Estimating Sedimentation Rates in Cayuga Lake, New York from sediment profiles of ^{137}Cs and ^{210}Pb Activity

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Abstract

Sedimentation at the southern end of Cayuga Lake N. Y. is a growing concern, and suspended-sediment plumes are visible in the lake during and after periods of storm runoff. Sedimentation rates estimated from depth profiles of radioisotopes in sediment cores collected in Cayuga Lake during 1981-98 indicate that the rate of sediment deposition during the past century has been greater than historic rates over the past several thousand years. Sedimentation rates of 2.4 to 8.1 mm/yr since the 1950's were computed from the maximum depth of penetration and the depth of maximum ^{137}Cs activity in sediment cores from nine sites; rates of 2.4 to 6 mm/yr since 1900 were computed from the exponential decrease of unsupported ^{210}Pb computed in cores from six of these sites. In contrast, a historic sedimentation rate of less than 1 mm/yr was previously estimated from radiocarbon-dated wood fragments found in two sediment cores from Cayuga Lake.

Changes in land use (deforestation, farming and development) in the Cayuga Lake basin in the past 200 years could have increased sediment deposition by increasing soil erosion, storm runoff and streambank erosion. A chronology of changes in the sedimentation rate over the past 150 years might be developed through correlation of ^{137}Cs and ^{210}Pb activities and other chronological markers, such as changes in pollen composition and isotopic composition of lead, with laminations of alternating light and dark bands in sediment cores. A complete sediment chronology could provide a basis for interpreting trends in sediment deposition and assessing the historical significance of major sediment sources and thereby indicate whether proposed changes in land use are likely to reduce sedimentation in the lake.

Introduction

Suspended-sediment plumes in Cayuga Lake (Fig. 1) have been a visible effect of European settlement in the basin since the early 1800's. An early traveller in June 1750 noted that lake waters were "clear as crystal" after several days of heavy rains (Beauchamp 1916), whereas sediment plumes are now commonly visible after periods of storm runoff. The sediment plume that accompanied tropical storm Agnes in June 1972 (Fig. 2) caused measurable changes in aquatic vegetation, including the emerging dominance of Eurasian watermilfoil, a non-native species (Johnson, this proceedings). A 1999 watershed characterization prepared by the Cayuga Lake Watershed Intermunicipal Organization reported that high suspended-sediment concentrations impair water quality for habitat and recreational use (D. Zorn, Genesee-Finger Lakes Regional Planning Council, written commun. 1999).

Widespread deforestation within the watershed in the 1800's (Fig. 3) probably increased the volume of sediment discharged to Cayuga Lake through storm runoff, but little information on recent sedimentation rates in the lake are available. The rate of sedimentation in the lake is needed for estimation of the contributions of known sediment sources; these contributions, in turn, must be known before the effects of erosion-control measures and land-use changes on sediment loads can be assessed.

Sedimentation rates can be estimated from depth profiles of radioisotopes in sediment cores. Fuller and others (1999) developed sediment chronologies from radioisotope profiles of ^{210}Pb, ^{234}Th, ^{137}Cs and $^{239,240}Pu$ to estimate sedimentation rates in San Francisco Bay. Heit and others (1986) calculated sedimentation rates in Cayuga Lake since 1900 from radioisotope profiles of ^{137}Cs, ^{210}Pb and $^{239,240}Pu$. Mullins (1998) estimated historic sedimentation rates in Cayuga from 6,000 to 1,000 yr BP by dating ^{14}C in wood fragments from sediment cores.

This paper presents additional estimates of sedimentation rates in Cayuga since 1900 as calculated from radioisotope profiles of ^{137}Cs and ^{210}Pb. Cesium-137 was a component of radioactive fallout produced through atmospheric testing of nuclear weapons in the 1950's and 1960's; it first entered the environment about 1952, and maximum input occurred in 1963-64 (Callender and Robbins 1994). Lead-210 is a member of the ^{238}U-decay series and is a decay product of ^{226}Rn, which in turn is produced by ^{226}Ra decay (Oldfield and Appleby 1984). The ^{210}Pb produced *in situ* through decay of ^{226}Ra within the sediment column is termed "supported ^{210}Pb." Lead-210 is also produced in the atmosphere and can enter lake water directly through fallout on the water surface or indirectly through upland runoff. These sources deposit ^{210}Pb near the top of the sediment column, where it is termed "excess"

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or "unsupported ^{210}Pb." Lead-210 activities within a sediment profile are generally highest at the sediment surface and approach a constant activity at depths where radioactive equilibrium with the in situ production ^{226}Ra is reached.

Methods

Core samples of lake sediments were collected in 1994 by the U.S. Geological Survey (USGS), which contracted the services of the research vessel "Explorer" from Hobart and William Smith Colleges, in cooperation with the Tompkins County Water Strategy Committee. Additional cores were obtained with a smaller vessel under the auspices of other USGS programs in 1996 and 1998. Thus, the data were not generated under a single, unified program, and the analytical results, therefore, must be correlated from one core location to another.

Sample collection

Sediment samples were collected at three locations in 1994, two locations in 1996, and one location in 1998 (Table 1, Fig. 1). A set of three 20-cm box cores and two 2-m and two 6-m piston cores were collected in 1994 from the "Explorer," a 20-m vessel equipped with a boom capable of handling 6-m piston cores. Three box cores 1 m long were collected in 1996 and 1998 from a 6-m craft with a 2-m boom. Several of the core samples listed herein also are referred to by Mullins (1998) or other authors in this proceedings (see Table 1).

Sediment in box cores was collected within a 15 x 15-cm plastic liner. Sediment in piston cores also were collected within plastic liners—7.5 cm in diameter for the 2-m cores and 2.3 cm in diameter for the 6-m cores. The box cores were sectioned into 1-cm intervals by upward extrusion and then sealed in glass jars in the field. The piston cores were cut into manageable lengths, sealed with end caps and stored under refrigeration.

Laboratory analyses

Subsamples from the box cores collected in 1994 were analyzed for ^{137}Cs activity at USDOE's Environmental Measurements Laboratory. Procedures entailed gamma counting 100-g (wet weight) aliquots of sediment for 1,000 min in sealed 90-cm^3 Teflon-lined aluminum; this was done with a germanium diode spectrometer and a 4000-channel analyzer (Gogolak and Miller 1977; Hardy and others 1978). The dry density (dry mass per volume of wet sediment) of 15-cm^3 subsamples of these samples was later measured by standard gravimetric techniques by Cornell University's Department of Ecology and Systematics. Samples from two piston cores collected in 1994 and three box cores collected in 1996 and 1998 were analyzed for ^{137}Cs by a similar method at a USGS laboratory in Reston Va, although the determinations were made on dry sediment.

