Update of AMP Statistical Framework - 2002

Phase I - Water Quality Monitoring

Topics

Overview of Statistical Framework

Update Variance Components (1993-2000 vs. 1993-1997 Data)

Update Precision & Power Estimates

Chlorophyll-a & Bacteria Sampling Frequency

Chlorophyll-a & Bacteria Duplicates

Chlorophyll-a Sampling Method (Epilimnetic vs. Photic Zone)

Spatial & Temporal Variations - Nearshore Monitoring

Lake Profile Monitoring & Averaging Procedures

Other ??

1/17/2002

A Statistical Framework for the Onondaga Lake Ambient Monitoring Program

prepared for

Onondaga County, Department of Drainage & Sanitation

by

William W. Walker, Jr., Ph.D., Environmental Engineer

Draft, July 13, 1998

Introduction

One of the primary purposes of the Ambient Monitoring Program is to provide information for supporting future decisions on wastewater and watershed management. Future decisions may be based in part upon changes detected in Onondaga Lake and Seneca River over the next several years. Decisions may also rely upon comparisons of monitored conditions with water quality standards or management goals. The ability to detect such changes and the reliability of such comparisons depends in part upon the design of the monitoring program. Decisions should not be made based upon the monitoring results without an adequate understanding of the sources and magnitudes of variability in the data.

This section describes and demonstrates a statistical framework (Figure 1) that is an integral part of the monitoring program. The framework has been designed to provide the following functions:

- identifying and quantifying sources of variability in the data;
- evaluating uncertainty associated with summary statistics;
- formulating and testing specific hypotheses; and
- refining monitoring program designs;

Continuous implementation of this framework over the course of the monitoring program will help to ensure that data-collection efforts are cost-effective and that the resulting data base is adequate to support future management decisions.

To some extent, elements of the framework are already in place under the existing lake monitoring program. Similar statistical concepts and procedures were used in evaluating of lake monitoring data collected through 1990 (Walker, 1991b). Routine trend analyses have become a standard component of annual lake monitoring reports (Stearns & Wheler, 1997). The framework is demonstrated below using data from the historical lake monitoring program. Steps required to implement the framework are also described. Methodologies will be refined and applied to key variables tracked

Monitoring Program Design for Trend Detection

Null Hypothesis (H_o): No Trend

Outcome of Hypothesis Test:

Test Outcome	Reality: No Trend	Reality: Trend
H_o Accepted	Correct	Type II Error max prob. = β
H_o Rejected	Type I Error max prob. = α	Correct

"Significance Level" = α, **Pre-Selected**

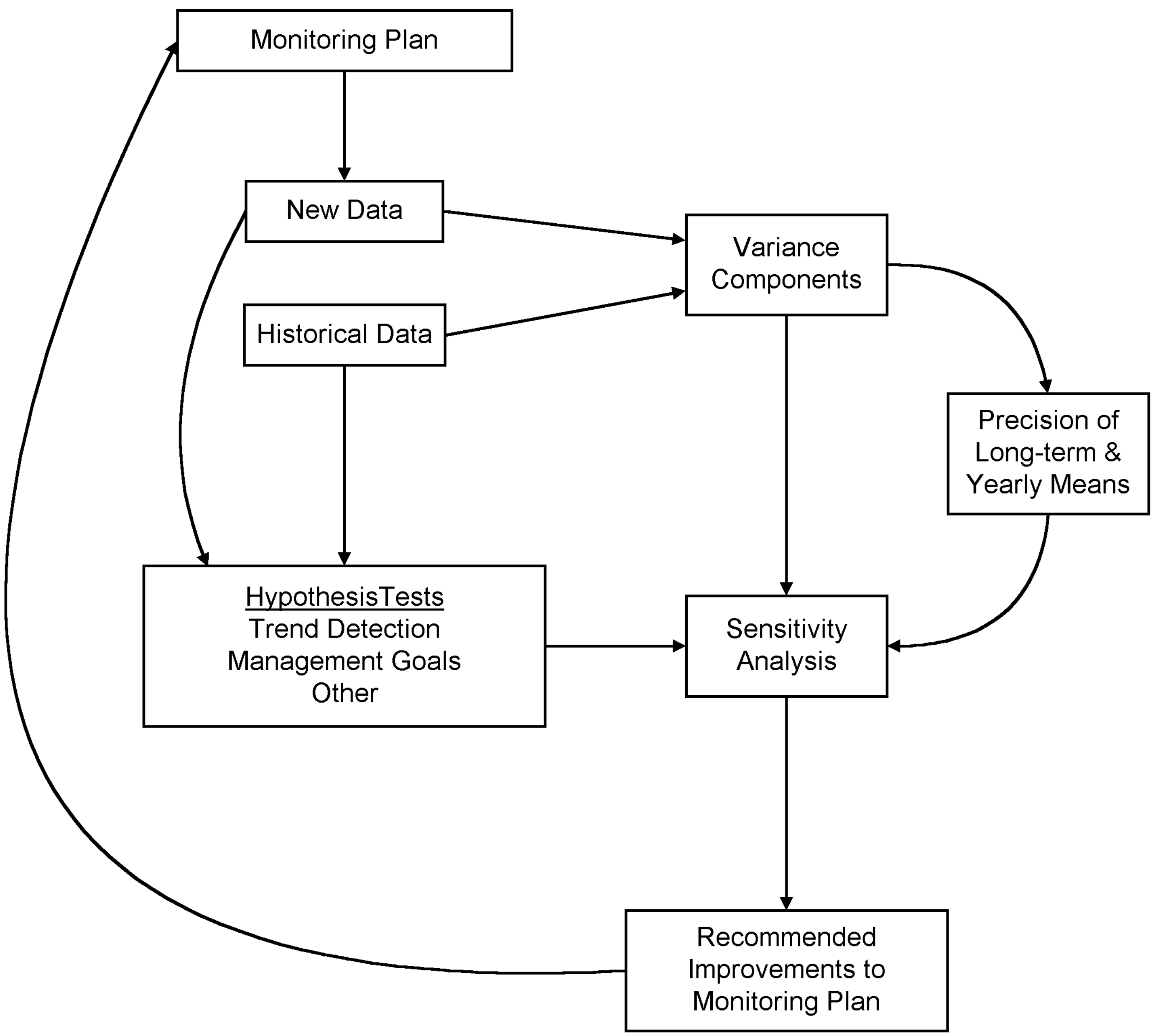
Maximum (β) = 1 - α

Power = Probability of Detecting Trend = 1 - β

= Function ("Trend Number" , α)

$$\text{Trend Number} \sim \frac{\text{Magnitude of Trend x (Years of Monitoring)}^{1.5}}{\text{Standard Deviation of Yearly Means}}$$

Statistical Framework for Ambient Monitoring Plan



Sampling Design Parameters:

n_y = number of years

n_d = number of sampling dates/year

n_z = number of depths / replicates per date

Variance Component Model:

$$S^2_{total} = S^2_{year} + S^2_{date} + S^2_{depth}$$

Variance of Mean for Individual Year: --> Precision of Yearly Mean

$$E_y^2 \sim S^2_{date} / n_d + S^2_{depth} / (n_d \times n_z)$$

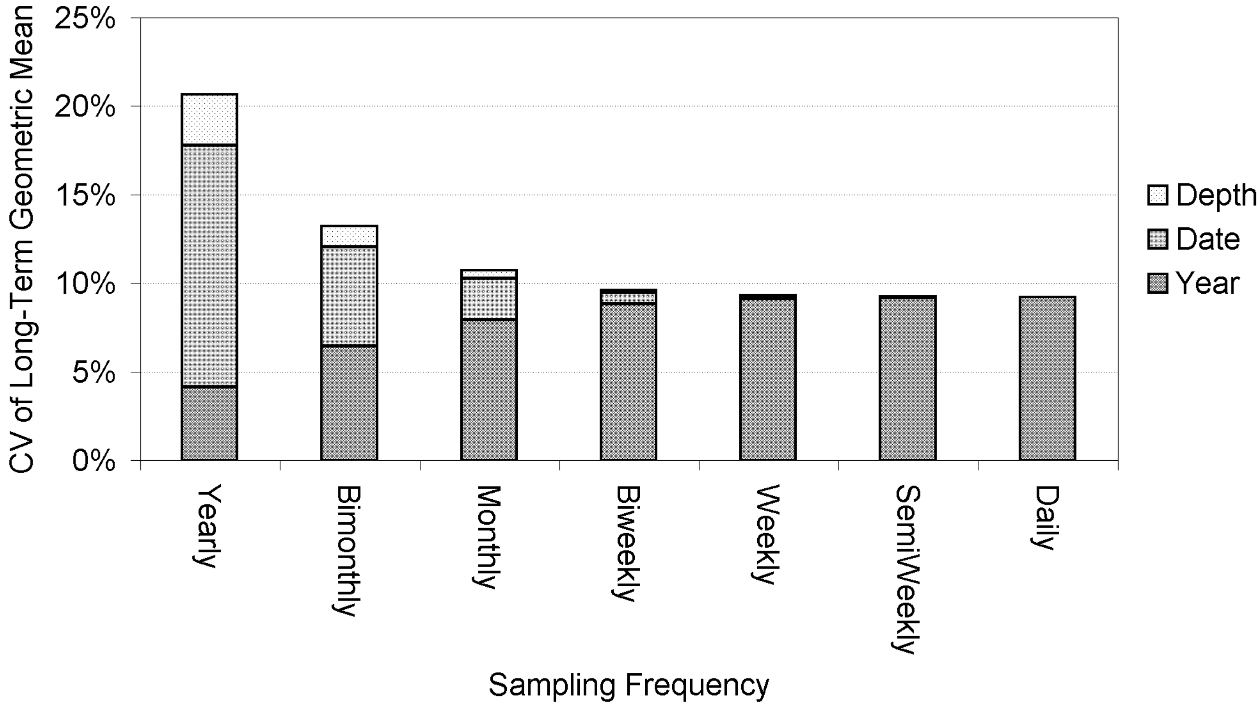
Variance of Yearly Mean Time Series: --> Power for Trend Detection

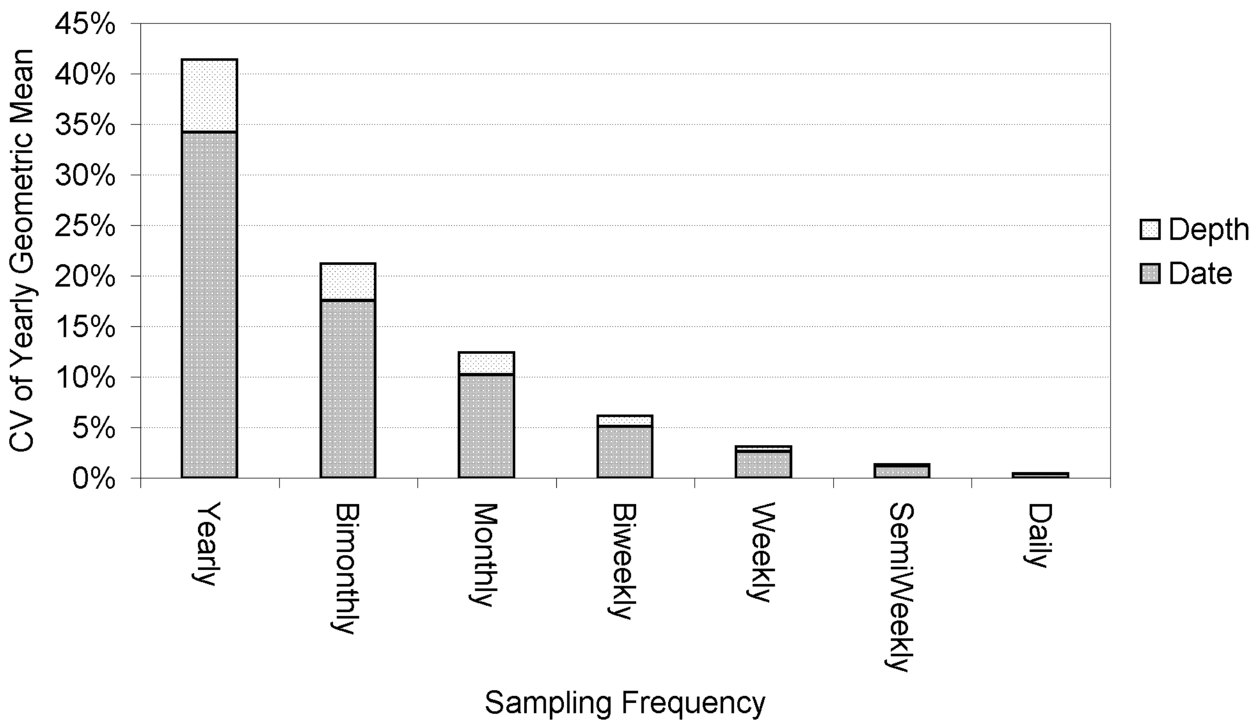
$$E_t^2 \sim S^2_{year} + S^2_{date} / n_d + S^2_{depth} / (n_d \times n_z)$$

Variance of Long-Term Mean: --> Precision of Long-Term Mean

$$E_\mu^2 \sim S^2_{year} / n_y + S^2_{date} / (n_d \times n_y) + S^2_{depth} / (n_y \times n_d \times n_z)$$

Precision in Long-term & Yearly Geometric Means





Shaded areas in each bar reflect percent of variance attributed to yearly, daily, or depth variation
Variable: Total Inorganic P
Duration = 5 years

