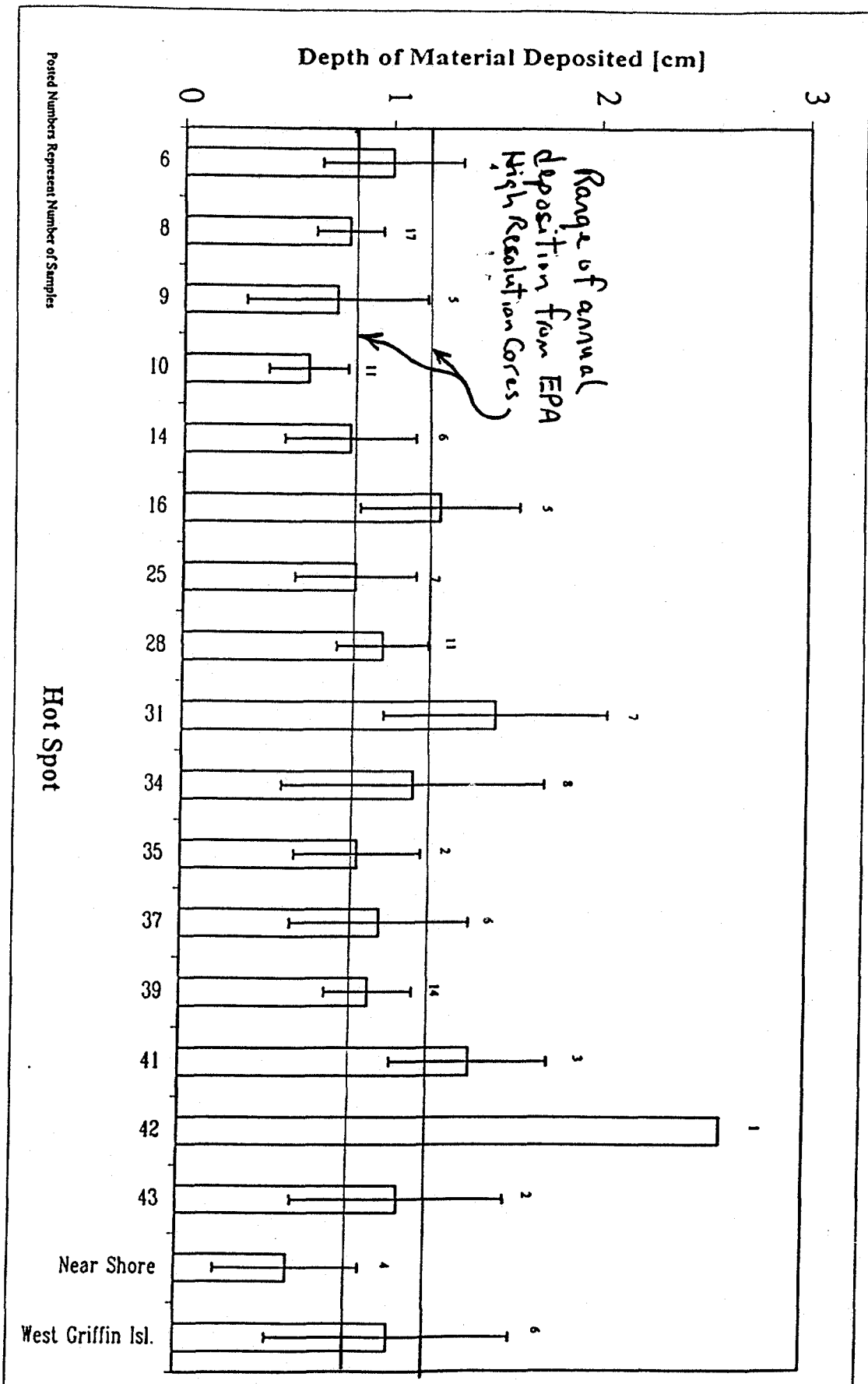


* Upper Bound

THE LOW RESOLUTION CORE STUDY BERYLLIUM DATA INDICATE WIDESPREAD BURIAL

- At the locations with detectable ^7Be (70% of samples), estimated deposition rates range from 0.2 to 3 cm/y
- Deposition rates at the locations with non-detect ^7Be could be as high as 0.5 cm/y

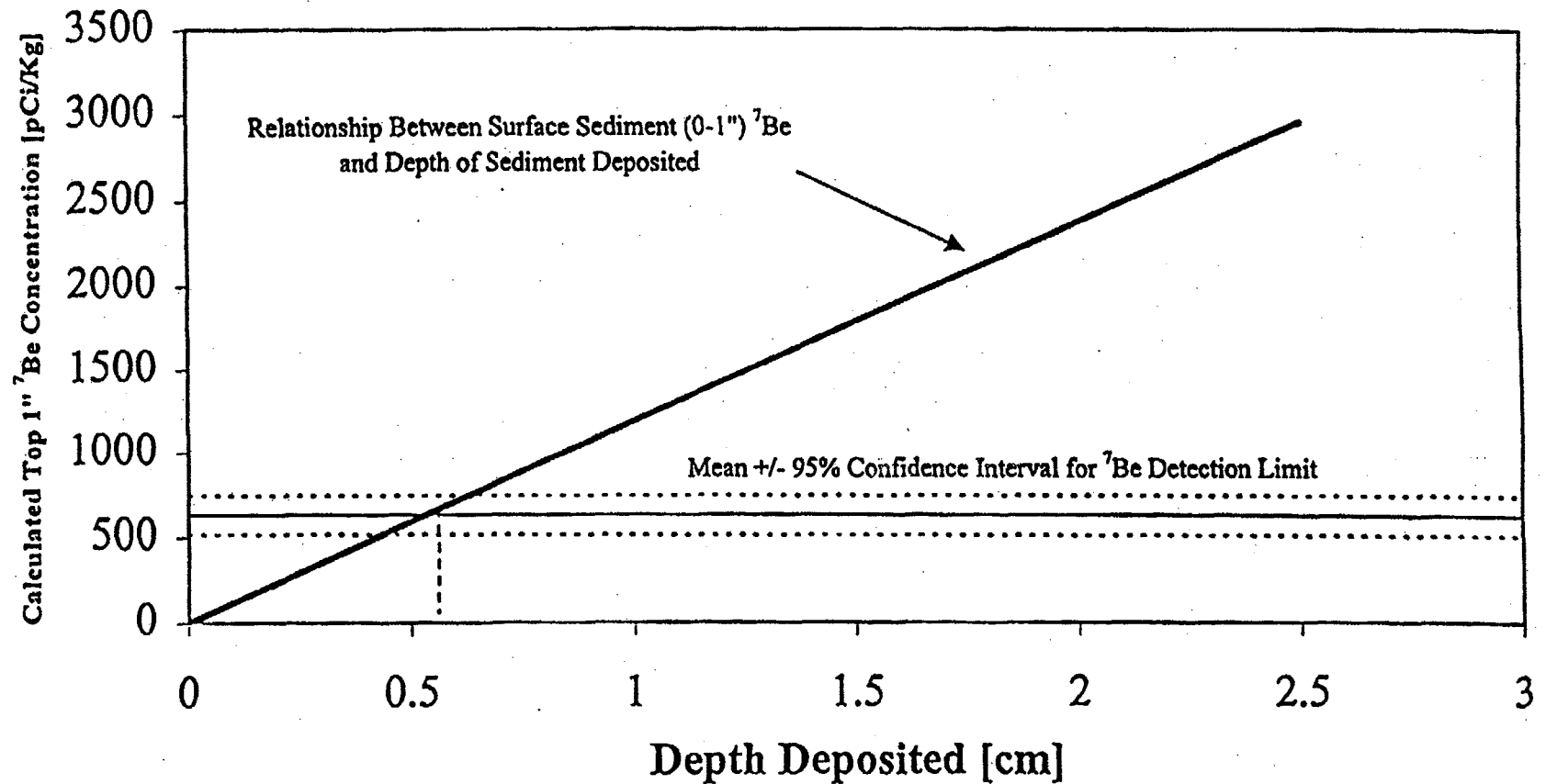
Computed Depth of Sediment Deposition Necessary to Produce Observed Levels of ⁷Be in the Top 1" Section of the 1994 Cores



Notes:

Water Column Particulate Phase ⁷Be Concentration Assumed to be 20,000 pCi/kg
Date of Sediment Deposition Assumed to be April 17, 1994

Estimated Relationship Between ^7Be Concentration and Depth of Sediment Deposited

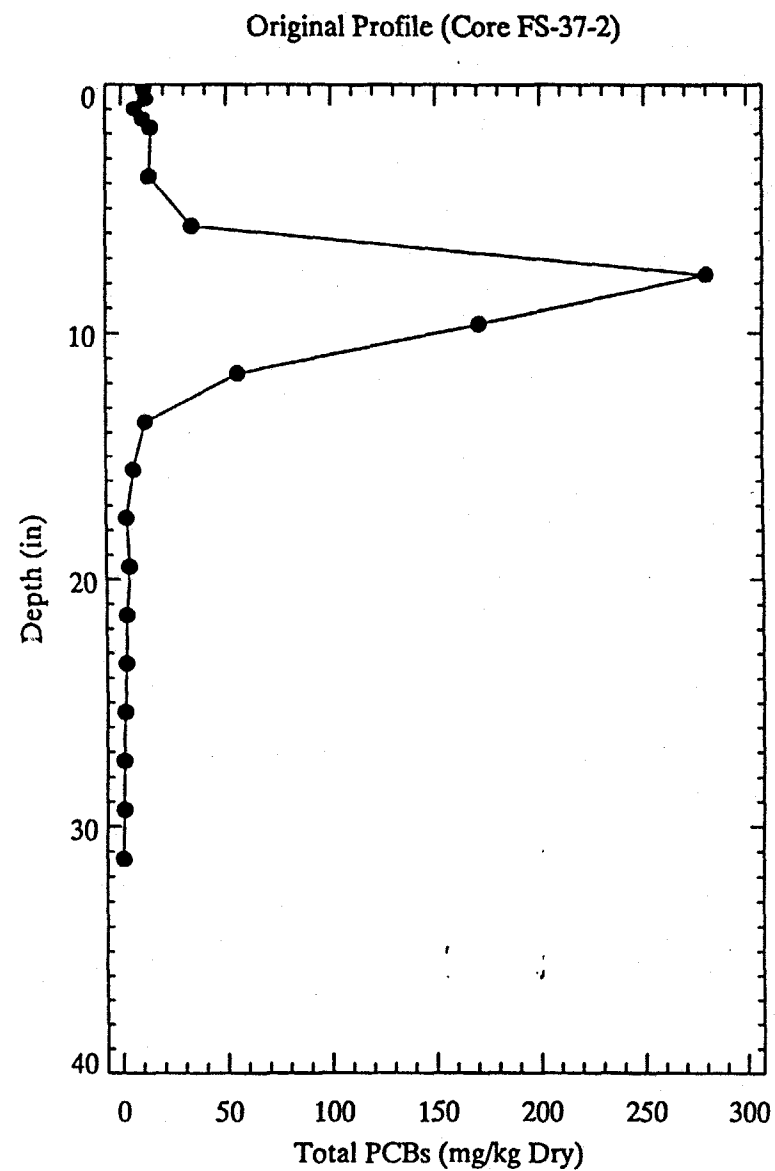
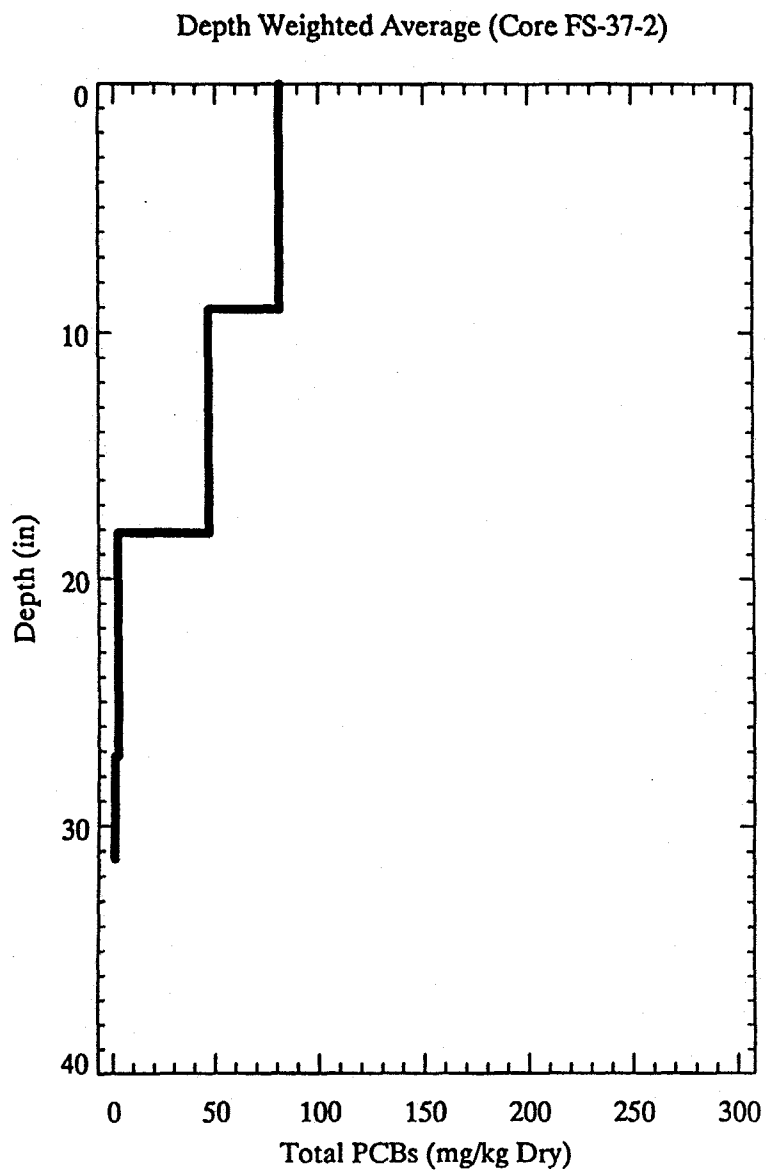


Notes: Assumed Date of Deposition: April 17, 1994
Assumed Initial ^7Be Concentration of 20,000 pCi/kg