Water content wc and grain density ρ_{grain} of sediment were measured by the gravimetric method on frozen subsamples from a 2-m piston core (94-IC) by Cornell University's Department of Geology. The dry density ρ_{dry}

$$\rho_{dry} = (1 - wc)\rho_{grain} \qquad (1)$$

of the subsamples was computed from the following relation,

Subsamples from the box cores and one piston core were analyzed for total ^{210}Pb activity by ^{210}Po distillation and alpha spectrometry methods (Eakins and Morrison 1978). Samples collected in 1994 were analyzed at the Science Museum of Minnesota, and samples collected in 1996 were analyzed at a USGS laboratory in St. Petersburg, Fla. The supported ^{210}Pb (defined by the ^{226}Ra activity) activity of the 1996 samples was measured at the USGS laboratory by gamma spectrometry at the 352 keV ^{214}Pb emission line (Baskaran and Naidu 1995). The supported ^{210}Pb activity for the 1994 samples was estimated from the asymptote approached by ^{210}Pb activities at the bottom of piston core 94-IB. Both ^{137}Cs and ^{210}Pb activities presented herein are in disintegrations per minute per gram (dpm/g, equivalent to 2.2 pCi) per gram dry weight of sediment.

Results

Physical characteristics of sediment

The interface between the water column and sediment was retrieved in all box core samples, but the piston cores overpenetrated the sediment surface by an unknown depth, as previously noted by Mullins (1998). As a result, depths of sediment in box-core samples were equivalent to depths from the top of the core, but sediment depths in piston cores could only be estimated from correlations with chronological markers from an adjacent box core. The upper 1 to 3 cm of the box-core samples typically contained loose, brown sediment with a relatively high water content; the remainder (as much as 1-m depth), resembled the entire length of piston-core samples (to 5.5-m depth), which consisted of firm, grayish-brown to grayish-black silty clay with no evidence of bioturbation. The organic content of the sediment in piston cores 94-IIB and 94-IIIB ranged from about 10 percent near the sediment surface to less than 7 percent at the 5-m depth (Mullins 1998). Radiocarbon dates for wood fragments discovered in these piston cores were obtained with an accelerator mass spectrometer at a USGS laboratory in Reston Va, as reported by Mullins (1998).

Faint bands or laminations of alternating light and dark material were visible in freshly exposed surfaces of piston core samples, but the laminations faded after several days of exposure to the atmosphere. Five thin sections of sediment from layered sections of core 94-IC were impregnated with a low-viscosity resin to indicate whether the laminations were related to differences in grain size, but no differences were detected (Karig and others, 1996). Mullins (1998) also noted laminations in a piston core of Cayuga Lake sediment collected near Long Point (Fig. 1). X-radiographs revealed millimeter-scale laminations throughout most of the core; these laminations also disappeared upon exposure to the atmosphere. This disappearance was attributed to oxidation of reduced metals, such as iron and manganese sulfides.

The dry density of sediment from the 20-cm box cores ranged from 0.31 to 0.66 g/cm^3 with a mean value of 0.47g/cm^3 (Table 2). The dry density of sediment from piston core 94-IC, computed from measured water contents, ranged from 0.19 to 0.41 g/cm^3 with a mean value of 0.36 g/cm^3 over the 213-cm core length (Fig. 4). Dry density showed little variation with depth, except in a section from core depths of 80 to 100 cm, in which the density was low because the water content was high.

^{137}Cs profiles

Sediment profiles of ^{137}Cs activity (Fig. 5) display maxima at depths ranging from 8.5 cm in core 98-I from the south end of Cayuga Lake to about 19.3 cm in core 96-II from Myers Point (Table 3). The depth of ^{137}Cs penetration within the sediment column ranges from 16 cm in core 94-IIIA from Milliken Station to 28 cm in core 96-II from Myers Point. Linear sedimentation rates[2] [LT^{-1}] were computed from (1) the maximum ^{137}Cs activity corresponding to the peak fallout in 1963, and (2) the depth of ^{137}Cs penetration corresponding to the first appearance of ^{137}Cs in 1952. Rates computed by these two methods are correlated (Fig. 6; correlation coefficent 0.76), except for core 98-I from the south end of Cayuga Lake. The spatial distribution of sedimentation rates calculated from ^{137}Cs profiles collected during 1981-98 shows no clear pattern (Fig. 7).

Three ^{137}Cs profiles of sediment collected near Milliken Station in 1981, 1994, and 1996 were compared after adjustment for the time elapsed between collection dates (fig. 8). The ^{137}Cs activities reported for core 81-IIB were decreased to account for radioactive decay after the collection date in 1981, and the ^{137}Cs profiles for cores 94-IIIA and 96-I were shifted downward to account for deposition of sediment between 1981 and the sample-collection date. Core profiles 81-IIB and 96-I show excellent agreement, but the maximum ^{137}Cs activity in core 94-IIIA is at a shallower depth, indicating a lower sedimentation rate. The sedimentation rates computed from ^{137}Cs profiles in seven of the cores range from 4.2 to 7.5 mm/yr, whereas the rates for cores 98-I and 94-IIIA were lower (2.4 to 3.1 mm/y). The poor correlation between ^{137}Cs profiles of the latter two cores and other profiles indicates that the lower rates reflect the effects of local deposition.

Heit and others (1986) computed the total ^{137}Cs inventory (pCi/cm^2) in soil columns at three sites on the shores of Cayuga Lake. The percentage of lake-sediment ^{137}Cs derived from direct fallout on the lake surface, calculated from the ratio between ^{137}Cs inventories in soil and in lake sediment columns, was from 54 to 61 percent. The reciprocal of this ratio, termed the focusing factor (Fuller and others 1999), is a measure of the trapping efficiency of the lake bottom; a factor greater than 1 indictates a net accumulation of sediment. Focusing factors for sediment cores collected in this study were obtained from the ^{137}Cs soil-inventory values reported by Heit and others (1986) after adjusting for radioactive decay from 1981 to the date on which each core was sampled. Focusing factors at most sites range from 1.2 to 2.1 (Table 4) and are generally in agreement with the values reported by Heit and others (1986). Focusing factors of 0.8, which indicate a possible loss of sediment, were obtained for sediment cores 96-II and 98-I. Sediment profiles in both of these cores were anomalous; the peak and first appearance of ^{137}Cs activities were poorly correlated in core 98-I, and ^{210}Pb activities at the sediment surface in core 96-IIA were low, as discussed below; this suggests that the sedimentation rates at these locations are not representative of those at other locations in the lake.

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2 referred to as sedimentation rates herein

^{210}*Pb profiles*

Lead-210 activities in box cores 94-IA, 94-IIA and 96-I generally decrease with depth below the sediment surface, although the values in the upper 2 to 3 cm are relatively constant and suggest a slight degree of mixing at the top of the sediment column (Fig. 9). The ^{210}Pb profile approaches the ^{226}Ra profile asymtopically in core 96-I, indicating that supported ^{210}Pb activity is about 2.5 dpm/g (Fig. 9C, Table 3). The ^{210}Pb profile in core 96-II from near Myers Point indicates that supported ^{210}Pb activity is about 2.1 dpm/g at depths below 30 cm (Fig. 9D). This profile is unusual, however, because the maximum ^{210}Pb activity is at a depth of 7 cm, and ^{210}Pb activity at the sediment surface shows little excess, indicating that old lake sediments occupy the top of the sediment column. These sediments could have been redeposited by slumping of part of the delta at the mouth of Salmon Creek (Fig. 7). The ^{210}Pb profile in piston core 94-IB indicates that supported ^{210}Pb is about 2.3 dpm/g (Fig. 9A), a value in good agreement with box cores 96-I and 96-II. The sediment depths in the piston core were estimated through a comparison of the ^{210}Pb and ^{137}Cs activities with those measured in box core 94-IA.

