APPENDIX 7 - MASS BALANCES NOVEMBER 2007

1. INTRODUCTION

The development and structure of a mass-balance modeling framework for Onondaga Lake is described in previous lake monitoring reports (Ecologic et al., 2006). The framework facilitates computation and analysis of mass balances for nutrients and other water-quality components using hydrologic and water quality data collected in the Lake and its tributaries since 1986. Results provide a basis for:

(1) Estimating the magnitude and precision of loads from each source;
(2) Assessing long-term trends in load and inflow concentration from each source and source category (point, nonpoint, total);
(3) Evaluating the adequacy of the monitoring program, based upon the precision of loads computed from concentration and flow data;
(4) Developing and periodic updating of an empirical nutrient loading model that predicts eutrophication-related water quality conditions (as measured by nutrient concentrations, chlorophyll-a, algal bloom frequency, transparency, and hypolimnetic oxygen depletion) as a function of yearly nutrient loads, inflows, and lake morphometry (Ecologic et al, 2006).
(5) Developing simple input/output models for other constituents; and
(6) Developing data summaries to support integration and interpretation of monitoring results in each yearly AMP report.

This appendix updates the mass-balance framework to include through 2006. Computations are linked directly to the AMP long-term water quality and hydrologic database (Figure 1). Recent mass balances for key water quality components are summarized. Long-term trends in total loads (point, nonpoint), inflow concentrations, and outflow concentrations are documented.

A separate section describes analyses of spatial and year-to-year variations in non-point phosphorus loads from the Lake tributaries, as they relate to land use and rainfall. With implementation of point-source phosphorus controls, nonpoint loads will become increasingly important as factors driving eutrophication-related water quality and the Lake.

2. LONG-TERM TRENDS

Yearly variations in precipitation and lake inflow volume are summarized in Figure 2. Over the 1990-2006 period, yearly runoff from the Onondaga Lake watershed varied from 31 to 75 cm and was strongly correlated with precipitation (r^2 = 0.82). Runoff was 64 cm in 2006, as compared with a 17-year mean of 53 cm. Precipitation was 120 cm in 2006, as compared with a mean of 99 cm. Both precipitation and runoff were just below the maximum values recorded over the 17-year period (76 cm and 126 cm, respectively, in 1990).

The following figures show long-term trends in each water quality component over the 1990-2006 period:

Figure 3	Total Inflow & Outflow Concentrations
Figure 4	Total Inflow & Outflow Loads
Figure 5	Total NonPoint & Total Metro Loads

The time series start in 1990 because that was the first year in which total phosphorus measurements were made in the lake tributaries. As observed for the first time in 2005, loads from Metro (sum of bypass and treated discharge) in 2006 were lower than total non-point loads in the cases of 5-Day BOD, Ammonia N, Nitrite N, Total Kjeldahl N, Soluble Reactive P, Total Dissolved P, and Total P. (Figure 5).

Ten-year (1997-2006) trends in concentration and load for each mass-balance term and water quality component are summarized in Table 1. Trends are tested using a linear regression of flow-weighted-mean concentration or load against year. Trend slopes that are significantly different from zero ($p < .10$ for a two-tailed hypothesis or $p < 0.05$ for a one-tailed hypothesis) are listed. A ten-year rolling window has been consistently used for trend analysis in yearly AMP reports. With a longer period, results would be strongly influenced by historical data that are not representative of current conditions with respect to municipal and industrial wastewater inputs. With a shorter period, results would be increasingly influenced by short-term variations in hydrology and other random factors.

Significant increasing trends in flow and loads are observed for most tributaries and constituents (Table 1). Interpreting these trends is complicated by the fact that precipitation generally increased over the 1997-2006 period (Figure 2). Since runoff volume is highly correlated with precipitation (R^2=0.82), apparent increasing trends in flow and load may reflect increasing precipitation, as opposed to a long-term changes potentially resulting from management activities or other anthropogenic factors. Apparent 10-year trends in tributary concentrations (Table 1) and lake concentrations (main report, Table ?) may also be influenced by the increasing trend in precipitation, but to a lesser extent. Adjustment of the time series for variations in precipitation would provide an improved basis for tracking long-term trends. This concept is explored further in Section 4 below. Because load trends are likely to be more strongly influenced by the trend in precipitation, trends in flow-weighted concentration are discussed below.

Decreasing trends in total inflow concentration are indicated for BOD-5, Ammonia N, Total Kjeldahl N, Nitrite N, Total N, & Filtered Organic Carbon, and Total P. An increasing trend in Nitrate N concentration reflects nitrification of the Metro effluent.

Decreasing trends in non-point inflow concentration are indicated for Calcium, Ammonia N, and Total Kjeldahl N. A small increasing trend in Total Inorganic Carbon (1%/yr) is also indicated.

Trends in lake outflow (12 foot samples considered most representative) concentrations generally mimic those observed in the total inflow. Decreasing trends in concentration are indicated for BOD-5, Chloride, Ammonia N, Total Kjeldahl N, Nitrite N, Total N, and Total P. Increasing trends in outflow concentration are indicated for Nitrate N, Silica, and Total Suspended Solids. Trends in BOD, Nitrogen species, and Total Phosphorus are likely to reflect lake responses to Metro treatment plant improvements implemented over the 10-year period.

3. MASS BALANCES

Five-year average (2001-2005) mass balances for the following constituents are summarized in the following tables:

Table 2	Chloride
Table 3	Total Phosphorus
Table 4	Soluble Reactive Phosphorus
Table 5	Total Nitrogen
Table 6	Ammonia Nitrogen

Since chloride is expected to be conservative, the chloride balance provides a basis for testing the accuracy and completeness of the data and methods used to develop the mass balances. Similar to results from previous years, outflow loads computed from 12-foot outlet samples exceeded inflow loads by 6% ± 2% or 11,206 ± 4,173 metric tons/year in 2002-2006 (Table 2). The inflow and outflow load time series for sodium and chloride are similar (Figure 4). Excess loads may be attributed to application of road deicing salts in ungauged portions of the watershed, salt springs contributing directly to the lake, and/or over-estimation of lake outflow volumes.

4. VARIATIONS IN NON-POINT PHOSPHORUS LOADS

Phosphorus concentrations in the Lake (Figure 6) and Lake outflow (Figure 4) decreased significantly as Metro improvements were implemented over the 1990-2006 period. With implementation of advanced treatment technology to achieve a 0.12 mg/L Total

Phosphorus concentration in the Metro discharge, future variations in Lake phosphorus concentrations are likely to be increasingly dependent on variations in nonpoint P loads. An improved understanding of spatial and temporal variations in nonpoint loads will facilitate interpretation of future trends in lake phosphorus concentration and other eutrophication-related variables. Variations in nonpoint loads will also be important for tracking the effectiveness of watershed management programs (agricultural BMP's, urban CSO control, etc).

Spatial variations in average non-point phosphorus loads from six subwatersheds in the Onondaga Lake basin over the 2002-2006 period are shown in Figure 7. These results are based upon detailed water and phosphorus balances in Table 3. Comparisons are made across subwatersheds with respect to drainage area, total flow, Total P load, Total P concentration, runoff (flow per unit watershed area), and Total P export (load per unit watershed area). The Onondaga Creek watershed is divided into two sub-watersheds: an upper portion above the Dorwin monitoring site and a lower portion between Dorwin and Kirkpatrick. Flows and loads from the lower subwatershed are estimated based upon the differences between the measured values at the two monitoring sites. The Harbor Brook watershed is subdivided in a similar fashion using data from the Velasko and Hiawatha monitoring sites.

Spatial variations in unit area runoff and P export adjust for differences in watershed size and would be expected to reflect variations in land use, geology, and other factors controlling watershed hydrologic response. Of the six gauged watersheds, three (Ley, Lower Onondaga, Lower Hiawatha) are predominately urban and three (Ninemile, Upper Onondaga, Upper Hiawatha) are predominately rural (undeveloped, agricultural, low-density urban). The unit area runoff from the individual subwatersheds varies from 22 to 75 cm/yr and there is no particular pattern with respect to land use. The three urban watersheds had higher phosphorus export rates (56-109 kg/km^2-yr), as compared with the rural watersheds (17-40 kg/km^2-yr). Similarly, the urban watersheds had higher runoff concentrations (82-503 ppb) as compared with the rural watersheds (44-64 ppb).

The Lower Harbor watershed had the lowest unit area runoff, but the highest P concentration and export. The runoff value is suspiciously low in the context of results from the other watersheds, especially given the urban character of the watershed. It is possible that the low runoff value reflects errors in the drainage area estimates, which were developed by the USGS in the early 1970's (W. Coon, USGS, personal communication). More recent GIS databases may provide improved estimates of drainage areas for use in these calculations. If the Lower Harbor watershed data are excluded, the other urban watersheds had slightly higher unit area runoff (64 -75 cm/yr), as compared with the rural watersheds (39 -63 cm/yr). This pattern would be consistent with the higher percentages of impervious area in the urban watersheds.