**PCB PEAKS ARE GENERALLY BURIED EVEN AT LOCATIONS WITH THE HIGHEST
PCB CONCENTRATIONS IN THE TOP 9 INCHES**

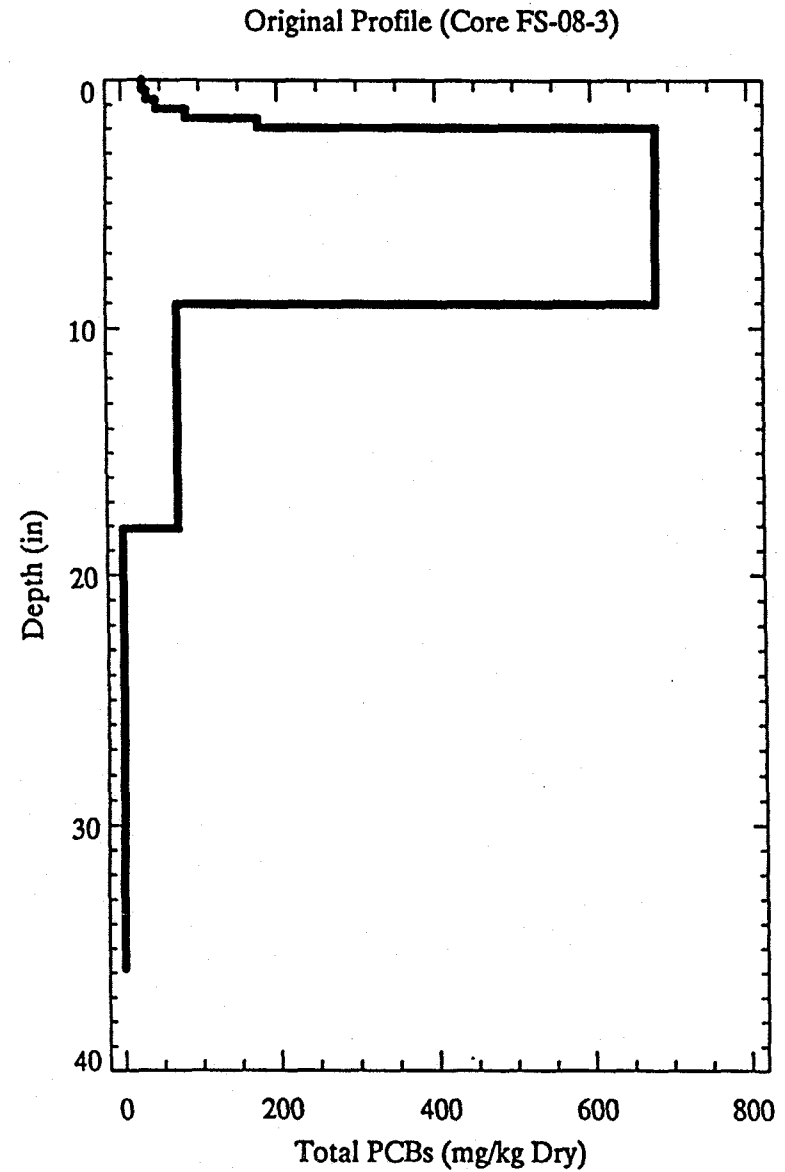
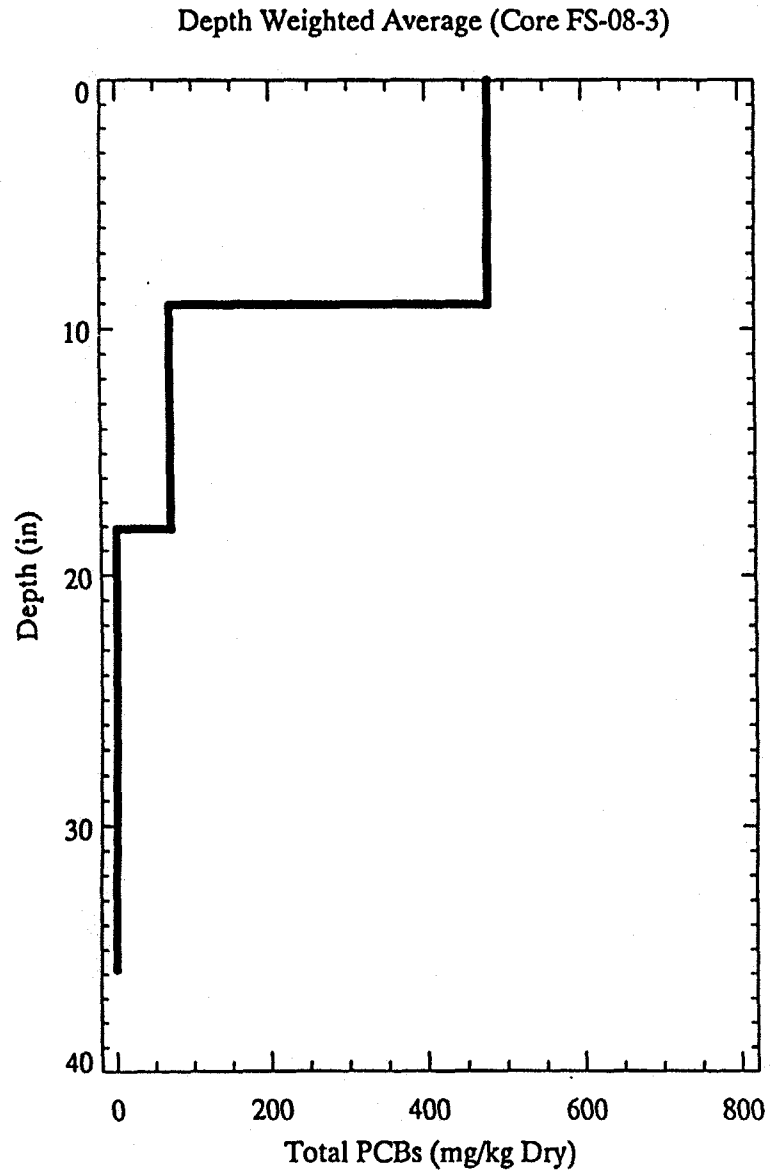
- In 11 cores collected in 1998 which showed the highest concentration in the top 9 inches, 8 had low concentrations at the surface and a concentration increase to a peak at depth

Comparison of Composite 0-9" Sections and Original Core Profile for 1998 Sediment Cores



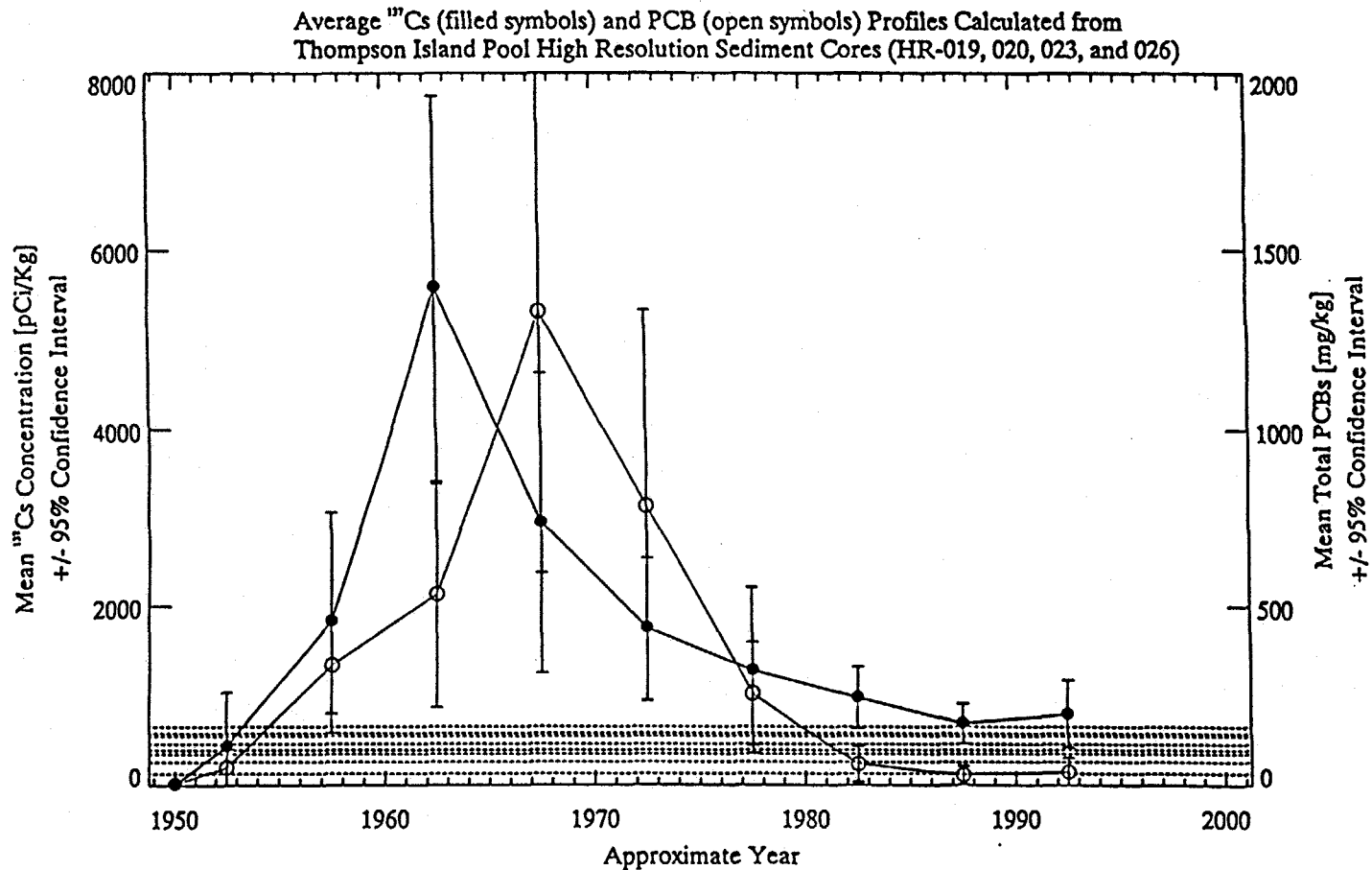
10.2222

Comparison of Composite 0-9" Section and Original Core Profile for 1998 Sediment Cores



10.2223

THE LOW RESOLUTION CORE STUDY ^{137}Cs DATA INDICATE THAT SURFACE SEDIMENTS ARE "RECENTLY" DEPOSITED, EVEN AT LOCATIONS THE REPORT CHARACTERIZED AS SCoured

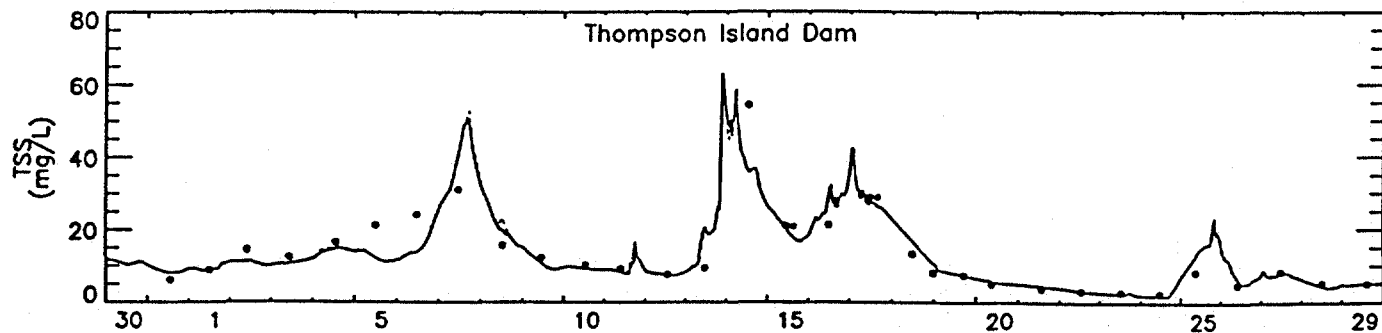
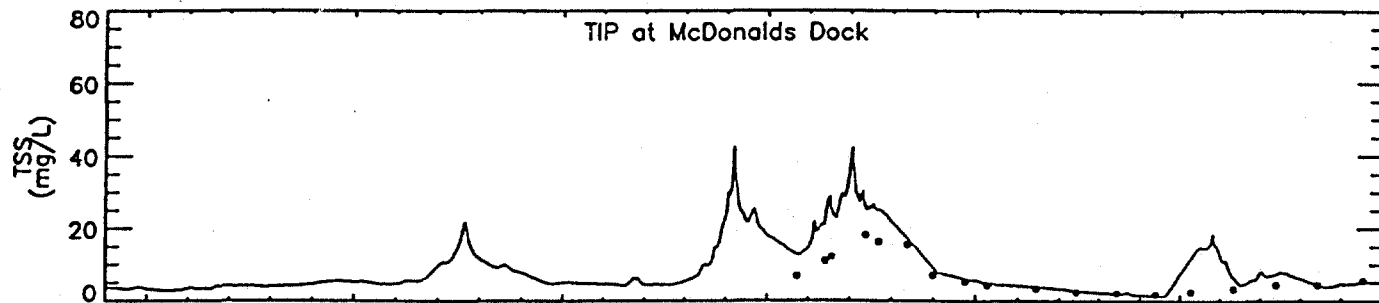
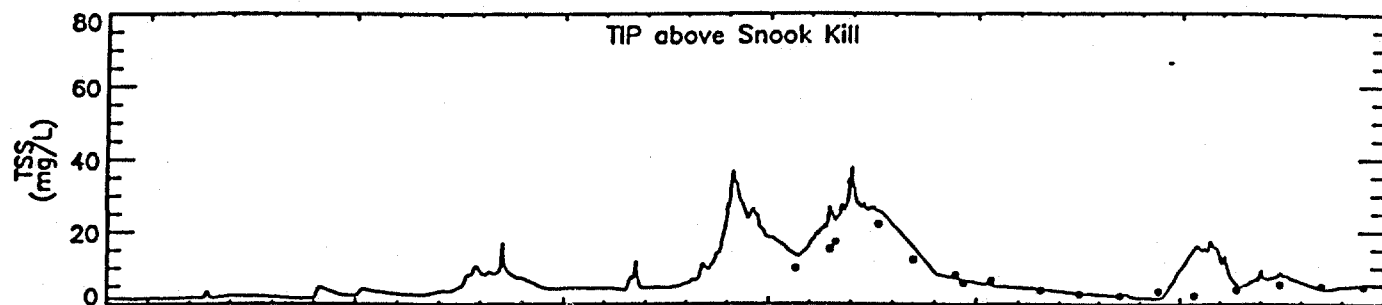
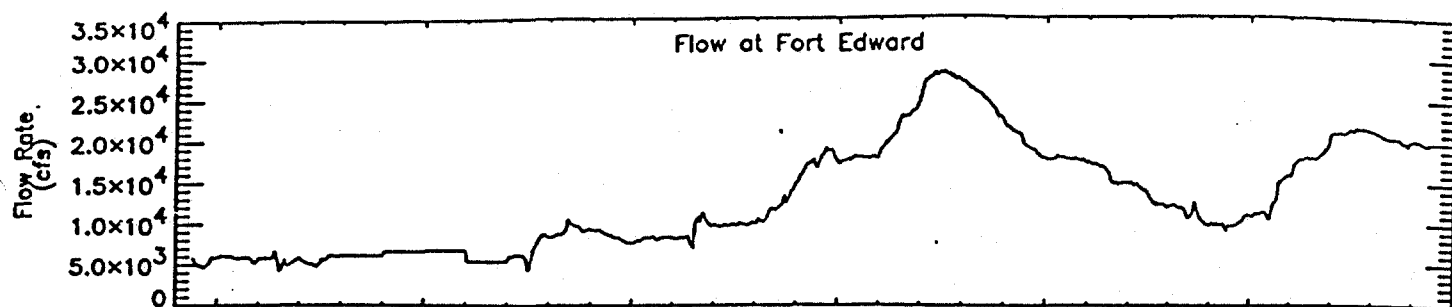


Notes:

- 1) Data Binned in 5 Year Intervals and Plotted at Midpoint
- 2) Horizontal dashed lines represent surface sediment (0-1") ^{137}Cs concentrations detected in cores TAMS identified as indicative of scour between 1984-1994 (03A, 04A, 09D, 10B, 10D, 11B, 11C, 12C)

