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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Introduction

One of the primary purposes of the Onondaga Lake Ambient Monitoring Program (AMP, Onondaga County, 1998b) is to provide information supporting future decisions on wastewater and watershed management. These decisions may be based in part upon changes detected in Onondaga Lake, its tributaries, and the 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 depend 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.

A previous report (Walker, 1998) describes and demonstrates a statistical framework with the following functions under the AMP:

- 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;

Initial implementation of the framework will occur in two phases. Phase I, focusing on key water-quality measurements, is described in this report. Phase II, focusing on biological measurements, will be described in a subsequent report. Subsequent updates and refinements over the course of the AMP will help to ensure that data-collection efforts are cost-effective and that the resulting database is adequate to support future management decisions.

Phase I is specifically concerned with the following water-quality components that are important from a management perspective:

- Total Phosphorus
- Total Nitrogen
- Total Kjeldahl Nitrogen
- Ammonia Nitrogen
- Chlorophyll-a
- Transparency
- Fecal Coliform Bacteria

Although the Phase I scope does not specifically include bacteria measurements, it requires review of sampling strategies to provide data for statistical evaluation of biological measurements in Phase II. Fecal coliforms have been added in partial fulfillment of this requirement. It is also efficient to consider fecal coliforms here because the scope and structure of historical bacteria data sets are similar to those of the other listed water quality components.

Variance components estimated from recent lake and tributary monitoring data are used to evaluate AMP designs based upon the following criteria:

- Precision of Yearly Geometric Means
- Precision of Long-term Geometric Means
- Power for Detecting Linear Trends
- Power for Detecting Step Changes

AMP designs are evaluated based upon the magnitudes of the above criteria and their sensitivities to monitoring frequency. The lake and tributary monitoring programs are further evaluated as bases for estimating loadings and formulating lake mass balances for nutrients and bacteria. Strategies and requirements for statistical evaluation of biological measurements under Phase II are discussed. Conclusions and suggested refinements to the AMP design are presented in a final section.

Data Compilation

The analysis is based primarily on data collected under Onondaga County's monitoring program between 1993 and 1997 (Appendix A). Although the entire database extends back to 1968, data from this 5-year period most closely reflects the overall AMP design, sampling procedures, and analytical methods. Supplementary analyses of lake data from 1988 to 1997 are conducted (Appendix B). Limited analyses of chlorophyll-a and fecal coliform measurements retrieved from the historical database (Walker, 1991) are also conducted. Table 1 summarizes recent and future (AMP) monitoring program designs for relevant water quality measurements.

Onondaga County has supplied cumulative lake and tributary data files previously used to support analyses described in the 1996 lake monitoring report (Stearns & Wheler, et al., 1997). These have been merged with 1997 files provided by the County and translated into file formats conducive to statistical analysis. Sample total nitrogen concentrations have been computed from TKN, nitrate, and nitrite concentrations. In computing lake mass balances, biweekly data have been supplemented with daily NPDES permit monitoring data for the Metro discharge between 1995 and 1997.

Concentration time series for each station and water quality variable derived from the County's biweekly monitoring program are plotted in Appendix A. Graphical and statistical methods have been used to identify potential outliers. These have been subsequently checked against lab records to eliminate data-entry or transcription errors. This screening process is currently incomplete. Remaining apparent outliers have been left in the database. Their impacts on statistical analyses have been minimized by using large sample counts and/or robust statistical methods. Since outliers would generally inflate variance, leaving outliers in the calibration data set generates conservative estimates of precision and power for trend detection. That is, when robust statistical methods are used for detecting changes or trends, the actual power may be higher than that estimated below, to the extent that calibrated variance components are influenced by outliers.

Given the apparent skewness in the distributions of these measurements, statistical analyses have been conducted on logarithmic scales. For purposes of display and computation of variance components, values below the detection limit have been set equal to detection limit. When a high percentage of observations are below detection, this procedure may cause under-estimation of variance and over-estimation of means.

Based upon review of time series plots in Appendix A, detection limit values are likely to influence statistical analyses of fecal coliform counts (detection limit = 2-5 cells/100 ml) and ammonia nitrogen concentrations in some tributaries (detection limit = 0.1 ppm). Since the fecal coliform detection limit is well below the lake standard (200 cells /100 ml as a monthly geometric mean), it appears to be adequate for the AMP. The historical ammonia detection limit, however, is clearly inadequate for tracking variations in Onondaga Creek, Harbor Brook, and the Crucible discharge. Resolution of ammonia levels was particularly low in 1997, when values were frequently rounded off the nearest 0.1 ppm at the above tributary stations. Mass-balance calculations (Appendix C-8) indicate that these sources account for a small percentage of the total ammonia load to the Lake (~1%). Therefore, the current detection limit is adequate for developing mass balances under current conditions. A lower detection limit (<= 0.05 ppm) is recommended to support future mass-balance calculations and trend analyses.

Appendix B contains time series plots of average concentrations in the epilimnion at the Lake South station between May and September, 1988-1997. Concentrations measured at depths between 0 and 6 meters have been averaged by day before plotting. Corresponding yearly summary statistics (arithmetic mean, geometric mean, coefficient of variation, relative standard error) are also listed.

Variance Components

Variance component models (Snedecor & Cochran, 1989) explicitly represent the sources and magnitudes of variability in monitoring data. They provide a basis for estimating the uncertainty associated with yearly and long-term summary statistics and for estimating the power of trend tests or other hypothesis tests (Walker, 1998). Given data collected at a given location in a well-mixed depth interval over a number of years, total measurement variance can be partitioned into the following components:

- **Year** (attributed to variations in climate, hydrology or other factors operating at a yearly time step)
- **Date** (variations within a given year attributed to season, weather, etc.)
- **Random** (variations on a given date within the sampled layer)

Calibration of the model involves application of a nested analysis of variance (Snedecor & Cochran, 1989) to data from several years of monitoring.

The model describes variations at a given location. It does not include a spatial component because the objective of the monitoring program is not to characterize spatially-averaged conditions in the lake or in a tributary. Historical sampling strategies primarily utilize data from the Lake South station to track long-term trends. Although sampled less frequently, data from the Lake North station can also be used for this purpose. This strategy will continue under the AMP. Spatial variations in near-shore areas following storm events will also be evaluated under the AMP.

The feasibility of resolving each variance component depends upon the design of the historical monitoring program used for calibration. If the data set does not include multiple samples on each date (e.g., most tributary data), it is not possible to calculate the random variance component. In such cases, the estimated date variance component reflects the combined effects of daily and random variations. This does not significantly influence computation of the performance measures described below. The random term can be estimated separately if the design includes replicate samples (e.g., lake outlet samples in 1997) and/or sampling at multiple depths (e.g., lake epilimnion). Further partitioning of the random term into vertical and replicate components is possible using data from the lake epilimnion in 1997 (single samples at 0 and 3 meters, duplicate samples at 6 meters for TKN, NH3-N, and TP, Table 1).

In using variance components to estimate the precision of yearly or long-term summary statistics or to estimate power for trend detection (Walker, 1998), variations at each level are assumed to be random. It is necessary to remove non-random (deterministic) variations from the historical data prior to estimating variance components. Fixed seasonal effects (i.e. seasonal patterns consistent from year to year) have been removed by subtracting monthly medians (computed from all years) from each sample. Long-term trends have been removed by regressing yearly medians against year. Without these adjustment procedures, it is likely that precision and power for trend detection would be under-estimated for some stations and variables.

Vertical gradients within the sampled layer represent another type of non-random variation. To partially control for this, the analysis is conducted separately for the epilimnion (0-6 meters) and hypolimnion (10-18 meters). The 9-meter sampled depth is not included because it is sometimes located within or below the thermocline. It is possible that vertical gradients are present on some sampling dates within each of these depth intervals (particularly, in the hypolimnion). Ignoring these gradients causes over-estimation of the random variance component and generates conservative estimates of precision (i.e., over-estimates relative standard errors). Because the performance measures discussed below are controlled primarily by the year and date variance components, assumptions regarding vertical structure have a relatively small impact on the results. Potential future refinements could involve computation of variance components for lake volume-weighted mean concentrations.

Further adjustments can be made to account for the effects of temporal serial correlation (Walker, 1998; Loftis et al., 1991; Muskens & Kateman, 1978). Such adjustments require additional assumptions regarding auto-correlation structure. They also rely upon estimation of a daily auto-correlation coefficient using historical data collected at a biweekly frequency. Results discussed below employ a conservative assumption that effects of serial correlation on the precision of yearly geometric means can be ignored. To the extent that positive serial correlation is present, these results may under-estimate precision (over-estimate relative standard errors). For sensitivity analysis purposes, results considering serial correlation are also presented. Serial correlation coefficients are computed from the time series of daily median values with fixed seasonal and yearly effects removed.

Variance component analyses have been performed for two depth intervals in the lake (Epilimnion = 0, 3, & 6 meter samples, Hypolimnion = 12, 15, 18 meter samples) and for each of the primary tributary monitoring stations (Table 1) using data from 1993-1997. Lake data have been restricted to May through September (growing season). This restriction is justified based upon incomplete sampling during other months and upon the assumption that conditions during this season are most likely to drive future management decisions with respect to nutrients and trophic state. Time series plots in Appendix A show lake measurements in both January-December and May-September periods. Variance components for each station and variable are listed in Table 2.

Performance Measures

Calibrated variance components are used to evaluate the following indicators of precision and power that can be viewed as performance measures (PM's) for the monitoring program (Walker, 1998):

1. Relative Standard Error (RSE) of Yearly Geometric Mean
2. RSE of Long-Term Geometric Mean Computed from 5 Years of Data
3. Probability of Detecting a 25% Step Change over a 10 Year Period
4. Probability of Detecting a 5%/Year Linear Trend Over a 10-year Period

In PM's 3 and 4, "detecting" means rejecting the null hypothesis in one-tailed t-test or regression slope test at a significance level of 0.05. PM 1 depends upon the date and random variance components and can be controlled by modifying the following sampling frequencies:

- Temporal (number of sampling dates per year or interval between dates)
- Replication (number of samples per date/depth interval).

The remaining PM's depend upon PM 1 and upon year-to-year variance components. The latter are inherent characteristics of the lake/watershed and are independent of the monitoring program design. For this reason, results for PM 1 are emphasized.

The AMP (Onondaga County, 1998b, p. 39) discusses a target value of 20% for the relative error of population means measured under the AMP. It also indicates that it may not be feasible to attain this goal for each parameter monitored, depending upon inherent variability. A 20% RSE for the yearly geometric mean is used below as an approximate criterion for evaluating the adequacy of the AMP design.

Each performance measure is evaluated for the following alternative sampling designs:

A. Current AMP Design (Biweekly Sampling)
B. Half Temporal Frequency (From Biweekly to Monthly Collection Intervals)
C. Double Temporal Frequency (From Biweekly to Weekly Collection Intervals)

D. Double Replication Frequency (From 1 to 2 Samples per Date and Depth Interval)
E. Current AMP Design (Biweekly Sampling, Considering Serial Correlation)

Designs A-D demonstrate potential sensitivity of each PM to hypothetical changes in program design. Designs A-D invoke the conservative assumption that serial correlation can be ignored in computing the performance measures. Designs A and E demonstrate sensitivity to this assumption.

Results

Table 2 lists variance components and performance measures for each design, variable, and station. Results for the AMP design are summarized in Table 3 (ignoring serial correlation) and Table 4 (considering serial correlation). Results for the AMP design and sensitivities to temporal sampling frequency are shown in the following figures:

1	Lake Epilimnion, All Variables
2	Lake Hypolimnion, All Variables
3	Total Phosphorus, All Stations
4	Total Nitrogen, All Stations
5	Total Kjeldahl Nitrogen, All Stations
6	Ammonia Nitrogen, All Stations
7	Fecal Coliforms, All Stations

Each figure shows PM's 1-3 for sampling designs A-C. Results for PM 4 (not shown in these figures but listed in Tables 2-4) are similar to those for PM 3.

Results generally indicate that the expected RSE of the yearly geometric means under the AMP design are well below the 20% criterion for transparency and nutrient concentrations (total phosphorus, total nitrogen, total kjeldahl nitrogen, ammonia nitrogen) and above the 20% criterion for biological measurements (chlorophyll-a and fecal coliforms). Measured in terms of increased power for trend or step change detection, there would be relatively little benefit to increasing the transparency or nutrient measurement frequency from biweekly to weekly (Design A vs. C). Power sensitivity to measurement frequency is greater, however, for the biological measurements.

PM values are insensitive to increased replication (Design A vs. D) at those stations for which random variance components could be estimated (Lake Outlet 2, Lake Epilimnion, Lake Hypolimnion). For the same total number of samples, doubling the sampling frequency (Design C) would provide greater benefit than doubling the number of samples per date (Design D).

Table 5 compares lake epilimnion PM 1 values derived from 1993-1997 variance components with values derived the 1988-1997 time series plotted in Appendix B. The latter estimates are computed directly from the time series of average epilimnetic concentrations on each date without adjustments for fixed seasonal effects, trends, or serial correlation. As expected, these estimates are slightly higher than those derived from the more elaborate variance component analysis. Values in column 4 of Table 5 (using variance components and considering serial correlation) are thought to be the most accurate estimates of relative standard error. Conclusions regarding the adequacy (or inadequacy) of AMP design relative to the 20% RSE criterion are insensitive to time period, statistical method, and consideration of arithmetic vs. geometric means.

Figures 8-14 show power curves for detecting step improvements in epilimnetic water quality over a 10-year monitoring period, as measured by increases in transparency or decreases in the nutrient concentrations, chlorophyll-a, or fecal coliform counts. Results are shown for step changes of various magnitudes and for sampling frequencies ranging from daily to yearly. Based upon these power curves, the following table summarizes step change magnitudes detectable with >80% probability over a 10-year period for biweekly and weekly sampling frequencies:

Water Quality Improvements Detectable with >80% Probability

	Sampling	Frequency
Variable	Biweekly	Weekly
Total P	-16%	-13%
Total N	-19%	-19%
TKN	-23%	-22%
NH3N	-31%	-30%
Chlorophyll-a	-48%	-40%
Fecal Coliforms	-55%	-48%
Secchi	40%	35%

For example, with a biweekly frequency, there would be >80% probability of detecting total phosphorus reductions of 16% or more or of detecting Secchi depth increases of 40% or more.

It is apparent that increasing sampling frequencies for nutrients would provide little benefit in terms of detecting water quality improvements. This reflects the fact that power for detecting changes is controlled primarily by random year-to-year variations that are independent of sampling program design. Based upon the 20% criterion for PM 1 and the sensitivity of the remaining PM's to alternative designs, the existing biweekly sampling frequency seems adequate for nutrients and transparency. It does not seem to be adequate, however, for chlorophyll-a or fecal coliforms. These variables are evaluated in greater detail below.

Discussion of Chlorophyll-a Data

PM 1 sensitivity to sampling frequency for chlorophyll-a and different analytical assumptions is summarized below:

RSE of May-Sept. Geometric Mean Chl-a, Lake Epilimnion

Adjustments		Sampling Frequency	
Season & Trend	Serial Correl.	Biweekly	Weekly
No	No	40%	28%
No	Yes	17%	9%
Yes	No	37%	26%
Yes	Yes	18%	9%

Adjustments of the data for fixed seasonal effects and long-term trend have relatively minor impacts on the results. Consideration of serial correlation, however, reduces RSE values for a biweekly sampling frequency from 40% to 17% (without season/trend adjustment) and from 37% to 18% (with season/trend adjustment). Computed serial correlation coefficients for a biweekly sampling interval are 0.44 and 0.31, respectively.

The biweekly design is marginally adequate (17-18%) relative to the 20% criterion when serial correlation is considered. Based upon the importance of chlorophyll-a as a key indicator of algal standing crop and upon the importance of eutrophication as a factor likely to drive future management decisions, it is recommended that the AMP sampling frequency for chlorophyll-a at the Lake South station be increased from biweekly to weekly between May and September. A corresponding increase in the measurement frequency for transparency (appropriately paired with chlorophyll-a measurements without additional cost) would provide secondary benefits.

As characterized by a log-scale standard deviation of 1.33, temporal variability in chlorophyll-a is higher than that typically encountered in other lake data sets (median values 0.4 – 0.7, Smeltzer et al, 1989). It is likely that this is related to the eutrophic character of the lake. Walker (1985) developed a regression model predicting chlorophyll-a variability as a function of mean concentration in Vermont lakes. Applying the regression model to Onondaga Lake data from 1993-1997 (mean = 18 ppb), the predicted log-scale standard deviation is

1.13 and is not significantly different from the observed value of 1.33. If management efforts are successful in reducing average chlorophyll-a concentrations, variability in the measurements would be expected to decrease and the precision and power for trend detection would be expected to increase.

The yearly data summaries in Appendix B show that chlorophyll-a was monitored at a weekly frequency in 1991 and 1992. The RSE of the arithmetic mean was 14-18% in these years vs. 20-57% in the remaining years between 1988 and 1997. The RSE of the geometric mean was 22-25% vs. 27-55%, respectively. The RSE of the geometric mean is strongly influenced by observations below 1 ppb. Further investigation indicates that constraining the observations to a minimum of 1 ppb results in better agreement between arithmetic and geometric RSE's. As demonstrated above, actual RSE's would be lower than those listed in Appendix B because fixed seasonal effects and serial correlation are ignored. Results further support the recommendation to increase chlorophyll-a monitoring frequency from biweekly to weekly.

The 1993-1997 data did not include any replicate samples for chlorophyll-a. To provide a basis for quantifying sampling variations, duplicate samples for chlorophyll-a should be collected on a monthly basis.

In 1993-1997, chlorophyll-a concentrations at the Lake South station were measured on composite samples derived from aliquots collected at 0, 3, 6, and 9 meters. Variations in the thermocline and/or photic zone depth may have contributed to variations in composite concentrations. Since September 1997, integrated tube samples have been collected over the depth of the epilimnion. Between 1984 and 1990, concentrations were measured separately at 0, 3, 6, and 12 meters. May-September average concentrations at each depth were 48 ± 12, 32 ± 4, 19 ± 3, and 10 ± 1 ppb, respectively. Figure 15 shows the difference between the 0-meter and 6-meter values as a function of sampling date. The differences tend to be positive (indicating declining chlorophyll-a concentrations with depth) and stronger during the peak growing season. Maximum differences range from 30 to >100 ppb in various years. It is reasonable to conclude that there would be greater differences between the surface and 9-meter concentrations. These results indicate that 0-9 meter composite values measured in 1993-1997 frequently under-estimate concentrations in the upper mixed layer. Interpolating between the 6 and 12 meter sampled depths, the 0-9 meter average concentration in 1984-1990 was 28 ± 4 ppb, as compared with a surface concentration of 48 ± 12 ppb and 3-meter concentration of 32 ± 4 ppb. Episodic surface scums may have contributed to the relatively high variability in the 0-meter samples.

From a modeling perspective, the epilimnetic-average chlorophyll-a may be useful as a relative measure of total biomass in the lake and is possibly less sensitive than surface values to scum formation and wind intensity. Because it is more closely coupled to aesthetics and transparency, however, the upper mixed layer average may be more relevant than the epilimnetic average from a management perspective. The 0-9 meter or epilimnetic composites are not ideal for developing relationships between chlorophyll-a and transparency that would be key to understanding the transparency response to decreasing nutrient loads. An alternative sampling strategy would be to collect integrated (tube) samples over twice the Secchi depth (~photic zone). The USEPA (1990) recommends integrated sampling over the top 6 feet of the water column, regardless of thermocline or Secchi depth. The 6-foot recommendation is partially based upon concern that the sample not penetrate the metalimnion and is probably more relevant to shallower lakes.

Given the potential multiple uses for the data, the AMP should collect sufficient data to characterize both the upper mixed layer and epilimnetic average chlorophyll-a concentrations. This could be accomplished by collecting two separate composite samples for chlorophyll-a: epilimnetic and photic zone. The latter can be approximated at twice the Secchi depth, but should not extend into the thermocline (which may occur during clearing events).

Additional insights might be gained by further analysis of historical chlorophyll-a and phaeophytin data. Correcting chlorophyll-a measurement for phaeophytin may reduce variability. This hypothesis should be investigated under Phase II this study.

Discussion of Fecal Coliform Data

PM 1 sensitivity to sampling frequency for fecal coliforms in the lake epilimnion and different analytical assumptions is summarized below:

RSE of May-Sept. Geometric Mean Fecal Coliforms, Lake Epilimnion

Adjustments		Sampling Frequency		
Season & Trend	Serial Correlation	Monthly	Biweekly	Weekly
No	No	62%	44%	31%
No	Yes	62%	44%	31%
Yes	No	57%	41%	29%
Yes	Yes	57%	41%	29%

Results are insensitive to adjustments. Significant serial correlation was not detected in the historical biweekly data. These results are consistent with analysis of the long-term data set (1988-1997) in Appendix B (median RSE for annual geometric mean at biweekly frequency = 43%, yearly range 27 to 51%).

Analysis of historical fecal coliform data (Walker, 1991) collected in the Lake by the Department of Health (DOH) yields similar results. In 1982-1985 and 1987, three stations were sampled consistently on a weekly basis between May and September. The within-year standard deviations, which control computation of the yearly RSE, ranged from 1.27 to 1.38, as compared with 1.45 for the 1993-1997 data. Corresponding PM 1 values ranged from 57 to 62% for a monthly sampling frequency, 38 to 42% for a biweekly sampling frequency, and 27 to 29% for a weekly frequency. Serial correlation was not detected in the weekly DOH data. This indicates that the time scale of significant coliform variations is shorter than a week.

The AMP design (Onondaga County, 1998b, p. 60) calls for biweekly measurements of fecal coliforms and enterococci at the Lake South station, coupled with quarterly sampling at the Lake North station. This follows the historical program used for tracking long-term variations in the Lake. The above analysis indicates that precision of yearly summary statistics and power for detecting trends would be substantially improved by increasing the bacteria sampling frequency from biweekly to weekly (on a similar schedule to that recommended above for chlorophyll-a and transparency). Even with weekly sampling, it is unlikely that the 20% RSE target can be reached (expected RSE for a weekly frequency = 29%). The actual RSE will be lower, however, because the weekly periodic data will be supplemented by event-based sampling data discussed below.

As shown in Figure 14, increasing the fecal coliform from biweekly to weekly would increase the probability of detecting a 50% reduction from 69% to 84%. Detecting a 50% reduction in bacterial levels would be a relatively ambitious goal, given the fact that measurements typically vary over two orders of magnitude (Appendices A & B). Given the inherent high variability in bacteria measurements, it is not clear that further increases in sampling frequency (twice weekly, daily) would be justified. It is not unreasonable to expect similar variability in other bacteria measurements required under the AMP (enterococci). The routine monitoring design for entercocci at the Lake South station should follow that recommended for fecal coliform. These recommendations can be re-examined in subsequent annual data reviews.

One possible approach to improving the precision and power of bacteria sampling program would be to develop empirical models that explain a portion of the variance. For example, it would be reasonable to hypothesize that measured bacteria counts are correlated with antecedent rainfall conditions. If such a correlation were found, it could be used to filter out storm-related variations from the original time series. The filtered time series would have lower variance and greater power for detecting long-term trends. This aspect is recommended for investigation in Phase II.

The AMP design (p. 27) also includes bacteria measurements at seven near-shore areas of the Lake under to the following schedule:

- monthly dry-weather sampling between June and September
- event-based sampling typically involving 3 events per year and 3 consecutive days per event in most years (1999-2001, 2003, 2005, 2006, 2008, & 2012).

This program will be coupled with event-based tributary sampling to evaluate the effectiveness of stormwater controls. Based upon typical variability in fecal coliform measurements quantified above, it is unlikely that this program would provide adequate data for assessing trends in seasonal-average concentrations at each lake station. The objective of the program, however, is to evaluate responses on an event basis, so there is no basis, at this point, to recommend a change in this design. Statistical evaluation of this plan will be considered in subsequent reports, once adequate baseline data are collected to estimate variability and characterize storm response at each station.

Determination of compliance with the Class B fecal coliform standard requires at least 5 samples per month. It is unlikely that the existing design will provide sufficient samples for this purpose. It is recommended that bacteria sampling frequency be increased to weekly at the near-shore stations in the northern portion of the lake designed as Class B. Weekly samples will be supplemented by event-based sampling described above. Transparency measurements should be conducted simultaneously.

Trend Analysis

The Seasonal Kendall Test (Hirsch et al., 1982, Hirsch & Slack, 1984) is proposed for use in tracking long-term water quality trends in the lake and tributaries. Generally, time series of 10 years or more are recommended for detecting long-term trends in water quality (Hirsch et al., 1982). For shorter records, there is greater risk that an apparent trend is attributed to a pattern which appears to be a trend, but is actually a random occurrence (Type I error) and there is greater risk that actual trends will go undetected, particularly if they are small (Type II error). Since power for detecting trends increases substantially with series length, longer series can be used when consistent data are available and cover a relevant time frame. Incremental progress under the AMP can be tracked with 10-year rolling trend tests. After 2007, the 10-year rolling tests can be supplemented by cumulative tests using data sets starting in 1998.

Preliminary trend analysis results for the most recent ten years of record (1988-1997) are summarized in Table 6. These are based upon the more conservative version of the Seasonal Kendall test (Hirsch & Slack, 1984). Values in the table are trend slopes (%/year) for those stations and variables for which a null hypothesis of no trend is rejected at the 0.10 level (two-tailed tests). Depending upon the hypothesized direction of change (increase or decrease), equivalent results would be obtained using one-tailed tests conducted at the 0.05 level. Results shown in Table 6 are preliminary, pending data verification and software refinements.

Under the AMP, one-tailed hypotheses of "no improvement" will be tested at the 0.05 significance level. The sign of the change will depend upon the water quality component. These test parameters are prescribed under the AMP (Onondaga County, 1998b). Since the 0.05 significance level is to some extent arbitrary, the computed probability levels will also be reported for each test, so that decisions can be made with other risk tolerances (e.g., 0.1 etc.).

Potential vertical and seasonal differences in lake response are investigated by conducting separate tests for different depth ranges (epilimnion (0-6 m), and hypolimnion (12-18 m)) and for different seasons (January-December, March-May, June-September, October-November). Focus on the June-September period permits specific evaluation of trends during the recreational season. Focus on the October-November period permits specific evaluation of trends during the fall turnover period. Tests based upon alternative depth or season ranges could be easily incorporated into the framework.

Tests are conducted for a wider array of water-quality components, compared with those investigated above. Although interpretations are beyond the scope of this report, results generally suggest improving lake water quality with respect to total and filtered organic carbon, total suspended solids, BOD, and Secchi Depth. Detection of long-term trends in phosphorus species within this period is somewhat hindered by relatively high concentrations measured in the lake during 1993 (Appendices A, B), when relatively high volumes of wastewater were bypassed around the Metro secondary treatment plant. This resulting spike in the middle of the time series makes it difficult to detect long-term trends that may have been present over the 1988 to 1997 period. Interpretation of the time series in the context of mass balances (see below) is needed to evaluate lake responses in a more complete fashion.

The adequacy of the biweekly sampling frequency to provide data for trend analysis is supported by the fact that trend magnitudes on the order of 1-3%

per year are identified for some water-quality components. Over a ten-year period, trends of 1-3% per year would amount to total changes of 10-34%. Changes of this magnitude would be of management significance and are apparently detectable with the historical biweekly sampling strategy and a 10-year record.

Application of an alternative version of the Seasonal Kendall test (Hirsch et al., 1982) yields a larger number of apparent trends (Table 7). This version may yield "false trends" in time series with significant serial correlation. On the other hand, Loftis et al. (1990) have criticized the 1984 version of the test (used in Table 6) because it is relatively weak (fails to detect actual trends) in data sets without serial correlation. Further literature review and refinements to the software are suggested to arrive at a single recommended procedure for conducting trend tests.

Although trend magnitudes are characterized by the median slope, the procedure tests for monotonic (generally increasing or generally decreasing) trends. Alternative non-parametric procedures (Helsel & Hirsch, 1992) can be used to test for step changes following implementation of specific control measures. These can be developed in subsequent annual reports.

Lake Mass Balances

The lake restoration plan calls for implementation of point and non-point source controls to reduce loadings of nutrients, solids, bacteria and other contaminants over the next several years. A key role of the AMP is to provide data for calculating loadings and evaluating the effectiveness of specific controls (Onondaga County, 1998b). Formulating annual or seasonal lake mass balances provides a basis for determining the relative importance of each source and for evaluating relationships between external loads and lake response (i.e. supporting lake modeling efforts). By estimating the error variance associated with each loading term, uncertainties in the total inflow and outflow loads can be tracked. The magnitudes of these uncertainties can be used, in turn, to evaluate the adequacy of the monitoring program to support lake modeling and management decisions regarding control of external loads.

As discussed in the AMP design document (Onondaga County, 1998b), the AUTOFLUX program (Walker, 1995) will be used to estimate the uncertainty in each monitored inflow or outflow. AUTOFLUX is a derivative of the FLUX, an interactive program developed for the Corps of Engineers to estimate loads based upon continuous flow and intermittent concentration measurements (Walker, 1996). AUTOFLUX was developed specifically for Onondaga County to facilitate repetitive calculations applied to large numbers of stations, years, and/or water quality components.

This section demonstrates application of AUTOFLUX to historical monitoring data and integration of results in the form of lake mass balances. Results provide a basis for evaluating uncertainties on overall mass balances and adequacies of the tributary monitoring plan. The methodology follows that initially described at the 1997 Onondaga Lake Advisors meeting (Walker,1997). Procedures are outlined below:

1. AUTOFLUX is used to estimate loads for each monitored source and outflow. Pending further validation of the 1993-1997 data sets, calculations exclude sample concentrations identified by AUTOFLUX as outliers at a significance level <0.01.

2. Ungauged non-point loads are estimated by scaling the total gauged non-point load (Ninemile + Harbor + Onondaga + Ley) based upon drainage area. Based upon drainage area values reported for USGS gauges, the total gauged area is 690 km^2 and the total ungauged area is 37 km^2. Ungauged flows and loads are estimated at 5.3% of the total gauged flows and loads.

3. Outflow volumes are estimated based upon a daily water balance that includes inflow, precipitation, evaporation, and change-in-storage terms. Daily precipitation rates are derived from the Hancock Airport weather station. Monthly-average evaporation rates for reservoirs in the Albany area (Van der Leeden et al. ,1990) are utilized. The storage term is estimated using daily elevation measurements reported by the USGS. The predicted lake daily outflow time series is smoothed using 5-day rolling averages.

4. Atmospheric loads are estimated based upon precipitation volume and nominal estimates of average rainfall concentrations for each water quality component.

5. Lake outflow loads are computed from the daily outflow time series and concentrations measured at three alternative locations: Lake South Epilimnion (0-6 meter samples), Lake Outlet sampled at a depth of 2 feet, and Lake Outlet sampled at a depth of 12 feet. Sampling and interpretation of data at the outlet are difficult because of hydraulic complexities caused by backwater from the Seneca River and density differences between the Lake and River. Since weak south-to-north gradients in lake water quality have been detected (Walker, 1991), the Lake South Epilimnion data may over-estimate outflow concentrations of some components. Another limitation is that Lake South station, unlike the outlet stations, has not been

historically sampled on a year-round basis. Results using the Lake Outlet sampled at 2 feet are emphasized.

6. Industrial withdrawals of cooling water from the Lake are not evaluated separately. The computed outflow volumes reflect the sum of cooling water withdrawals and net discharge to the Seneca River.

7. Mass balances are developed on an annual (January-December) basis. Future development of seasonal (May-September) balances is suggested. The latter may be more relevant to evaluating management strategies for water quality components with relatively short time scales that are of primary concern during growing season (e.g., bacteria and possibly nutrients).

8. The change-in-storage term of the mass balance is not quantified. In future iterations, this term could be estimated from the time series of volume-weighted-mean concentrations and lake elevation.

9. Variance in the total inflow load estimates is calculated as the sum of variances of the individual sources. A coefficient of variation (CV) of 0.3 is assumed for the ratio of ungauged to total gauged non-point loads. A CV of 0.2 is assumed for atmospheric loads. These assumptions generally have little impact on the results because the corresponding loads are small relative to other sources.

10. To supplement the overall mass balances, unit area contributions from each watershed are summarized in the form of runoff (cm/yr) and unit area load (kg/km2-yr). Differences in unit area loads across watersheds reflect land use and other factors contributing to non-point loads. Total and unit area contributions from the lower portion of the Onondaga Creek watershed are computed based upon measured values at the Dorwin and Spencer stations. Similar calculations are performed for Harbor Brook based upon the Velasko and Hiawatha stations; these are possible starting in 1997 when flow monitoring at Velasko was initiated.

The assumptions and procedures used in the calculations can be refined in future reports. Preliminary results developed below are adequate for evaluating the monitoring plan and discussing potential applications of the results.

Calculations have been performed for chloride, total phosphorus, nitrogen species (kjeldahl, ammonia, nitrate, nitrite), and fecal coliforms. Detailed results for 1997 and 1993-1997 average are listed in Appendix C. Table 8 summarizes inflow loads (municipal, non-point, total) and outflow loads (Lake

Epilimnion, Outlet @ 2 feet, Outlet @ 12 feet) for each water quality component and years 1993, 1994, 1995, 1996, 1997, and 1993-1997 average. The mean and relative standard error of each term are listed. Results for total nitrogen are computed as the sum of the kjeldahl, nitrate, and nitrate values.

Figure 16 compares total input and total output estimates for each year, expressed in terms of average inflow and outflow concentrations of chloride, total phosphorus, total nitrogen, and fecal coliforms. Discussion of the management implications of these balances is beyond the scope of this report. Uncertainty estimates derived from the calculations are useful for evaluating historical and future monitoring plans.

Relative standard errors of the yearly total inflow load estimates range from 4 to 7% for chloride, 3 to 10% for phosphorus, 2 to 5% for nitrogen, and 15 to 28% for fecal coliforms. Relative standard errors of the 5-year-average loads are 3% for chloride, 5% for phosphorus, 2% for nitrogen, and 16% for fecal coliforms. As expected based upon the variance component analyses, there is considerably greater uncertainty in the estimates of fecal coliform loads. Figure 16 suggests that these levels of uncertainty do not significantly impede detection of year-to-year variations in loads or detection of differences between inflow and outflow loads in specific years. These estimates are based upon the 1993-1997 sampling regime, which did not include specific high-flow sampling events. Reductions in RSE values would be expected under the AMP, which requires both routine and event-oriented sampling.

Tracking chloride loads provides a means of checking the accuracy of the overall water balances and computational framework. Since chloride can be assumed to be conservative, inputs and outputs should balance to within an acceptable margin of error. Consideration of the change-in-storage term will provide an improved basis for tracking chloride balances, since differences between chloride inputs and output over any time frame may be partially attributed to changes in chloride storage within the lake. Over the 1993-1997 period, chloride inputs and outputs (as measured by the 2-foot Outlet samples) differed by 3%. The computed net retention term has a relative standard error of 112%, which indicates that it is not significantly different from zero, considering uncertainty in the input (RSE = 3%) and output (RSE = 3%) loads.

Refinements to the load calculation algorithms used in AUTOFLUX will be needed to properly handle event-oriented sampling. Seasonal stratification of samples may be more appropriate than flow stratification for some inputs. In particular, Metro discharge concentrations of fecal coliforms and ammonia are strongly seasonal. Consideration of seasonal variations (or separate computation of loads for different seasons) may provide better estimates of annual load and uncertainty in these cases. These refinements to AUTOFLUX can be made in future annual updates.

Tracking total and local inputs from Onondaga Creek and Harbor Brook (bottom of Appendix C tables) provides a basis for evaluating the effectiveness of non-point control measures implemented in the lower portions of these watersheds. Because they are determined by difference between results at two monitoring stations, the computed local inputs have relatively high error variances. Estimates of uncertainty in local inputs are probably inflated because they do not account for possible temporal correlation in concentrations measured at the upstream and downstream station on each stream. Time-series analysis of paired sample concentrations is likely to provide a more powerful method for detecting long-term trends in local inputs. Development of appropriate statistical procedures is suggested for future work.

Biological Measurements

The AMP (p. 5) indicates that progress towards "swimmable fishable" conditions in Onondaga Lake will be assessed based upon the following measurements:

- Water transparency (mid-lake and nearshore)
- Ammonia and Nitrite N concentrations
- Dissolved Oxygen (including fall mixing events)
- Bacterial concentration following storm-events in near-shore areas
- Contaminant burden in fish flesh
- Fish reproductive success
- Macrophyte (rooted aquatic plants) density and species composition
- Algae density and species composition
- Benthic macroinvertebrate density & species composition in littoral areas

Evaluation of monitoring programs for biological variables will be conducted under Phase II of this study and be completed in time for incorporation into the year 2000 monitoring plan. Recommendations for collection of data in 1999 to support Phase II evaluations are discussed below.

The historical monitoring program provides sufficient data on algal and zooplankton populations to characterize temporal variability. Since 1995, plankton identifications and enumerations have been conducted by Dr. Ed Mills on biweekly samples collected between May and October. This program should be continued in 1999. The depth sampling regime should be modified to include both epilimnetic and photic-zone composites, as recommended above for chlorophyll-a. Chlorophyll-a and phaeophytin measurements should be conducted on splits from the same samples that are studied by Dr. Mills.

Surveys conducted in 1989 by Wagner (1998) provide the only known historical data on macroinvertebrates in the littoral zones of the Lake. These data should be acquired and used as a partial basis for designing preliminary surveys to be conducted in the littoral zones and tributaries during 1999. The latter should include sufficient replicate samples to characterize measurement variability at each site.

Limited or no data on the remaining biological components (contaminant burdens, fish reproduction, macrophyte density, tributary macroinvertebrates) are available. It is not clear that the general variance component model used above for water quality measurements is relevant for the biological measurements. The monitoring objective may be to characterize the population at a particular location and season, rather than estimate the spatial and/or annual mean. Development of a statistical framework for biological measurements will require clear definition of objectives and initial sampling data to characterize variability on the required spatial and temporal scales.

The following measures are recommended to support statistical evaluation of biological measurements:

1. Specific goals and objectives for collecting each biological measurement must be clearly defined by the NYDEC and/or Onondaga County. This includes relevant metrics and the spatial and temporal scales over which they must be quantified. Without a clear definition of objectives and scale, it is not possible to develop a statistically-based program. For example, characterizing the macroinvertebrate population on a specific date in a specific littoral region of the lake is a considerably different measurement problem than characterizing the spatially- and temporally-averaged population. Is tracking changes over time at specific representative locations sufficient to support management decisions, or is it necessary to track changes in the entire population, spatially integrated over the entire littoral zone? These types of questions must be addressed for each biological measurement.

2. Given the defined objectives, measurement methods and a preliminary sampling plan should be developed by experienced biologist(s). The preliminary sampling plan should include sufficient replicates to characterize inherent variability in the measurement at each location.

3. Once initial surveys have been conducted, the resulting data can be analyzed to characterize variability and evaluate the power of the sampling

program to detect trends or step changes of various magnitudes. These results, in turn, can be used for refining the program.

Steps 1 and 2 should be conducted as soon as possible to provide a basis for designing initial surveys in 2000. Data from these surveys can be used to develop and implement appropriate statistical design concepts in subsequent years. Both the objectives and the designs may change as data are collected and analyzed over the course of the AMP.

Conclusions & Recommendations

1. The AMP designs for total phosphorus, total nitrogen, total kjeldahl nitrogen, ammonia nitrogen, transparency, chlorophyll-a, and fecal coliforms have been evaluated based using previously-defined criteria (Walker, 1998), including the expected precision of yearly and long-term geometric means, power for detecting trends, and adequacy to support lake mass-balance calculations.

2. The AMP biweekly sampling frequency for total phosphorus, total nitrogen, total kjeldahl nitrogen, and ammonia nitrogen is adequate for trend detection and mass-balance calculations, especially when supplemented with prescribed high-flow tributary sampling.

3. For estimating yearly means, detecting trends, and calculating loads, there would be no significant benefit to increasing the number of replicates or sampled depths on each date.

4. While it is adequate for developing ammonia mass balances, the 0.1 ppm detection limit for ammonia nitrogen under the 1993-1997 monitoring program is inadequate for measuring ammonia concentrations in some tributaries. A lower detection limit (<= 0.05 ppm) is recommended to support tracking of future reductions in tributary and lake ammonia concentrations following reductions in external loads.