A Statistical Framework for the Onondaga Lake Ambient Monitoring Program Phase I

prepared for

Onondaga County, Department of Drainage & Sanitation

by

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January 15, 1999

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A Statistical Framework for the Onondaga Lake Ambient Monitoring Program - Phase II

prepared for

Department of Drainage & Sanitation
Onondaga County, New York

by

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February 22, 2000

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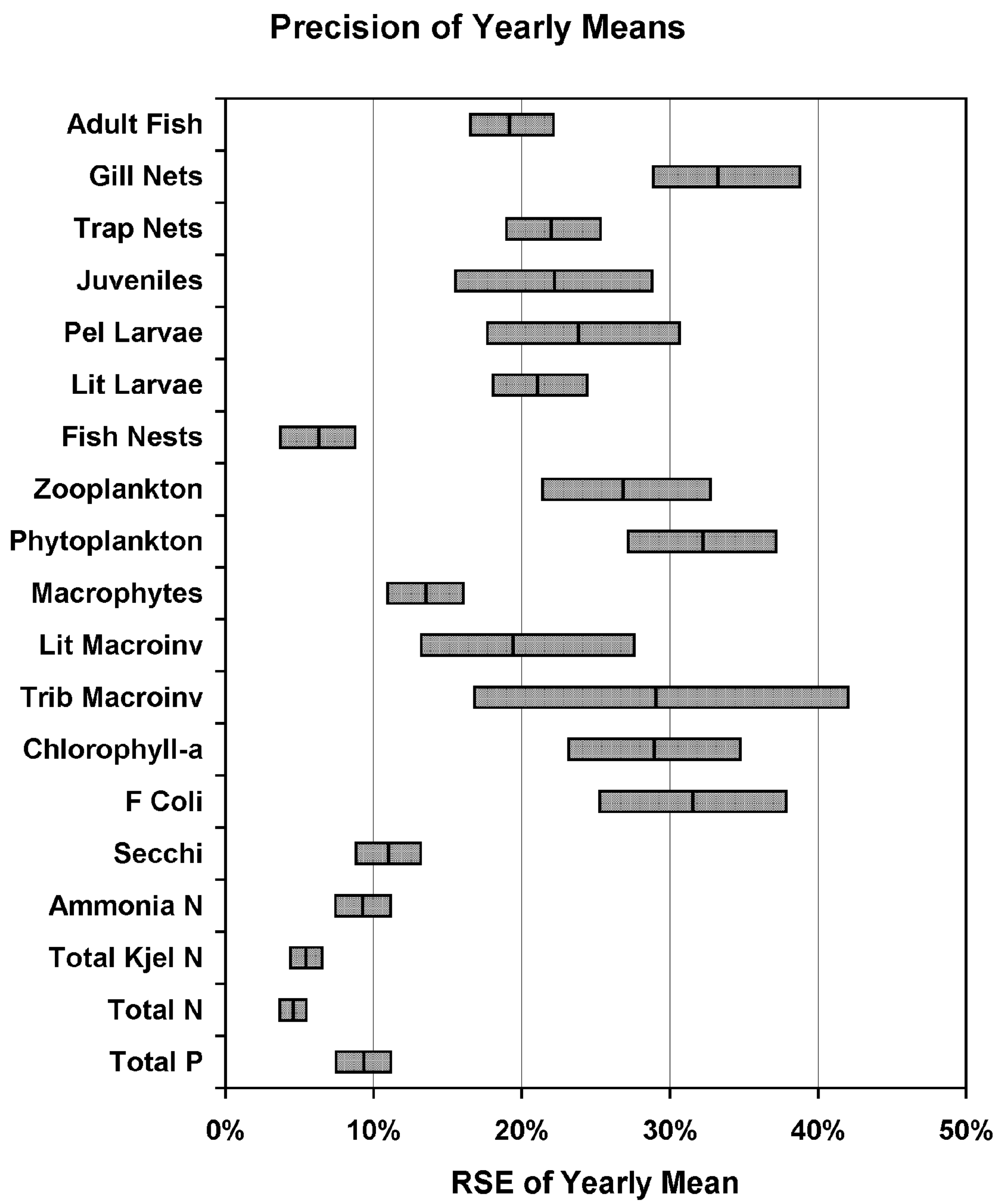
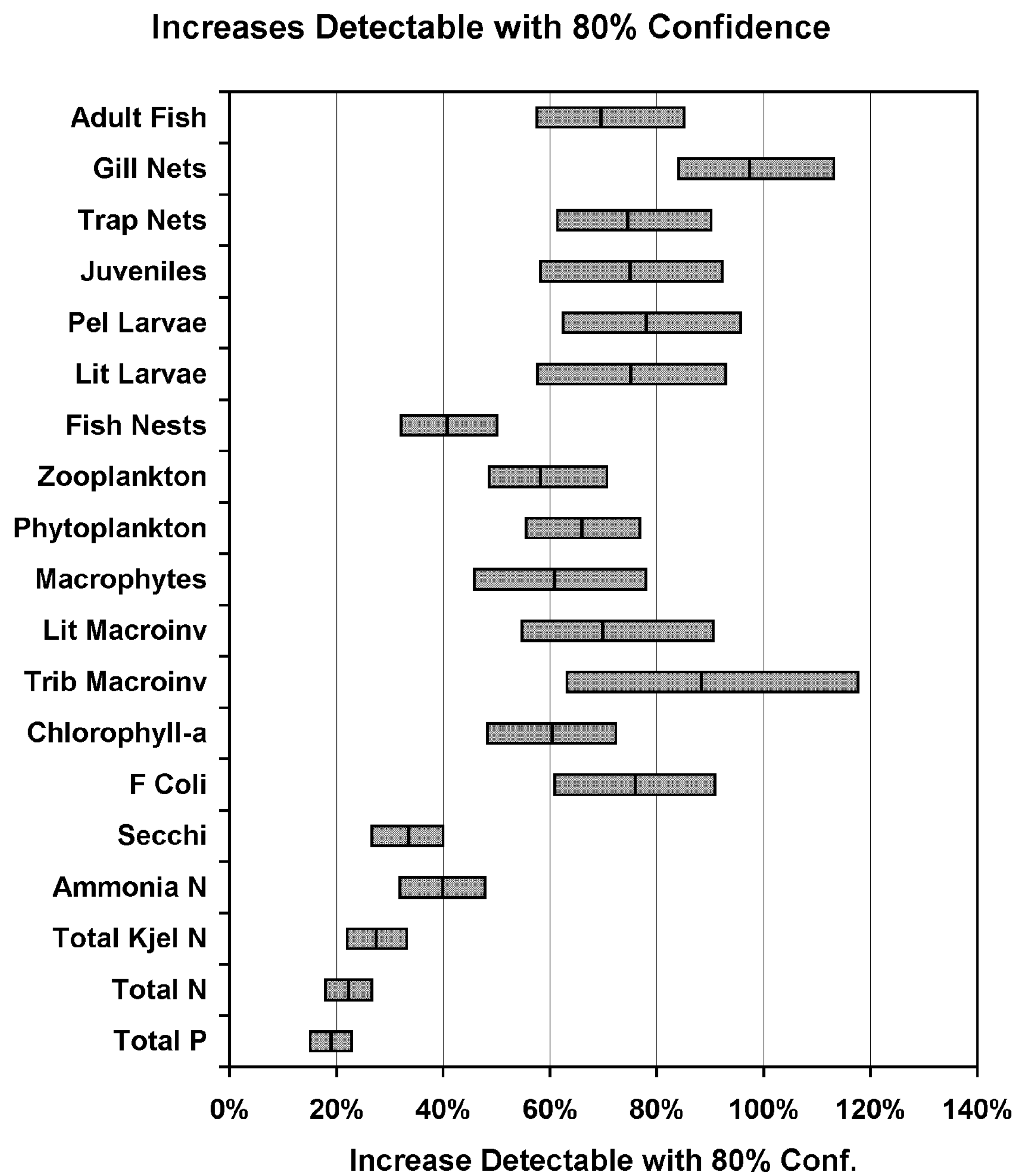
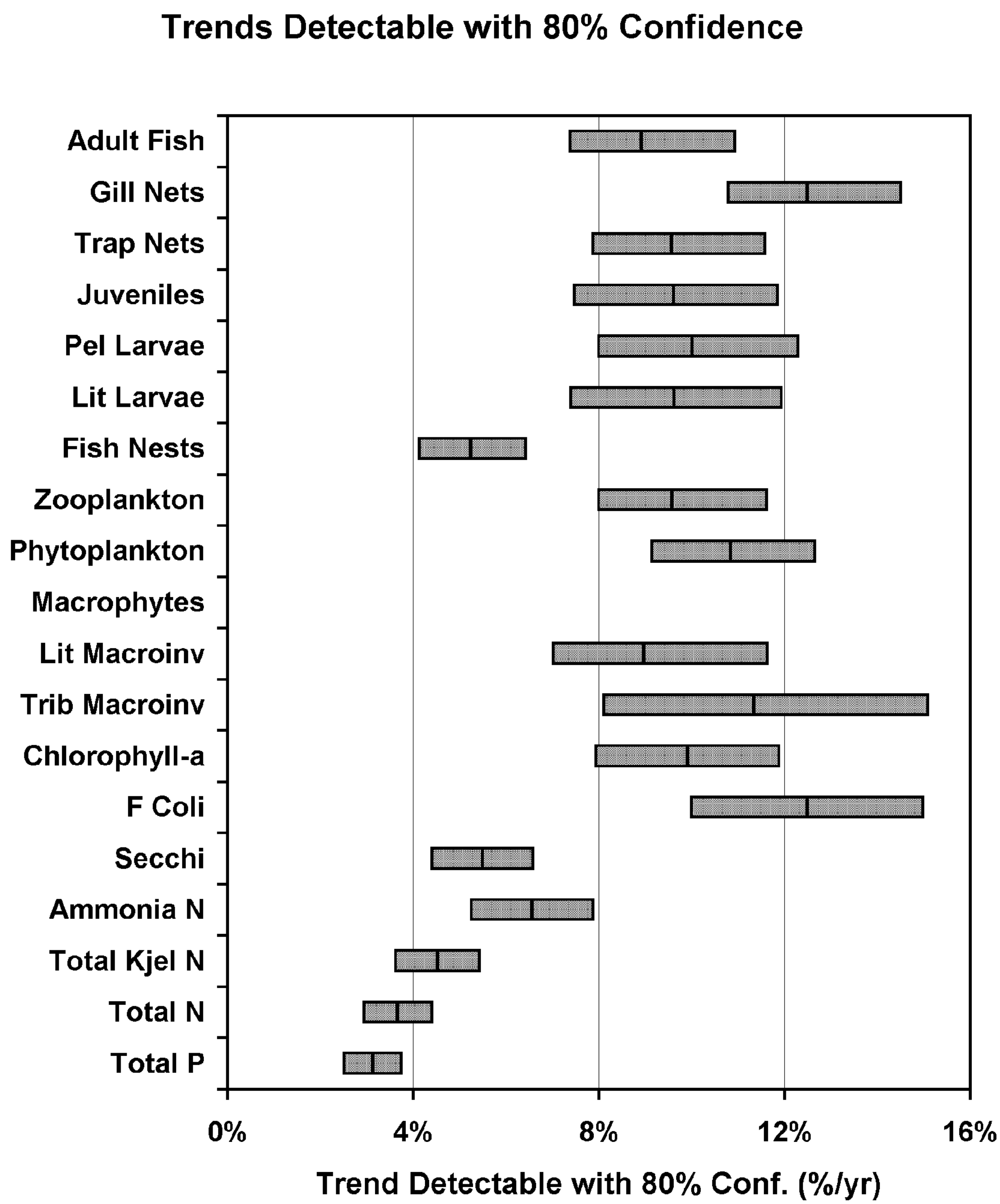


Bars show 10th, 50th, & 90th percentile estimates.



An increase of 100% means a doubling.
Bars show 10th, 50th, & 90th percentile estimates.


Trends Detectable with 80% Confidence
Adult Fish
Gill Nets
Trap Nets
Juveniles
Pel Larvae
Lit Larvae
Fish Nests
Zooplankton
Phytoplankton
Macrophytes
Lit Macroinv
Trib Macroinv
Chlorophyll-a
F Coli
Secchi
Ammonia N
Total Kjel N
Total N
Total P
0%
4%
8%
12%
16%
Trend Detectable with 80% Conf. (%/yr)

Update of AMP Statistical Framework - 2002
Phase I - Water Quality Monitoring
Preliminary Conclusions

Variance Components (1993-2000) Similar to Previous Analysis (1993-1997)

Existing Design Meets AMP Precision Goal (RSE < 20%) for Water Quality
- Lake & Tributary Concentrations
- Tributary Loads & Lake Mass Balances

Variations Among Replicates 13% for Chl-a and 46% for Fecal Coliforms

Chlorophyll-a & Fecal Coliform Precision Improved by Weekly Sampling

RSE's	Chl-a	Fcoli
Biweekly	34%	38%
Weekly	24%	27%

Precision Consistent with Other Biological Parameters

Epilimnetic Chl-a Composites May Fail To Detect Surface Blooms

Significant Variations Detected in Nearshore Monitoring Program
- South vs. North
- Deep vs. Nearshore
- Storm Event vs. Dry Weather

Reduction of Ammonia Detection Limit (0.1 to 0.05 ppb) in 1999 Adequate for Measuring Trib Loads; Tracking future reductions in Lake Ammonia Levels will Require a Lower DL.

Historical Vertical Sampling for Nutrients (7 Discrete Depths)
- Provides Good Spatial & Temporal Resolution
- No Significant Difference Among 0, 1, 3, 6 meter samples

1/17/2002

Update of AMP Statistical Framework - 2002
Phase I - Water Quality Monitoring
Preliminary Recommendations

Bacteria Monitoring
- Continue Weekly Frequency
- Drop Duplicates at Lake South
- Add Duplicates at One Lake Nearshore Station (Storm Event)

Chlorophyll-a Monitoring
- Continue Photic Zone Sampling at Weekly Frequency
- Duplicates Consistent with Other WQ Parameters

Lake Nearshore Monitoring - Storm Events
- Add Lake South Station (Control)
- Add Turbidity?