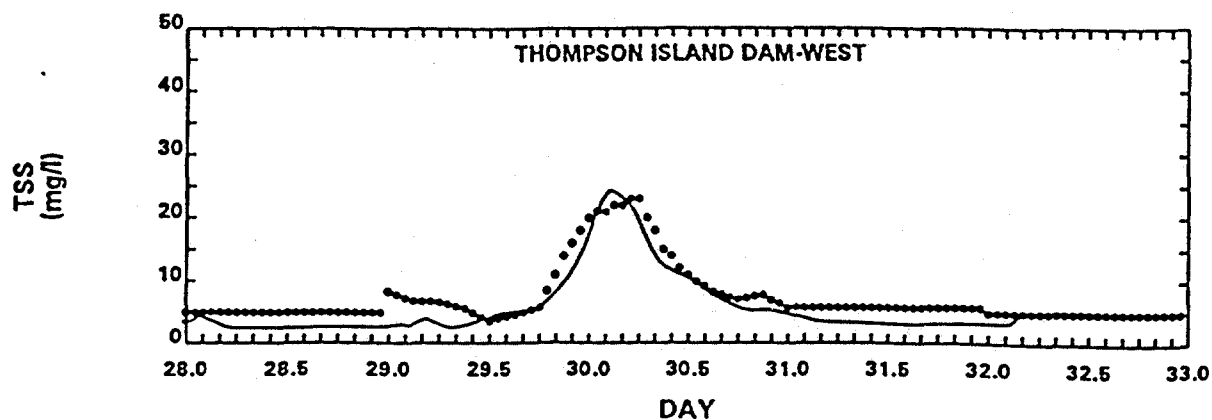
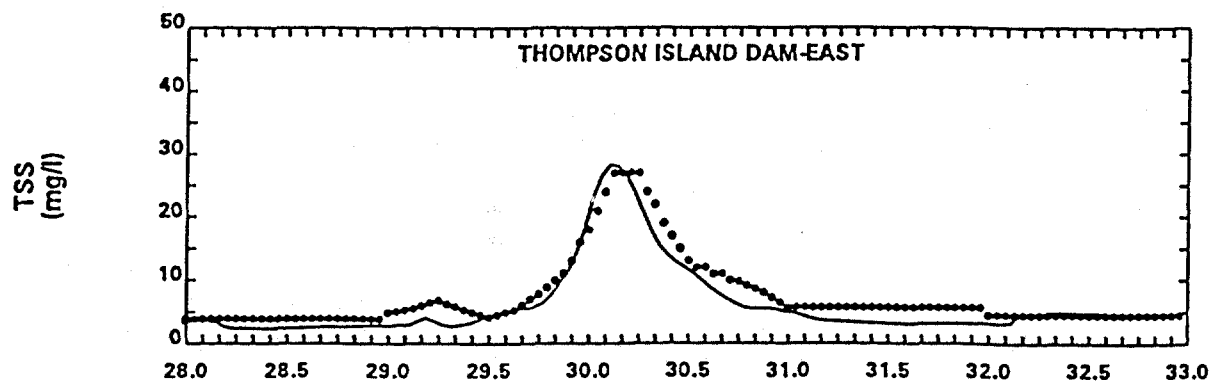
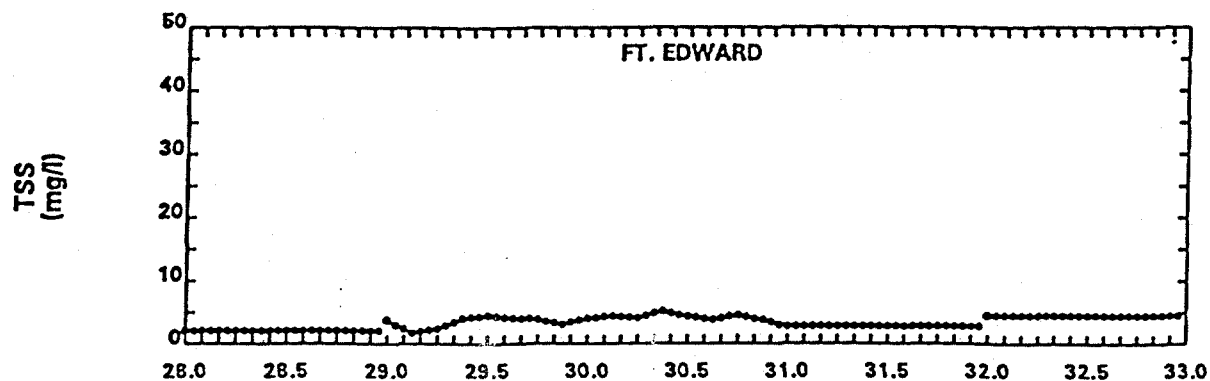
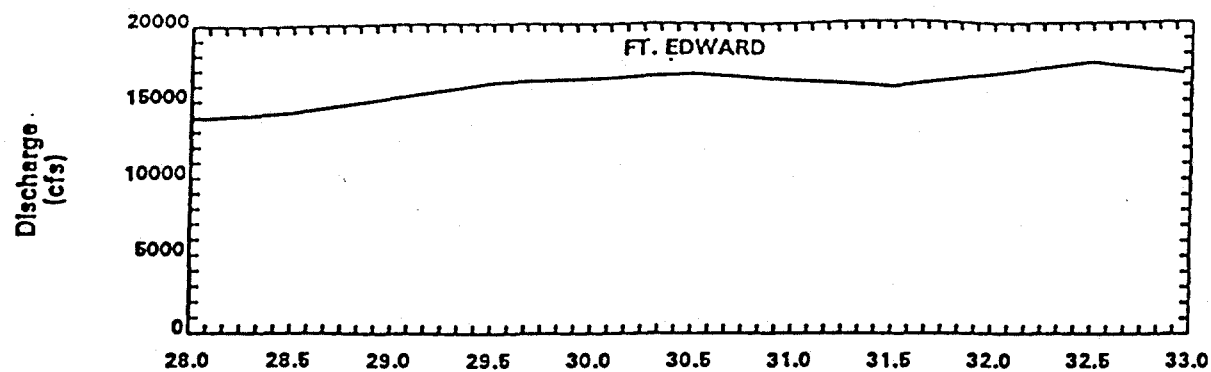
SEDIMENT TRANSPORT MODELING INDICATES DEPOSITION IN THE FINE SEDIMENTS

- Net deposition occurred in 93% of cohesive bed areas between January 1977 and March 1998
- The average sedimentation rate in cohesive bed areas was 0.8 cm/y during that period (total deposition of 17 cm or 6.6 inches)
- 8.5% of the solids entering the TIP are trapped (87% of this in the cohesive bed areas)
 - Consistent with analyses conducted by EPA contractor (LTI)

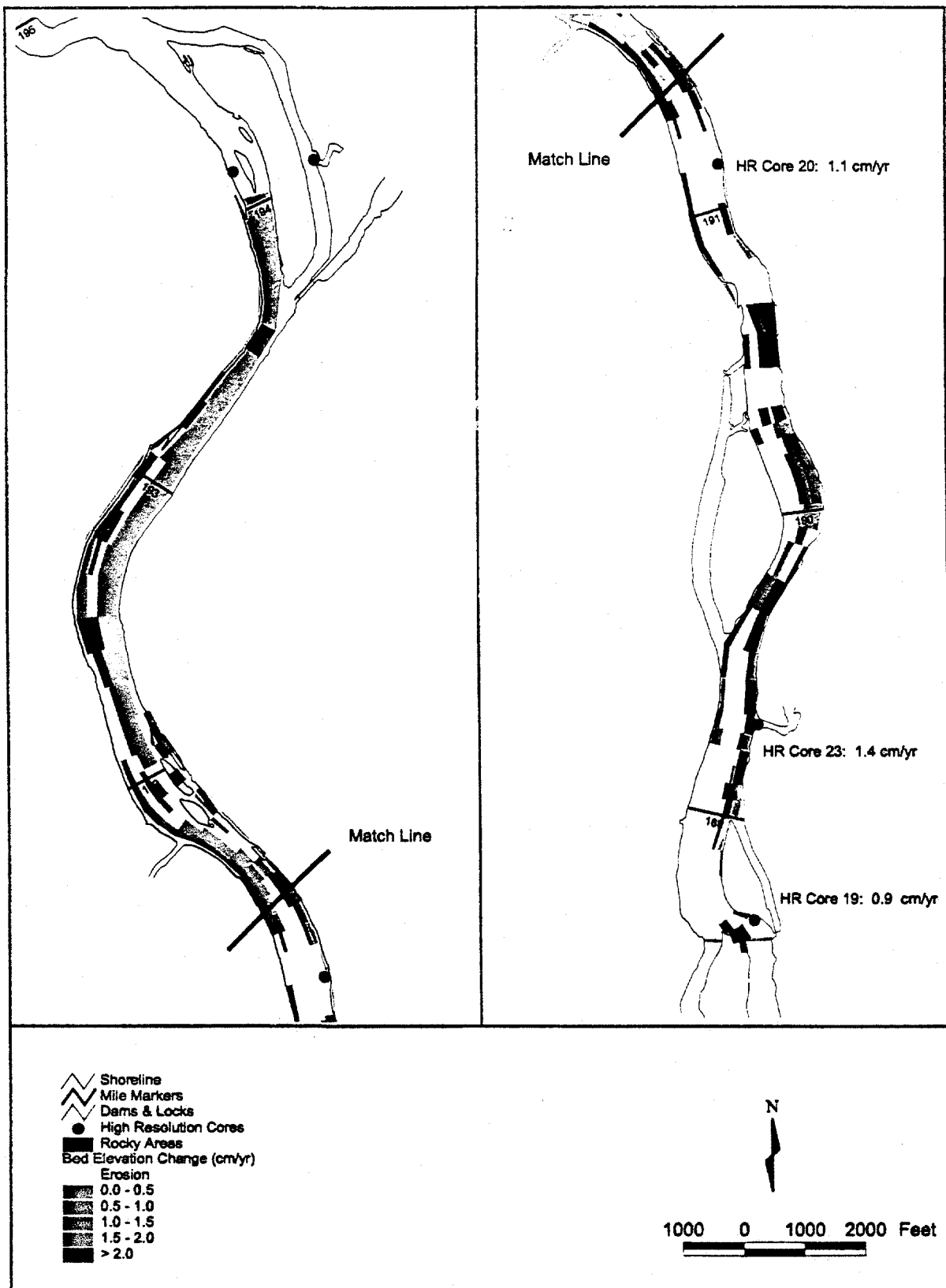


March 30 - April 29, 1994

Comparison of predicted (solid line) and observed suspended sediment concentrations at three locations in the Thompson Island Pool during the 1994 spring flood.

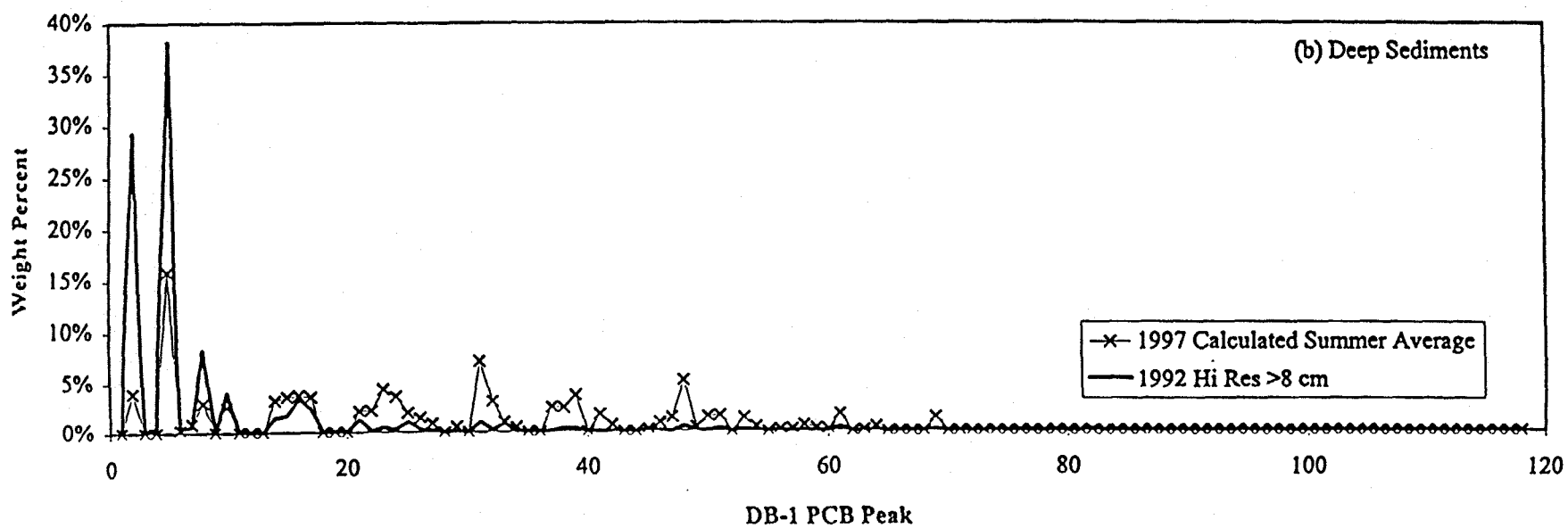
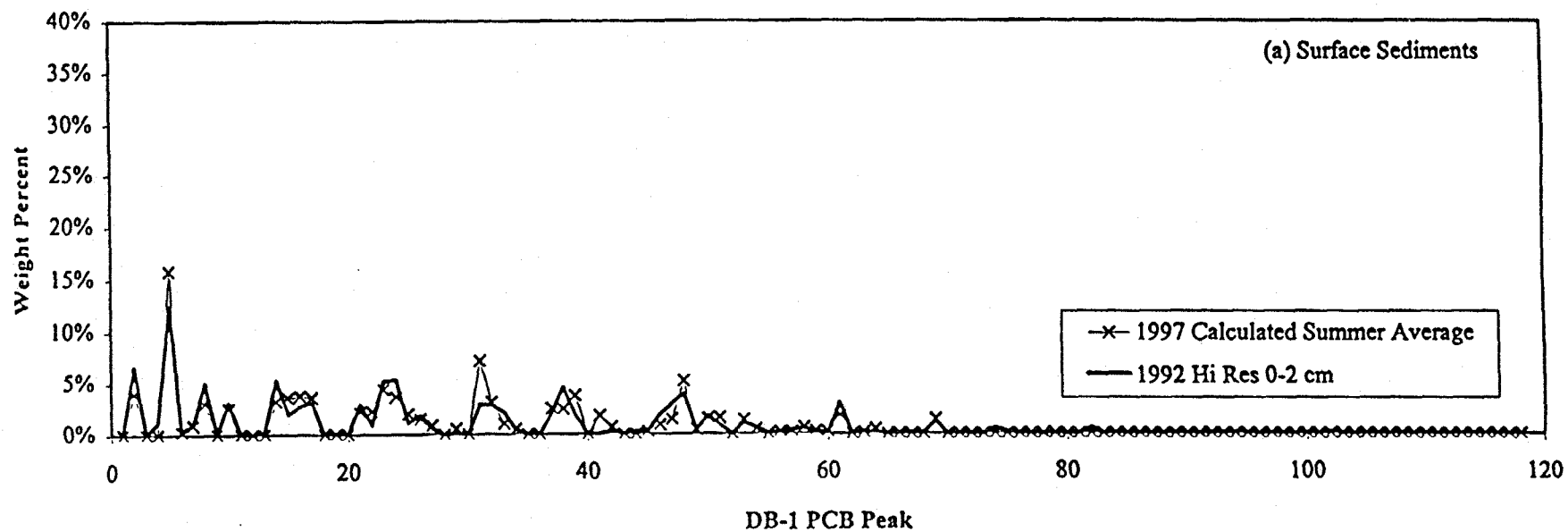


Comparison of predicted (solid line) and measured suspended sediment concentrations at the Thompson Island dam during the 1997 spring flood (May 2 to 6, 1997).

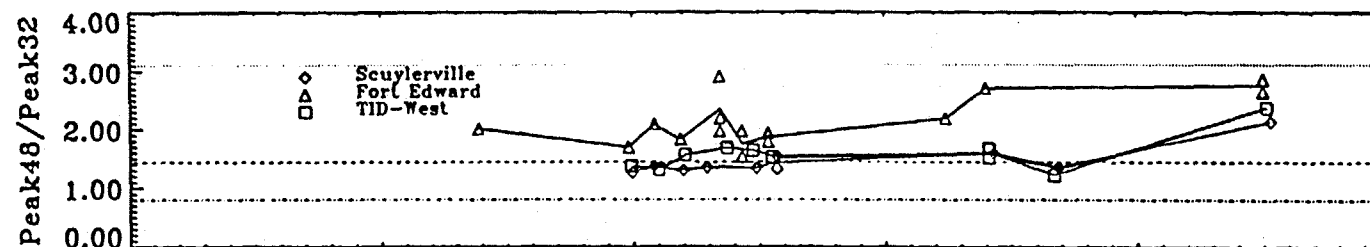
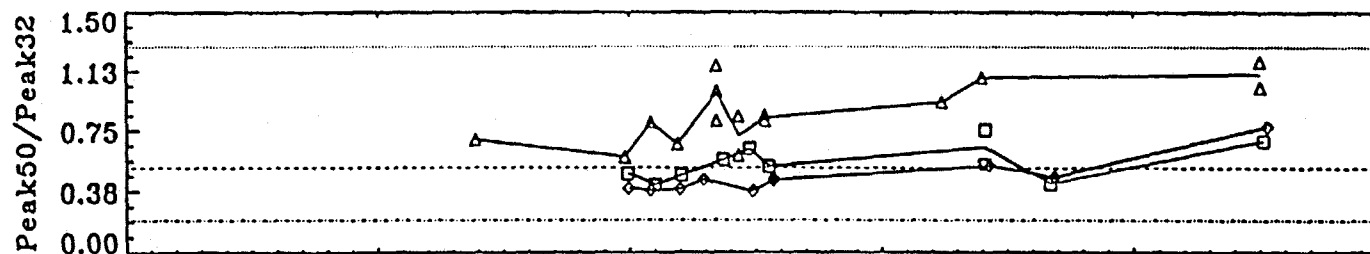


Predicted average deposition rates (cm/yr) for 21-year period (January 1977 to March 1998). Measured deposition rates at three high resolution core locations as shown.

Comparison of PCB Peak Compositions for Calculated Diffusional Sediment Source (1997 Summer Average)
with (a) Surface and (b) Deep Sediments from 1992 EPA High Resolution Cores Collected from TIP



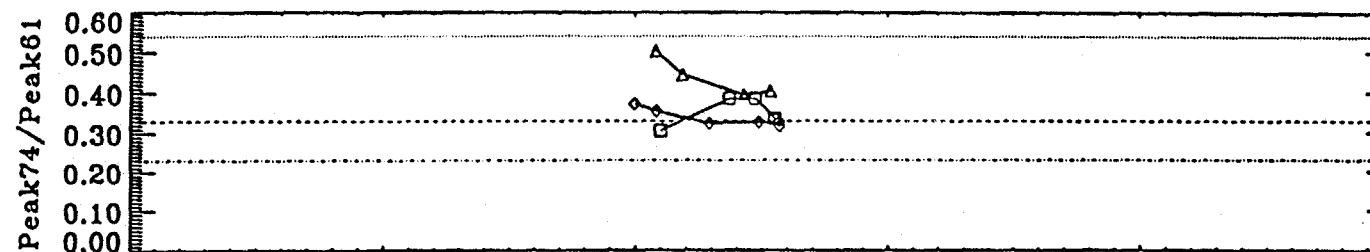
Temporal trends in DB-1 capillary column peak ratios from three stations on the Upper Hudson River during the January 1998 high flow event.