Sedimentation rates were estimated from depth profiles of unsupported ^{210}Pb activity values from the constant-flux constant-sedimentation rate (CF-CS) model (Oldfield and Appleby 1984) which assumes that the sedimentation rate and the ^{210}Pb activity of sediment particles are constant. The sediment-accumulation rate ω $[MT^{-1}L^{-2}]$ can then be estimated from the exponential decay of ^{210}Pb activity C in the sediment column from the following relation

$$C = C_0 e^{(-km)/\omega} \qquad (2)$$

where

C_0 is the unsupported ^{210}Pb activity at the sediment surface $[ML^{-3}]$,

m is cumulative dry mass of sediment $[ML^{-2}]$, and

k is the ^{210}Pb radioactive decay rate (0.03144 yr^{-1}) $[T^{-1}]$.

If the dry density of sediment is assumed constant throughout the sediment column, then $m = \rho_{dry}d$, and $\omega = \rho_{dry}r$, and the linear sedimentation rate r can be computed from the slope $-k/r$ obtained from plots of log C vs. sediment depth d.

Profiles of unsupported ^{210}Pb in cores 94-IA, 94-IIA, and 96-I fit the CF-CS model well and yield sedimentation rates ranging from 3.8 to 4.4 mm/yr (Fig. 9). These values indicate that the sedimentation rate in the lake has been relatively constant over the past 90 years (four half-lives of radioactive decay), although the difference between unsupported ^{210}Pb-activity values obtained from analytical results and the values obtained from eq. 2 indicate year-to-year variability in the sedimentation rate. Depths of sediment deposited in 1949 and 1951 were calculated for cores 94-IA,B and 96-I (Fig. 10) from the ^{210}Pb-activity values corresponding to two half-lives of radioactive decay (44.5 yr). These sediment depths match reasonably well the depths corresponding to the first appearance of ^{137}Cs in 1952 and further support the applicability of the CF-CS model to sediment cores in Cayuga Lake.

Discussion

Sedimentation rates in Cayuga Lake computed from depth profiles of radioisotope activities in sediment cores by Heit and others (1986) and the present study provide nine values computed from ^{137}Cs profiles and six values computed from ^{210}Pb profiles (Table 4). The rates computed from peak concentrations of ^{137}Cs ranged from 2.4 to 8.1 mm/yr with a median value of 5.5 mm/yr (Fig. 11), and the rates computed from unsupported ^{210}Pb profiles were lower—2.4 to 6 mm/yr with a median value of 4.0 mm/yr. These Cayuga Lake rates are higher than the 2.3- to 5.3-mm/yr values estimated from single sediment profiles from each of six other Finger Lakes (Clifford Callinan, New York State Department of Environmental Conservation, oral commun.,1999); sedimentation rates estimated from ^{137}Cs and ^{210}Pb profiles in Seneca Lake, for example, which is similar in size to Cayuga Lake, were from 2 to 3 mm/yr. Seneca Lake has a smaller drainage area (1,267 km^2) than Cayuga Lake (2,034 km^2), and wetlands at its inlet could remove sediment from storm runoff and thereby decrease sedimentation in the lake. Wetlands at the southern end of Cayuga Lake were removed by land filling in the early 1900's and no longer provide this function.

A sedimentation rate of 0.8 mm/yr for Cayuga Lake from 6,000 to 1,000 yr BP was estimated by Mullins (1998) from ^{14}C dating of wood fragments found in piston cores 94-IIB and 94-IIIB. Sediment depths in the two cores were correlated through a comparison of $CaCO_3$ profiles, which both showed a distinctive decrease in $CaCO_3$ content at about 3,400 yr BP, determined by ^{14}C dating. The rate computed by Mullins (1998) is the best estimate of sedimentation under conditions that prevailed in the basin prior to European settlement in the early 1800's. In contrast, rates computed in this study reflect sedimentation within the past century and are considerably greater than the sedimentation rate prior to 1800 (0.8 mm/yr). Rates over the past 50 years (5.5 mm/yr), estimated from the ^{137}Cs profiles, are generally higher than rates over the past 90 years (4 mm/yr) estimated from ^{210}Pb profiles (fig. 6). The variability in the small number of estimates is large, however, and whether sedimentation rates have continued to increase in latter half of the 20th century cannot be discerned from the available data.

Increased sedimentation rates during the past century probably reflect the combined effects of European settlement, including deforestation, farming, and urban and residential development. Widespread deforestation that accompanied settlement in the 1800's greatly altered the pattern of vegetation in the watershed by replacing hardwood forests with fields (Marks and deGloria, this volume). This change probably increased storm runoff and soil erosion, which increased the rate of sedimentation in Cayuga Lake. Some of this sediment load was probably stored within tributary channel deposits (Karig, this volume). Although soil erosion within the watershed probably declined in the 20th century as the result of soil conservation practices and decreasing agricultural acreage, erosion of stream-channel deposits by storm runoff continues to deliver sediment to Cayuga Lake. Storm runoff has increased during the past century as a result of urban and residential development as construction of paved surfaces and runoff-diversion structures continues.

Conclusions and Suggestions for Further Study

Sediment profiles indicate that the rate of sedimentation in Cayuga Lake has increased sharply in the past 200 years, probably as a result of human activities in the watershed. The relative contributions from past and present sediment sources is uncertain, however, because (1) none of the reported chronologic markers can be used to estimate sedimentation rates before 1900, and (2) the wide range in estimated sedimentation rates since 1900 prevents the delineation of a trend.

Defining the historical trend in sedimentation rate would facilitate decisions regarding changes in current land-use practices within the basin to decrease the transport of sediment to Cayuga Lake. For example, if the sedimentation rate has increased steadily since 1900, then control of the current sediment sources could possibly decrease sedimentation in the lake, whereas, if the sedimentation rate has remained essentially constant since the 1800's deforestation, changes in current practices will probably have only a minor effect on sedimentation.

Collection and analysis of additional sediment cores could help define historical trends in the sedimentation rate if additional chronologic markers could be obtained to date sediment deposited before 1900. Heit and others (1986) report finding charcoal and pollen in lake sediments that presumeably resulted from the burning of hardwood forests and the introduction of grasslands following deforestation of the basin in the 1800's. Graney and others (1995) and William White (Cornell University, written commun., 1999) report that other stable isotopes of lead (^{204}Pb, ^{206}Pb, ^{207}Pb and ^{208}Pb) can be used to date sediment because they reflect the changing isotopic composition of atmospheric lead that accompained smelting of ores beginning in the 1890's. Thomas Kraemer (U.S. Geological Survey, oral comun.,1999) found high concentrations of arsenic in lake sediments in core 98-I, which he attributed to an industrial spill in the City of Ithaca in the 1930's. Although these sediment records could be useful in correlating sediment cores, the pollen and charcoal might not provide useful information because the rate and timing of deforestation are poorly documented, and the arsenic-spill and atmospheric-lead data are too recent to indicate sedimentation rates during the 1800's.