5. Based upon relatively high variance in historical measurements, it is recommended that AMP sampling frequencies for chlorophyll-a, transparency, and bacteria (fecal coliforms, enterococci) at the Lake South station be increased from biweekly to weekly between May and September. This will provide much-improved bases for detecting long-term trends in these variables.

6. To provide a basis for quantifying sampling variations, duplicate chlorophyll-a and bacteria samples should be collected at the Lake South station on a monthly basis between May and September.

7. The vertical sampling regime for chlorophyll-a prescribed under the AMP (epilimnetic composite) is inadequate for characterizing algal populations in the upper mixed layer, which are likely to be more closely coupled with water transparency. Historical data reveal significant vertical chlorophyll-a gradients within the epilimnion. The vertical sampling regime should be modified to provide both epilimnetic and photic zone (2X Secchi depth, but above thermocline) zone) estimates.

8. Phytoplankton counts should be conducted on both epilimnetic and photic-zone composites at a biweekly frequency between May and October. Chlorophyll-a should be measured on these same samples.

9. It is recommended that weekly bacteria and transparency measurements be conducted at the near-shore stations in the northern portion of the lake designed as Class B. Weekly samples at these locations will be supplemented by event-based sampling described in the AMP. This will provide a basis for determination of compliance with Class B standards in potential bathing areas.

10. Hypotheses regarding trends in lake or tributary water quality can be evaluated using the Seasonal Kendall Test. The lake data can be stratified to test for trends within specific depth intervals and/or seasons. Applications to 1988-1997 data further demonstrate the adequacy of the biweekly sampling frequency as a basis for detecting trends of relatively small magnitude (1-3% per year) in basic water quality components. Conclusions are sensitive, however, to the version of the test that is employed (Hirsch et al., 1982 vs. Hirsch & Slack, 1984). Further work is needed to develop specific procedures to be used in testing for trends and step changes.

11. The tributary monitoring design is adequate to support formulation of lake mass-balance calculations on a yearly or seasonal basis. Tracking the magnitudes and uncertainties in various source terms over time will provide a basis for testing hypotheses regarding the effectiveness of specific point and non-point source control measures.

12. Refinements to the AUTOFLUX program are recommended to support load calculations based upon future event sampling and to provide improved estimates of annual load and uncertainty for sources with strong seasonal patterns.

13. Data collected by Wagner (1998) should be acquired and used as a partial basis for designing preliminary macroinvertebrate surveys to be conducted in the littoral zones and tributaries during 1999. The latter should include sufficient replicate samples to characterize measurement variability at each site.

14. General recommendations for developing a basis for statistical evaluation of biological sampling programs include (a) clear definition of objectives, (b) development of preliminary survey designs by qualified biologists, and (c) subsequent statistical analysis to characterize variability, evaluate power for trend detection, and develop refinements to the data-collection program.

15. It is recommended that Phase II of this project include formulation of specific hypotheses to be tested based upon water quality and biological measurements. The hypotheses should be formulated to measure success of the lake restoration program with respect to water-quality and biological features identified in the AMP. Evaluating the power of each test as a function of sampling frequency may lead to further refinements in the monitoring plan. In some cases, it will be possible to utilize historical monitoring data as a basis for software development and demonstration purposes.

References

Helsel, D.R. and R.M. Hirsch, Statistical Methods in Water Resources, Elsevier, 1992.

Hirsch R.M., J.R. Slack, & R.A. Smith, "Techniques of Trend Analysis for Monthly Water Quality Data", Water Resources Research, Vol. 18, No. 1, pp. 107-121, February 1982.

Hirsch R.M. & J.R. Slack, "A Nonparametric Trend Test for Seasonal Data with Serial Dependence", Water Resources Research, Vol. 20, No. 6, pp. 727-732, June 1984.

Knowlton, M.F., M.V. Hoyer, & J.R. Jones, "Sources of Variability in Phosphorus and Chlorophyll and Their Effects on Use of Lake Survey Data, Water Resources Bulletin, Volume 20, pp. 397-407, 1984.

Loftis, J.C., C. H. Taylor, & P.L. Chapman, "Multivariate Methods for Detecting Water Quality Trends", Colorado Water Resources Research Institute, Colorado State University, Technical Report No. 56, February 1990.

Loftis, J.C., G.C. McBride, & J.C. Ellis, "Considerations of Scale in Water Quality Monitoring and Data Analysis", Water Resources Bulletin, Vol. 27, No. 2, pp. 255-264, April 1991.

Muskens, P.J.W.M. and G. Kateman, "Sampling of Internally Correlated Lots. The Reproducibility of Gross Samples as a Function of Sample Size, Lot Size, and Number of Samples", Analytical Chimica Acta, Vol. 103, pp. 1-9, 1978.

Onondaga County, "Quality Assurance Program Plan – 1998 Ambient Monitoring Program", Department of Drainage and Sanitation, prepared for NYSDEC, May 1998a.

Onondaga County, "Ambient Monitoring Program", Department of Drainage & Sanitation, Syracuse, New York, July 1998b.

Smeltzer, E., W.W. Walker, & V. Garrison, "Eleven Years of Lake Eutrophication Monitoring in Vermont: A Critical Evaluation", in "Enhancing States' Lake Management Programs", U.S. Environmental Protection Agency, pp. 53-62, 1989.

Snedecor, G.W. & W.G. Cochran, Statistical Methods, 8th Edition, The Iowa State University Press, 1989.

Stearns & Wheler, Inc., R. Canale, & E. Mills, Onondaga County Department of Drainage and Sanitation, C. Driscoll, "Report and Appendix A – Onondaga Lake Monitoring Program 1996 Annual Report, Onondaga County, NewYork, September 1997.

Van der Leeden, F., F.L. Troise, & D.K. Todd, The Water Encyclopedia, Lewis Publishers, Second Edition, 1990.

U.S. Environmental Protection Agency, "Monitoring Lake and Reservoir Restoration", Office of Water, Assessment and Watershed Protection Division, Washington, EPA-440/4-90-007, August 1990.

Wagner, B.A., "The Benthic Macroinvertebrate Community of the Littoral Zone of Onondaga Lake", presented at 18th Annual Symposium, North American Lake Management Society, Banff, Alberta, Canada, November 1998.

Walker, W.W., "Statistical Bases for Mean Chlorophyll-a Criteria", in "Lake and Reservoir Management: Practical Applications", North American Lake Management Society, pp. 57-62, 1985.

Walker, W.W., "Compilation and Review of Onondaga Lake Water Quality Data", prepared for Onondaga County, Department of Drainage & Sanitation, December 1991.

Walker, W. W., "Onondaga Lake Data-Base Update, 1991-1995", Data Base & Software for Trend Analysis and Load Calculations, prepared for Stearns & Wheler, Inc. & Onondaga County Department of Drainage and Sanitation, Syracuse, New York, September 1995.

Walker, W.W., "Simplified Procedures for Eutrophication Assessment and Prediction: User Manual", prepared for Headquarters, U.S. Army Corps of Engineers, Instruction Report W-96-2, Waterways Experiment Station, September 1996.

Walker, W.W., "Mass Balance Calculations for Onondaga Lake", prepared for Stearns & Wheler and Onondaga County Department of Drainage & Sanitation, presented at Lake Advisors Meeting, August 13, 1997.

Walker, W.W., "A Statistical Framework for the Onondaga Lake Ambient Monitoring Program", prepared for Onondaga County, Department of Drainage & Sanitation, July 1998.

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Lake and Tributary Monitoring Program Design, 1993-1997

Variable	Frequency	Depths	Tributaries	Depths
Total Phosphorus Total Kjeldahl Nitrogen Ammonia Nitrogen	biweekly	0,3,6,9,12,15,18 m	biweekly	mid-channel, grab
Nitrite Nitrogen Nitrate Nitrogen	biweekly	composites 0-9, 12-18 m	biweekly	mid-channel, grab
Chlorophyll-a	biweekly	composite, 0-9 m	not measured	
Transparency	biweekly	surface	not measured	
Fecal Coliform Bacteria	biweekly	surface	biweekly	mid-channel, grab

Lake Stations:
- South (biweekly sampling)
- North (quarterly sampling)

Tributary Stations	Flow Measurements
Nine Mile Creek @ Lakeland (Route 48)	Daily
Harbor Brook @ Hiawatha Blvd	Daily
Harbor Brook @ Velakso Road	Daily
Onondaga Creek @ Spencer Street	Daily
Onondaga Creek @ Dorwin Avenue	Daily
Ley Creek @ Park Street	Daily
METRO Effluent	Daily
METRO Bypass	Daily
Allied East Flume	
Crucible Steel	
Onondaga Lake Outlet, 2 Feet	
Onondaga Lake Outlet, 12 Feet	

Notes:
Duplicate samples collected at Lake South (6 meters depth) and Lake Outlet (2 feet) in 1997.

Total P also analyzed at 1 meter depth, Lake South, June-September, 1997 & AMP.

Metro effluent and bypass data supplemented with daily NPDES permit monitoring data.

AMP also specifies sampling of 5 high-flow events per year at each tributary site.

AMP specifies collection of flow-weighted cross-sections (vs. mid-channel grabs) at tributary stations.

Results of Variance Component Analysis

Station	Variable	Standard Deviations (Nat. Logs)					Serial Corr.	Sampl. per Date	Relative Std. Error Yearly Geom.Mean					Relative Std. Error Long-Term Geom. Mean					Prob. of Detection Linear Trend (5%/yr)					Prob. of Detection Step Change (25%)				
		Year	Date	Depth	Rep	Total			A	B	C	D	E	A	B	C	D	E	A	B	C	D	E	A	B	C	D	E
1EPIL	CHLA	0.1907	1.2292	0.0000	0.0000	1.2439	0.3458	1	37%	53%	26%	n/a	17%	19%	25%	15%	n/a	12%	23%	16%	33%	n/a	46%	21%	15%	29%	n/a	38%
1EPIL	FCOLI	0.3021	1.3392	0.0000	0.0000	1.3729	-0.1628	1	41%	57%	29%	n/a	41%	23%	29%	19%	n/a	23%	18%	14%	23%	n/a	18%	17%	13%	21%	n/a	17%
2HYPO	FCOLI	0.3408	0.8846	0.0000	0.0000	0.9480	0.1595	1	27%	38%	19%	n/a	15%	19%	23%	17%	n/a	17%	22%	18%	25%	n/a	27%	20%	16%	22%	n/a	23%
ALLIEDF	FCOLI	0.2413	1.3256	0.0000	0.0000	1.3474	-0.0076	1	26%	37%	18%	n/a	26%	16%	20%	14%	n/a	16%	29%	22%	36%	n/a	29%	26%	20%	31%	n/a	26%
CRUCIBLE	FCOLI	0.1912	1.2649	0.0000	0.0000	1.2793	0.0467	1	25%	35%	18%	n/a	17%	14%	18%	12%	n/a	11%	35%	25%	46%	n/a	47%	30%	22%	39%	n/a	39%
DORWIN	FCOLI	0.0000	1.1083	0.0000	0.0000	1.1083	-0.0543	1	22%	31%	15%	n/a	22%	10%	14%	7%	n/a	10%	59%	36%	85%	n/a	59%	49%	31%	74%	n/a	49%
HARBOR	FCOLI	0.6246	1.4111	0.0000	0.0000	1.5432	0.1295	1	28%	39%	20%	n/a	16%	31%	33%	29%	n/a	29%	13%	12%	14%	n/a	14%	13%	12%	13%	n/a	13%
HARBOR2	FCOLI	0.7792	0.9375	0.0000	0.7678	1.6325	-0.1716	1	24%	34%	17%	21%	24%	36%	38%	36%	36%	36%	11%	11%	12%	12%	11%	11%	10%	11%	11%	11%
LEY	FCOLI	0.0000	1.2893	0.0000	0.0000	1.2893	0.1531	1	25%	36%	18%	n/a	14%	11%	16%	8%	n/a	6%	48%	29%	74%	n/a	89%	40%	25%	63%	n/a	80%
METRO	FCOLI	0.0000	1.6737	0.0000	0.0000	1.6737	-0.0355	1	33%	46%	23%	n/a	33%	15%	21%	10%	n/a	15%	32%	20%	54%	n/a	32%	28%	19%	45%	n/a	28%
NINEMILE	FCOLI	0.0000	1.2668	0.0000	0.0000	1.2668	-0.1867	1	25%	35%	18%	n/a	25%	11%	16%	8%	n/a	11%	49%	29%	76%	n/a	49%	41%	26%	64%	n/a	41%
OUTLET12	FCOLI	0.0000	1.0422	0.0000	0.0000	1.0422	-0.0010	1	20%	29%	14%	n/a	20%	9%	13%	6%	n/a	9%	64%	39%	88%	n/a	64%	53%	33%	79%	n/a	53%
OUTLET2	FCOLI	0.0000	1.0794	0.0000	0.0000	1.0794	-0.0278	1	21%	30%	15%	n/a	21%	9%	13%	7%	n/a	9%	61%	37%	86%	n/a	61%	51%	32%	76%	n/a	51%
SPENCER	FCOLI	0.0000	1.2305	0.0000	0.0000	1.2305	0.2532	1	24%	34%	17%	n/a	12%	11%	15%	8%	n/a	5%	51%	31%	78%	n/a	96%	43%	27%	66%	n/a	91%
1EPIL	NH3N	0.2103	0.2821	0.1921	0.0958	0.4647	0.1482	3	9%	13%	7%	9%	5%	10%	11%	10%	10%	10%	54%	49%	58%	55%	59%	43%	38%	46%	43%	46%
2HYPO	NH3N	0.1625	0.2074	0.1556	0.1027	0.3727	0.3921	3	7%	10%	5%	7%	3%	8%	9%	8%	8%	7%	75%	69%	78%	76%	80%	60%	55%	64%	61%	66%
ALLIEDF	NH3N	0.1364	0.4575	0.0000	0.0000	0.4774	-0.0552	1	9%	13%	6%	n/a	9%	7%	8%	7%	n/a	7%	81%	71%	86%	n/a	81%	69%	59%	75%	n/a	69%
CRUCIBLE	NH3N	0.0852	0.3422	0.0000	0.0000	0.3526	0.0674	1	7%	9%	5%	n/a	4%	5%	6%	4%	n/a	4%	98%	94%	99%	n/a	99%	94%	86%	97%	n/a	98%
DORWIN	NH3N	0.0507	0.2724	0.0000	0.0000	0.2771	0.1138	1	5%	8%	4%	n/a	3%	3%	4%	3%	n/a	3%	100%	99%	100%	n/a	100%	100%	99%	100%	n/a	100%
HARBOR	NH3N	0.1309	0.4774	0.0000	0.0000	0.4950	-0.0035	1	9%	13%	7%	n/a	9%	7%	8%	7%	n/a	7%	82%	71%	87%	n/a	82%	70%	59%	77%	n/a	70%
HARBOR2	NH3N	0.1640	0.1469	0.0000	0.2754	0.4474	0.2145	1	6%	9%	4%	5%	3%	8%	8%	8%	8%	7%	76%	71%	78%	78%	79%	60%	56%	63%	62%	64%
LEY	NH3N	0.0000	0.6305	0.0000	0.0000	0.6305	0.2734	1	12%	17%	9%	n/a	6%	6%	8%	4%	n/a	3%	95%	76%	99%	n/a	100%	89%	64%	99%	n/a	100%
METRO	NH3N	0.1747	0.4521	0.0000	0.0000	0.4847	0.3491	1	9%	13%	6%	n/a	4%	9%	10%	8%	n/a	8%	67%	60%	71%	n/a	74%	55%	49%	59%	n/a	62%
NINEMILE	NH3N	0.0945	0.5387	0.0000	0.1655	0.5949	0.0193	1	11%	16%	8%	11%	8%	6%	8%	5%	6%	6%	88%	73%	95%	89%	94%	78%	61%	89%	79%	88%
OUTLET12	NH3N	0.1524	0.3904	0.0000	0.0000	0.4191	0.2782	1	8%	11%	5%	n/a	4%	8%	8%	7%	n/a	7%	78%	71%	81%	n/a	84%	65%	58%	70%	n/a	72%
OUTLET2	NH3N	0.0000	0.6840	0.0000	0.1302	0.7084	0.0038	1	14%	19%	10%	14%	11%	6%	9%	4%	6%	5%	91%	68%	99%	91%	97%	83%	57%	98%	83%	94%
SPENCER	NH3N	0.0502	0.3178	0.0000	0.0000	0.3217	0.0393	1	6%	9%	4%	n/a	4%	4%	5%	3%	n/a	3%	100%	98%	100%	n/a	100%	100%	96%	100%	n/a	100%
1EPIL	SECCHI	0.1576	0.4673	0.0000	0.0000	0.4932	0.1965	1	14%	20%	10%	n/a	8%	9%	11%	8%	n/a	8%	61%	47%	71%	n/a	76%	50%	38%	59%	n/a	63%
1EPIL	TKN	0.1488	0.1693	0.0747	0.0836	0.2756	0.1781	3	5%	8%	4%	5%	3%	7%	8%	7%	7%	7%	83%	79%	85%	83%	85%	69%	64%	71%	69%	72%
2HYPO	TKN	0.1448	0.1319	0.1234	0.1057	0.3019	0.4171	3	5%	7%	3%	4%	2%	7%	7%	7%	7%	7%	85%	82%	87%	86%	88%	71%	66%	73%	71%	74%
ALLIEDF	TKN	0.0897	0.3037	0.0000	0.0000	0.3167	-0.0240	1	6%	8%	4%	n/a	6%	5%	5%	4%	n/a	5%	98%	95%	99%	n/a	98%	94%	88%	97%	n/a	94%
CRUCIBLE	TKN	0.1579	0.3978	0.0000	0.0000	0.4280	0.0863	1	8%	11%	6%	n/a	5%	8%	9%	7%	n/a	7%	75%	68%	79%	n/a	80%	63%	56%	67%	n/a	68%
DORWIN	TKN	0.0535	0.5545	0.0000	0.0000	0.5571	-0.1950	1	11%	15%	8%	n/a	11%	5%	7%	4%	n/a	5%	95%	81%	99%	n/a	95%	90%	69%	98%	n/a	90%
HARBOR	TKN	0.1003	0.6671	0.0000	0.0000	0.6746	-0.0227	1	13%	18%	9%	n/a	13%	7%	9%	6%	n/a	7%	80%	61%	91%	n/a	80%	69%	51%	82%	n/a	69%
HARBOR2	TKN	0.1154	0.5452	0.0000	0.2252	0.6419	-0.1420	1	12%	16%	8%	11%	12%	7%	9%	6%	7%	7%	81%	65%	89%	82%	81%	69%	54%	80%	71%	69%
LEY	TKN	0.0000	0.5681	0.0000	0.0000	0.5681	0.2816	1	11%	16%	8%	n/a	5%	5%	7%	4%	n/a	2%	97%	83%	100%	n/a	100%	94%	72%	100%	n/a	100%
METRO	TKN	0.1218	0.3324	0.0000	0.0000	0.3540	0.3101	1	7%	9%	5%	n/a	3%	6%	7%	6%	n/a	6%	90%	85%	93%	n/a	94%	81%	74%	85%	n/a	87%
NINEMILE	TKN	0.0604	0.2960	0.0000	0.1855	0.4001	0.1277	1	7%	10%	5%	6%	4%	4%	5%	3%	4%	3%	99%	97%	100%	99%	100%	99%	92%	100%	99%	100%
OUTLET12	TKN	0.0871	0.2454	0.0000	0.0000	0.2604	0.3623	1	5%	7%	3%	n/a	2%	4%	5%	4%	n/a	4%	99%	97%	99%	n/a	99%	97%	93%	98%	n/a	99%
OUTLET2	TKN	0.0000	0.4870	0.0000	0.0872	0.5024	0.0658	1	10%	14%	7%	10%	6%	4%	6%	3%	4%	3%	99%	91%	100%	99%	100%	98%	82%	100%	98%	100%
SPENCER	TKN	0.0000	0.5641	0.0000	0.0000	0.5641	0.0054	1	11%	16%	8%	n/a	9%	5%	7%	3%	n/a	4%	97%	84%	100%	n/a	99%	94%	73%	100%	n/a	99%

Table

Results of Variance Component Analysis

		Standard Deviations (Nat. Logs)						Sampl.	Relative Std. Error Yearly Geom.Mean					Relative Std. Error Long-Term Geom. Mean					Prob. of Detection Linear Trend (5%/yr)					Prob. of Detection Step Change (25%)				
Station	**Variable**	**Year**	**Date**	**Depth**	**Rep**	**Total**	**Serial Corr.**	**per Date**	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**	**A**	**B**	**C**	**D**	**E**
1EPIL	TN	0.1201	0.1193	0.0000	0.0935	0.2148	0.1055	1	5%	6%	3%	4%	3%	6%	6%	6%	6%	6%	93%	91%	94%	94%	95%	83%	79%	86%	84%	86%
2HYPO	TN	0.0934	0.0937	0.0000	0.0000	0.1323	0.3058	1	3%	4%	2%	n/a	1%	4%	5%	4%	n/a	4%	99%	98%	99%	n/a	99%	96%	95%	97%	n/a	97%
ALLIEDF	TN	0.0218	0.2745	0.0000	0.0000	0.2754	-0.0158	1	5%	8%	4%	n/a	5%	3%	4%	2%	n/a	3%	100%	100%	100%	n/a	100%	100%	100%	100%	n/a	100%
CRUCIBLE	TN	0.0000	0.4580	0.0000	0.0000	0.4580	-0.1587	1	9%	13%	6%	n/a	9%	4%	6%	3%	n/a	4%	99%	94%	100%	n/a	99%	99%	87%	100%	n/a	99%
DORWIN	TN	0.0505	0.2925	0.0000	0.0000	0.2968	0.0079	1	6%	8%	4%	n/a	4%	3%	4%	3%	n/a	3%	100%	99%	100%	n/a	100%	100%	98%	100%	n/a	100%
HARBOR	TN	0.0155	0.2443	0.0000	0.0000	0.2448	0.0127	1	5%	7%	3%	n/a	4%	2%	3%	2%	n/a	2%	100%	100%	100%	n/a	100%	100%	100%	100%	n/a	100%
HARBOR2	TN	0.0788	0.1307	0.0000	0.0642	0.1776	0.2257	1	3%	4%	2%	3%	1%	4%	4%	4%	4%	4%	100%	99%	100%	100%	100%	99%	98%	99%	99%	99%
LEY	TN	0.0000	0.4836	0.0000	0.0000	0.4836	0.2591	1	9%	13%	7%	n/a	5%	4%	6%	3%	n/a	2%	99%	92%	100%	n/a	100%	98%	83%	100%	n/a	100%
METRO	TN	0.0662	0.1829	0.0000	0.0000	0.1945	0.2193	1	4%	5%	3%	n/a	2%	3%	4%	3%	n/a	3%	100%	100%	100%	n/a	100%	100%	99%	100%	n/a	100%
NINEMILE	TN	0.0000	0.2432	0.0000	0.0938	0.2770	-0.0285	1	5%	7%	4%	5%	5%	2%	3%	2%	2%	2%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
OUTLET12	TN	0.0921	0.1431	0.0000	0.0000	0.1702	0.2009	1	3%	4%	2%	n/a	1%	4%	4%	4%	n/a	4%	99%	99%	99%	n/a	99%	97%	96%	98%	n/a	98%
OUTLET2	TN	0.0000	0.4053	0.0000	0.0553	0.4128	0.1476	1	8%	11%	6%	8%	5%	4%	5%	3%	4%	2%	100%	97%	100%	100%	100%	100%	93%	100%	100%	100%
SPENCER	TN	0.0188	0.2161	0.0000	0.0000	0.2169	0.1401	1	4%	6%	3%	n/a	2%	2%	3%	2%	n/a	1%	100%	100%	100%	n/a	100%	100%	100%	100%	n/a	100%
1EPIL	TP	0.0573	0.2688	0.2169	0.1538	0.4658	-0.0361	3	9%	13%	7%	9%	9%	5%	6%	4%	5%	5%	97%	88%	99%	98%	97%	94%	78%	99%	95%	94%
2HYPO	TP	0.2783	0.4249	0.3724	0.0000	0.7317	0.5095	3	14%	20%	10%	14%	6%	14%	15%	13%	14%	13%	35%	30%	38%	35%	40%	28%	25%	31%	29%	32%
ALLIEDF	TP	0.0000	0.3102	0.0000	0.0000	0.3102	0.1876	1	6%	9%	4%	n/a	3%	3%	4%	2%	n/a	1%	100%	100%	100%	n/a	100%	100%	99%	100%	n/a	100%
CRUCIBLE	TP	0.2476	0.6133	0.0000	0.0000	0.6614	0.1756	1	12%	17%	8%	n/a	7%	12%	13%	12%	n/a	11%	42%	37%	45%	n/a	47%	35%	31%	37%	n/a	38%
DORWIN	TP	0.2804	0.7152	0.0000	0.0000	0.7682	0.0417	1	14%	20%	10%	n/a	10%	14%	15%	13%	n/a	13%	35%	30%	37%	n/a	38%	29%	26%	32%	n/a	32%
HARBOR	TP	0.3479	0.6952	0.0000	0.0000	0.7774	0.1227	1	14%	19%	10%	n/a	8%	17%	18%	16%	n/a	16%	27%	25%	28%	n/a	29%	23%	21%	24%	n/a	25%
HARBOR2	TP	0.3688	0.7790	0.0000	0.1576	0.8902	-0.0163	1	16%	22%	11%	15%	16%	18%	19%	17%	18%	18%	24%	22%	26%	25%	24%	21%	20%	23%	21%	21%
LEY	TP	0.1642	0.5930	0.0000	0.0000	0.6153	0.4049	1	12%	16%	8%	n/a	5%	9%	10%	8%	n/a	8%	65%	54%	72%	n/a	78%	54%	44%	60%	n/a	66%
METRO	TP	0.0000	0.4851	0.0000	0.0556	0.4914	0.2331	1	10%	14%	7%	10%	5%	4%	6%	3%	4%	2%	99%	91%	100%	99%	100%	98%	83%	100%	98%	100%
NINEMILE	TP	0.0978	0.5491	0.0000	0.0688	0.5662	-0.0002	1	11%	15%	8%	11%	11%	7%	8%	6%	7%	7%	88%	73%	94%	88%	88%	78%	61%	88%	78%	78%
OUTLET12	TP	0.0868	0.2941	0.0000	0.0000	0.3066	0.1487	1	6%	8%	4%	n/a	3%	5%	5%	4%	n/a	4%	98%	96%	99%	n/a	99%	96%	90%	98%	n/a	98%
OUTLET2	TP	0.0895	0.4152	0.0000	0.1040	0.4495	0.1016	1	8%	12%	6%	8%	5%	5%	7%	5%	5%	5%	95%	87%	98%	95%	98%	89%	76%	95%	89%	96%
SPENCER	TP	0.2980	0.7434	0.0000	0.0000	0.8009	0.0304	1	15%	21%	10%	n/a	10%	15%	16%	14%	n/a	14%	32%	28%	34%	n/a	34%	27%	24%	29%	n/a	29%

Column	**Freq.**	**Samples/Date**	**Serial Correlation Adjustment**
A (AMP)	Biweekly	1X	No
B	Monthly	1X	No
C	Weekly	1X	No
D	Biweekly	2X	No
E (AMP)	Biweekly	1X	Yes

Summary of Statistical Performance Measures for AMP Design
Ignoring Serial Correlation

Relative Standard Error (RSE) of Yearly Geometric Mean

	TP	TN	TKN	NH3N	FCOLI	SECCHI	CHLA
1EPIL	9%	5%	5%	9%	41%	14%	37%
2HYPO	14%	3%	5%	7%	27%	#N/A	#N/A
OUTLET12	6%	3%	5%	8%	20%	#N/A	#N/A
OUTLET2	8%	8%	10%	14%	21%	#N/A	#N/A
LEY	12%	9%	11%	12%	25%	#N/A	#N/A
HARBOR	14%	5%	13%	9%	28%	#N/A	#N/A
SPENCER	15%	4%	11%	6%	24%	#N/A	#N/A
NINEMILE	11%	5%	7%	11%	25%	#N/A	#N/A
ALLIEDF	6%	5%	6%	9%	26%	#N/A	#N/A
CRUCIBLE	12%	9%	8%	7%	25%	#N/A	#N/A
METRO	10%	4%	7%	9%	33%	#N/A	#N/A

RSE of Long-Term Geometric Mean Computed from 5 Years of Data

	TP	TN	TKN	NH3N	FCOLI	SECCHI	CHLA
1EPIL	5%	6%	7%	10%	23%	9%	19%
2HYPO	14%	4%	7%	8%	19%	#N/A	#N/A
OUTLET12	5%	4%	4%	8%	9%	#N/A	#N/A
OUTLET2	5%	4%	4%	6%	9%	#N/A	#N/A
LEY	9%	4%	5%	6%	11%	#N/A	#N/A
HARBOR	17%	2%	7%	7%	31%	#N/A	#N/A
SPENCER	15%	2%	5%	4%	11%	#N/A	#N/A
NINEMILE	7%	2%	4%	6%	11%	#N/A	#N/A
ALLIEDF	3%	3%	5%	7%	16%	#N/A	#N/A
CRUCIBLE	12%	4%	8%	5%	14%	#N/A	#N/A
METRO	4%	3%	6%	9%	15%	#N/A	#N/A

Probability of Detecting a 5%/year Trend over 10 Years

	TP	TN	TKN	NH3N	FCOLI	SECCHI	CHLA
1EPIL	97%	93%	83%	54%	18%	61%	23%
2HYPO	35%	99%	85%	75%	22%	#N/A	#N/A
OUTLET12	98%	99%	99%	78%	64%	#N/A	#N/A
OUTLET2	95%	100%	99%	91%	61%	#N/A	#N/A
LEY	65%	99%	97%	95%	48%	#N/A	#N/A
HARBOR	27%	100%	80%	82%	13%	#N/A	#N/A
SPENCER	32%	100%	97%	100%	51%	#N/A	#N/A
NINEMILE	88%	100%	99%	88%	49%	#N/A	#N/A
ALLIEDF	100%	100%	98%	81%	29%	#N/A	#N/A
CRUCIBLE	42%	99%	75%	98%	35%	#N/A	#N/A
METRO	99%	100%	90%	67%	32%	#N/A	#N/A

Probability of Detecting a 25% Step Change over 10 years

	TP	TN	TKN	NH3N	FCOLI	SECCHI	CHLA
1EPIL	94%	83%	69%	43%	17%	50%	21%
2HYPO	28%	96%	71%	60%	20%	#N/A	#N/A
OUTLET12	96%	97%	97%	65%	53%	#N/A	#N/A
OUTLET2	89%	100%	98%	83%	51%	#N/A	#N/A
LEY	54%	98%	94%	89%	40%	#N/A	#N/A
HARBOR	23%	100%	69%	70%	13%	#N/A	#N/A
SPENCER	27%	100%	94%	100%	43%	#N/A	#N/A
NINEMILE	78%	100%	99%	78%	41%	#N/A	#N/A
ALLIEDF	100%	100%	94%	69%	26%	#N/A	#N/A
CRUCIBLE	35%	99%	63%	94%	30%	#N/A	#N/A
METRO	98%	100%	81%	55%	28%	#N/A	#N/A

Summary of Statistical Performance Measures for AMP Design
Considering Serial Correlation

Relative Standard Error (RSE) of Yearly Geometric Mean

	TP	TN	TKN	NH3N	FCOLI	SECCHI	CHLA
1EPIL	9%	3%	3%	5%	41%	8%	17%
2HYPO	6%	1%	2%	3%	15%	#N/A	#N/A
OUTLET12	3%	1%	2%	4%	20%	#N/A	#N/A
OUTLET2	5%	5%	6%	11%	21%	#N/A	#N/A
LEY	5%	5%	5%	6%	14%	#N/A	#N/A
HARBOR	8%	4%	13%	9%	16%	#N/A	#N/A
SPENCER	10%	2%	9%	4%	12%	#N/A	#N/A
NINEMILE	11%	5%	4%	8%	25%	#N/A	#N/A
ALLIEDF	3%	5%	6%	9%	26%	#N/A	#N/A
CRUCIBLE	7%	9%	5%	4%	17%	#N/A	#N/A
METRO	5%	2%	3%	4%	33%	#N/A	#N/A

RSE of Long-Term Geometric Mean Computed from 5 Years of Data

	TP	TN	TKN	NH3N	FCOLI	SECCHI	CHLA
1EPIL	5%	6%	7%	10%	23%	8%	12%
2HYPO	13%	4%	7%	7%	17%	#N/A	#N/A
OUTLET12	4%	4%	4%	7%	9%	#N/A	#N/A
OUTLET2	5%	2%	3%	5%	9%	#N/A	#N/A
LEY	8%	2%	2%	3%	6%	#N/A	#N/A
HARBOR	16%	2%	7%	7%	29%	#N/A	#N/A
SPENCER	14%	1%	4%	3%	5%	#N/A	#N/A
NINEMILE	7%	2%	3%	6%	11%	#N/A	#N/A
ALLIEDF	1%	3%	5%	7%	16%	#N/A	#N/A
CRUCIBLE	11%	4%	7%	4%	11%	#N/A	#N/A
METRO	2%	3%	6%	8%	15%	#N/A	#N/A

Probability of Detecting a 5%/year Trend over 10 Years

	TP	TN	TKN	NH3N	FCOLI	SECCHI	CHLA
1EPIL	97%	95%	85%	59%	18%	76%	46%
2HYPO	40%	99%	88%	80%	27%	#N/A	#N/A
OUTLET12	99%	99%	99%	84%	64%	#N/A	#N/A
OUTLET2	98%	100%	100%	97%	61%	#N/A	#N/A
LEY	78%	100%	100%	100%	89%	#N/A	#N/A
HARBOR	29%	100%	80%	82%	14%	#N/A	#N/A
SPENCER	34%	100%	99%	100%	96%	#N/A	#N/A
NINEMILE	88%	100%	100%	94%	49%	#N/A	#N/A
ALLIEDF	100%	100%	98%	81%	29%	#N/A	#N/A
CRUCIBLE	47%	99%	80%	99%	47%	#N/A	#N/A
METRO	100%	100%	94%	74%	32%	#N/A	#N/A

Probability of Detecting a 25% Step Change over 10 years

	TP	TN	TKN	NH3N	FCOLI	SECCHI	CHLA
1EPIL	94%	86%	72%	46%	17%	63%	38%
2HYPO	32%	97%	74%	66%	23%	#N/A	#N/A
OUTLET12	98%	98%	99%	72%	53%	#N/A	#N/A
OUTLET2	96%	100%	100%	94%	51%	#N/A	#N/A
LEY	66%	100%	100%	100%	80%	#N/A	#N/A
HARBOR	25%	100%	69%	70%	13%	#N/A	#N/A
SPENCER	29%	100%	99%	100%	91%	#N/A	#N/A
NINEMILE	78%	100%	100%	88%	41%	#N/A	#N/A
ALLIEDF	100%	100%	94%	69%	26%	#N/A	#N/A
CRUCIBLE	38%	99%	68%	98%	39%	#N/A	#N/A
METRO	100%	100%	87%	62%	28%	#N/A	#N/A

Relative Standard Errors of Yearly Means
Lake Epilimnion, May-September

Column	1	2	3	4
Type of Mean	Arithmetic	Geometric	Geometric	Geometric
Period	88-97	88-97	93-97	93-97
Method	Direct	Direct	VC	VC
Fixed Seasonal Variations	Ignored	Ignored	Removed	Removed
Serial Correlation	Ignored	Ignored	Ignored	Considered
Total Phosphorus	12%	12%	9%	9%
Total Nitrogen	4%	5%	5%	3%
Total Kjeldahl N	8%	8%	5%	3%
Ammonia N	10%	11%	9%	5%
Secchi Depth	20%	17%	14%	8%
Chlorophyll-a	31%	41%	37%	17%
Fecal Coliforms	43%	43%	41%	41%

Columns 1 & 2 from Appendix B, Median Values Over 10 years

Columns 3 & 4 Computed from 1993-1997 Variance Components, Table 2

Concentration Trends, 1988-1997, Hirsch & Slack (1984) Test

Station:	**Epilimnion**				**Hypolimnion**				**Outlet12**	**Outlet2**	**Metro**	**Spencer**	**Ley**	**Harbor**	**Ninemile**
Season:	**Jan-Dec**	**Mar-May**	**Jun-Sep**	**Oct-Nov**	**Jan-Dec**	**Mar-May**	**Jun-Sep**	**Oct-Nov**	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**	**Jan-Dec**
COND										-1.3	3.0			1.9	-4.3
NA								2.9			4.5		3.8	4.8	-4.1
CA					-2.0	-2.6	-2.5		-1.7	-2.1					
CL											3.1		2.8	3.5	-5.5
SO4									-	-	-	-	-	-	-
TP											-4.3		-5.7		
TIP									-	-	-	-	-	-	-
ORTHOP-F											-16.8		-11.4		-12.3
TN										-2.5		-2.5	-3.0	-2.6	-1.8
TKN													-3.9	-8.8	-4.6
NH3N													-6.0		-7.5
NO3N							6.6				-8.5	-2.0			
NO2N							5.9					0.0			
SIO2										8.2	-2.6	-1.6		-1.0	
TEMP		-2.6													-1.3
DO-F							0.0			-2.1	-	-1.7			-0.8
PH-F											0.0				
ALK	1.1		1.9					1.8			1.5			0.8	
TIC											1.6			0.9	
TOC	-3.0		-3.0	-3.9	-2.5			-4.8	-2.6	-2.3			-2.9	-5.3	
TOC_F	-2.9		-3.4	-3.7	-2.7		-2.6	-4.5	-	-	-	-	-	-	-
BOD5				-9.4				-9.6		-3.5					
TSS	-6.6			-11.5	-5.6			-11.2	-6.9	-13.5	-5.2	-12.5	-4.3	-5.7	-6.3
TS					-	-	-	-	-	-	-	-	-	-	-
CHLA					-	-	-	-	-	-	-	-	-	-	-
SECCHI	3.4	3.8	3.0		-	-	-	-	-	-	-	-	-	-	-
FCOLI		-14.2							0.2	0.0	0.0	-7.7	-9.5		

Trend magnitudes in % per year.

Trends significant at $p < .10$ (two-tailed tests), Seasonal Kendall Test, Considering Serial Correlation, Hirsch & Slack, 1984.

\- = no test conducted, data not collected

blank = test conducted & trend not significant.

Table

Concentration Trends, 1988-1997, Hirsch et al. (1982) Test

Station:	Epilimnion				Hypolimnion				Outlet12	Outlet2	Metro	Spencer	Ley	Harbor	Ninemile
Season:	Jan-Dec	Mar-May	Jun-Sep	Oct-Nov	Jan-Dec	Mar-May	Jun-Sep	Oct-Nov	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec	Jan-Dec
COND										-1.3	3.0		1.4	1.9	-4.3
NA	2.1		2.5	2.8	1.8		1.6	2.9	1.1		4.5	1.8	3.8	4.8	-4.1
CA	-1.0	-2.3	-0.9		-2.0	-2.6	-2.5		-1.7	-2.1		0.6		1.4	-2.7
CL		-2.6			-1.1	-2.7			-1.4	-1.6	3.1		2.8	3.5	-5.5
SO4								1.3	-	-	-	-	-	-	-
TP											-4.3	-6.2	-5.7		-4.2
TIP	-5.8	-7.7	-6.6	-4.7	-3.9	-10.2	-3.8		-	-	-	-	-	-	-
ORTHOP-F									-4.3		-16.8	-8.5	-11.4	-4.4	-12.3
TN	-1.5		-1.8		-2.3		-3.2		-1.8	-2.5		-2.5	-3.0	-2.6	-1.8
TKN					-2.6		-3.4			-3.6	2.4	-4.3	-3.9	-8.8	-4.6
NH3N					-2.2		-2.9				2.1	0.0	-6.0	-0.7	-7.5
NO3N	-2.2	-1.9	-3.9				6.6		-2.3	-1.9	-8.5	-2.0	-2.2	-0.8	
NO2N	-3.0		-5.0		0.0		5.9				-4.1	0.0	-3.0	0.0	0.0
SIO2				-4.5	5.8		6.3		6.9	8.2	-2.6	-1.6	-1.2	-1.0	
TEMP	-0.6	-2.6			-0.7						1.5				-1.3
DO-F					0.0		0.0			-2.1	-	-1.7		-0.6	-0.8
PH-F					0.2		0.1		0.2		0.0	-0.2	0.3		
ALK	1.1	0.5	1.9			0.5		1.8	0.5		1.5	0.4		0.8	
TIC									0.7		1.6			0.9	
TOC	-3.0	-1.9	-3.0	-3.9	-2.5	-1.7	-2.4	-4.8	-2.6	-2.3		-1.5	-2.9	-5.3	-3.7
TOC_F	-2.9	-1.7	-3.4	-3.7	-2.7		-2.6	-4.5	-	-	-	-	-	-	-
BOD5		-3.0		-9.4	0.0			-9.6	0.0	-3.5		0.0	0.0		0.0
TSS	-6.6	-5.9	-5.4	-11.5	-5.6	-5.8		-11.2	-6.9	-13.5	-5.2	-12.5	-4.3	-5.7	-6.3
TS		-1.7			-	-	-	-	-	-	-	-	-	-	-
CHLA					-	-	-	-	-	-	-	-	-	-	-
SECCHI	3.4	3.8	3.0	5.4	-	-	-	-	-	-	-	-	-	-	-
FCOLI		-14.2			0.0		0.0		0.2	0.0	0.0	-7.7	-9.5		-6.5

Trend magnitudes in % per year.