Avg. in Plunge Pool Samples

Avg. in 1991 Surface Sedimen

Avg. in "De-chlorinated" Sedi



Jan-08

Jan-09

Jan-10

Jan-11

Jan-12

Jan-13

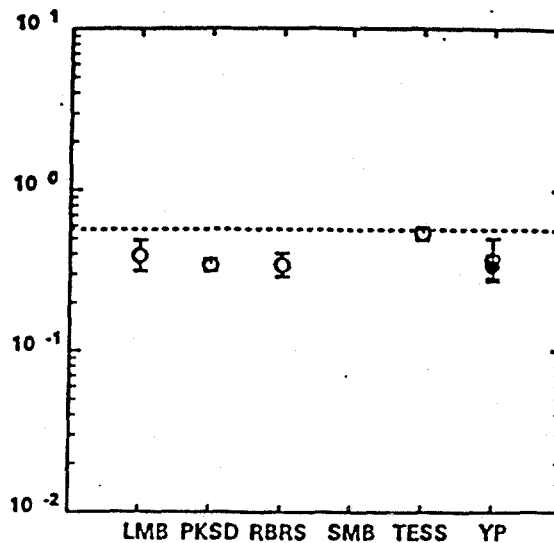
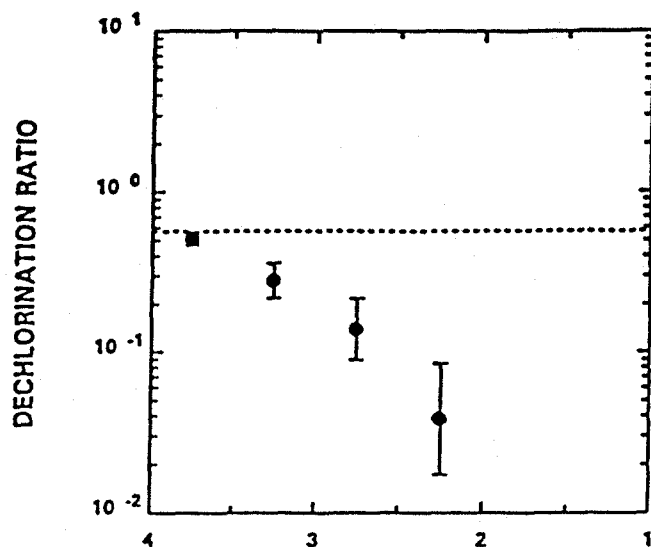
1998

PCB congener ratios calculated for fish and sediment
collected from the Thompson Island Pool

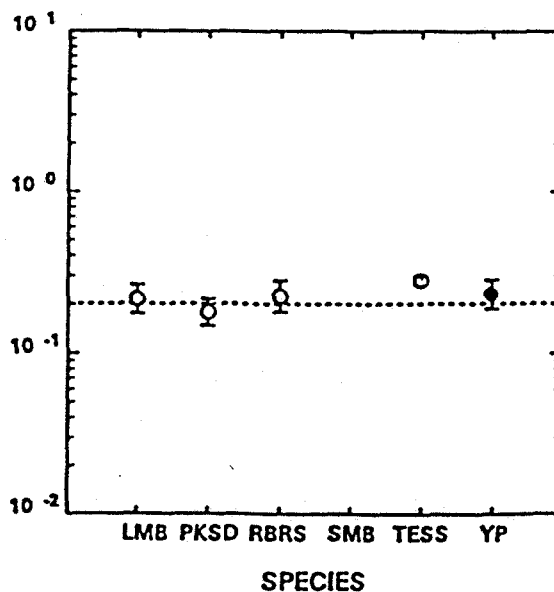
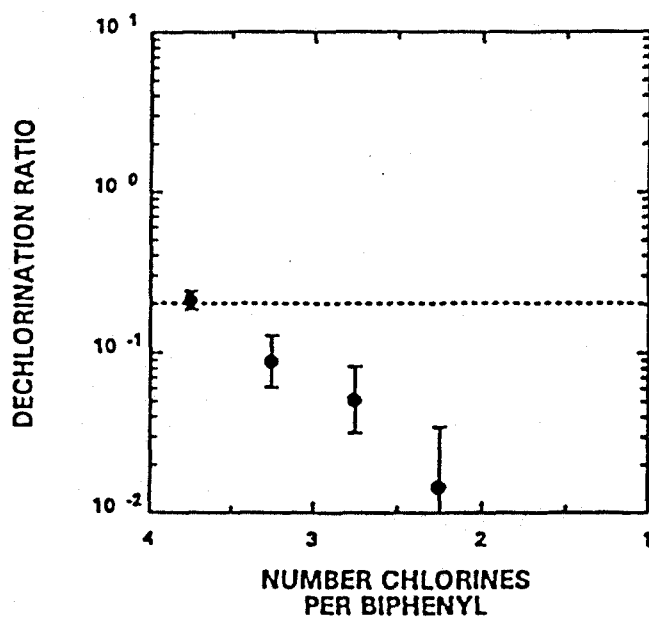
SEDIMENT

FISH

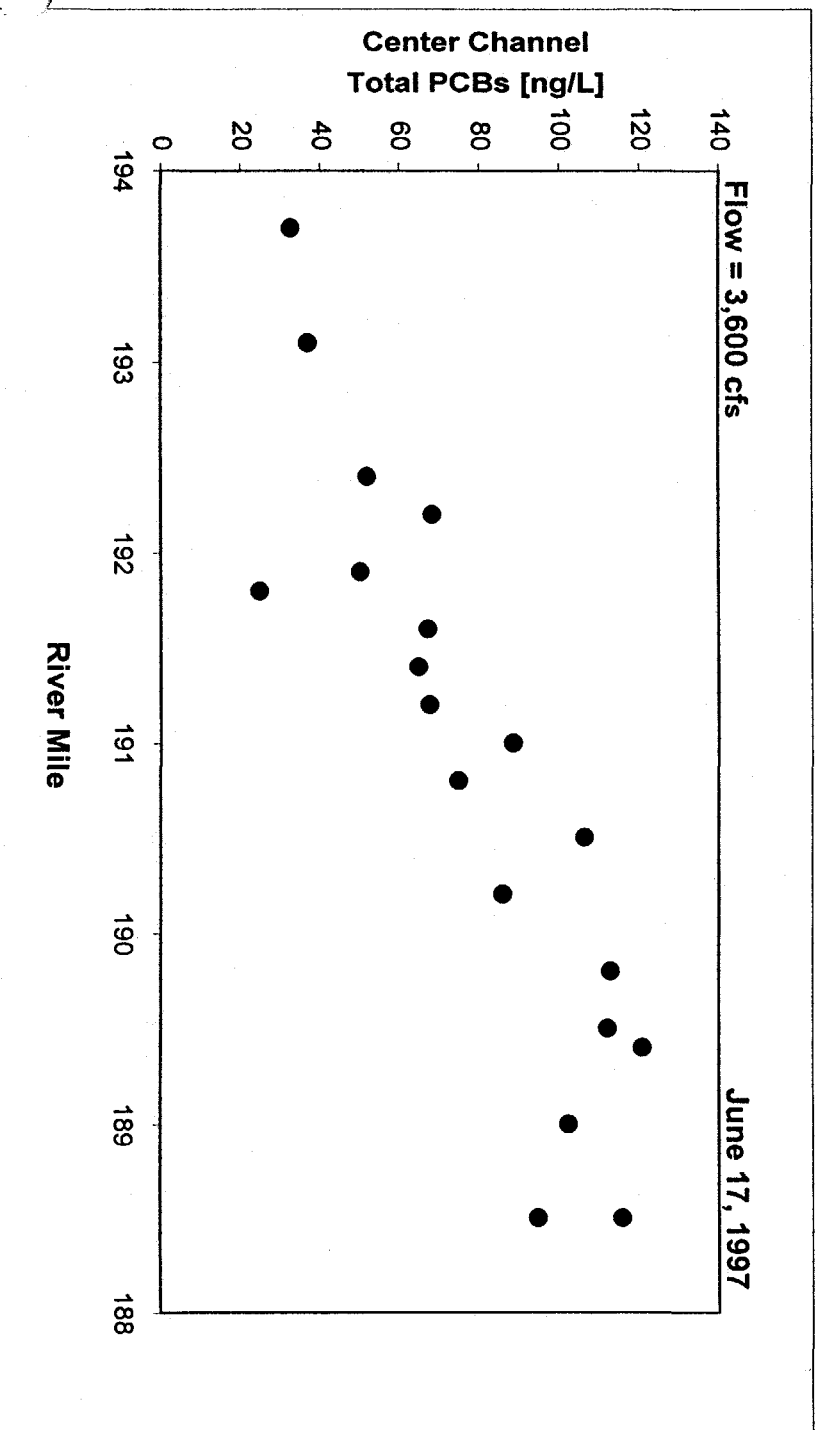
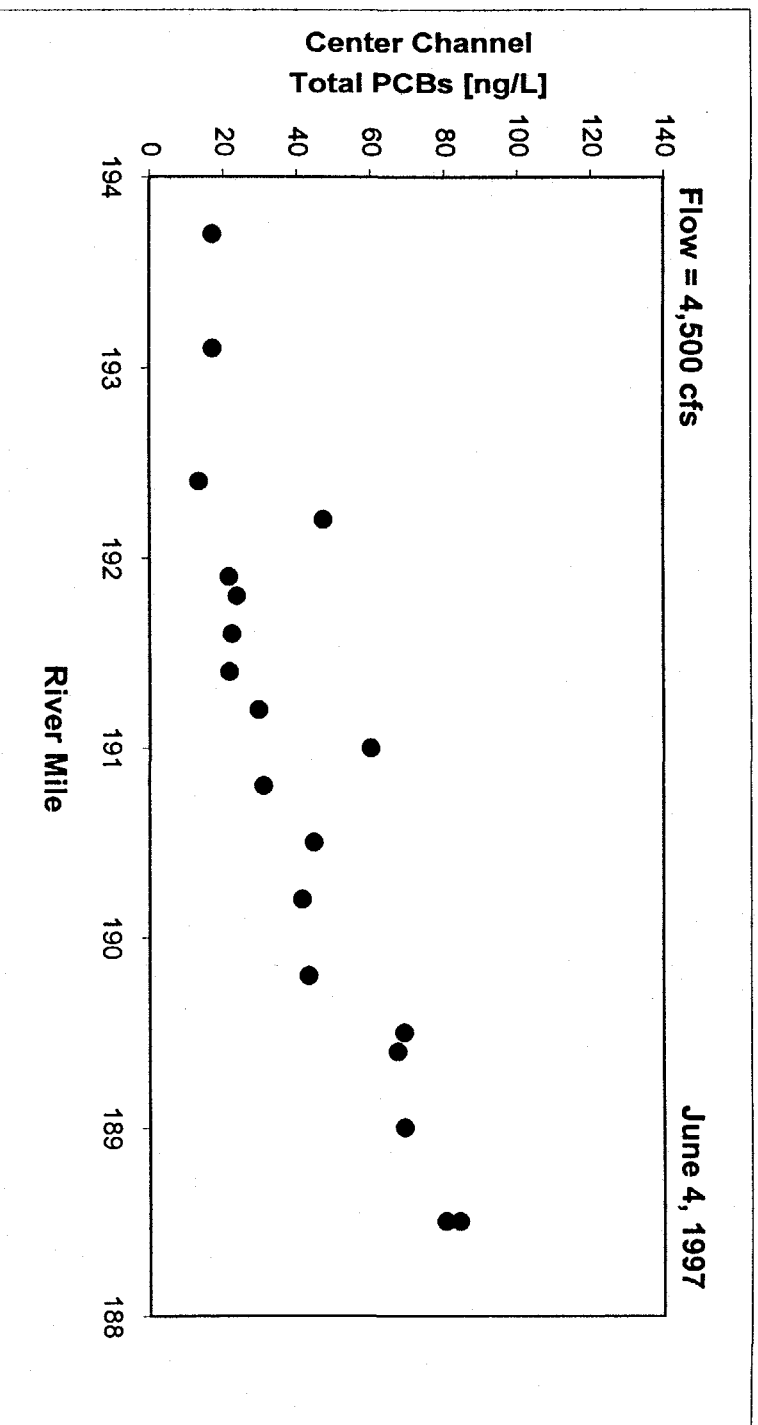
56:49



60:49



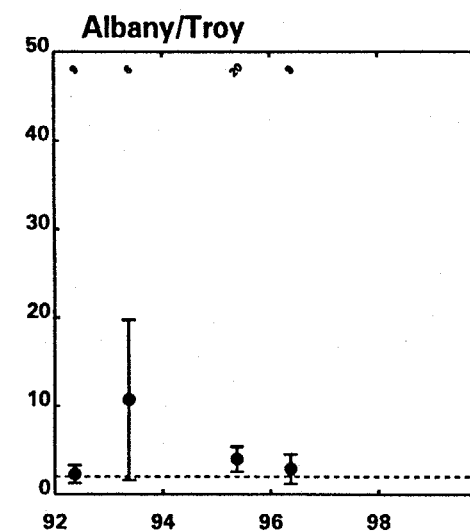
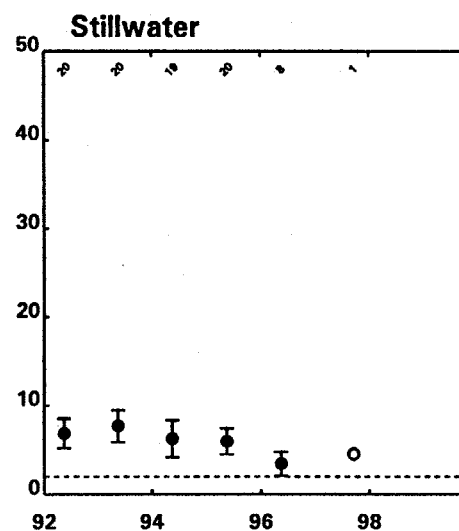
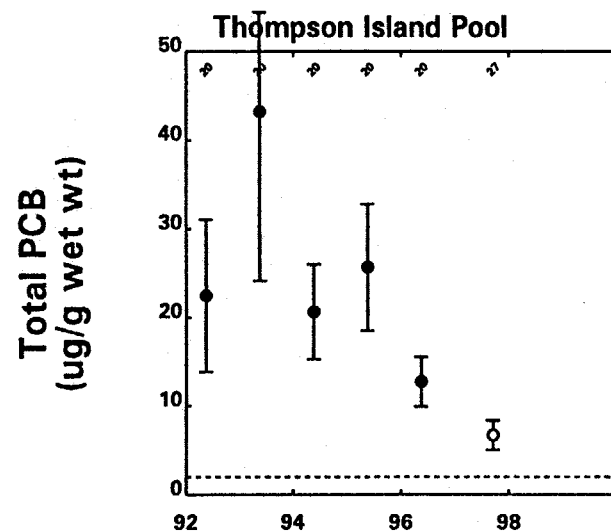
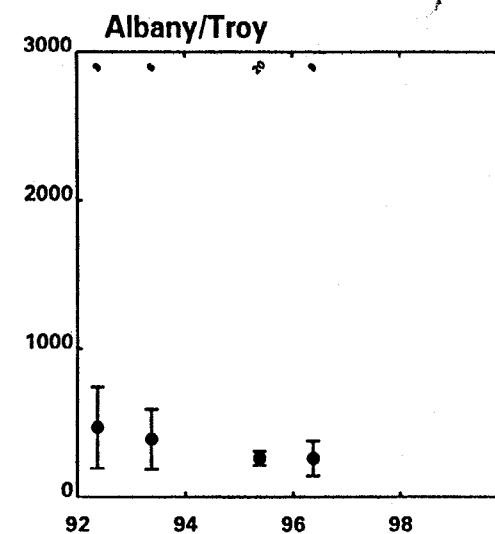
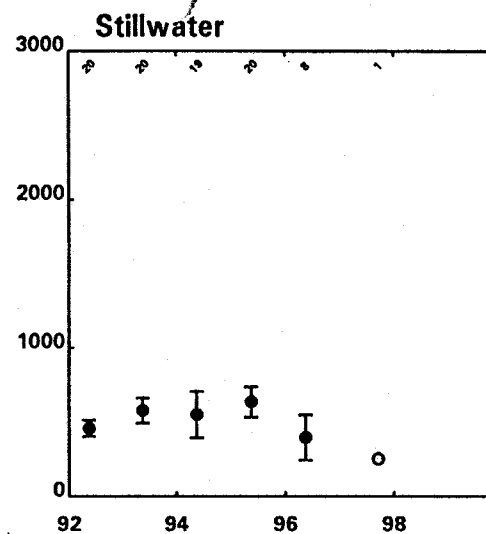
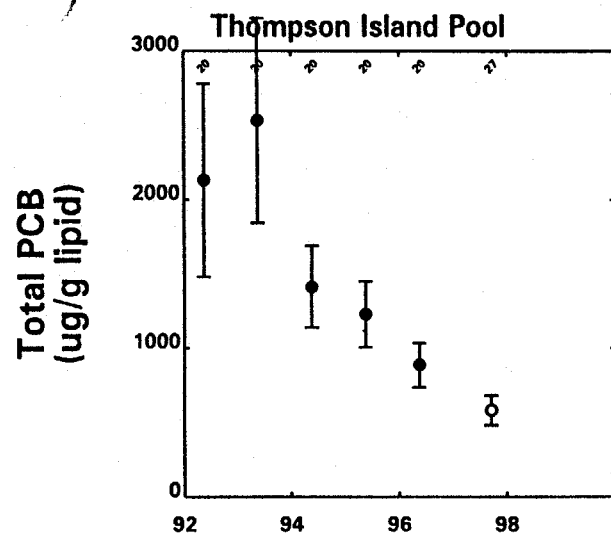
Center Channel PCB Concentrations From the 1997 Time Of Travel Surveys