Further studies regarding the origin and distribution of laminations observed in sediment cores might permit the extrapolation of sediment dates from known chronologic markers and might discover whether the distribution of laminations within depth profiles are periodic and can be correlated from one location to another. Sediment cores obtained with a 1-m box core would provide a sediment record of sufficient length to document the effects of human activity within the basin in the 1800's. A complete set of analyses would include ^{137}Cs, stable isotopes of lead ($^{204 \text{ to } 210}Pb$), arsenic, pollen, charcoal, and calcium carbonate.

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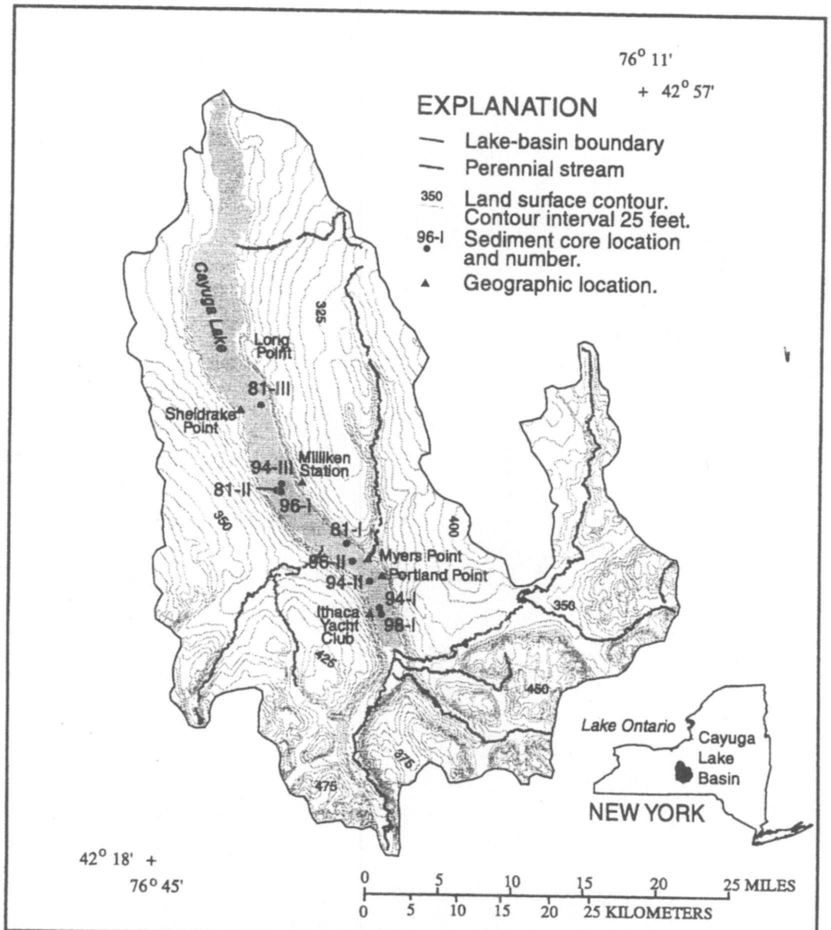


Base from U.S. Geological Survey digital data, 1:24,000, 1998
New York coordinate system, West Zone

Figure 1. Sediment coring locations in Cayuga Lake

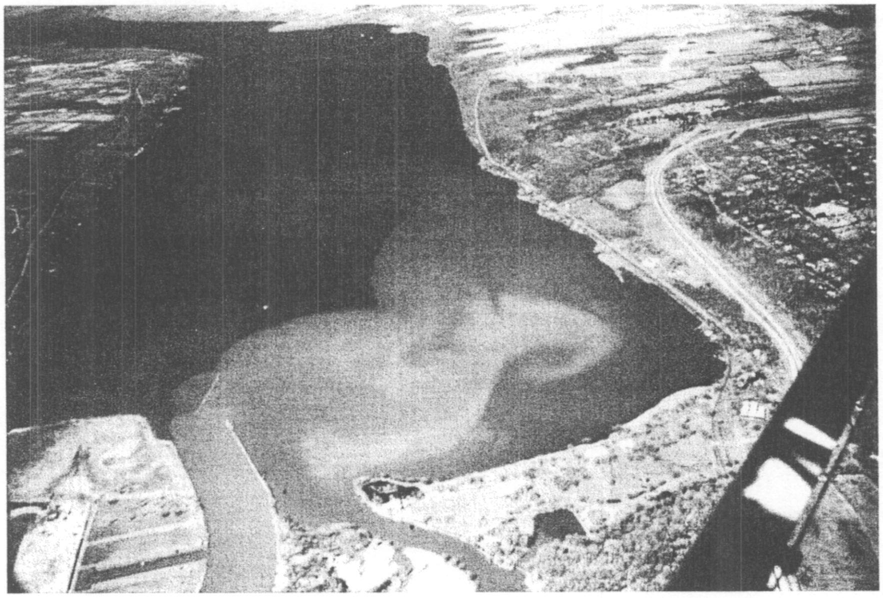


Figure 2. Suspended sediment plume in Cayuga Lake created by storm runoff from tropical storm Agnes, June 1972.

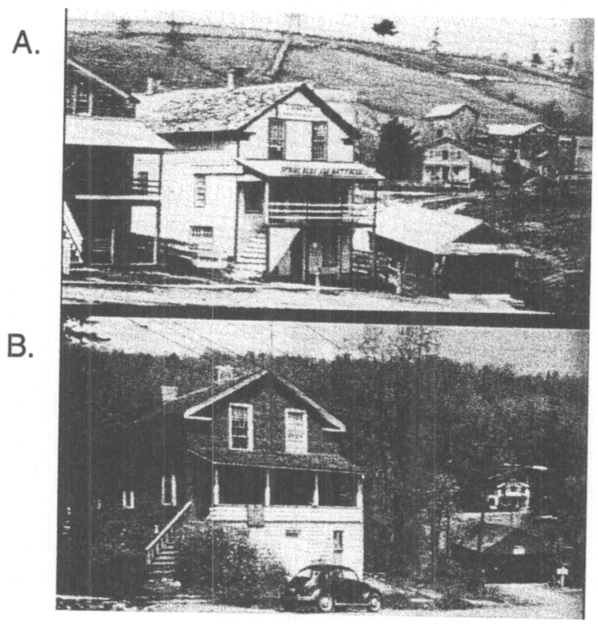


Figure 3. Deforestation in 1870 (A) and subsequent regrowth of vegetation by 1970 (B) near Protts Hill, Newfield, N.Y.

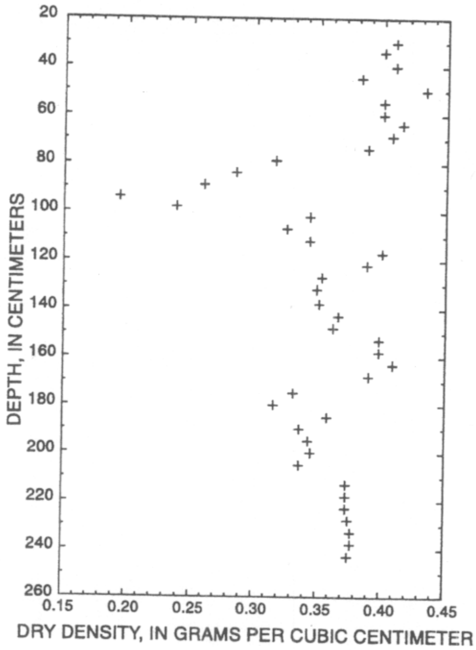


Figure 4. Dry density depth profile at core location 94-IC near Ithaca Yacht Club, Cayuga Lake.