Trends significant at p < .10 (two-tailed tests), Seasonal Kendall Test, Ignoring Serial Correlation, Hirsch et al, 1982.

- = no test conducted, data not collected   blank = test conducted & trend not significant.

Summary of Lake Mass Balances, 1993-1997

		Volume		Municipal		NonPoint		Total Inflow		Alternative Estimates of Outflow Load					
Variable	Year	Inflow	Outflow	Load	RSE	Load	RSE	Load	RSE	EPIL	RSE	Outlet2	RSE	Outlet12	RSE
CL	93	544.23	535.37	30888	10%	191731	8%	223015	7%	206629	9%	167359	5%	193062	3%
CL	94	482.39	473.54	28338	12%	140684	6%	169356	5%	208791	6%	171618	7%	210957	4%
CL	95	314.27	305.41	26582	11%	95491	6%	122323	5%	161666	2%	126140	5%	156273	2%
CL	96	541.31	532.45	32153	10%	139039	4%	171640	4%	217872	5%	202056	4%	232393	4%
CL	97	368.97	360.12	33959	13%	110668	4%	144984	4%	169370	2%	137045	7%	169306	2%
CL	Mean	450.23	441.38	30384	5%	135523	3%	166264	3%	192866	2%	160844	3%	192398	2%
TP	93	544.23	535.37	106586	6%	40908	6%	148004	5%	108380	7%	94584	7%	107188	7%
TP	94	482.39	473.54	68941	11%	28822	21%	98173	10%	67053	16%	54430	17%	70069	14%
TP	95	314.27	305.41	44742	3%	14883	17%	59979	5%	49630	5%	44809	7%	48133	7%
TP	96	541.31	532.45	55265	3%	42461	12%	98251	5%	74331	10%	65377	7%	74103	7%
TP	97	368.97	360.12	34156	2%	14812	7%	49334	3%	33179	8%	35534	10%	38136	8%
TP	Mean	450.23	441.38	61938	3%	28377	6%	90748	3%	66515	5%	58947	4%	67526	4%
TKN	93	544.23	535.37	1789477	4%	244484	4%	2048169	4%	1415832	6%	1174574	7%	1314120	5%
TKN	94	482.39	473.54	1699677	7%	243800	8%	1955689	6%	1454592	4%	1174013	8%	1511879	4%
TKN	95	314.27	305.41	1713127	2%	129477	7%	1852978	2%	1013743	10%	768899	12%	1018209	10%
TKN	96	541.31	532.45	1771285	2%	304838	11%	2089941	2%	1531386	5%	1310382	5%	1508043	4%
TKN	97	368.97	360.12	1309740	3%	219104	15%	1539502	3%	974584	4%	779675	9%	896432	5%
TKN	Mean	450.23	441.38	1656661	2%	228341	5%	1897256	2%	1278027	3%	1041509	3%	1249737	3%
NH3N	93	544.23	535.37	1248502	4%	102278	5%	1352830	4%	923264	6%	719418	10%	837769	7%
NH3N	94	482.39	473.54	1312889	8%	77799	5%	1392613	8%	1166424	10%	769990	12%	1115611	6%
NH3N	95	314.27	305.41	1459090	1%	55110	7%	1515822	1%	728317	12%	550058	16%	764346	13%
NH3N	96	541.31	532.45	1387139	2%	149313	26%	1538872	3%	1053849	5%	841285	7%	996096	5%
NH3N	97	368.97	360.12	1040984	2%	94591	30%	1137017	3%	655492	8%	494242	12%	621910	6%
NH3N	Mean	450.23	441.38	1289721	2%	95818	10%	1387431	2%	905469	4%	674999	5%	867146	3%
NO3N	93	544.23	535.37	116036	16%	409386	4%	534437	5%	523489	7%	516509	8%	510312	5%
NO3N	94	482.39	473.54	169296	31%	354792	6%	531920	11%	432637	8%	436737	7%	448654	7%
NO3N	95	314.27	305.41	98409	24%	207230	6%	312278	8%	476172	12%	343477	15%	392574	14%
NO3N	96	541.31	532.45	91573	30%	488970	11%	590041	10%	616479	6%	663957	8%	691249	7%
NO3N	97	368.97	360.12	225375	24%	246706	3%	479248	11%	442305	4%	376866	5%	425061	4%
NO3N	Mean	450.23	441.38	140138	12%	341417	4%	489585	4%	498216	3%	467509	4%	493570	4%

Table 8

Summary of Lake Mass Balances, 1993-1997

		Volume		Municipal		NonPoint		Total Inflow		Alternative Estimates of Outflow Load					
Variable	Year	Inflow	Outflow	Load	RSE	Load	RSE	Load	RSE	EPIL	RSE	Outlet2	RSE	Outlet12	RSE
NO2N	93	544.23	535.37	43075	19%	14432	13%	59499	14%	62753	27%	50131	25%	55489	19%
NO2N	94	482.39	473.54	43176	20%	11444	20%	56212	16%	38224	13%	25010	17%	29906	13%
NO2N	95	314.27	305.41	36686	18%	6166	11%	44337	15%	79247	18%	45017	24%	55920	20%
NO2N	96	541.31	532.45	32093	19%	12351	9%	46757	13%	52887	20%	40570	16%	53238	16%
NO2N	97	368.97	360.12	59365	21%	5439	7%	66016	19%	40229	19%	22237	9%	30283	7%
NO2N	Mean	450.23	441.38	42879	9%	9966	7%	54564	7%	54668	10%	36593	10%	44967	8%
TN Calc	93	544.23	535.37	1948588	4%	668302	3%	2642106	3%	2002073	5%	1741214	5%	1879921	4%
TN Calc	94	482.39	473.54	1912149	6%	610037	5%	2543821	5%	1925453	4%	1635760	6%	1990439	4%
TN Calc	95	314.27	305.41	1848222	2%	342873	4%	2209592	2%	1569162	7%	1157393	9%	1466703	8%
TN Calc	96	541.31	532.45	1894951	3%	806159	8%	2726740	3%	2200751	4%	2014909	4%	2252530	4%
TN Calc	97	368.97	360.12	1594479	4%	471249	7%	2084767	4%	1457118	3%	1178778	6%	1351776	3%
TN Calc	Mean	450.23	441.38	1839678	2%	579724	3%	2441405	2%	1830912	2%	1545611	3%	1788274	2%
FCOLI	93	544.23	535.37	97941310	29%	7119533	29%	105077662	27%	1072759	48%	205357	35%	304494	47%
FCOLI	94	482.39	473.54	12307262	34%	7976976	22%	20313900	22%	129848	26%	398557	69%	334606	35%
FCOLI	95	314.27	305.41	22975634	16%	2205753	18%	25194242	15%	666768	31%	230318	52%	230271	45%
FCOLI	96	541.31	532.45	23702054	36%	8088733	32%	31820537	28%	1249149	61%	1425177	49%	1522330	48%
FCOLI	97	368.97	360.12	6940924	44%	9279345	15%	16227284	21%	442263	44%	102921	19%	144026	15%
FCOLI	Mean	450.23	441.38	32773437	19%	6934068	12%	39726725	16%	712157	27%	472466	33%	507145	30%

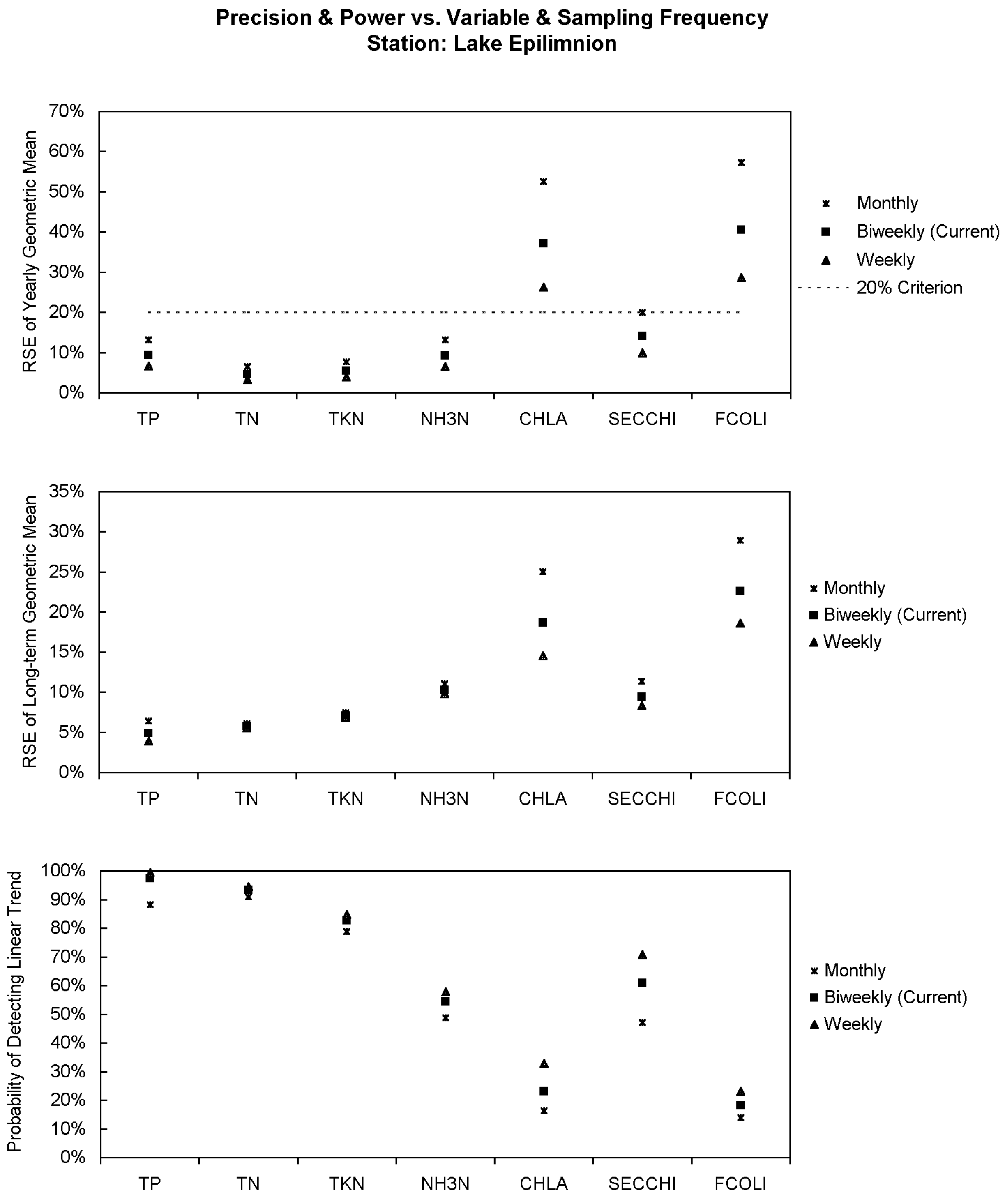
Volume units = million m3

Load Units = metric tons for CL, 10^9 Cells for FCOLI, kilograms for others

RSE = Relative Standard Error = Standard Error/ Mean

List of Figures

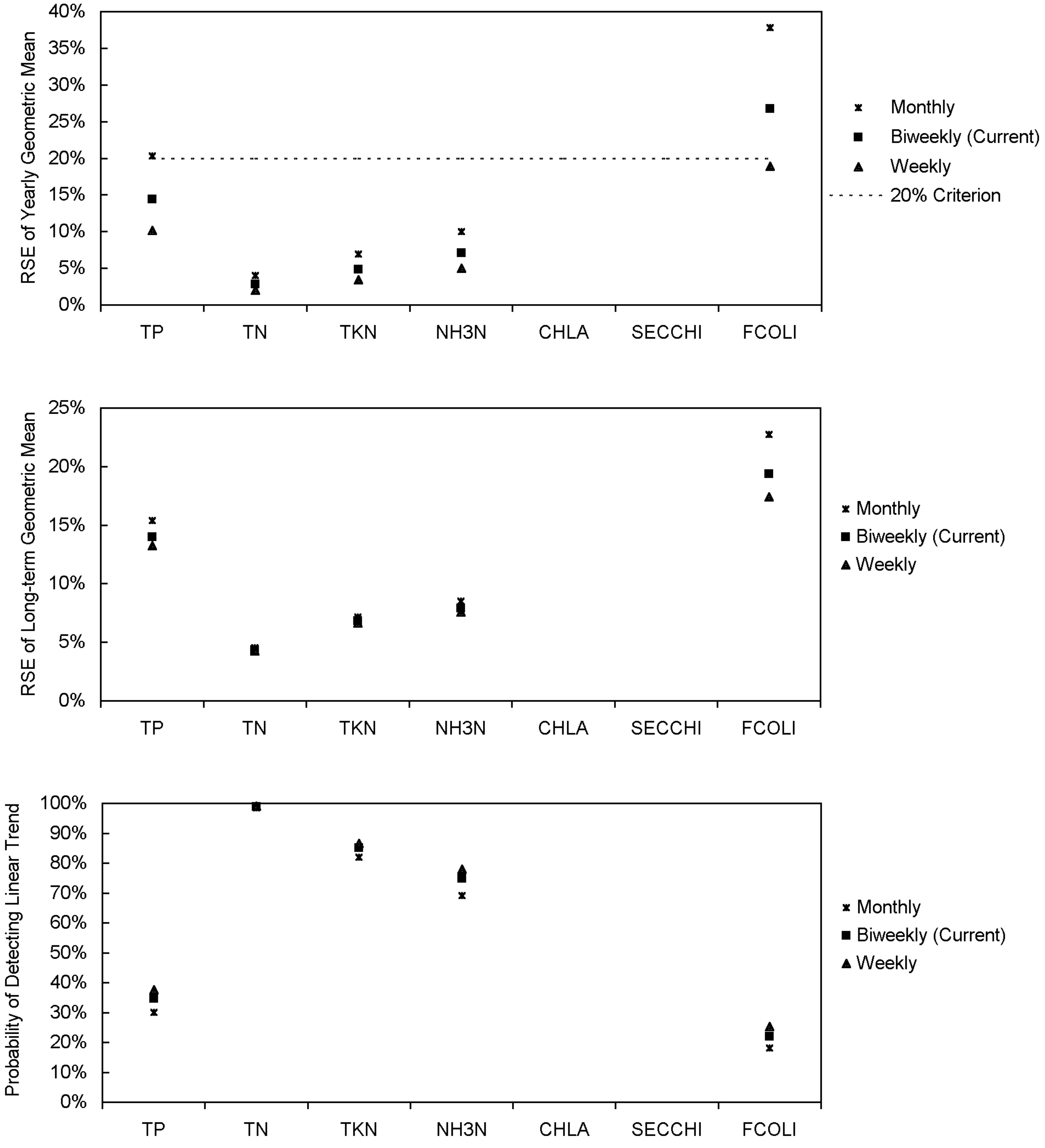
Figure



a -Relative Standard Error (RSE) of yearly geometric mean.
b -Relative Standard Error (RSE) of long-term geometric mean calculated from 5 years of data
c -Probability of detecting hypothetical trend of 5%/yr based upon 10 years of data.

Figure

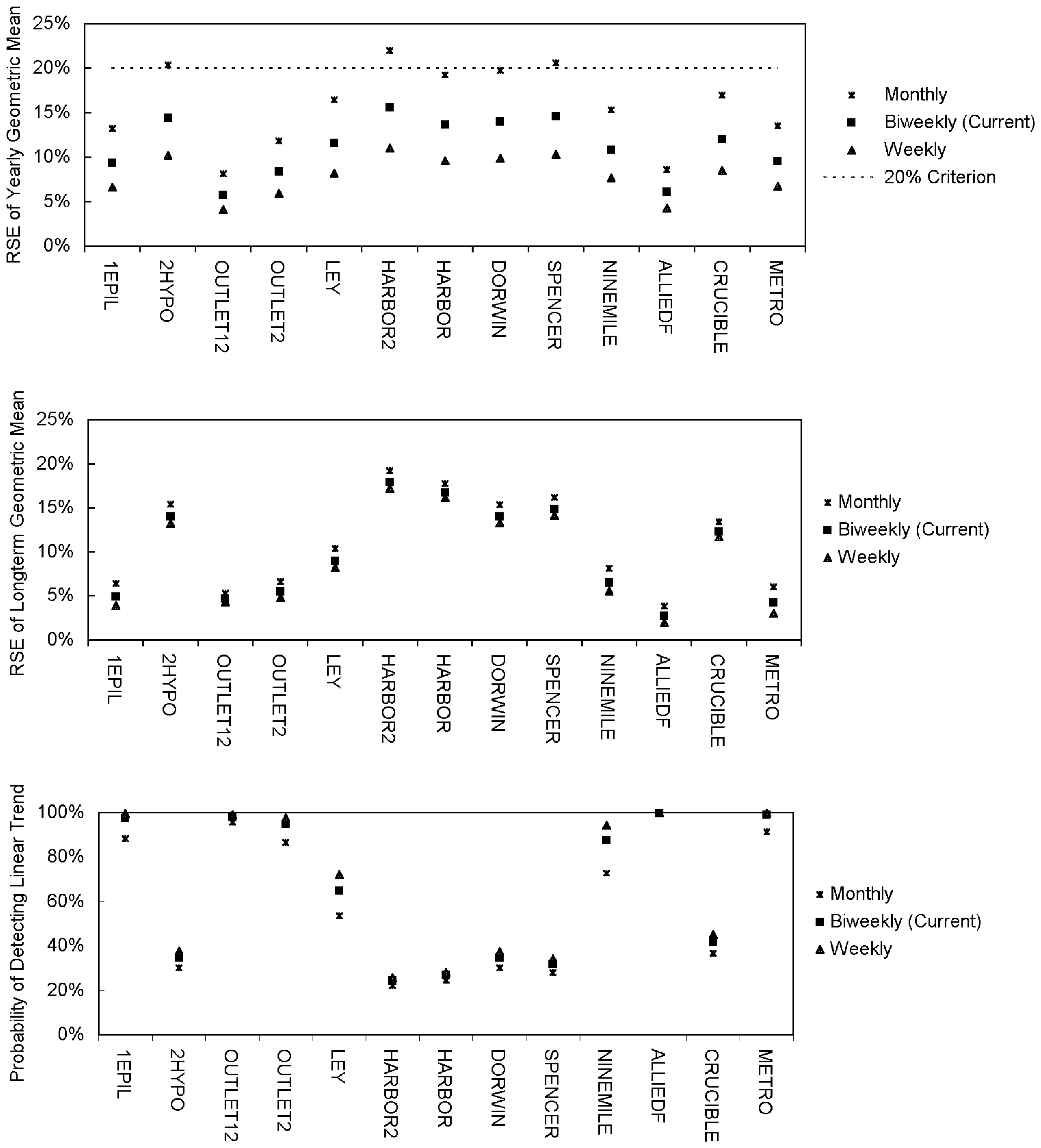
Precision & Power vs. Variable & Sampling Frequency
Station: Lake Hypolimnion



a -Relative Standard Error (RSE) of yearly geometric mean.
b -Relative Standard Error (RSE) of long-term geometric mean calculated from 5 years of data
c -Probability of detecting hypothetical trend of 5%/yr based upon 10 years of data.

Figure

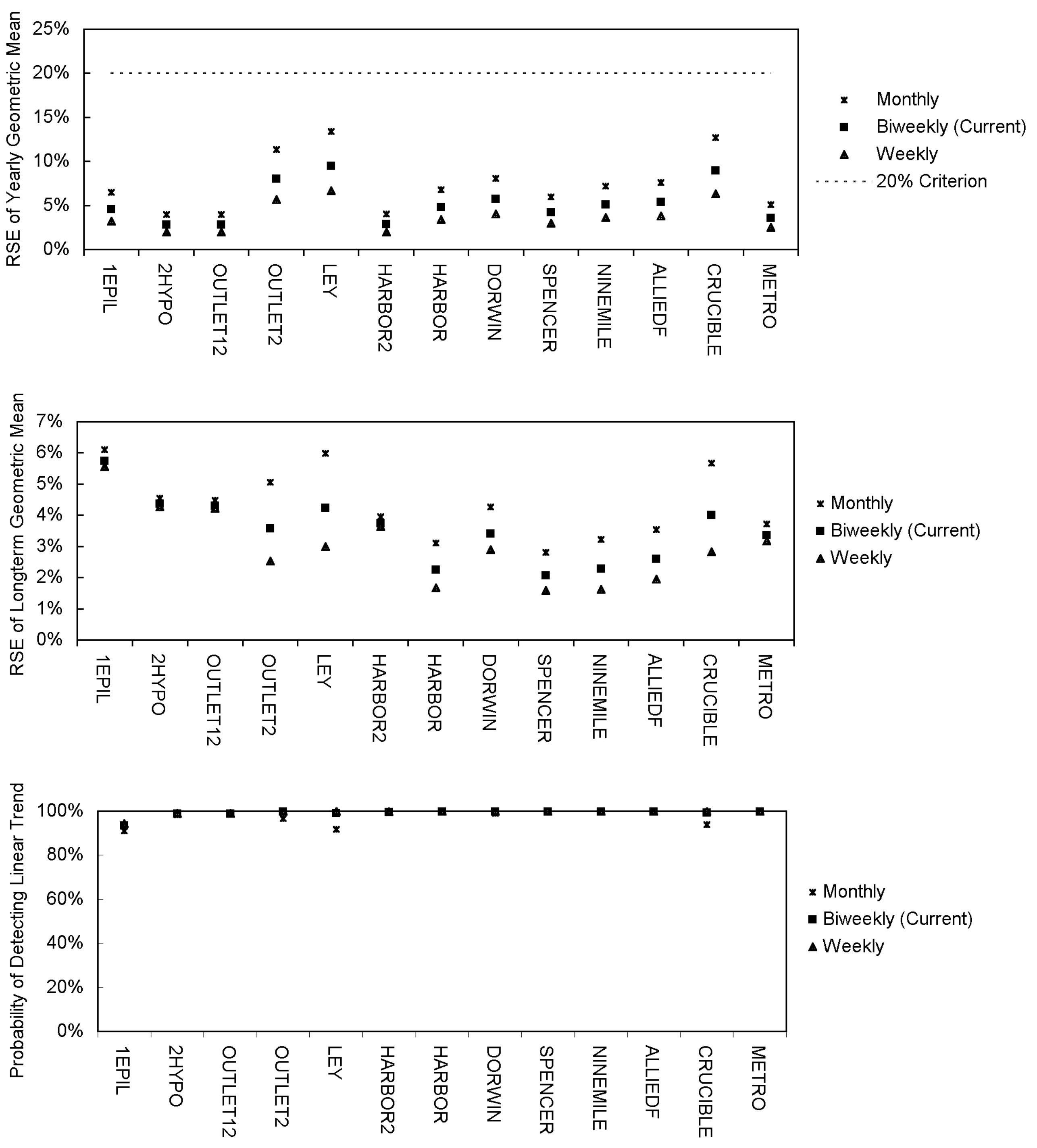
Precision & Power vs. Station & Sampling Frequency
Variable: Total Phosphorus



c -Relative Standard Error (RSE) of yearly geometric mean.
b -Relative Standard Error (RSE) of long-term geometric mean calculated from 5 years of data
c -Probability of detecting hypothetical trend of 5%/yr based upon 10 years of data.

Figure

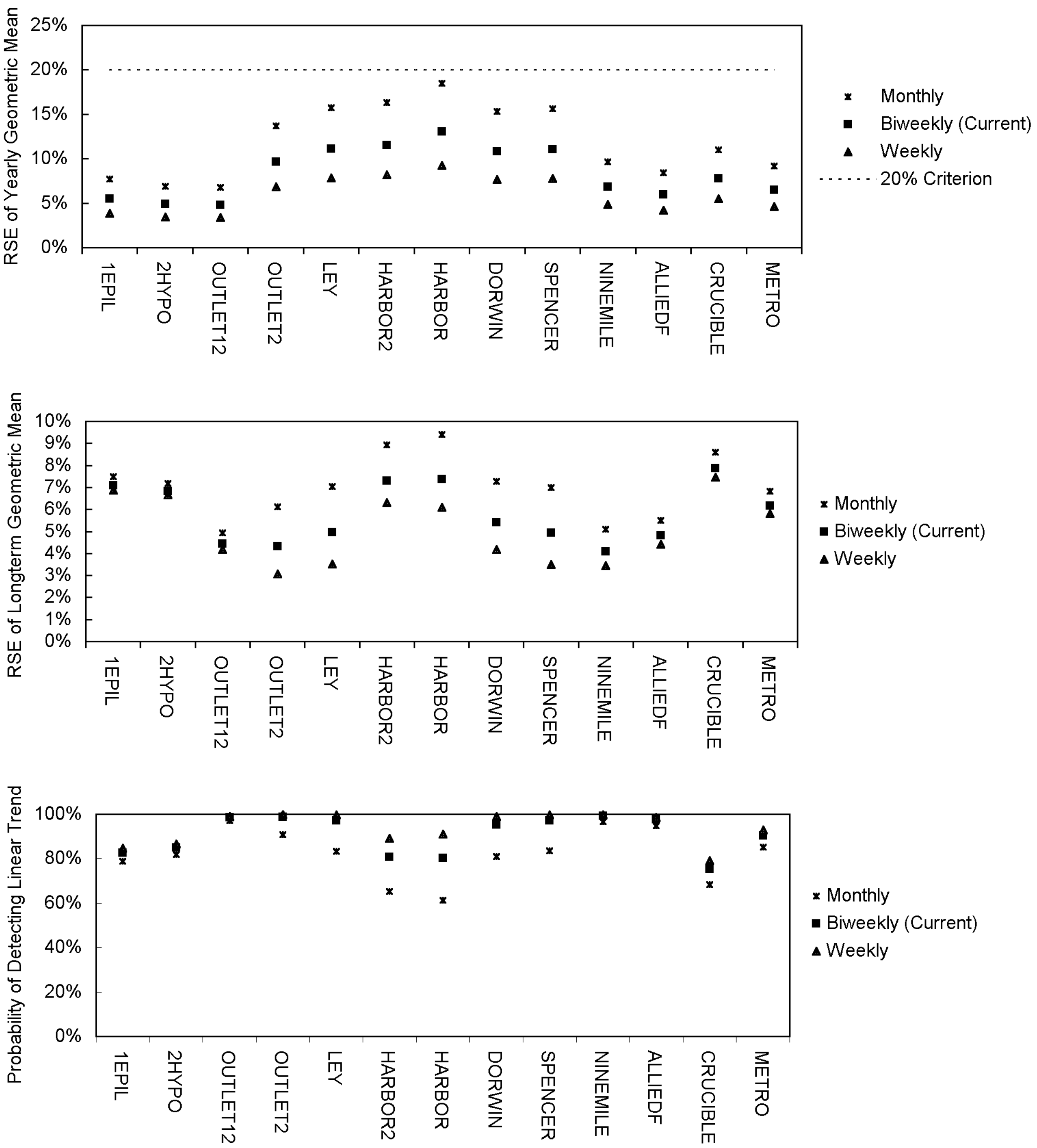
Precision & Power vs. Station & Sampling Frequency
Variable: Total Nitrogen



c -Relative Standard Error (RSE) of yearly geometric mean.
b -Relative Standard Error (RSE) of long-term geometric mean calculated from 5 years of data
c -Probability of detecting hypothetical trend of 5%/yr based upon 10 years of data.

Figure

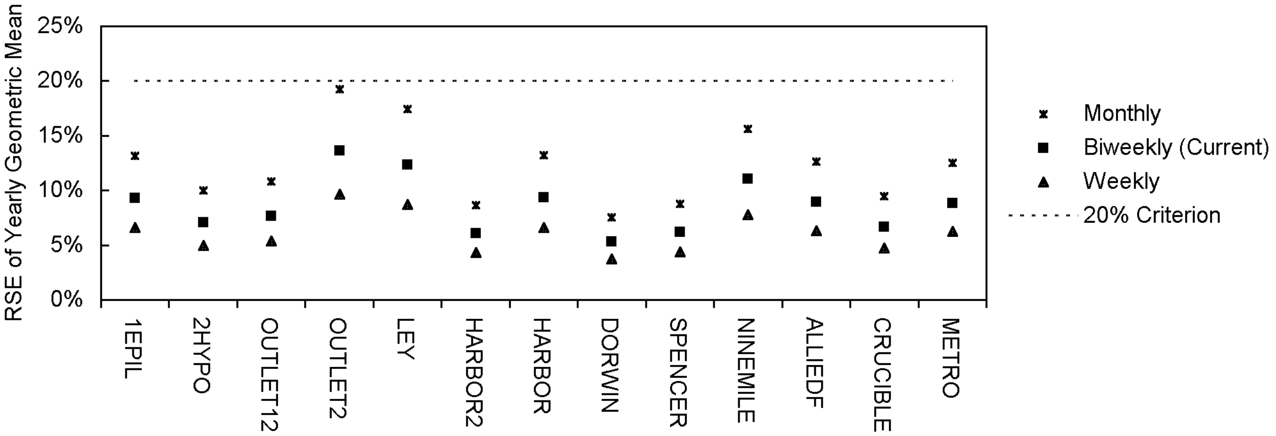
Precision & Power vs. Station & Sampling Frequency
Variable: Total Kjeldahl Nitrogen

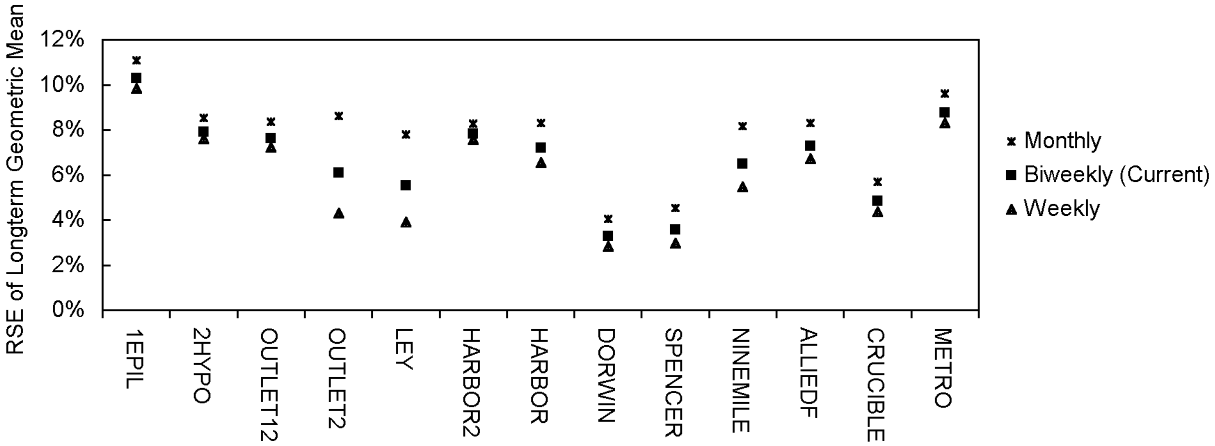


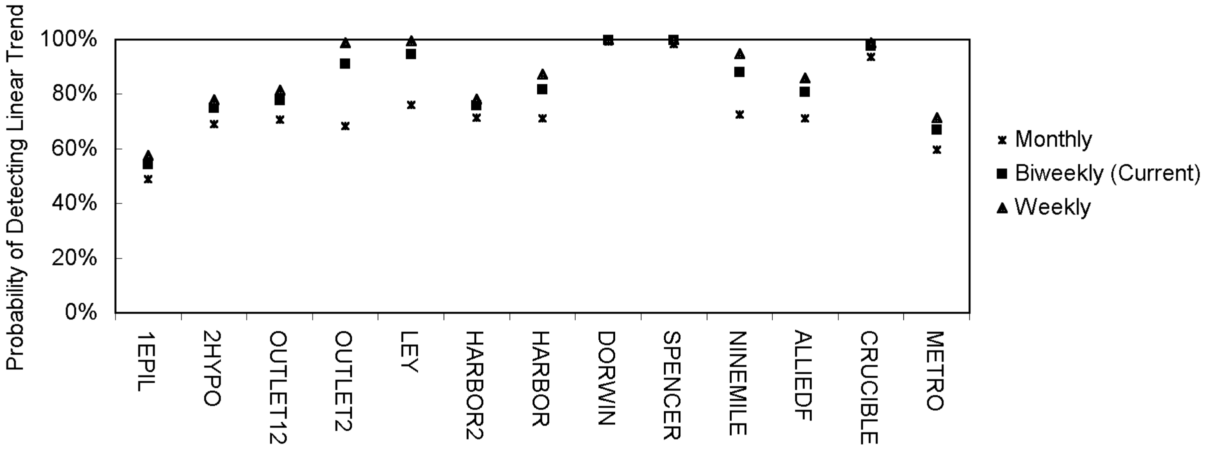
c -Relative Standard Error (RSE) of yearly geometric mean.
b -Relative Standard Error (RSE) of long-term geometric mean calculated from 5 years of data
c -Probability of detecting hypothetical trend of 5%/yr based upon 10 years of data.

Figure

Precision & Power vs. Station & Sampling Frequency
Variable: Ammonia Nitrogen



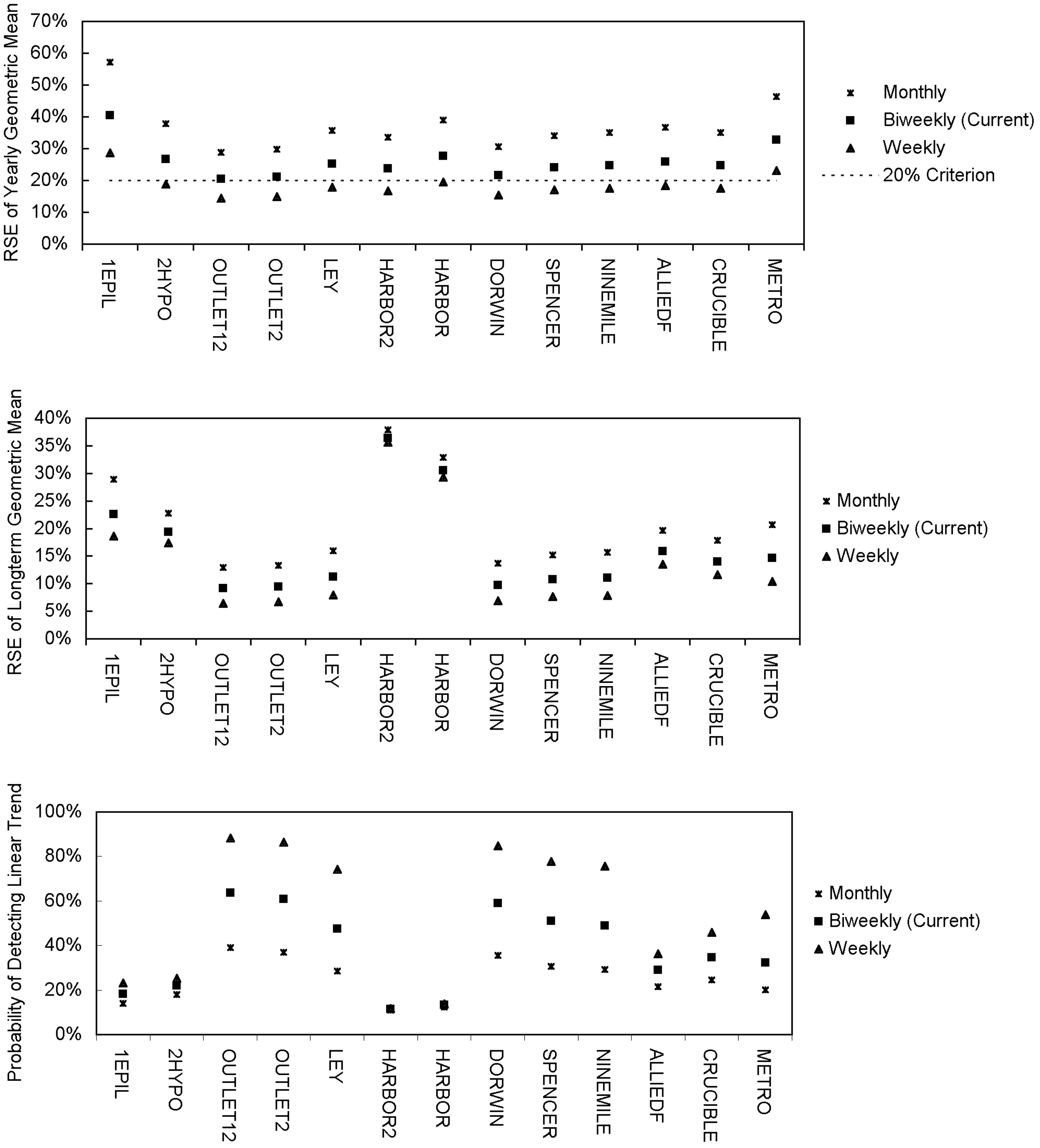




c -Relative Standard Error (RSE) of yearly geometric mean.
b -Relative Standard Error (RSE) of long-term geometric mean calculated from 5 years of data
c -Probability of detecting hypothetical trend of 5%/yr based upon 10 years of data.

