Secaucus High School Marsh Sediment Study

September 2012
(Revised to include May 2011 sampling results)

1. Executive summary

This study measures if the Secaucus High School Marsh (SHS), restored in 2007, will or will not accumulate metals and organics when opened to the tides of the Hackensack River, ultimately contaminating the clean engineered sediments used in the restoration. The restoration was completed by removing approximately 1.5 foot of surface sediments (mainly the *Phragmites australis* rhizosphere) and replacing them with clean engineered sediments. Two high marsh areas totaling eight acres received different engineered sediments. The Northeast (NE) high marsh area received fresh water pond dredge and a 6” cap of sand. The Southeast (SE) high marsh received marine dredge, 6” of fresh water pond dredge and a cap of sand and compost mix. Plantings in both areas included *Spartina patens*, *Distichlis spicata* and others.

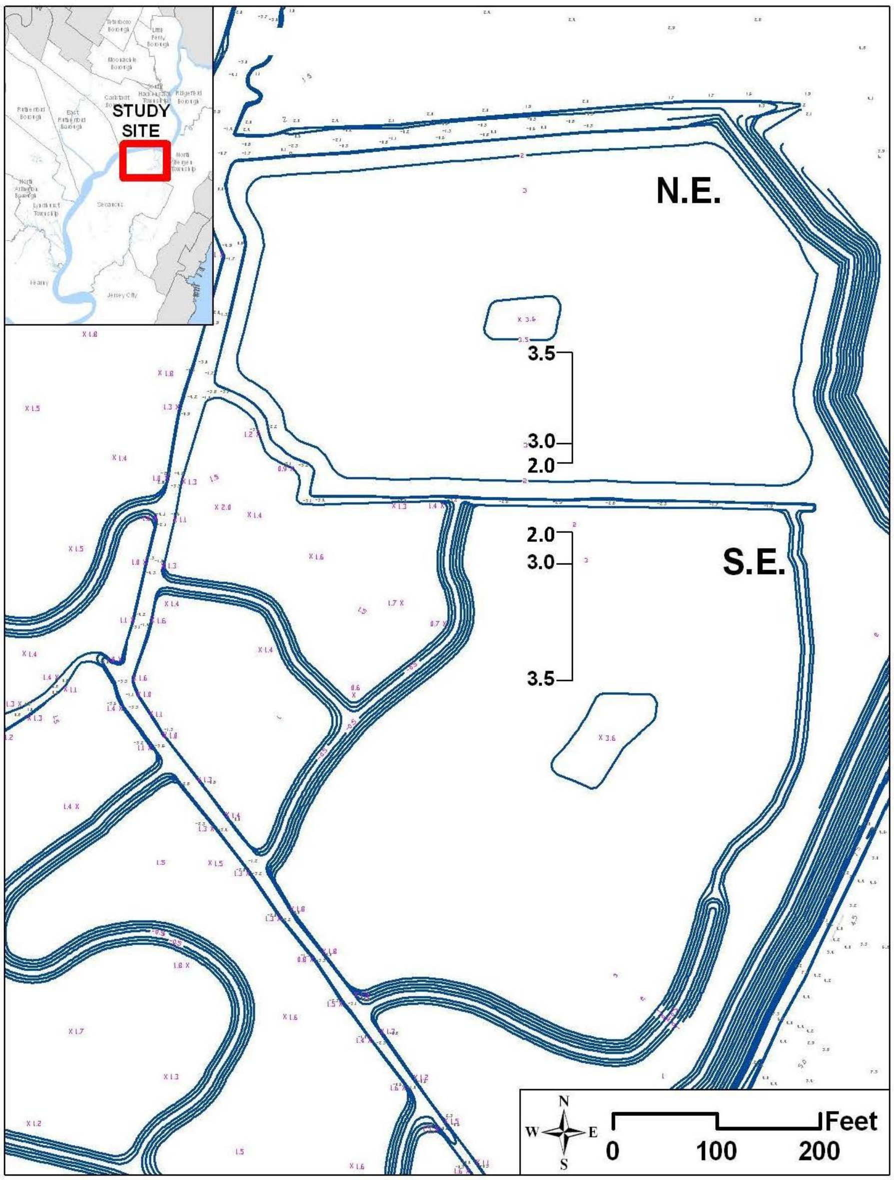
Points at three different terrain elevations in each area have been sampled each year since 2007 and this report presents the findings up to 2011. May 2011 represents the fourth sampling after the marshes were open to the tides and it occurred 12 months after the 2010 sampling period. Results indicate that 2010 metal concentrations have decreased significantly compared to the previous year, but in 2011 all metals show an increase in concentration. However, the concentrations in 2011 are still lower than the initial concentrations in 2007 (except iron, cadmium and lead). The higher terrain elevation sampling points (3.5 and 3 feet) have lower metal concentrations than the lower elevation sampling points (2.0 feet). The SE area amended with compost mix on the surface had a significantly lower metal concentration than the NE area over a three year period, but over time this difference has become smaller. In terms of the organics, 2011 showed lower concentrations of PCBs and OCPs compared to the previous four years, and the higher terrain elevations (3.5 and 3 feet) had lower PCB and OCP concentrations compared to the 2.0 feet elevation points over the same period.

2. Background

The enhancement of the SHS wetland included the construction of two high-marsh areas (NE and SE) along the eastern side of the site totaling approximately eight acres. The imported sediment material was emplaced on the surface remaining after removal of the *Phragmites* saturated rhizosphere. The NE high marsh surface has a core of freshwater pond dredge, and a 6” cap of I-11 sand. The SE high marsh has a small inner core of marine dredge material from off the New Jersey coast, an approximately 6” deep middle layer of freshwater pond dredge, and about a 6" cap of 5:1 mix of sand to leaf compost. The different layers of materials taper towards the periphery of the high marsh areas. High marsh plantings include *Spartina patens* (saltmeadow hay), *Distichlis spicata* (saltgrass), *Spartina cynosuroides* (big cordgrass) and *Juncus gerardii* (saltmeadow rush).

This first sampling took place October 31, 2007, after the site work was completed with plantings, but prior to the restoration of tidal flow. Subsequent sampling had taken place June 27, 2008; April 23, 2009; April 29, 2010; May 11, 2011. A transect was established perpendicular to the ditch separating the NE and SE high marsh areas and connecting the highest elevation in each marsh (Figure 1). Samples are taken at three points in each area: at 3.5, 3.0 and 2.0 foot contours where elevations coincide with the spring high water level, mean high water level, and low marsh respectively. At each point, three replicate sediment samples were taken at the surface (0-10”) and at depths (>10”). In addition, each time the sediments were sampled, grab samples of water from the drainage ditches were also taken.

Figure 1: Secaucus High School Marsh Sediment Study Site



3. Methods

A total of 36 sediment samples are collected every year beginning in 2007. Three replicates for each depth, contour interval and high marsh area are collected each year (Table 1).