The impacts of rainfall on year-to-year variations in nonpoint phosphorus loads over the 1990-2006 period are further explored in Figures 8 and 9. Adjustment of load or concentration time series for variations driven by hydrologic factors tends to increase power for detecting long-term trends (Hirsch et al, 1982; Walker, 2000). Figure 8 shows that approximately 60% of the variation in the nonpoint phosphorus load (expressed per unit area of watershed) is explained by variations in annual precipitation. The load/rainfall regression can be used to adjust the measured loads for variations in precipitation using the formula given in Figure 8. The adjusted loads correspond to the 1990-2006 average precipitation (99 cm/yr). Regressing the adjusted load time series against year indicates that non-point load decreased an average of 3.1%/yr (standard error = 1.2%/yr) over the 1990-2006 period.

Trends in total and nonpoint P loads are shown in Figure 9, with and without adjusting the nonpoint loads for variations in precipitation using the algorithm described above. Regression analyses indicate significant ($p<.05$) decreasing trends of -8.2 %/yr in point-source loads, -3.1 %/yr in adjusted non-point loads, and -6.0%/yr in the total load (point + adjusted non-point). These results indicate that reductions in both point and nonpoint loads contributed to reductions in lake phosphorus concentrations over the 1990-2007 period (Figure 6).

Additional analysis is recommended to determine whether the apparent trend in nonpoint loads can be attributed to specific subwatersheds. Refinement of the mass balance framework is recommended to facilitate tracking of trends in phosphorus and other constituents from the six subwatersheds on a routine basis. Adjustment of load time series for variations in precipitation will increase power for detecting trends that may result from watershed management activities or other anthropogenic factors.

5 . REFERENCES

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Table 1 10-Year Trends in Load & Flow-Wtd-Mean Concentration

Load Trends (% / yr) * **Period: 1997 to 2006** **Precip Trend = 3.5 +/- 0.8 % / yr**

Term	FLOW	ALK	BOD5	CA	CL	NA	NH3N	NO2N	NO3N	TKN	TN	SIO2	TIC	TOC	TOC_F	SRP	TP	TSS
Metro			-8%	3%	4%	3%	-21%	-15%	14%	-18%	-4%			-5%	-6%			
Bypass																		
Allied	15%	15%	16%	15%	15%	16%		11%	16%		13%	12%	15%	14%	13%		12%	16%
Crucible	-9%	-7%	-8%	-9%	-9%	-11%	-8%	-18%	-20%	-10%	-17%	-6%	-7%	-9%	-9%			
Harbor/Hiawatha	7%	7%	7%	6%	7%	9%	-5%		8%	5%	8%	7%	7%	9%	9%	15%	8%	
Ley/Park	5%	5%		5%	5%	7%						5%	5%	5%	5%			
Ninemile/Rt48	6%	7%	6%	3%				3%	7%		5%	7%	7%	10%	8%	8%	5%	
Onond./Kirkpatrick	6%	7%	6%	7%	6%	7%		9%	6%	5%	6%	7%	7%	9%	8%		5%	11%
Harbor/Velasko	6%	7%	7%	5%	6%	8%	-5%		7%	5%	7%	6%	7%	10%	9%	9%		
Onondaga/Dorwin	6%	7%	7%	7%	3%	5%	-6%	12%	9%	8%	9%	8%	7%	8%	7%		10%	16%
Total Gauged	5%	5%		4%	4%	5%	-18%	-11%	11%	-12%		5%	5%					8%
NonPoint Gauged	6%	7%	5%	4%	4%	6%		5%	7%		5%	7%	6%	8%	8%		5%	9%
Ungauged	6%	7%	5%	4%	4%	6%		5%	7%		5%	7%	6%	8%	8%		5%	9%
Total NonPoint	6%	7%	5%	4%	4%	6%		5%	7%		5%	7%	6%	8%	8%		5%	9%
Total Industrial	-5%			-5%				7%	-6%									
Total Municipal			-7%	3%	3%	3%	-21%	-15%	14%	-17%	-3%			-5%	-6%			
Total Inflow	5%	5%		4%	4%	5%	-18%	-10%	11%	-12%		5%	5%					8%
Total Outflow	5%	6%	3%	4%	3%	4%	-15%	-3%	10%	-9%		11%	6%	4%	4%			9%
Retention			-8%		-10%		-25%	-31%	12%	-18%	-4%				-14%			8%
Outlet2	5%	6%	4%	6%	5%	6%	-12%		11%	-7%		10%	6%	4%	4%			11%
Outlet12	5%	6%	3%	4%	3%	4%	-15%	-3%	10%	-9%		11%	6%	4%	4%			9%

Concentration Trends (% / yr) **Period: 1997 to 2006**

Term	ALK	BOD5	CA	CL	NA	NH3N	NO2N	NO3N	TKN	TN	SIO2	TIC	TOC	TOC_F	SRP	TP	TSS
Metro		-9%	2%	3%		-22%	-16%	13%	-18%	-4%			-6%	-7%			
Bypass						-8%			-7%	-6%			-9%	-10%			
Allied					2%	-18%	-5%		-11%	-3%	-5%		-3%	-3%	-7%	-4%	
Crucible	3%				-2%		-8%	-12%			3%	3%					7%
Harbor/Hiawatha			-1%			-11%	-5%								8%		
Ley/Park						-6%	-7%	-2%	-5%	-4%						-2%	
Ninemile/Rt48	1%		-4%	-7%	-4%	-8%	-3%		-4%			1%					
Onond./Kirkpatrick						-7%						1%					
Harbor/Velasko			-2%			-12%	-10%										
Onondaga/Dorwin	1%			-3%		-12%			2%	3%	2%	1%					10%
Total Gauged		-7%				-22%	-15%	6%	-16%	-6%				-3%		-5%	
NonPoint Gauged			-2%			-7%			-3%			1%					
Ungauged			-2%			-7%			-3%			1%					
Total NonPoint			-2%			-7%			-3%			1%					
Total Industrial	3%	3%			3%		14%				3%	3%					6%
Total Municipal		-8%	2%	3%		-21%	-16%	13%	-18%	-4%			-6%	-7%			
Total Inflow		-6%				-21%	-14%	6%	-16%	-6%				-3%		-5%	
Total Outflow		-2%		-2%		-19%	-8%	5%	-13%	-4%	6%					-4%	4%
Outlet2					1%	-16%	-6%	6%	-11%	-2%	5%	1%					7%
Outlet12		-2%		-2%		-19%	-8%	5%	-13%	-4%	6%					-4%	4%

Trends Significant at $p < .10$ (2-tailed hypothesis), based upon linear regression of yearly values

* Load trends partially reflect increases in precipitation

Table 2 Chloride Balance for 2002-2006

Variable: Chloride **Average for Years: 2002 thru 2006**

						Percent of Total Inflow				Drain.		Export
Term	**Flow 10^6 m3**	**Load mtons**	**Std Error mtons**	**Conc ppm**	**RSE %**	**Sampl per yr**	**Flow %**	**Load %**	**Error %**	**Area km2**	**Runoff cm**	**mtons/ km2**
Metro Effluent	93.48	37780	2117	404	6%	30	17%	19%	37%			
Metro Bypass	2.28	982	181	430	18%	4	0%	0%	0%			
East Flume	0.72	353	15	492	4%	28	0%	0%	0%			
Crucible	1.79	689	14	385	2%	28	0%	0%	0%			
Harbor Brook	11.58	3088	207	267	7%	29	2%	2%	0%	31.4	36.9	98.5
Ley Creek	42.12	13715	1348	326	10%	31	8%	7%	15%	66.1	63.7	207.5
Ninemile Creek	164.02	51863	797	316	2%	31	30%	26%	5%	298.1	55.0	174.0
Onondaga Creek	185.75	78733	1775	424	2%	30	34%	40%	26%	285.1	65.1	276.1
Nonpoint Gauged	403.47	147399	2376	365	2%	121	74%	75%	47%	680.7	59.3	216.5
Nonpoint Ungauged	27.48	10040	1359	365	14%	0	5%	5%	15%	46.4	59.3	216.5
NonPoint Total	430.96	157439	2738	365	2%	121	80%	80%	62%	727.0	59.3	216.5
Industrial	2.51	1043	21	415	2%	56	0%	1%	0%			
Municipal	95.76	38762	2125	405	5%	34	18%	20%	38%			
Total External	529.22	197244	3465	373	2%	210	98%	100%	100%	727.0	72.8	271.3
Precipitation	12.36	12	1	1	9%	0	2%	0%	0%	11.7	105.6	1.1
Total Inflow	541.58	197256	3465	364	2%	210	100%	100%	100%	738.7	73.3	267.0
Evaporation	8.86						2%			11.7	75.7	
Outflow	532.72	208462	2326	391	1%		98%	106%	45%	738.7	72.1	282.2
Retention	0.00	-11206	4173		37%		0%	-6%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	532.72	208462	2326	391	1%	27	98%	106%	45%	738.7	72.1	282.2
Outlet 2 Feet	532.72	188114	4316	353	2%	27	98%	95%	155%	738.7	72.1	254.6
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	10.63	2421	83	228	3%	29	2%	1%	0%	27.0	39.4	89.8
Downstream - Hiawatha	11.58	3088	207	267	7%	29	2%	2%	0%	31.4	36.9	98.5
Local Inflow	0.95	668	223	703	33%		0%	0%	0%	4.4	21.6	151.5
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	143.73	16145	297	112	2%	37	27%	8%	1%	229.4	62.7	70.4
Downstream - Kirkpatrick	185.75	78733	1775	424	2%	30	34%	40%	26%	285.1	65.1	276.1
Local Inflow	42.03	62588	1800	1489	3%		8%	32%	27%	55.7	75.4	1123.1