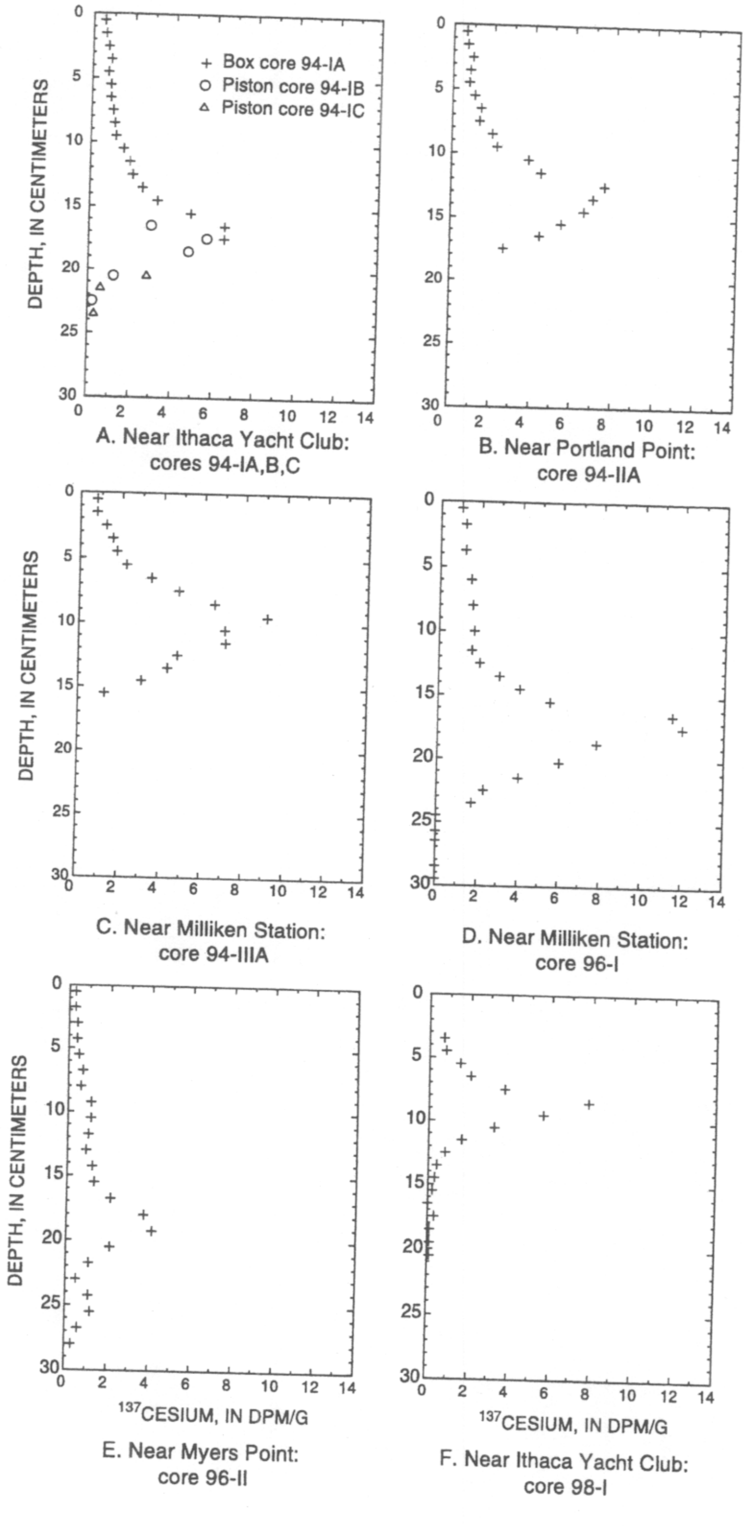


Figure 5. ^{137}Cs depth profiles at core locations (A) 94-IA,B,C near Ithaca Yacht Club, (B) 94-IIA near Portland Point, (C) 94-IIIA near Milliken Station, (D) 96-I near Milliken Station, (E) 96-II near Myers Point, and (F) 98-I near Ithaca Yacht Club.

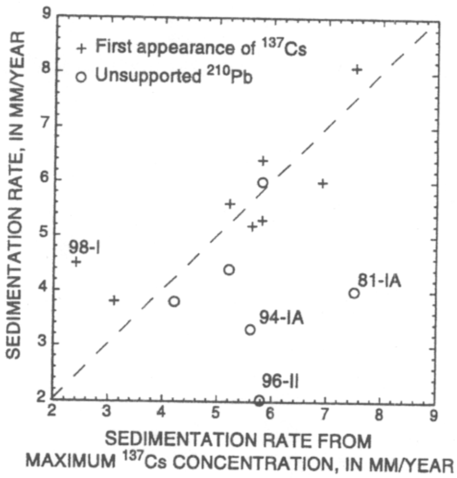
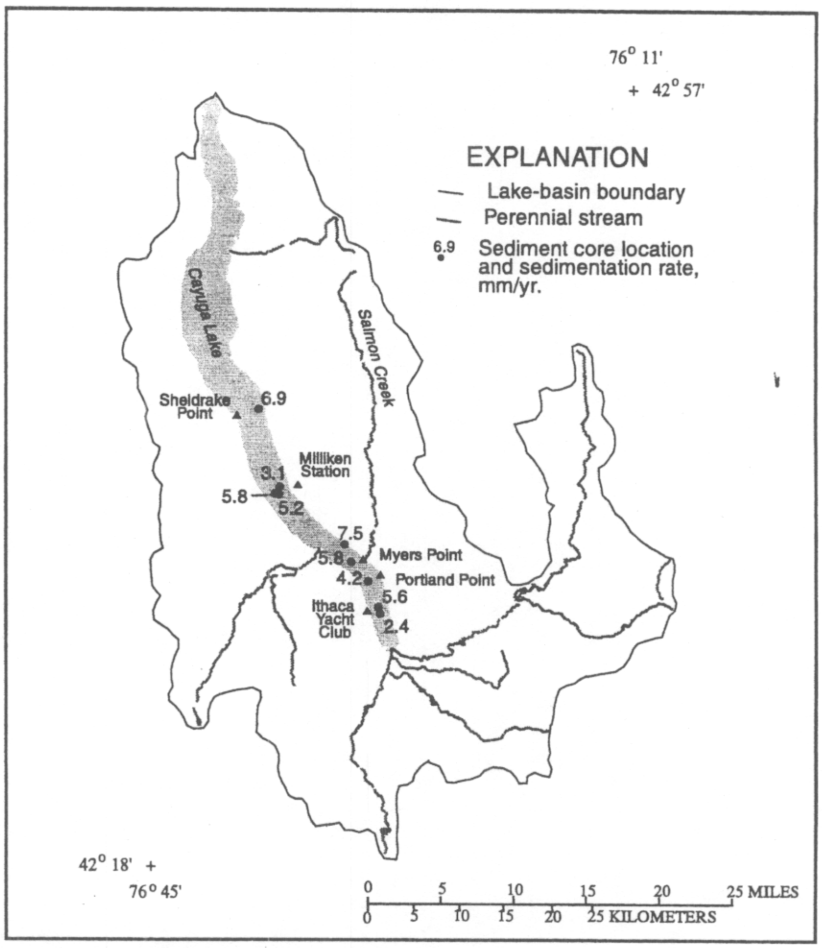


Figure 6. Sedimentation rates computed from ^{137}Cs and ^{210}Pb activities in depth profiles.