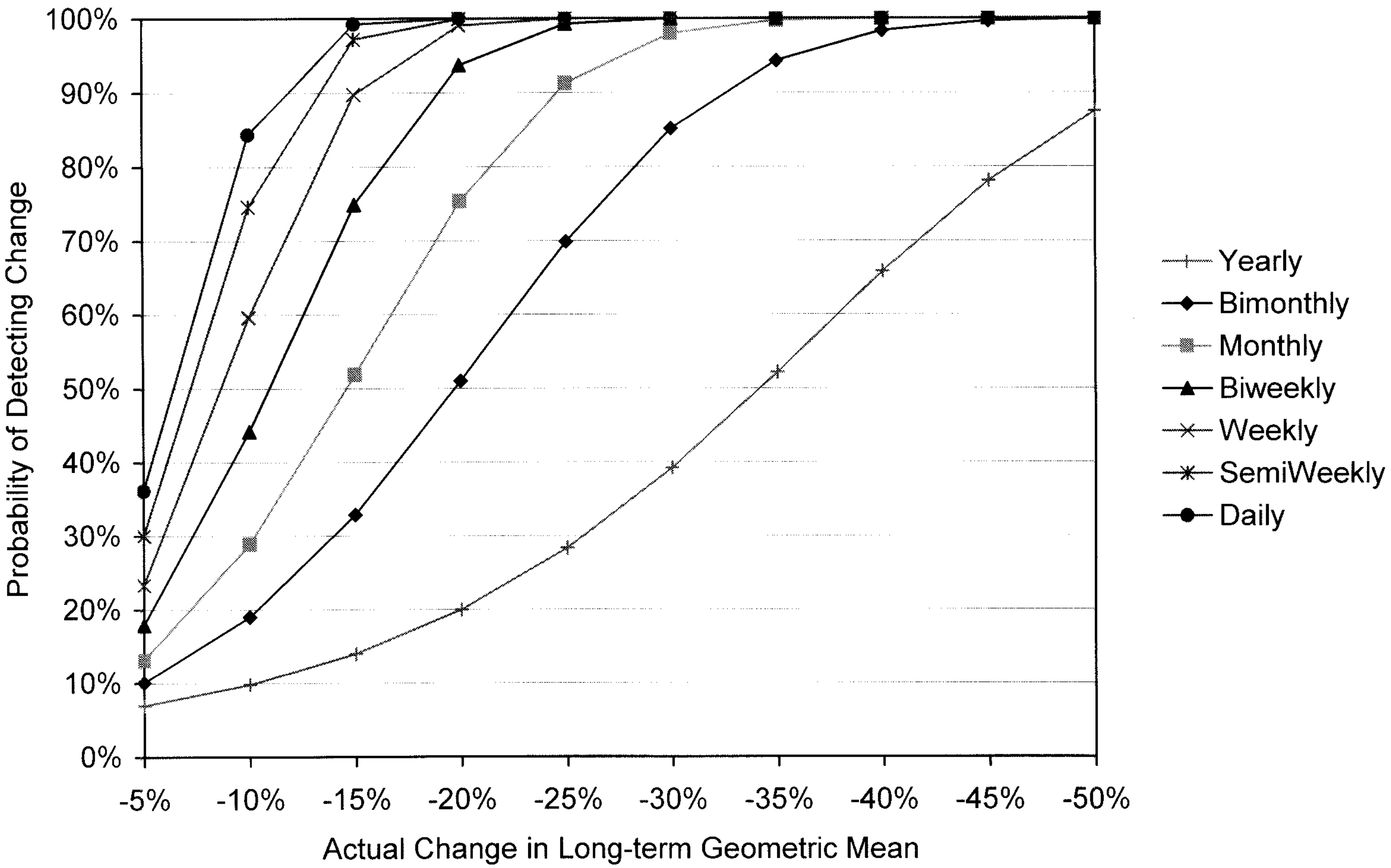
Figure

Precision & Power vs. Station & Sampling Frequency
Variable: Fecal Coliforms



c -Relative Standard Error (RSE) of yearly geometric mean.
b -Relative Standard Error (RSE) of long-term geometric mean calculated from 5 years of data
c -Probability of detecting hypothetical trend of 5%/yr based upon 10 years of data.

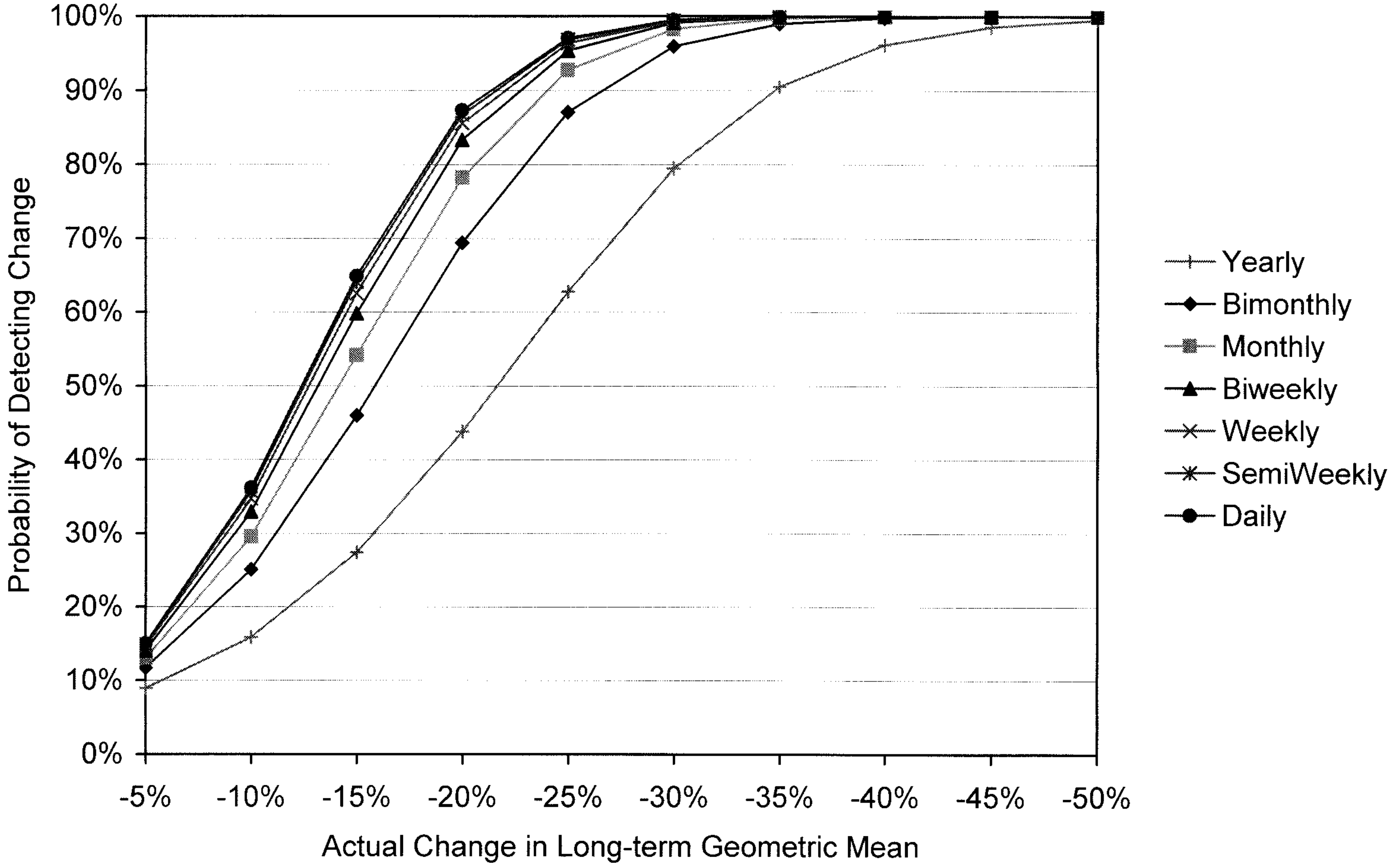
Power Curves for Detecting Reductions in Phosphorus Concentration



Station: Lake Epilimnion.
Probability of detecting a step decrease of specified magnituce based upon 10 years of monitoring data with change occuring after year 5, sampling at specified frequencies.

Figure

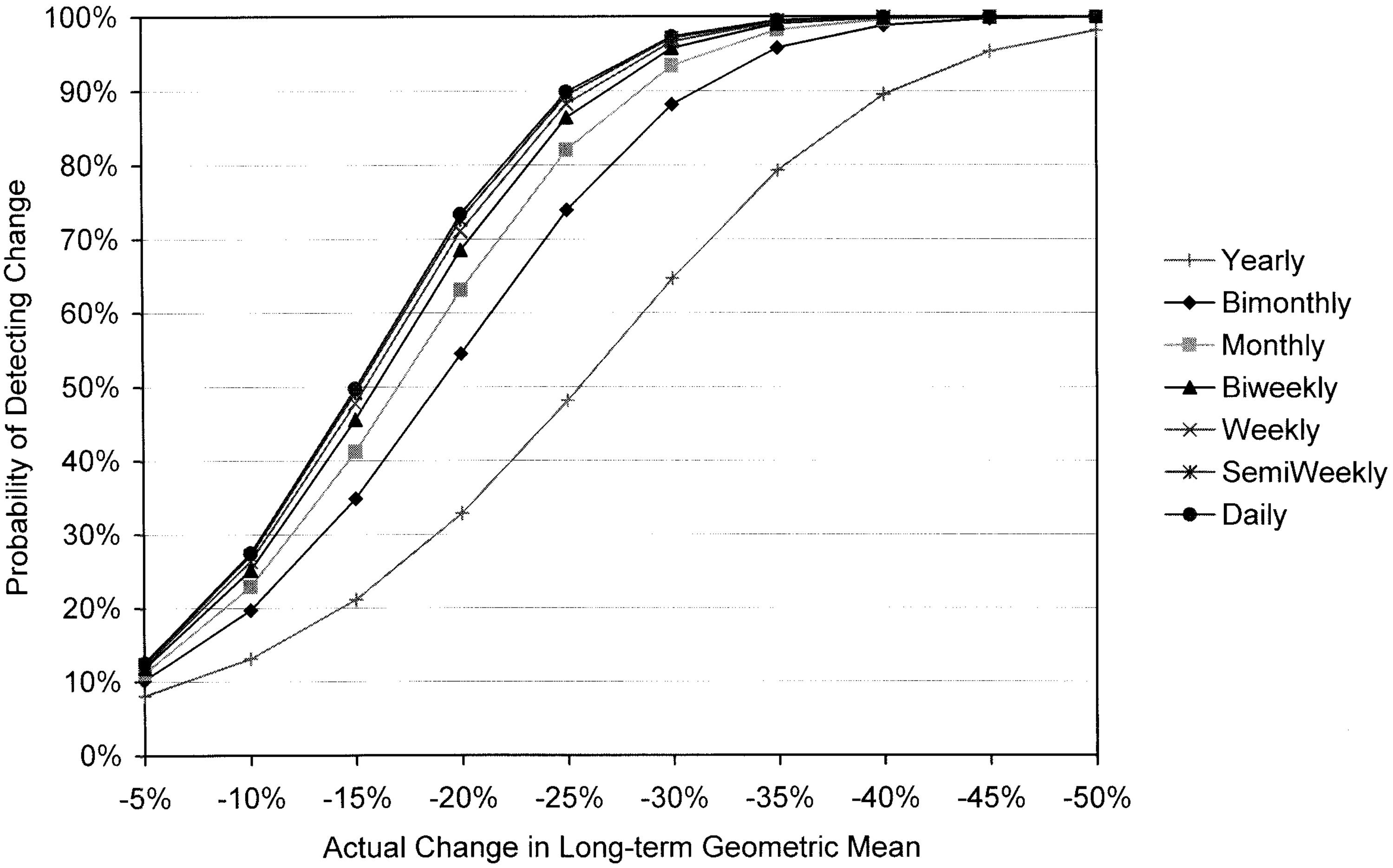
Power Curves for Detecting Reductions in Total Nitrogen Concentration



Station: Lake Epilimnion.
Probability of detecting a step decrease of specified magnituce based upon 10 years of monitoring data with change occuring after year 5, sampling at specified frequencies.

Figure

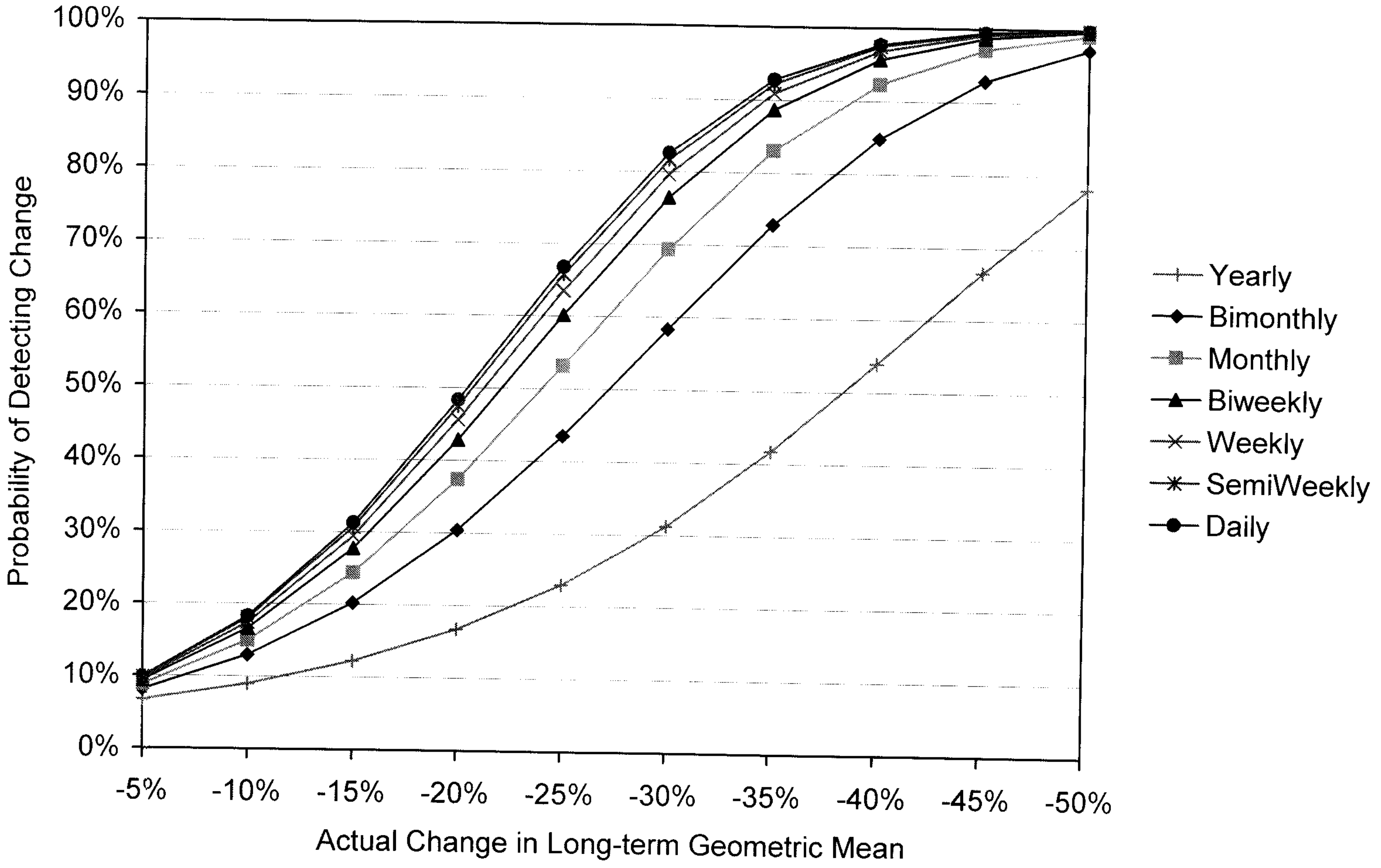
Power Curves for Detecting Reductions in TKN Concentration



Station: Lake Epilimnion.
Probability of detecting a step decrease of specified magnituce based upon 10 years of monitoring data with change occuring after year 5, sampling at specified frequencies.

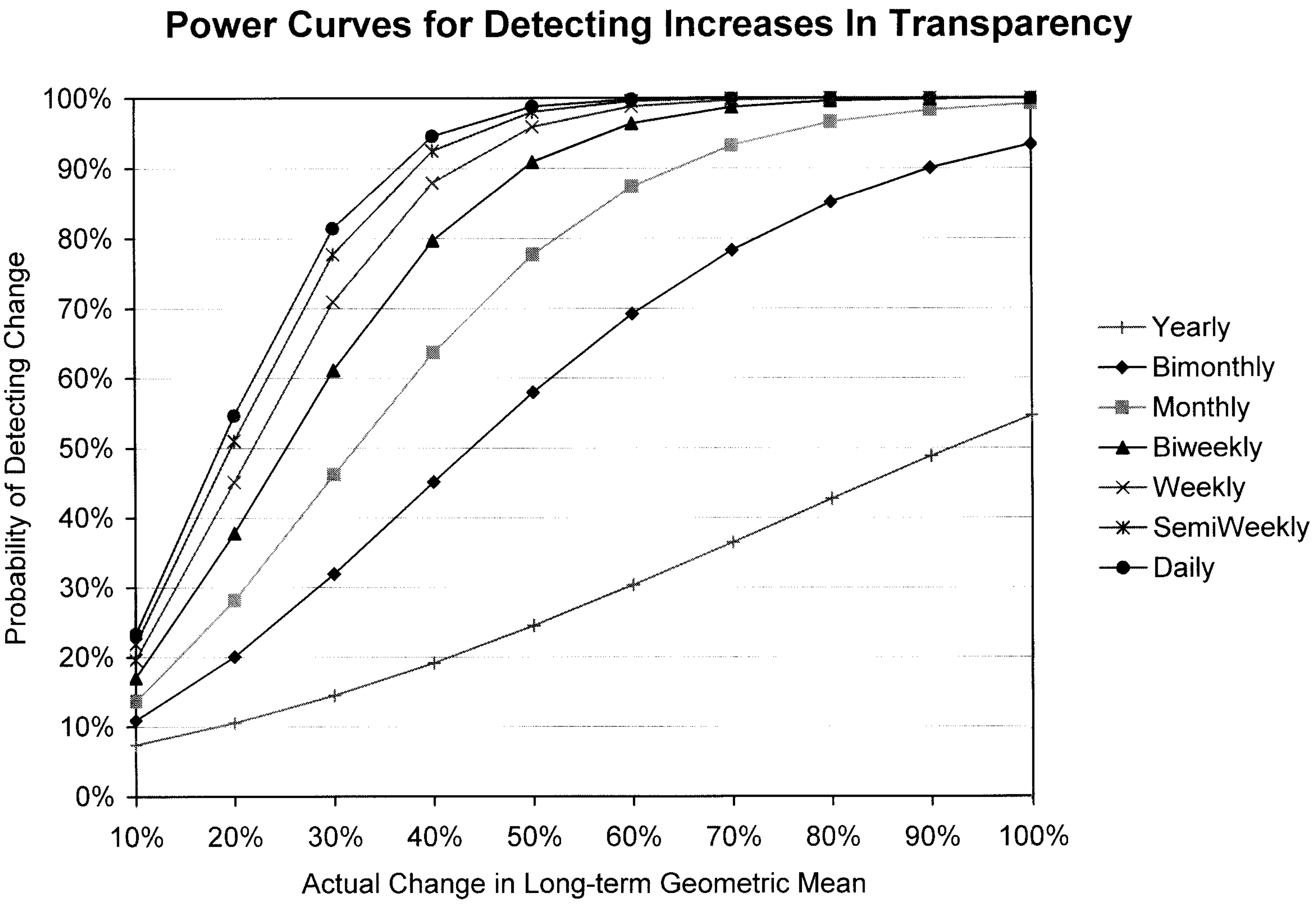
Figure

Power Curves for Detecting Reductions in Ammonia Nitrogen Concentration



Station: Lake Epilimnion.

Probability of detecting a step decrease of specified magnituce based upon 10 years of monitoring data with change occuring after year 5, sampling at specified frequencies.

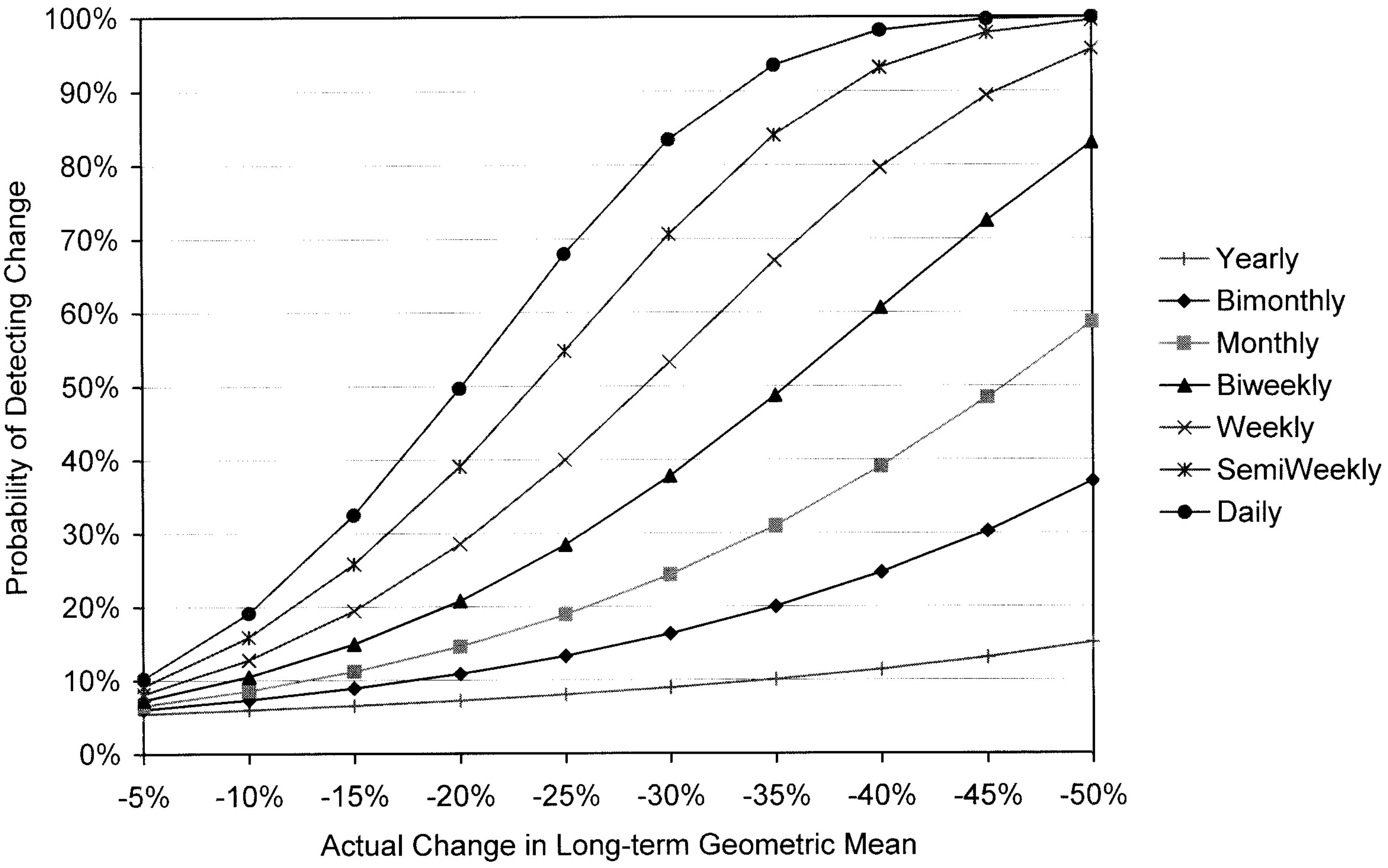


Station: Lake Epilimnion.
Probability of detecting a step increase of specified magnitude based upon 10 years of monitoring data with change occuring after year 5, sampling at specified frequencies.

Figure

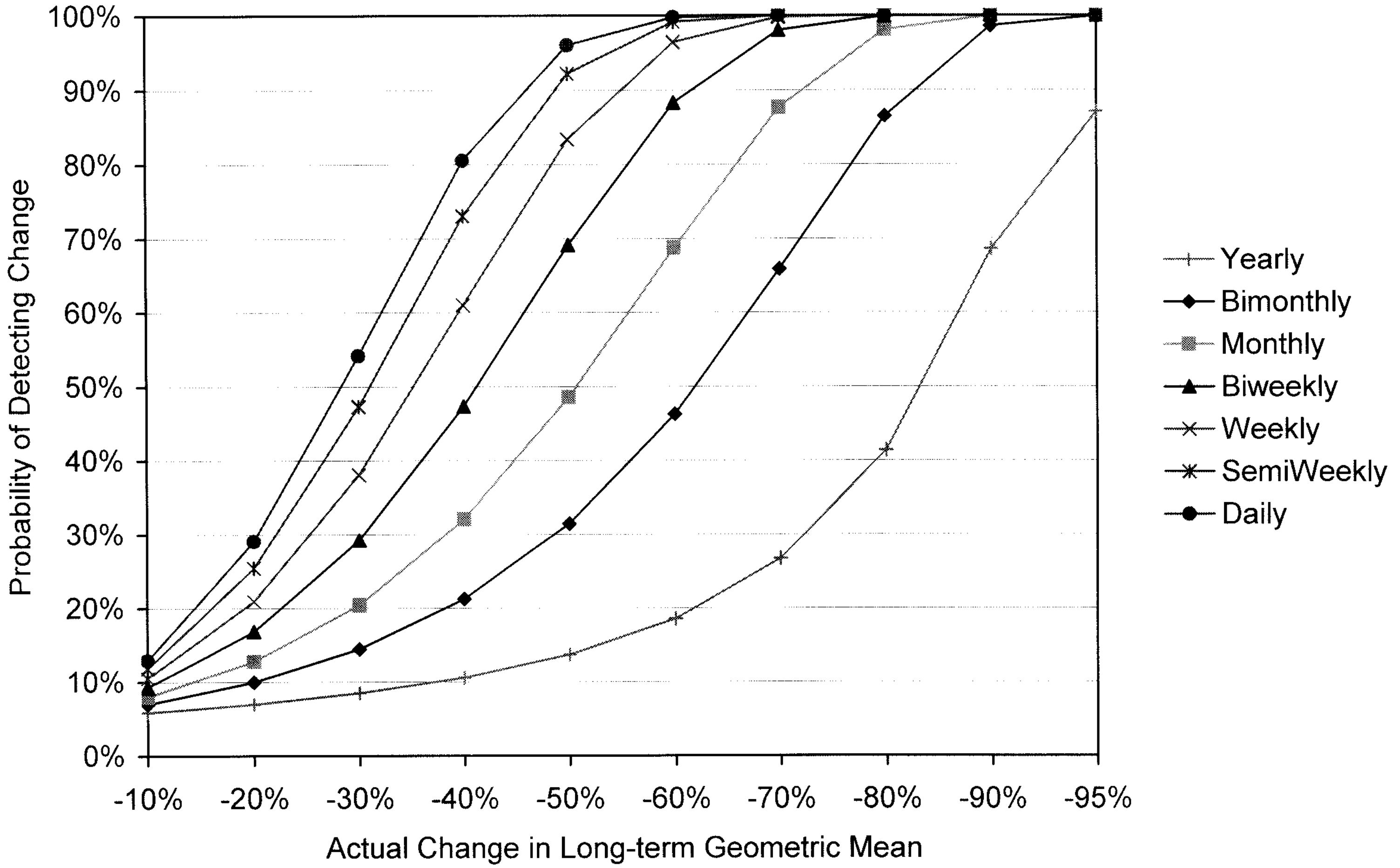
Figure

Power Curves for Detecting Reductions in Chlorophyll-a Concentration



Station: Lake Epilimnion.
Probability of detecting a step decrease of specified magnituce based upon 10 years of monitoring data with change occuring after year 5, sampling at specified frequencies.

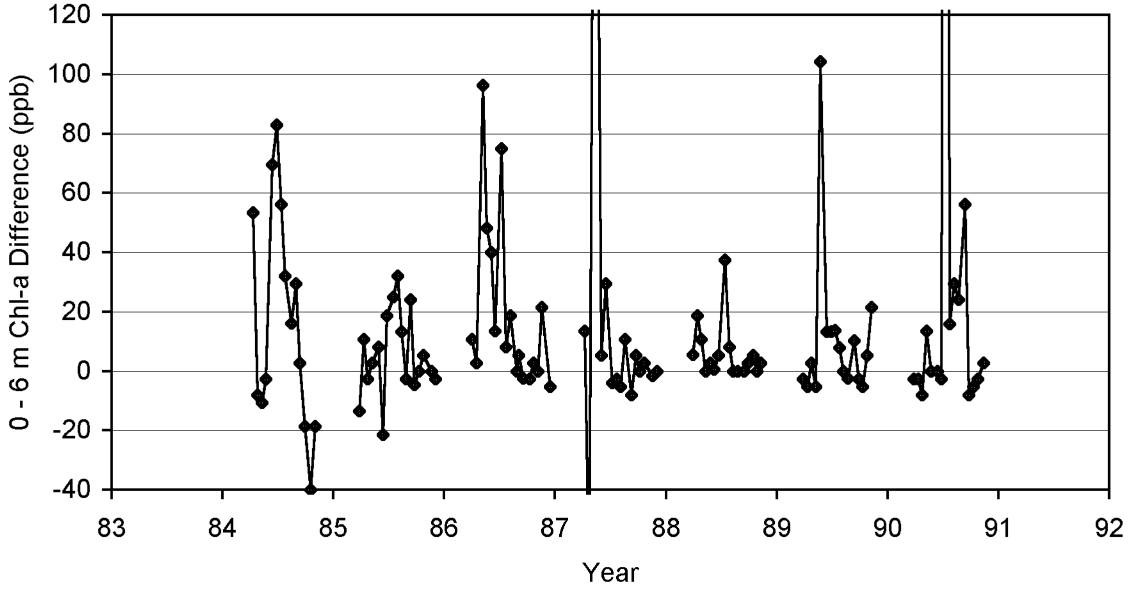
Power Curves for Detecting Reductions in Fecal Coliform Counts



Station: Lake Epilimnion.
Probability of detecting a step decrease of specified magnituce based upon 10 years of monitoring data with change occuring after year 5, sampling at specified frequencies.

Figure

Vertical Chlorophyll-a Gradients, 1984-1990

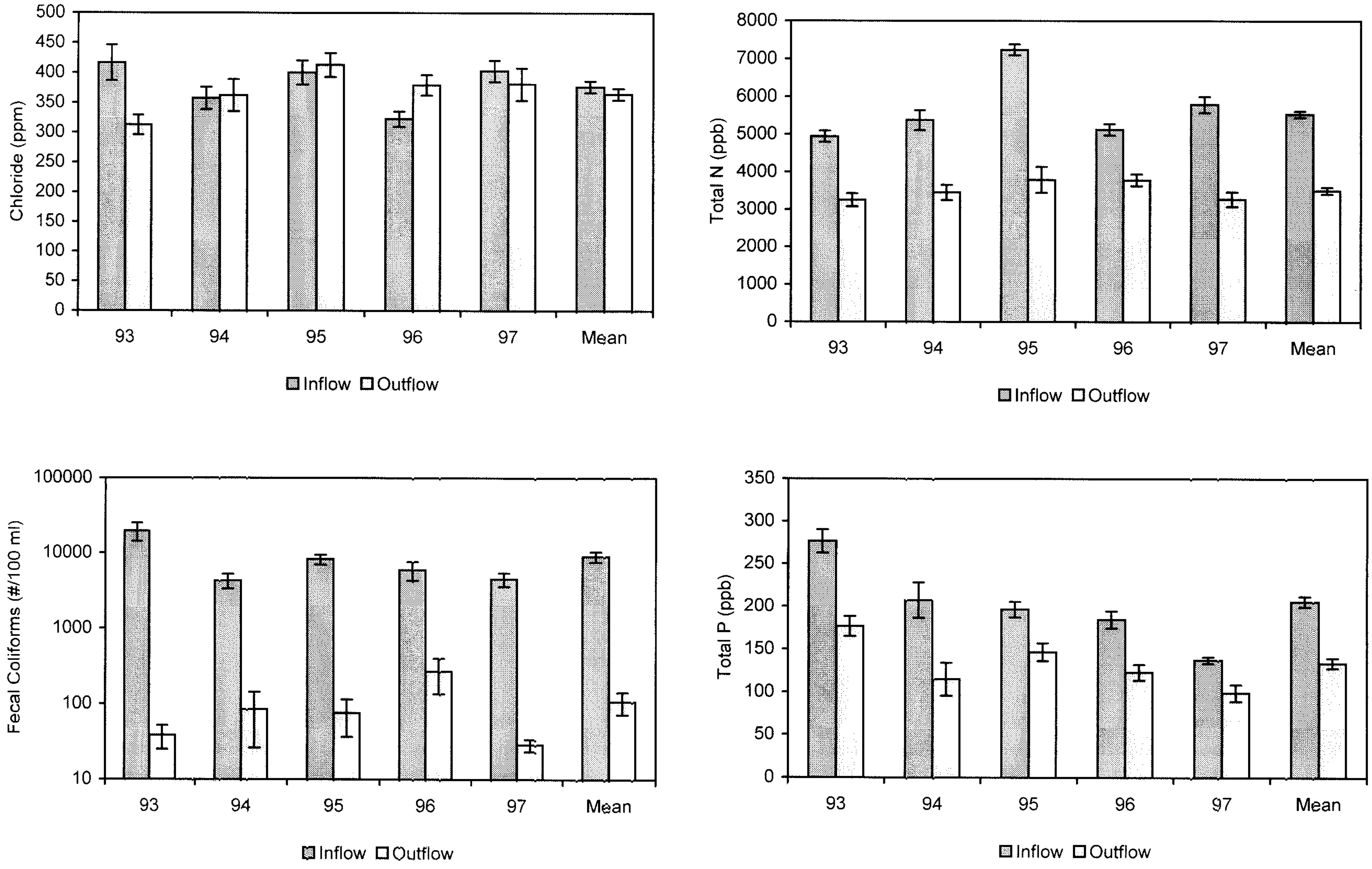


Y = Chlorophyll-a at 0 meters (ppb) - Chlorophyll-a at 6 meters (ppb)

Figur

Figure

Yearly Lake Inflow & Outflow Concentrations

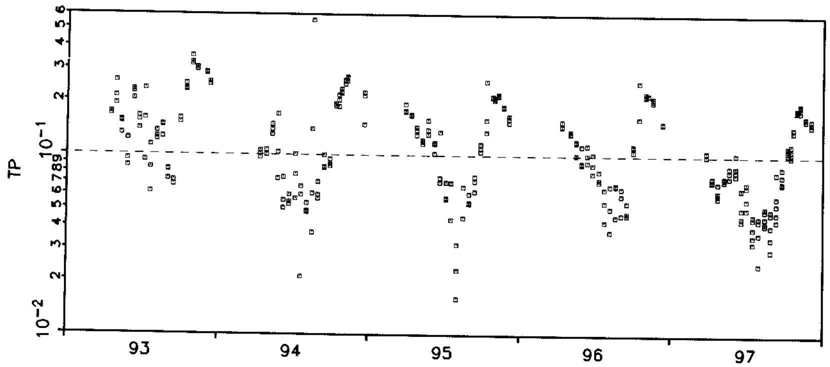


Means +/- 1 Standard Error

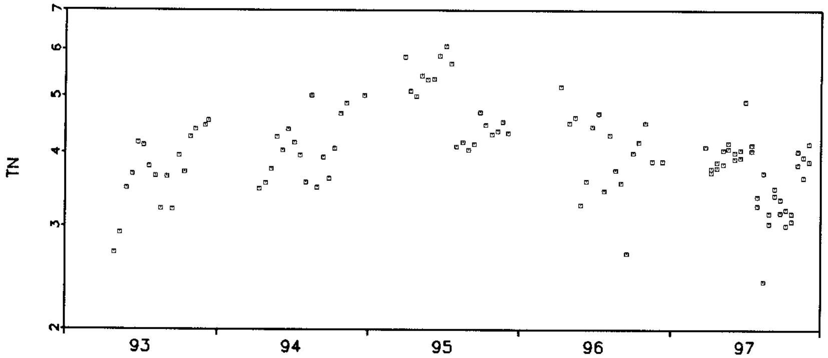
Appendix A

Time Series Plots
1993-1997

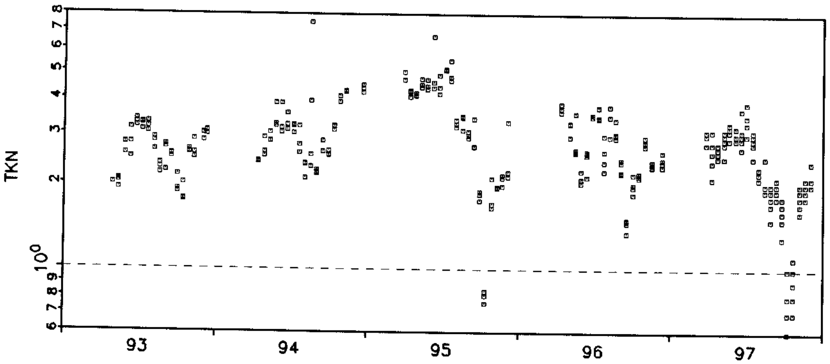
Jan-Dec Epilimnion Station = SOUTH



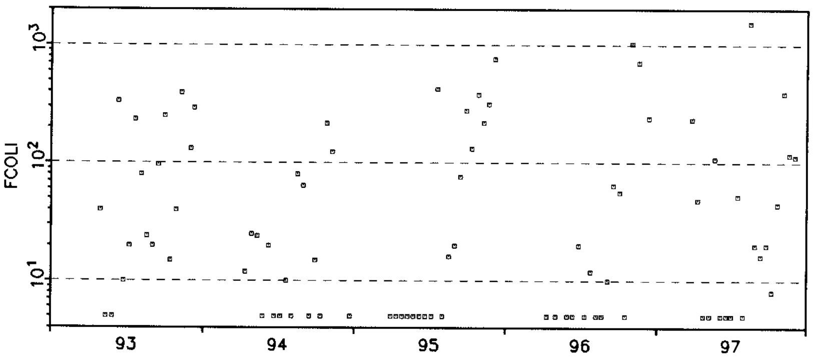
Jan-Dec Epilimnion Station = SOUTH



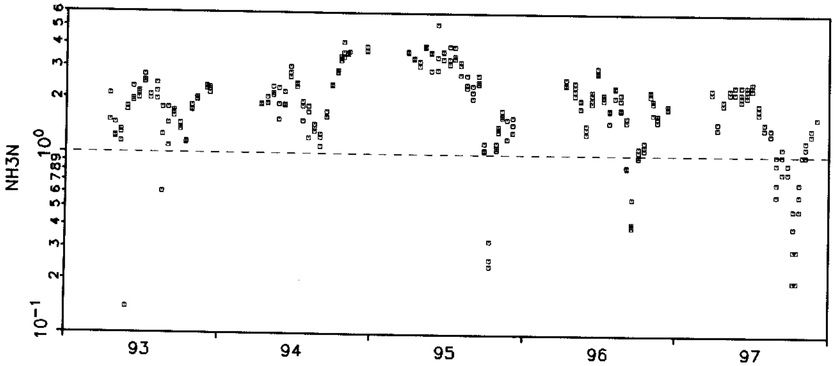
Jan-Dec Epilimnion Station = SOUTH



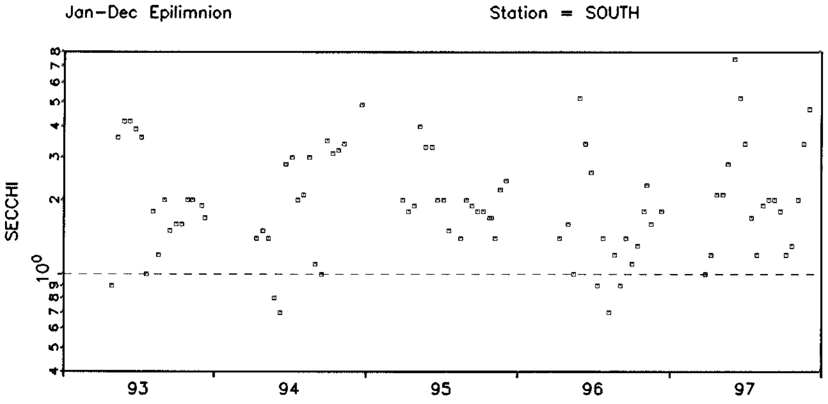
Jan-Dec Epilimnion Station = SOUTH

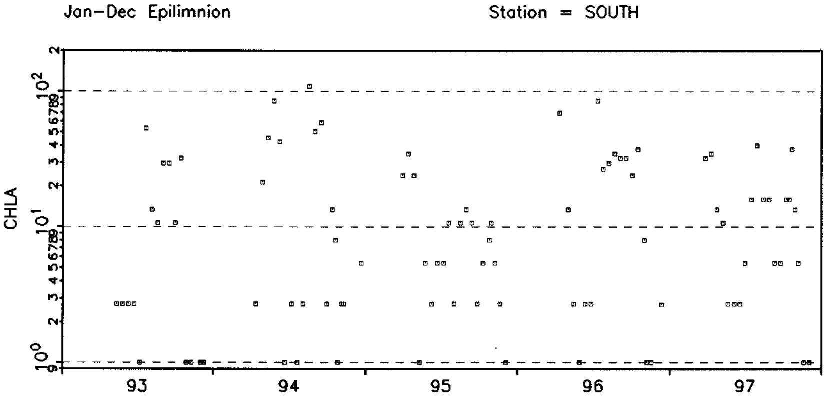


Jan-Dec Epilimnion Station = SOUTH

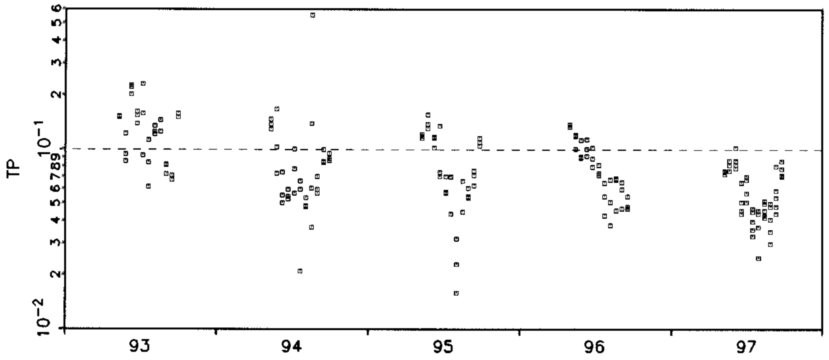


A.