Lake Overflow Rate 45.53 m/yr Calib. Settling Rate -2.4 m/yr RSE % = Relative Std. Error of Load & Inflow Conc. Estimates

Lake Residence Time 0.24 years Calib. Retention Coef. -6% Error % = Percent of Variance in Total Inflow Load Estimate

Table 3 Total Phosphorus Balance for 2002-2006

Variable: **Total Phosphorus** **Average for Years:** **2002** **thru** **2006**

							Percent of Total Inflow			**Drain.**		**Export**
	Flow	**Load**	**Std Error**	**Conc**	**RSE**	**Sampl**	**Flow**	**Load**	**Error**	**Area**	**Runoff**	**kg /**
Term	**10^6 m3**	**kg**	**kg**	**ppb**	**%**	**per yr**	**%**	**%**	**%**	**km2**	**cm**	**km2**
Metro Effluent	93.48	28884	343	309	1%	361	17%	48%	4%			
Metro Bypass	2.28	2488	85	1090	3%	43	0%	4%	0%			
East Flume	0.72	112	7	156	6%	28	0%	0%	0%			
Crucible	1.79	214	8	119	4%	28	0%	0%	0%			
Harbor Brook	11.58	941	132	81	14%	29	2%	2%	1%	31.4	36.9	30.0
Ley Creek	42.12	3703	388	88	10%	31	8%	6%	5%	66.1	63.7	56.0
Ninemile Creek	164.02	8769	576	53	7%	32	30%	15%	10%	298.1	55.0	29.4
Onondaga Creek	185.75	12652	1623	68	13%	30	34%	21%	79%	285.1	65.1	44.4
Nonpoint Gauged	403.47	26065	1770	65	7%	121	74%	44%	94%	680.7	59.3	38.3
Nonpoint Ungauged	27.48	1775	269	65	15%	0	5%	3%	2%	46.4	59.3	38.3
NonPoint Total	430.96	27841	1791	65	6%	121	80%	46%	96%	727.0	59.3	38.3
Industrial	2.51	326	11	130	3%	56	0%	1%	0%			
Municipal	95.76	31372	354	328	1%	404	18%	52%	4%			
Total External	529.22	59539	1825	113	3%	580	98%	99%	100%	727.0	72.8	81.9
Precipitation	12.36	371	33	30	9%	0	2%	1%	0%	11.7	105.6	31.7
Total Inflow	541.58	59910	1826	111	3%	580	100%	100%	100%	738.7	73.3	81.1
Evaporation	8.86						2%			11.7	75.7	
Outflow	532.72	39943	1125	75	3%		98%	67%	38%	738.7	72.1	54.1
Retention	0.00	19966	2144		11%		0%	33%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	532.72	39943	1125	75	3%	27	98%	67%	38%	738.7	72.1	54.1
Outlet 2 Feet	532.72	38693	1185	73	3%	27	98%	65%	42%	738.7	72.1	52.4
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	10.63	463	148	44	32%	29	2%	1%	1%	27.0	39.4	17.2
Downstream - Hiawatha	11.58	941	132	81	14%	29	2%	2%	1%	31.4	36.9	30.0
Local Inflow	0.95	479	199	504	42%		0%	1%	1%	4.4	21.6	108.6
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	143.73	9227	1631	64	18%	37	27%	15%	80%	229.4	62.7	40.2
Downstream - Kirkpatrick	185.75	12652	1623	68	13%	30	34%	21%	79%	285.1	65.1	44.4
Local Inflow	42.03	3425	2301	81	67%		8%	6%	159%	55.7	75.4	61.5

Lake Overflow Rate 45.53 m/yr Calib. Settling Rate 22.8 m/yr

Lake Residence Time 0.24 years Calib. Retention Coef. 33%

RSE % = Relative Std. Error of Load & Inflow Conc. Estimates

Error % = Percent of Variance in Total Inflow Load Estimate

Table 4 Soluble Reactive Phosphorus Balance for 2002-2006

Variable: **Soluble Reactive P** **Average for Years:** **2002** **thru** **2006**

							Percent of Total Inflow					
	Flow	**Load**	**Std Error**	**Conc**	**RSE**	**Sampl**	**Flow**	**Load**	**Error**	**Drain. Area**	**Runoff**	**Export kg /**
Term	**10^6 m3**	**kg**	**kg**	**ppb**	**%**	**per yr**	**%**	**%**	**%**	**km2**	**cm**	**km2**
Metro Effluent	93.48	8474	787	91	9%	29	17%	64%	73%			
Metro Bypass	2.28	630	399	276	63%	4	0%	5%	19%			
East Flume	0.72	44	4	61	10%	28	0%	0%	0%			
Crucible	1.79	79	5	44	6%	28	0%	1%	0%			
Harbor Brook	11.58	351	41	30	12%	29	2%	3%	0%	31.4	36.9	11.2
Ley Creek	42.12	604	36	14	6%	31	8%	5%	0%	66.1	63.7	9.1
Ninemile Creek	164.02	1300	161	8	12%	32	30%	10%	3%	298.1	55.0	4.4
Onondaga Creek	185.75	1412	199	8	14%	30	34%	11%	5%	285.1	65.1	5.0
Nonpoint Gauged	403.47	3666	262	9	7%	121	74%	28%	8%	680.7	59.3	5.4
Nonpoint Ungauged	27.48	250	38	9	15%	0	5%	2%	0%	46.4	59.3	5.4
NonPoint Total	430.96	3916	264	9	7%	121	80%	29%	8%	727.0	59.3	5.4
Industrial	2.51	122	7	49	5%	56	0%	1%	0%			
Municipal	95.76	9104	883	95	10%	33	18%	68%	92%			
Total External	529.22	13142	922	25	7%	210	98%	99%	100%	727.0	72.8	18.1
Precipitation	12.36	185	17	15	9%	0	2%	1%	0%	11.7	105.6	15.8
Total Inflow	541.58	13328	922	25	7%	210	100%	100%	100%	738.7	73.3	18.0
Evaporation	8.86						2%			11.7	75.7	
Outflow	532.72	21707	1995	41	9%		98%	163%	469%	738.7	72.1	29.4
Retention	0.00	-8380	2198		26%		0%	-63%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	532.72	21707	1995	41	9%	27	98%	163%	469%	738.7	72.1	29.4
Outlet 2 Feet	532.72	20057	1285	38	6%	27	98%	150%	194%	738.7	72.1	27.2
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	10.63	108	15	10	14%	29	2%	1%	0%	27.0	39.4	4.0
Downstream - Hiawatha	11.58	351	41	30	12%	29	2%	3%	0%	31.4	36.9	11.2
Local Inflow	0.95	242	43	255	18%		0%	2%	0%	4.4	21.6	55.0
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	143.73	704	106	5	15%	31	27%	5%	1%	229.4	62.7	3.1
Downstream - Kirkpatrick	185.75	1412	199	8	14%	30	34%	11%	5%	285.1	65.1	5.0
Local Inflow	42.03	708	225	17	32%		8%	5%	6%	55.7	75.4	12.7

Lake Overflow Rate	45.53 m/yr	Calib. Settling Rate	-17.6 m/yr	RSE % = Relative Std. Error of Load & Inflow Conc. Estimates
Lake Residence Time	0.24 years	Calib. Retention Coef.	-63%	Error % = Percent of Variance in Total Inflow Load Estimate