TIP Organic Carbon Normalized Surface Sediment PCB Concentrations:
1) Both Inside and Outside NYSDEC "hot spots" in 1984 (0-2.5 In.), and
2) for Coarse Grained and Fine Grained Sediments Collected in 1991 (0-5 cm)

Sediment Survey	Location/ Sediment Type	# Observations	Mean PCB Concentration (mg kg oc ⁻¹)	Std. Deviation (mg kg oc ⁻¹)
1984 NYDEC	Inside "hot spots" ¹	155	2045	2069
	Outside "hot spots"	117	2030	1827
1991 GE	Coarse Sediments	16	2941	1824
	Fine Sediments	41	2185	2265

1) These statistics excludes one sample collected in 1984 which contained 331,000 mg PCB/kg oc⁻¹.



All sizes

Apr - Sep

All tissues (see database notes)

Males & Females

Mean +/- 2 std errors

Vertical line at Sept 17, 1991

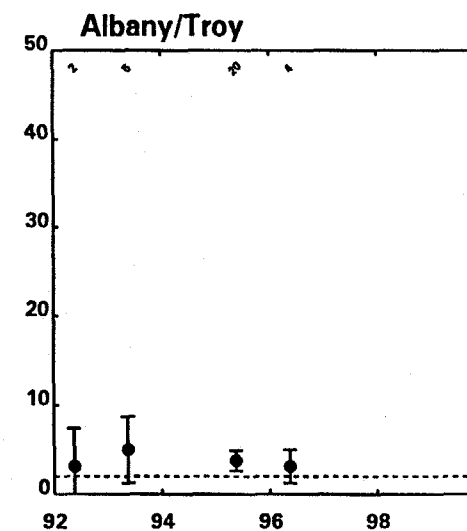
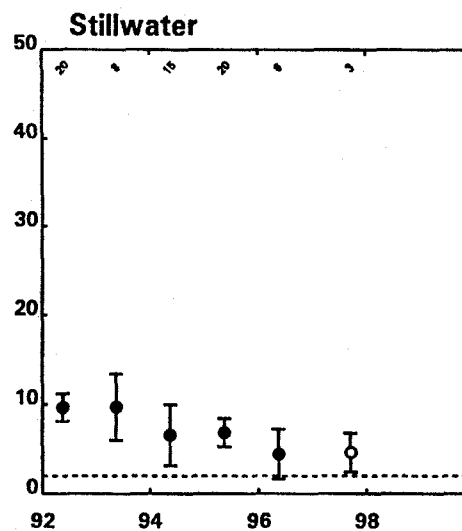
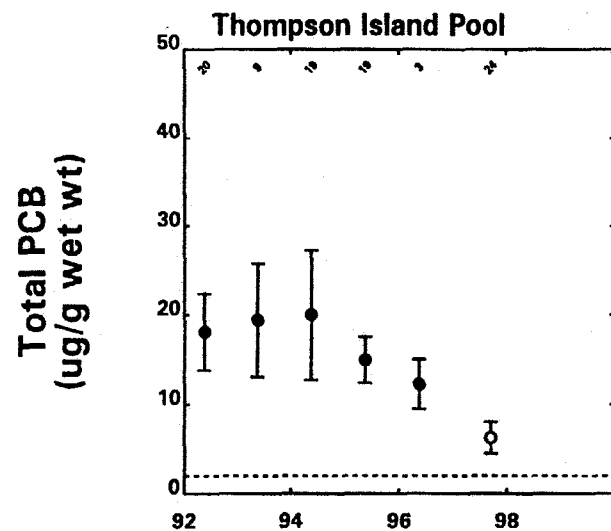
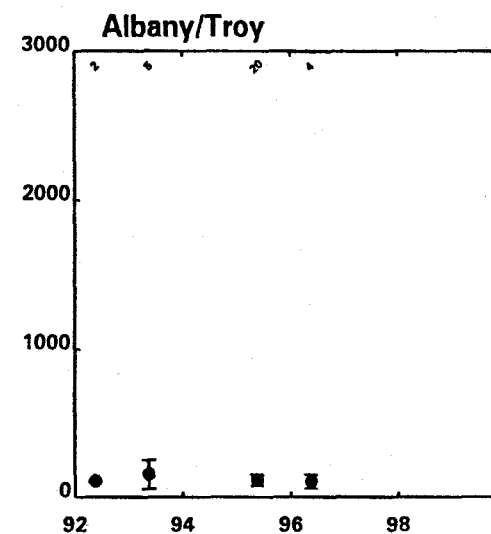
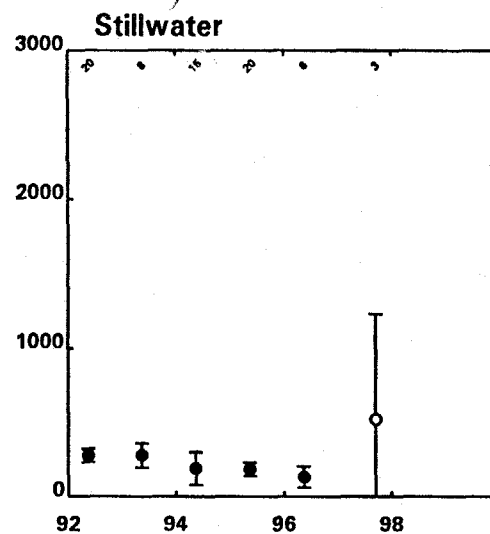
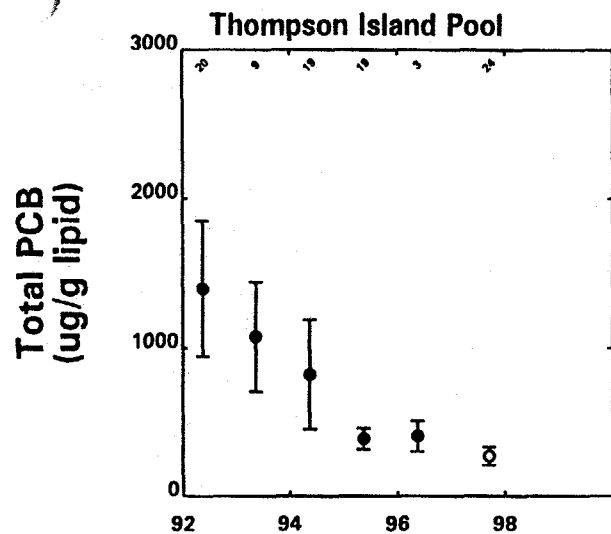
Values are plotted approximately at the midpoint of each season

Number of observations are indicated on each panel

Temporal patterns in Total PCB Concentration in LMB

Tue Jan 27, 1998 17:29:22

/petro4/geco0510/ANALYSIS/BIOTA/MISC_BIOTA [temp14ajunk]



All sizes

Apr - Sep

All tissues (see database notes)

Males & Females

Mean $\pm$ 2 std errors

Vertical line at Sept 17, 1991

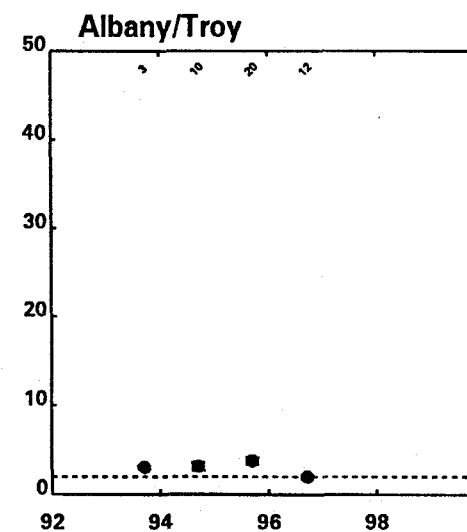
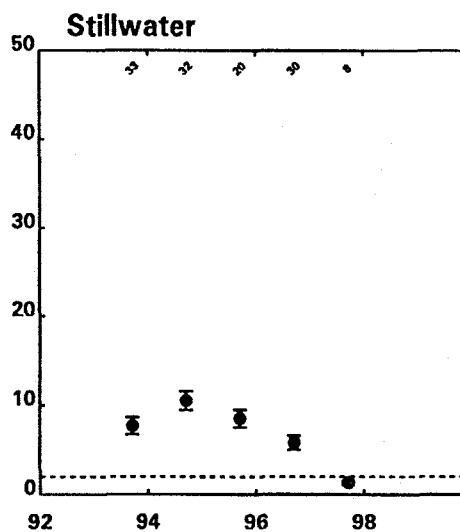
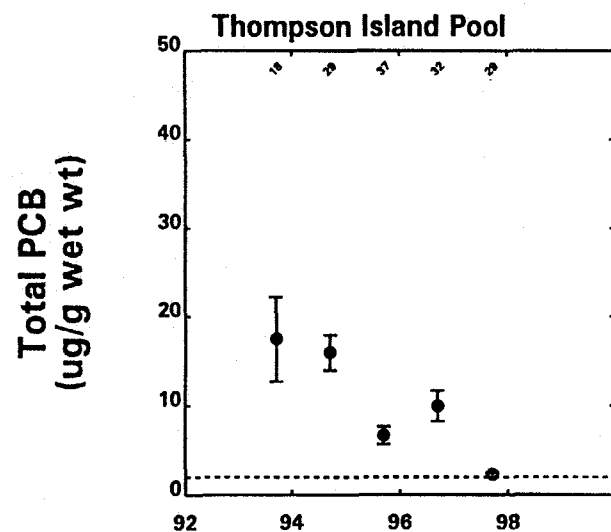
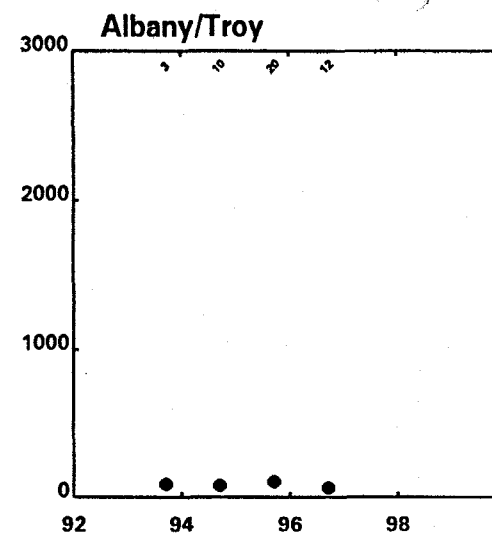
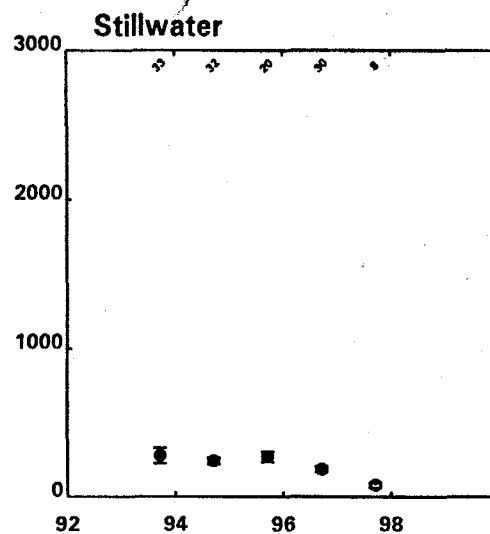
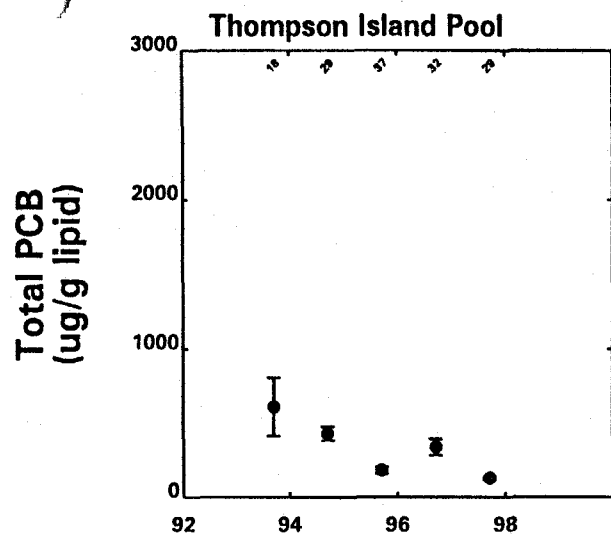
Values are plotted approximately at the midpoint of each season

Number of observations are indicated on each panel

Temporal patterns in Total PCB Concentration in BB

Tue Jan 27, 1998 17:29:33

/petro4/geco0510/ANALYSIS/BIOTA/MISC_BIOTA [temp14ajunk]



Yearling

Aug - Nov

All tissues (see database notes)

Males & Females

Mean +/- 2 std errors

Vertical line at Sept 17, 1991

Values are plotted approximately at the midpoint of each season

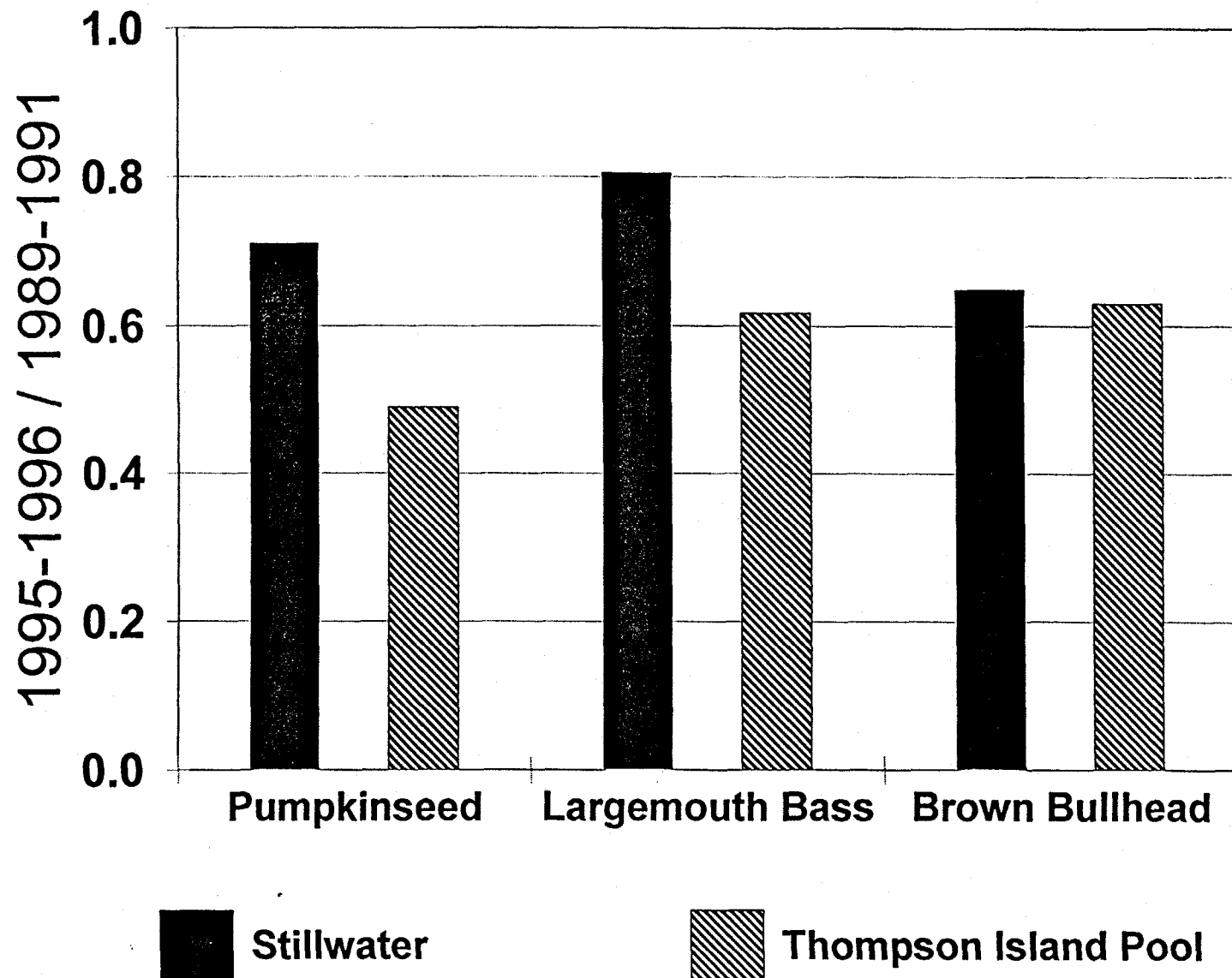
Number of observations are indicated on each panel