Table 1.- Sediment samples

High Marsh	Southeast						Northeast					
Contour Elevation (feet)	3.5		3.0		2.0		3.5		3.0		2.0	
Depth (inches)	0-10	>10	0-10	>10	0-10	>10	0-10	>10	0-10	>10	0-10	>10

The parameters Conductivity, DO, pH, Salinity and Temperature are measured directly from the water in the ditch using a YSI Model 6820 multi-parameter water quality sensor. In addition, surface grab samples are obtained for analysis in the MERI laboratory for metals and conventional parameters (NJDEP #02437). Prior to 2011, the laboratory analyzed water samples only for Total Metals. Beginning in 2011, water samples were analyzed for both Total Metals and Dissolved Metals.

Each sediment metal value is the average of 3 replicates; total PCBs and Pesticides (OCPs) values represent only one analysis. In addition to the compilation of the summary statistics for each variable, the entire data set was analyzed to estimate the effect of each variable – elevation, marsh depth, and time period – by fitting a generalized linear regression model. Indicator variables were used in the regression model to estimate the effects of different levels of these variables. Statistically significant results are presented at the 5% level (i.e., $p<0.05$).

4. Results

4.1. Water quality results from drainage ditch

The water quality measurements for nine metals and thirteen additional water parameters from water in the ditch are shown in Table 2.

Table 2: Water quality results from ditch samples between 2007 and 2011

Parameter	Units	Total 10/31/2007	Total 6/27/2008	Total 4/23/2009	Total 4/29/2010	Total 5/11/2011	Dissolved 5/11/2011
Cadmium	µg /L	0.566	0.777	0.197	0.264	0.883	0.677
Chromium	µg /L	47.7	17.5	10.3	11.0	12.3	5.20
Copper	µg /L	17.6	19.8	18.1	15.5	16.8	10.6
Iron	µg /L	2812	1883	992	739	1456	156
Lead	µg /L	23.6	19.9	2.42	4.50	3.36	0.85
Manganese	µg /L	n/a	n/a	n/a	203	743	716
Mercury	µg /L	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Nickel	µg /L	42.3	11.2	4.62	3.30	5.72	3.59
Zinc	µg /L	101	98.6	37.0	21.2	41.3	27.0
Fecal Coliforms	Col/100ml	245	590	98	156	46.0	
COD	mg/L	74.5	106	65.7	62.7	30.0	
NH 4	mg/L	0.95	2.31	2.80	3.36	1.40	
Nitrate	mg/L	4.74	0.61	4.38	2.62	N/A	
TSS	mg/L	96.8	20.8	22.3	52.0	39.2	
Temperature	^{o}C	15.5	33.7	22.5	15.3	18.6	
Conductivity	mS/cm	14.2	12.3	16.9	4.22	2.09	
Salinity	ppt	8.25	6.95	9.96	2.25	1.05	
Chloride	mg/L	4639	3256	2816	1098	N/A	
Sulfate	mg/L	586	480	338	152	N/A	
pH	SU	7.21	7.83	7.04	7.83	7.97	
DO	mg/L	4.87	2.30	6.09	11.4	10.5	
DO%	% sat	51.6	34.0	74.4	114	113.3	

4.2. Sediment concentrations with elevation differences

The average and standard deviation for each parameter measured are shown in Table 3 and Table 4. The former depicts the overall time average of each elevation and the latter shows the different terrain elevations over time respectively.

Table 3: Metal and organics concentrations at different elevations (2.0, 3.0 and 3.5 feet)

Parameter	Units	2.0 feet		3.0 feet		3.5 feet	
		Avg.	S.D.	Avg.	S.D.	Avg.	S.D.
Cd	mg/kg	4.05	1.04	1.68	0.71	1.54	0.281
Cr	mg/kg	404	200	41.7	27.7	18.7	4.59
Cu	mg/kg	125	47.6	35.7	4.71	30.2	8.86
Fe	mg/kg	29575	2672	10577	1358	9468	1075
Hg	mg/kg	5.23	2.97	1.15	0.75	0.94	0.87
Mn	mg/kg	872	510	432	372	102	18.4
Ni	mg/kg	86.7	23.6	23.9	8.37	13.7	1.53
Pb	mg/kg	191	45.7	106	26.4	94.4	22.6
Zn	mg/kg	320	103	104	19.2	90.1	25.7
PCBs	µg /kg	304	155	48.9	20.1	30.5	13.4
OCPs	µg /kg	27.4	15.7	23.3	16.0	14.2	74.2
pH	SU	6.17	1.08	7.10	0.54	6.94	0.75
% Moist	%	65.5	1.63	27.6	5.25	22.2	3.02
% OM	%	24.4	2.45	7.56	1.83	5.08	0.85
% Fines	%	27.1	10.8	11.4	5.47	14.7	1.97

Table 4: Metal and organics concentrations at different elevations (2.0, 3.0 and 3.5 feet) by date

Parameter	Units	Sampling Date														
		October 31, 2007			June 27, 2008			April 23, 2009			April 29, 2010			May 11, 2011		
		Elevation (feet)														
		2.0	3.0	3.5	2.0	3.0	3.5	2.0	3.0	3.5	2.0	3.0	3.5	2.0	3.0	3.5
Cd	mg/kg	4.48	1.11	1.03	3.55	0.92	0.97	5.39	1.99	1.47	2.60	1.72	1.50	4.21	2.68	2.73
Cr	mg/kg	642	59.2	19.3	518	80.3	23.0	443	33.0	16.3	128	12.1	12.1	289	24.0	22.7
Cu	mg/kg	177	34.7	30.3	146	43.8	34.6	148	32.6	16.1	57.0	35.4	30.2	97.1	32.2	40.0
Fe	mg/kg	28552	8276	7829	28946	11829	9977	32958	11214	9050	26048	10883	9849	31370	10681	10634
Hg	mg/kg	9.60	1.63	0.22	3.48	1.78	1.27	6.62	0.42	0.21	1.95	0.25	0.72	4.51	1.69	2.30
Mn	mg/kg	679	809	105	1433	865	116	1387	213	83.0	305	101	83.3	555	173	123
Ni	mg/kg	87.8	32.2	12.1	95.2	33.7	14.1	120	19.6	12.0	57.6	16.6	14.8	72.8	17.3	15.3
Pb	mg/kg	224	80.3	93.1	199	85.1	98.6	232	101	59.1	117	118	99.0	184	145	122
Zn	mg/kg	379	88.1	82.9	409	131	114	395	95.7	55.5	189	118	103	227	89.0	94.9
PCBs	µg /kg	475	44.3	32.3	347	64.8	51.3	414	74.4	17.7	157	32.0	31.5	126	28.8	19.7
OCPs	µg /kg	39.9	31.1	24.0	43.1	22.3	24.3	27.4	45.3	13.1	22.7	13.8	7.95	3.74	3.76	1.66
pH	SU	4.78	6.95	6.87	6.01	6.85	6.92	5.58	6.41	5.75	7.25	7.65	7.59	7.25	7.65	7.59
% Moist	%	63.1	21.8	19.1	66.9	33.4	22.6	67.1	23.4	19.6	65.2	27.0	26.6	65.0	32.6	23.0
% OM	%	21.1	6.91	4.80	25.4	10.8	5.98	27.8	7.06	3.76	23.9	6.53	5.43	23.9	6.51	5.42
% Fines	%	29.5	9.00	12.4	23.2	10.9	13.6	15.0	6.57	16.3	40.7	19.2	16.3			

With the exceptions of Mn (October '07), OCP (April' 09) and Pb (April '10,), elevation 2.0 feet yields the highest results for all constituents. The differences in data between elevations 2.0 and 3.0 are significantly higher than the difference between data in elevations 3.0 and 3.5 (Figure 1-7). For PCBs, this result is statistically significant ($p<0.05$). For the first four samplings, the metal values have been higher in 2.0 feet than in 3.0 feet. However, the data has shown the opposite for the May 2011 sampling (Figure 6). The data for zinc (Figure 7) is a good example that shows the difference between elevations 2.0 feet and higher is decreasing with time.