Table 5 Total Nitrogen Balance for 2002-2006

Variable: **Total Nitrogen** **Average for Years:** **2002** **thru** **2006**

Term	**Flow 10^6 m3**	**Load kg**	**Std Error kg**	**Conc ppb**	**RSE %**	**Sampl per yr**	**Percent of Total Inflow: Flow %**	**Percent of Total Inflow: Load %**	**Error %**	**Drain. Area km2**	**Runoff cm**	**Export kg/ km2**
Metro Effluent	93.48	1131098	27108	12101	2%	99	17%	60%	82%			
Metro Bypass	2.28	27551	1126	12073	4%	4	0%	1%	0%			
East Flume	0.72	4352	117	6059	3%	28	0%	0%	0%			
Crucible	2.76	2596	135	941	5%	23	1%	0%	0%			
Harbor Brook	11.58	24681	833	2131	3%	28	2%	1%	0%	31.4	36.9	786.9
Ley Creek	42.12	56301	2544	1337	5%	28	8%	3%	1%	66.1	63.7	851.8
Ninemile Creek	164.02	279475	7418	1704	3%	27	30%	15%	6%	298.1	55.0	937.5
Onondaga Creek	185.75	286516	7398	1542	3%	28	34%	15%	6%	285.1	65.1	1004.9
Nonpoint Gauged	403.47	646973	10813	1604	2%	110	74%	34%	13%	680.7	59.3	950.5
Nonpoint Ungauged	27.48	44067	6008	1604	14%	0	5%	2%	4%	46.4	59.3	950.5
NonPoint Total	430.96	691040	12370	1604	2%	110	79%	37%	17%	727.0	59.3	950.5
Industrial	3.48	6948	179	1999	3%	51	1%	0%	0%			
Municipal	95.76	1158649	27131	12100	2%	103	18%	62%	82%			
Total External	530.19	1856637	29819	3502	2%	264	98%	99%	100%	727.0	72.9	2553.7
Precipitation	12.36	23479	2107	1900	9%	0	2%	1%	0%	11.7	105.6	2006.7
Total Inflow	542.55	1880116	29893	3465	2%	264	100%	100%	100%	738.7	73.4	2545.0
Evaporation	8.86						2%			11.7	75.7	
Outflow	533.69	1384695	25548	2595	2%		98%	74%	73%	738.7	72.2	1874.4
Retention	0.00	495421	39323		8%		0%	26%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	533.69	1384695	25548	2595	2%	27	98%	74%	73%	738.7	72.2	1874.4
Outlet 2 Feet	533.69	1296098	26693	2429	2%	27	98%	69%	80%	738.7	72.2	1754.5
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	8.96	22482	1043	2510	5%	22	2%	1%	0%	27.0	33.2	834.0
Downstream - Hiawatha	11.58	24681	833	2131	3%	28	2%	1%	0%	31.4	36.9	786.9
Local Inflow	2.63	2198	1334	837	61%		0%	0%	0%	4.4	59.6	498.9
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	143.73	235197	25996	1636	11%	31	26%	13%	76%	229.4	62.7	1025.3
Downstream - Kirkpatrick	185.75	286516	7398	1542	3%	28	34%	15%	6%	285.1	65.1	1004.9
Local Inflow	42.03	51319	27028	1221	53%		8%	3%	82%	55.7	75.4	920.8

Lake Overflow Rate 45.61 m/yr Calib. Settling Rate 16.3 m/yr RSE % = Relative Std. Error of Load & Inflow Conc. Estimates
Lake Residence Time 0.24 years Calib. Retention Coef. 26% Error % = Percent of Variance in Total Inflow Load Estimate

Table 6 Ammonia Nitrogen Balance for 2002-2006

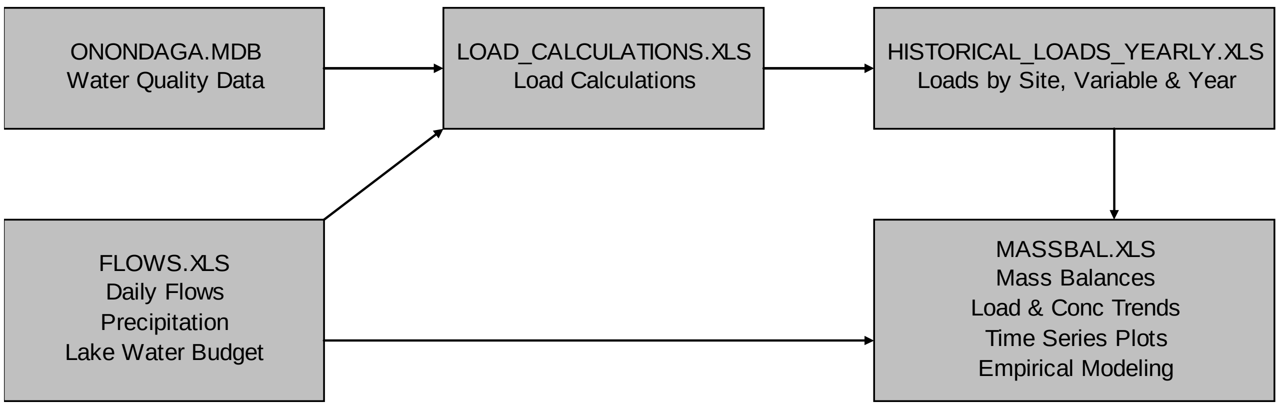
Variable: Ammonia Nitrogen **Average for Years: 2002 thru 2006**

Term	Flow 10^6 m3	Load kg	Std Error kg	Conc ppb	RSE %	Sampl per yr	Percent of Total Inflow: Flow %	Percent of Total Inflow: Load %	Percent of Total Inflow: Error %	Drain. Area km2	Runoff cm	Export kg/ km2
Metro Effluent	93.48	243580	4490	2606	2%	361	17%	73%	56%			
Metro Bypass	2.28	13166	759	5770	6%	43	0%	4%	2%			
East Flume	0.72	369	19	514	5%	28	0%	0%	0%			
Crucible	1.79	335	92	187	28%	28	0%	0%	0%			
Harbor Brook	11.58	994	94	86	9%	28	2%	0%	0%	31.4	36.9	31.7
Ley Creek	42.12	12622	829	300	7%	28	8%	4%	2%	66.1	63.7	191.0
Ninemile Creek	164.02	39646	3647	242	9%	27	30%	12%	37%	298.1	55.0	133.0
Onondaga Creek	185.75	15292	928	82	6%	28	34%	5%	2%	285.1	65.1	53.6
Nonpoint Gauged	403.47	68555	3855	170	6%	111	74%	21%	41%	680.7	59.3	100.7
Nonpoint Ungauged	27.48	4669	682	170	15%	0	5%	1%	1%	46.4	59.3	100.7
NonPoint Total	430.96	73224	3915	170	5%	111	80%	22%	42%	727.0	59.3	100.7
Industrial	2.51	704	94	281	13%	56	0%	0%	0%			
Municipal	95.76	256746	4554	2681	2%	404	18%	77%	57%			
Total External	529.22	330675	6006	625	2%	571	98%	100%	100%	727.0	72.8	454.8
Precipitation	12.36	1236	111	100	9%	0	2%	0%	0%	11.7	105.6	105.6
Total Inflow	541.58	331910	6007	613	2%	571	100%	100%	100%	738.7	73.3	449.3
Evaporation	8.86						2%			11.7	75.7	
Outflow	532.72	260923	10578	490	4%		98%	79%	310%	738.7	72.1	353.2
Retention	0.00	70987	12165		17%		0%	21%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	532.72	260923	10578	490	4%	27	98%	79%	310%	738.7	72.1	353.2
Outlet 2 Feet	532.72	234895	10952	441	5%	27	98%	71%	332%	738.7	72.1	318.0
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	10.63	595	45	56	8%	28	2%	0%	0%	27.0	39.4	22.1
Downstream - Hiawatha	11.58	994	94	86	9%	28	2%	0%	0%	31.4	36.9	31.7
Local Inflow	0.95	399	104	420	26%		0%	0%	0%	4.4	21.6	90.5
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	143.73	8256	408	57	5%	35	27%	2%	0%	229.4	62.7	36.0
Downstream - Kirkpatrick	185.75	15292	928	82	6%	28	34%	5%	2%	285.1	65.1	53.6
Local Inflow	42.03	7036	1014	167	14%		8%	2%	3%	55.7	75.4	126.3

Lake Overflow Rate 45.53 m/yr   Calib. Settling Rate 12.4 m/yr   RSE % = Relative Std. Error of Load & Inflow Conc. Estimates

Lake Residence Time 0.24 years   Calib. Retention Coef. 21%   Error % = Percent of Variance in Total Inflow Load Estimate