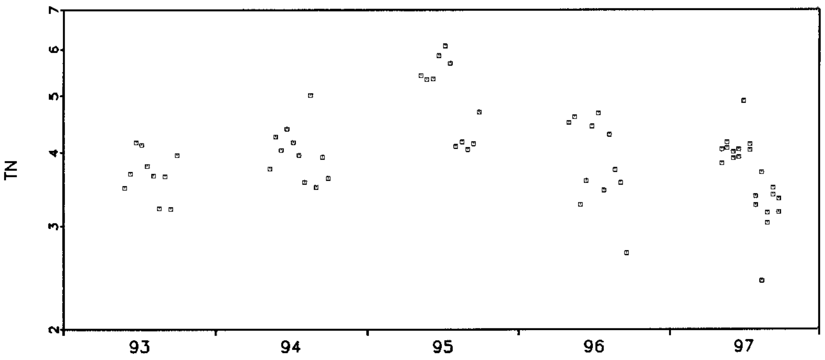

Jan-Dec Epilimnion
Station = SOUTH
SECCHI
4
5
6
7
8
9
10^0
2
3
4
5
6
7
8
93
94
95
96
97


Jan-Dec Epilimnion
Station = SOUTH
CHLA
9
10^0
2
3
4
5
6
7
8
9
10^1
2
3
4
5
6
7
8
9
10^2
2
93
94
95
96
97

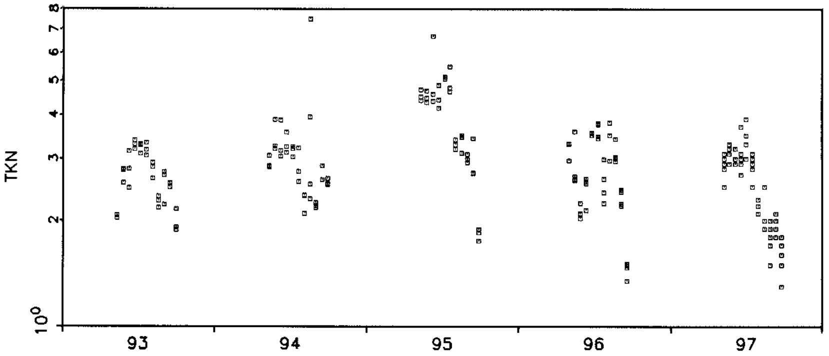
May–Sept Epilimnion Station = SOUTH



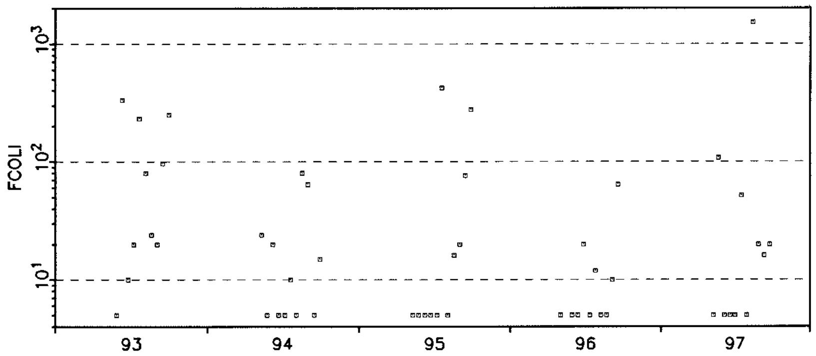
May–Sept Epilimnion Station = SOUTH



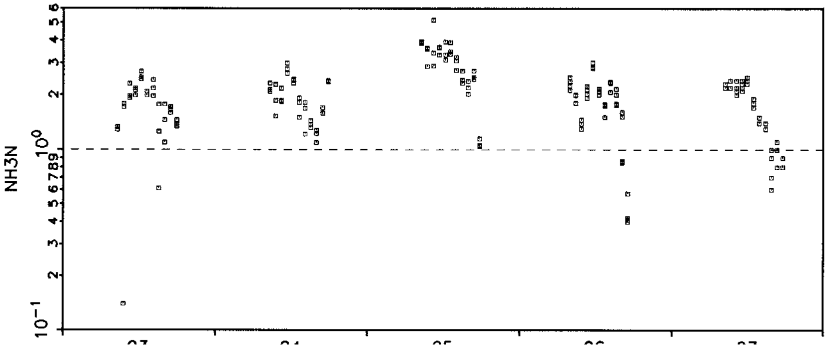
May–Sept Epilimnion Station = SOUTH

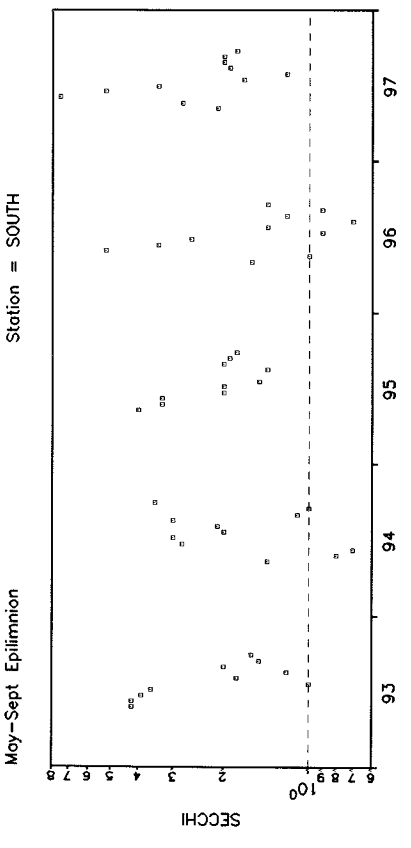


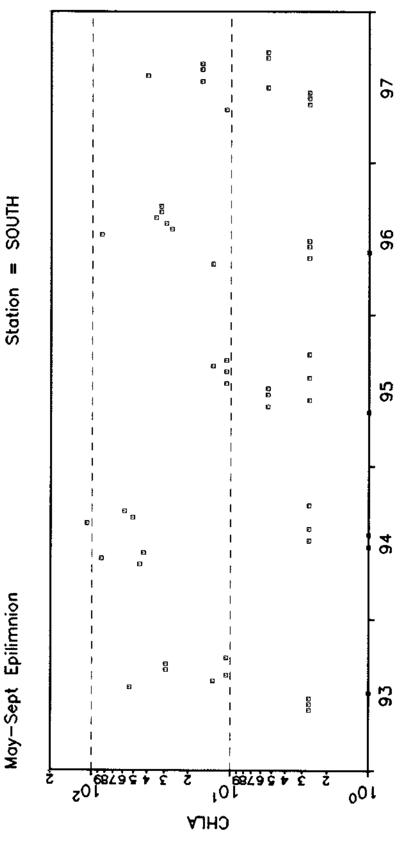
May–Sept Epilimnion Station = SOUTH

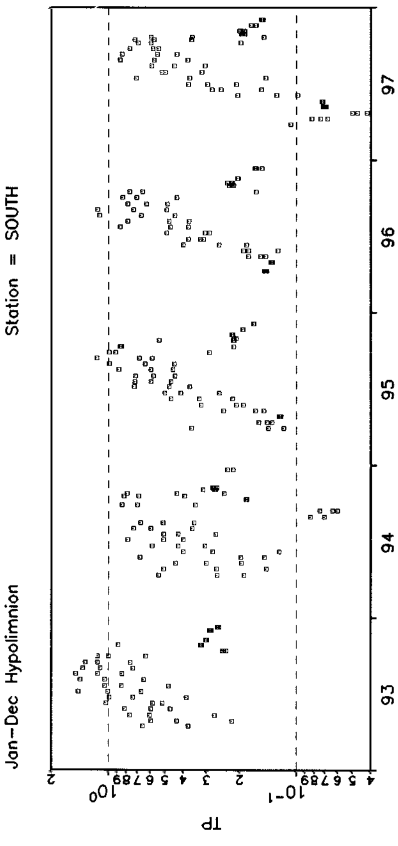


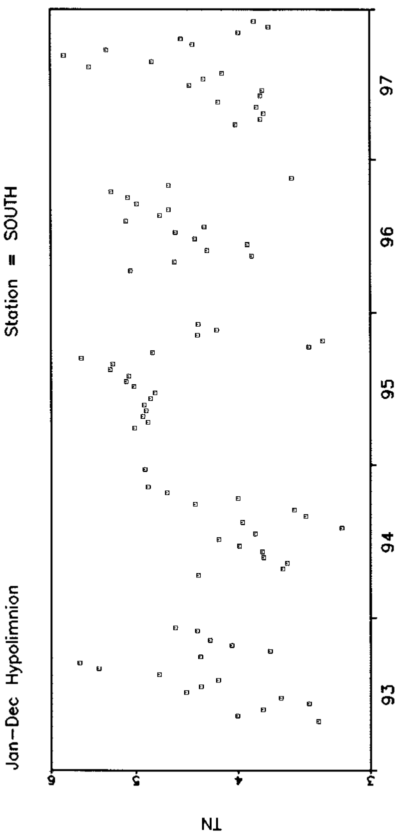
May–Sept Epilimnion Station = SOUTH

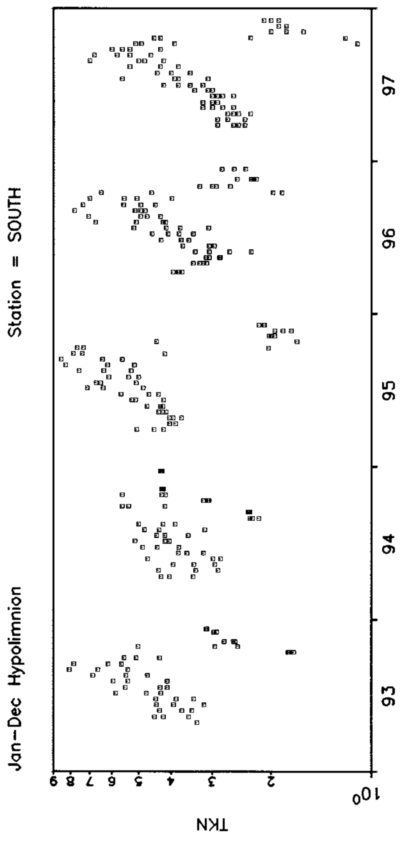


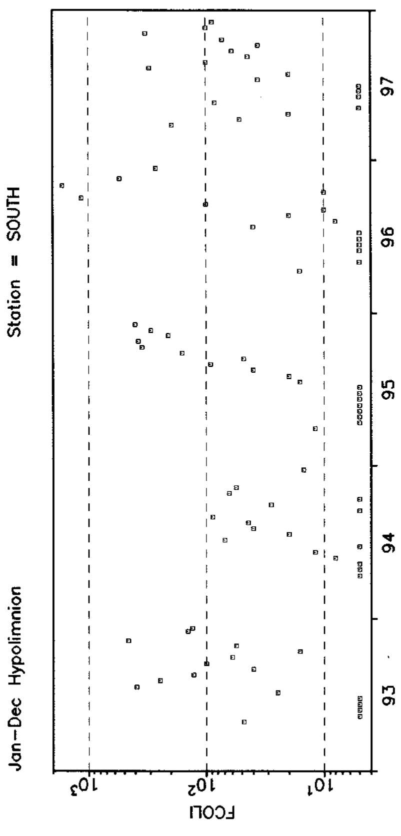

May-Sept Epilimnion
Station = SOUTH
SECCHI
10^0
2
3
4
5
6
7
8
9
93
94
95
96
97

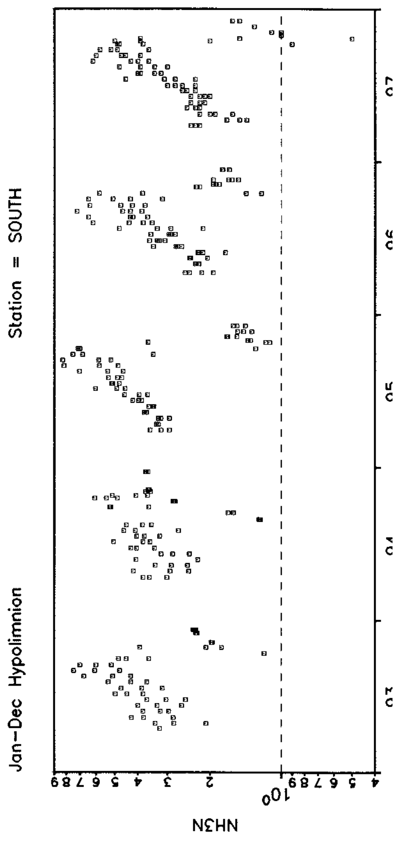

May-Sept Epilimnion
Station = SOUTH
CHLA
10^0
10^1
10^2
2
3
4
5
6
7
8
9
93
94
95
96
97

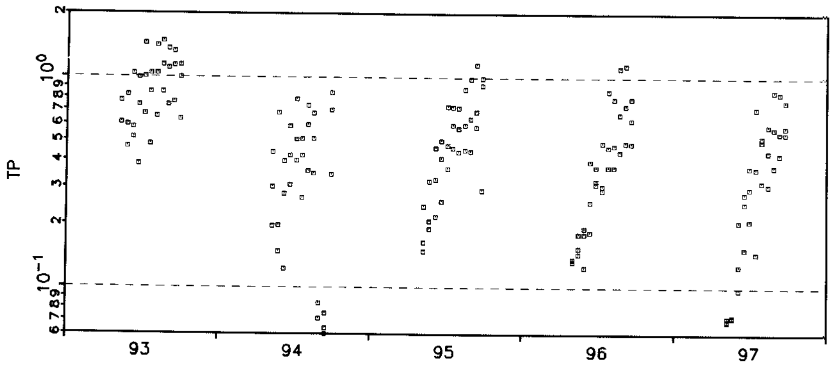

Jan-Dec Hypolimnion
Station = SOUTH
TP
10⁰
10⁻¹
2 3 4 5 6 7 8 9
93
94
95
96
97

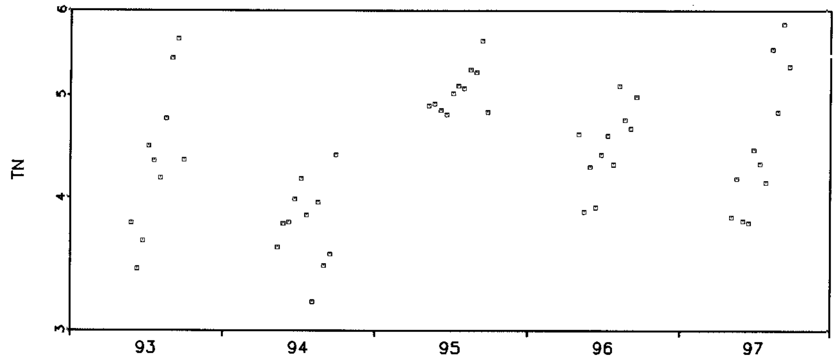

Jan-Dec Hypolimnion
Station = SOUTH
TN
3
4
5
6
93
94
95
96
97

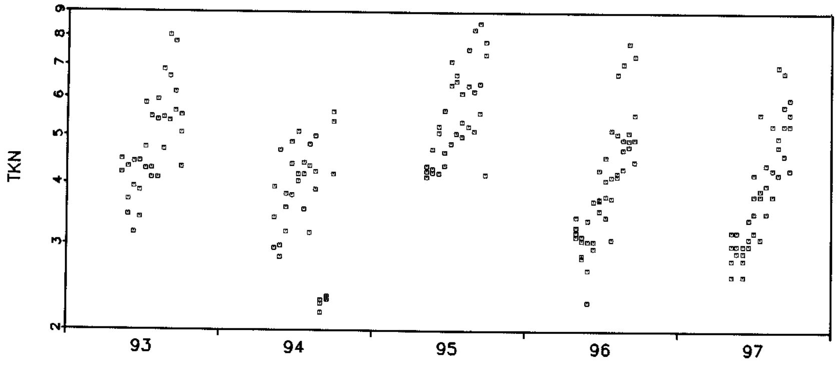

Jan-Dec Hypolimnion
Station = SOUTH
TKN
10⁰
2 3 4 5 6 7 8 9
93
94
95
96
97

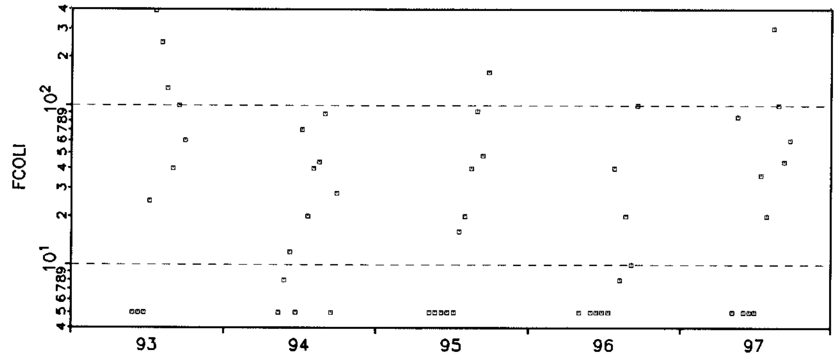

Jan-Dec Hypolimnion
Station = SOUTH
FCOLI
10¹
10²
10³
93
94
95
96
97

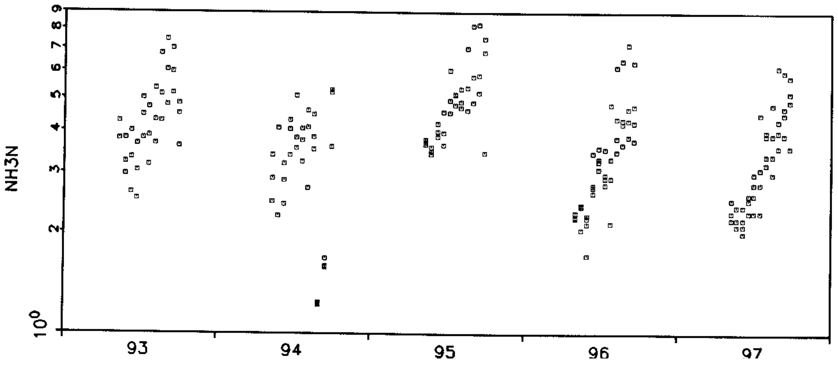

Jan-Dec Hypolimnion
Station = SOUTH
NH3N
10⁰
2 3 4 5 6 7 8 9
93
94
95
96
97

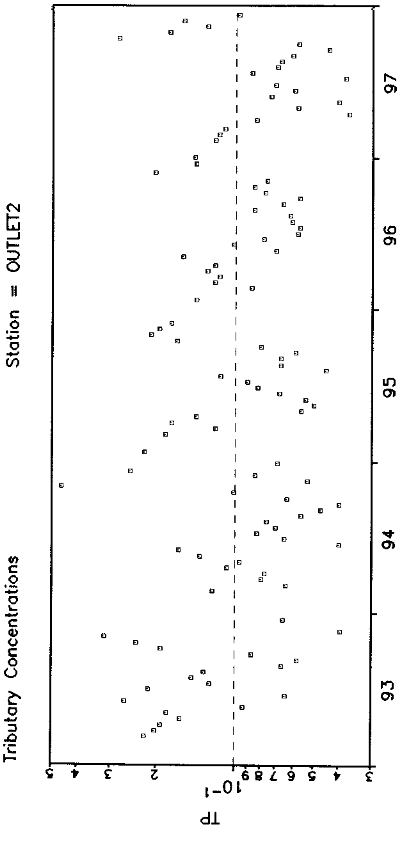

May-Sept Hypolimnion Station = SOUTH

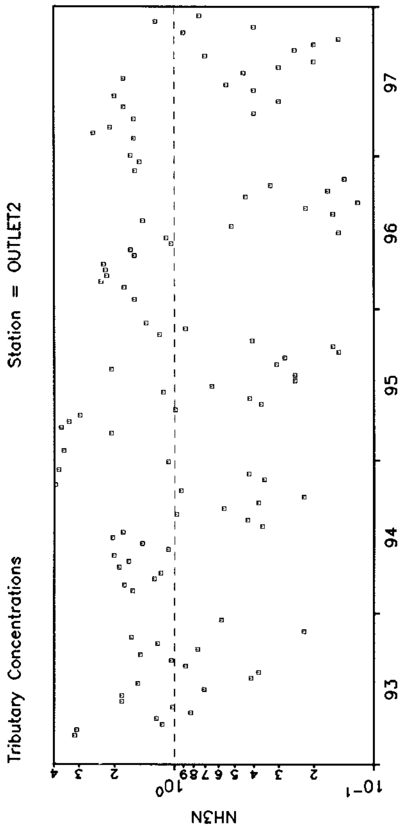

May-Sept Hypolimnion Station = SOUTH

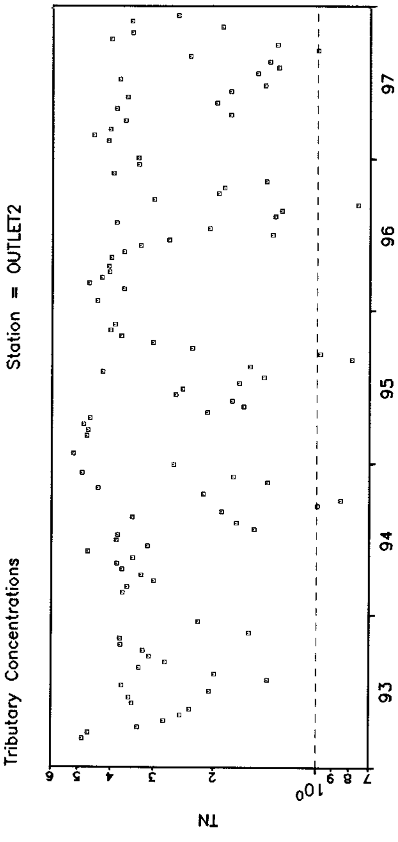

May-Sept Hypolimnion Station = SOUTH

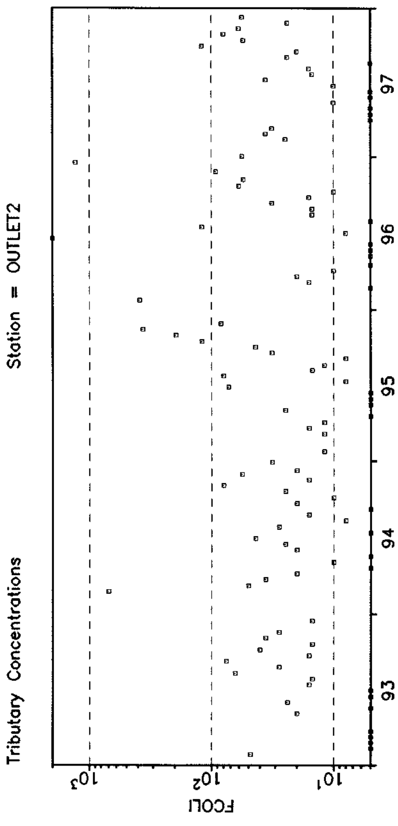

May-Sept Hypolimnion Station = SOUTH

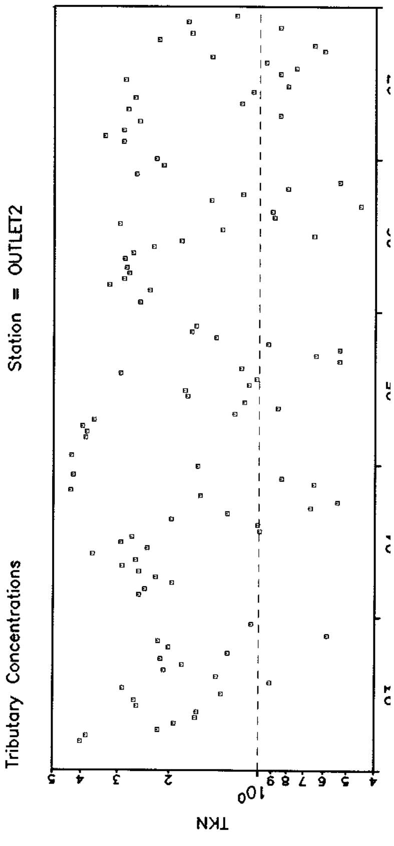

May-Sept Hypolimnion Station = SOUTH

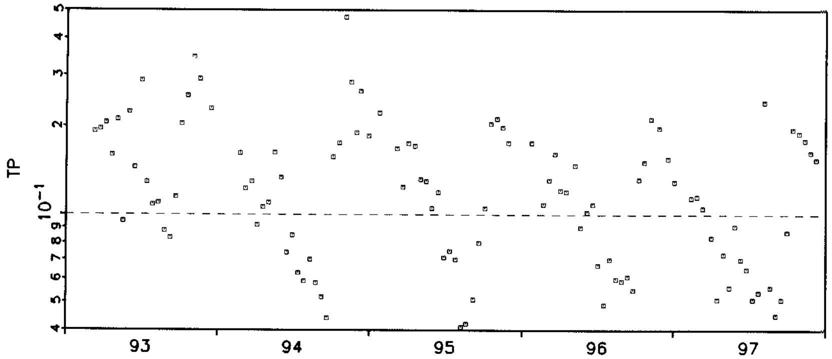

Tributary Concentrations
Station = OUTLET2
TP
5
4
3
2
10^-1
9
8
7
6
5
4
3
93
94
95
96
97

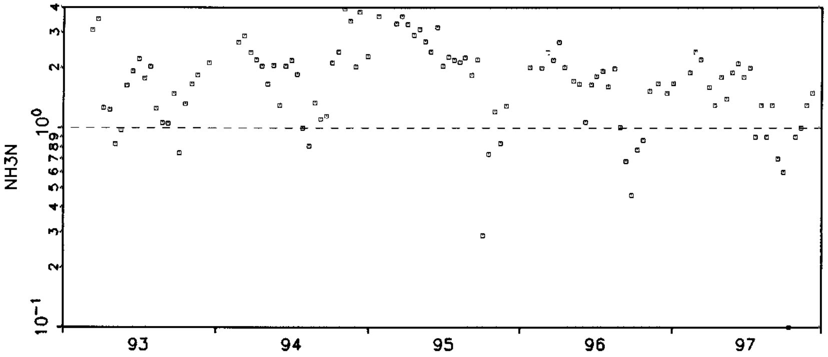

Tributary Concentrations
Station = OUTLET2
NH3N
4
3
2
10^0
9
8
7
6
5
4
3
2
10^-1
93
94
95
96
97

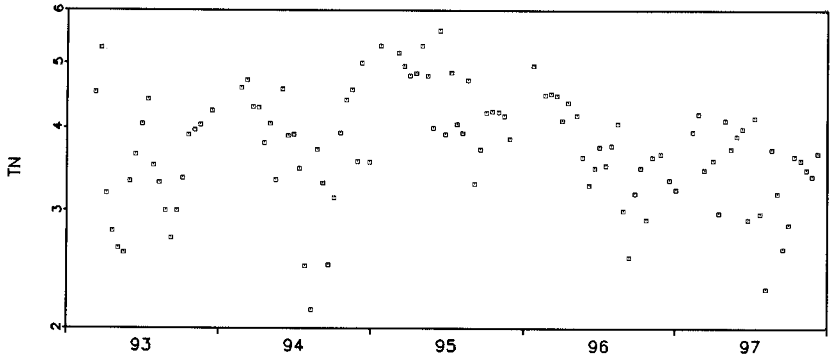

Tributary Concentrations
Station = OUTLET2
TN
6
5
4
3
2
10^0
9
8
7
93
94
95
96
97

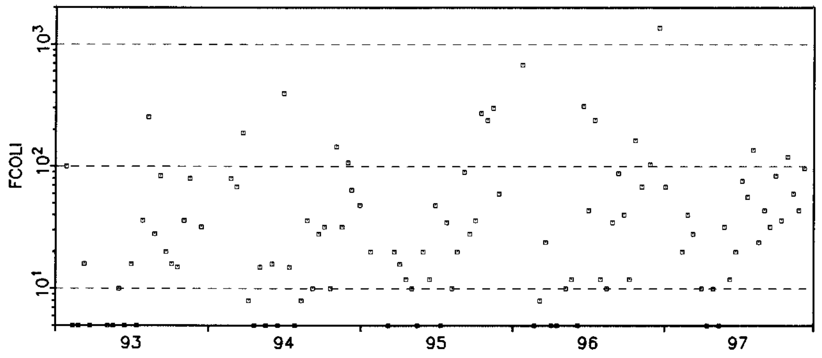

Tributary Concentrations
Station = OUTLET2
FCOLI
10^3
10^2
10^1
93
94
95
96
97

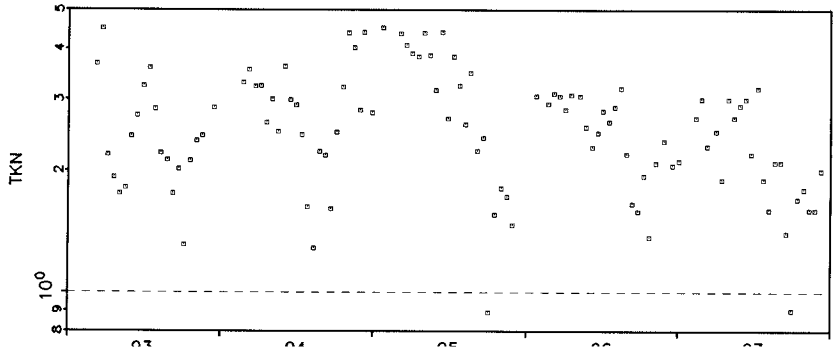

Tributary Concentrations
Station = OUTLET2
TKN
5
4
3
2
10^0
9
8
7
6
5
4


Tributary Concentrations Station = OUTLET12

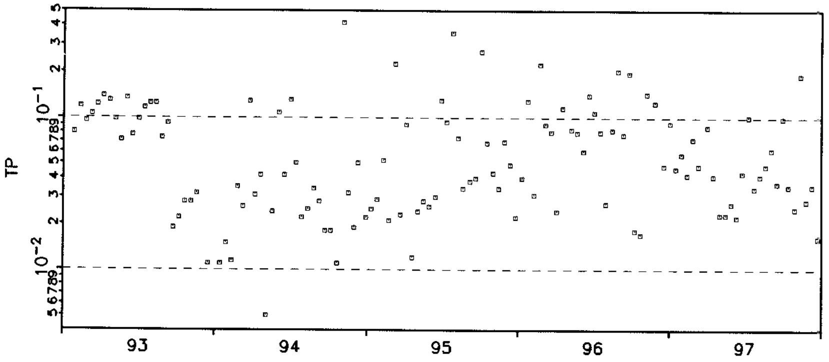

Tributary Concentrations Station = OUTLET12


Tributary Concentrations Station = OUTLET12

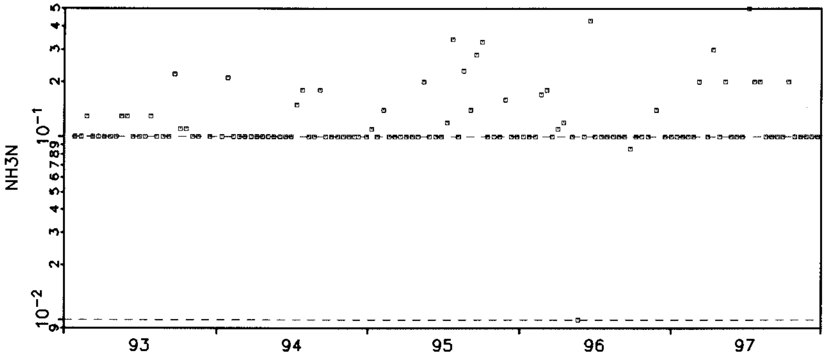

Tributary Concentrations Station = OUTLET12


Tributary Concentrations Station = OUTLET12

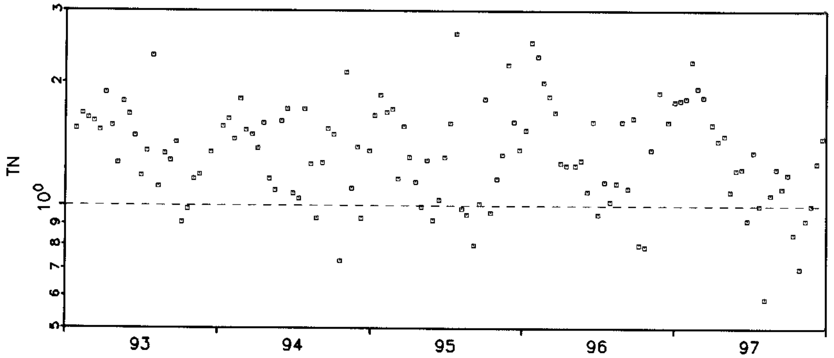
Tributary Concentrations Station = SPENCER



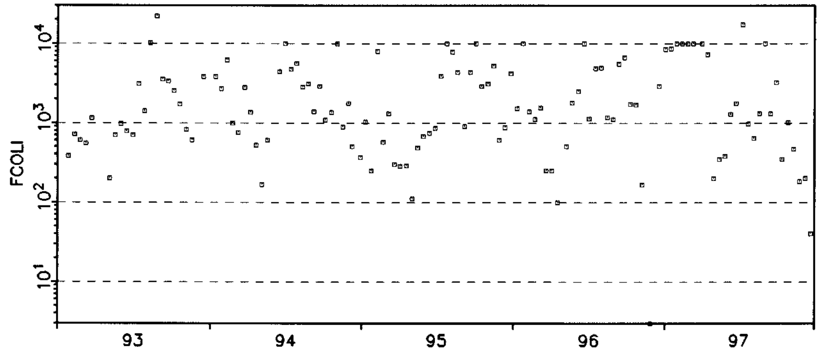
Tributary Concentrations Station = SPENCER



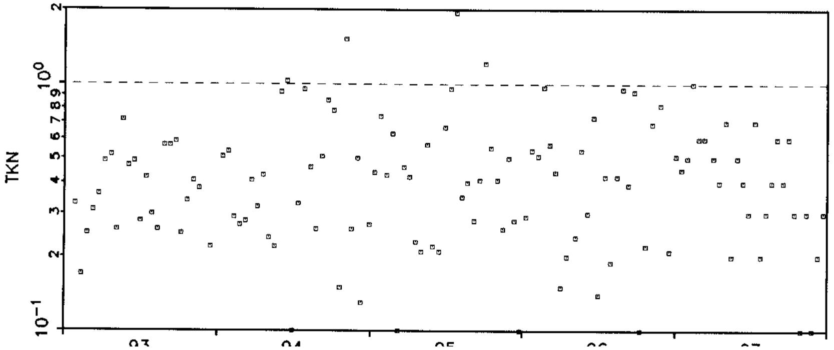
Tributary Concentrations Station = SPENCER



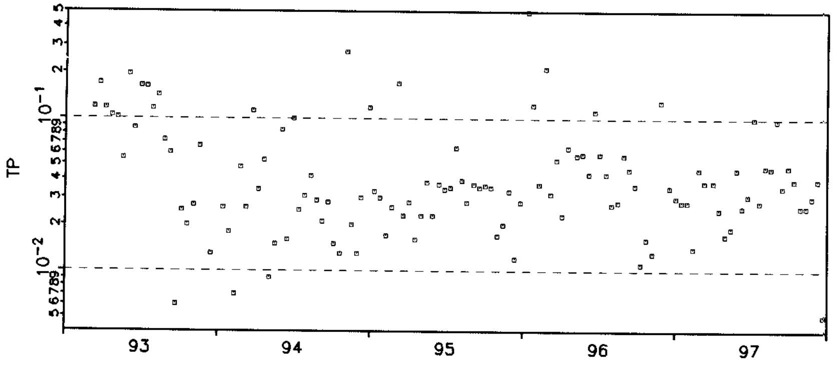
Tributary Concentrations Station = SPENCER



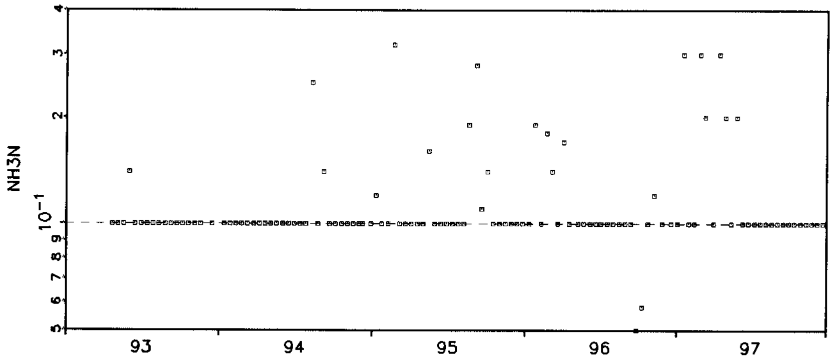
Tributary Concentrations Station = SPENCER



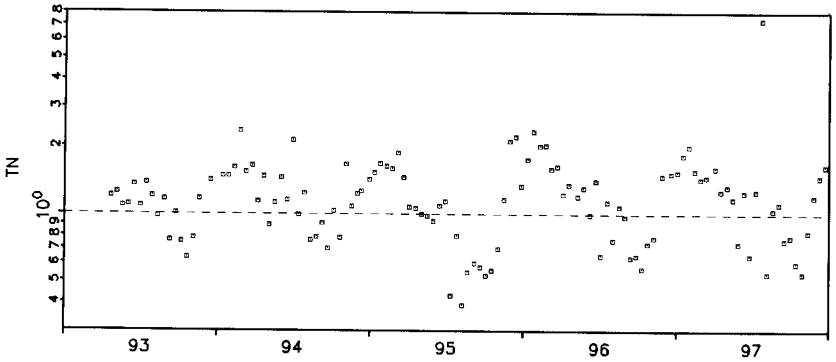
Tributary Concentrations Station = DORWIN



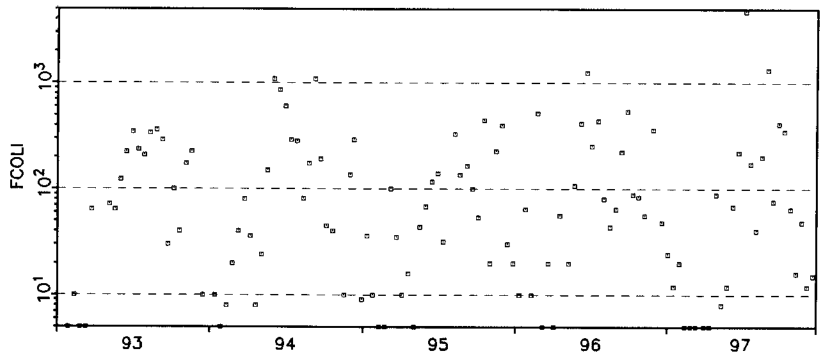
Tributary Concentrations Station = DORWIN



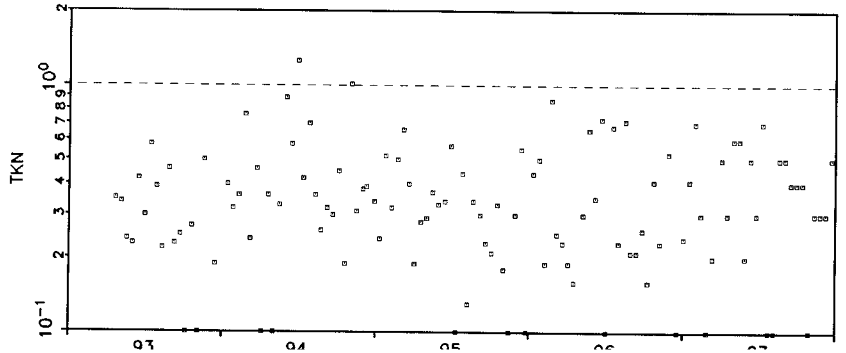
Tributary Concentrations Station = DORWIN