The PCBs concentration also decreases as the elevation increases; the data shows the average concentration of 304 µg /kg at elevation 2.0 feet, 48.9 µg/kg at elevation 3.0 feet and 30.5 µg /kg at elevation 3.5 feet (Table 3). The same occurred with OCP's where concentration are 27.4 µg /kg, 23.3 µg /kg, 14.2 µg /kg for elevations 2.0, 3.0, 3.5 feet respectively.

The pH values for elevation 2.0 feet during all samplings are lower than for elevations 3.0 and 3.5 feet. Other soil physical parameters (% Moisture and % Organic Matter) have opposite trend – their values are decreasing with elevation increase which are similar to the metal concentrations behavior.

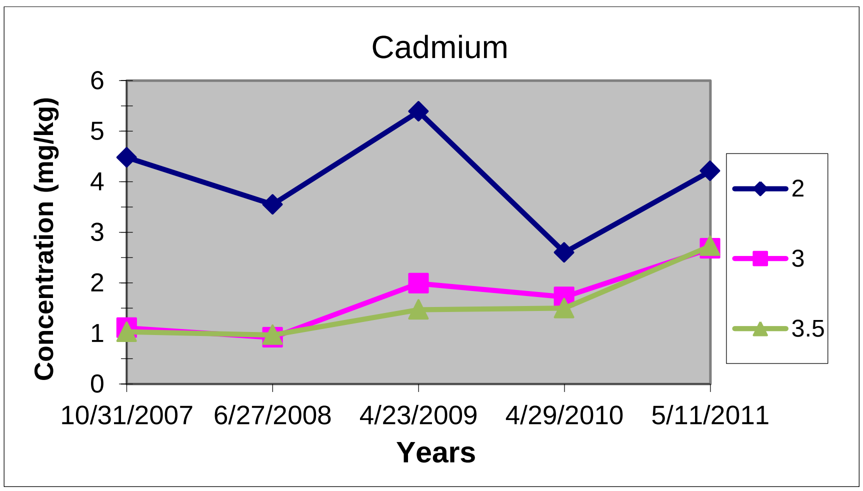


Figure 1: Cadmium concentrations for all elevations over time

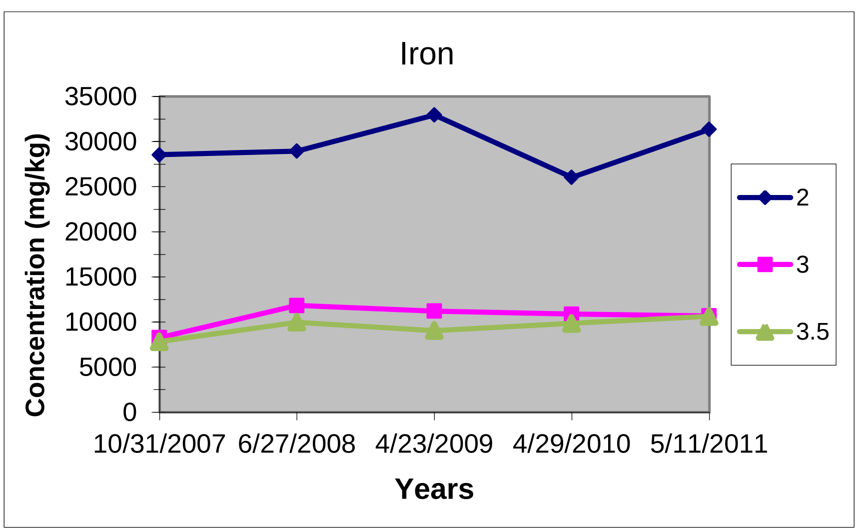


Figure 2: Iron concentrations for all elevations over time

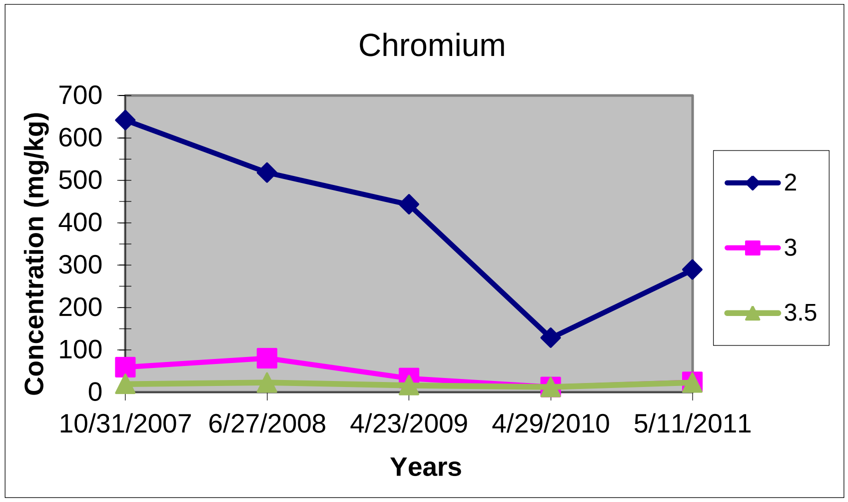


Figure 3: Chromium concentrations for all elevations over time