Figure 1
Mass Balance Computations Integrated with AMP Long-Term Database



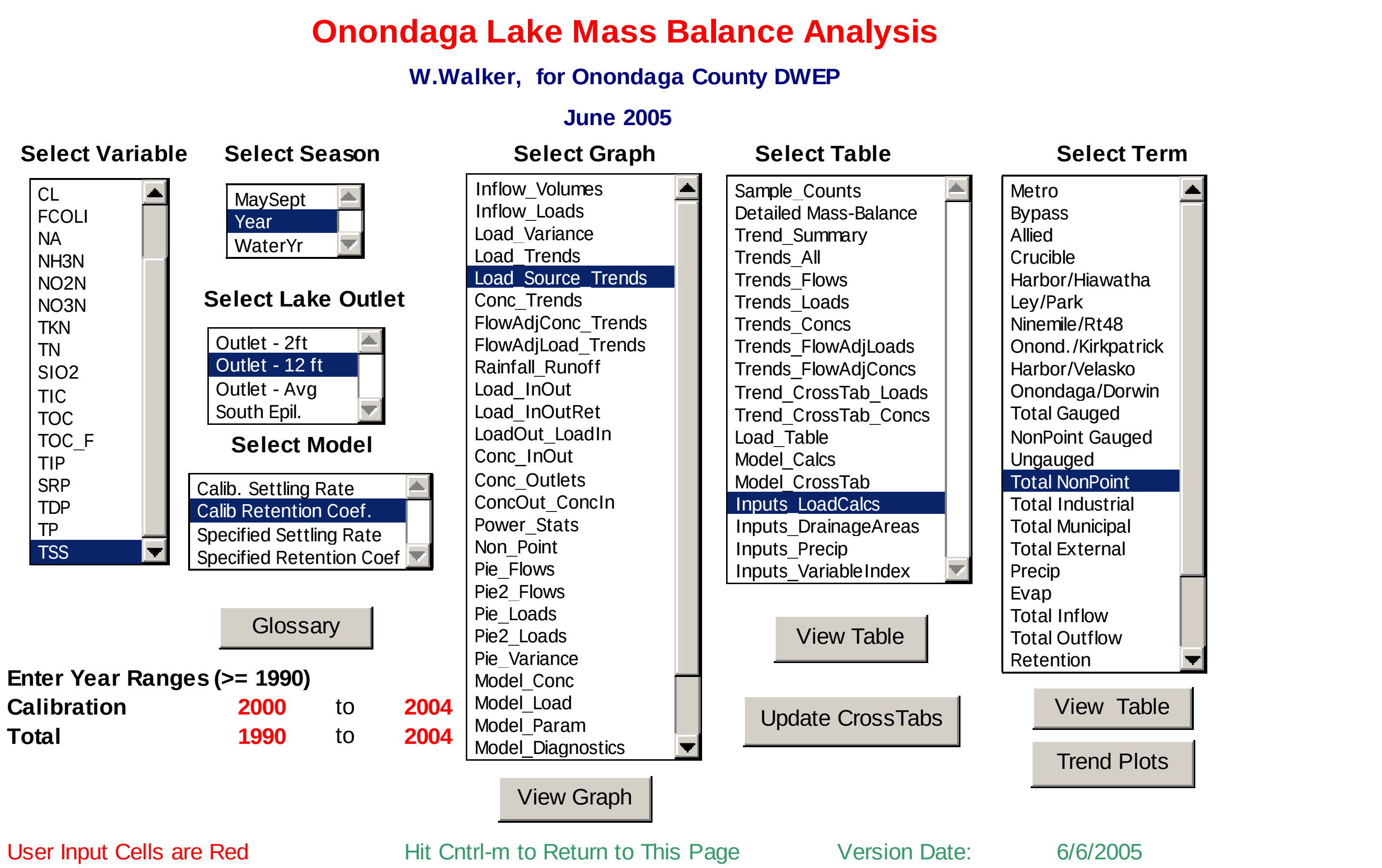
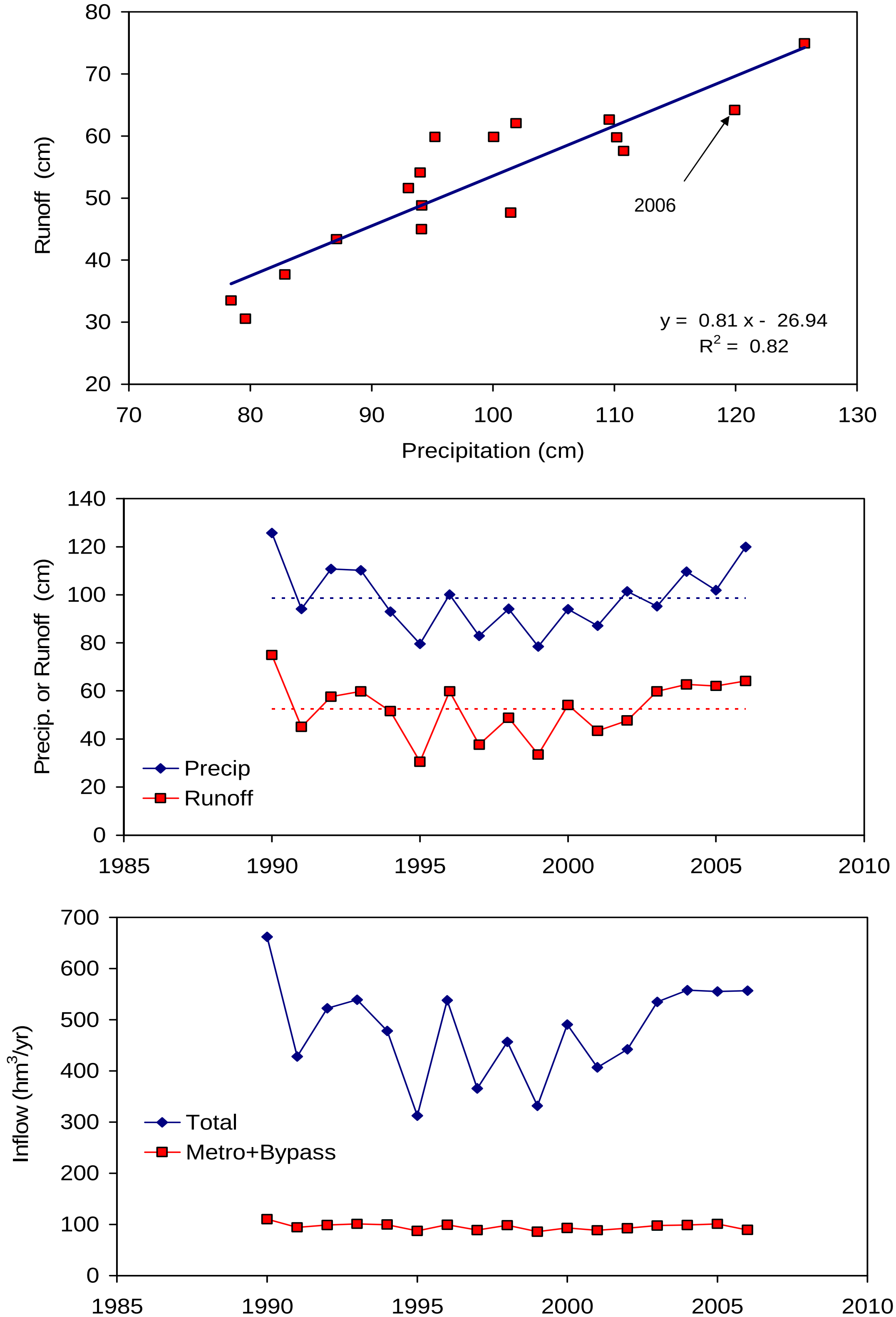


Figure 2
Precipitation, Runoff, & Lake Inflow Volumes



X Axis: Calendar Year

Figure 3
Long-Term Trends in Total Inflow & Outflow Concentrations

Squares = Inflow, Circles = Outflow   Error Bars = +/- 1 Standard Error   X-Axis = Calendar Year