Lake Nearshore Monitoring - Dry Weather
- Add Nearshore Stations at South End of Lake
- Add Turbidity?

Conduct More Detailed Analysis & Modeling of Nearshore Data

Possible Need for Lower Ammonia Detection Limit

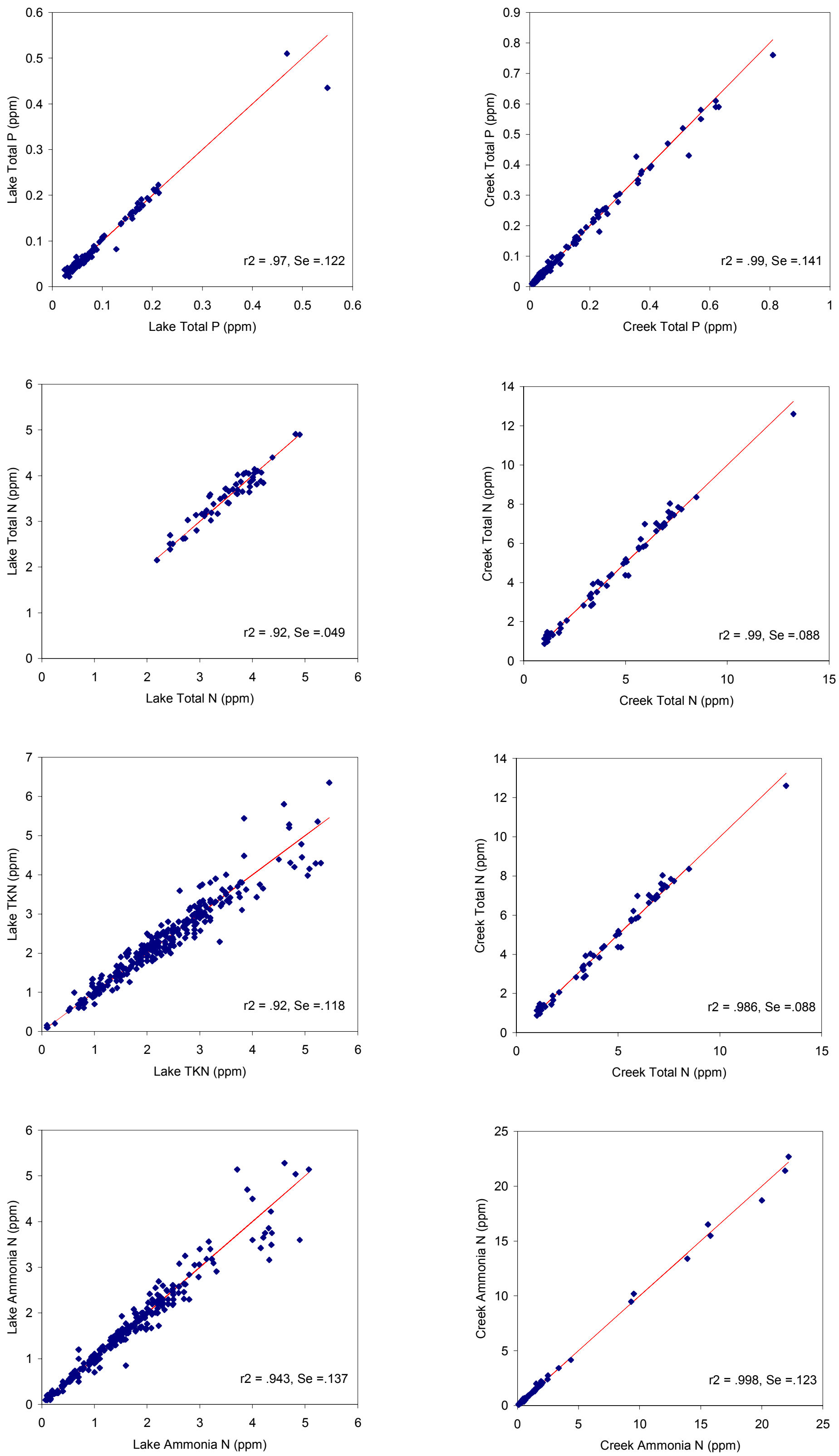
No Compelling Reason to Change Lake Vertical Sampling Design

Use Consistent Averaging Procedure for Mean Mixed-Layer Values

Future Updates of Framework Should Evaluate Power for Testing Specific Hypotheses Formulated Around Specific Management Goals

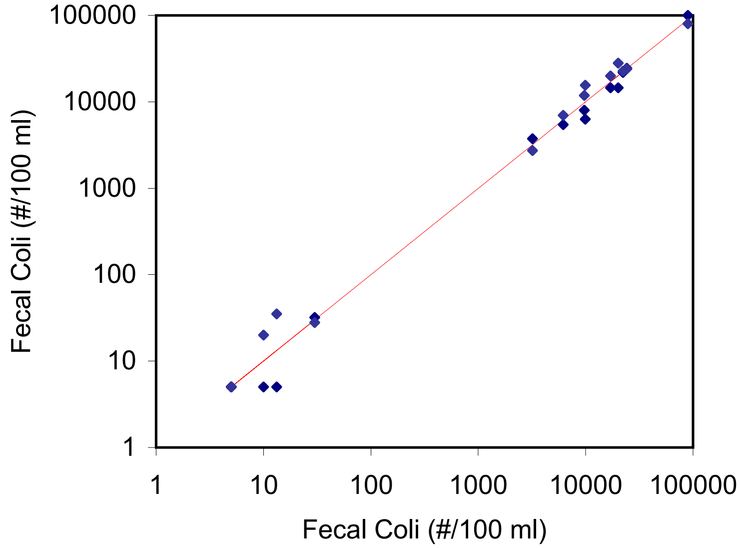
1/7/2002

Analysis of Duplicate Samples from Lake and Creek Monitoring Programs



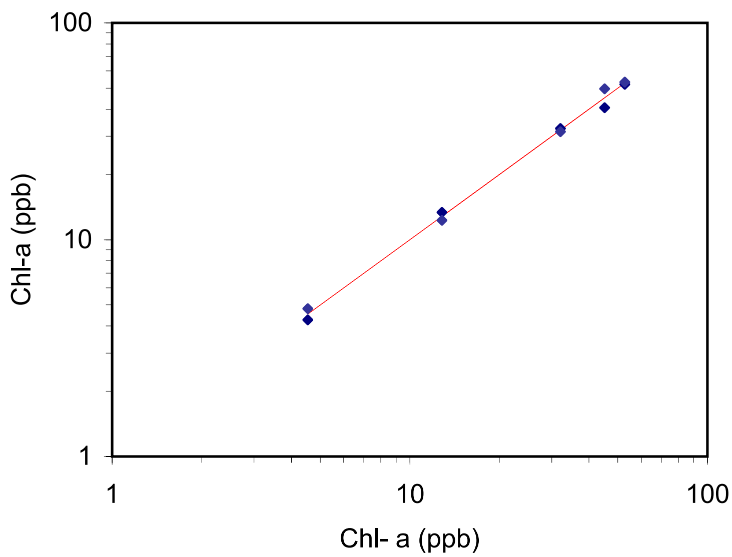
r^2 = squared correlation coef between duplicate measurements
Se = replicate sampling error (standard deviation of ln-transformed values) ~percent

Replicate Fecal Coliform & Chl-a Measurements



Replicate Standard Deviation = 46%

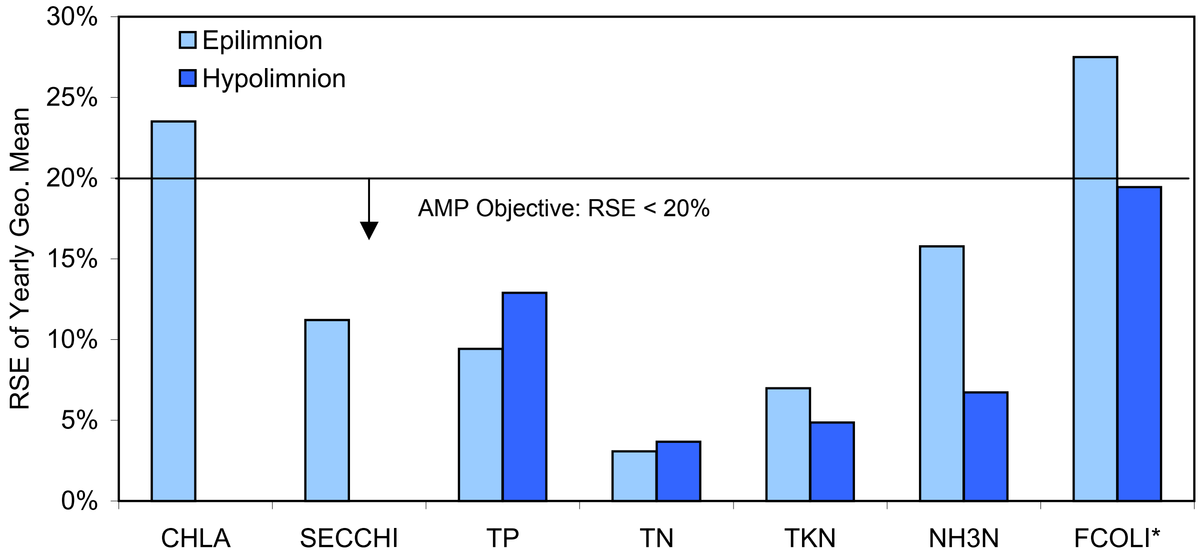
Percent of Variance in Yearly Geometric Mean = 13%

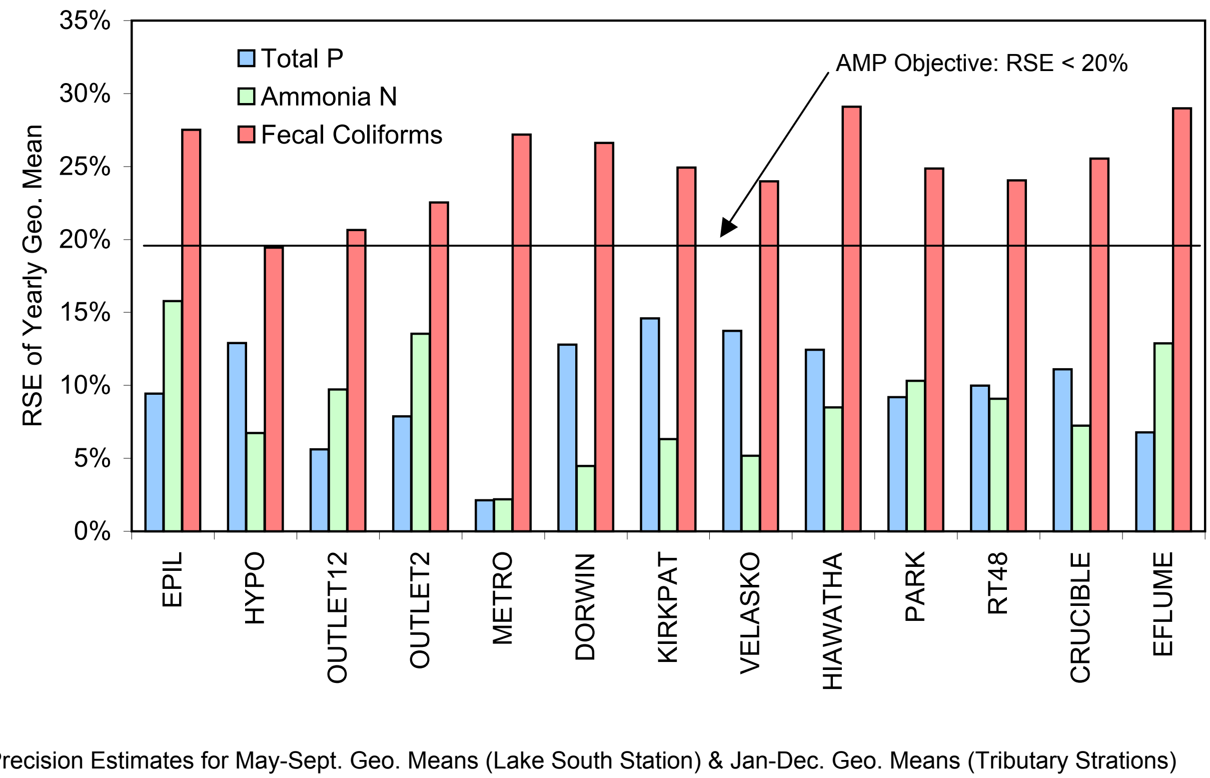


Replicate Standard Deviation = 13%

Percent of Variance in Yearly Geometric Mean = 1%

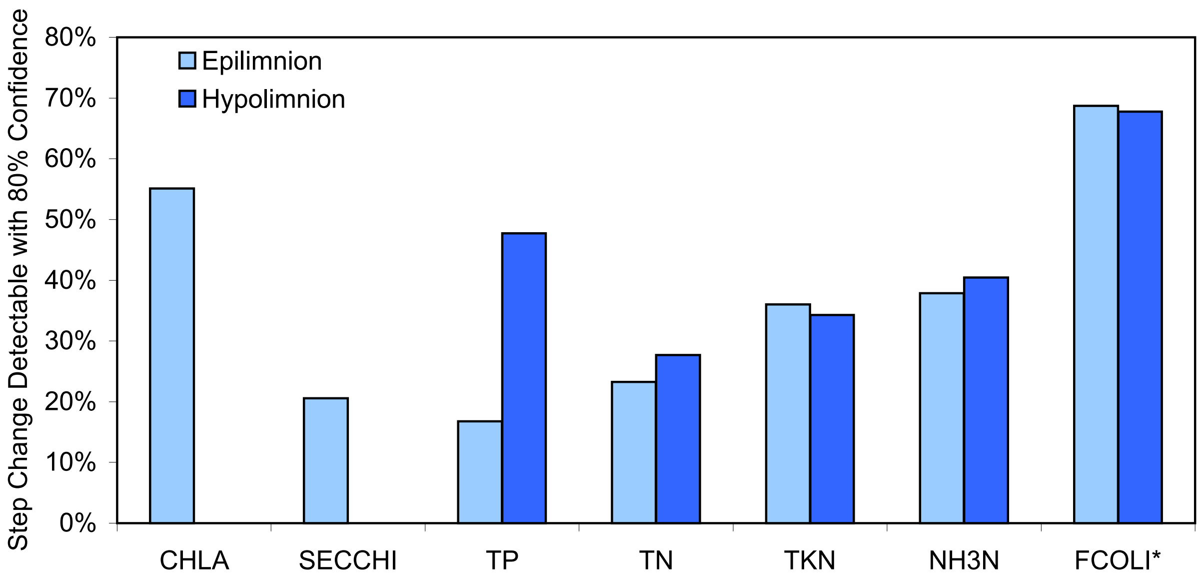
Precision Estimates for Lake & Tributary Stations