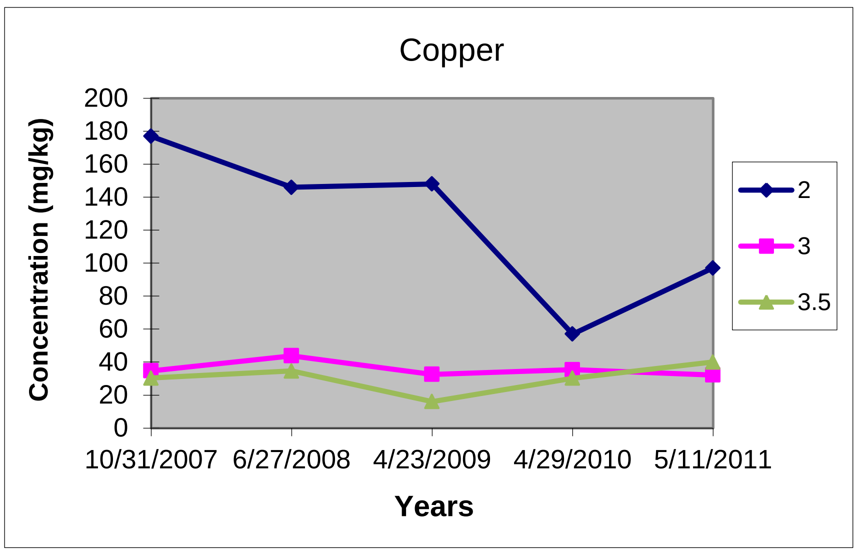


Figure 4: Copper concentrations for all elevations over time

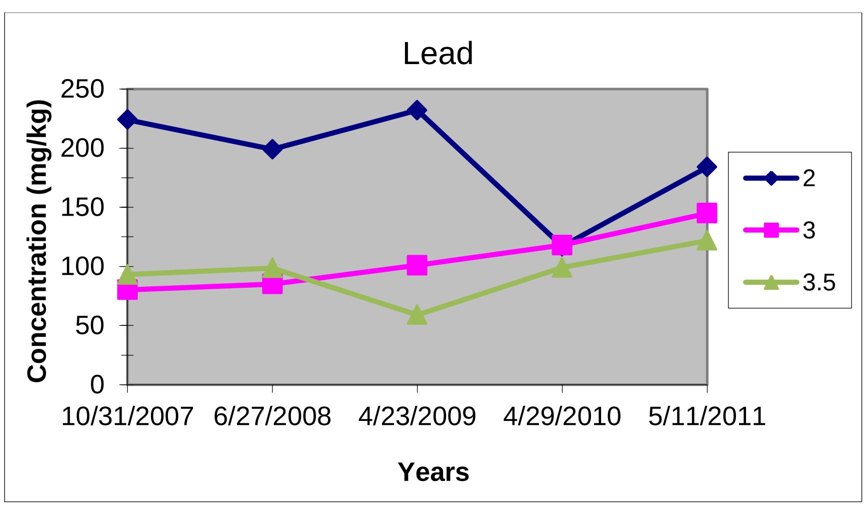


Figure 5: Lead concentrations for all elevations over time

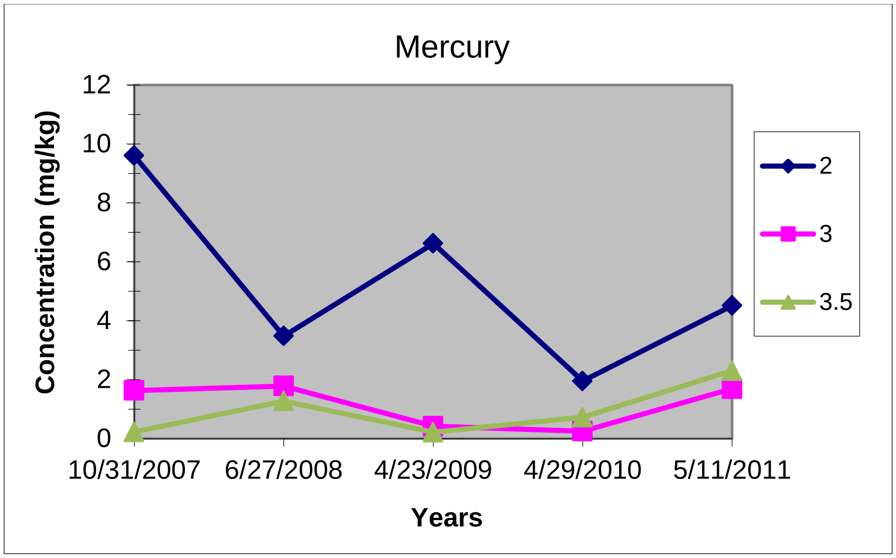


Figure 6: Mercury concentrations for all elevations over time

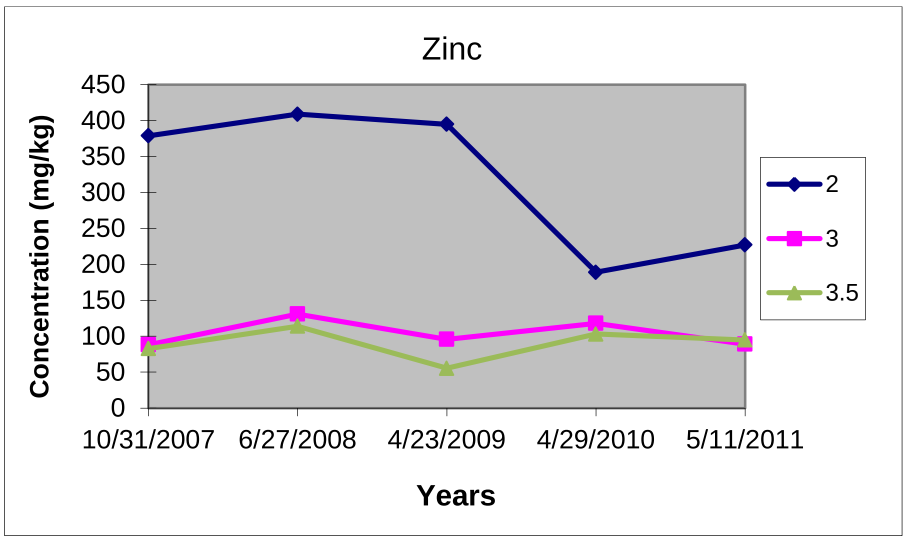


Figure 7: Zinc concentrations for all elevations over time

4.3. Sediment concentrations with depth differences

For the majority of metals and organics, the overall concentrations measured at the surface of the engineered soil (0-10 inches in depth) are less than the concentration at the horizon below (>10 inches in depth) (Figure 8). However, Chromium, Mercury, Manganese, PCBs and OCPs have not followed this trend (Figure 9, 10 and Table 5, 6).

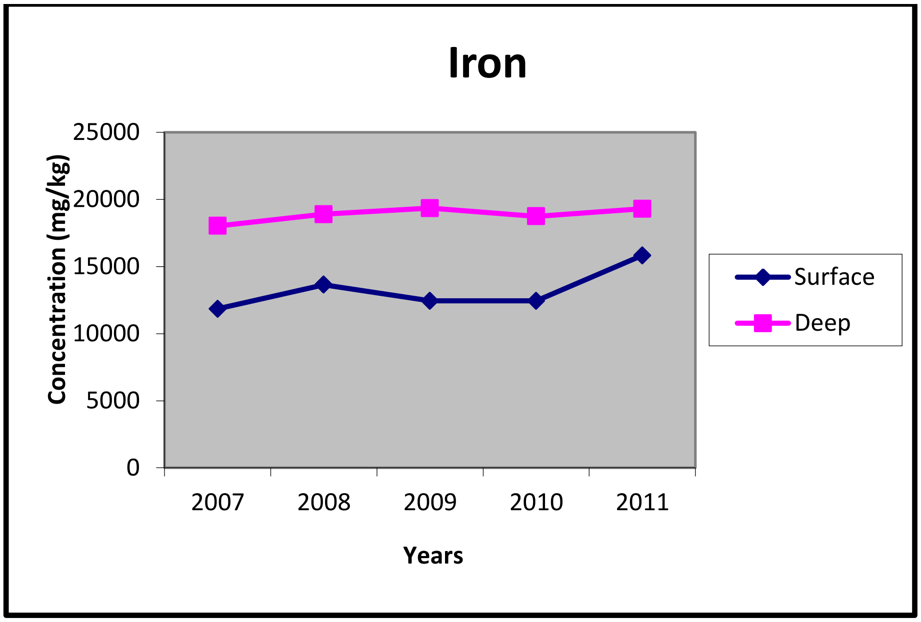


Figure 8: Iron concentrations for Surface/ Deep Samples for all elevations over time