Temporal patterns in Total PCB Concentration in PKSD

Tue Jan 27, 1998 17:30:10

/petro4/geco0510/ANALYSIS/BIOTA/MISC_BIOTA [temp14ajunk]

Changes in PCB Levels in Upper Hudson River Fish Ratios of 2-Year Averages, ug/g lipid



10.2237

APPROACH USED IN THE LOW RESOLUTION CORE STUDY

Thompson Island Pool:

Resample at a limited number of the locations sampled in 1984 and calculate the changes in PCB mass present at these locations

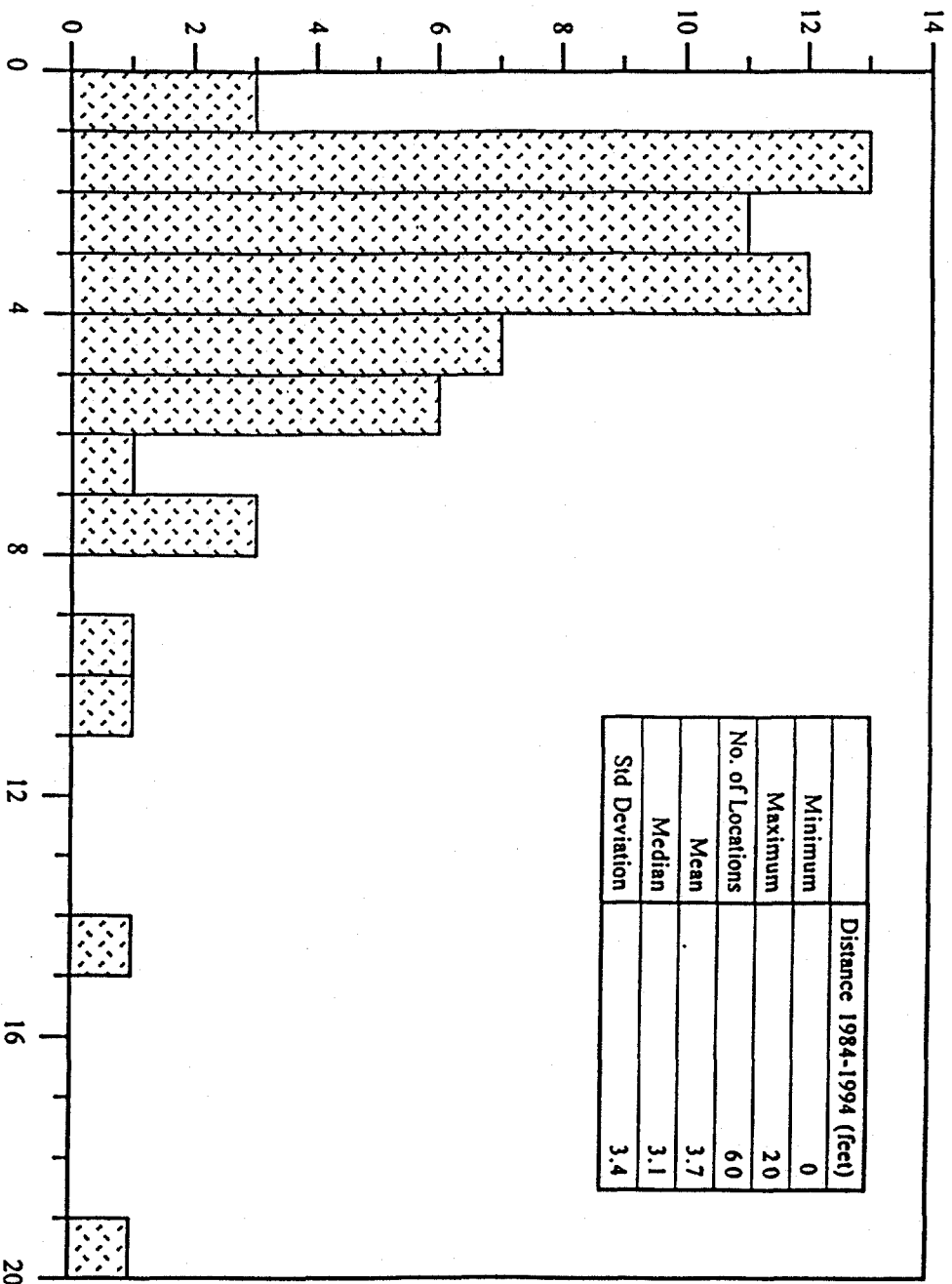
Regions Below the TIP:

Sample in the largest hot spots. Calculate the PCB mass from these data and compare to a mass calculated from data collected in 1976-78

THE ESTIMATES OF MASS CHANGE PRESENTED IN THE LOW RESOLUTION CORING REPORT ARE UNRELIABLE

- The necessary data quality objectives were unachievable
 - *spatial estimation error (change over short distances) of < a few percent*
 - *analytical error of < a few percent*
- The sampling design and analysis biased the results
 - *the selected 1984 samples were not representative of the TIP hot spots*
 - *locations of lower initial (1984) mass were removed from the analysis*
- Unquantifiable error was introduced by data extrapolation
 - *surface sediment PCB concentrations to depths not sampled*
 - *sampled locations to nonsampled locations*

No. of Occurrences



	Distance 1984-1994 (feet)
Minimum	0
Maximum	20
No. of Locations	60
Mean	3.7
Median	3.1
Std Deviation	3.4

Distance Between 1984 and 1994
Sediment Sample Location Pairs (feet)

Source: TAMS/Gradient Database, Release 3.5

TAMS

Figure 2-1

Distance Between 1984 and 1994 Sediment Sample Locations

**THE PHASE 2 REPORT VOLUME 2C - DATA EVALUATION AND INTERPRETATION
REPORT INDICATES THE MAGNITUDE OF THE SPATIAL ESTIMATION ERROR**

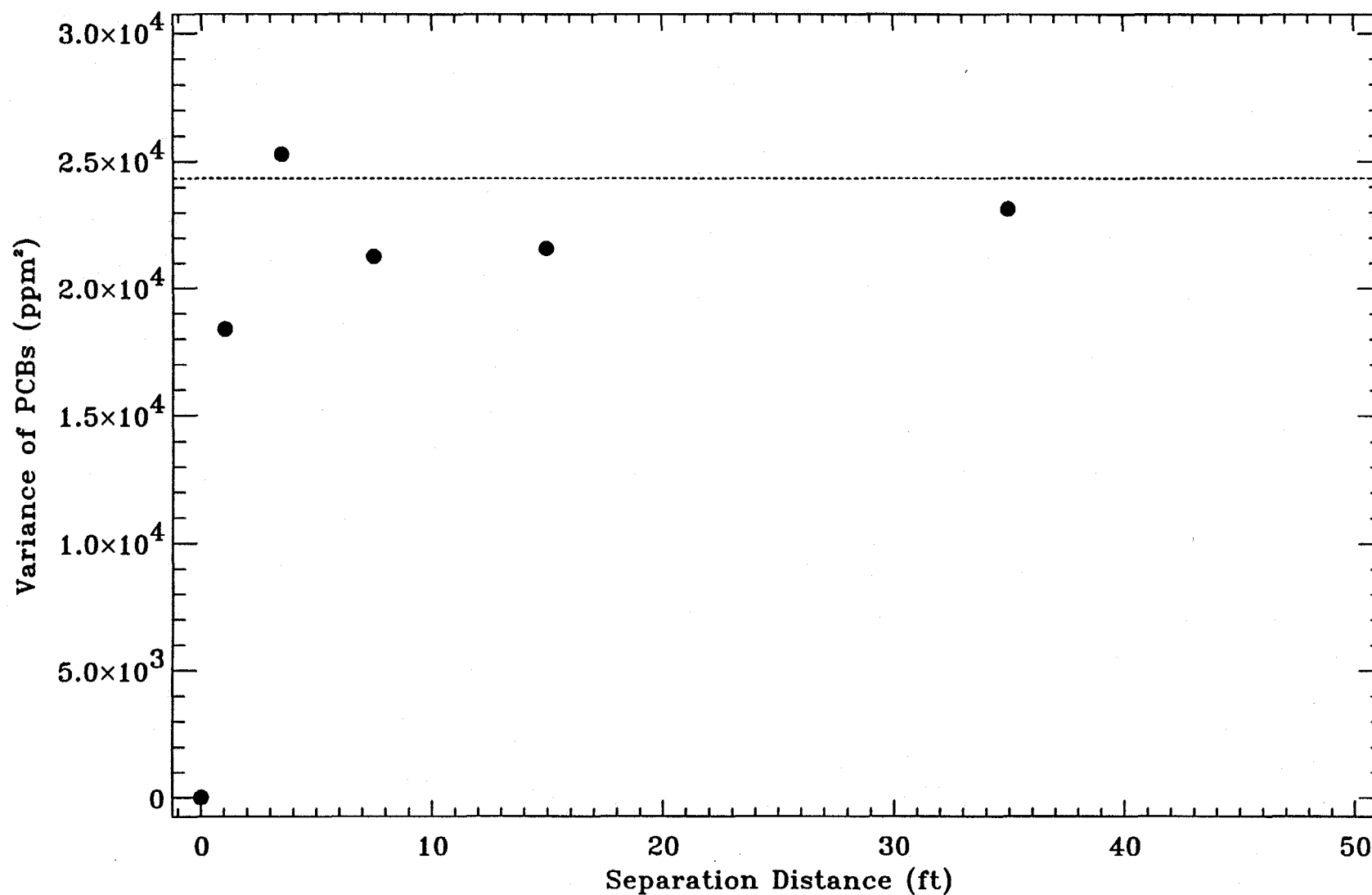
On page 4-25 the DEIR states:

“As noted in the Phase 1 Report ..., the 1984 sediment survey revealed a high degree of heterogeneity in the distribution of PCBs in Thompson Island Pool sediments. Indeed, it was not unusual for samples taken only a few meters apart horizontally to exhibit order-of-magnitude differences in PCB concentrations ...”

Ratio of PCB Levels in Paired Samples from the H7 ("Hot Spot" 5) Site at Various Distances of Separation

Distance Between Paired Samples (feet)	Average Ratio of the Paired Samples (High/Low)
0 – 2	2.1
2 – 5	5.5
5 – 10	21.5

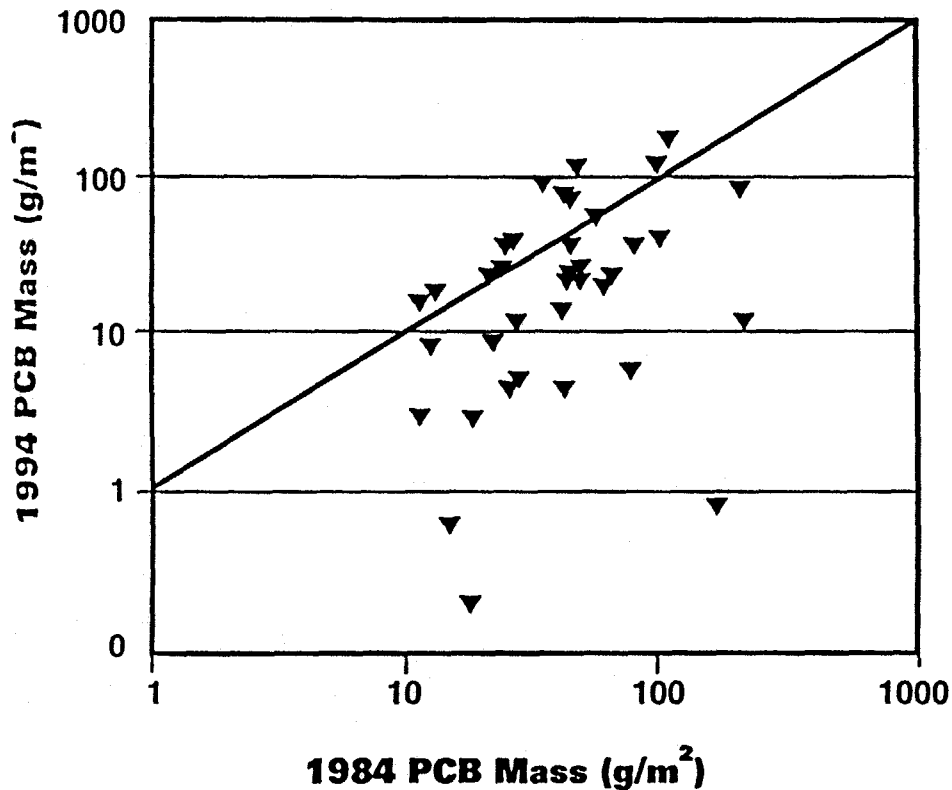
Semi-variogram of 1990/91 GE Data Collected from the H7 site ("Hot Spot" 5) illustrating variance of data versus separation distance. Dashed line indicates variance of full 1990/91 GE data at H7 site.