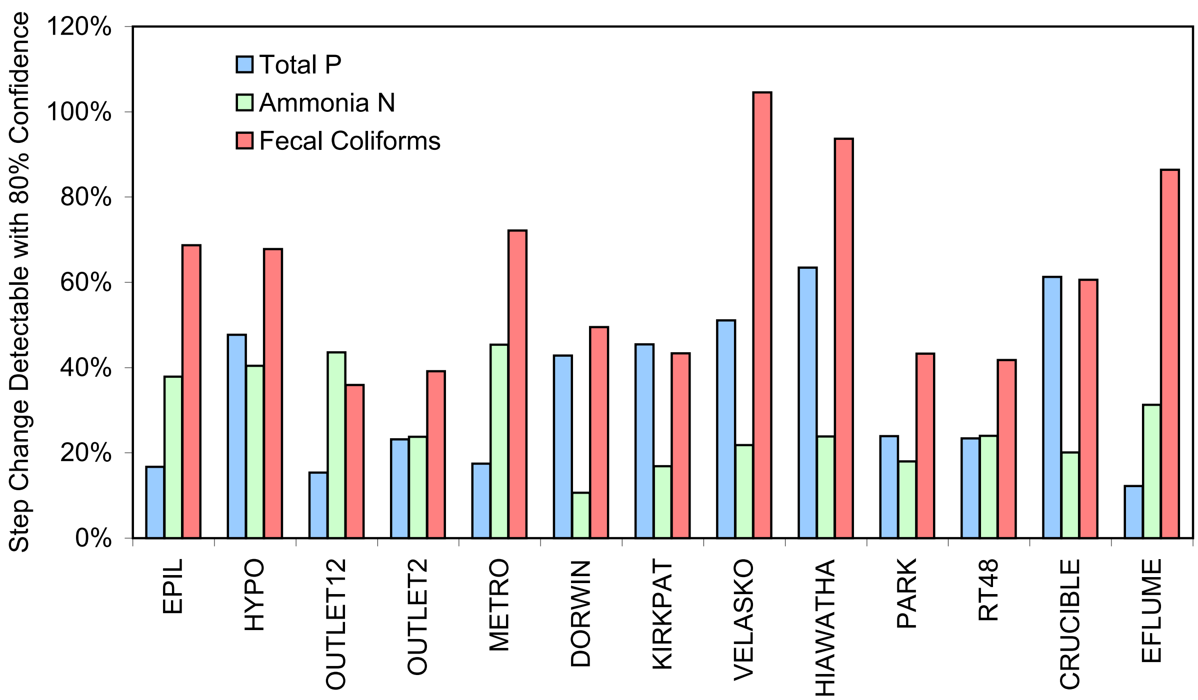




Precision Estimates for May-Sept. Geo. Means (Lake South Station) & Jan-Dec. Geo. Means (Tributary Strations)
RSE's for Total N & TKN lower than those shown above for TP, NH3N, & Fecal Coli

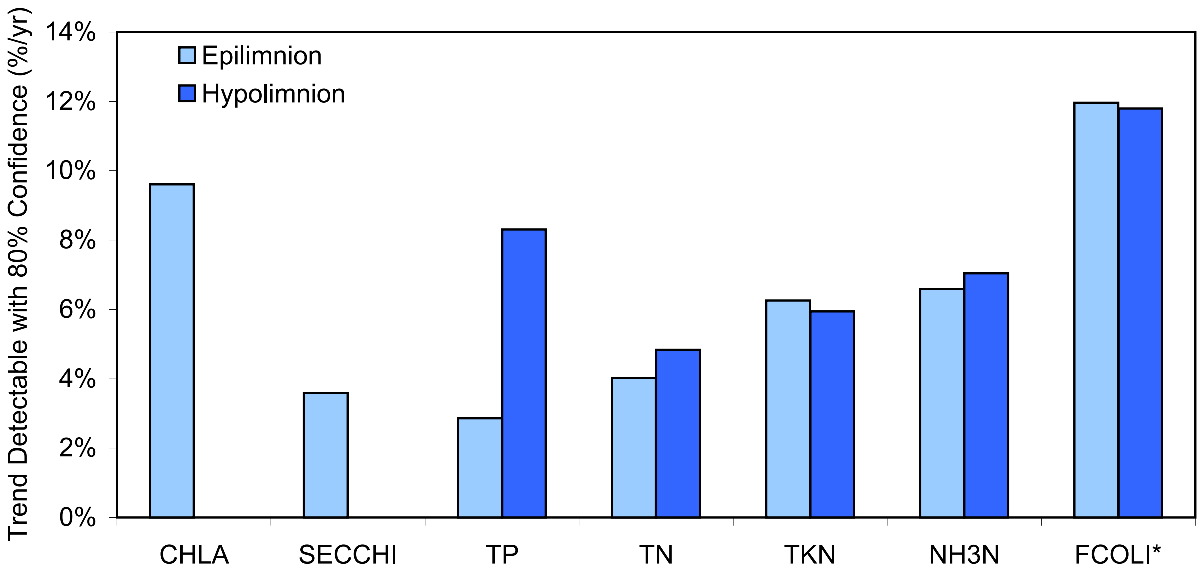
Power for Detecting Step Changes

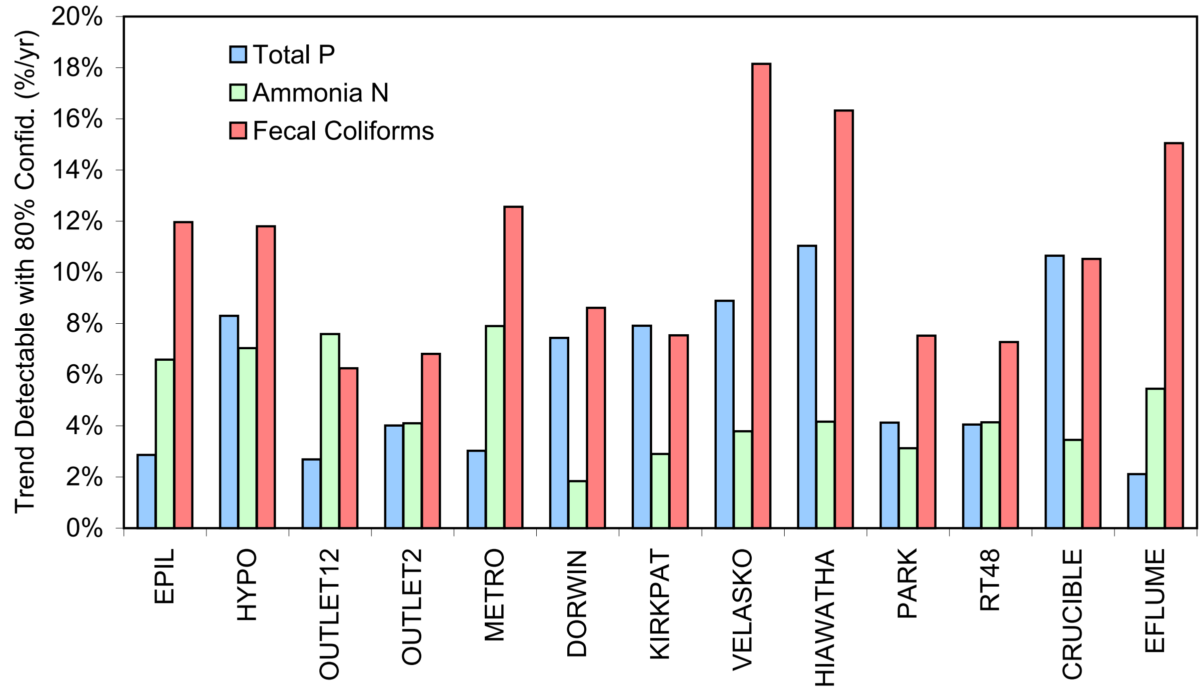




Power for Detecting Step Change Based upon 10 Years of Data (5 Before & 5 After Hypothetical Step Change)
Using t-test at 5%/10% Significance Level for 1-Tailed & 2-Tailed Hypotheses, Respectively

Power for Detecting Trends





Power for Detecting Linear Trend upon 10 Years of Data
Regression of Yearly Geometric Means at 5%/10% Significance Level for 1-Tailed & 2-Tailed Hypotheses, Respectively

Updated 1/2/2002

Onondaga Lake Mass Balance Analysis

W.Walker, for Onondaga County D&S, July 2000

Select Variable

ALK
BOD5
CA
CL
FCOLI
NA
NH3N
NO2N
NO3N
ORTHOP_F
TIC
TIP
TKN
TN
TOC
TP
TSS

Select Season

MaySept
Year
WaterYr

Select Lake Outlet

Outlet - 2ft
Outlet - 12 ft
Outlet - Avg
South Epil.

Select Model

Calib. Settling Rate
Calib Retention Coef.
Specified Settling Rate
Specified Retention Coef

Glossary

Select Graph

Inflow_Volumes
Inflow_Loads
Load_Variance
Load_Trends
Load_Source_Trends
Conc_Trends
FlowAdjConc_Trends
FlowAdjLoad_Trends
Load_InOut
Load_InOutRet
LoadOut_LoadIn
Conc_InOut
Conc_Outlets
ConcOut_ConcIn
Power_Stats
Non_Point
Pie_Flows
Pie2_Flows
Pie_Loads
Pie2_Loads
Pie_Variance
Model_Conc
Model_Load
Model_Param
Model_Diagnostics
Model_Epil

View Graph

Select Table

Sample_Counts
Detailed Mass-Balance
Trend_Summary
Trends_All
Trends_Flows
Trends_Loads
Trends_Concs
Trends_FlowAdjLoads
Trends_FlowAdjConcs
Trend_CrossTab_Loads
Trend_CrossTab_Concs
Load_Table
Model_Calcs
Model_CrossTab
Inputs_AUTOFLUX
Inputs_DrainageAreas
Inputs_Precip
Inputs_VariableIndex

View Table

Update CrossTabs

Select Term

Metro
Bypass
Allied
Crucible
Harbor/Hiawatha
Ley/Park
Ninemile/Rt48
Onond./Kirkpatrick
Harbor/Velasko
Onondaga/Dorwin
Total Gauged
NonPoint Gauged
Ungauged
Total NonPoint
Total Industrial
Total Municipal
Total External
Precip
Evap
Total Inflow
Total Outflow
Retention

View Table

Trend Plots

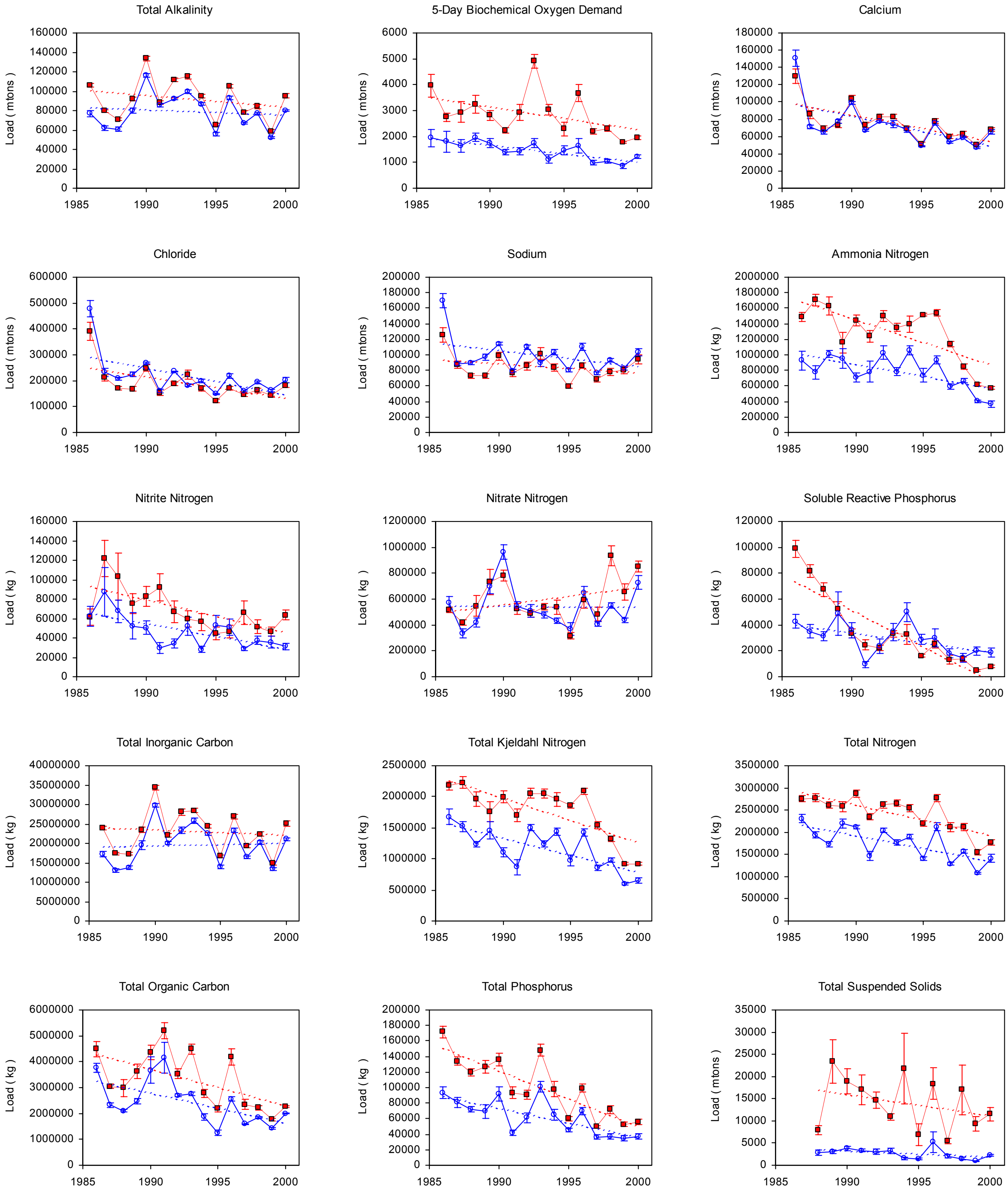
Enter Year Ranges (>= 1986)