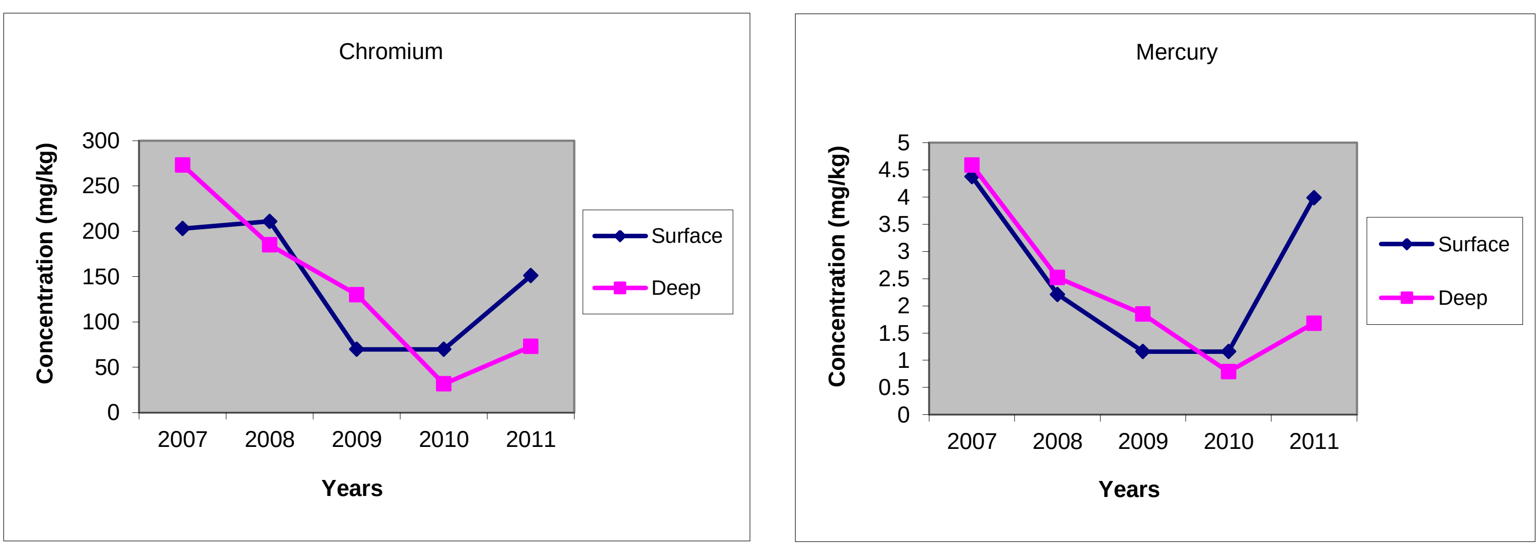


Figure 9: Chromium and Mercury concentrations for Surface/ Deep Samples for all elevations over time

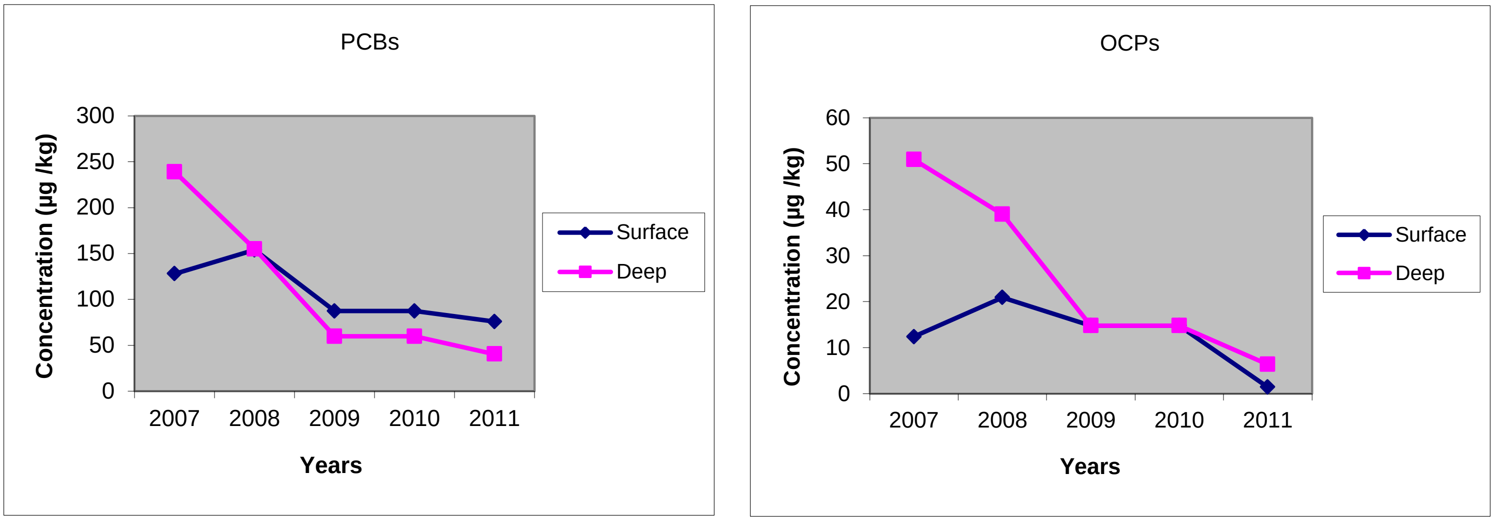


Figure 10: Organics concentrations for Surface/ Deep Samples for all elevations over time

Table 5: Average constituent concentration at the surface and below 10" for NE and SE samples, overall

Parameter	Units	Overall			
		Surface		Deep	
		Avg.	S.D.	Avg.	S.D.
Cd	mg/kg	2.13	0.533	2.67	0.766
Cr	mg/kg	159	56.2	133	75.9
Cu	mg/kg	56.0	13.0	66.1	15.2
Fe	mg/kg	13993	1960	19271	565
Hg	mg/kg	2.85	1.32	1.89	0.69
Mn	mg/kg	450	309	426	241
Ni	mg/kg	32.4	4.93	52.3	13.8
Pb	mg/kg	97.5	9.23	158	26.4
Zn	mg/kg	128	26.7	223	49.4
PCBs	µg /kg	124	41.8	95.8	58.8
OCPs	µg /kg	41.1	55.9	23.2	15.7
pH	SU	6.87	0.72	6.88	0.715
% Moist	%	34.9	4.27	41.9	1.70
% OM	%	8.44	1.98	15.4	2.33
% Fines	%	11.4	3.39	25.2	12.8