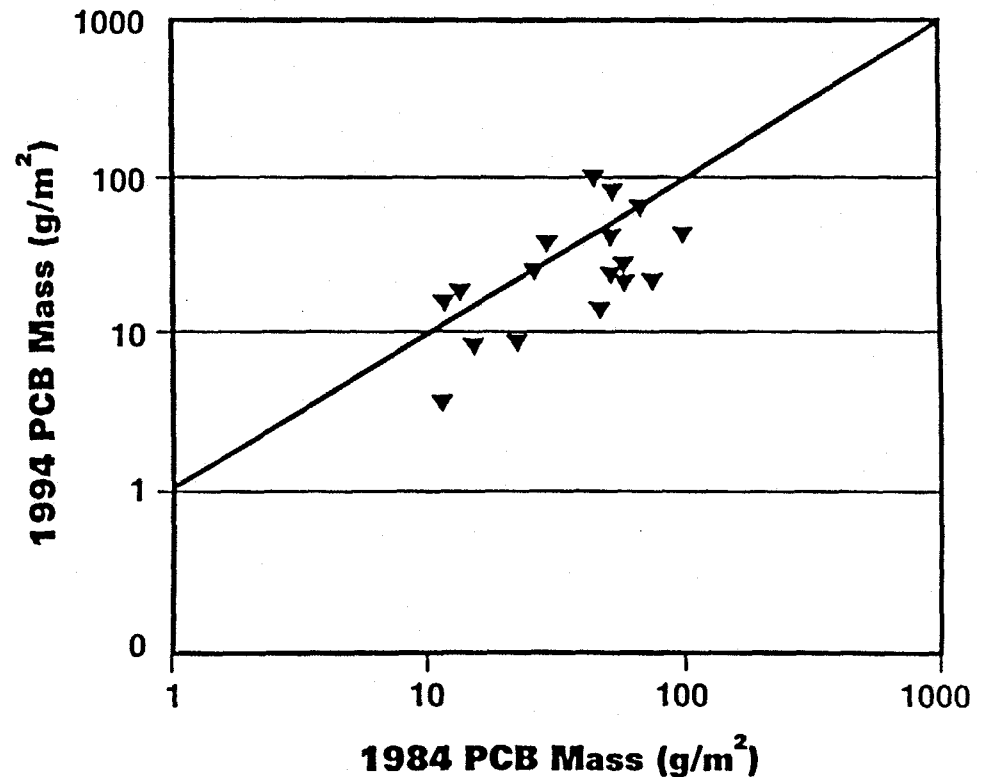
10.2243

EFFECT OF INCLUDING NON-MATCHED DATA ON 1984-1994 PCB MASS COMPARISONS

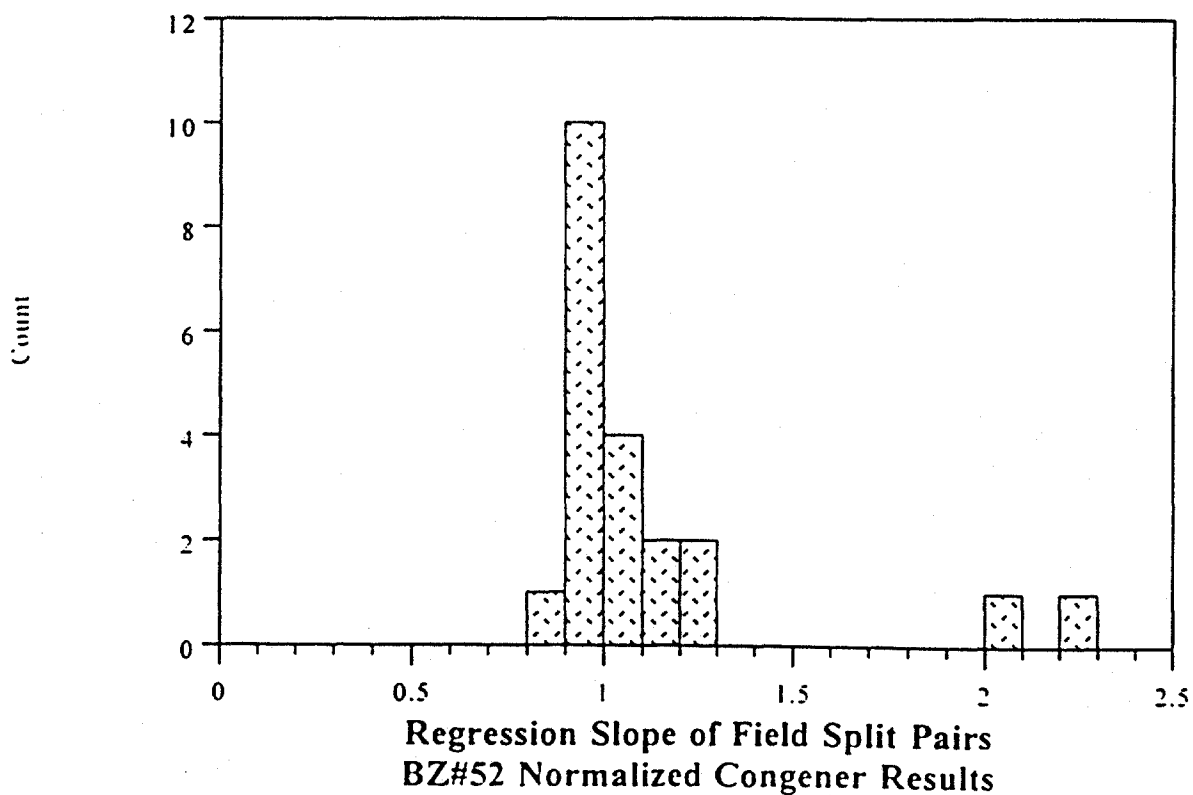
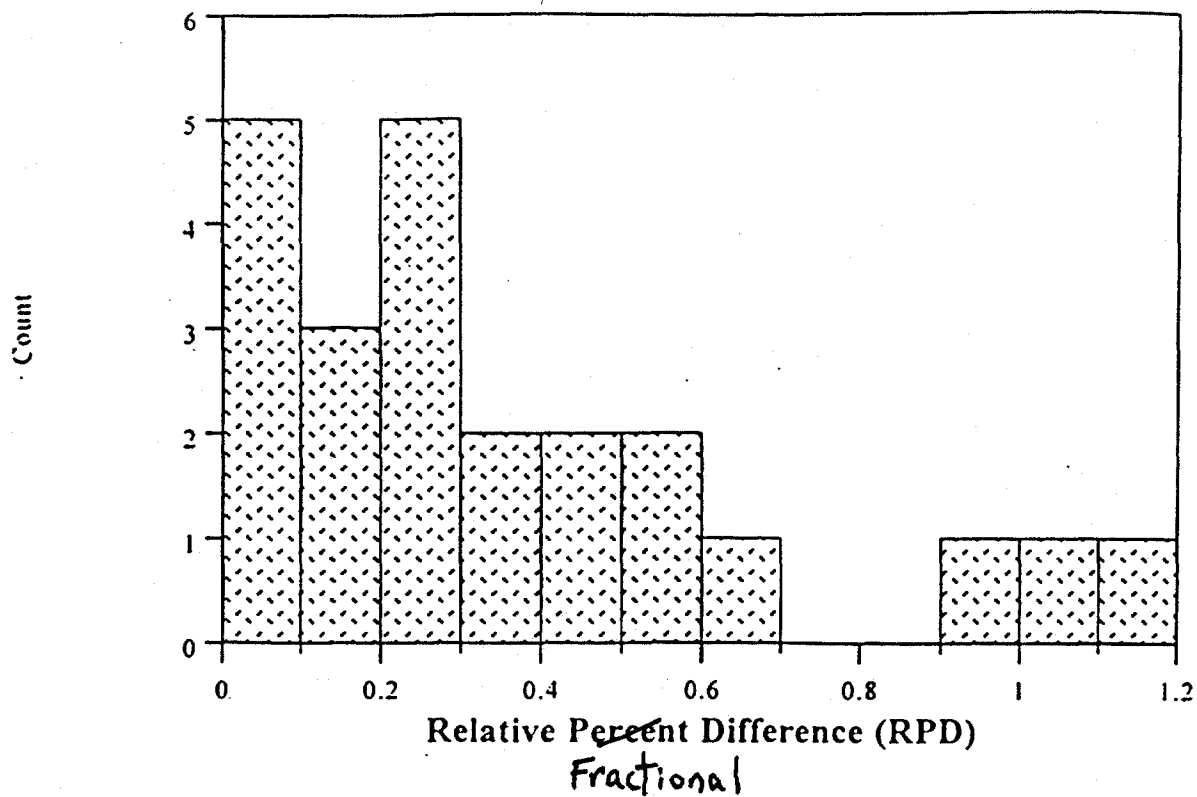
Including non-matched data
(cores more than 5 feet apart
and sediment grab samples)



Including only matched data
(cores fewer than 5 feet apart)



CONCLUSION: EPA's use of non-matched data in almost half the sample locations led to an over-estimated loss of PCBs from Thompson Island Pool sediments.

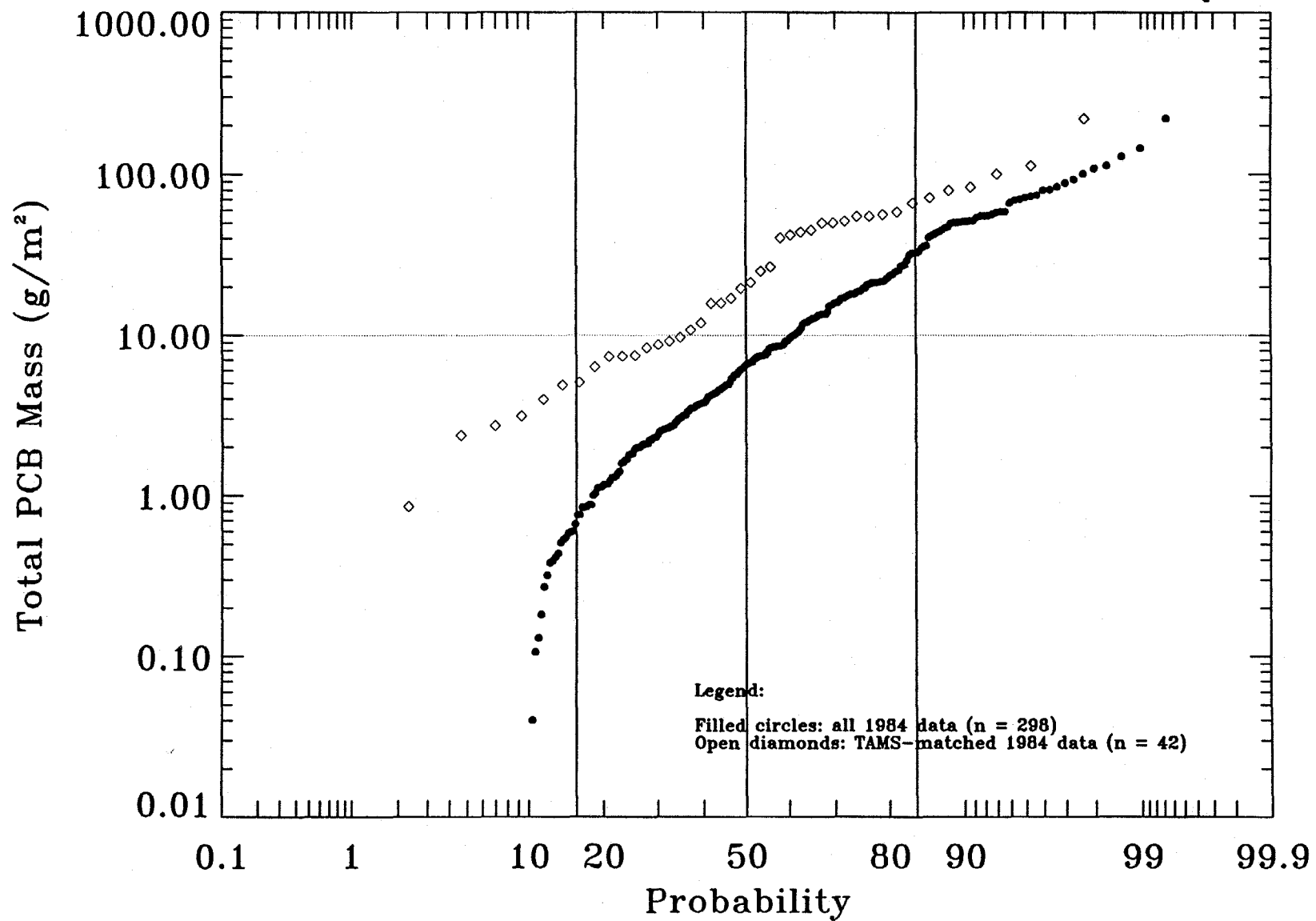


Source: TAMIS/Gradient Database. Release 3.5

TAMIS

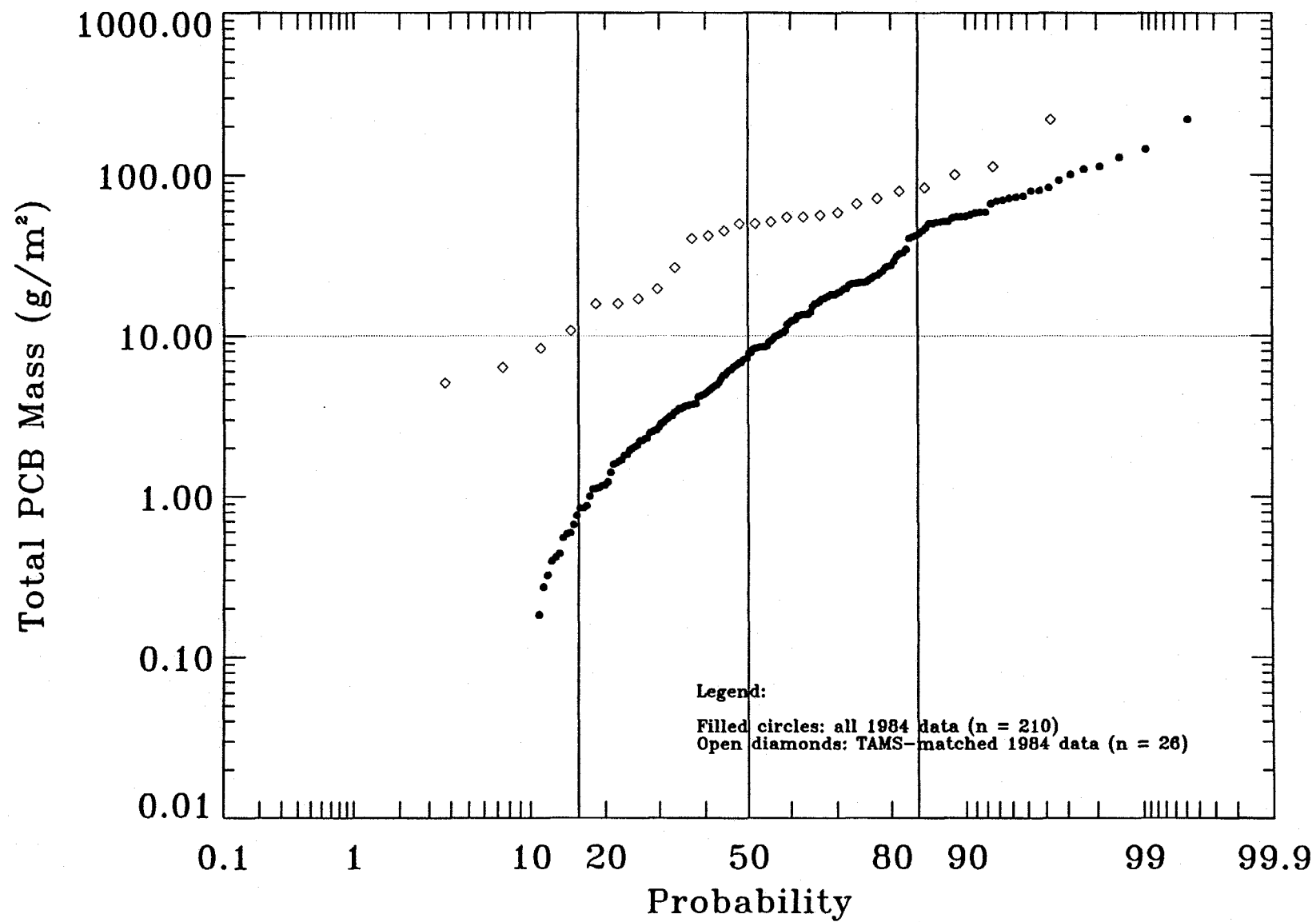
Figure 2-6
Precision in Total PCB Concentration for Low Resolution Core Field Splits

Probability distribution of estimated PCB mass for cores collected from TIP.



10.2246

Probability distribution of estimated PCB mass for cores collected from within 1976-1978 NYSDEC defined "hot spot" areas of TIP.



10.2247

THE ESTIMATED MASS CHANGE DIFFERS GREATLY DEPENDING ON WHETHER LOCATIONS WHERE THE PCB INVENTORY IN 1984 WAS LESS THAN 10 g/m² ARE EXCLUDED

	<u>Average Mass Loss</u>	<u>95% Confidence Limits</u>
Core-pairs with 1984 inventory > 10 g/m ²	79	73% mass loss to 85% mass loss
All core-pairs	21	31% <i>mass gain</i> to 73% mass loss

The conclusion changes from 80% mass loss to no significant mass change!