Calibration	1996	to	2000
Total	1996	to	2000

OK

User Input Cells are Red   Hit Cntrl-m to Return to This Page   Version Date: 1/15/2002

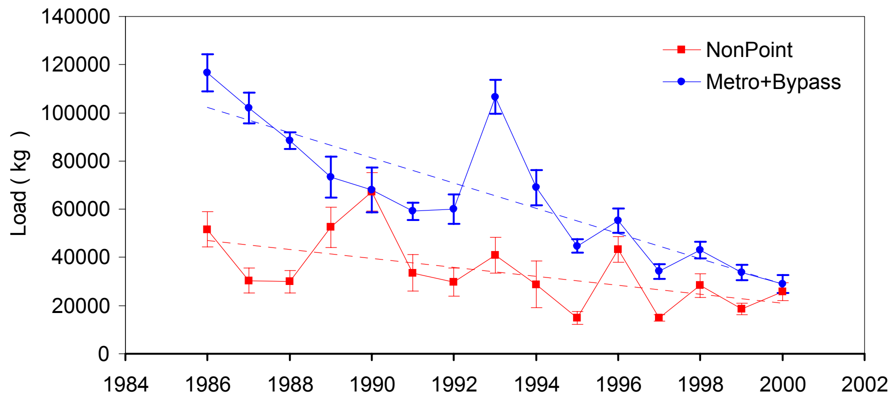
Long-Term Trends in Total Inflow & Outflow Loads

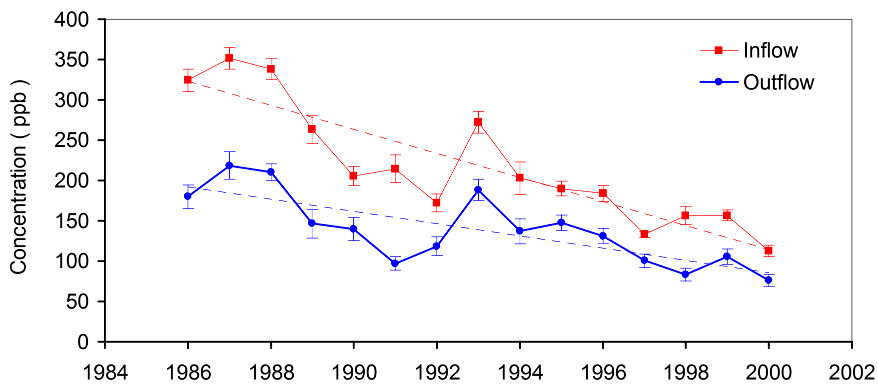


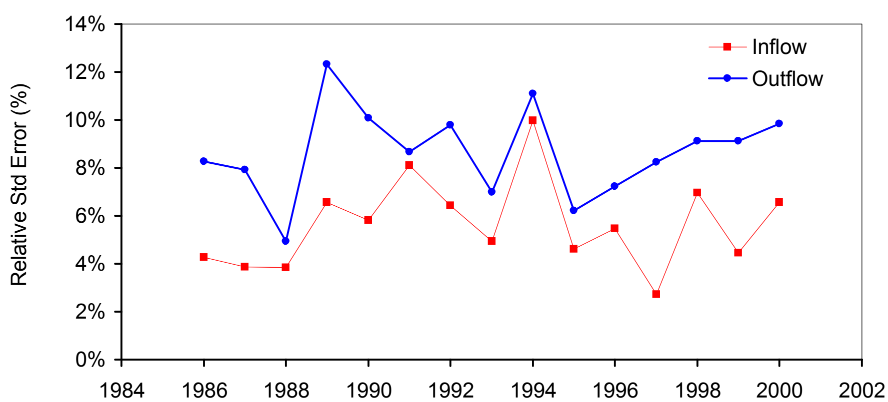
Squares = Inflow, Circles = Outflow Error Bars = +/- 1 Standard Error Dotted Lines = Linear Trends X-Axis = Calendar Year

Long-Term Trends in Lake Mass Balances

Variable: Total Phosphorus **Season: Year**







Error Bars Show Mean Estimate +/- 1 Standard Error
Dashed Lines Show Trend Estimated by Linear Regression

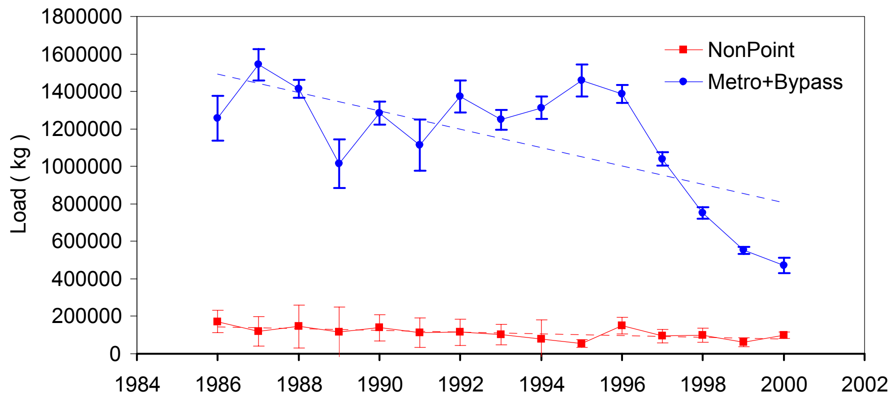
Pooled Estimates for 1996-2000:

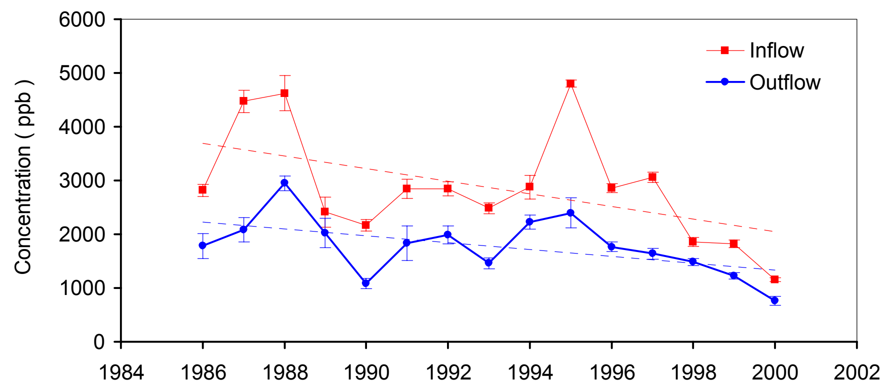
Mass-Balance Term	Metro	Nonpoint	Total In	Outflow
Relative Standard Error of Yearly Value*	2%	13%	5%	9%
Detrended Year-to-Year CV	14%	24%	15%	16%
Trend Detectable with 80% Conf. (%/yr)**	4%	7%	5%	5%
Change Detectable with 80% Confidence**	24%	41%	26%	28%

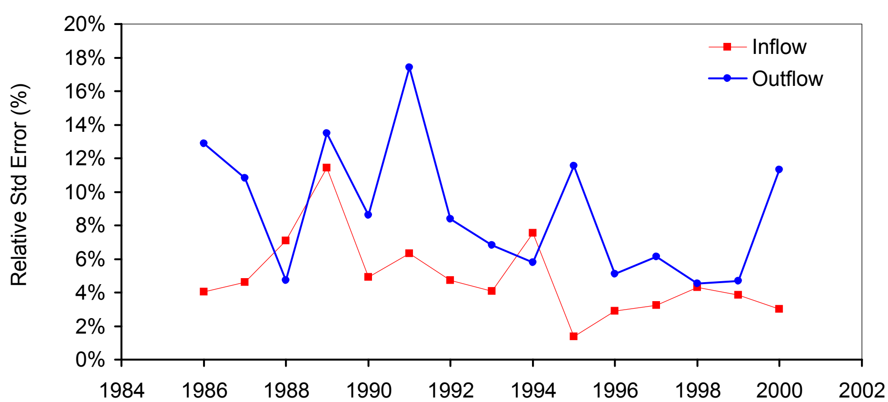
* AMP Precision Goal is RSE < 20%

** Power statistics evaluated for hypothetical trend tests with 10 years of data & 10% significance level (1-Tailed) or 5% significance level (2-Tailed)

Long-Term Trends in Lake Mass Balances
Variable: Ammonia Nitrogen **Season: Year**







Error Bars Show Mean Estimate +/- 1 Standard Error
Dashed Lines Show Trend Estimated by Linear Regression

Pooled Estimates for 1996-2000:

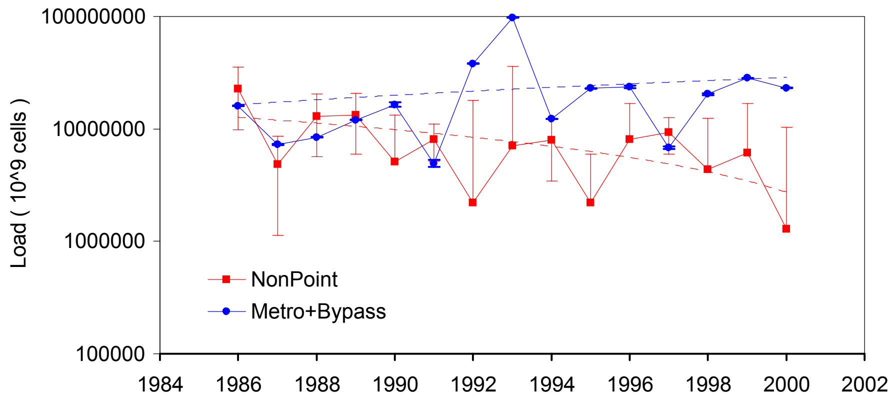
Mass-Balance Term	Metro	Nonpoint	Total In	Outflow
Relative Standard Error of Yearly Value*	3%	17%	3%	6%
Detrended Year-to-Year CV	10%	7%	16%	9%
Trend Detectable with 80% Conf. (%/yr)**	3%	2%	5%	3%
Change Detectable with 80% Confidence**	18%	12%	28%	16%

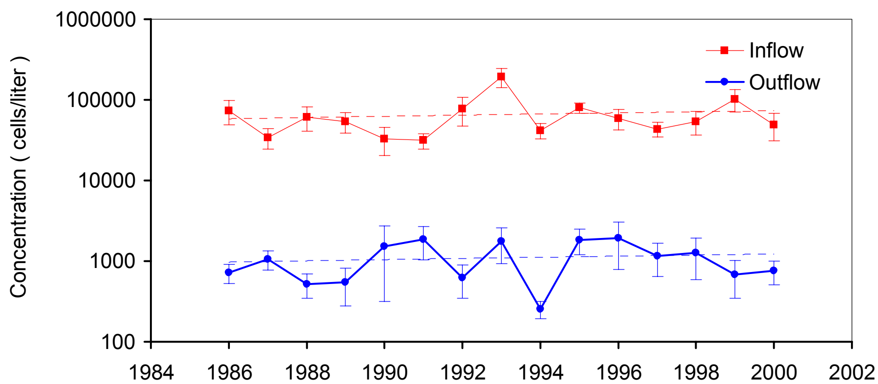
* AMP Precision Goal is RSE < 20%

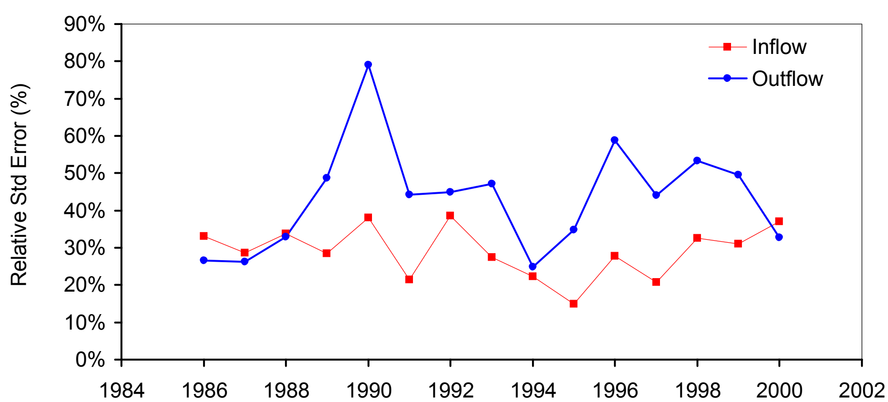
** Power statistics evaluated for hypothetical trend tests with 10 years of data & 10% significance level (1-Tailed) or 5% significance level (2-Tailed)

Long-Term Trends in Lake Mass Balances

Variable: Fecal Coliforms **Season: Year**







Error Bars Show Mean Estimate +/- 1 Standard Error
Dashed Lines Show Trend Estimated by Linear Regression