Base from U.S. Geological Survey digital data, 1:24,000, 1998
New York coordinate system, West Zone

Figure 7. Sedimentation rates (mm/yr) in Cayuga Lake computed from maximum 137Cs activities in depth profiles.

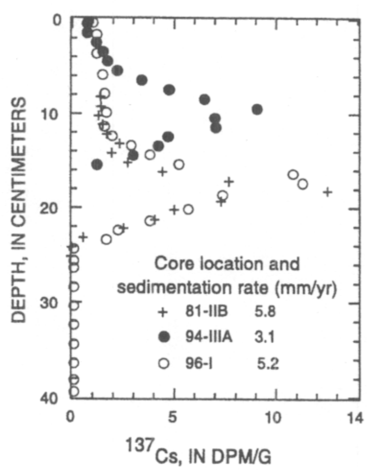


Figure 8. Depth profiles of 137Cs activities in Cayuga Lake near Milliken Station.

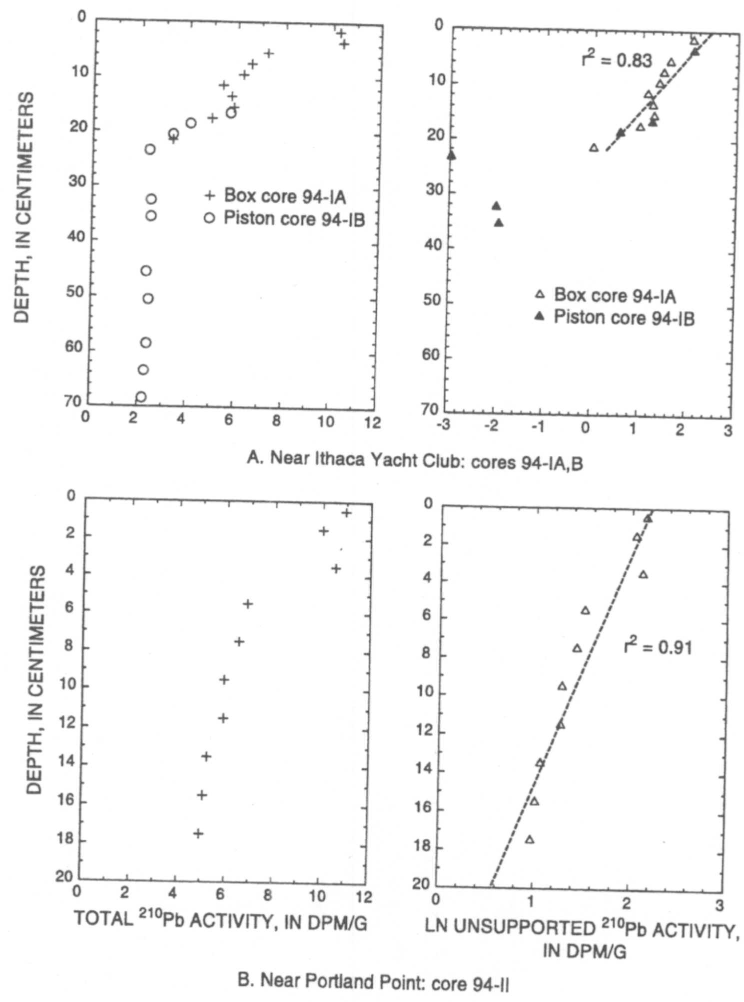


Figure 9. Total and excess ^{210}Pb depth profiles at core locations (A) 94-IA,B near Ithaca Yacht Club and (B) 94-IIA near Portland Point.

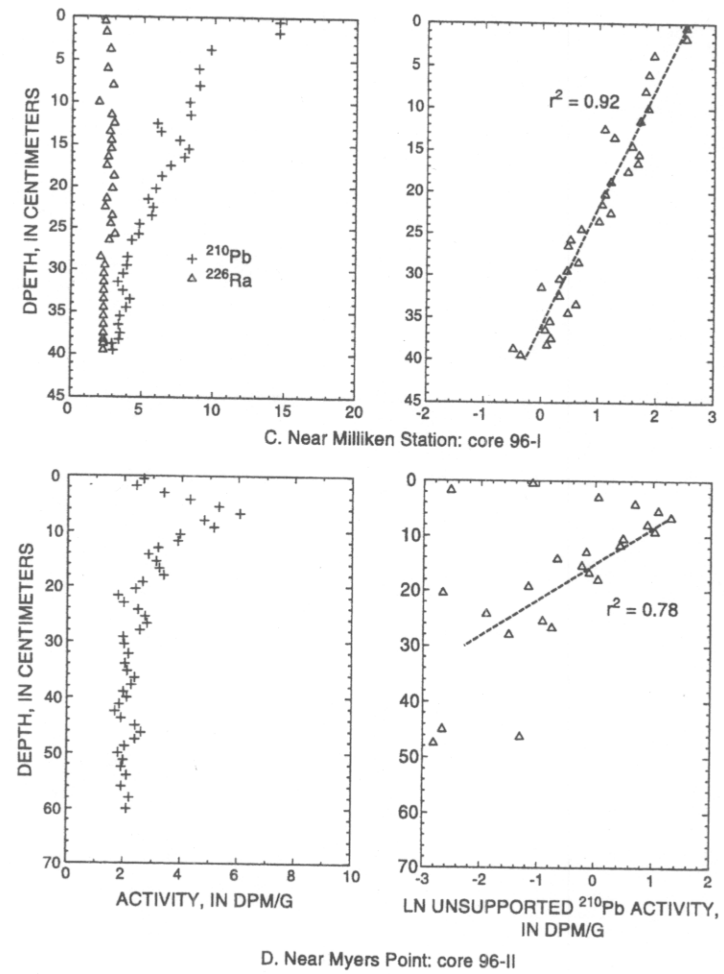


Figure 9 con't. Total and excess ^{210}Pb depth profiles at core locations (C) 96-I near Milliken Station and (D) 96-II near Myers Point.