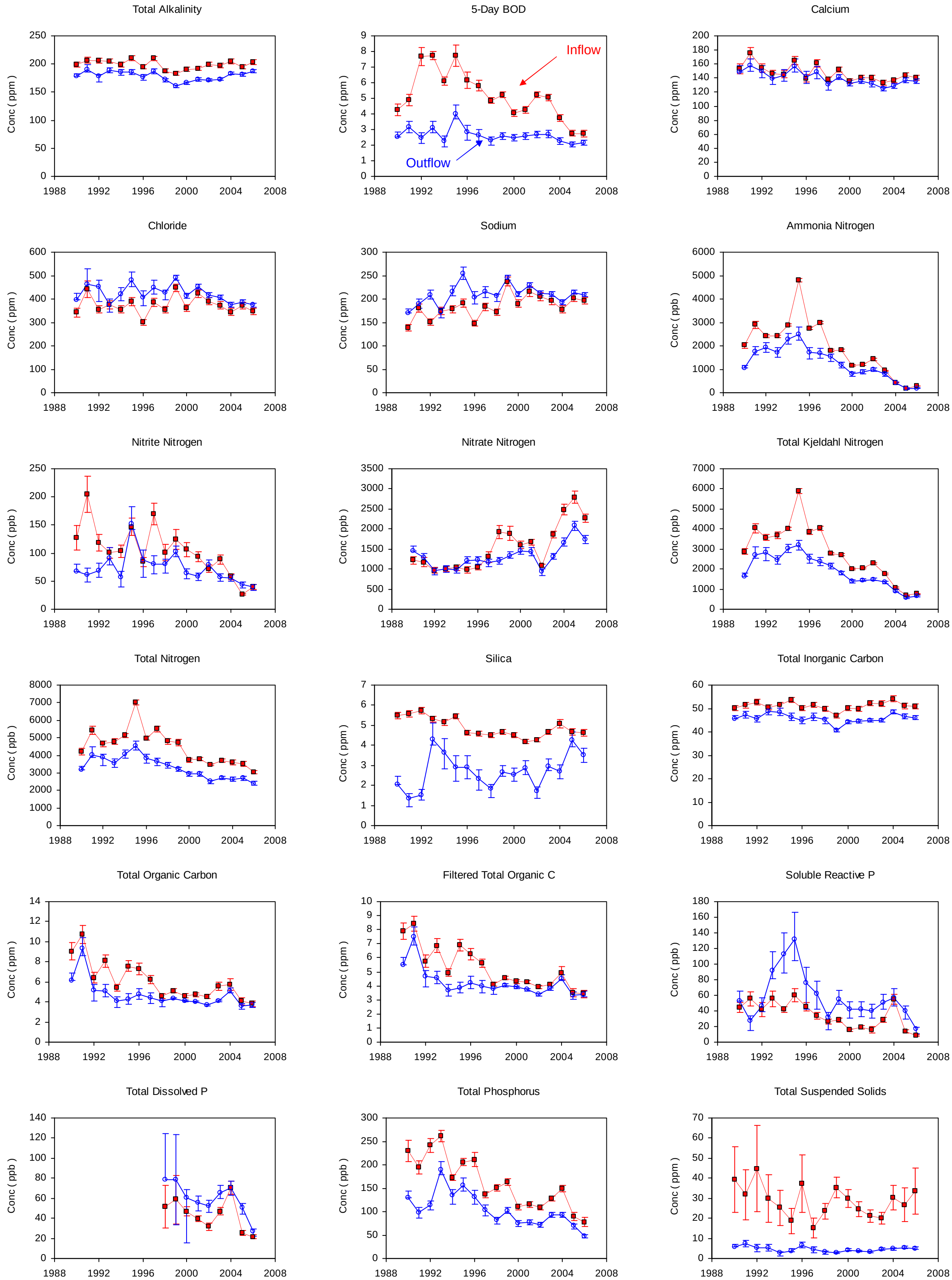


Figure 4
Long-Term Trends in Total Inflow & Outflow Loads

Squares = Inflow, Circles = Outflow   Error Bars = +/- 1 Standard Error   X-Axis = Calendar Year

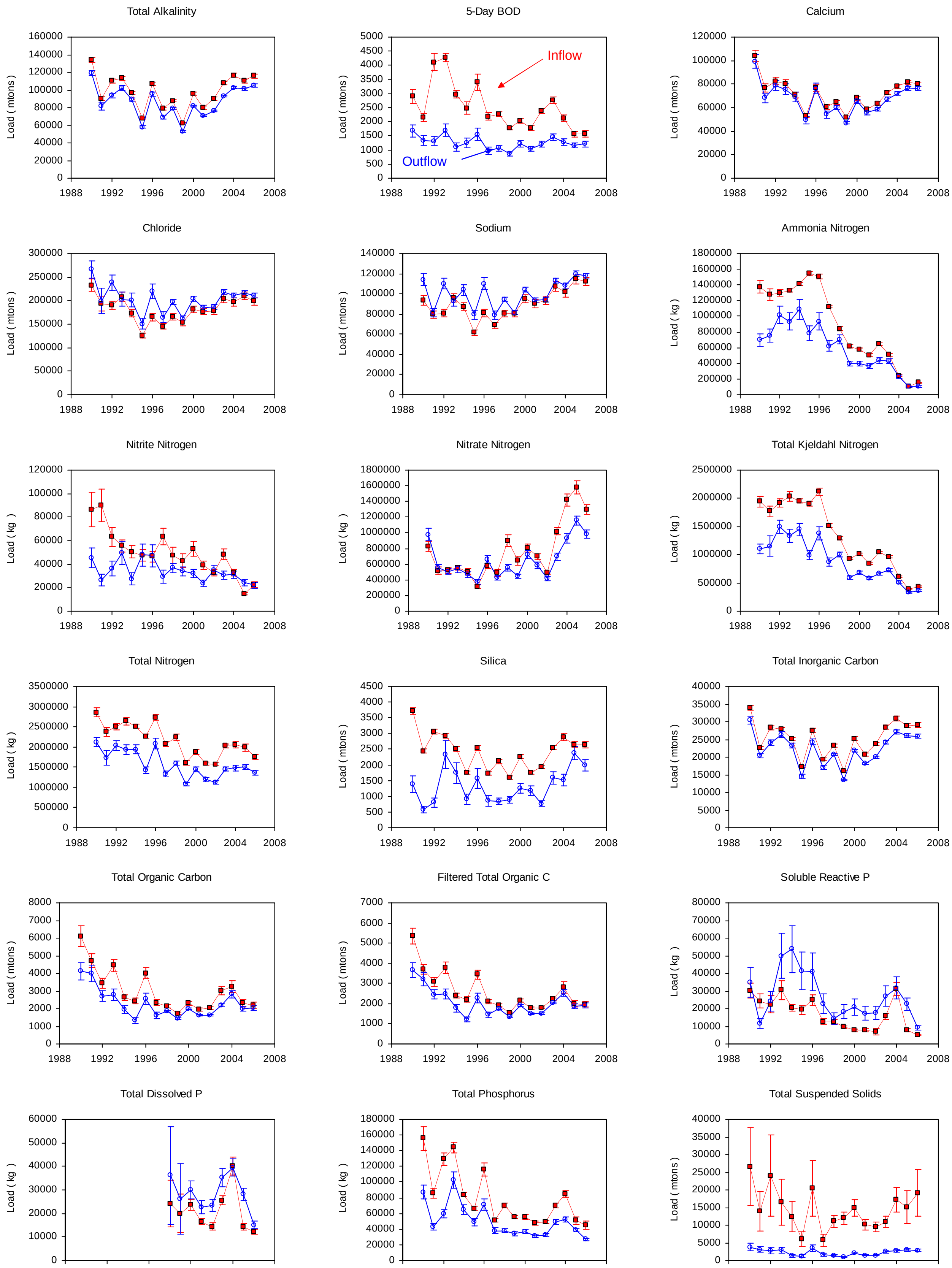


Figure 5
Long-Term Trends in NonPoint & Metro Loads

Squares = NonPoint Sources, Circles = Metro + Bypass   Error Bars = +/- 1 Standard Error   X-Axis = Calendar Year