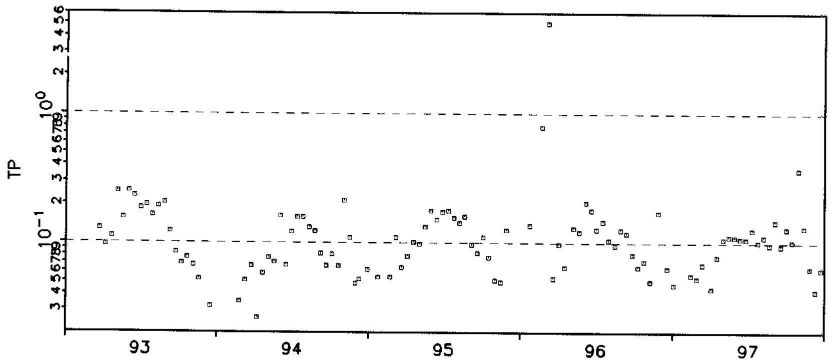
Tributary Concentrations Station = DORWIN



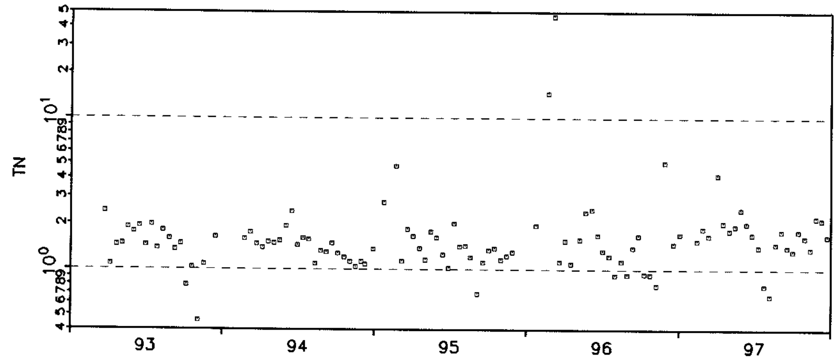
Tributary Concentrations Station = DORWIN



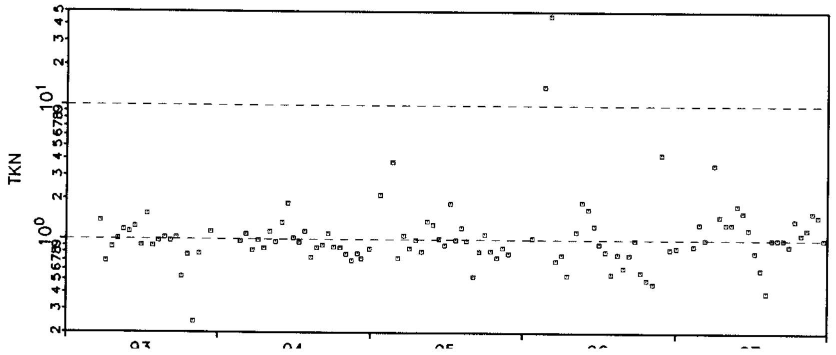
Tributary Concentrations Station = LEY



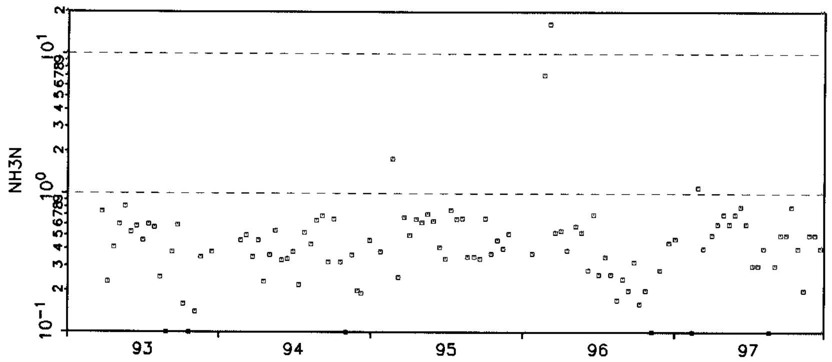
Tributary Concentrations Station = LEY



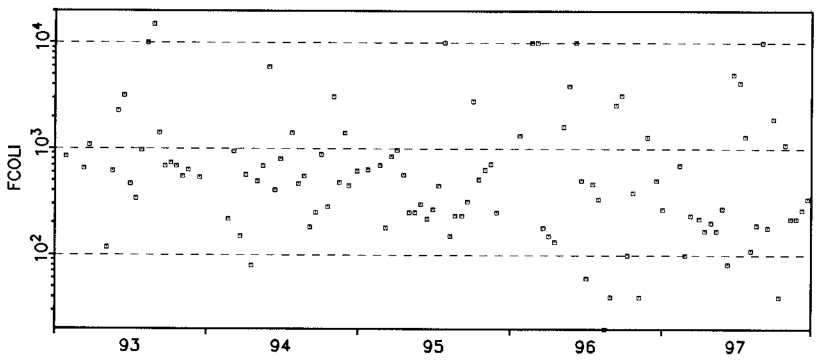
Tributary Concentrations Station = LEY

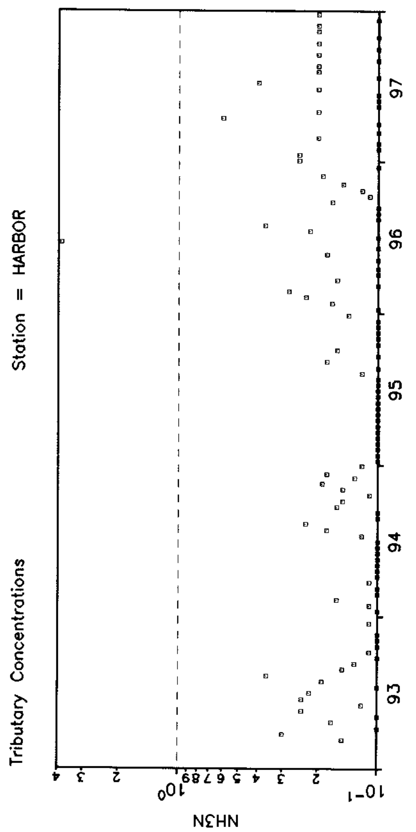


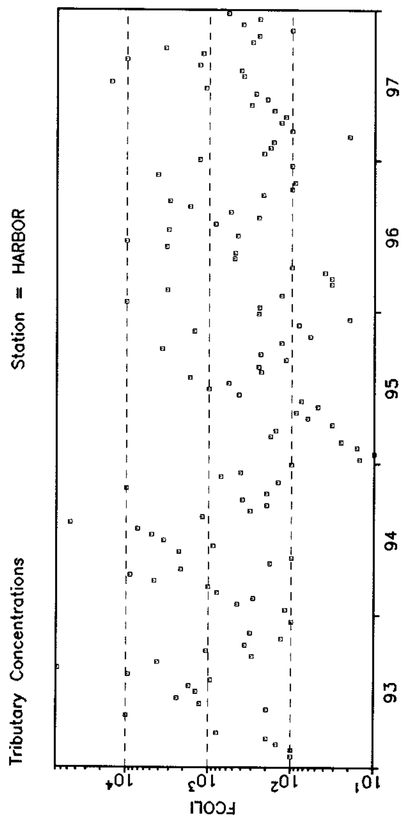
Tributary Concentrations Station = LEY

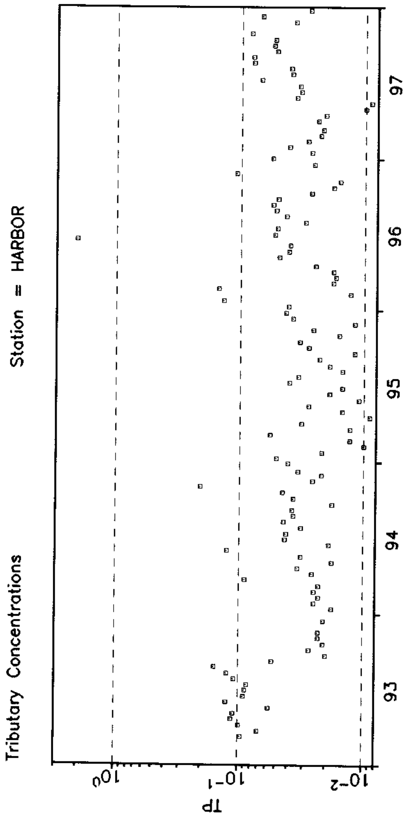


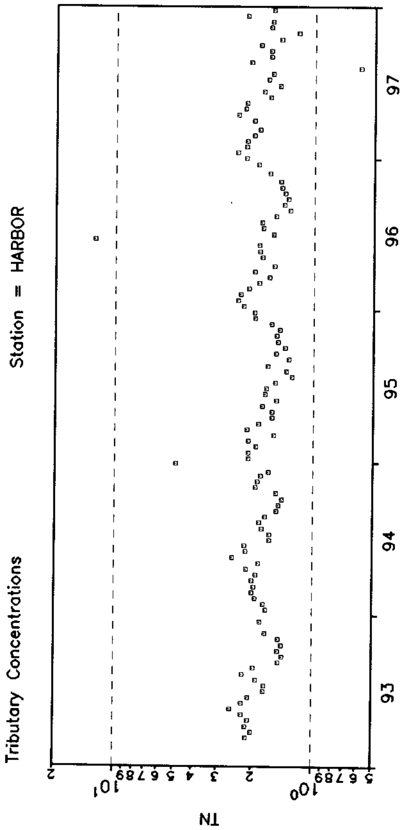
Tributary Concentrations Station = LEY

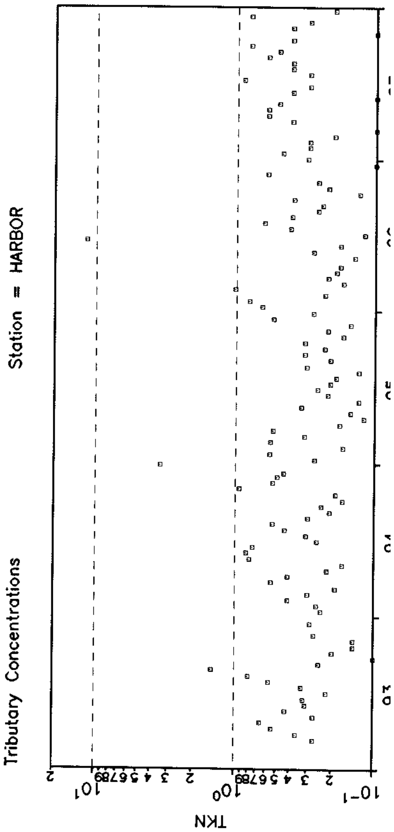


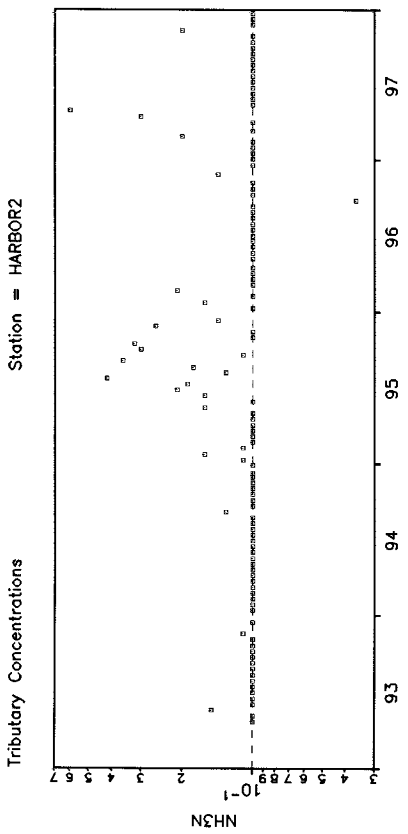

Tributary Concentrations
Station = HARBOR
NH3N
10^0
10^-1
93
94
95
96
97

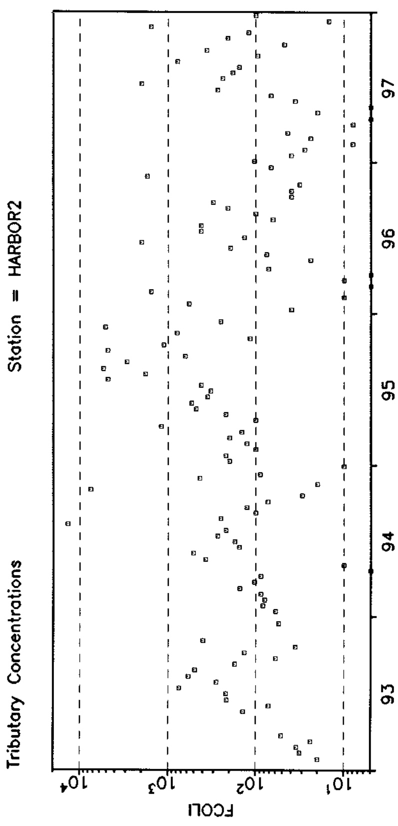

Tributary Concentrations
Station = HARBOR
FCOLI
10^4
10^3
10^2
10^1
93
94
95
96
97

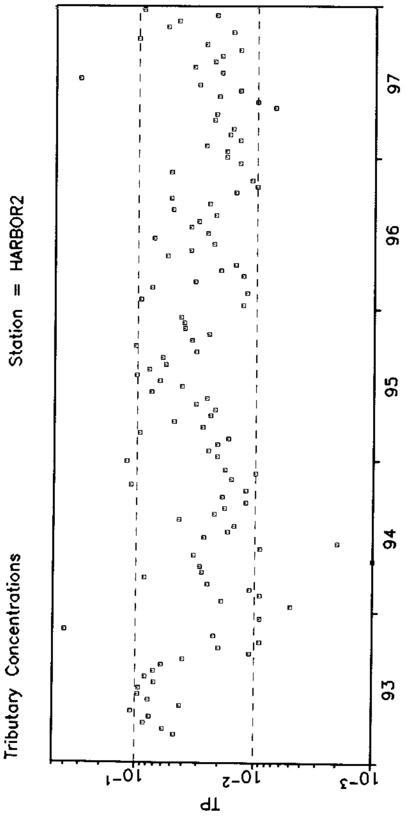

Tributary Concentrations
Station = HARBOR
TP
10^0
10^-1
10^-2
93
94
95
96
97

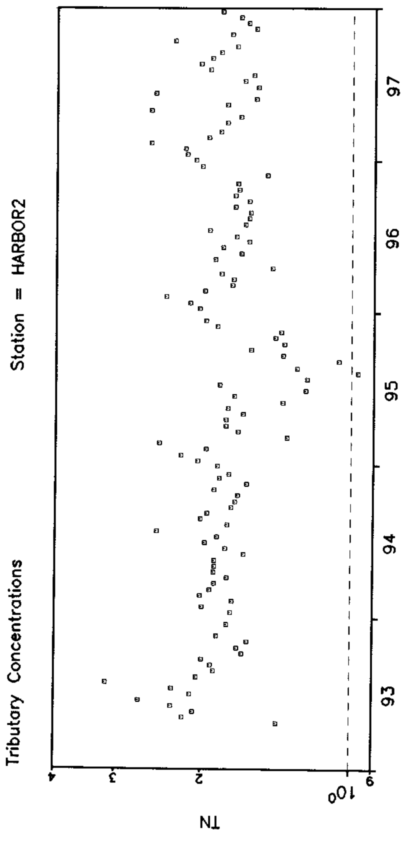

Tributary Concentrations
Station = HARBOR
TN
10^1
10^0
93
94
95
96
97

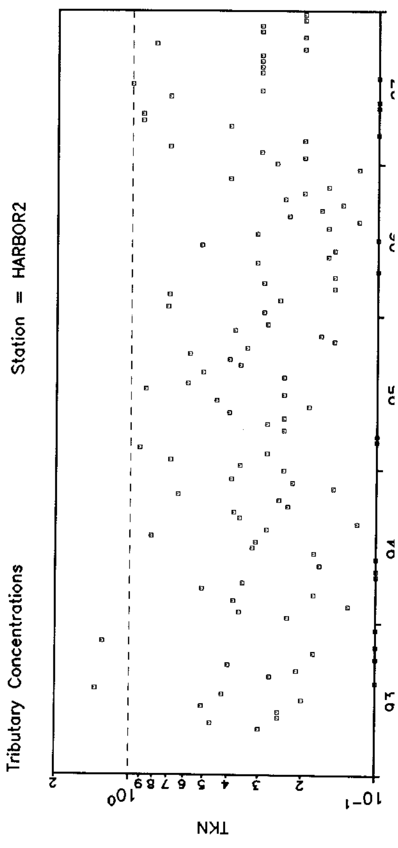

Tributary Concentrations
Station = HARBOR
TKN
10^1
10^0
10^-1

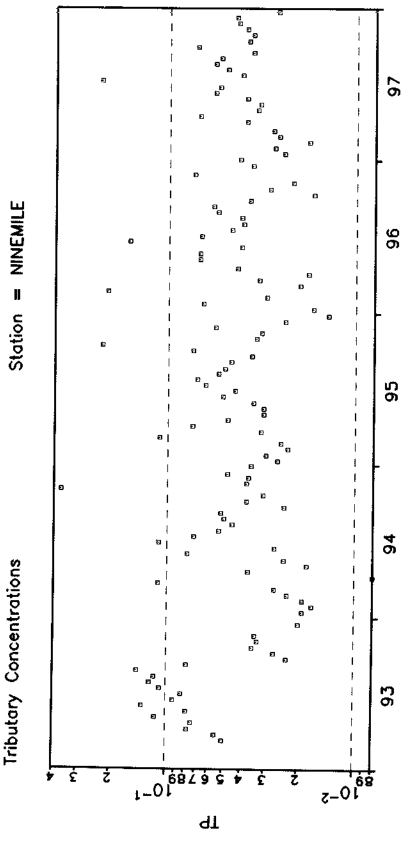

Tributary Concentrations
Station = HARBOR2
NH3N
10⁻¹
93
94
95
96
97

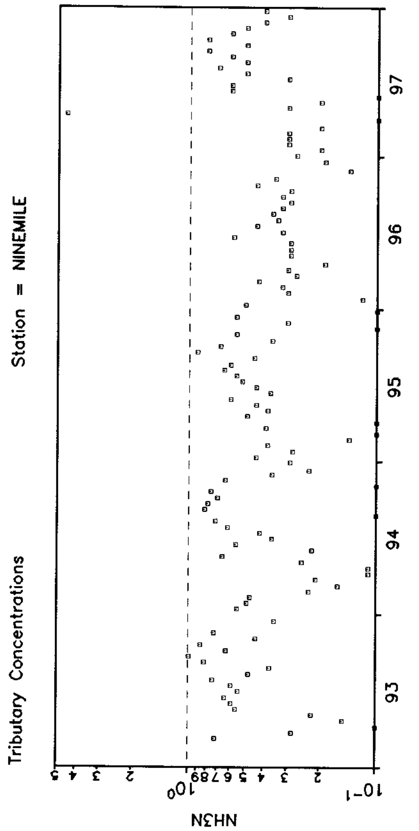

Tributary Concentrations
Station = HARBOR2
FCOLI
10⁴
10³
10²
10¹
93
94
95
96
97

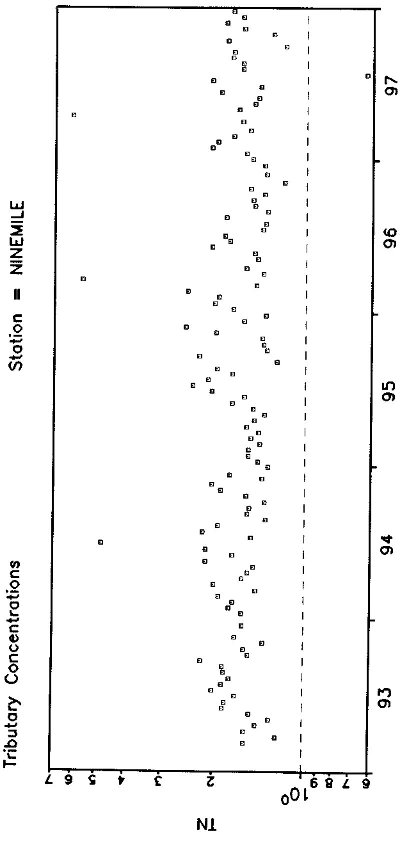

Tributary Concentrations
Station = HARBOR2
TP
10⁻¹
10⁻²
10⁻³
93
94
95
96
97

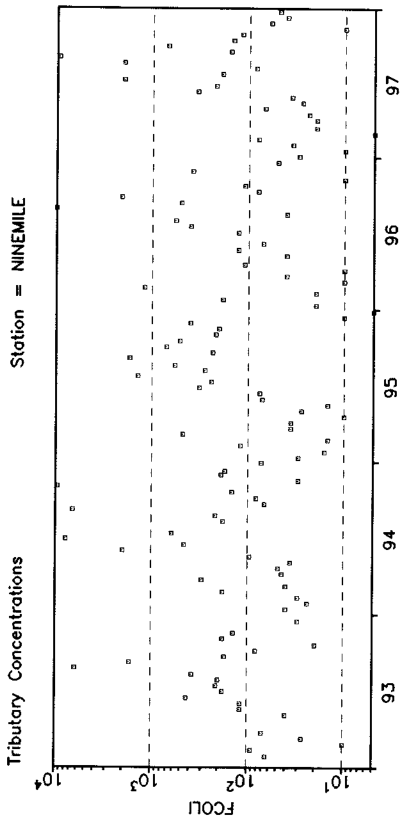

Tributary Concentrations
Station = HARBOR2
TN
4
3
2
10⁰
9
93
94
95
96
97

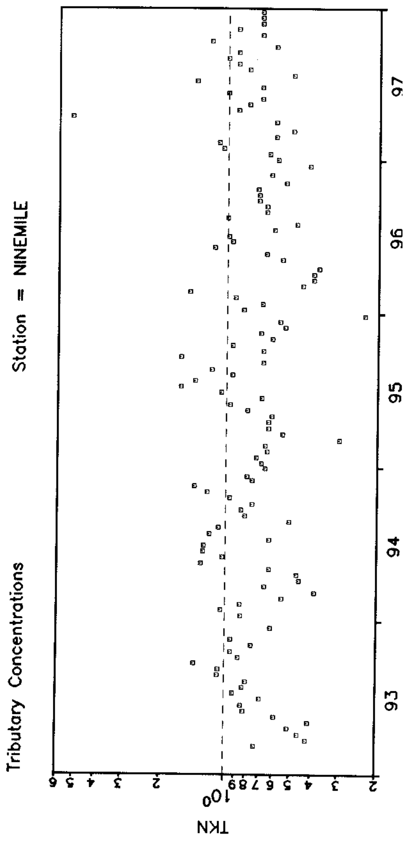

Tributary Concentrations
Station = HARBOR2
TKN
2
10⁰
10⁻¹
93
94
95
96
97


Tributary Concentrations
Station = NINEMILE
TP
10⁻¹
10⁻²
93
94
95
96
97

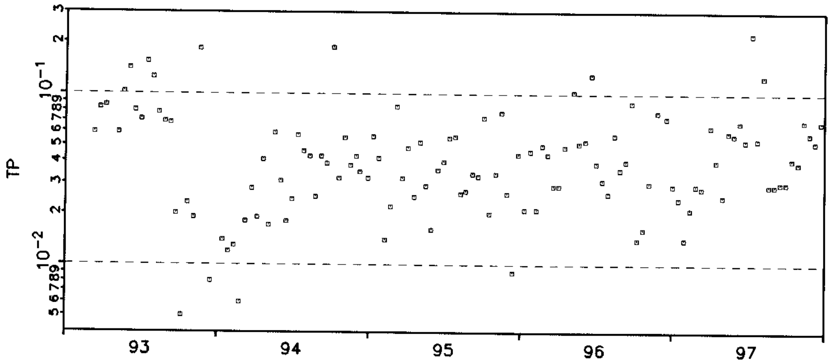

Tributary Concentrations
Station = NINEMILE
NH3N
10⁰
10⁻¹
93
94
95
96
97


Tributary Concentrations
Station = NINEMILE
TN
10⁰
93
94
95
96
97

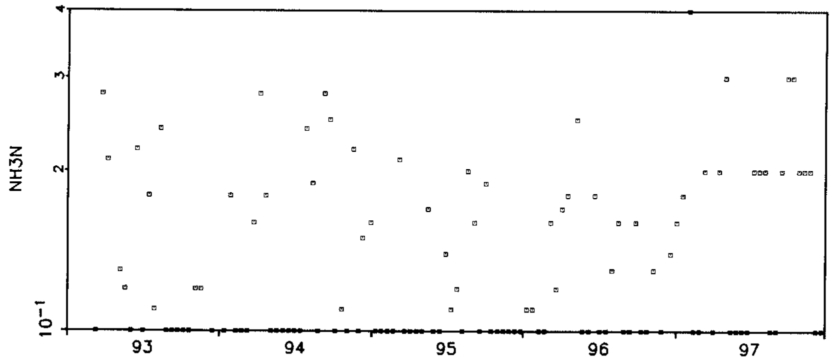

Tributary Concentrations
Station = NINEMILE
FCOLI
10⁴
10³
10²
10¹
93
94
95
96
97


Tributary Concentrations
Station = NINEMILE
TKN
10⁰
93
94
95
96
97

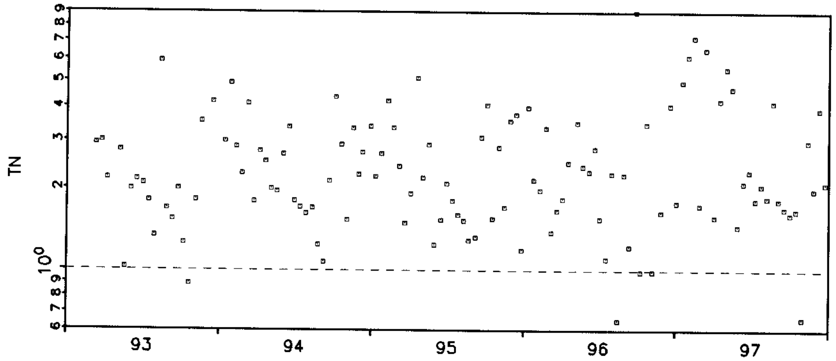
Tributary Concentrations Station = CRUCIBLE



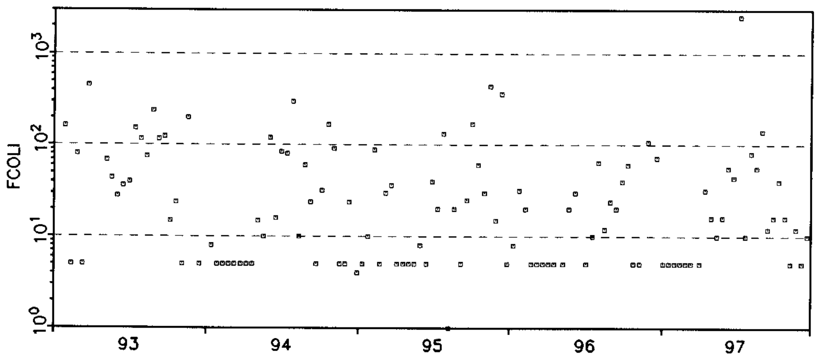
Tributary Concentrations Station = CRUCIBLE



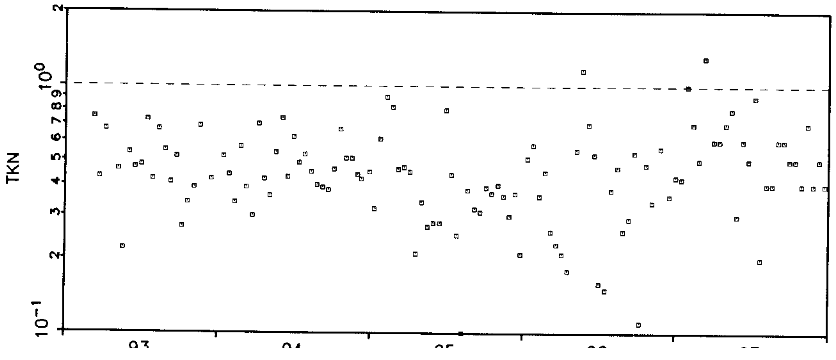
Tributary Concentrations Station = CRUCIBLE



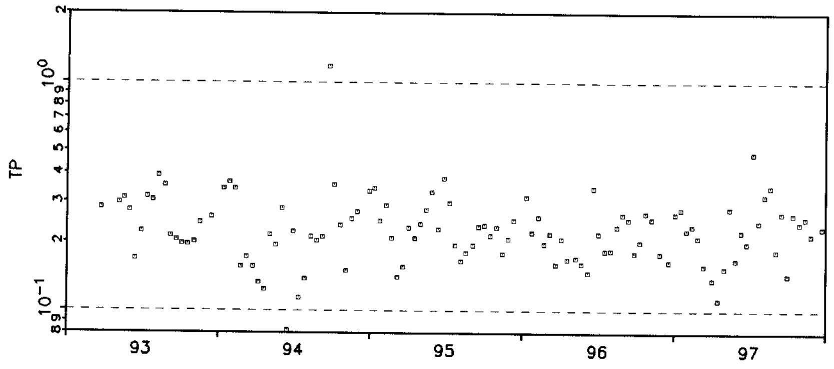
Tributary Concentrations Station = CRUCIBLE



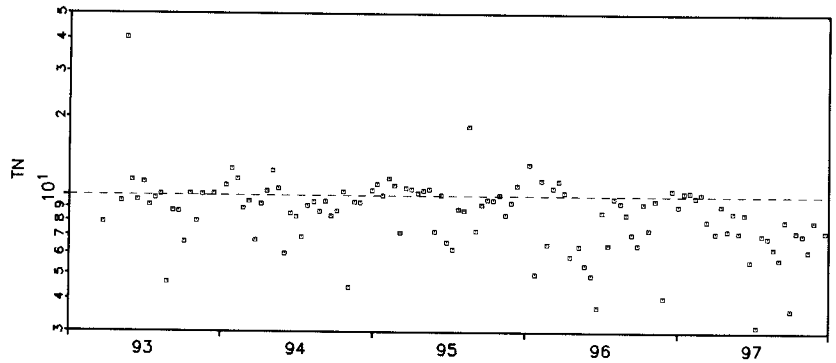
Tributary Concentrations Station = CRUCIBLE



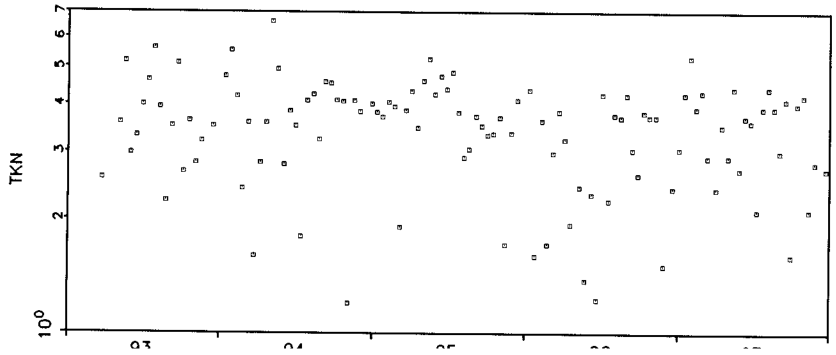
Tributary Concentrations Station = ALLIEDF



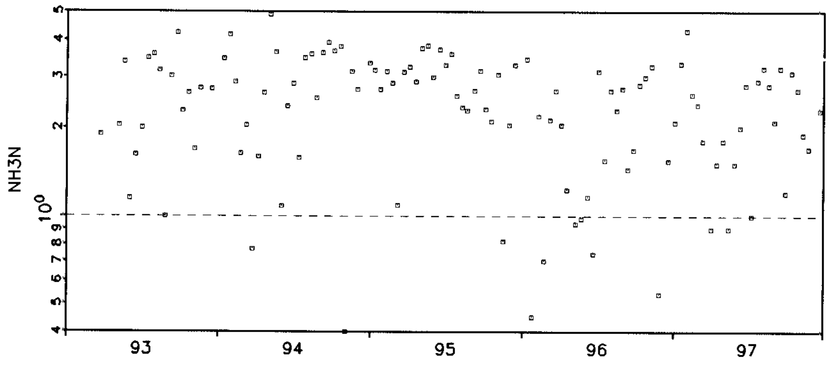
Tributary Concentrations Station = ALLIEDF



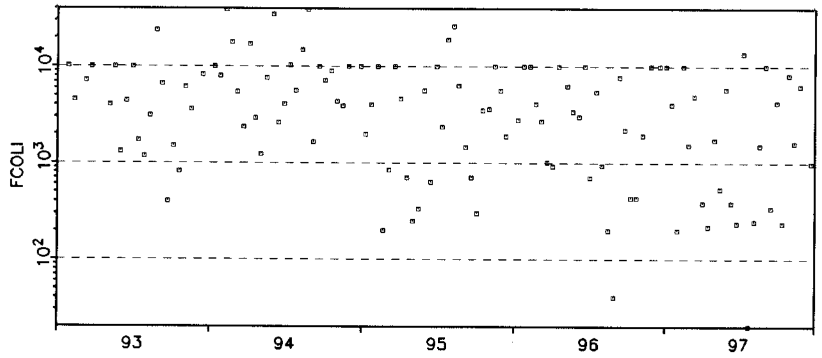
Tributary Concentrations Station = ALLIEDF

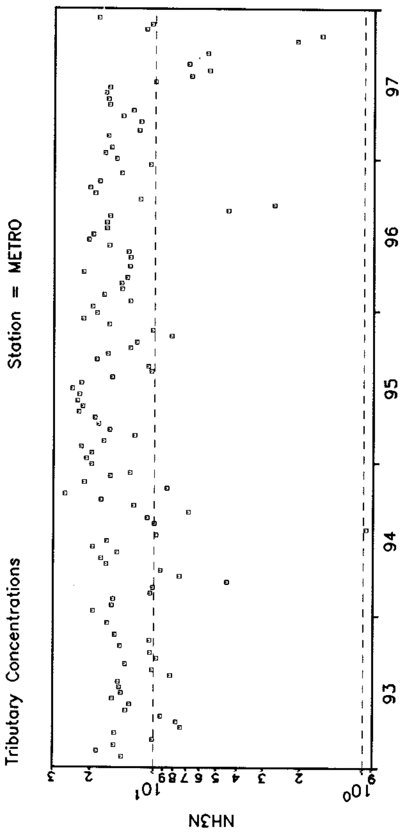


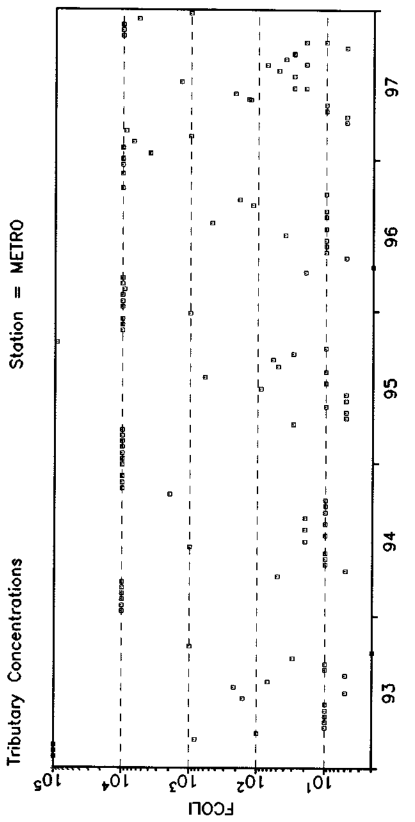
Tributary Concentrations Station = ALLIEDF

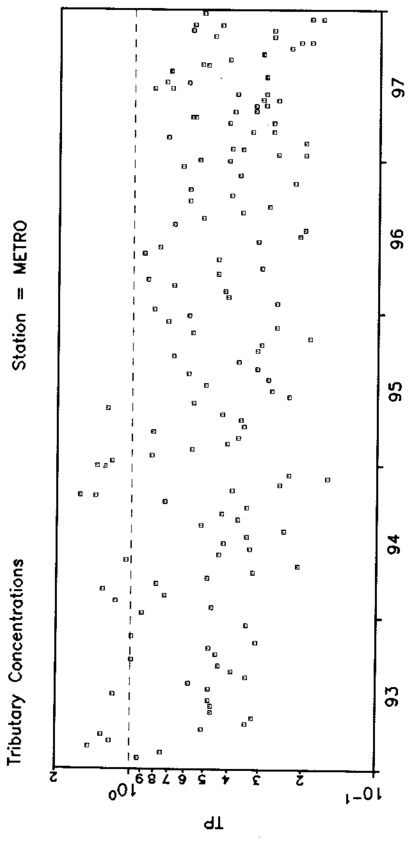


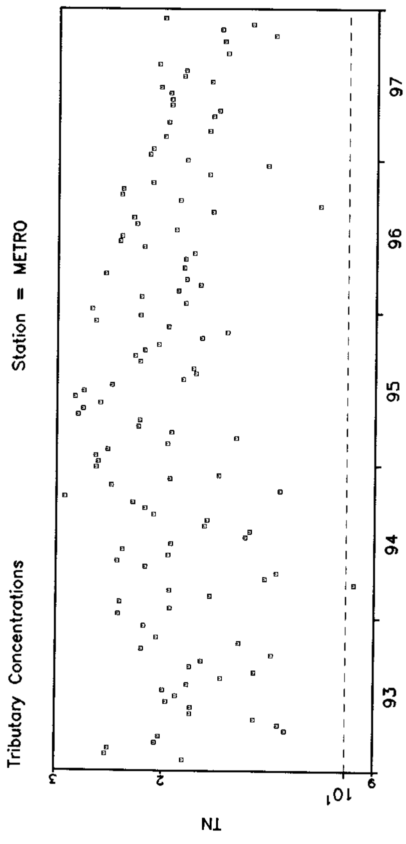
Tributary Concentrations Station = ALLIEDF

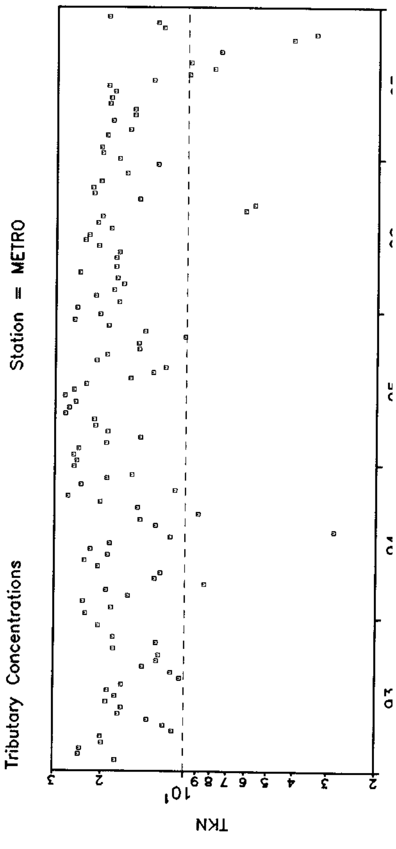


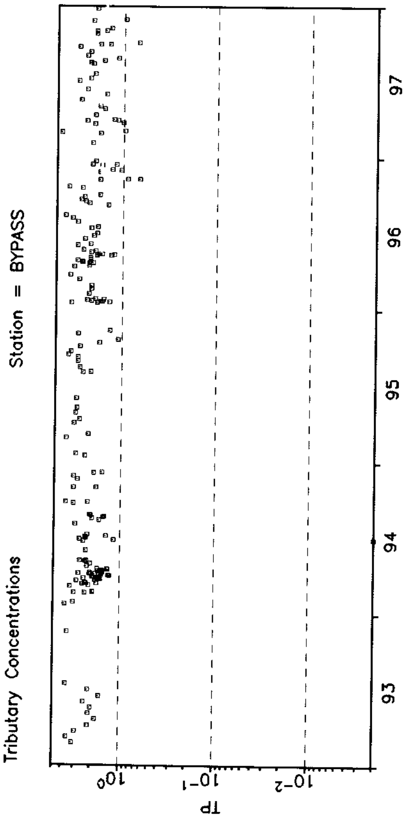

Tributary Concentrations
Station = METRO
NH3N
10^1
10^0
93
94
95
96
97

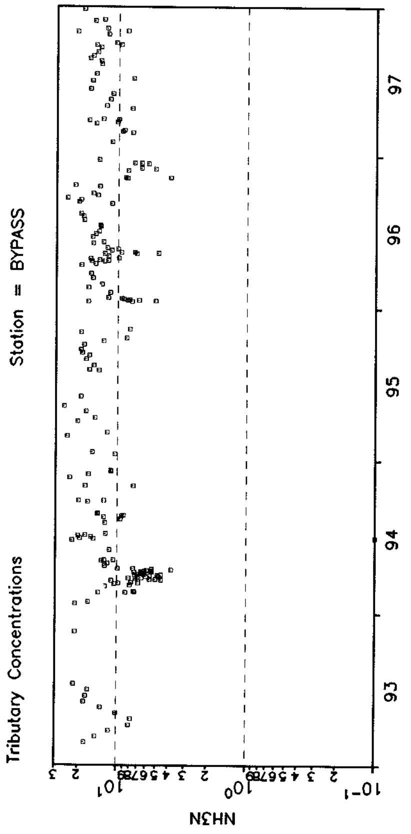

Tributary Concentrations
Station = METRO
FCOLI
10^5
10^4
10^3
10^2
10^1
93
94
95
96
97