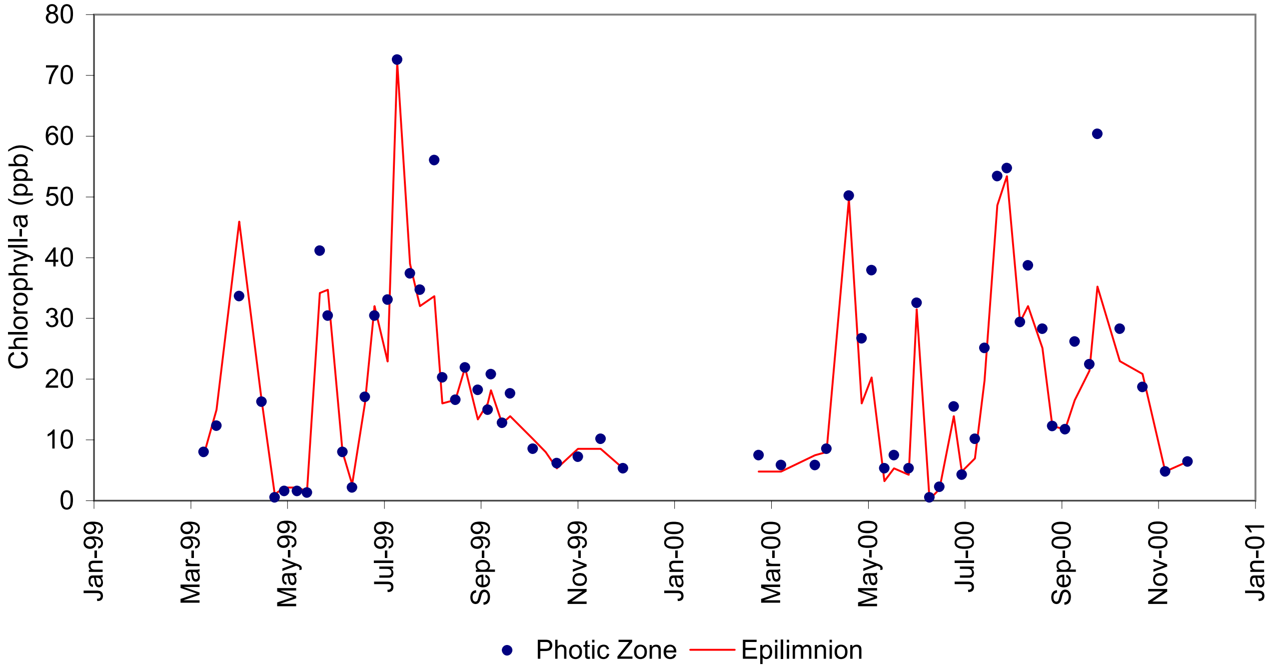
Pooled Estimates for 1996-2000:

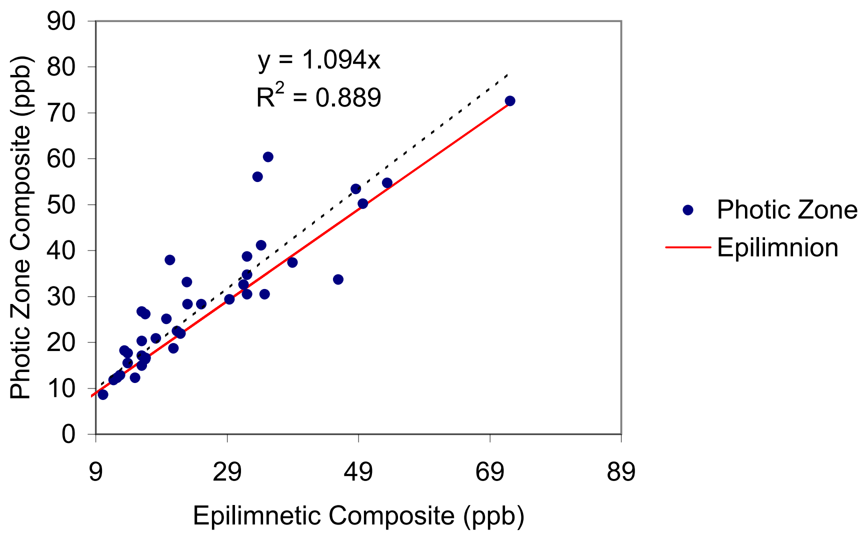
Mass-Balance Term	Metro	Nonpoint	Total In	Outflow
Relative Standard Error of Yearly Value*	39%	25%	30%	48%
Detrended Year-to-Year CV	43%	62%	42%	22%
Trend Detectable with 80% Conf. (%/yr)**	13%	19%	13%	7%
Change Detectable with 80% Confidence**	75%	107%	73%	38%

* AMP Precision Goal is RSE < 20%

** Power statistics evaluated for hypothetical trend tests with 10 years of data & 10% significance level (1-Tailed) or 5% significance level (2-Tailed)

Comparison of Epilimnetic & Photic-Zone Composite Chlorophyll-a Samples
Lake South Station, 1999-2000

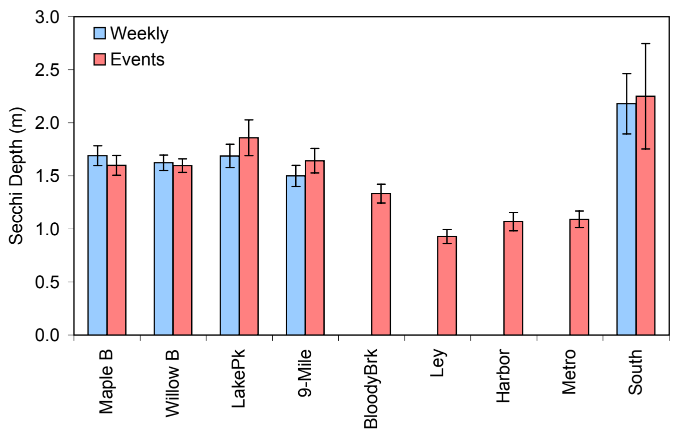


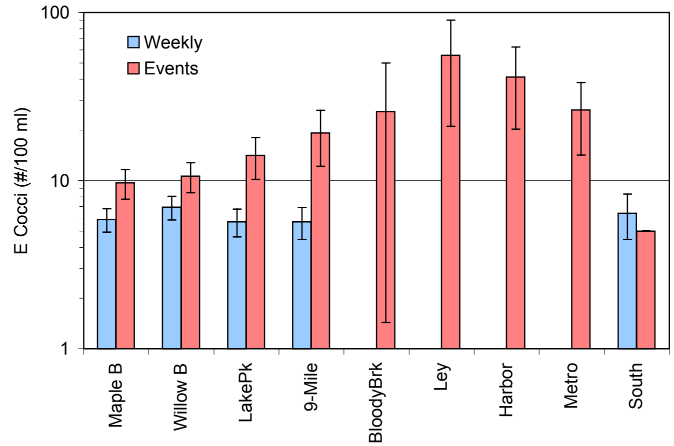


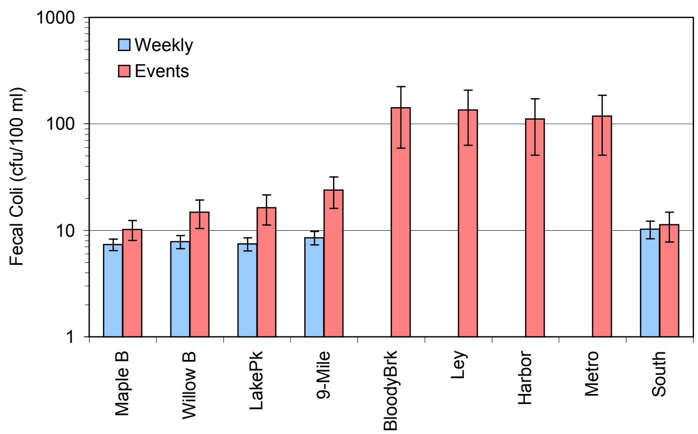
Paired t-Test Using Ln-Transformed Values:

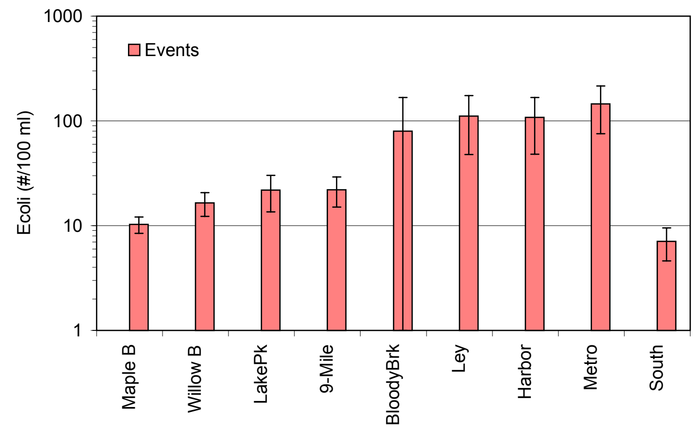
Mean Difference =	9.1 +/- 3.4%
t =	2.69
p =	0.009

Transparency & Bacteria Data from Nearshore Lake Stations, 1999-2000







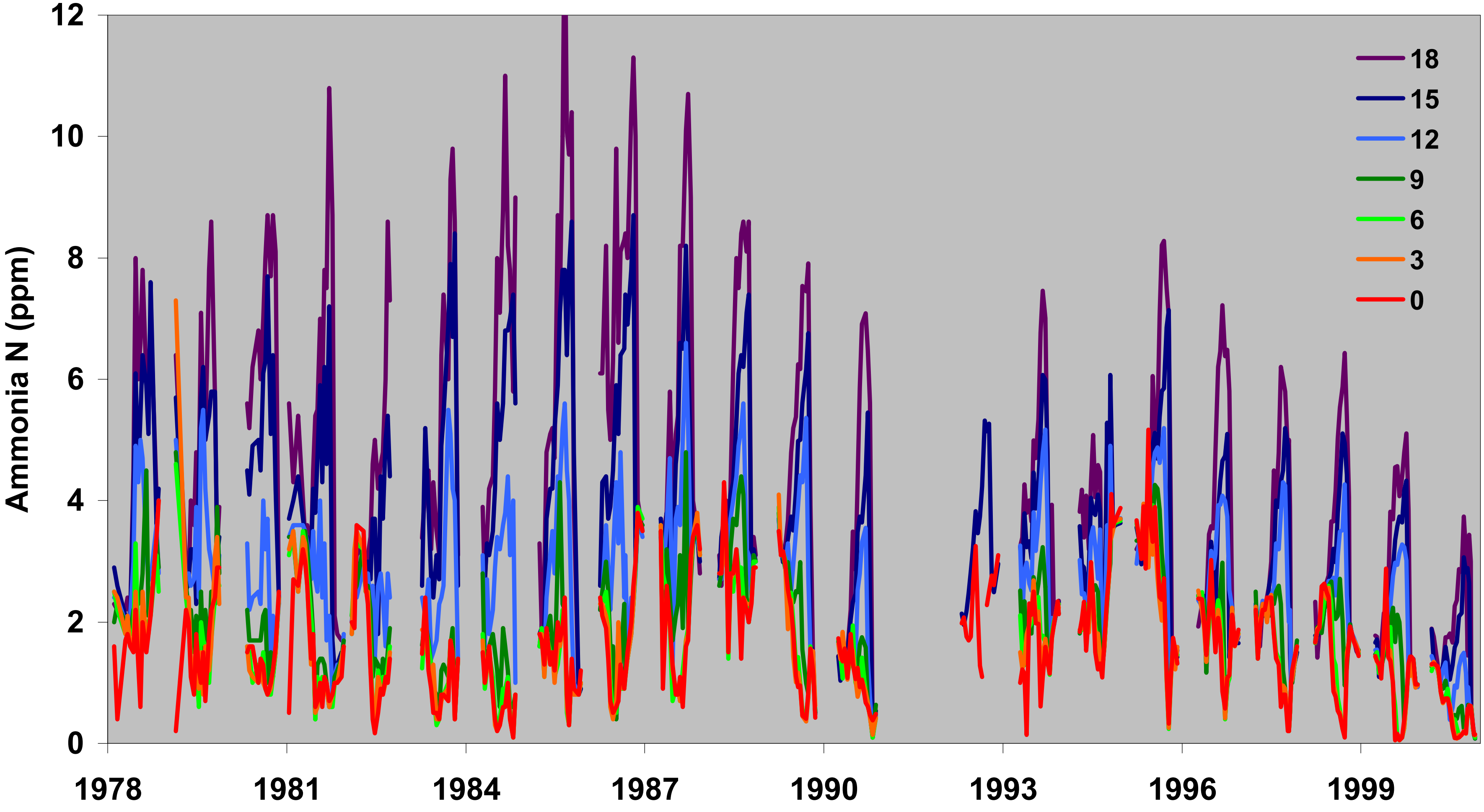


Lakeshore Sites Arranged in North --> South Direction
Secchi Depths: Arithmetic Means +/- 1 Std Error
Fecal Coliforms: Geometric Means +/- 1 Std Error
Values with >=3 Observations Plotted
Weekly = Periodic (Dry-Weather) Monitoring
Event = Storm Event (Wet-Weather) Monitoring
Lower Detection Limit for Bacteria Samples = 5 Organisms/100 ml