Table 6: Average constituent concentration at the surface and below 10" for NE and SE samples, by date

Parameter	Units	Sample Date									
		October 31, 2007		June 27, 2008		April 23, 2009		April 29, 2010		May 11, 2011	
		Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep	Surface	Deep
Cd	mg/kg	2.13	2.32	1.44	2.11	1.82	2.92	1.82	2.07	2.76	3.66
Cr	mg/kg	203	273	211	185	69.9	130	69.9	31.7	151	73.1
Cu	mg/kg	69.8	92.6	61.0	65.4	35.9	66.9	35.9	46.2	51.4	61.5
Fe	mg/kg	11848	18030	13640	18896	12446	19346	12446	18741	15822	19301
Hg	mg/kg	4.38	4.59	2.21	2.52	1.16	1.85	1.16	0.79	3.99	1.68
Mn	mg/kg	261	800	800	490	136	399	136	190	286	281
Ni	mg/kg	37.0	50.9	34.9	60.9	26.5	53.1	26.5	32.9	27.7	42.6
Pb	mg/kg	99.4	165	90.3	136	86.7	160	86.7	136	101	200
Zn	mg/kg	153	214	156	254	109	219	109	164	95.0	179
PCBs	µg /kg	128	239	154	155	87.3	59.8	87.3	59.8	75.8	40.5
OCPs	µg /kg	12.4	50.9	20.9	39.0	14.8	14.8	14.8	14.8	1.41	6.35
pH	SU	6.40	5.99	6.68	6.51	7.62	7.37	7.62	7.37	7.62	7.37
% Moist	%	27.9	41.4	38.3	43.6	37.7	41.4	37.7	41.4	36.7	43.6
% OM	%	7.24	14.6	5.52	19.2	9.97	13.9	9.97	13.9	9.97	13.9
% Fines	%	10.7	14.6	12.7	19.1	15.0	35.8	15.0	35.8		

4.4. Sediment concentrations with marsh area differences

The overall average concentrations for almost all the parameters measured at the SE Marsh are lower than the NE marsh except Mn and Fe (Table 7). Before the restoration of tidal flow to the site in November, 2007, the NE Marsh had much higher concentrations than the SE Marsh. Over time, this difference has decreased. In some cases, the concentrations for the SE Marsh are now higher than the numbers for the NE Marsh, especially in the 2010 and 2011 samplings (Figure 11, Table 8).

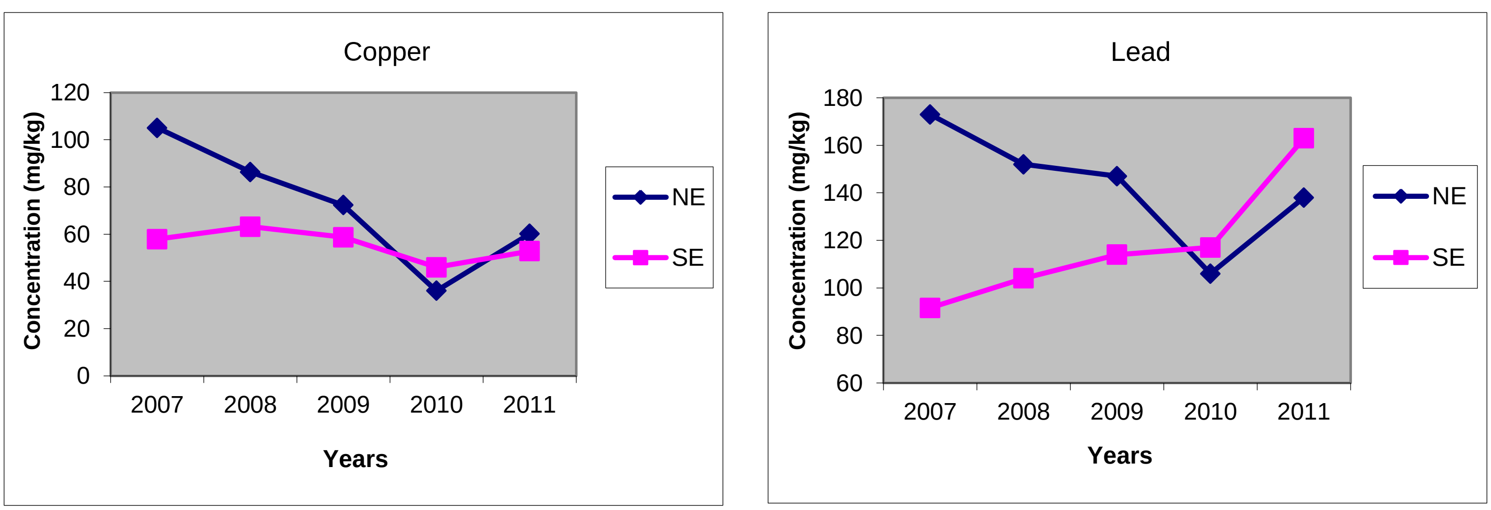


Figure 11: Copper and Lead concentrations for NE and SE marshes over time

Table 7: Difference in constituent concentration between NE and SE areas, overall

Parameter	Units	Overall			
		North		South	
		Avg.	S.D.	Avg.	S.D.
Cd	mg/kg	2.56	0.57	2.29	0.76
Cr	mg/kg	194	121	114	35.8
Cu	mg/kg	71.9	26.1	55.7	6.57
Fe	mg/kg	16476	962	16624	1573
Hg	mg/kg	3.34	2.12	1.82	0.46
Mn	mg/kg	454	241	482	328
Ni	mg/kg	42.7	12.1	40.0	8.29
Pb	mg/kg	143	24.5	118	27.2
Zn	mg/kg	184	55.1	159	17.5
PCBs	µg /kg	147	69.8	108	67.6
OCPs	µg /kg	25.6	14.5	18.0	10.3
pH	SU	6.29	0.81	6.65	0.66
% Moist	%	37.9	2.20	38.9	4.75
% OM	%	12.8	1.41	12.3	1.41
% Fines	%	17.6	6.96	15.8	7.12

Table 8: Difference in constituent concentration between NE and SE areas, by date