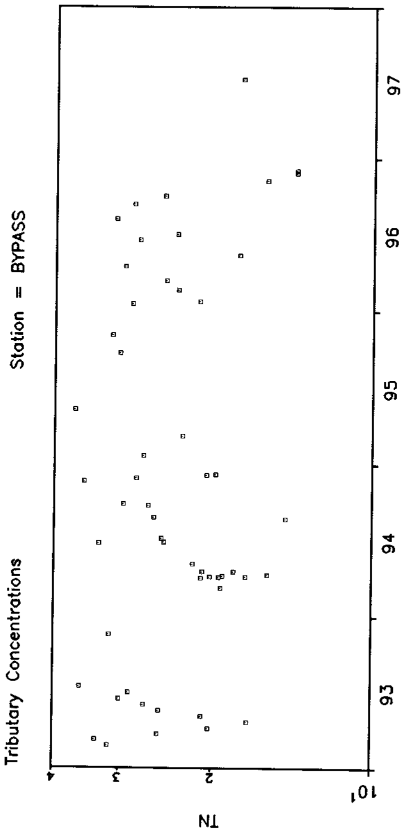

Tributary Concentrations
Station = METRO
TP
10^0
10^-1
93
94
95
96
97

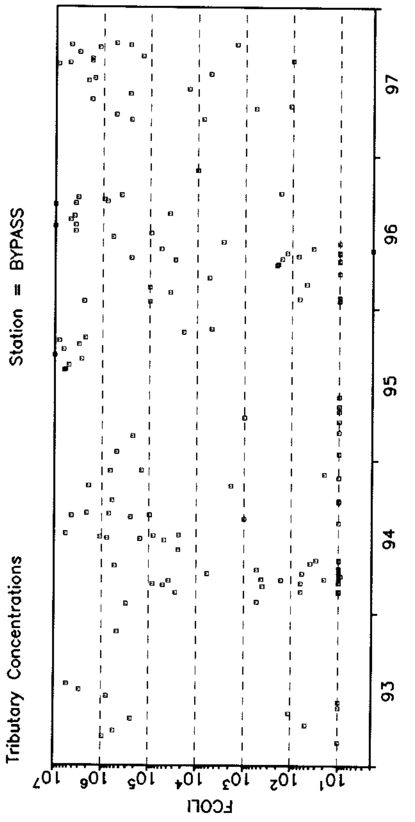

Tributary Concentrations
Station = METRO
TN
10^1
93
94
95
96
97

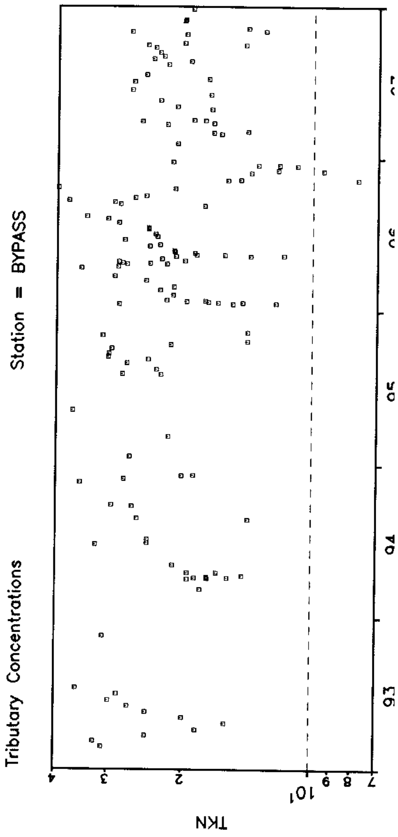

Tributary Concentrations
Station = METRO
TKN
10^1


Tributary Concentrations Station = BYPASS
TP
10^0
10^-1
10^-2
93
94
95
96
97


Tributary Concentrations Station = BYPASS
NH3N
2 3
10^1
10^0
10^-1
2 3 4 5 6 7 8 9
93
94
95
96
97


Tributary Concentrations Station = BYPASS
TN
10^1
2
3
4
93
94
95
96
97

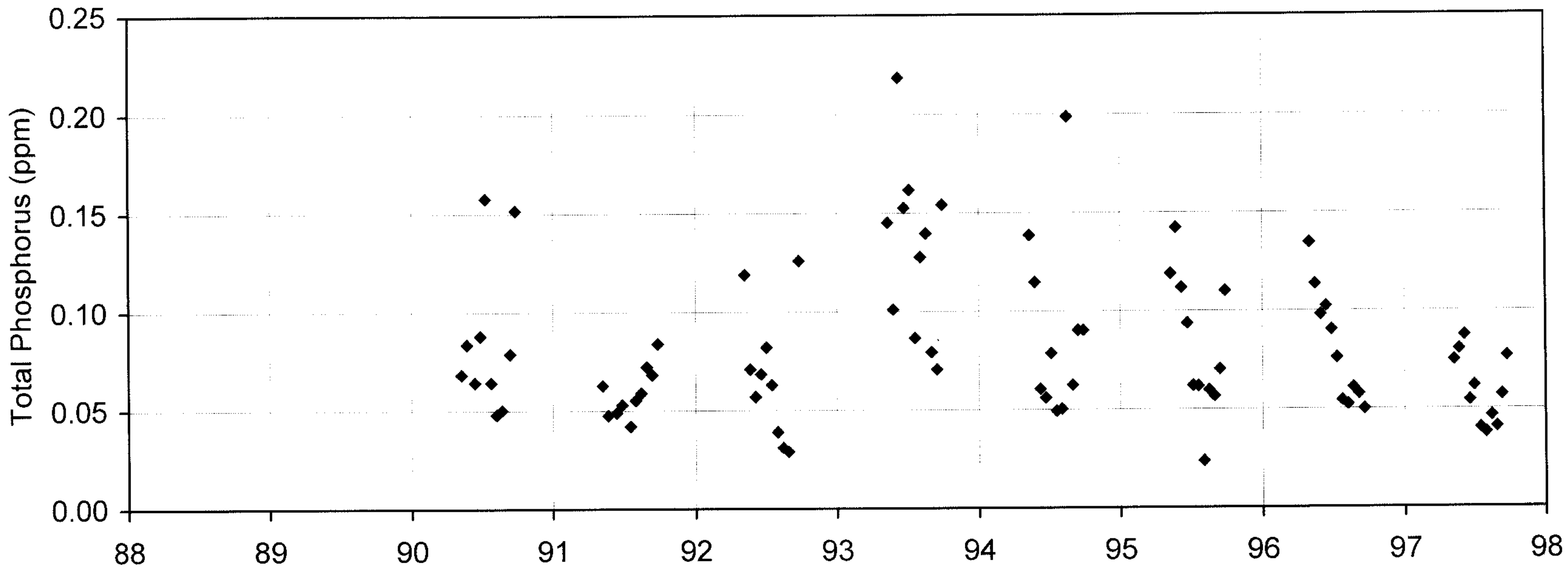

Tributary Concentrations Station = BYPASS
FCOLI
10^7
10^6
10^5
10^4
10^3
10^2
10^1
93
94
95
96
97


Tributary Concentrations Station = BYPASS
TKN
10^1
2
3
4
7 8 9
93
94
95
96

Appendix B

Time Series Plots & Annual Statistical Summaries
Lake Epilimnion, 1988-1987

Total Phosphorus Time Series, Lake Epilimnion, May-September 1988-1997



Yearly Summary

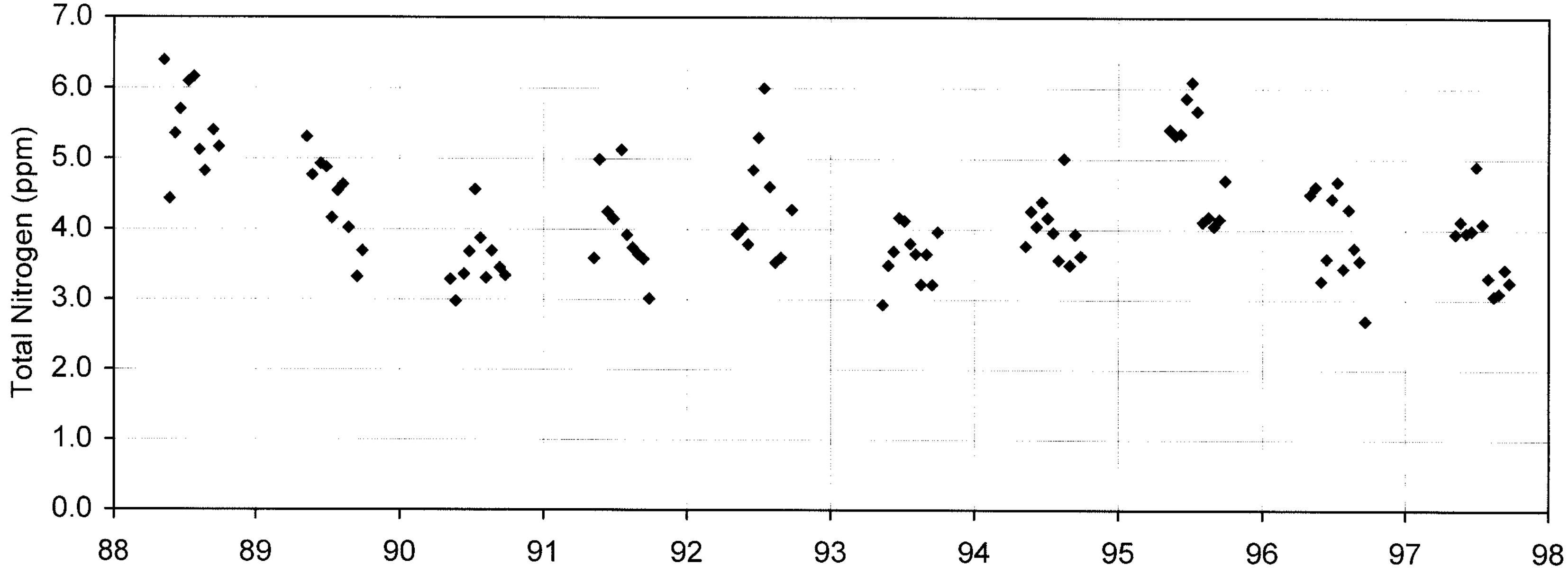
Year	Count	Arithmetic Mean Mean	CV	RSE	Geometric Mean Mean	CV	RSE
88	0						
89	0						
90	10	0.09	45%	14%	0.08	40%	13%
91	10	0.06	22%	7%	0.06	21%	7%
92	10	0.07	49%	15%	0.06	51%	16%
93	11	0.13	33%	10%	0.12	35%	10%
94	11	0.09	51%	15%	0.08	45%	13%
95	11	0.08	42%	13%	0.07	50%	15%
96	11	0.08	35%	11%	0.08	35%	11%
97	11	0.06	30%	9%	0.06	30%	9%
Median	11	0.08	39%	12%	0.08	38%	12%
Mean	9	0.08	38%	12%	0.08	38%	12%

CV = Coefficient of Variation

RSE = Relative Standard Error
= Standard Error / Mean

Observations averaged over 0-6 meters

Total Nitrogen Time Series, Lake Epilimnion, May-September 1988-1997



Yearly Summary

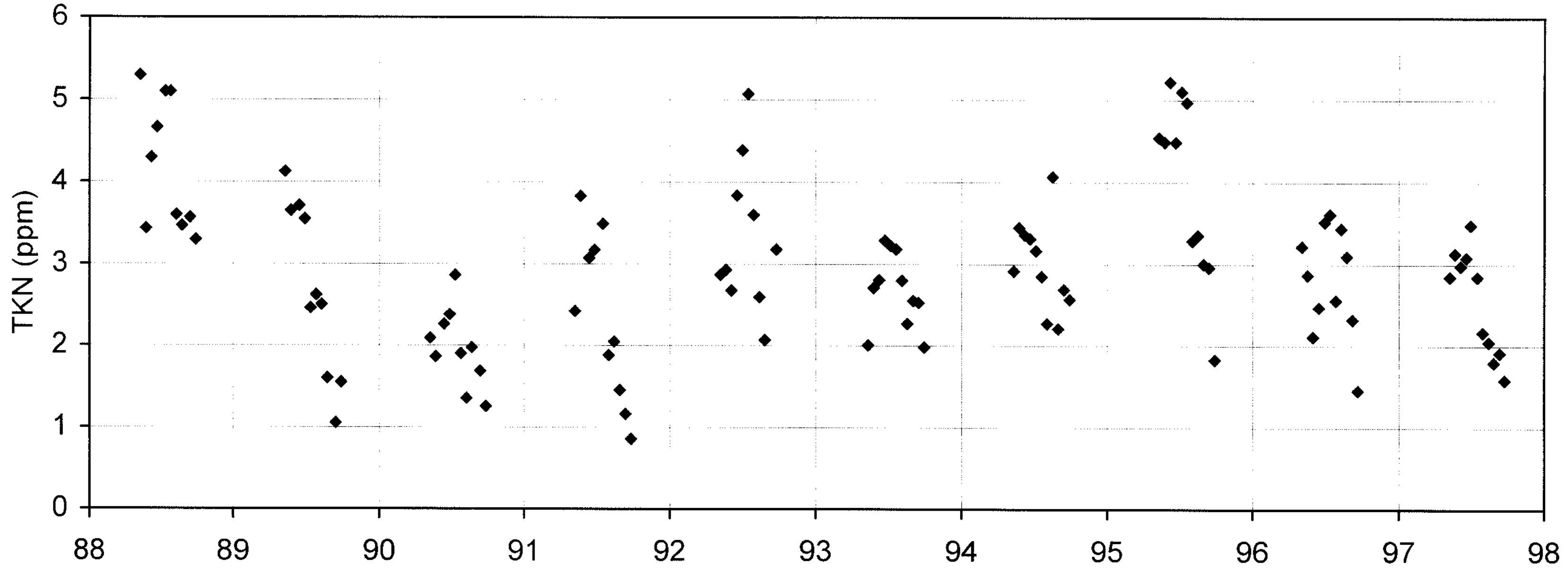
Year	Count	Arithmetic Mean			Geometric Mean		
		Mean	CV	RSE	Mean	CV	RSE
88	10	5.47	11%	4%	5.43	12%	4%
89	10	4.43	14%	4%	4.39	15%	5%
90	10	3.56	12%	4%	3.53	12%	4%
91	10	4.00	16%	5%	3.96	16%	5%
92	10	4.39	18%	6%	4.33	17%	6%
93	11	3.63	11%	3%	3.61	11%	3%
94	11	4.02	11%	3%	4.00	10%	3%
95	11	4.99	15%	5%	4.94	16%	5%
96	11	3.89	17%	5%	3.84	17%	5%
97	11	3.74	15%	5%	3.71	15%	4%
Median	11	4.01	14%	4%	3.98	15%	5%
Mean	11	4.21	14%	4%	4.17	14%	4%

CV = Coefficient of Variation

RSE = Relative Standard Error
= Standard Error / Mean

Observations averaged over 0-6 meters

TKN Time Series, Lake Epilimnion, May-September 1988-1997



Yearly Summary

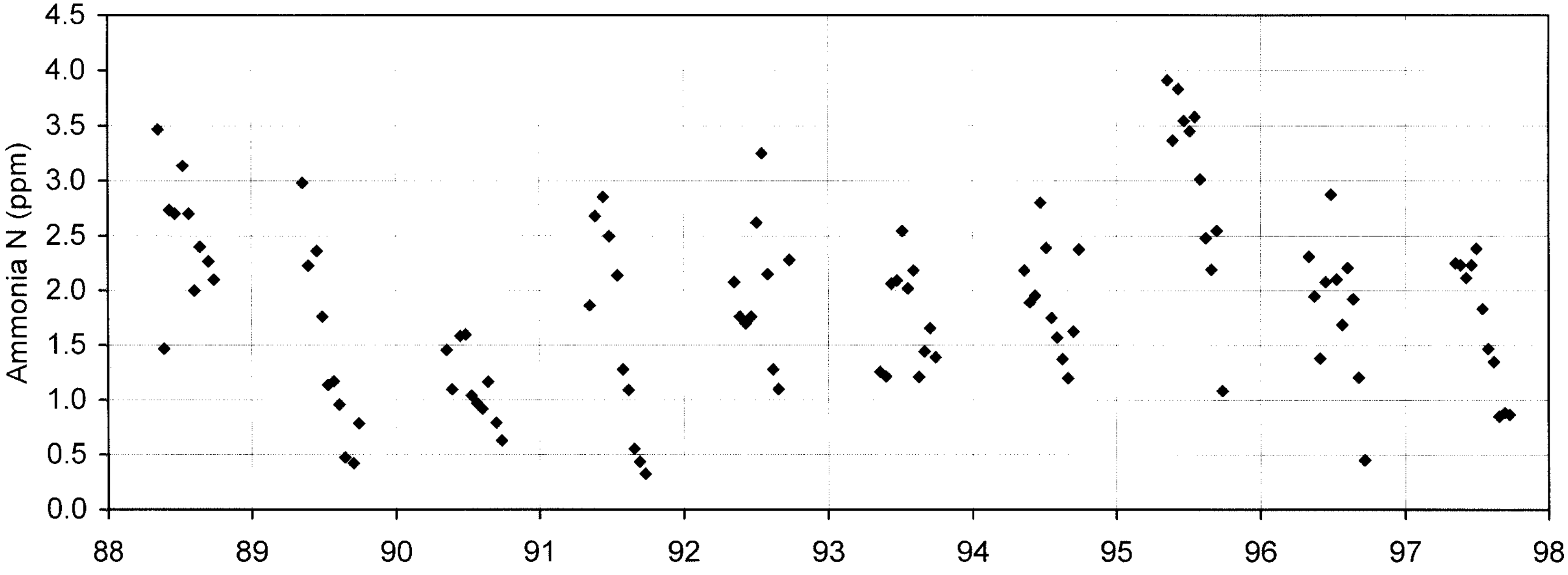
		Arithmetic Mean			Geometric Mean		
Year	Count	Mean	CV	RSE	Mean	CV	RSE
88	10	4.18	19%	6%	4.12	19%	6%
89	10	2.68	39%	12%	2.47	45%	14%
90	10	1.96	24%	8%	1.91	25%	8%
91	10	2.34	44%	14%	2.11	50%	16%
92	10	3.32	27%	9%	3.22	27%	8%
93	11	2.67	17%	5%	2.63	18%	5%
94	11	2.99	18%	6%	2.94	19%	6%
95	11	3.93	28%	8%	3.77	32%	10%
96	11	2.79	24%	7%	2.70	27%	8%
97	11	2.54	25%	8%	2.46	27%	8%
Median	11	2.74	25%	8%	2.67	27%	8%
Mean	11	2.94	27%	8%	2.83	29%	9%

CV = Coefficient of Variation

RSE = Relative Standard Error
= Standard Error / Mean

Observations averaged over 0-6 meters

Ammonia N Time Series, Lake Epilimnion, May-September 1988-1997



Yearly Summary

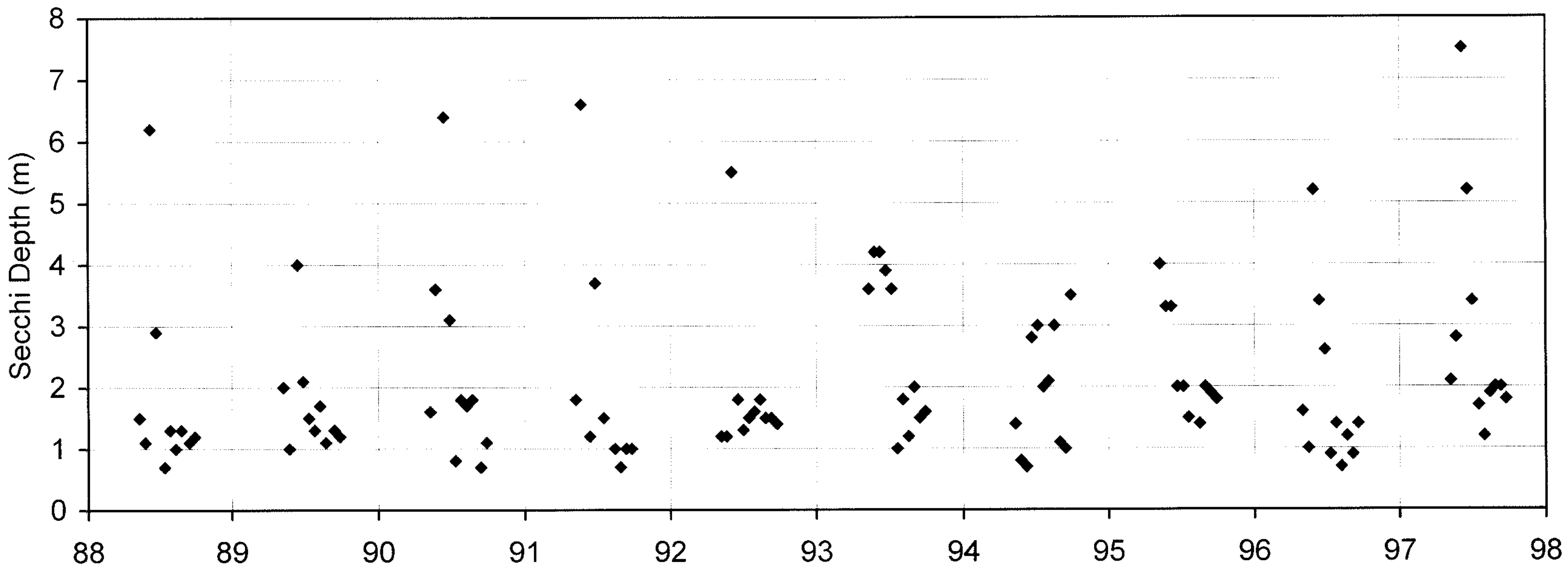
Year	Count	Arithmetic Mean Mean	CV	RSE	Geometric Mean Mean	CV	RSE
88	10	2.50	23%	7%	2.43	25%	8%
89	10	1.43	60%	19%	1.19	67%	21%
90	10	1.13	29%	9%	1.08	30%	10%
91	10	1.57	61%	19%	1.24	80%	25%
92	10	2.00	32%	10%	1.91	32%	10%
93	11	1.73	27%	8%	1.68	27%	8%
94	11	1.92	25%	8%	1.86	26%	8%
95	11	3.00	28%	9%	2.85	37%	11%
96	11	1.83	35%	11%	1.68	50%	15%
97	11	1.68	37%	11%	1.56	42%	13%
Median	11	1.78	30%	10%	1.68	35%	11%
Mean	11	1.88	36%	11%	1.75	41%	13%

CV = Coefficient of Variation

RSE = Relative Standard Error
= Standard Error / Mean

Observations averaged over 0-6 meters

Transparency Time Series, Lake Epilimnion, May-September 1988-1997



Yearly Summary

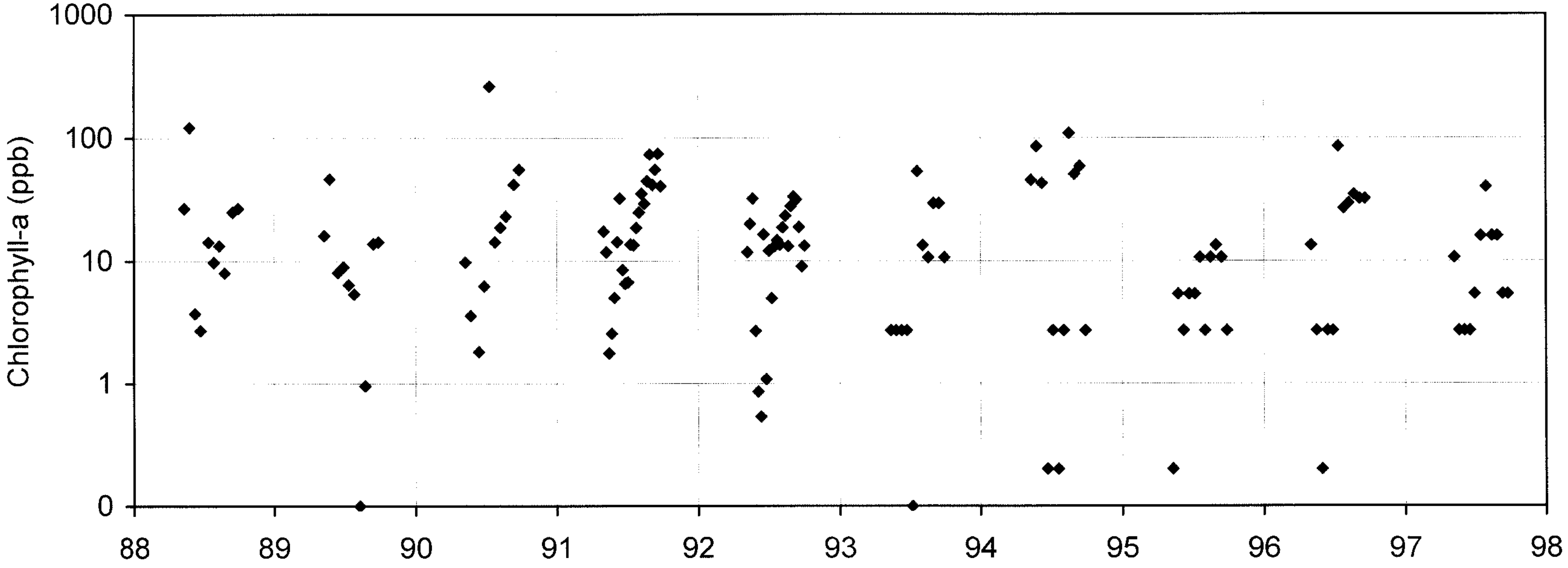
		Arithmetic Mean			Geometric Mean		
Year	**Count**	**Mean**	**CV**	**RSE**	**Mean**	**CV**	**RSE**
88	10	1.83	90%	28%	1.47	62%	20%
89	10	1.72	51%	16%	1.58	41%	13%
90	10	2.26	76%	24%	1.81	68%	22%
91	9	2.06	94%	31%	1.56	72%	24%
92	11	1.85	67%	20%	1.65	42%	13%
93	11	2.60	49%	15%	2.29	54%	16%
94	11	1.95	52%	16%	1.69	58%	17%
95	10	2.32	38%	12%	2.19	35%	11%
96	11	1.85	75%	22%	1.52	62%	19%
97	11	2.87	66%	20%	2.48	53%	16%
Median	11	2.00	66%	20%	1.67	56%	17%
Mean	10	2.13	66%	20%	1.82	55%	17%

CV = Coefficient of Variation

RSE = Relative Standard Error
= Standard Error / Mean

Observations averaged over 0-6 meters

Chlorophyll-a Time Series, Lake Epilimnion, May-September 1988-1997



Yearly Summary

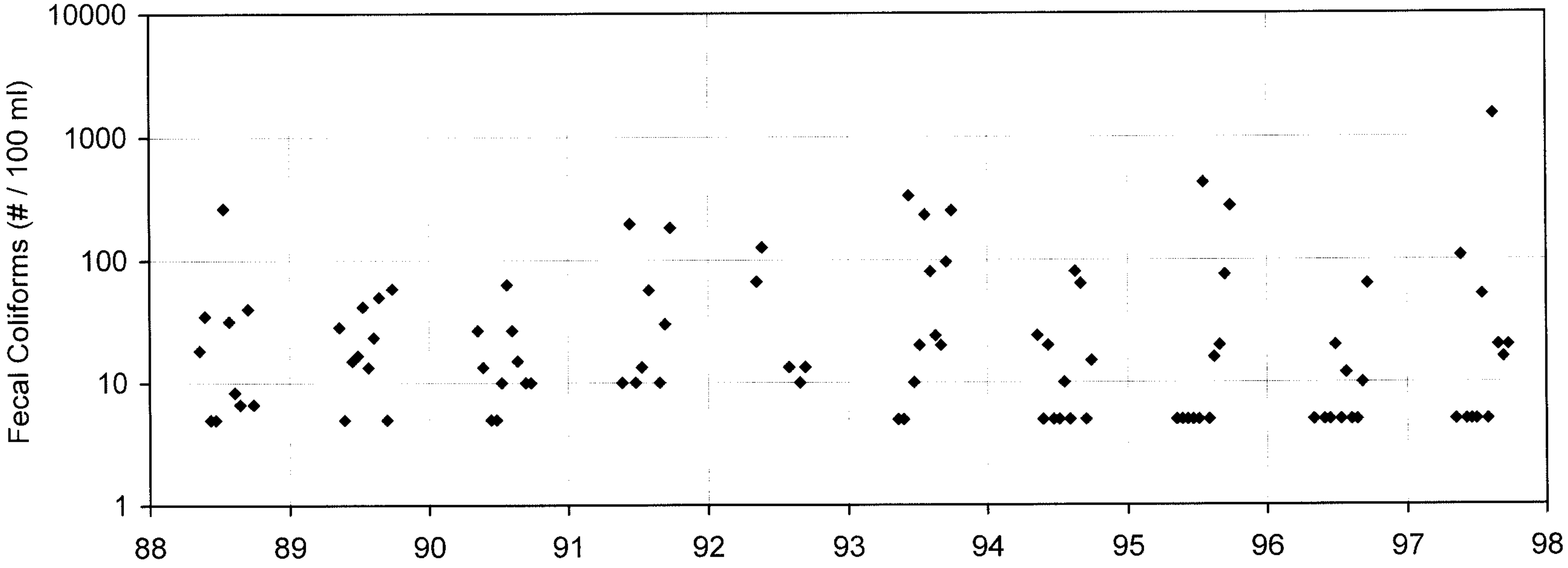
Year	Count	Arithmetic Mean Mean	CV	RSE	Geometric Mean Mean	CV	RSE
88	10	25.2	139%	44%	14.2	109%	35%
89	10	12.0	110%	35%	5.7	173%	55%
90	10	43.6	180%	57%	16.5	144%	45%
91	22	26.0	83%	18%	17.2	103%	22%
92	22	15.1	66%	14%	10.0	119%	25%
93	11	14.4	116%	35%	6.0	175%	53%
94	11	36.5	105%	32%	9.3	237%	71%
95	11	6.4	68%	20%	4.3	118%	36%
96	11	23.8	104%	31%	10.2	178%	54%
97	11	11.2	99%	30%	7.7	90%	27%
Median	11	19.5	104%	31%	9.6	131%	41%
Mean	13	21.4	107%	32%	10.1	145%	42%

CV = Coefficient of Variation

RSE = Relative Standard Error
= Standard Error / Mean

Observations averaged over 0-6 meters

Fecal Coliform Time Series, Lake Epilimnion, May-September 1988-1997



Yearly Summary

Year	Count	Arithmetic Mean Mean	CV	RSE	Geometric Mean Mean	CV	RSE
88	10	42.2	188%	60%	17.0	127%	40%
89	10	25.7	73%	23%	19.2	87%	27%
90	10	18.5	95%	30%	13.7	79%	25%
91	8	63.8	125%	44%	30.8	128%	45%
92	5	46.0	111%	49%	27.2	114%	51%
93	11	97.8	121%	36%	39.4	155%	47%
94	11	21.6	120%	36%	12.5	105%	32%
95	11	76.5	184%	55%	17.4	171%	52%
96	10	13.6	135%	43%	8.7	86%	27%
97	11	160.1	282%	85%	19.7	179%	54%
Median	10	44.1	123%	43%	18.3	120%	43%
Mean	10	56.6	143%	46%	20.6	123%	40%

CV = Coefficient of Variation

RSE = Relative Standard Error
= Standard Error / Mean

Observations averaged over 0-6 meters

Appendix C
Mass Balance Calculations

Variable	Years 1997	 1993-1997
Chloride	1	2
Total P	3	4
TKN	5	6
Ammonia N	7	8
Nitrate N	9	10
Nitrite N	11	12
Fecal Coliforms	13	14

Mass Balance Summary - Onondaga Lake
Variable: CL Chloride

Years: 97 thru 97 Season: Year

Term	Flow 10^6 m3	Load mtons	Std Error mtons	Conc ppm	RSE %	Sample Count	Percent of Total Inflow Flow %	Percent of Total Inflow Load %	Percent of Total Inflow Error %	Drainage Area km2	Runoff cm	Export mtons/ km2
Metro Effluent	88.25	33884	4436	384	13%	22	24%	23%	48%			
Metro Bypass	0.48	76	0	158	0%	1	0%	0%	0%			
East Flume	0.16	83	5	535	7%	25	0%	0%	0%			
Crucible	0.76	265	10	349	4%	26	0%	0%	0%			
Harbor Brook	6.56	1822	148	278	8%	26	2%	1%	0%	29.3	22.4	62.2
Ley Creek	28.27	8172	755	289	9%	24	8%	6%	1%	77.5	36.5	105.4
Ninemile Creek	98.51	52983	2972	538	6%	26	27%	37%	21%	298.1	33.0	177.7
Onondaga Creek	122.57	42053	3047	343	7%	26	33%	29%	22%	285.1	43.0	147.5
Nonpoint Gauged	255.91	105031	4325	410	4%	102	69%	72%	45%	690.0	37.1	152.2
Nonpoint Ungauged	13.73	5637	1707	410	30%	0	4%	4%	7%	37.0	37.1	152.2
NonPoint Total	269.64	110668	4650	410	4%	102	73%	76%	52%	727.0	37.1	152.2
Industrial	0.91	348	11	380	3%	51	0%	0%	0%			
Municipal	88.73	33959	4436	383	13%	23	24%	23%	48%			
Total External	359.28	144975	6427	404	4%	176	97%	100%	100%	727.0	49.4	199.4
Precipitation	9.69	10	2	1	20%	0	3%	0%	0%	11.7	82.9	0.8
Total Inflow	368.97	144984	6427	393	4%	176	100%	100%	100%	738.7	49.9	196.3
Evaporation	8.86						2%			11.7	75.7	
Outflow	360.12	137045	9725	381	7%		98%	95%	229%	738.7	48.7	185.5
Retention	0.00	7940	11657		147%		0%	5%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	360.12	169306	3435	470	2%	23	98%	117%	29%	738.7	48.7	229.2
Outlet 2 Feet	360.12	137045	9725	381	7%	23	98%	95%	229%	738.7	48.7	185.5
Lake Epil	360.12	169370	2577	470	2%	21	98%	117%	16%	738.7	48.7	229.3
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	6.20	1631	123	263	8%	26	2%	1%	0%	26.2	23.6	62.2
Downstream - Hiawatha	6.56	1822	148	278	8%	26	2%	1%	0%	29.3	22.4	62.2
Local Inflow	0.36	191	192	524	101%		0%	0%	0%	3.0	11.9	62.7
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	94.44	13291	675	141	5%	26	26%	9%	1%	232.3	40.7	57.2
Downstream - Spencer	122.57	42053	3047	343	7%	26	33%	29%	22%	285.1	43.0	147.5
Local Inflow	28.13	28762	3121	1023	11%		8%	20%	24%	52.9	53.2	544.0

Lake Overflow Rate	30.78	m/yr
Lake Residence Time	0.35	years

RSE % = Relative Standard Error of Load & Inflow Conc. Estimates
Error % = Percent of Variance in Total Inflow Load Estimate

Mass Balance Summary - Onondaga Lake

Variable: CL **Chloride** **Years:** 93 thru 97 **Season:** Year

							Percent of Total Inflow			Drainage		Export
Term	Flow 10^6 m3	Load mtons	Std Error mtons	Conc ppm	RSE %	Sample Count	Flow %	Load %	Error %	Area km2	Runoff cm	mtons/ km2
Metro Effluent	88.80	28261	1525	318	5%	24	20%	17%	13%			
Metro Bypass	6.00	2123	193	354	9%	9	1%	1%	0%			
East Flume	0.31	131	5	421	4%	23	0%	0%	0%			
Crucible	0.70	215	9	307	4%	24	0%	0%	0%			
Harbor Brook	9.10	1975	81	217	4%	25	2%	1%	0%	29.3	31.1	67.4
Ley Creek	38.08	10391	770	273	7%	22	8%	6%	3%	77.5	49.1	134.1
Ninemile Creek	132.08	66701	2184	505	3%	25	29%	40%	26%	298.1	44.3	223.8
Onondaga Creek	146.76	49553	3120	338	6%	25	33%	30%	53%	285.1	51.5	173.8
Nonpoint Gauged	326.03	128620	3886	395	3%	97	72%	77%	82%	690.0	47.2	186.4
Nonpoint Ungauged	17.50	6903	976	395	14%	0	4%	4%	5%	37.0	47.2	186.4
NonPoint Total	343.52	135523	4007	395	3%	97	76%	82%	87%	727.0	47.2	186.4
Industrial	1.01	346	11	342	3%	48	0%	0%	0%			
Municipal	94.80	30384	1537	320	5%	34	21%	18%	13%			
Total External	439.34	166253	4292	378	3%	178	98%	100%	100%	727.0	60.4	228.7
Precipitation	10.90	11	1	1	9%	0	2%	0%	0%	11.7	93.1	0.9
Total Inflow	450.23	166264	4292	369	3%	178	100%	100%	100%	738.7	60.9	225.1
Evaporation	8.86						2%			11.7	75.7	
Outflow	441.38	160844	4269	364	3%		98%	97%	99%	738.7	59.7	217.7
Retention	0.00	5420	6053		112%		0%	3%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	441.38	192398	3003	436	2%	21.8	98%	116%	49%	738.7	59.7	260.4
Outlet 2 Feet	441.38	160844	4269	364	3%	22	98%	97%	99%	738.7	59.7	217.7
Lake Epil	441.38	192866	4806	437	2%	19	98%	116%	125%	738.7	59.7	261.1
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	#N/A	#N/A	#N/A	#N/A	#N/A	6	#N/A	#N/A	#N/A	26.2	#N/A	#N/A
Downstream - Hiawatha	9.10	1975	81	217	4%	25	2%	1%	0%	29.3	31.1	67.4
Local Inflow	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A	#N/A	#N/A	3.0	#N/A	#N/A
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	113.75	13072	441	115	3%	24	25%	8%	1%	232.3	49.0	56.3
Downstream - Spencer	146.76	49553	3120	338	6%	25	33%	30%	53%	285.1	51.5	173.8
Local Inflow	33.01	36481	3151	1105	9%		7%	22%	54%	52.9	62.4	690.0

Lake Overflow Rate	37.72 m/yr
Lake Residence Time	0.29 years

RSE % = Relative Standard Error of Load & Inflow Conc. Estimates
Error % = Percent of Variance in Total Inflow Load Estimate