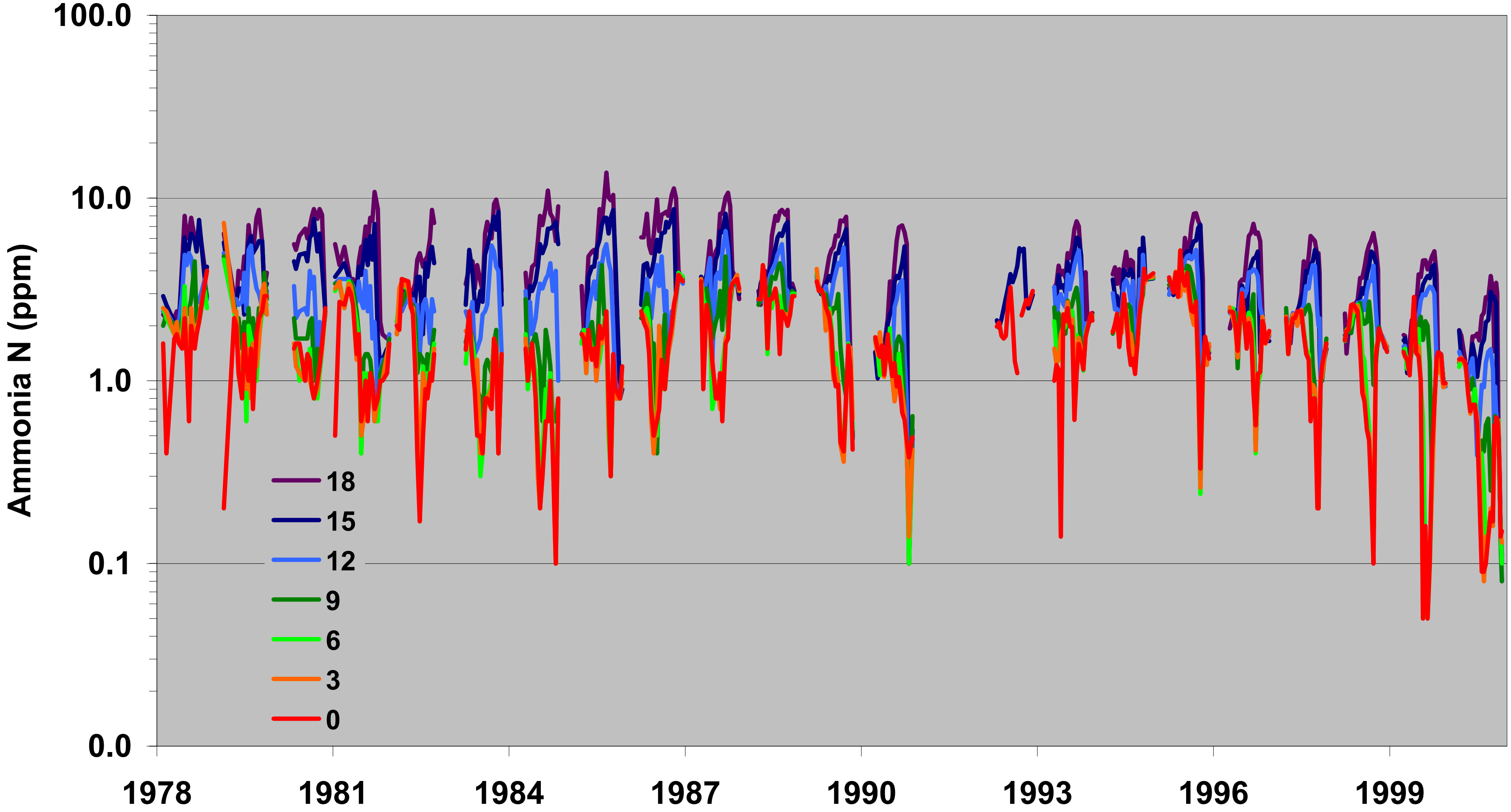
Sample Counts

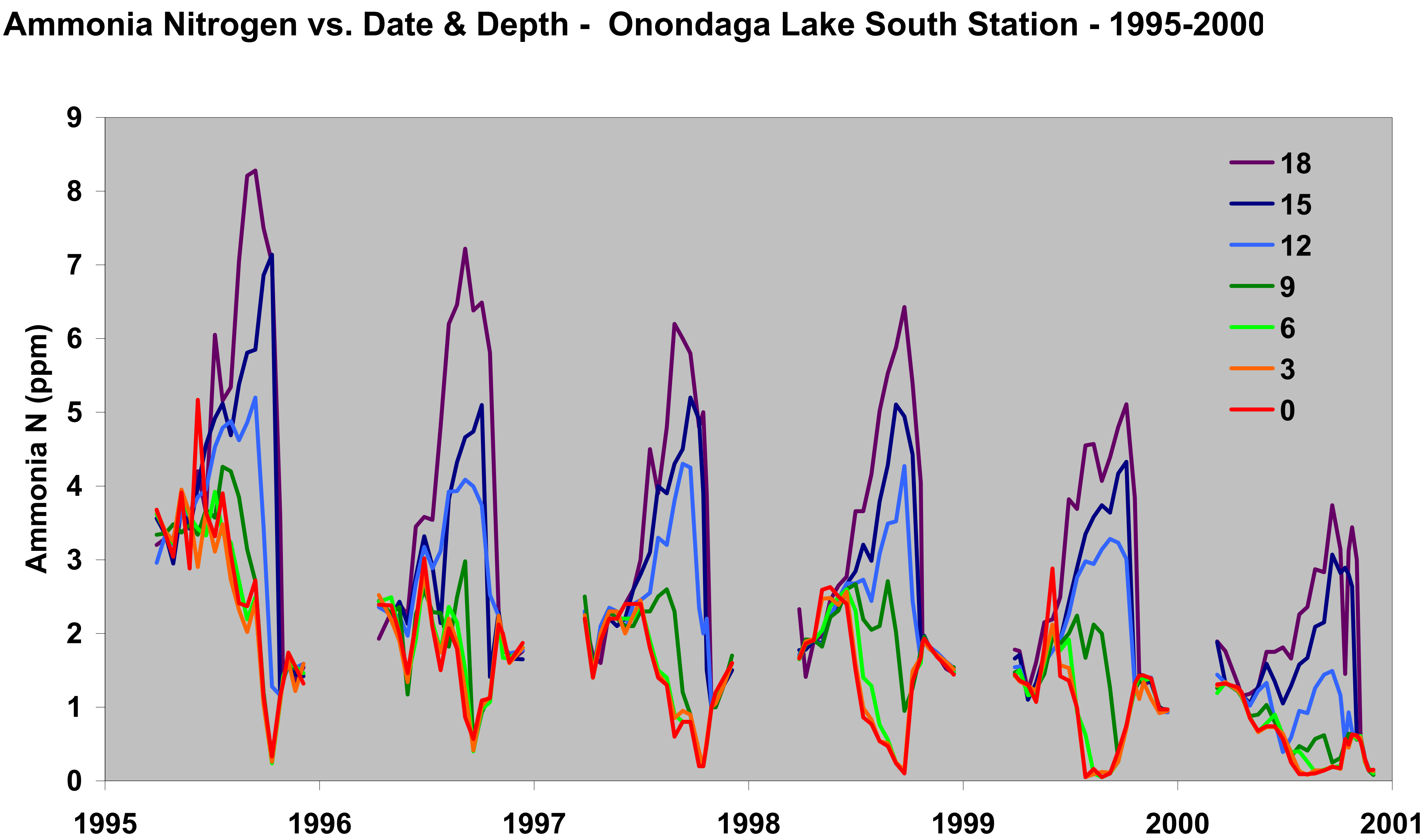
		Maple B	Willow B	LakePk	9-Mile	BloodyBrk	Ley	Harbor	Metro	South
Secchi	Weekly	34	34	32	32	0	0	2	0	34
	Event	22	22	22	21	3	22	22	22	10
Fcoli	Weekly	34	34	32	32	0	0	2	0	36
	Event	22	22	22	21	3	20	19	20	10

Ammonia Nitrogen vs. Date & Depth - Onondaga Lake South Station - 1978-2000



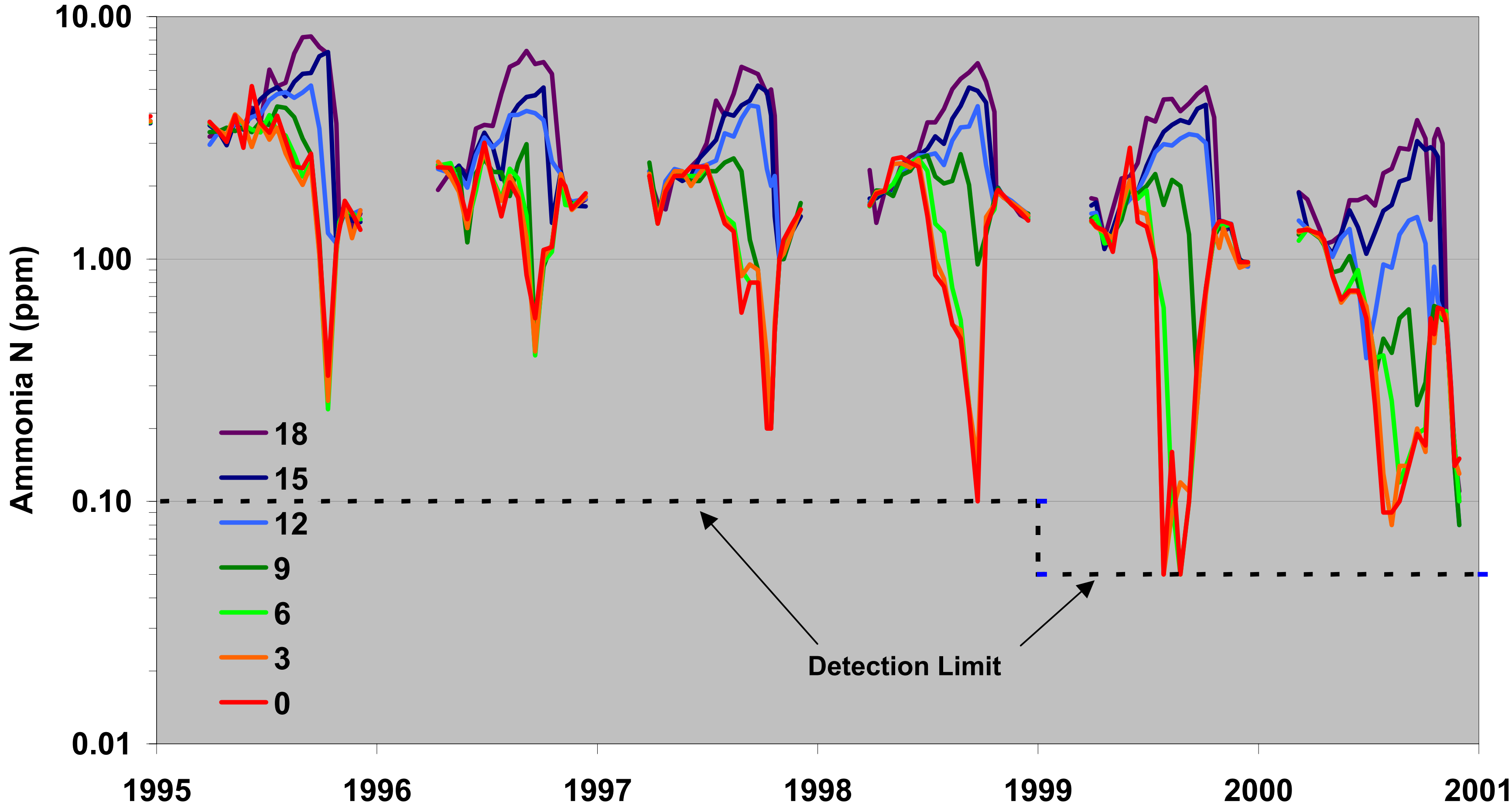
Ammonia Nitrogen vs. Date & Depth - Onondaga Lake South Station - 1978-2000



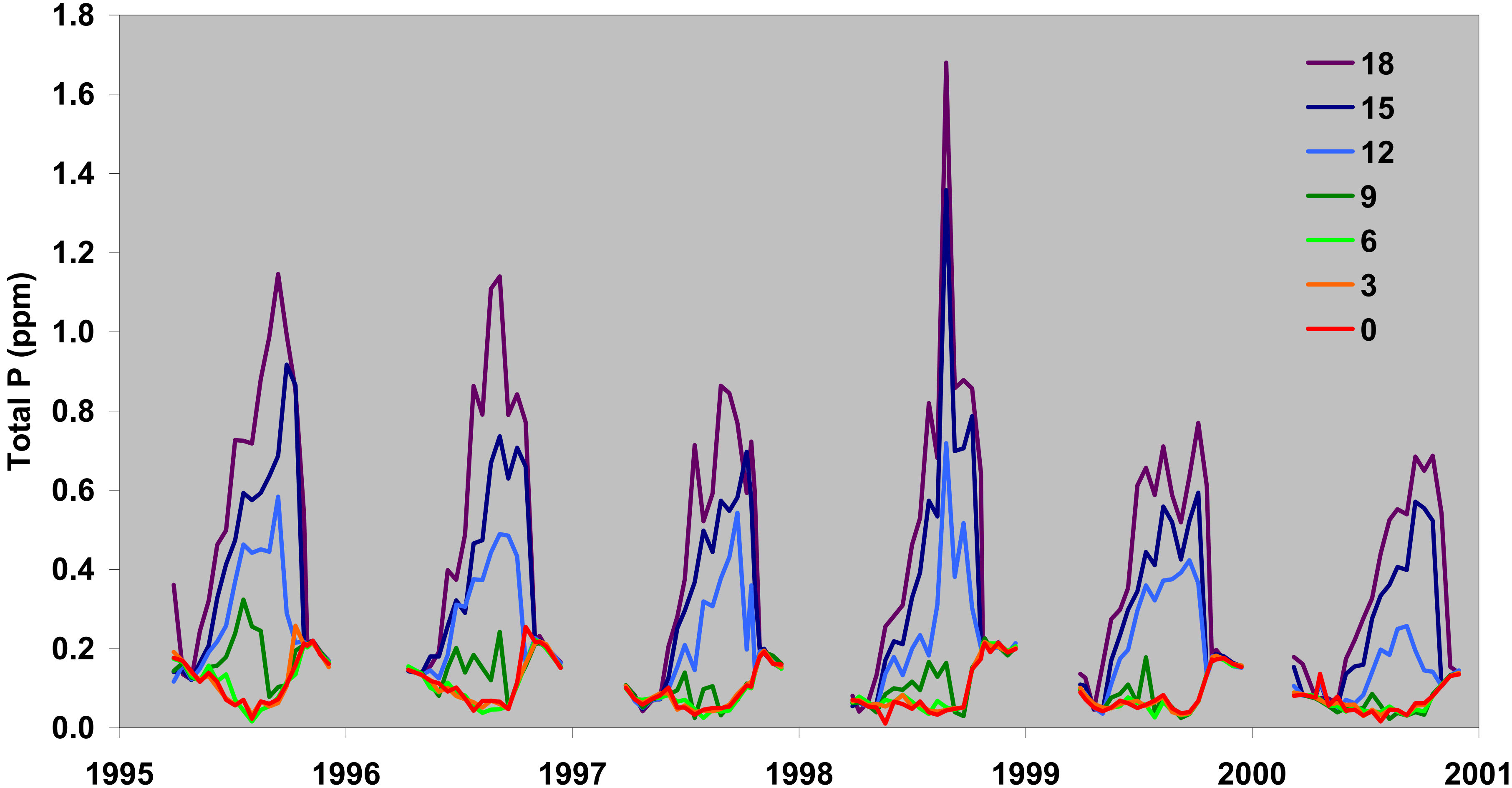


Ammonia Nitrogen vs. Date & Depth - Onondaga Lake South Station - 1995-2000
Ammonia N (ppm)
0
1
2
3
4
5
6
7
8
9
1995
1996
1997
1998
1999
2000
2001
18
15
12
9
6
3
0