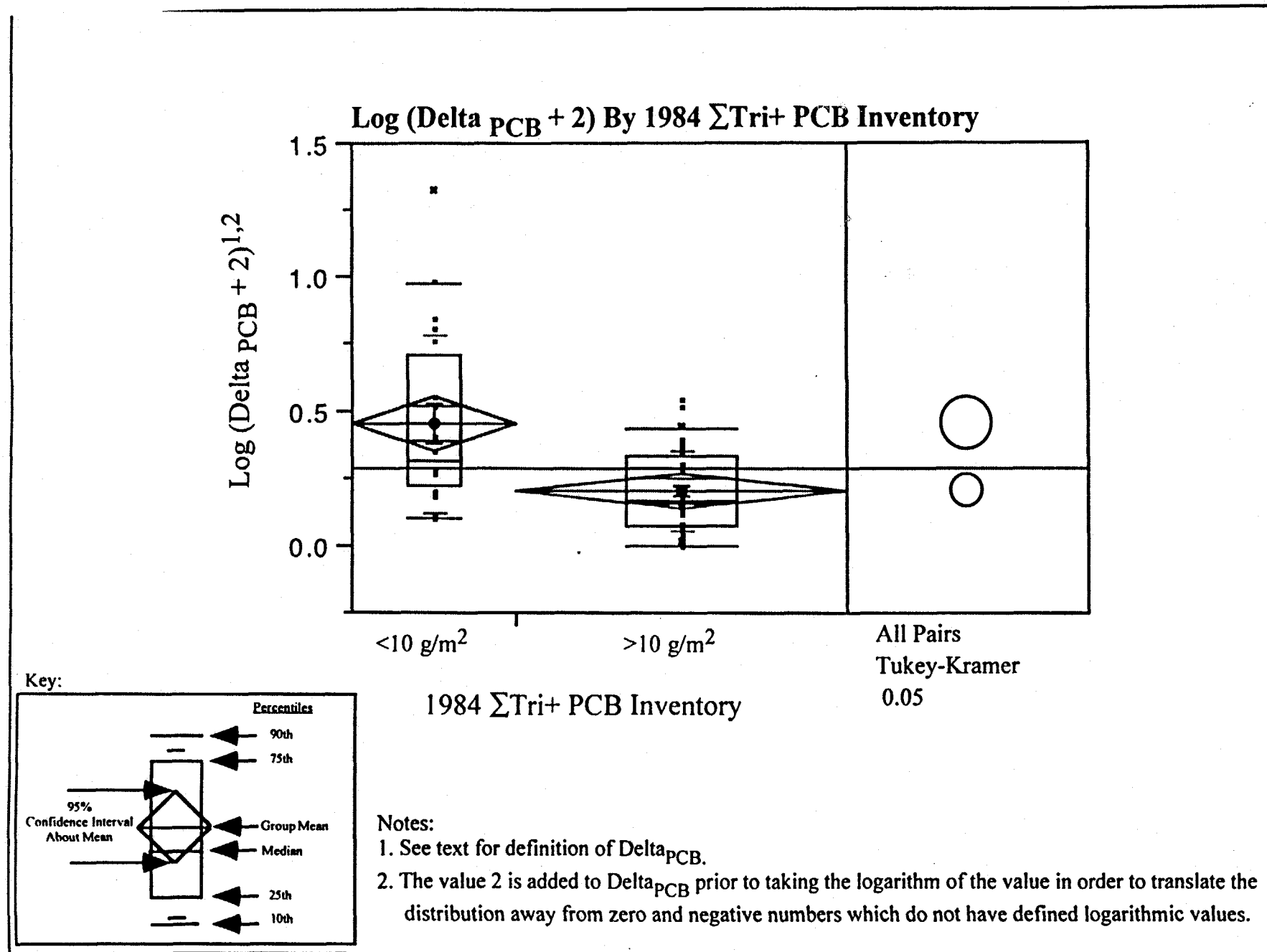


Figure 4-14
Percent Mass Change (ΔPCB) by 1984 $\Sigma\text{Tri} + \text{PCB}$ Inventory

**THE ERROR INTRODUCED BY SPLITTING THE DATA SET WAS HIGHLIGHTED BY
STANFORD UNIVERSITY STATISTICIAN PAUL SWITZER**

“for any collection of paired measurements ... higher initial concentrations will tend to show a decrease on average and lower initial concentrations will tend to show an increase on average -- *in the absence of any distributional changes!*”

“very short-scale variability is often comparable to total variability [see Figures 4-9 to 4-12 and 4-14 to 4-16 in the 1997 report]. This fact, by itself, can be used to show that even small locations errors induce a large spurious regression effect that would account for most of the reported 1994 PCB decrease at locations with high 1984 PCB.”

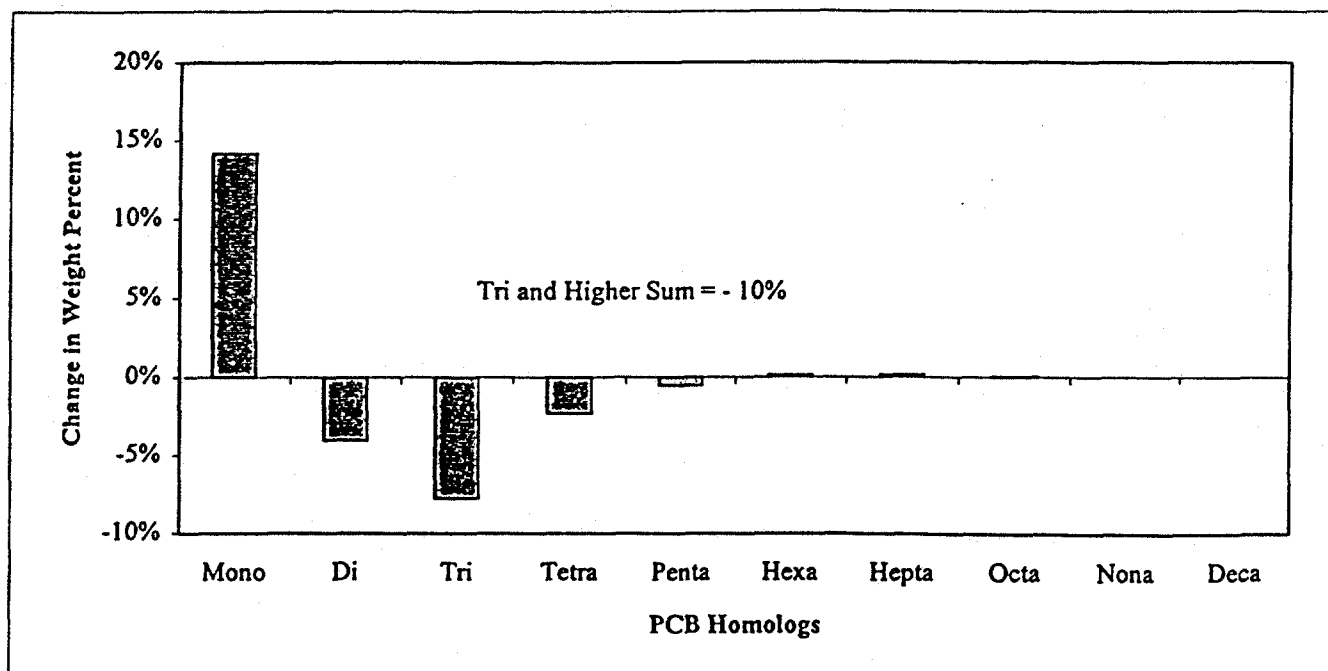
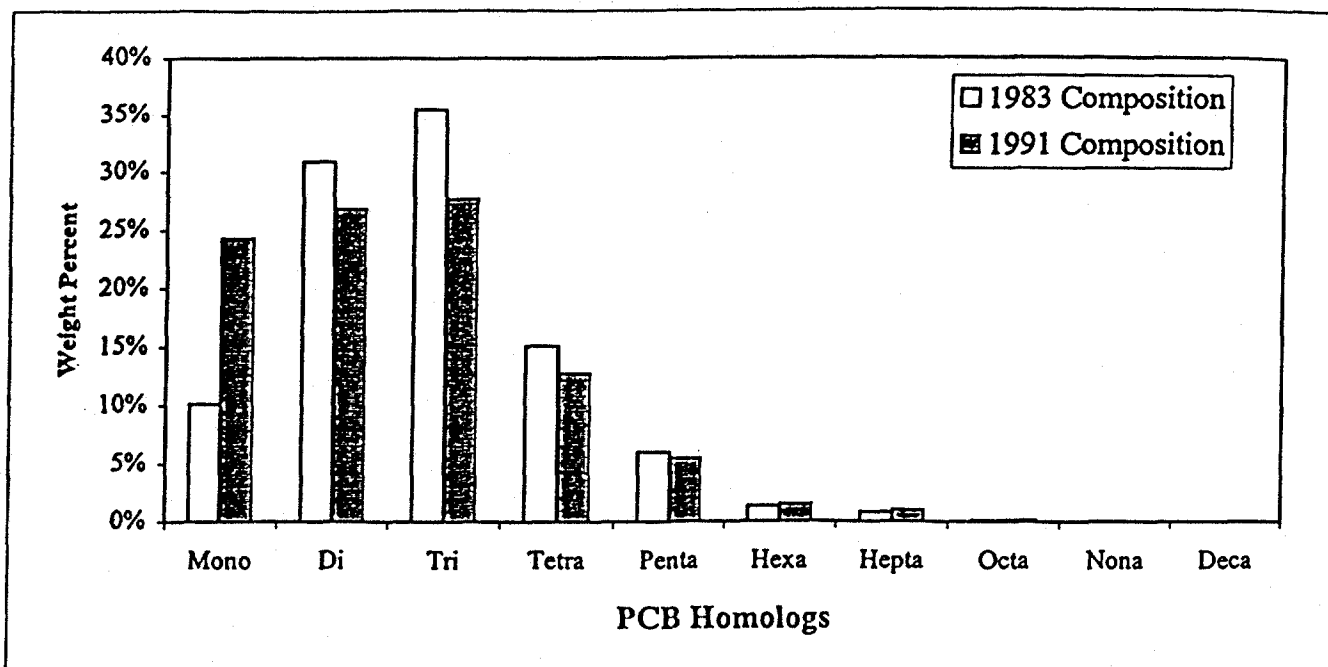
THE ANALYSIS IS FURTHER COMPROMISED BY INACCURACIES, ERRORS AND OMISSIONS

- A fraction of total PCBs (1984) was compared to total PCBs (1994)
- 1984 surface PCB data were extrapolated to deeper depths for comparison to 1994 cores
- The geometric mean was used to estimate the average mass loss
- The full vertical extent of the PCB inventory was not captured in all samples

PCB INVENTORIES MUST BE COMPARED USING THE SAME MEASURE OF PCBs

- The Low Resolution Coring Report discusses the importance of this point
- The report presents a comparison using different measures of PCBs and, without explanation, omits a comparison using the same measure of PCBs
- 1984 data do not include PCBs that have only one or two chlorine atoms
- 1994 data include all of the PCBs
- Comparison should be based on the fraction of PCBs with three or more chlorine atoms
- *Correcting this error in the report changes the estimated mass change from 40% to 80%*

PCB Composition of TIP Sediment Deposited in Approximately 1968 assessed from
Core Sections Collected in 1983 and 1991 (Total Concentration > 500 ppm).



Data Source: McNulty, 1997

**JOHN BROWN AND COWORKERS OBSERVED SIGNIFICANT DECLORINATION IN
SEDIMENTS COLLECTED IN THE 1980s**

“... it was evident that in the upper Hudson River as a whole a massive (40 to 70 metric ton) conversion of tri-, tetra-, and higher chlorobiphenyls to mono-, di- and 2,6,X'-trichlorobiphenyls ... had occurred, particularly in the subsurface...”

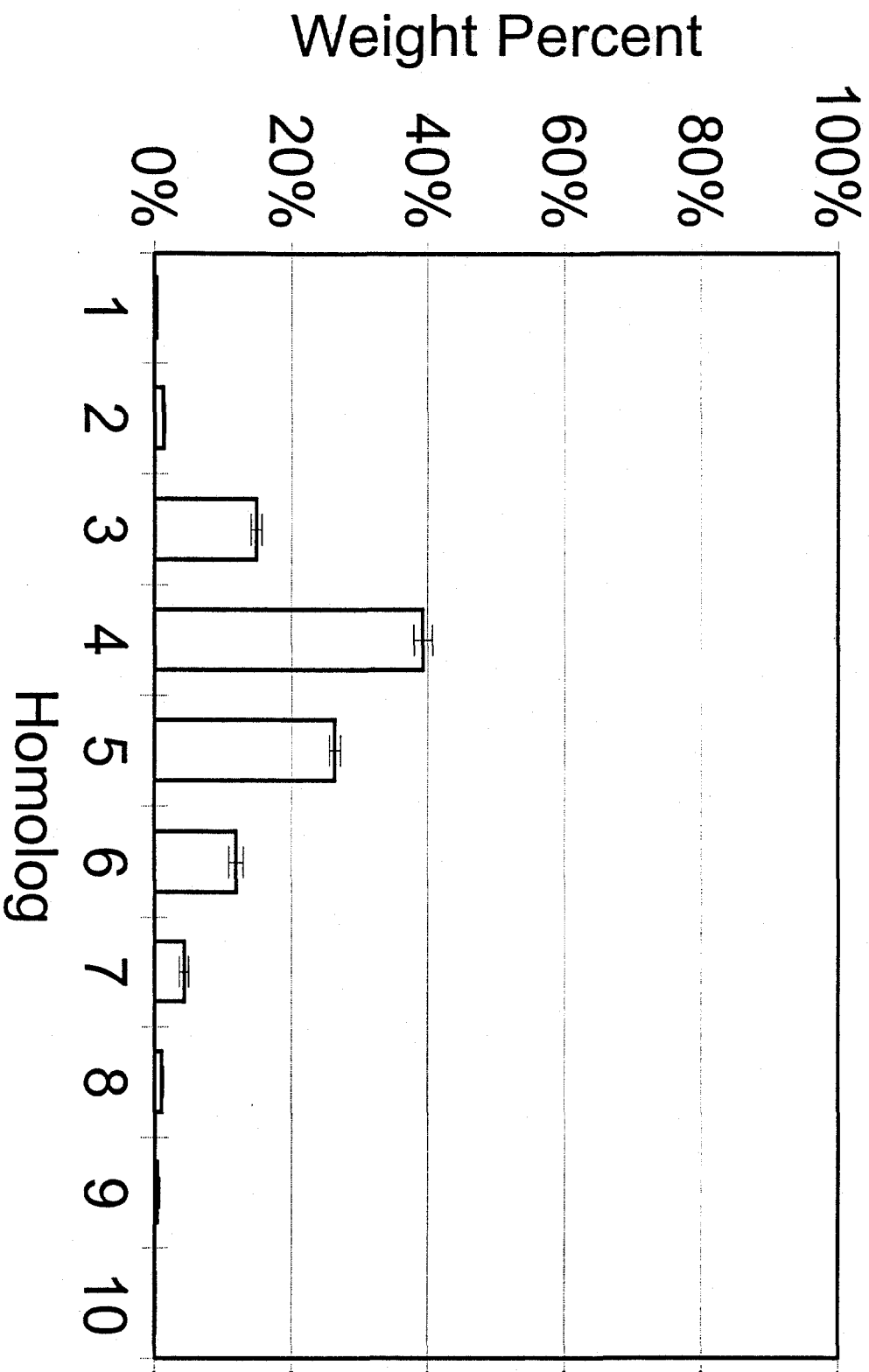
Brown et al., 1987, Science. 236:709-712.

CONTRIBUTION OF LOW CHLORINATED PCBs (Aroclor 1221) TO TOTAL PCBs IN 1977**Fraction of 1221 within Total PCB ***
1976 - 1978 Data

Data Set	Number	Average	Std Dev
All Samples	1765	0.17	0.15
Surface	969	0.15	0.14
All Samples w/in TIP	545	0.19	0.17
All Samples w/in Hot Spots	472	0.19	0.18
All Samples w/in Hot Spots in the TIP	288	0.22	0.19

* Total PCB = 1.22*1016 + 1221 + 1254

Homolog Composition of Fish Upper Hudson River



Mean +/- 2 standard errors

All species and all locations

Data source: 1993 EPA and NOAA

THE CALCULATED PCB INVENTORY CHANGES IN HOT SPOTS DOWNSTREAM OF THE TIP IS ALSO UNRELIABLE BECAUSE OF OVERWELMING UNCERTAINTY

- Reported mass changes vary from an increase of greater than an order of magnitude (Hot Spot 28) to a decrease of about 80% (Hot Spot 31)
- Increases in Hot Spots 28 and 39 (1000% and 200%) were dismissed
- None of the mean changes is statistically different from no change

Calculated Mean and Range (95% confidence limits) of Estimated Mass Changes in
"Hot Spots"

"Hot Spot"	Mean Mass Change (g/m ²) ¹	Range of Mass Change (g/m ²)
25	0	+28 to -28
28	175	+347 to -3
31	-43	+5 to -90
34	-10	+4 to -24
35	2	+16 to -12
37	1-0	+1 to -21
39	27	+67 to -13

¹ Negative values indicate mass loss

SUMMARY

- The estimated PCB mass loss in the “highly contaminated” sediments of the TIP cannot be relied on because the methodology is flawed:
 - 1) Spatial variation compromises direct comparison of individual 1984 and 1994 samples [page 4-25 of the DEIR]
 - 2) PCB measurements are highly inaccurate due to analytical error [page 2-18 of the Report]
 - 3) The sampling design introduced a bias that forced a conclusion of mass loss
 - 4) The bias was exacerbated by partitioning of the data set based on 1984 mass
 - 5) Extrapolations were conducted without statistical basis [page 2-15 of the Report]
- This approach yields an estimate which cannot be reconciled with the mass balance on which the fate and transport model relies