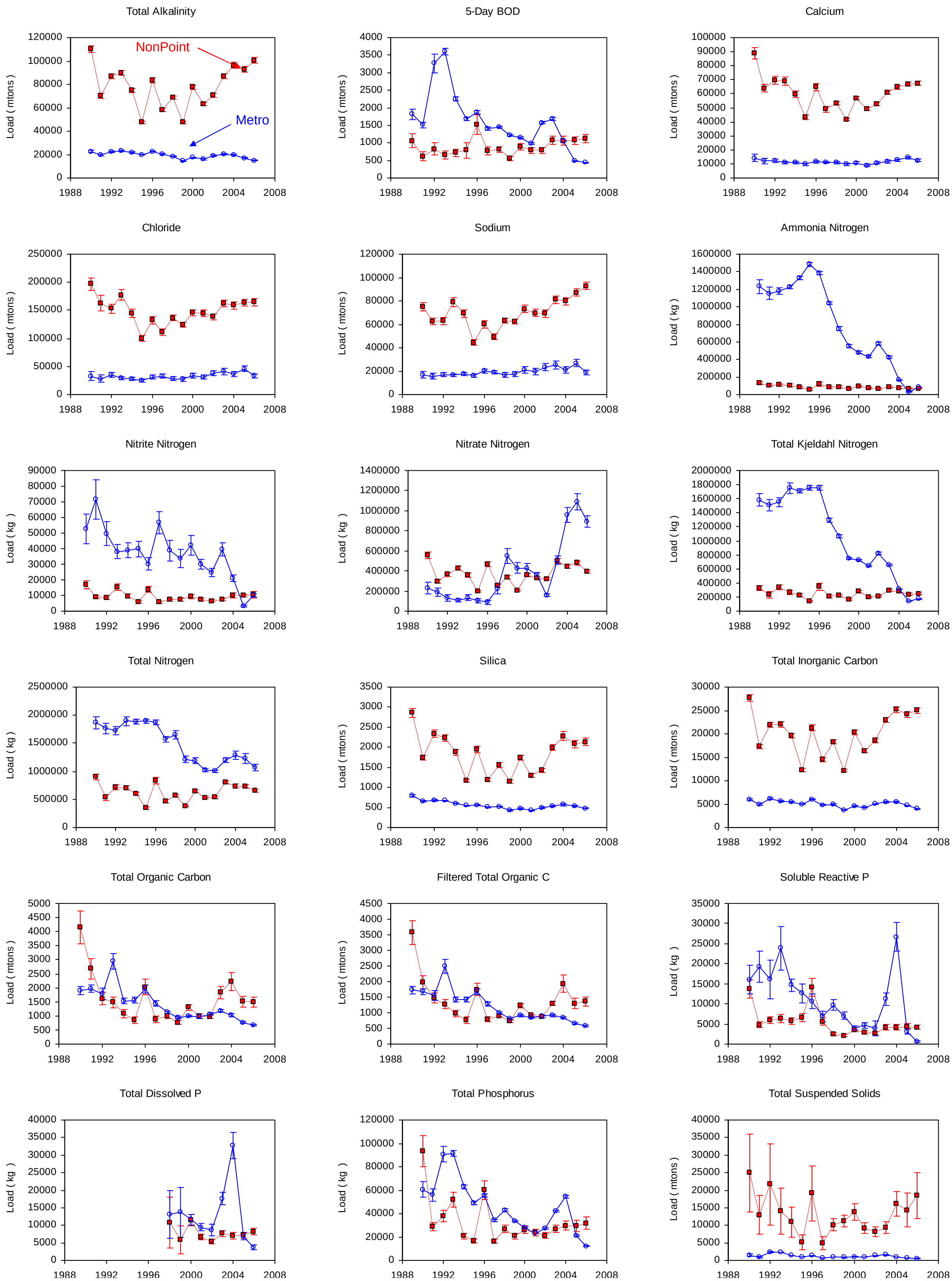
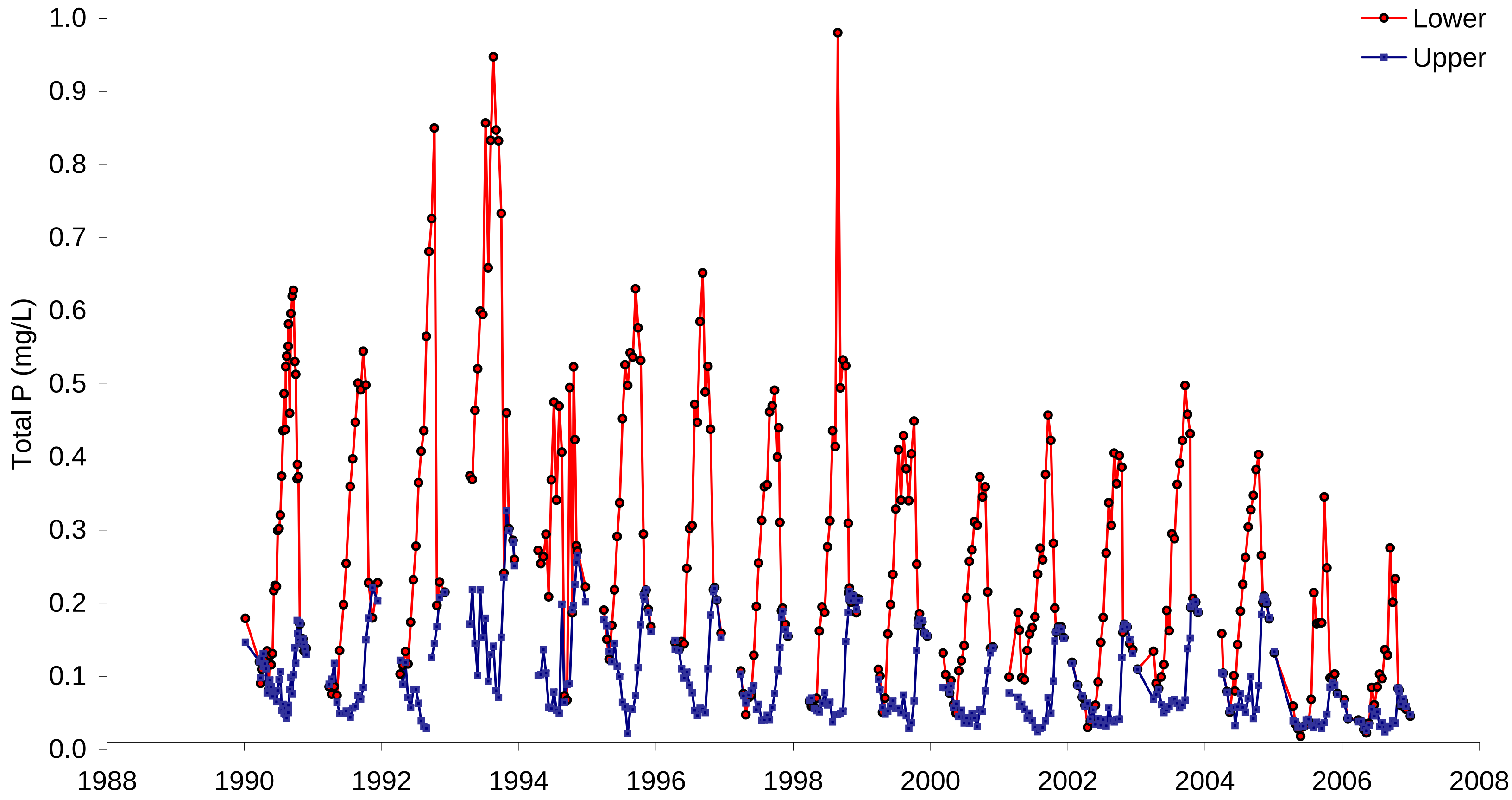