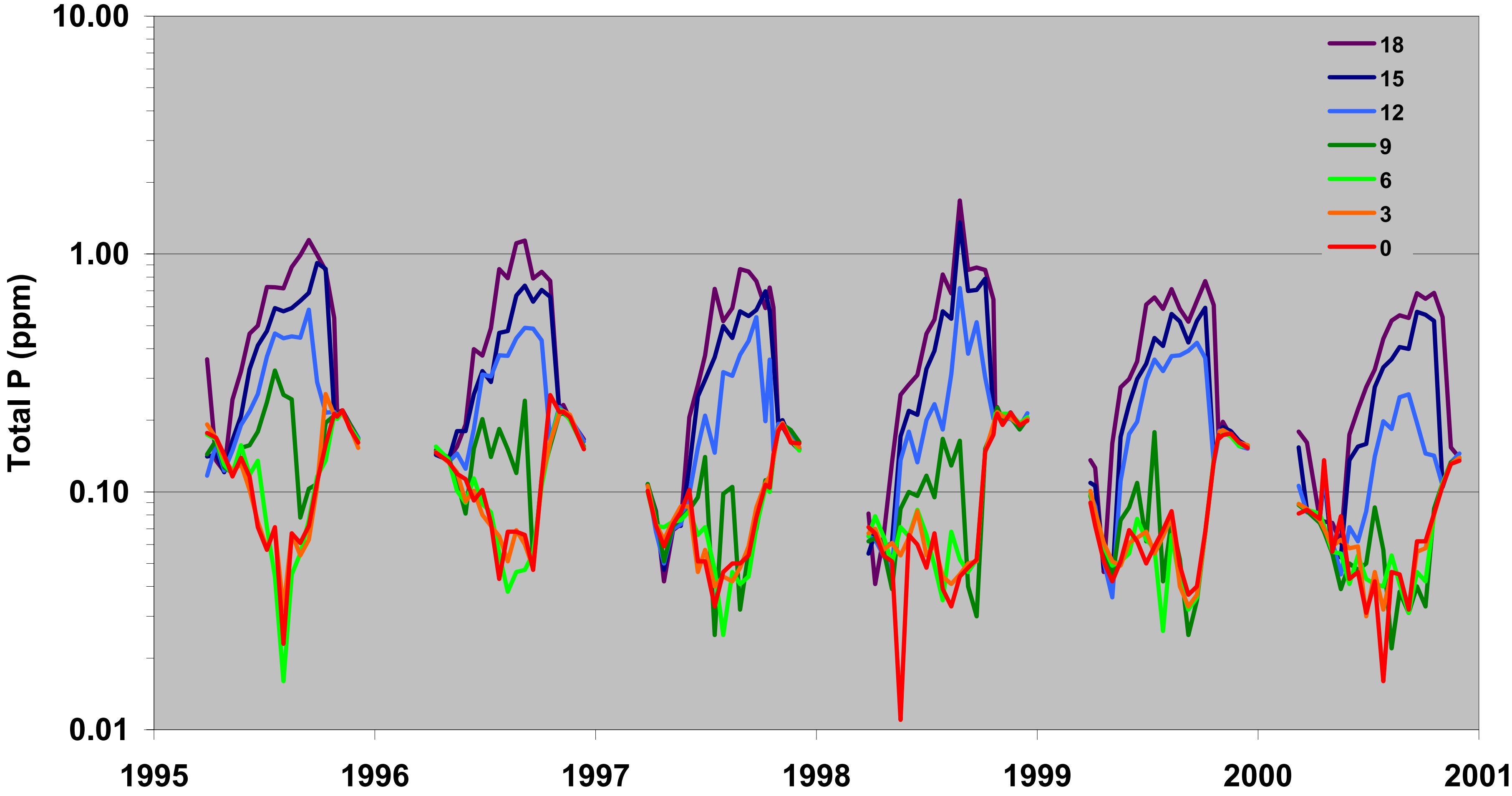
Ammonia Nitrogen vs. Date & Depth - Onondaga Lake South Station - 1995-2000

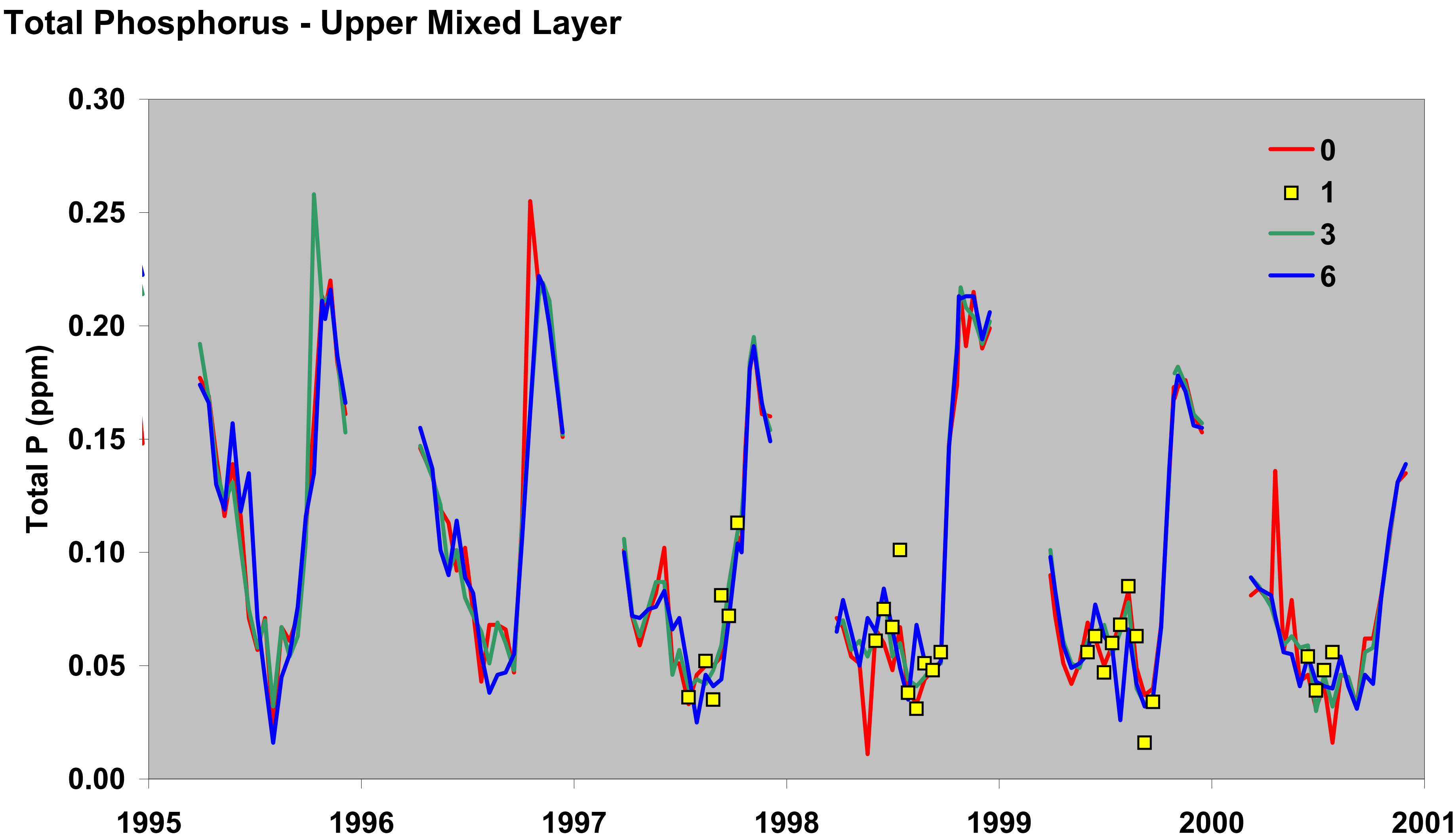


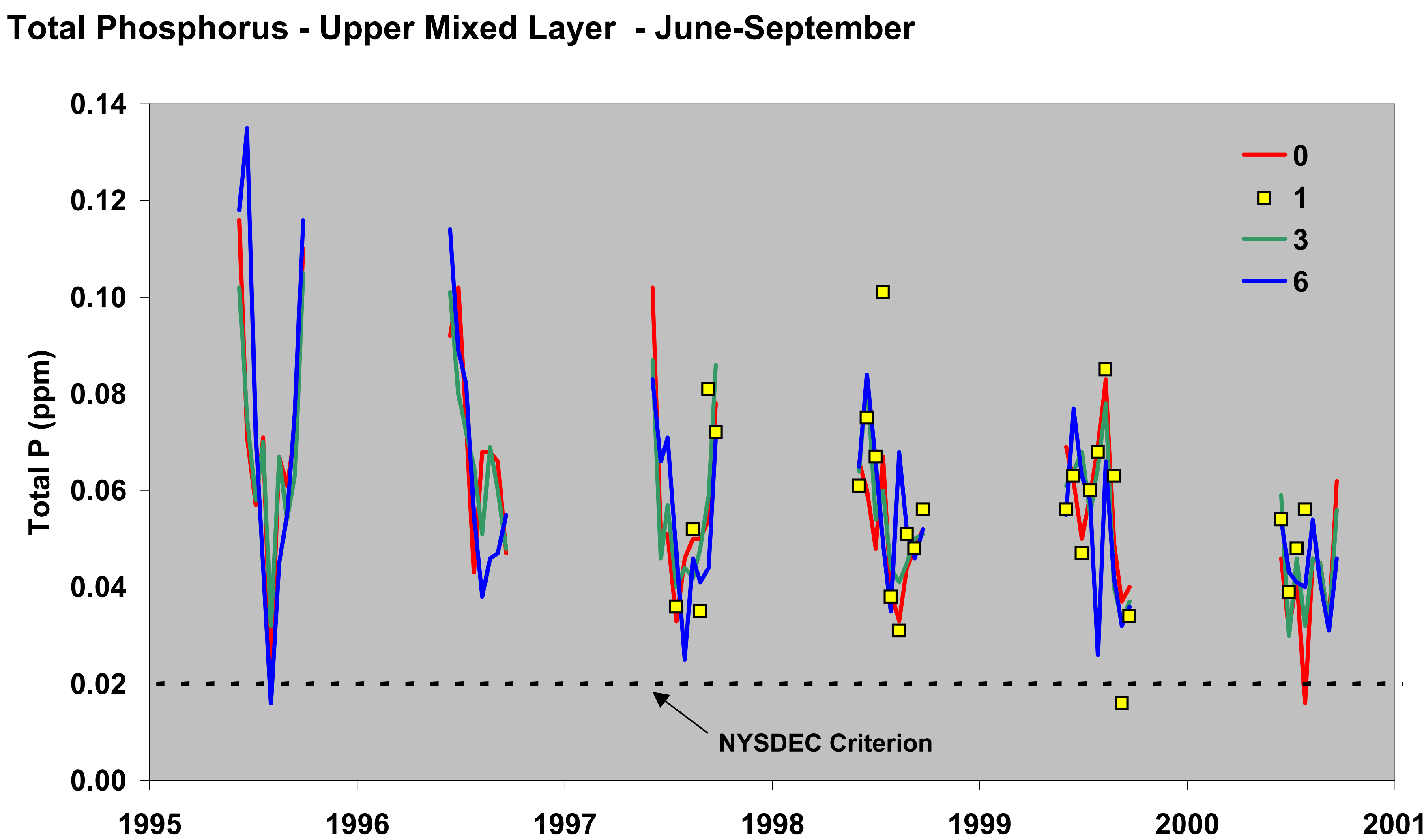
Total Phosphorus vs. Date & Depth - Onondaga Lake South Station



Total Phosphorus vs. Date & Depth - Onondaga Lake South Station




Total Phosphorus - Upper Mixed Layer
Total P (ppm)
0.30
0.25
0.20
0.15
0.10
0.05
0.00
1995
1996
1997
1998
1999
2000
2001
0
1
3
6



Total Phosphorus - Upper Mixed Layer - June-September
Total P (ppm)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
0.00
1995
1996
1997
1998
1999
2000
2001
0
1
3
6
NYSDEC Criterion