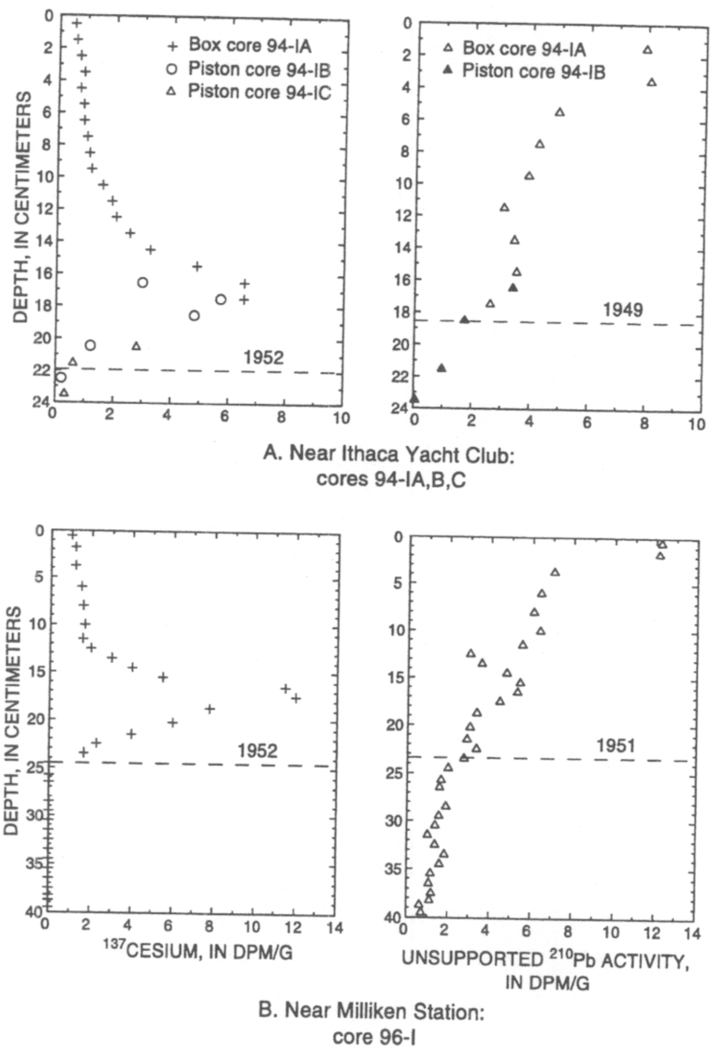


Figure 10. Depth profiles showing sediment dates of 1949 to 1952 estimated from first appearance of ^{137}Cs and two half-lives of radioactive decay of unsupported ^{210}Pb at core locations (A) 94-IA,B,C near Ithaca Yacht Club and (B) 96-I near Milliken Station.

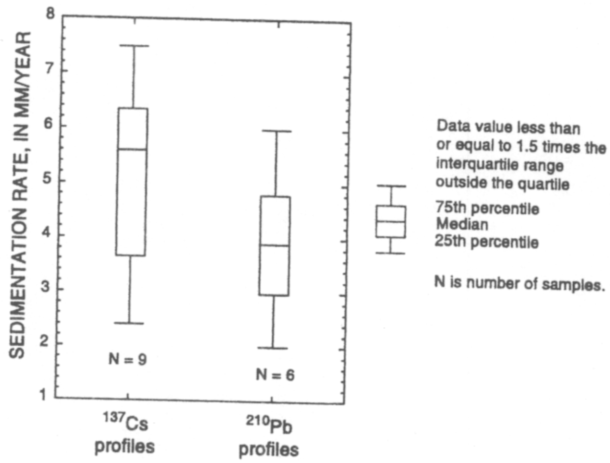


Figure 11. Boxplots of sedimentation rates computed by USGS and USDOE (Heit et al, 1986) from ^{137}Cs and ^{210}Pb depth profiles in Cayuga Lake.

Table 1. Core-sampling locations in Cayuga Lake, N.Y.

Year sampled	Location	Core number	Core type	Latitude	Longitude	Depth, meters
1994	Ithaca Yacht Club	94-IA	20-cm box	42 29.80	76 31.85	80.3
		94-IB[1]	2-m piston	42 29.81	76 31.85	76.
		94-IC[2]	2-m piston	42 29.22	76 31.31	60.3
	Portland Point	94-IIA	20-cm box	42 31.17	76 32.61	87.
		94-IIB[3]	6-m piston	42 31.15	76 32.57	82.3
	Milliken Station	94-IIIA	20-cm box	42 36.15	76 39.08	116.5
		94-IIIB[4]	6-m piston	42 35.94	76 38.96	107.8
1996	Milliken Station	96-I	1m-box	42 35.76	76 39.12	122.
	Myers Point	96-II	1m-box	42 32.19	76 33.87	108.
1998	Ithaca Yacht Club	98-I	1m-box	42 29.44	76 31.71	68.

1 referred to by Hairston, this proceedings

2 referred to by White, this proceedings

3 referred to as CL-2 in Mullins, 1998

[4]4 referred to as CL-1 in Mullins, 1998

Table 2. Cesium and lead activities in sediment cores from Cayuga Lake, N.Y., 1994.
[dpm/g: disintegrations per gram; Cs: cesium; Pb: lead].

Core number and type	Location	Depth interval, in cm Top	Bottom	Activity, in dpm/g dry weight ^{137}Cs	Total ^{210}Pb	Unsupported ^{210}Pb	Dry density g/cm
94-IA	Ithaca Yacht Club	0	1	.54			.31
20-cm box core		1	2	.61	10.27	7.93	.42
		2	3	.74			.47
		3	4	.89	10.42	8.09	.43
		4	5	.76			.46
		5	6	.88	7.25	4.92	.54
		6	7	.90			.66
		7	8	1.02	6.58	4.25	.50
		8	9	1.11			.61
		9	10	1.19	6.25	3.91	.58
		10	11	1.58			.50
		11	12	1.90	5.40	3.07	.59
		12	13	2.05			.59
		13	14	2.53	5.76	3.43	.50
		14	15	3.26			.57
		15	16	4.89	5.86	3.53	.54
		16	17	6.54			.57
		17	18	6.53	4.96	2.63	.61
94-IB	Ithaca Yacht Club	16.5	17.5	3.	5.73	3.4	
2-m piston core		17.5	18.5	5.7			
		18.5	19.5	4.8	4.07	1.74	
		20.5	21.5	1.2			
		21.5	22.5	.1	3.33	1.	
		22.5	23.5	.02			
		23.5	24.5	.3	2.36	.03	
		32.5	33.5		2.46	.13	
		35.5	36.5		2.47	.14	
94-IC	Ithaca Yacht Club	20	21	2.8			
2-m piston core		21	22	.6			
		22	22	.2			
		24.5	29.5				.4
		30.5	35.5				.41
		35.5	40.5				.38
		40.5	45.5				.43
		45.5	50.5				.4
		50.5	55.5				.4
		54.5	59.5				.42
		59.5	64.5				.41
		64.5	69.5				.39
		69.5	74.5				.32
		74.5	79.5				.28
		79.5	84.5				.26

		84.5	89.5				.19
		88.5	93.5				.24
		92.5	97.5				.34
		97.5	102.5				.33
		102.5	107.5				.34
		107.5	112.5				.4
		112.5	117.5				.39
		117.5	122.5				.35
		122.5	127.5				.35
		128.5	133.5				.35
		133.5	138.5				.37
		138.5	143.5				.36
		143.5	148.5				.4
		148.5	153.5				.4
		153.5	158.5				.41
		158.5	163.5				.39
		165.5	170.5				.33
		170.5	175.5				.32
		175.5	180.5				.36
		180.5	185.5				.34
		185.5	190.5				.34
		190.5	195.5				.35
		195.5	200.5				.34
		203.5	208.5				.37
		208.5	213.5				.37
		213.5	218.5				.37
		218.5	223.5				.37
		223.5	228.5				.38
		228.5	233.5				.38
		233.5	238.5				.37
94-IIA 20-cm box core	Portland Point	0	1	.62	10.95	8.62	.33
		1	2	.69	10.01	7.68	.34
		2	3	.95			.36
		3	4	.83	10.55	8.22	.38
		4	5	.79			.42
		5	6	1.07	6.86	4.53	.50
		6	7	1.40			.55
		7	8	1.33	6.52	4.18	.55
		8	9	1.98			.49
		9	10	2.23	5.91	3.58	.56
		10	11	3.79			.48
		11	12	4.41	5.90	3.57	.53
		12	13	7.54			.44
		13	14	6.98	5.23	2.90	.56
		14	15	6.55			.53
		15	16	5.46	5.08	2.75	.46
		16	17	4.38			.53
		17	18	2.63	4.96	2.63	.55
94-IIIA 20-cm box core	Milliken Station	0	1	.78			.33
		1	2	.78			.31
		2	3	1.23			.32