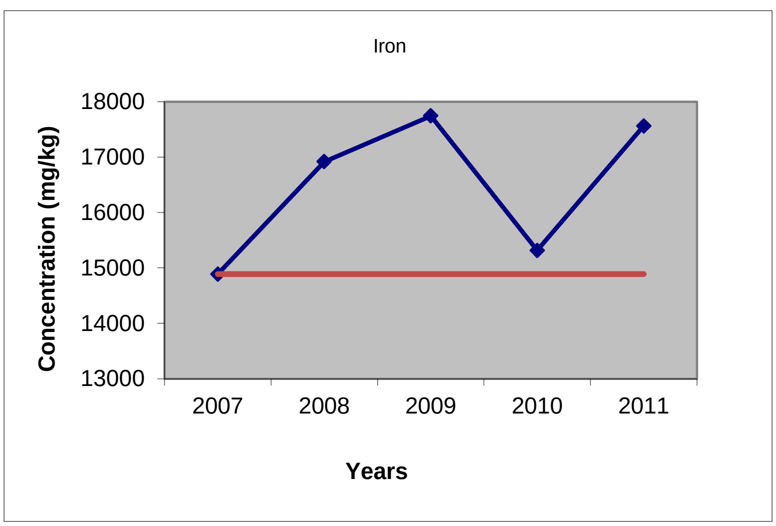
Parameter	Units	Sample Date									
		October 31, 2007		June 27, 2008		April 23, 2009		April 29, 2010		May 11, 2011	
		North	South	North	South	North	North	North	South	North	South
Cd	mg/kg	2.75	1.70	2.01	1.61	3.09	2.81	1.89	1.99	3.05	3.36
Cr	mg/kg	327	149	303	111	182	146	40.4	61.2	120	104
Cu	mg/kg	105	57.9	86.3	63.2	72.3	58.7	36.0	46.0	60.1	52.8
Fe	mg/kg	15470	14408	17096	16739	17360	18121	15390	15797	17064	18059
Hg	mg/kg	6.68	2.30	2.54	1.81	3.00	1.84	0.88	1.07	3.58	2.08
Mn	mg/kg	708	352	592	1016	575	548	163	162	231	336
Ni	mg/kg	54.6	33.4	50.1	45.2	48.8	52.0	26.2	33.2	34.0	36.3
Pb	mg/kg	173	91.6	152	104	147	114	106	117	138	163
Zn	mg/kg	205	161	261	175	191	173	141	132	122	152
PCBs	µg /kg	259	109	159	150	141	196	93.2	53.9	84.4	31.5
OCPs	µg /kg	35.8	27.6	39.9	20.0	30.4	26.8	17.3	12.3	4.64	3.125
pH	SU	6.34	6.06	6.66	6.52	5.84	5.98	7.65	7.34	7.65	7.34
% Moist	%	36.3	33.0	36.8	45.1	37.3	36.1	37.2	41.9	41.7	38.6
% OM	%	10.7	11.2	13.3	14.8	13.6	12.1	12.2	11.8	14.3	11.8
% Fines	%	19.7	14.2	17.1	14.7	8.41	8.71	25.1	25.7		

4.5. Sediment concentrations with time period differences

We can see a decrease in average concentrations for all parameters except Cadmium, Iron and Lead during 2007-2010 (Table 9). These three metals have higher concentrations over time than the initial concentration (Figure 12). However, all of the remaining metals show an increase in concentration in 2011 but still lower than in 2007 (Figure 13.) For PCBs and OCPs, there is a significant decrease in concentrations in year 2011 compared to 2007 (Figure 14).

Table 9: Summary of Temporal Effects

Parameter	Units	Concentrations						
		Overall		Sample Date				
		Avg.	S.D.	10/31/2007	6/27/2008	4/23/2009	4/29/2010	5/11/2011
Cd	mg/kg	2.43	0.62	2.21	1.81	2.95	1.95	3.21
Cr	mg/kg	155	75.4	240	207	164	50.8	112
Cu	mg/kg	63.6	15.9	80.8	74.8	65.5	40.6	56.4
Fe	mg/kg	16484	1309	14886	16917	17741	15314	17561
Hg	mg/kg	2.53	1.17	4.21	2.18	2.42	0.98	2.84
Mn	mg/kg	469	250	531	804	561	166	284
Ni	mg/kg	41.4	8.70	44.0	47.6	50.4	29.7	35.1
Pb	mg/kg	130	13.9	132	128	131	111	150
Zn	mg/kg	170	36.7	183	218	182	129	137
PCBs	µg /kg	128	57.8	184	154	169	73.5	58.1
OCPs	µg /kg	21.8	12.0	31.7	29.9	28.6	14.8	3.88
pH	SU	6.74	0.73	6.20	6.59	5.91	7.50	7.50
% Moist	%	38.4	2.62	34.7	40.9	36.7	39.6	40.2
% OM	%	12.4	1.16	10.9	14.0	12.9	12.0	12.0
% Fines	%	16.7	6.90	17.0	15.9	8.56	25.4	



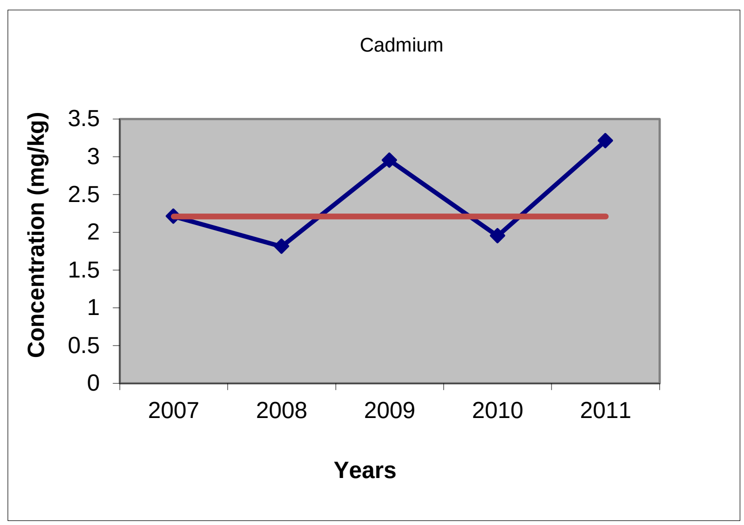
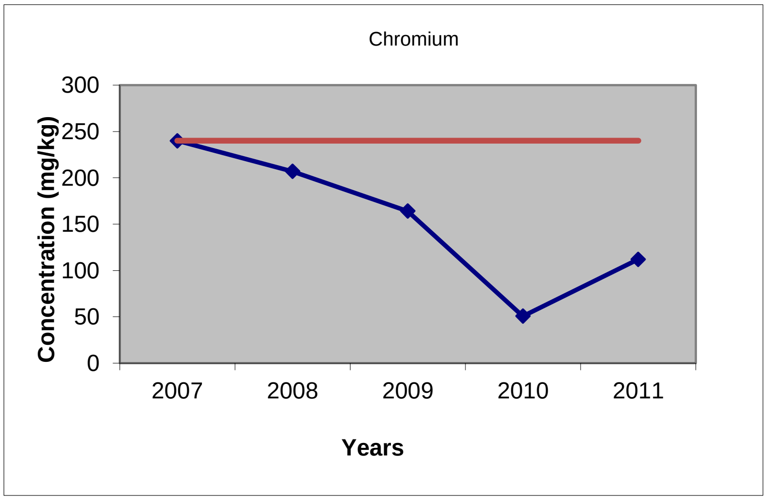


Figure 12: Iron and Cadmium average concentrations for all elevations and depths over time. The red line marks initial concentration.