Mass Balance Summary - Onondaga Lake

Variable: TP **Total Phosphorus** **Years:** 97 thru 97 **Season:** Year

Term	Flow 10^6 m3	Load kg	Std Error kg	Conc ppb	RSE %	Sample Count	Percent of Total Inflow			Drainage Area km2	Runoff cm	Export kg / km2
							Flow %	Load %	Error %			
Metro Effluent	88.25	33288	765	377	2%	363	24%	67%	33%			
Metro Bypass	0.48	868	54	1808	6%	35	0%	2%	0%			
East Flume	0.16	34	2	222	6%	25	0%	0%	0%			
Crucible	0.76	41	8	54	20%	26	0%	0%	0%			
Harbor Brook	6.56	261	42	40	16%	25	2%	1%	0%	29.3	22.4	8.9
Ley Creek	28.27	2684	383	95	14%	24	8%	5%	8%	77.5	36.5	34.6
Ninemile Creek	98.51	4138	500	42	12%	26	27%	8%	14%	298.1	33.0	13.9
Onondaga Creek	122.57	6974	861	57	12%	26	33%	14%	42%	285.1	43.0	24.5
Nonpoint Gauged	255.91	14058	1068	55	8%	101	69%	28%	64%	690.0	37.1	20.4
Nonpoint Ungauged	13.73	754	233	55	31%	0	4%	2%	3%	37.0	37.1	20.4
NonPoint Total	269.64	14812	1093	55	7%	101	73%	30%	67%	727.0	37.1	20.4
Industrial	0.91	76	9	83	11%	51	0%	0%	0%			
Municipal	88.73	34156	767	385	2%	398	24%	69%	33%			
Total External	359.28	49043	1335	137	3%	550	97%	99%	100%	727.0	49.4	67.5
Precipitation	9.69	291	58	30	20%	0	3%	1%	0%	11.7	82.9	24.9
Total Inflow	368.97	49334	1336	134	3%	550	100%	100%	100%	738.7	49.9	66.8
Evaporation	8.86						2%			11.7	75.7	
Outflow	360.12	35534	3547	99	10%		98%	72%	704%	738.7	48.7	48.1
Retention	0.00	13800	3790		27%		0%	28%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	360.12	38136	3152	106	8%	23	98%	77%	556%	738.7	48.7	51.6
Outlet 2 Feet	360.12	35534	3547	99	10%	23	98%	72%	704%	738.7	48.7	48.1
Lake Epil	360.12	33179	2547	92	8%	21	98%	67%	363%	738.7	48.7	44.9
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	6.20	371	201	60	54%	26	2%	1%	2%	26.2	23.6	14.1
Downstream - Hiawatha	6.56	261	42	40	16%	25	2%	1%	0%	29.3	22.4	8.9
Local Inflow	0.36	-110	205	-302	187%		0%	0%	2%	3.0	11.9	-36.1
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	94.44	3192	303	34	9%	26	26%	6%	5%	232.3	40.7	13.7
Downstream - Spencer	122.57	6974	861	57	12%	26	33%	14%	42%	285.1	43.0	24.5
Local Inflow	28.13	3782	913	134	24%		8%	8%	47%	52.9	53.2	71.5

Lake Overflow Rate 30.78 m/yr
Lake Residence Time 0.35 years

RSE % = Relative Standard Error of Load & Inflow Conc. Estimates
Error % = Percent of Variance in Total Inflow Load Estimate

Mass Balance Summary - Onondaga Lake
Variable: TP **Total Phosphorus** **Years:** 93 thru 97 **Season:** Year

Term	Flow 10^6 m3	Load kg	Std Error kg	Conc ppb	RSE %	Sample Count	Percent of Total Inflow Flow %	Load %	Error %	Drainage Area km2	Runoff cm	Export kg / km2
Metro Effluent	88.80	48173	1878	542	4%	229	20%	53%	47%			
Metro Bypass	6.00	13764	960	2293	7%	36	1%	15%	12%			
East Flume	0.31	70	2	226	3%	23	0%	0%	0%			
Crucible	0.70	36	3	51	7%	24	0%	0%	0%			
Harbor Brook	9.10	579	50	64	9%	24	2%	1%	0%	29.3	31.1	19.8
Ley Creek	38.08	4896	670	129	14%	22	8%	5%	6%	77.5	49.1	63.2
Ninemile Creek	132.08	8509	964	64	11%	25	29%	9%	12%	298.1	44.3	28.5
Onondaga Creek	146.76	12948	1278	88	10%	25	33%	14%	22%	285.1	51.5	45.4
Nonpoint Gauged	326.03	26932	1736	83	6%	96	72%	30%	40%	690.0	47.2	39.0
Nonpoint Ungauged	17.50	1445	230	83	16%	0	4%	2%	1%	37.0	47.2	39.0
NonPoint Total	343.52	28377	1751	83	6%	96	76%	31%	41%	727.0	47.2	39.0
Industrial	1.01	106	3	105	3%	48	0%	0%	0%			
Municipal	94.80	61938	2109	653	3%	266	21%	68%	59%			
Total External	439.34	90421	2741	206	3%	409	98%	100%	100%	727.0	60.4	124.4
Precipitation	10.90	327	29	30	9%	0	2%	0%	0%	11.7	93.1	27.9
Total Inflow	450.23	90748	2741	202	3%	409	100%	100%	100%	738.7	60.9	122.8
Evaporation	8.86						2%			11.7	75.7	
Outflow	441.38	58947	2602	134	4%		98%	65%	90%	738.7	59.7	79.8
Retention	0.00	31802	3780		12%		0%	35%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	441.38	67526	2751	153	4%	21.8	98%	74%	101%	738.7	59.7	91.4
Outlet 2 Feet	441.38	58947	2602	134	4%	22	98%	65%	90%	738.7	59.7	79.8
Lake Epil	441.38	66515	3141	151	5%	19	98%	73%	131%	738.7	59.7	90.0
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	#N/A	#N/A	#N/A	#N/A	#N/A	6	#N/A	#N/A	#N/A	26.2	#N/A	#N/A
Downstream - Hiawatha	9.10	579	50	64	9%	24	2%	1%	0%	29.3	31.1	19.8
Local Inflow	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A	#N/A	#N/A	3.0	#N/A	#N/A
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	113.75	8669	845	76	10%	25	25%	10%	10%	232.3	49.0	37.3
Downstream - Spencer	146.76	12948	1278	88	10%	25	33%	14%	22%	285.1	51.5	45.4
Local Inflow	33.01	4278	1532	130	36%		7%	5%	31%	52.9	62.4	80.9

Lake Overflow Rate	37.72 m/yr
Lake Residence Time	0.29 years

RSE % = Relative Standard Error of Load & Inflow Conc. Estimates
Error % = Percent of Variance in Total Inflow Load Estimate

Mass Balance Summary - Onondaga Lake
Variable: TKN **Total Kjeldahl Nitrogen** **Years:** 97 thru 97 **Season:** Year

Term	Flow	Load	Std Error	Conc	RSE	Sample	Percent of Total Inflow			Drainage Area	Runoff	Export kg /
	10^6 m3	kg	kg	ppb	%	Count	Flow %	Load %	Error %	km2	cm	km2
Metro Effluent	88.25	1300773	40348	14740	3%	120	24%	84%	60%			
Metro Bypass	0.48	8967	420	18681	5%	33	0%	1%	0%			
East Flume	0.16	527	29	3399	6%	25	0%	0%	0%			
Crucible	0.76	437	39	576	9%	26	0%	0%	0%			
Harbor Brook	6.56	3016	508	459	17%	26	2%	0%	0%	29.3	22.4	103.0
Ley Creek	28.27	42082	11670	1489	28%	24	8%	3%	5%	77.5	36.5	543.0
Ninemile Creek	98.51	102561	30269	1041	30%	26	27%	7%	34%	298.1	33.0	344.1
Onondaga Creek	122.57	60286	4554	492	8%	26	33%	4%	1%	285.1	43.0	211.4
Nonpoint Gauged	255.91	207944	32763	813	16%	102	69%	14%	39%	690.0	37.1	301.4
Nonpoint Ungauged	13.73	11160	3782	813	34%	0	4%	1%	1%	37.0	37.1	301.4
NonPoint Total	269.64	219104	32980	813	15%	102	73%	14%	40%	727.0	37.1	301.4
Industrial	0.91	964	49	1055	5%	51	0%	0%	0%			
Municipal	88.73	1309740	40351	14762	3%	153	24%	85%	60%			
Total External	359.28	1529808	52114	4258	3%	306	97%	99%	100%	727.0	49.4	2104.1
Precipitation	9.69	9694	1939	1000	20%	0	3%	1%	0%	11.7	82.9	828.5
Total Inflow	368.97	1539502	52150	4172	3%	306	100%	100%	100%	738.7	49.9	2083.9
Evaporation	8.86						2%			11.7	75.7	
Outflow	360.12	779675	66843	2165	9%		98%	51%	164%	738.7	48.7	1055.4
Retention	0.00	759827	84780		11%		0%	49%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	360.12	896432	41024	2489	5%	23	98%	58%	62%	738.7	48.7	1213.4
Outlet 2 Feet	360.12	779675	66843	2165	9%	23	98%	51%	164%	738.7	48.7	1055.4
Lake Epil	360.12	974584	41183	2706	4%	19	98%	63%	62%	738.7	48.7	1319.2
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	6.20	2764	517	446	19%	26	2%	0%	0%	26.2	23.6	105.3
Downstream - Hiawatha	6.56	3016	508	459	17%	26	2%	0%	0%	29.3	22.4	103.0
Local Inflow	0.36	253	725	694	287%		0%	0%	0%	3.0	11.9	82.9
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	94.44	35330	4714	374	13%	26	26%	2%	1%	232.3	40.7	152.1
Downstream - Spencer	122.57	60286	4554	492	8%	26	33%	4%	1%	285.1	43.0	211.4
Local Inflow	28.13	24955	6554	887	26%		8%	2%	2%	52.9	53.2	472.0

Lake Overflow Rate	30.78 m/yr
Lake Residence Time	0.35 years

RSE % = Relative Standard Error of Load & Inflow Conc. Estimates
Error % = Percent of Variance in Total Inflow Load Estimate

Mass Balance Summary - Onondaga Lake

Variable: TKN **Total Kjeldahl Nitrogen** **Years:** 93 thru 97 **Season:** Year

							Percent of Total Inflow			Drainage		Export
Term	**Flow 10^6 m3**	**Load kg**	**Std Error kg**	**Conc ppb**	**RSE %**	**Sample Count**	**Flow %**	**Load %**	**Error %**	**Area km2**	**Runoff cm**	**kg / km2**
Metro Effluent	88.80	1526282	28226	17188	2%	86	20%	80%	79%			
Metro Bypass	6.00	130379	9885	21721	8%	26	1%	7%	10%			
East Flume	0.31	1025	35	3301	3%	23	0%	0%	0%			
Crucible	0.70	331	13	472	4%	24	0%	0%	0%			
Harbor Brook	9.10	5069	1009	557	20%	25	2%	0%	0%	29.3	31.1	173.0
Ley Creek	38.08	44824	5482	1177	12%	22	8%	2%	3%	77.5	49.1	578.3
Ninemile Creek	132.08	98785	7390	748	7%	25	29%	5%	5%	298.1	44.3	331.4
Onondaga Creek	146.76	68033	4757	464	7%	25	33%	4%	2%	285.1	51.5	238.6
Nonpoint Gauged	326.03	216710	10408	665	5%	96	72%	11%	11%	690.0	47.2	314.1
Nonpoint Ungauged	17.50	11630	1702	665	15%	0	4%	1%	0%	37.0	47.2	314.1
NonPoint Total	343.52	228341	10546	665	5%	96	76%	12%	11%	727.0	47.2	314.1
Industrial	1.01	1356	37	1341	3%	48	0%	0%	0%			
Municipal	94.80	1656661	29906	17475	2%	112	21%	87%	89%			
Total External	439.34	1886358	31711	4294	2%	256	98%	99%	100%	727.0	60.4	2594.5
Precipitation	10.90	10898	982	1000	9%	0	2%	1%	0%	11.7	93.1	931.5
Total Inflow	450.23	1897256	31727	4214	2%	256	100%	100%	100%	738.7	60.9	2568.2
Evaporation	8.86						2%			11.7	75.7	
Outflow	441.38	1041509	35670	2360	3%		98%	55%	126%	738.7	59.7	1409.8
Retention	0.00	855747	47738		6%		0%	45%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	441.38	1249737	31845	2831	3%	21.8	98%	66%	101%	738.7	59.7	1691.7
Outlet 2 Feet	441.38	1041509	35670	2360	3%	22	98%	55%	126%	738.7	59.7	1409.8
Lake Epil	441.38	1278027	34148	2896	3%	18	98%	67%	116%	738.7	59.7	1730.0
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	#N/A	#N/A	#N/A	#N/A	#N/A	6	#N/A	#N/A	#N/A	26.2	#N/A	#N/A
Downstream - Hiawatha	9.10	5069	1009	557	20%	25	2%	0%	0%	29.3	31.1	173.0
Local Inflow	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A	#N/A	#N/A	3.0	#N/A	#N/A
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	113.75	45052	3241	396	7%	24	25%	2%	1%	232.3	49.0	194.0
Downstream - Spencer	146.76	68033	4757	464	7%	25	33%	4%	2%	285.1	51.5	238.6
Local Inflow	33.01	22981	5757	696	25%		7%	1%	3%	52.9	62.4	434.7

Lake Overflow Rate	37.72 m/yr
Lake Residence Time	0.29 years

RSE % = Relative Standard Error of Load & Inflow Conc. Estimates
Error % = Percent of Variance in Total Inflow Load Estimate

Mass Balance Summary - Onondaga Lake
Variable: NH3N **Ammonia Nitrogen** **Years:** 97 thru 97 **Season:** Year

							Percent of Total Inflow			Drainage		Export
Term	Flow 10^6 m3	Load kg	Std Error kg	Conc ppb	RSE %	Sample Count	Flow %	Load %	Error %	Area km2	Runoff cm	kg / km2
Metro Effluent	88.25	1035582	22610	11735	2%	363	24%	91%	38%			
Metro Bypass	0.48	5402	379	11253	7%	33	0%	0%	0%			
East Flume	0.16	341	28	2199	8%	25	0%	0%	0%			
Crucible	0.76	132	13	174	9%	26	0%	0%	0%			
Harbor Brook	6.56	1399	254	213	18%	26	2%	0%	0%	29.3	22.4	47.8
Ley Creek	28.27	12951	1416	458	11%	24	8%	1%	0%	77.5	36.5	167.1
Ninemile Creek	98.51	56789	28446	576	50%	26	27%	5%	61%	298.1	33.0	190.5
Onondaga Creek	122.57	18635	3175	152	17%	26	33%	2%	1%	285.1	43.0	65.4
Nonpoint Gauged	255.91	89773	28659	351	32%	102	69%	8%	61%	690.0	37.1	130.1
Nonpoint Ungauged	13.73	4818	2111	351	44%	0	4%	0%	0%	37.0	37.1	130.1
NonPoint Total	269.64	94591	28737	351	30%	102	73%	8%	62%	727.0	37.1	130.1
Industrial	0.91	473	31	518	7%	51	0%	0%	0%			
Municipal	88.73	1040984	22613	11733	2%	396	24%	92%	38%			
Total External	359.28	1136048	36567	3162	3%	549	97%	100%	100%	727.0	49.4	1562.5
Precipitation	9.69	969	194	100	20%	0	3%	0%	0%	11.7	82.9	82.9
Total Inflow	368.97	1137017	36568	3082	3%	549	100%	100%	100%	738.7	49.9	1539.1
Evaporation	8.86						2%			11.7	75.7	
Outflow	360.12	494242	58643	1372	12%		98%	43%	257%	738.7	48.7	669.0
Retention	0.00	642775	69110		11%		0%	57%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	360.12	621910	38184	1727	6%	23	98%	55%	109%	738.7	48.7	841.8
Outlet 2 Feet	360.12	494242	58643	1372	12%	23	98%	43%	257%	738.7	48.7	669.0
Lake Epil	360.12	655492	53759	1820	8%	21	98%	58%	216%	738.7	48.7	887.3
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	6.20	880	174	142	20%	26	2%	0%	0%	26.2	23.6	33.5
Downstream - Hiawatha	6.56	1399	254	213	18%	26	2%	0%	0%	29.3	22.4	47.8
Local Inflow	0.36	519	307	1426	59%		0%	0%	0%	3.0	11.9	170.3
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	94.44	15535	2195	164	14%	26	26%	1%	0%	232.3	40.7	66.9
Downstream - Spencer	122.57	18635	3175	152	17%	26	33%	2%	1%	285.1	43.0	65.4
Local Inflow	28.13	3100	3860	110	125%		8%	0%	1%	52.9	53.2	58.6

Lake Overflow Rate 30.78 m/yr
Lake Residence Time 0.35 years

RSE % = Relative Standard Error of Load & Inflow Conc. Estimates
Error % = Percent of Variance in Total Inflow Load Estimate

Mass Balance Summary - Onondaga Lake

Variable: NH3N **Ammonia Nitrogen** **Years:** 93 thru 97 **Season:** Year

							Percent of Total Inflow			Drainage		Export
Term	**Flow 10^6 m3**	**Load kg**	**Std Error kg**	**Conc ppb**	**RSE %**	**Sample Count**	**Flow %**	**Load %**	**Error %**	**Area km2**	**Runoff cm**	**kg / km2**
Metro Effluent	88.80	1223915	24186	13783	2%	229	20%	88%	82%			
Metro Bypass	6.00	65806	5589	10963	8%	36	1%	5%	4%			
East Flume	0.31	702	32	2262	5%	23	0%	0%	0%			
Crucible	0.70	101	4	144	4%	24	0%	0%	0%			
Harbor Brook	9.10	1667	332	183	20%	25	2%	0%	0%	29.3	31.1	56.9
Ley Creek	38.08	25828	7645	678	30%	22	8%	2%	8%	77.5	49.1	333.2
Ninemile Creek	132.08	46065	5850	349	13%	25	29%	3%	5%	298.1	44.3	154.5
Onondaga Creek	146.76	17379	829	118	5%	25	33%	1%	0%	285.1	51.5	61.0
Nonpoint Gauged	326.03	90938	9668	279	11%	97	72%	7%	13%	690.0	47.2	131.8
Nonpoint Ungauged	17.50	4880	862	279	18%	0	4%	0%	0%	37.0	47.2	131.8
NonPoint Total	343.52	95818	9707	279	10%	97	76%	7%	13%	727.0	47.2	131.8
Industrial	1.01	803	32	794	4%	48	0%	0%	0%			
Municipal	94.80	1289721	24824	13604	2%	265	21%	93%	87%			
Total External	439.34	1386341	26654	3156	2%	409	98%	100%	100%	727.0	60.4	1906.8
Precipitation	10.90	1090	98	100	9%	0	2%	0%	0%	11.7	93.1	93.1
Total Inflow	450.23	1387431	26654	3082	2%	409	100%	100%	100%	738.7	60.9	1878.1
Evaporation	8.86						2%			11.7	75.7	
Outflow	441.38	674999	33818	1529	5%		98%	49%	161%	738.7	59.7	913.7
Retention	0.00	712432	43059		6%		0%	51%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	441.38	867146	29526	1965	3%	21.8	98%	63%	123%	738.7	59.7	1173.8
Outlet 2 Feet	441.38	674999	33818	1529	5%	22	98%	49%	161%	738.7	59.7	913.7
Lake Epil	441.38	905469	35372	2051	4%	19	98%	65%	176%	738.7	59.7	1225.7
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	#N/A	#N/A	#N/A	#N/A	#N/A	6	#N/A	#N/A	#N/A	26.2	#N/A	#N/A
Downstream - Hiawatha	9.10	1667	332	183	20%	25	2%	0%	0%	29.3	31.1	56.9
Local Inflow	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A	#N/A	#N/A	3.0	#N/A	#N/A
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	113.75	13778	624	121	5%	24	25%	1%	0%	232.3	49.0	59.3
Downstream - Spencer	146.76	17379	829	118	5%	25	33%	1%	0%	285.1	51.5	61.0
Local Inflow	33.01	3601	1037	109	29%		7%	0%	0%	52.9	62.4	68.1

Lake Overflow Rate	37.72 m/yr
Lake Residence Time	0.29 years

RSE % = Relative Standard Error of Load & Inflow Conc. Estimates
Error % = Percent of Variance in Total Inflow Load Estimate

Mass Balance Summary - Onondaga Lake
Variable: NO3N **Nitrate Nitrogen**

Years: 97 thru 97 **Season:** Year

Term	Flow 10^6 m3	Load kg	Std Error kg	Conc ppb	RSE %	Sample Count	Percent of Total Inflow Flow %	Percent of Total Inflow Load %	Percent of Total Inflow Error %	Drainage Area km2	Runoff cm	Export kg / km2
Metro Effluent	88.25	225370	53554	2554	24%	22	24%	47%	97%			
Metro Bypass	0.48	5	0	10	0%	1	0%	0%	0%			
East Flume	0.16	522	24	3365	5%	25	0%	0%	0%			
Crucible	0.76	1799	279	2370	15%	26	0%	0%	0%			
Harbor Brook	6.56	9464	878	1442	9%	26	2%	2%	0%	29.3	22.4	323.1
Ley Creek	28.27	14865	943	526	6%	24	8%	3%	0%	77.5	36.5	191.8
Ninemile Creek	98.51	87309	3160	886	4%	26	27%	18%	0%	298.1	33.0	292.9
Onondaga Creek	122.57	122503	6878	999	6%	26	33%	26%	2%	285.1	43.0	429.6
Nonpoint Gauged	255.91	234140	7678	915	3%	102	69%	49%	2%	690.0	37.1	339.3
Nonpoint Ungauged	13.73	12566	3792	915	30%	0	4%	3%	0%	37.0	37.1	339.3
NonPoint Total	269.64	246706	8564	915	3%	102	73%	51%	2%	727.0	37.1	339.3
Industrial	0.91	2320	280	2539	12%	51	0%	0%	0%			
Municipal	88.73	225375	53554	2540	24%	23	24%	47%	97%			
Total External	359.28	474401	54235	1320	11%	176	97%	99%	100%	727.0	49.4	652.5
Precipitation	9.69	4847	969	500	20%	0	3%	1%	0%	11.7	82.9	414.3
Total Inflow	368.97	479248	54243	1299	11%	176	100%	100%	100%	738.7	49.9	648.7
Evaporation	8.86						2%			11.7	75.7	
Outflow	360.12	376866	18671	1047	5%		98%	79%	12%	738.7	48.7	510.1
Retention	0.00	102382	57367		56%		0%	21%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	360.12	425061	18273	1180	4%	23	98%	89%	11%	738.7	48.7	575.4
Outlet 2 Feet	360.12	376866	18671	1047	5%	23	98%	79%	12%	738.7	48.7	510.1
Lake Epil	360.12	442305	19667	1228	4%	21	98%	92%	13%	738.7	48.7	598.7
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	6.20	8724	701	1407	8%	26	2%	2%	0%	26.2	23.6	332.4
Downstream - Hiawatha	6.56	9464	878	1442	9%	26	2%	2%	0%	29.3	22.4	323.1
Local Inflow	0.36	740	1124	2032	152%		0%	0%	0%	3.0	11.9	242.8
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	94.44	99555	8994	1054	9%	26	26%	21%	3%	232.3	40.7	428.6
Downstream - Spencer	122.57	122503	6878	999	6%	26	33%	26%	2%	285.1	43.0	429.6
Local Inflow	28.13	22948	11323	816	49%		8%	5%	4%	52.9	53.2	434.0

Lake Overflow Rate 30.78 m/yr
Lake Residence Time 0.35 years

RSE % = Relative Standard Error of Load & Inflow Conc. Estimates
Error % = Percent of Variance in Total Inflow Load Estimate

Mass Balance Summary - Onondaga Lake
Variable: NO3N **Nitrate Nitrogen** **Years:** 93 thru 97 **Season:** Year

Term	Flow 10^6 m3	Load kg	Std Error kg	Conc ppb	RSE %	Sample Count	Percent of Total Inflow Flow %	Load %	Error %	Drainage Area km2	Runoff cm	Export kg / km2
Metro Effluent	88.80	134751	17089	1517	13%	24	20%	28%	65%			
Metro Bypass	6.00	5386	673	897	12%	9	1%	1%	0%			
East Flume	0.31	1169	81	3765	7%	23	0%	0%	0%			
Crucible	0.70	1412	90	2016	6%	24	0%	0%	0%			
Harbor Brook	9.10	13312	324	1462	2%	25	2%	3%	0%	29.3	31.1	454.5
Ley Creek	38.08	19514	930	512	5%	22	8%	4%	0%	77.5	49.1	251.8
Ninemile Creek	132.08	135150	10501	1023	8%	25	29%	28%	25%	298.1	44.3	453.4
Onondaga Creek	146.76	156051	6241	1063	4%	25	33%	32%	9%	285.1	51.5	547.3
Nonpoint Gauged	326.03	324027	12255	994	4%	97	72%	66%	33%	690.0	47.2	469.6
Nonpoint Ungauged	17.50	17390	2525	994	15%	0	4%	4%	1%	37.0	47.2	469.6
NonPoint Total	343.52	341417	12513	994	4%	97	76%	70%	35%	727.0	47.2	469.6
Industrial	1.01	2581	121	2553	5%	48	0%	1%	0%			
Municipal	94.80	140138	17103	1478	12%	34	21%	29%	65%			
Total External	439.34	484136	21191	1102	4%	178	98%	99%	100%	727.0	60.4	665.9
Precipitation	10.90	5449	491	500	9%	0	2%	1%	0%	11.7	93.1	465.7
Total Inflow	450.23	489585	21197	1087	4%	178	100%	100%	100%	738.7	60.9	662.7
Evaporation	8.86						2%			11.7	75.7	
Outflow	441.38	467509	18524	1059	4%		98%	95%	76%	738.7	59.7	632.8
Retention	0.00	22076	28150		128%		0%	5%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	441.38	493570	17573	1118	4%	21.8	98%	101%	69%	738.7	59.7	668.1
Outlet 2 Feet	441.38	467509	18524	1059	4%	22	98%	95%	76%	738.7	59.7	632.8
Lake Epil	441.38	498216	16677	1129	3%	19	98%	102%	62%	738.7	59.7	674.4
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	#N/A	#N/A	#N/A	#N/A	#N/A	6	#N/A	#N/A	#N/A	26.2	#N/A	#N/A
Downstream - Hiawatha	9.10	13312	324	1462	2%	25	2%	3%	0%	29.3	31.1	454.5
Local Inflow	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A	#N/A	#N/A	3.0	#N/A	#N/A
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	113.75	116650	5539	1025	5%	24	25%	24%	7%	232.3	49.0	502.2
Downstream - Spencer	146.76	156051	6241	1063	4%	25	33%	32%	9%	285.1	51.5	547.3
Local Inflow	33.01	39401	8344	1194	21%		7%	8%	15%	52.9	62.4	745.2

Lake Overflow Rate 37.72 m/yr
Lake Residence Time 0.29 years

RSE % = Relative Standard Error of Load & Inflow Conc. Estimates
Error % = Percent of Variance in Total Inflow Load Estimate

Mass Balance Summary - Onondaga Lake
Variable: NO2N **Nitrite Nitrogen** **Years:** 97 thru 97 **Season:** Year

Term	Flow 10^6 m3	Load kg	Std Error kg	Conc ppb	RSE %	Sample Count	Percent of Total Inflow Flow %	Percent of Total Inflow Load %	Percent of Total Inflow Error %	Drainage Area km2	Runoff cm	Export kg / km2
Metro Effluent	88.25	59350	12264	673	21%	22	24%	90%	100%			
Metro Bypass	0.48	14	0	30	0%	1	0%	0%	0%			
East Flume	0.16	200	10	1290	5%	25	0%	0%	0%			
Crucible	0.76	43	6	57	15%	26	0%	0%	0%			
Harbor Brook	6.56	109	26	17	24%	26	2%	0%	0%	29.3	22.4	3.7
Ley Creek	28.27	1074	209	38	19%	24	8%	2%	0%	77.5	36.5	13.9
Ninemile Creek	98.51	2281	291	23	13%	26	27%	3%	0%	298.1	33.0	7.7
Onondaga Creek	122.57	1698	154	14	9%	26	33%	3%	0%	285.1	43.0	6.0
Nonpoint Gauged	255.91	5162	391	20	8%	102	69%	8%	0%	690.0	37.1	7.5
Nonpoint Ungauged	13.73	277	86	20	31%	0	4%	0%	0%	37.0	37.1	7.5
NonPoint Total	269.64	5439	400	20	7%	102	73%	8%	0%	727.0	37.1	7.5
Industrial	0.91	243	12	266	5%	51	0%	0%	0%			
Municipal	88.73	59365	12264	669	21%	23	24%	90%	100%			
Total External	359.28	65047	12270	181	19%	176	97%	99%	100%	727.0	49.4	89.5
Precipitation	9.69	969	194	100	20%	0	3%	1%	0%	11.7	82.9	82.9
Total Inflow	368.97	66016	12272	179	19%	176	100%	100%	100%	738.7	49.9	89.4
Evaporation	8.86						2%			11.7	75.7	
Outflow	360.12	22237	1897	62	9%		98%	34%	2%	738.7	48.7	30.1
Retention	0.00	43780	12418		28%		0%	66%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	360.12	30283	1992	84	7%	23	98%	46%	3%	738.7	48.7	41.0
Outlet 2 Feet	360.12	22237	1897	62	9%	23	98%	34%	2%	738.7	48.7	30.1
Lake Epil	360.12	40229	7564	112	19%	21	98%	61%	38%	738.7	48.7	54.5
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	6.20	358	228	58	64%	26	2%	1%	0%	26.2	23.6	13.6
Downstream - Hiawatha	6.56	109	26	17	24%	26	2%	0%	0%	29.3	22.4	3.7
Local Inflow	0.36	-249	230	-683	92%		0%	0%	0%	3.0	11.9	-81.6
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	94.44	1630	235	17	14%	26	26%	2%	0%	232.3	40.7	7.0
Downstream - Spencer	122.57	1698	154	14	9%	26	33%	3%	0%	285.1	43.0	6.0
Local Inflow	28.13	68	281	2	415%		8%	0%	0%	52.9	53.2	1.3

Lake Overflow Rate 30.78 m/yr
Lake Residence Time 0.35 years

RSE % = Relative Standard Error of Load & Inflow Conc. Estimates
Error % = Percent of Variance in Total Inflow Load Estimate

Mass Balance Summary - Onondaga Lake
Variable: NO2N **Nitrite Nitrogen** **Years:** 93 thru 97 **Season:** Year

Term	Flow 10^6 m3	Load kg	Std Error kg	Conc ppb	RSE %	Sample Count	Percent of Total Inflow Flow %	Percent of Total Inflow Load %	Percent of Total Inflow Error %	Drainage Area km2	Runoff cm	Export kg / km2
Metro Effluent	88.80	42053	3859	474	9%	24	20%	77%	97%			
Metro Bypass	6.00	826	51	138	6%	9	1%	2%	0%			
East Flume	0.31	584	31	1883	5%	23	0%	1%	0%			
Crucible	0.70	44	3	63	6%	24	0%	0%	0%			
Harbor Brook	9.10	183	23	20	12%	25	2%	0%	0%	29.3	31.1	6.2
Ley Creek	38.08	1435	127	38	9%	22	8%	3%	0%	77.5	49.1	18.5
Ninemile Creek	132.08	4487	431	34	10%	25	29%	8%	1%	298.1	44.3	15.1
Onondaga Creek	146.76	3355	481	23	14%	25	33%	6%	2%	285.1	51.5	11.8
Nonpoint Gauged	326.03	9459	658	29	7%	97	72%	17%	3%	690.0	47.2	13.7
Nonpoint Ungauged	17.50	508	80	29	16%	0	4%	1%	0%	37.0	47.2	13.7
NonPoint Total	343.52	9966	663	29	7%	97	76%	18%	3%	727.0	47.2	13.7
Industrial	1.01	629	31	622	5%	48	0%	1%	0%			
Municipal	94.80	42879	3859	452	9%	34	21%	79%	97%			
Total External	439.34	53474	3916	122	7%	178	98%	98%	100%	727.0	60.4	73.6
Precipitation	10.90	1090	98	100	9%	0	2%	2%	0%	11.7	93.1	93.1
Total Inflow	450.23	54564	3917	121	7%	178	100%	100%	100%	738.7	60.9	73.9
Evaporation	8.86						2%			11.7	75.7	
Outflow	441.38	36593	3726	83	10%		98%	67%	90%	738.7	59.7	49.5
Retention	0.00	17971	5406		30%		0%	33%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	441.38	44967	3584	102	8%	21.8	98%	82%	84%	738.7	59.7	60.9
Outlet 2 Feet	441.38	36593	3726	83	10%	22	98%	67%	90%	738.7	59.7	49.5
Lake Epil	441.38	54668	5226	124	10%	19	98%	100%	178%	738.7	59.7	74.0
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	#N/A	#N/A	#N/A	#N/A	#N/A	6	#N/A	#N/A	#N/A	26.2	#N/A	#N/A
Downstream - Hiawatha	9.10	183	23	20	12%	25	2%	0%	0%	29.3	31.1	6.2
Local Inflow	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A	#N/A	#N/A	3.0	#N/A	#N/A
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	113.75	2555	283	22	11%	24	25%	5%	1%	232.3	49.0	11.0
Downstream - Spencer	146.76	3355	481	23	14%	25	33%	6%	2%	285.1	51.5	11.8
Local Inflow	33.01	799	558	24	70%		7%	1%	2%	52.9	62.4	15.1

Lake Overflow Rate	37.72 m/yr
Lake Residence Time	0.29 years

RSE % = Relative Standard Error of Load & Inflow Conc. Estimates
Error % = Percent of Variance in Total Inflow Load Estimate

Mass Balance Summary - Onondaga Lake
Variable: FCOLI **Fecal Coliforms** **Years:** 97 thru 97 **Season:** Year

Term	Flow 10^6 m3	Load 10^9 cells	Std Error 10^9 cells	Conc cells/liter	RSE %	Sample Count	Percent of Total Inflow Flow %	Percent of Total Inflow Load %	Percent of Total Inflow Error %	Drainage Area km2	Runoff cm	Export 10^9 cells/ km2
Metro Effluent	88.25	573282	136088	6496	24%	213	24%	4%	0%			
Metro Bypass	0.48	6367642	3067083	13265921	48%	23	0%	39%	84%			
East Flume	0.16	5784	1594	37313	28%	25	0%	0%	0%			
Crucible	0.76	1232	1019	1624	83%	26	0%	0%	0%			
Harbor Brook	6.56	192826	130115	29376	67%	26	2%	1%	0%	29.3	22.4	6583.2
Ley Creek	28.27	434519	218609	15371	50%	24	8%	3%	0%	77.5	36.5	5606.4
Ninemile Creek	98.51	241230	125020	2449	52%	26	27%	1%	0%	298.1	33.0	809.2
Onondaga Creek	122.57	7938135	1307670	64767	16%	26	33%	49%	15%	285.1	43.0	27840.3
Nonpoint Gauged	255.91	8806711	1338040	34414	15%	102	69%	54%	16%	690.0	37.1	12763.0
Nonpoint Ungauged	13.73	472634	158937	34414	34%	0	4%	3%	0%	37.0	37.1	12763.0
NonPoint Total	269.64	9279345	1347446	34414	15%	102	73%	57%	16%	727.0	37.1	12763.0
Industrial	0.91	7016	1892	7676	27%	51	0%	0%	0%			
Municipal	88.73	6940924	3070101	78230	44%	236	24%	43%	84%			
Total External	359.28	16227284	3352780	45166	21%	389	97%	100%	100%	727.0	49.4	22319.4
Precipitation	9.69	0	0	0		0	3%	0%	0%	11.7	82.9	0.0
Total Inflow	368.97	16227284	3352780	43980	21%	389	100%	100%	100%	738.7	49.9	21965.9
Evaporation	8.86						2%			11.7	75.7	
Outflow	360.12	102921	19230	286	19%		98%	1%	0%	738.7	48.7	139.3
Retention	0.00	16124364	3352835		21%		0%	99%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	360.12	144026	22138	400	15%	23	98%	1%	0%	738.7	48.7	195.0
Outlet 2 Feet	360.12	102921	19230	286	19%	23	98%	1%	0%	738.7	48.7	139.3
Lake Epil	360.12	442263	194036	1228	44%	19	98%	3%	0%	738.7	48.7	598.7
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	6.20	22827	13409	3682	59%	26	2%	0%	0%	26.2	23.6	869.8
Downstream - Hiawatha	6.56	192826	130115	29376	67%	26	2%	1%	0%	29.3	22.4	6583.2
Local Inflow	0.36	169999	130804	467031	77%		0%	1%	0%	3.0	11.9	55797.3
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	94.44	150536	101440	1594	67%	26	26%	1%	0%	232.3	40.7	648.1
Downstream - Spencer	122.57	7938135	1307670	64767	16%	26	33%	49%	15%	285.1	43.0	27840.3
Local Inflow	28.13	7787599	1311598	276863	17%		8%	48%	15%	52.9	53.2	147292.7

Lake Overflow Rate	30.78	m/yr
Lake Residence Time	0.35	years

RSE % = Relative Standard Error of Load & Inflow Conc. Estimates
Error % = Percent of Variance in Total Inflow Load Estimate

Mass Balance Summary - Onondaga Lake
Variable: FCOLI **Fecal Coliforms** **Years:** 93 thru 97 **Season:** Year

Term	Flow 10^6 m3	Load 10^9 cells	Std Error 10^9 cells	Conc cells/liter	RSE %	Sample Count	Percent of Total Inflow Flow %	Percent of Total Inflow Load %	Percent of Total Inflow Error %	Drainage Area km2	Runoff cm	Export 10^9 cells/ km2
Metro Effluent	88.80	5654485	1426292	63676	25%	61	20%	14%	5%			
Metro Bypass	6.00	27118951	5941252	4518018	22%	32	1%	68%	93%			
East Flume	0.31	18663	1809	60126	10%	24	0%	0%	0%			
Crucible	0.70	557	210	795	38%	25	0%	0%	0%			
Harbor Brook	9.10	322337	73016	35411	23%	25	2%	1%	0%	29.3	31.1	11004.8
Ley Creek	38.08	1073632	391119	28191	36%	22	8%	3%	0%	77.5	49.1	13852.6
Ninemile Creek	132.08	660444	225139	5000	34%	24	29%	2%	0%	298.1	44.3	2215.6
Onondaga Creek	146.76	4524476	651405	30830	14%	25	33%	11%	1%	285.1	51.5	15868.1
Nonpoint Gauged	326.03	6580888	795815	20185	12%	96	72%	17%	2%	690.0	47.2	9537.3
Nonpoint Ungauged	17.50	353180	65973	20185	19%	0	4%	1%	0%	37.0	47.2	9537.3
NonPoint Total	343.52	6934068	798544	20185	12%	96	76%	17%	2%	727.0	47.2	9537.3
Industrial	1.01	19220	1821	19011	9%	49	0%	0%	0%			
Municipal	94.80	32773437	6110056	345700	19%	93	21%	82%	98%			
Total External	439.34	39726725	6162018	90424	16%	238	98%	100%	100%	727.0	60.4	54641.1
Precipitation	10.90	0	0	0		0	2%	0%	0%	11.7	93.1	0.0
Total Inflow	450.23	39726725	6162018	88236	16%	238	100%	100%	100%	738.7	60.9	53775.7
Evaporation	8.86						2%			11.7	75.7	
Outflow	441.38	472466	153923	1070	33%		98%	1%	0%	738.7	59.7	639.5
Retention	0.00	39254259	6163940		16%		0%	99%				
Alternative Estimates of Lake Output												
Outlet 12 Feet	441.38	507145	153263	1149	30%	22	98%	1%	0%	738.7	59.7	686.5
Outlet 2 Feet	441.38	472466	153923	1070	33%	22	98%	1%	0%	738.7	59.7	639.5
Lake Epil	441.38	712157	192433	1613	27%	18	98%	2%	0%	738.7	59.7	964.0
Upstream/Downstream Contrast- Harbor Brook												
Upstream - Velasko	#N/A	#N/A	#N/A	#N/A	#N/A	6	#N/A	#N/A	#N/A	26.2	#N/A	#N/A
Downstream - Hiawatha	9.10	322337	73016	35411	23%	25	2%	1%	0%	29.3	31.1	11004.8
Local Inflow	#N/A	#N/A	#N/A	#N/A	#N/A		#N/A	#N/A	#N/A	3.0	#N/A	#N/A
Upstream/Downstream Contrast - Onondaga Creek												
Upstream - Dorwin	113.75	165823	32197	1458	19%	24	25%	0%	0%	232.3	49.0	714.0
Downstream - Spencer	146.76	4524476	651405	30830	14%	25	33%	11%	1%	285.1	51.5	15868.1
Local Inflow	33.01	4358652	652200	132056	15%		7%	11%	1%	52.9	62.4	82438.4

Lake Overflow Rate 37.72 m/yr
Lake Residence Time 0.29 years

RSE % = Relative Standard Error of Load & Inflow Conc. Estimates
Error % = Percent of Variance in Total Inflow Load Estimate