3	4	1.55	.38
4	5	1.76	.36
5	6	2.23	.35
6	7	3.45	.39
7	8	4.78	.42
8	9	6.52	.43
9	10	9.09	.44
10	11	7.04	.39
11	12	7.08	.33
12	13	4.74	.31
13	14	4.27	.32
14	15	3.03	.38
15	16	1.26	.36

Table 3. Cesium, radon and lead activity in sediment cores from Cayuga Lake, N.Y., 1996 and 1998. [dpm/g: disintegrations per gram; Cs: cesium; Pb: lead; Ra: radium].

Core number	Location	Depth interval, in cm		Activity, in dpm/g dry weight			
		Top	Bottom	^{137}Cs	Ra	Total ^{210}Pb	Unsupported ^{210}Pb
96-I	Milliken Station	0	1	1	2.3	14.54	12.24
1-m box core		1	2.5	1.2	2.4	14.54	12.14
		2.5	5	1.2	2.7	9.74	7.04
		5	7	1.5	2.5	8.91	6.41
		7	9	1.6	2.9	8.96	6.06
		9	11	1.7	1.9	8.28	6.38
		11	12	1.6	2.8	8.34	5.54
		12	13	2	3	6.01	3.01
		13	14	3	2.7	6.27	3.57
		14	15	4	2.8	7.59	4.79
		15	16	5.5	2.8	8.24	5.44
		16	17	11.5	2.6	7.92	5.32
		17	18	12	2.5	6.97	4.47
		18	19.5	7.8	3	6.35	3.35
		19.5	21	6	2.9	5.93	3.03
		21	22	4	2.5	5.39	2.89
		22	23	2.3	2.4	5.75	3.35
		23	24	1.7	2.9	5.65	2.75
		24	25	< .1	2.8	4.79	1.99
		25	26.5	< .1	3.1	4.75	1.65
		26.5	28	< .1	2.7	4.28	1.58
		28	29	< .1	2.1	3.99	1.89
		29	30	< .1	2.4	3.95	1.55
		30	31	< .1		3.7	1.37
		31	32	< .1		3.33	1
		32	33	< .1		3.69	1.36
		33	34	< .1		4.16	1.83
		34	35	< .1		3.92	1.59
		35	36	< .1		3.49	1.16
		36	37	< .1		3.4	1.07
		37	38	< .1		3.52	1.19
		38	38.5	< .1		3.44	1.11
		38.5	39	< .1		2.94	.61
		39	40	< .1		3.03	.7
96-II	Myers Point	0	1	0.3		2.66	.33
1-m box core		1	2.5	0.3		2.41	.08
		2.5	3.5	0.4		3.38	1.05
		3.5	5	0.4		4.3	1.97
		5	6	0.5		5.31	2.98
		6	7.5	0.7		6.05	3.72
		7.5	8.5	0.6		4.79	2.46
		8.5	10	1.1		5.14	2.81
		10	11	1.1		3.95	1.62
		11	12.5	1		3.87	1.54
		12.5	13.5	0.9		3.18	.85
		13.5	15	1.2		2.84	.51

		15	16	1.3	3.12	.79
		16	17.5	2.1	3.23	.9
		17.5	18.5	3.7	3.38	1.05
		18.5	20	4.1	2.64	.31
		20	21	2.1	2.4	.07
		21	22.5	1.1	1.8	-.53
		22.5	23.5	0.5	2.	-.33
		23.5	25	1.1	2.48	.15
		25	26	1.2	2.73	.4
		26	27.5	0.6	2.8	.47
		27.5	28.5	0.3	2.55	.22
		28.5	30	<.1	1.98	-.35
		30	31		2.02	-.31
		31	33.5		2.16	-.17
		33.5	34.5		2.04	-.29
		34.5	36		2.12	-.21
		36	37		2.37	.04
		37	38.5		2.26	-.07
		38.5	39.5		1.99	-.34
		39.5	40.5		2.11	-.22
		40.5	42		1.85	-.48
		42	43		1.7	-.63
		43	44.5		1.92	-.41
		44.5	45.5		2.4	.07
		45.5	47		2.6	.27
		47	48		2.39	.06
		48	49.5		2.04	-.29
		49.5	50.5		1.81	-.52
		50.5	52		1.99	-.34
		52	53		1.93	-.4
		53	55		2.12	-.21
		55	57		1.94	-.39
		57	59		2.21	-.12
		59	61		2.12	-.21
98-I	Ithaca Yacht Club	3	4	.7		
1-m box core		4	5	.8		
		5	6	1.5		
		6	7	2.		
		7	8	3.7		
		8	9	7.8		
		9	10	5.6		
		10	11	3.2		
		11	12	1.6		
		12	13	.8		
		14	15	.4		
		15	16	.3		
		16	17	.2		
		17	18	<.1		
		18	19	.3		
		19	20	.1		
		20	21	.1		

21	22	.1
22	26	< .1

Table 4. Sedimentation and accumulation rates and focusing factors calculated from ^{137}Cs and ^{210}Pb concentrations in sediment cores.[dpm/g: disintegrations per gram; Cs: cesium; Pb: lead].

Core Location	^{137}Cs activity depth, cm		^{137}Cs inventory pCi/cm^2	Focusing factor	Sedimentation rates mm/yr			Mass accumulation rate g/cm^2 per yr
	Maximum	First appearance			Maximum ^{137}Cs activity	First ^{137}Cs appearance	Unsupported ^{210}Pb activity	
81-IA Myers Point	13.5	23.5	18.4	1.8	7.5	8.1	4	.4
81-IIB Milliken Station	10.5	15.5	17.0	1.6	5.8	5.3	6	.3
81-IIIC Sheldrake Point	12.5	17.5	19.4	1.9	6.9	6.	--	.2
94-IA Ithaca Yacht Club	17.5	22.	9.5	1.2	5.6	5.2	3.3	.3
94-IIA Portland Point	13.	--	12.1	1.6	4.2	--	3.8	.2
94-IIIA Milliken Station	9.5	16.	11.2	1.4	3.1	3.8	--	.1
96-I Milliken Station	17.5	24.5	15.2	2.1	5.2	5.6	4.4	--
96-II Myers Point	19.3	28.	6.1	0.8	5.8	6.4	2.	--
98-I Ithaca Yacht Club	8.5	20.5	5.3	0.8	2.4	4.5	--	--

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