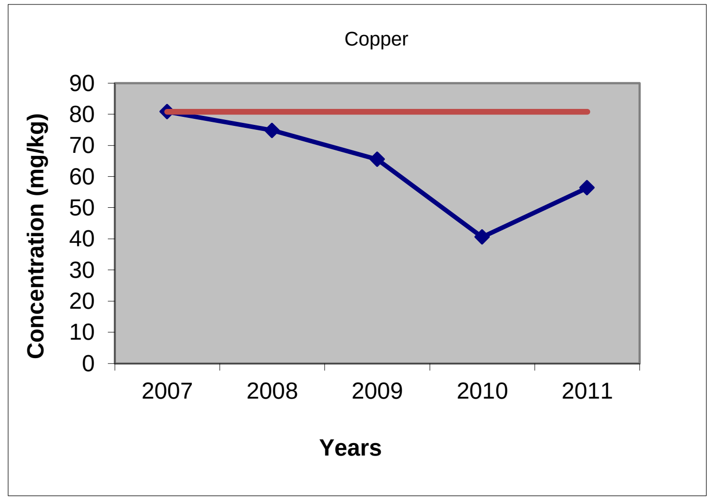
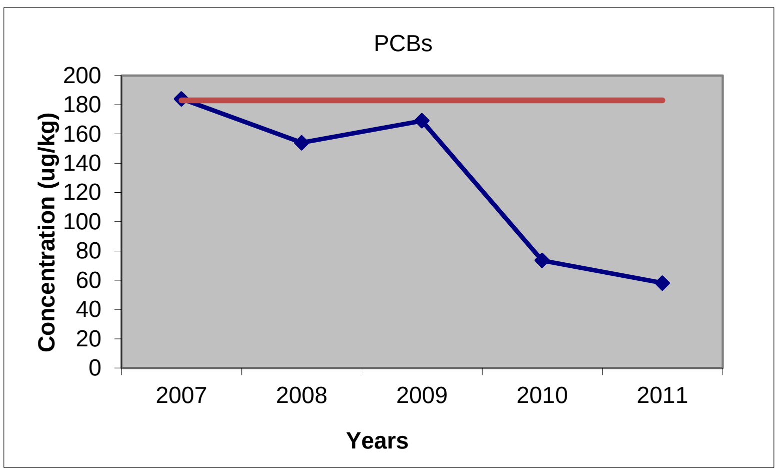


Figure 13: Chromium and Copper concentrations for all elevations and depths over time. The red line marks initial concentration.



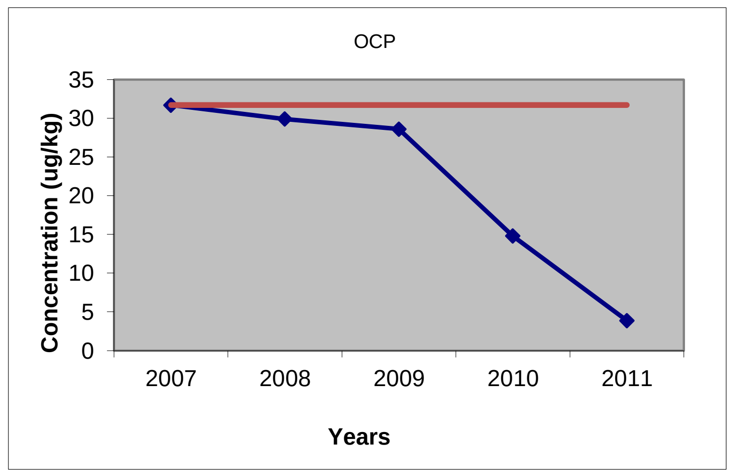


Figure 14: PCBs and OCPs concentrations for all elevations and depths over time. The red line marks initial concentration.

4.6. Statistical Analysis

A. Metals

- 5 Metals (Cr, Cu, Hg, Ni and Zn) had statically significantly lower concentrations in April 2010 compared to the previous three sampling periods. Among these five metals, Zn exhibited no change from April 2010 to May 2011. For the other four metals, the May 2011 sampling showed higher concentrations than those in April 2010. The increases were statically significant for Cu and Hg.
- 3 Metals (Fe, Mn and Pb) have about the same concentration for all 5 periods.
- For Cd, the average concentrations in April 2009 and May 2011 were significantly higher than those of the remaining 3 periods.
- The patterns with regard to Marsh location, depth and elevation in the 5 period and 4 period summaries are generally similar to those for the 3 period summary, prepared two years earlier.

B. Organics

- The results for 5 periods (years 2007 – 2011) are similar to those for 4 periods (years 2007 – 2010). The changes are:
- While the 3-period data did not show any effect of periods (i.e., the PCBs and OCPs concentrations were similar for all 3 periods), the April 2010 data (the 4th period) showed reduction in concentration in April 2010, when compared to the previous 3 periods by 95.4 ug/Kg and 15.3 ug/Kg for PCBs and OCPs, respectively. The May 2011 data (the 5th period) showed a further reduction of 15.4 ug/kg for PCBs and 10.9 ug/kg for OCPs, compared to data from April 2010.
- The effects of depth and elevation for May 2011 are similar to those for April 2010.

Statistically significant effects at p-value < 0.05:

- For PCBs, elevation has a statistically significant effect. The PCBs concentration decreased by 255 ug/Kg and 273 ug/Kg for elevations 3.0 ft and 3.5 ft respectively. Furthermore, there has been a decrease in the PCB concentration of 111 ug/Kg in the year 2011 compared to the average of year 2007-2009.

- For OCPs the interactions between depth and elevation have statistically significant effects. As compared to the other two levels an elevation of 3.0 ft results in a 19.8 ug/Kg increase in the concentration of OCPs. However, the OCP concentration is lower by 44.1 ug/Kg and 17.9 ug/Kg for the combinations of "surface & 3 ft elevation" and "surface & 3.5 ft elevation" respectively, as compared to the other combinations of depth and elevation. Furthermore, there has been a decrease of 26.2 ug/Kg in the OCPs concentration in the year 2011 when compared to the average of year 2007-2009.

5. Discussion

For the first four years of this study, the surface sediments remained cleaner than the subsurface samples, leading to the conclusion that there was no recontamination by legacy subsurface sediments and tidal inundation of the marsh. However, the 2011 sampling has shown some changes to this trend. It is very important to investigate the cause of these changes if the next sampling yields results similar to the 2011 sampling. Additionally, it was decided to sample the creek water at high tide for metals on a monthly basis and to take core samples at SHS again after the summer. During the winter, the metal concentration in the Hackensack River may decrease due to lower temperatures, as exhibited by the Water Quality data. The hypothesis is that if we see a difference in metal concentrations in the sediment on a seasonal basis, then the contamination is from the tides. However, if no difference is observed then the contamination could be leaching up from the legacy subsurface.