Figure 6
Long-Term Trends in Lake Phosphorus Concentration

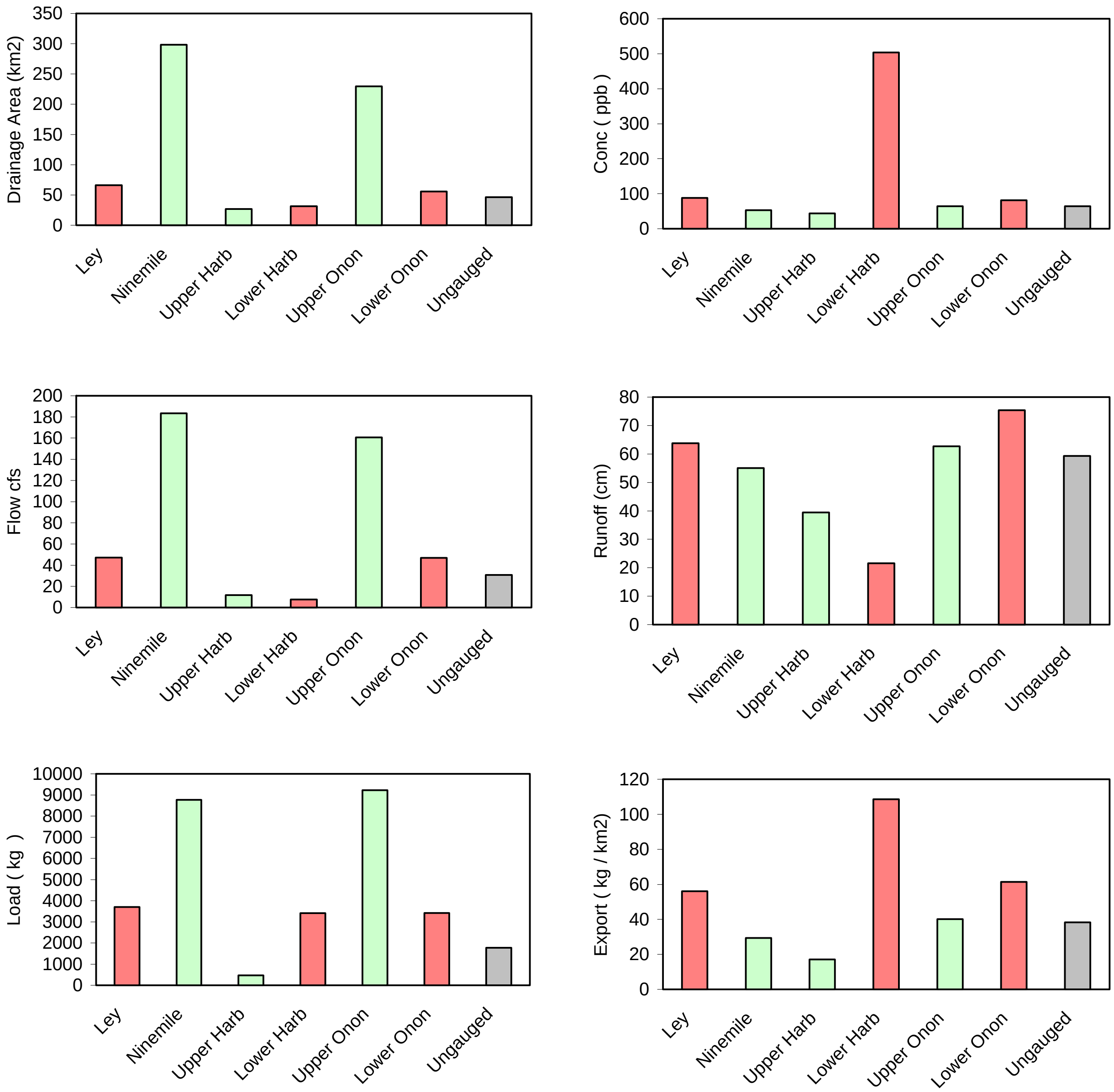


Lower 9 - 18 meters, South Deep station
Upper 0 - 3 meters

Figure 7
Spatial Variations in NonPoint Phosphorus Loads

Variable: Total Phosphorus Period: 2002 - 2006

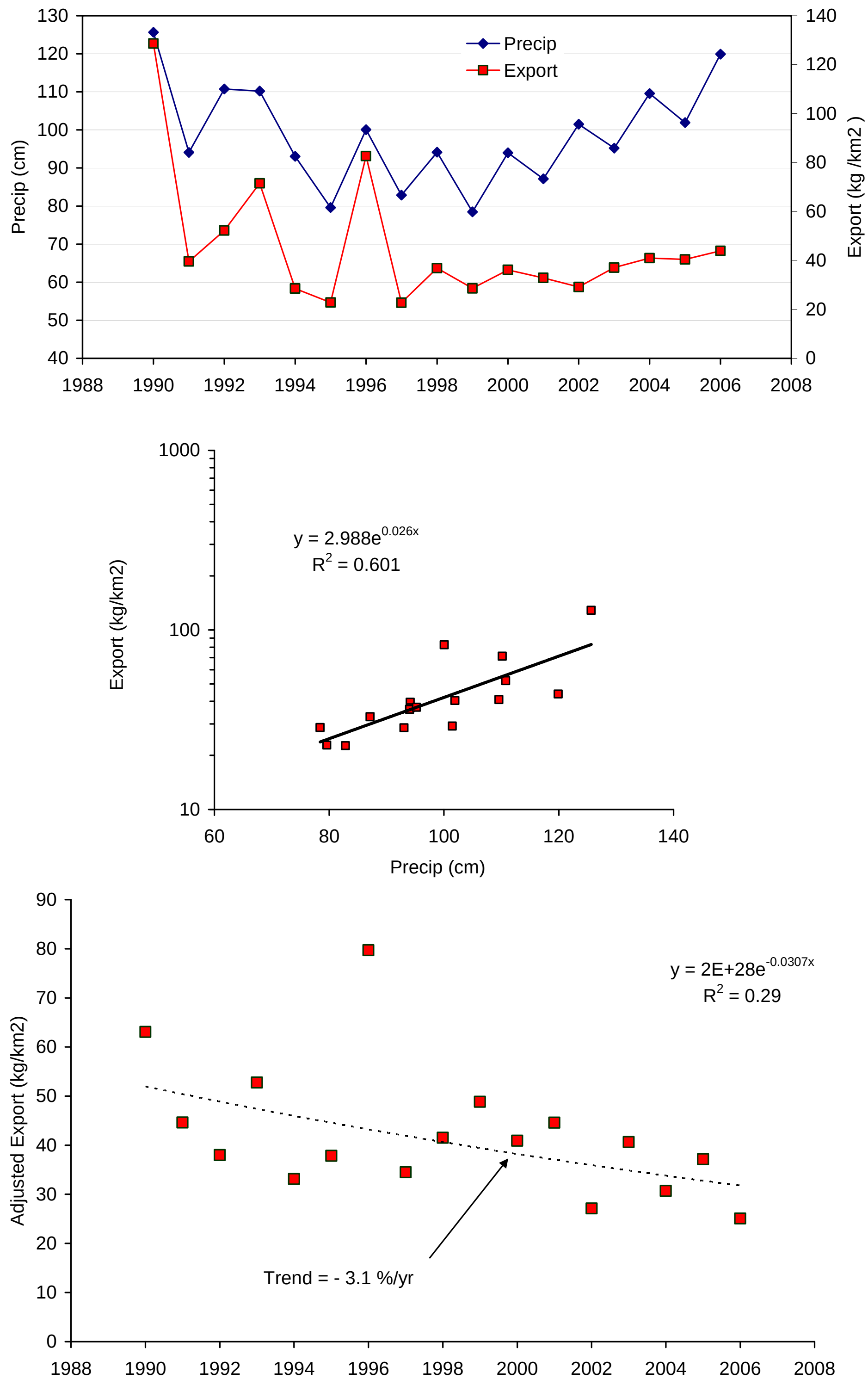
Total Values Unit Area Values



Label	Description
Ley	Above Park
Ninemile	Above Lakeland
Upper Harb	Above Velasko
Lower Harb	Between Velasko & Hiawatha
Upper Onon	Above Dorwin
Lower Onon	Between Dorwin & Kirkpatrick
Ungauged	Ungauged Watershed

Red	Basically Urban Areas
Green	Basically Rural Areas (Agric, Undeveloped)
Grey	Estimated Ungauged Assuming Average Unit Area Export from Gauged Areas

Figure 8
Adjustment of Non-Point P Loads for Variations in Rainfall



P_Export = Total Nonpoint Load (kg/yr) / Watershed Area (km2)

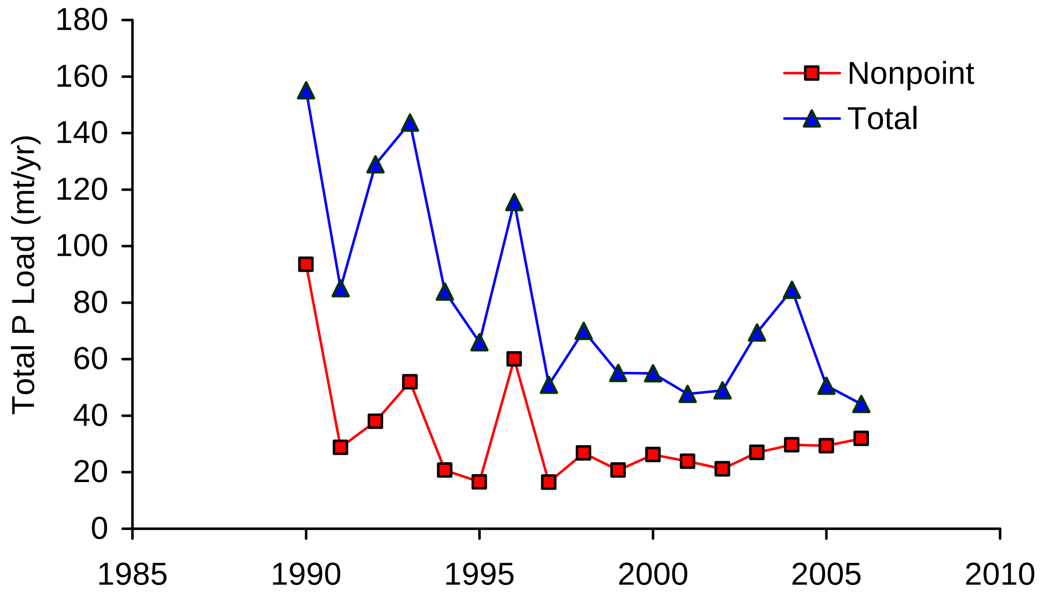
Precip = Hancock Airport Precipitation (cm)

Adjusted_P_Export = P_Export Adjusted for Yearly Variations in Precipitation

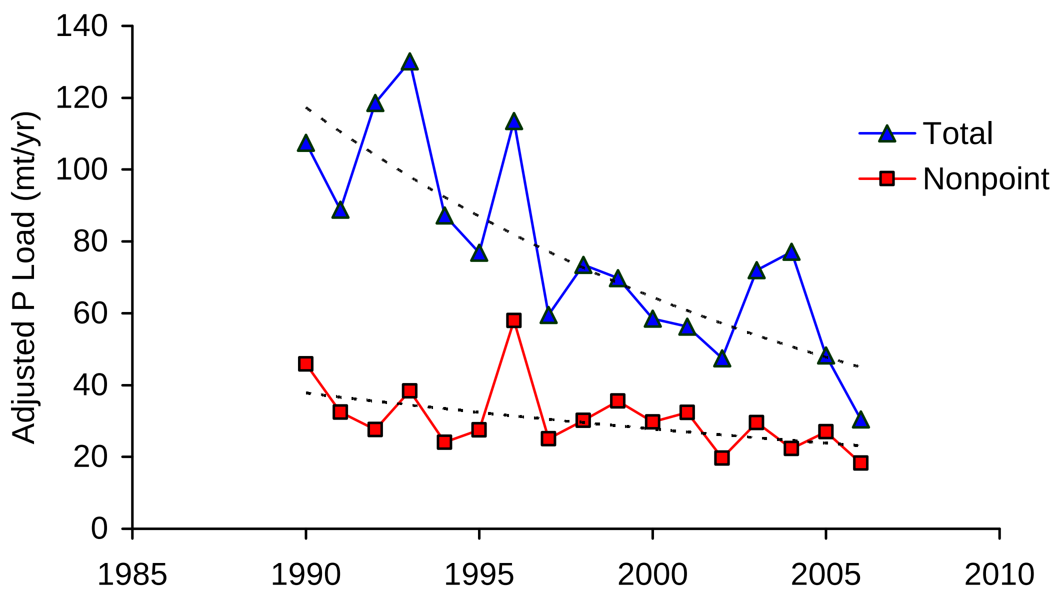
Adjusted_P_Export = Measured_P_Export x Exp [.026 x (Mean_Precip - Precip)]

Figure 9
Trends in Total & NonPoint Phosphorus Loads

Measured Loads:



Adjusted for Variations in Precipitation:



Trend Slopes (%/yr)	Slope	Std Error	p	
Point	-8.2%	1.7%	0.000	
Adjusted Nonpoint	-3.1%	1.2%	0.026	adjusted for variations in precip
Total	-6.0%	1.1%	0.000	point + adjusted nonpoint